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EAST ASIA

A CLIMATOLOGICAL STUDY
VOLUME II: MARITIME

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13. Abstract: A climatological study of East Asia. This volume concentrates on the portion of East Asia that is directly influenced by a maritime weather regime. The region includes southeast and northeast China, Taiwan, and the Korean peninsula. After describing the geography and major meteorological features of the entire region, the study discusses in detail the climatic controls of each of East Asia's four "zones of climatic commonality." Each "season" is defined and discussed in considerable detail with emphasis on general weather, clouds, visibility, winds, precipitation, temperature, hazards, and trafficability.

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DEDICATION

This study is dedicated to Mr. John S. Freeman,
whose life tragically ended too soon. We will miss him.

PREFACE

This study was prepared by the Air Force Combat Climatology Center's Readiness Support Branch (AFCCC/DOJ), in response to a support assistance request (SAR) from the Air Force Global Weather Center (AFGWC), Offutt AFB, Neb.

The project would not have been possible without the dedicated support of many people and agencies. We also appreciate the assistance of Mr. David Pigors, Mr. Charles Travers, Mr. Gary Swanson, Ms. Susan Keller, Ms. Susan Tarbell, Ms. Lisa Mefford, and Ms. Randa Simon of the Air Force Weather Technical Library. Without their help, much of the information in this document, necessarily obtained from multiple sources, would simply not have been made available to us.

Thanks to all the people in the AFCCC Environmental Applications Branch who provided the immense amount of data required for the preparation of this regional. The work of MSgt Joan Bergman is especially appreciated.

Finally, the authors owe sincere gratitude to AFCCC's Technical Publishing Team—Mr. Gene Newman and TSgt Edward L. Branch. Without their patience, cooperation, and creativity, this project would not have been possible.

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INTRODUCTION

Area of Interest. This second volume of a two-volume set describes the geography, climatology, and meteorology of those areas of East Asia that have a heavy maritime influence in their weather regimes. Maritime East Asia consists of four "zones of climatic commonality" as shown in Figure 1-1. Each zone is further described on the next page.

Figure 1-1. Maritime East Asia and Its Four "Zones of Climatic Commonality."

Southeast China. Southeast China's northern border with the remainder of mainland China approximates the long-term 800-mm mean annual precipitation isopleth. The eastern and part of the southern boundary of southeast China consists of a coastline that borders the East China Sea, Taiwan Strait, South China Sea, and the Gulf of Tonkin. The borders between China and Vietnam, Laos, and Myanmar (formerly known as Burma) define the rest of the southern border. In the west, southeast China's border is on the eastern edge of the Tibetan Plateau where it approximately coincides with the 2,000-meter elevation contour.

Northeastern China. Siberia borders this region along the north and northeast. The eastern part is bordered by North Korea and the Yellow Sea. The southern border is marked by the 800-mm mean annual precipitation line. The western border follows the 200-mm mean annual precipitation isopleth northward to the border shared with Mongolia. Much of the western border follows the outline of the extreme eastern portion of the Gobi Desert. The remaining border along the northwest is the China-Mongolia border.

Taiwan. Taiwan is a mountainous island oriented north-northeast to south-southwest about 100 miles (161 km) off the southeast coast of the China.

Korea. Korea is located at the juncture of the northeast Asian continent and the Japanese archipelago and is bordered to the north by China and Siberia. The west coast is bounded by the Yellow Sea and the east coast by the Sea of Japan. The Korea Strait lies at the peninsula's southwestern tip.

Study Content. Chapter 2 provides a general discussion of the major meteorological features that affect maritime East Asia. The features include semipermanent climatic controls, synoptic disturbances, and mesoscale and local features. Chapters 3 through 6 provides specific effects of the above features on the climatic commonality zone discussed in each chapter. Meteorologists using this study should read and consider the general discussion in Chapter 2 before they try to understand or apply the individual climatic zone discussions in Chapters 3 through 6.

Each chapter first discusses geography (including topography, rivers and drainage systems, lakes and water bodies), major climatic controls, and if appropriate, special climatic controls. Weather for each season is then discussed with the following elements highlighted:

General Weather
Sky Cover
Visibility
Surface Winds
Upper-Air Winds
Precipitation/Thunderstorms
Temperature
Hazards
Trafficability

Conventions. The spellings of place names and geographical features are those used by the Air Force Master Weather Station Catalog or the National Imagery and Mapping Agency (NIMA). Distances and elevations are in feet and statute miles with conversions to meters and kilometers (km) as appropriate. Cloud and ceiling heights are in feet. When the term "ceiling" is used, it means 5/8 cumulative cloud coverage at any level unless otherwise stated. Temperatures are in degrees Fahrenheit (°F) with Celsius (°C) conversions. Wind speeds are in knots. Precipitation amounts are in millimeters (mm). Charts are labeled in Universal Coordinated Time (UTC) or Zulu (Z) time. Otherwise, local time (L) is used.

Data Sources. Most of the information used in preparing this study came from two sources within AFCCC. Studies, books, atlases, and so on were supplied by the Air Force Weather Technical Library (AFWTL). Climatological data came directly from the climatic database maintained at OL-A, AFCCC—the division of AFCCC responsible for maintaining and managing this database.

Related References. This study, while more than ordinarily comprehensive, is certainly not the only source of climatological information for the military meteorologist concerned with East Asia. Staff weather officers and forecasters are urged to contact the AFWTL for more data on the study area.

Chapter 2

MAJOR METEOROLOGICAL FEATURES OF EAST ASIA

Sea-Surface Conditions. Ocean currents play an important role in determining the climate of coastal East Asia. The ocean currents affecting East Asia are shown in Figure 2-1 and described below. The strength and position of these currents fluctuate during the year. Some only appear seasonally, but the Kuroshio Current is present year-round.

The warm northeastward-flowing Kuroshio Current is the primary current of the western Pacific Ocean. It is the second strongest ocean current in the world, after the Atlantic's Gulf Stream. Although the Kuroshio Current is always present, its strength and direction vary considerably from year to year.

During the summer monsoon, the Kuroshio Current is joined by another warm, northward-flowing current from the Java Sea. These two currents meet north of the Philippines and then split in the East China Sea. The main branch is the Kuroshio, which continues northeastward south of Japan into the North Pacific and eastward to the United States.

The warm Tsushima Current flows northeastward from the split through the Tsushima Straits and off the northwest coast of Japan. Due to the prevailing cold, northwesterly flow in winter, the warming effect of the Tsushima Current is significant along the west coast of Japan. It provides warmth and moisture to the cold, dry Siberian air mass over the Sea of Japan. The modified air mass becomes warm and wet, and it yields an enormous amount of snowfall.

The Tsushima Current splits between Hokkaido and Honshu. One branch turns eastward through the Tsugaru Straits between Hokkaido and Honshu. This branch has been associated with the frequent development of towering cumulus over the Tsugaru Straits. The other branch continues northward along the west coast of Honshu to Sakhalin where it modifies and turns southwestward along the coast of Siberia and the Korean peninsula as the cold Liman Current.

The Kuroshio Counter Current flows southward along China's coast during the winter monsoon and draws cold water into the South China Sea. This causes strong sea-surface temperature gradients along the eastern and southern coast of China. The strong temperature gradients help make this coastal region a favorable location for cyclogenesis.

Figure 2-1 also shows mean sea-surface temperatures (SSTs) around East Asia. Warm waters destabilize the atmosphere and lead to the development of cumuliform clouds. Cold waters stabilize the atmosphere and generally favor stratiform clouds. The general circulation patterns and ocean currents of the region strongly affect the SSTs. The warm, northward-flowing Kuroshio Current and the cold, southward-flowing Kuroshio Counter Current contribute to the strong temperature gradient that develops during the winter monsoon. The mean position of frontal zones off China's coast is closely related to this strong temperature gradient. SSTs are warmest during July, August, and September.

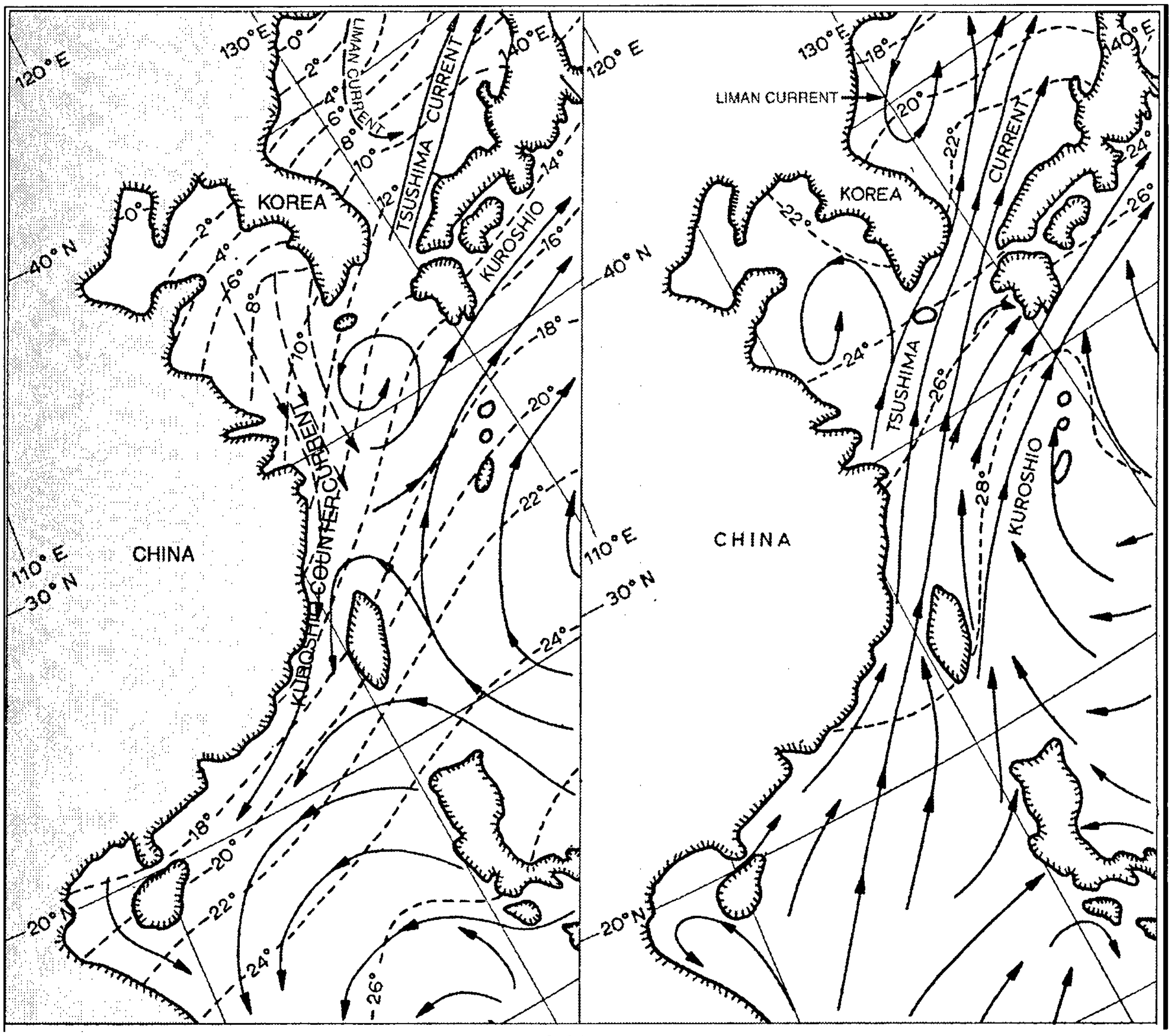


Figure 2-1. Stream Drift and Sea-Surface Temperatures in the Northwest Pacific and the China Seas. The sea currents contribute to a strong temperature gradient that is associated with the mean position of frontal zones off China's coast.

Maritime Pressure Features. These features include the North Pacific high, the South Pacific high, the Aleutian low, South Indian Ocean (Mascarene) high, and the El Niño cycle.

North Pacific High. This subtropical high, centered off the North American coast, is farthest north and west in July and August (Figure 2-2). It is an important component of the east Asian monsoon system. The seasonal shift in the position of the subtropical high is closely related to the advance and retreat of major rain belts in East Asia.

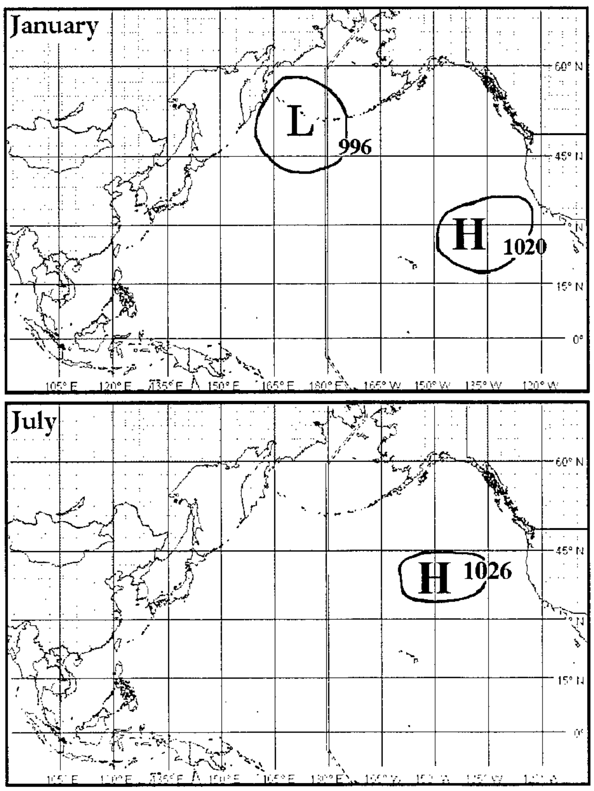


Figure 2-2. Major Maritime Pressure Features. Positions of the Aleutian low and North Pacific high during winter; bottom, position of the North Pacific high during summer.

The North Pacific high forms a ridge that extends westward into Asia around 28° N in July and August. This ridge reaches its mean northernmost position over East Asia (near 40° N) in August. Its position is linked to the movement of the monsoon trough and to oscillations in convective activity in the southwestern Pacific. The major rain belt is normally located poleward of the ridge axis.

The position of the subtropical high is closely related to the activity of the summer monsoon in East Asia. An active summer monsoon can be expected if the North Pacific high shifts farther north and west than normal. An inactive summer monsoon is likely when the subtropical high is farther east and south than normal.

During the winter monsoon, the North Pacific high retreats to near 30° N, 130° W. The North Pacific high oscillates between a shallow and a deep flow pattern. Each phase lasts about 10 days and causes fluctuations in the winter monsoon. This is part of a phenomenon known as the low frequency oscillation. With a shallow high, no 200-mb ridge is evident; strong upper-level westerlies prevail to south of the equator, while at 700 mb, easterlies predominate south of the high. Easterly waves tend to develop, typhoons are rare, and polar troughs are absent. With a deep high, there is a strong ridge at 200 mb. At 700 mb, equatorial westerlies dominate south of 10° N. Typhoons develop between the northeast trade winds and the westerlies.

South Pacific High. This is the Southern Hemisphere's counterpart to the North Pacific high. Mean central pressure ranges from 1018 mb in March to 1025 mb in September. The cell migrates from 32° S, 102° W in January to 26° S, 98° W in July. From these mean positions it ridges westward into the western Pacific (the ridging is visible in Figure 2-3). The high slopes equatorward with height.

Outflow from the South Pacific high forms the South Pacific trades. The strength and position of this high display a periodicity similar to that of the North Pacific high. This affects typhoon formation in the western Pacific.

South Indian Ocean (Mascarene) High. The mean central pressure of the Mascarene high ranges from 1021 mb in April to 1028 mb in August, though the pressure can exceed 1040 mb during the Southern Hemisphere winter. The high's annual movement is mainly east-west from 30° S, 87° E in January to 29° S, 65° E in July (Figure 2-3). The high slopes equatorward and westward with height.

Cross-equatorial flow from this high is one of the primary drivers of the summer monsoon flow. Its large east-west movement causes seasonal variations in the strength of the equatorial westerlies.

Aleutian Low. The Aleutian low sits over the Aleutian Islands in the North Pacific and affects East Asia primarily during the winter monsoon. It reaches its maximum strength in January with a

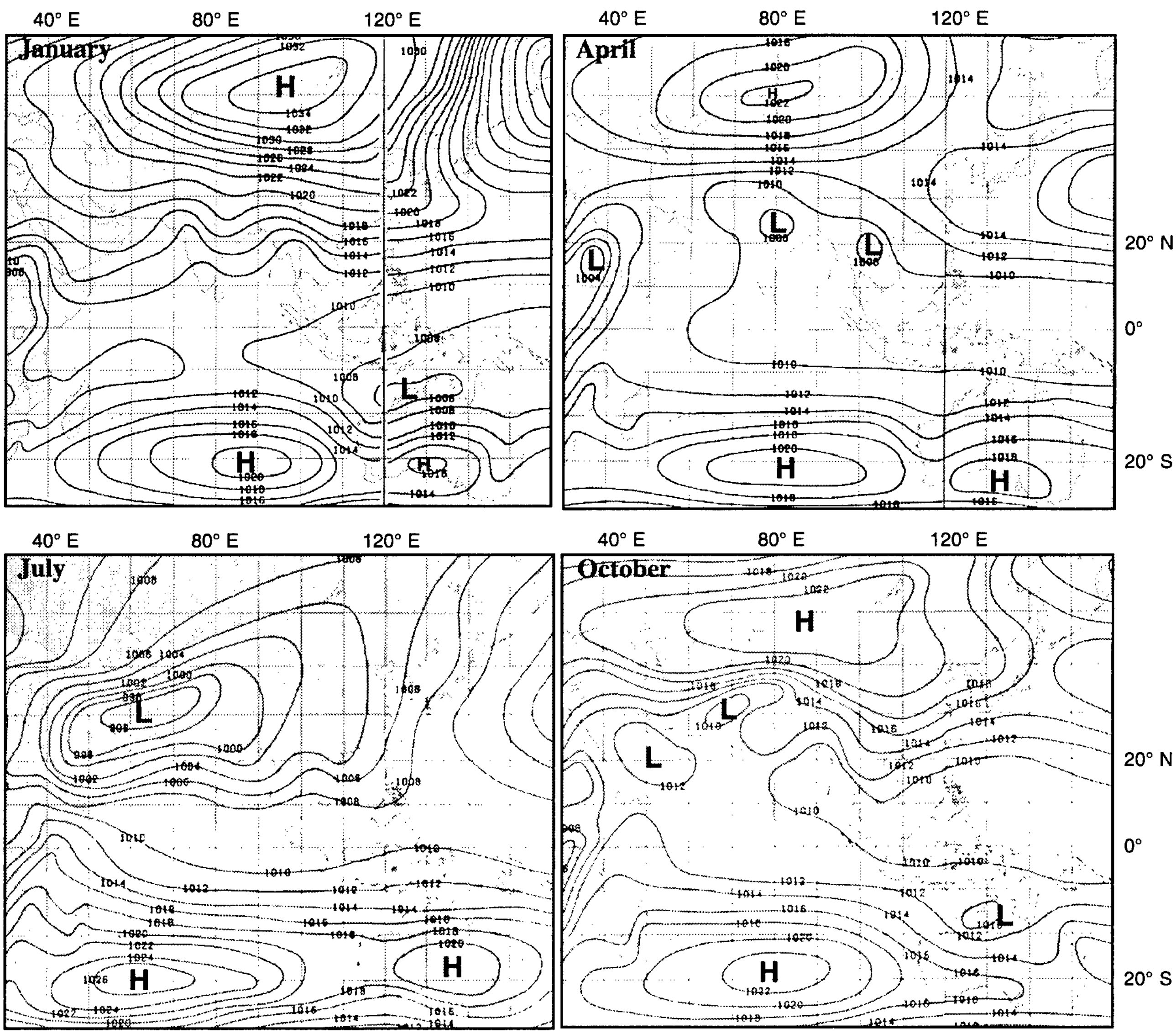


Figure 2-3. Mean Sea-Level Pressure for January, April, July, and October. The figure shows the position of the major pressure systems and how they migrate from season to season.

central pressure near 996 mb (Figure 2-2). Eastward moving storms tend to converge in this area, especially during winter. The Aleutian low acts with the Asiatic high to establish a strong pressure gradient over East Asia. The strength of this pressure gradient is directly related to the strength of the winter monsoon experienced by much of Asia.

El Niño-Southern Oscillation (ENSO). The Southern Oscillation is a complex, global atmospheric/oceanic phenomena involving periodic changes in atmospheric pressure, sea-surface temperature, and air temperature. The concept of ENSO refers to the linking together of oceanic and atmospheric changes in the Pacific Ocean region. It is characterized by two phases, a warm "El Niño" and a cold "La Niña," with short intervening transitions. The time to complete one cycle varies between 2 and 10 years and averages around 3 years. Atmospheric circulation changes occurring near the equator and in association with these phases are shown in Figure 2-4. Shaded areas in the figure indicate sea-surface temperatures above 27° C.

The El Niño phase lasts an average of 18 months. It normally begins with elevated sea-surface temperatures in the eastern Pacific, usually in

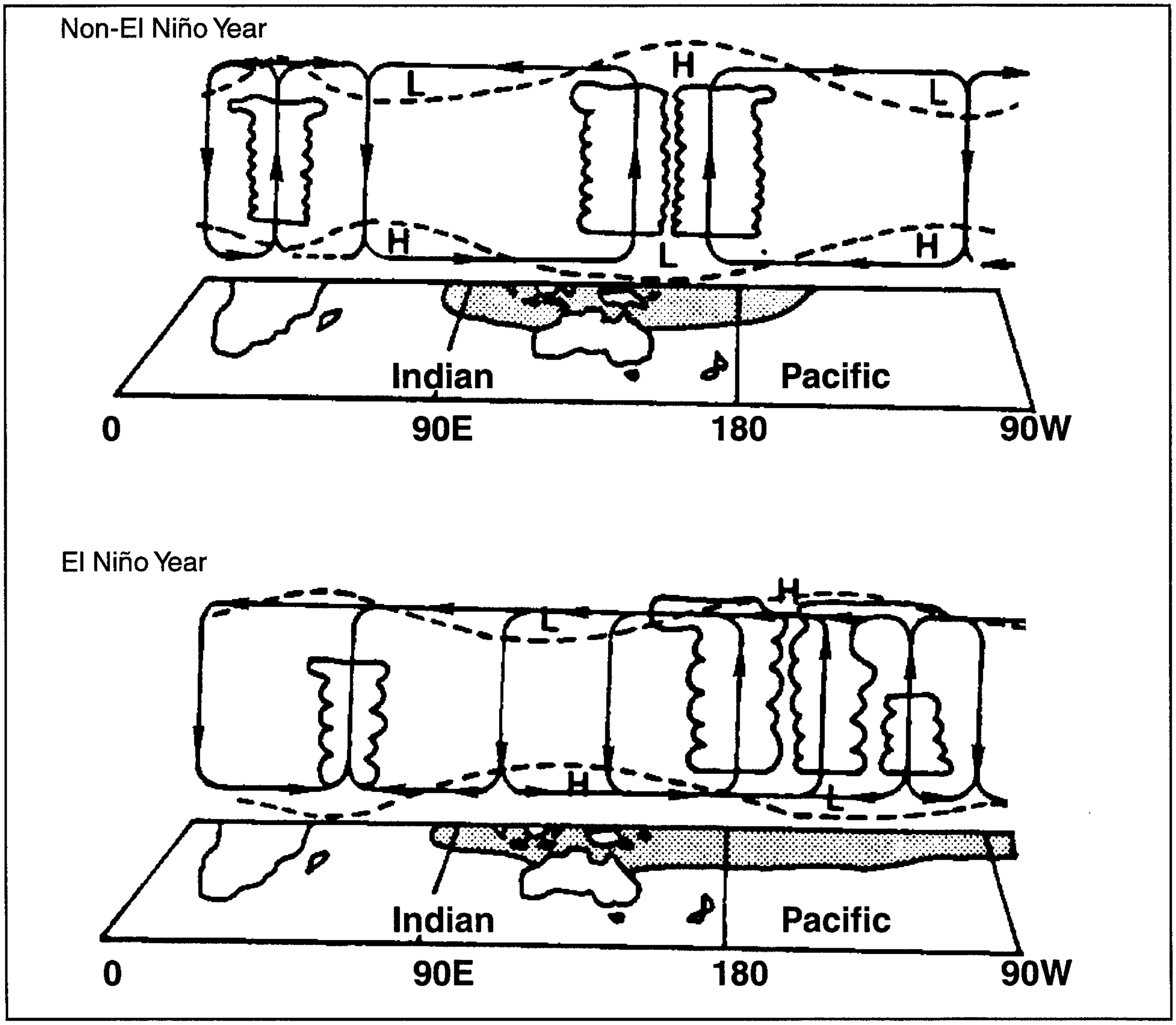


Figure 2-4. Equatorial Circulation Model during non-El Niño Years and El Niño Years. Sea-surface temperatures are above 27° C in shaded areas. The dashed lines indicate how pressure surfaces change during non-El Niño Years and El Niño years.

December. These temperature anomalies gradually diminish as they propagate westward, however, and temperatures in the South China Sea and western Pacific Ocean are 2° to 3°C colder than normal. These lower temperatures are linked to changes in the summer rainfall amounts in China.

When El Niño appears, the subtropical high shifts southward resulting is below normal convective activity over the South China Sea. A drought occurs over southern China, while flooding occurs in the area between the Yangtze and the Huaihe rivers. On the other hand, when the ENSO event begins to decay, the subtropical high shifts northward, strong convective activity returns to the South China Sea, and a drought may develop between the Yangtze and the Huaihe Rivers. Summer precipitation over north China and El Niño are not strongly related, but several studies indicate a close relationship between the ENSO and cool summers in northeastern Asia.

The North Pacific high is generally weaker than normal and positioned farther east during the onset years of El Niño. This relationship helps explain the below normal rainfall amounts over much of East Asia during El Niño. The intensity of the Kuroshio Current may also be affected by ENSO. Other atmospheric changes associated with the southern oscillation are not fully understood.

Radical changes to the monsoon system appear to be linked to the El Niño cycle. The North Pacific high strengthens and shifts unusually far south during the summer monsoon. The high covers a larger area and extends farther westward. Also, the primary convergence zone of the near equatorial trade wind convergence (NETWC), which is normally over the Indian Ocean, shifts closer to New Guinea. During the winter monsoon the NETWC generally disappears, and it is replaced by easterlies. In the upper troposphere, the subtropical westerlies prevail to the equator. Cold surges occur less frequently, and there are fewer typhoons in El Niño years, particularly between July and November. Cyclogenesis over the East China Sea can increase by as much as 20 percent over a "normal year" during an El Niño year.

Continental Pressure Features.

Asiatic High. The Asiatic high is a strong, but shallow high-pressure cell that dominates much of the Asian continent from late September to late April. It is the strongest cold anticyclone in the Northern Hemisphere and rarely extends above 850 mb. It is normally overlaid by westerlies aloft. The mean central pressure is strongest (1038 mb) in January, when the high is centered over western Mongolia (see Figure 2-5). The Asiatic high is created and supported mainly by radiational cooling, though migratory Arctic air masses temporarily reinforce and intensify it. This produces multiple centers. The central pressure occasionally exceeds 1050 mb for up to 3 days; the highest recorded pressure is 1083 mb. Variations in the high result in a 10- to 12-day periodicity in the strength of the winter monsoon.

Australian High. This thermal high is present during the winter in the Southern Hemisphere. It is strongest in July, when it is near 28° S, 128° E with a central pressure of about 1022 mb (see Figure 2-3). It is neither as strong nor as persistent as the Asiatic high and is crossed regularly by disturbances and migratory highs.

Australian high air is warm and dry upon leaving Australia, but it picks up moisture as it crosses the South China Sea. When unusually strong, the Australian high causes subsidence over the Malay Peninsula and decreases the amount of moisture available in the monsoon flow over East Asia.

West China Trough. The Asiatic high forms two ridges. One points southeastward to the Chinese coast and Taiwan, and the other stretches southwestward along the eastern Indian coast and merges with the Indian high. Between these two ridges, the broad west China trough stretches from central Myanmar to southwestern China. The lee-side effects of the Tibetan Plateau intensify this trough. Active cold surges often occur when this trough is weak.

Australian Heat Low. This low develops during the Southern Hemisphere summer. It strengthens the winter monsoon by increasing the pressure gradient between Asia and Australia. Its mean January position is 17° S, 135° E, with a mean pressure of 1006 mb (see Figure 2-3).

Asiatic Low. From May to early October, this low anchors the eastern end of a broad, low-level thermal trough extending from northwestern India across southern Pakistan, Iran, Saudi Arabia, and into the Sahara. The low, which normally is cloud-free, is strongest in July when its central pressure averages 994 mb. Its mean position in July is near 35° N, 65° E. This thermal low draws in the NETWC and anchors its western end. Flow around the Tibetan Plateau dynamically enhances the troughing in India.

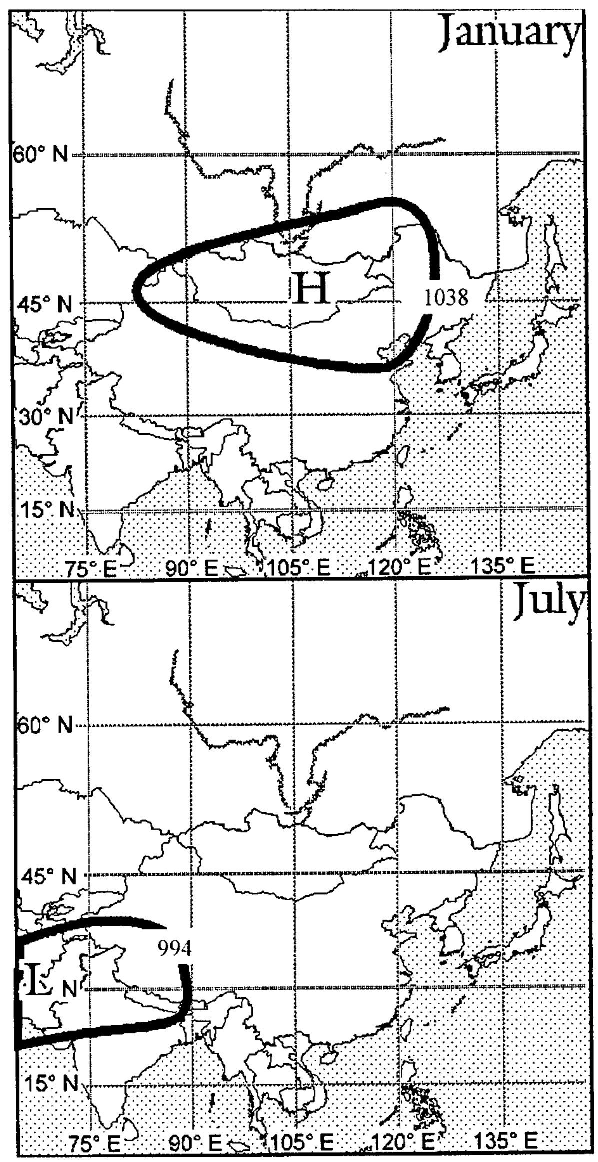


Figure 2-5. Major Continental Pressure Features. Top, Asiatic high; bottom, Asiatic low.

Monsoon Climate. During the Northern Hemisphere winter, the warm oceanic ridge and the Asiatic high work together to form a continuous belt of high pressure. During summer, heat lows replace the Asiatic high. This seasonal reversal of the pressure gradient gives rise to the northeast and southwest monsoons that affect East Asia. The term "monsoon" is commonly applied to those areas of the world where there is a seasonal reversal of prevailing winds, but the generally accepted definition of a monsoon climate includes satisfaction of the following criteria:

- The prevailing seasonal wind direction shifts by at least 120 degrees between January and July,

- Wind speeds must equal or exceed 6 knots,

- No more than one cyclone-anticyclone alternation occurs every 2 years in either month in a 250 x 250 NM (460 x 460 km) square.

- The average frequency of prevailing wind direction in January and July exceeds 40 percent.

Near Equatorial Trade Wind Convergence (NETWC). The NETWC, also known as the Intertropical Convergence Zone (ITCZ) or the monsoon trough, results from the convergence of the outflows from Northern and Southern Hemisphere high-pressure systems. During the winter monsoon, the NETWC is the boundary between the outflows from the South Indian Ocean high and the Asiatic high. During the summer monsoon, it is the boundary between the outflows from the South Indian Ocean high and the North Pacific high. The northernmost position of the NETWC occurs during August, while its southernmost position occurs in February. The latitudinal position of the NETWC is determined by the movement of the subtropical ridge.

The NETWC is characterized by great horizontal wind shear with the westerlies or southwesterly winds situated to the south and the easterlies or northeasterly trade winds to the north. In the transition zone from the westerlies to easterlies, there exists a relatively calm doldrum where the wind is weak and highly variable. The existence of the doldrum indicates an active NETWC, with large areas of cloud systems or clusters. This makes the NETWC a source region for tropical cyclones. It is estimated that about 80 percent of all tropical cyclones originate in or just poleward of the NETWC.

Winter Monsoon. The winter monsoon occurs when the NETWC migrates to the south during the Northern Hemisphere winter. This allows outflow from the Asiatic high to dominate the region. Stable weather and cold, northeasterly winds typify the winter monsoon. It is also characterized by a succession of cold air surges that sometimes bring freezing temperatures as far south as Hong Kong. The cold outbreaks are often accompanied by high winds, sharp temperature drops, freezing rain, heavy snowfalls, severe frost, and sandstorms. Figure 2-6 shows the usual positions of the polar front and NETWC during the winter monsoon. Figure 2-7 shows a cross section of the wind flow during the winter monsoon.

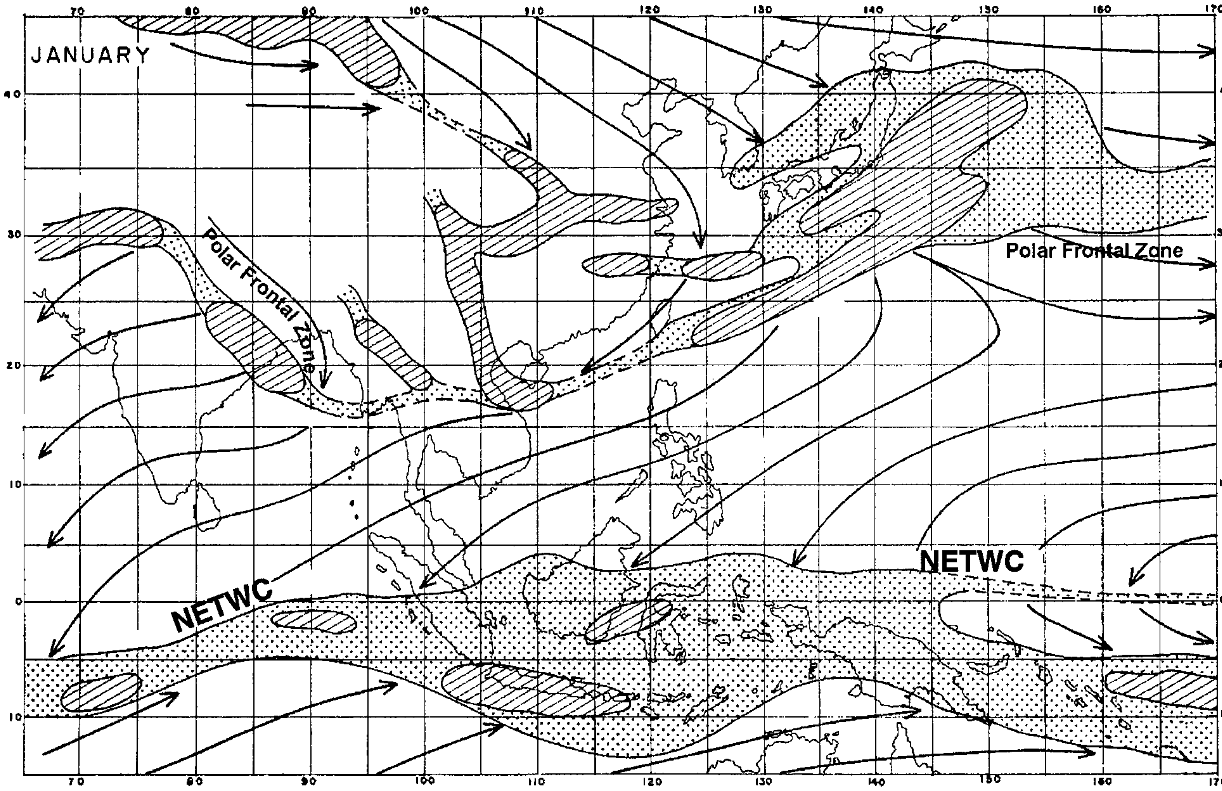


Figure 2-6. January Mean Position of NETWC and Polar Frontal Zones. Arrows indicate the mean wind flow direction; stippled areas indicate steady winds; and hatched areas show where the wind direction is more variable.

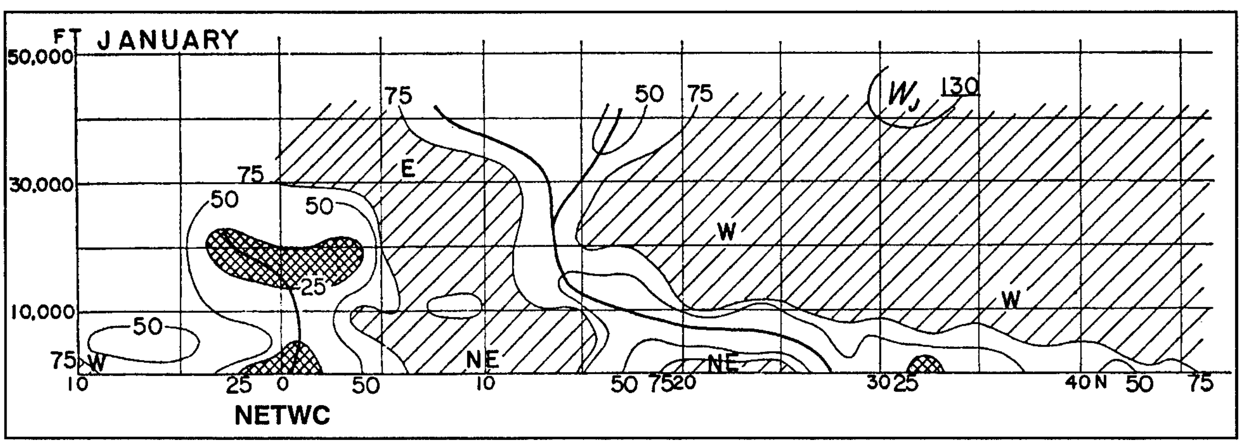


Figure 2-7. January Vertical Cross Section along 120° E. Striped areas indicate wind direction is steady. W_J indicates westerly jet axis; W indicates westerly, E indicates easterly, etc. Underlined values indicate wind speeds. Cross-hatched areas indicate variable wind directions or a shear zone. Thin lines are isopleths of wind steadiness (25, 50, 75 percent of the time). Heavy lines (steadiness-minimum lines) indicate the point at which winds are minimally steady before becoming variable.

The onset of the winter monsoon is abrupt as it rapidly moves southward. It penetrates northeastern China in early September and reaches Hainan Island by the second week in October (see Figure 2-8). The pressure field over the Asian region quickly reverses in September as the Asiatic low weakens and the pressure over East Asia increases slightly. The dynamic effect of the Tibetan Plateau plays a large role in the rapid movement of the winter monsoon into southern China.

By the end of October, the winter monsoon is firmly in place. The winter monsoon circulation reaches its maximum development in January when the Asiatic high is at full strength and the Aleutian low is well-established. The circulation pattern gradually weakens from February through March. The winter monsoon's end, in April (south) and May (north), comes as the NETWC moves north. The subtropical jet moves north of the Tibetan Plateau while the Tibetan high and tropical easterly jet establish themselves.

Precipitation is at a minimum over most of East Asia during the winter monsoon with one notable exception. Northeast Taiwan, which is sheltered from the southerly flow in the summer by mountains, is exposed to the northeasterly flow in the winter. Thus, its precipitation maximum occurs in December.

Typhoon activity is still possible during the winter monsoon season, although the occurrence of these destructive storms is greatly reduced. Any typhoon approaching the coast of China or Korea will be weakened by entrainment of the winter monsoon's cold, dry air and the vertical shearing of the strong upper-level westerlies.

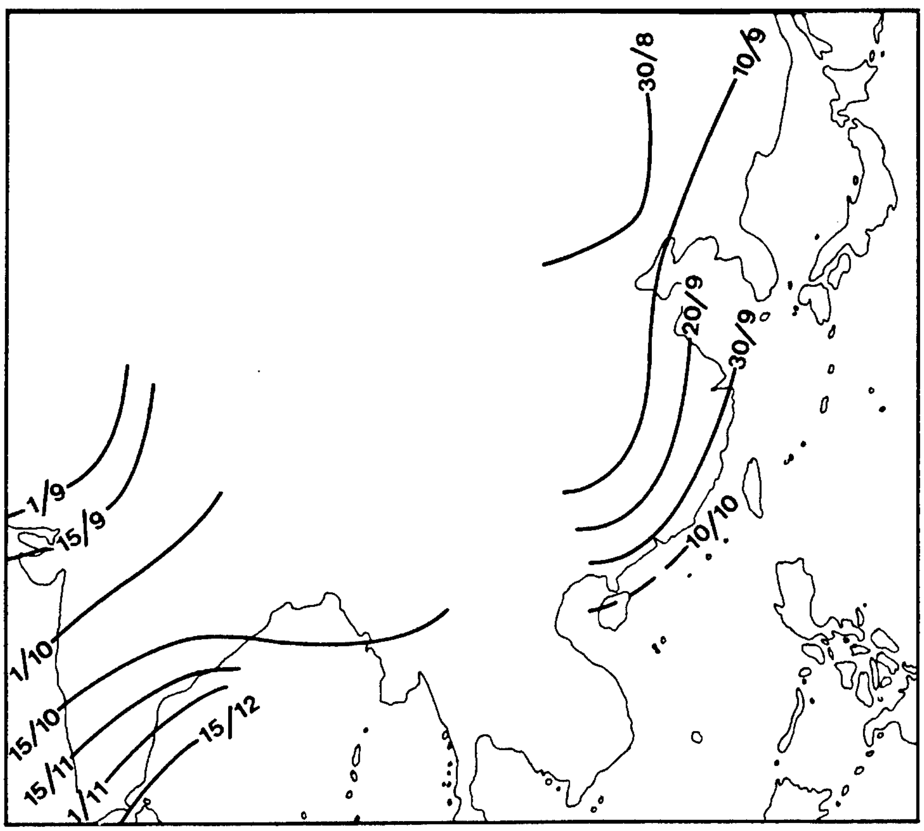


Figure 2-8. Mean Onset Date (Day/Month) of the Winter Monsoon over East and South Asia. High terrain blocks the wind flow and causes the gaps in the wind as indicated in the figure.

Summer Monsoon. The summer monsoon season develops in response to the northward movement of the subtropical high-pressure ridge in the western Pacific. The onset of the monsoon starts in early May over the northern part of the South China Sea and ends in late July over northern China. See Figure 2-9 for the mean onset dates.

As the subtropical ridge moves northward and strengthens, changes in the circulation pattern over the region take place. The cold, dry high-pressure system over Mongolia is replaced by a large thermal trough. The subtropical westerly jet moves north of the Tibetan Plateau and gradually decreases in intensity. The Tibetan high moves onto the plateau and tropical easterly jet

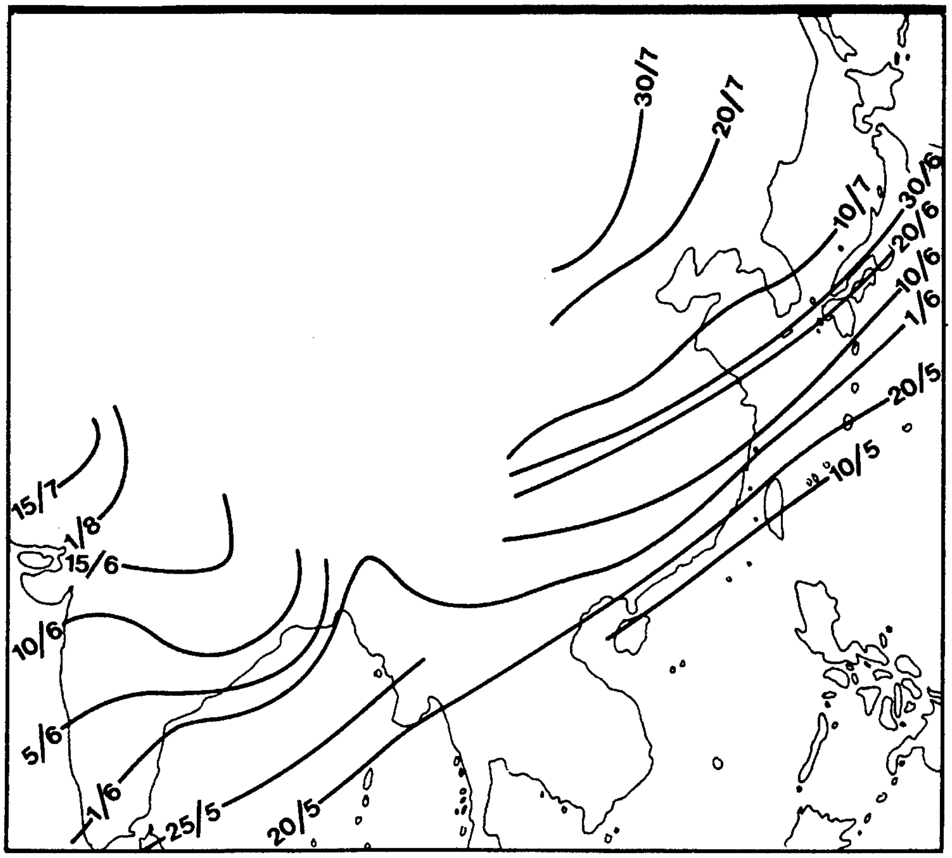


Figure 2-9 Mean Onset Date (Day/Month) of the Summer Monsoon over East and South Asia. High terrain blocks the wind flow and causes the gaps in the wind as indicated in the figure.

sets up south of the Himalaya Mountains. In the meantime, the NETWC moves northward into the South China Sea. Figure 2-10 shows the usual positions of the polar front and the NETWC during the summer monsoon. Figure 2-11 shows a cross section of the wind flow during the summer monsoon.

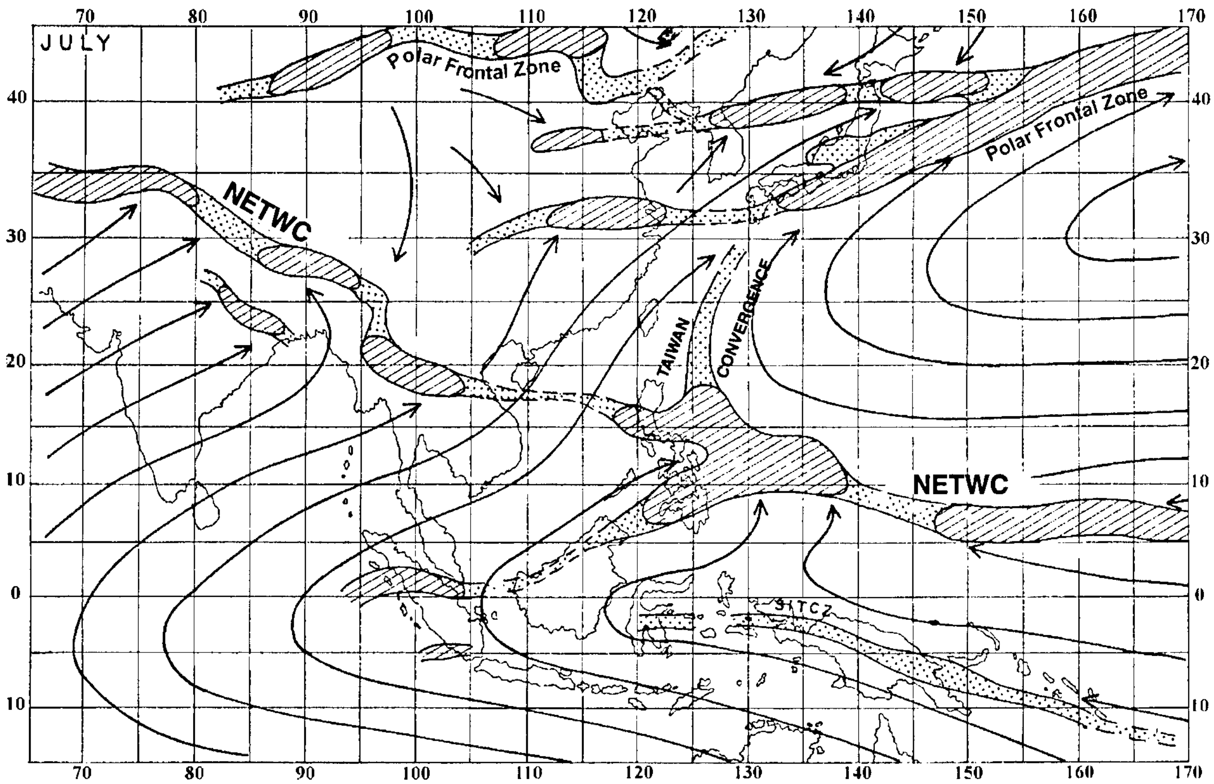


Figure 2-10. July Mean Position of the NETWC and Polar Frontal Zones. Arrows indicate the mean wind flow direction; stippled areas indicate steady winds; and hatched areas show where the wind direction is more variable.

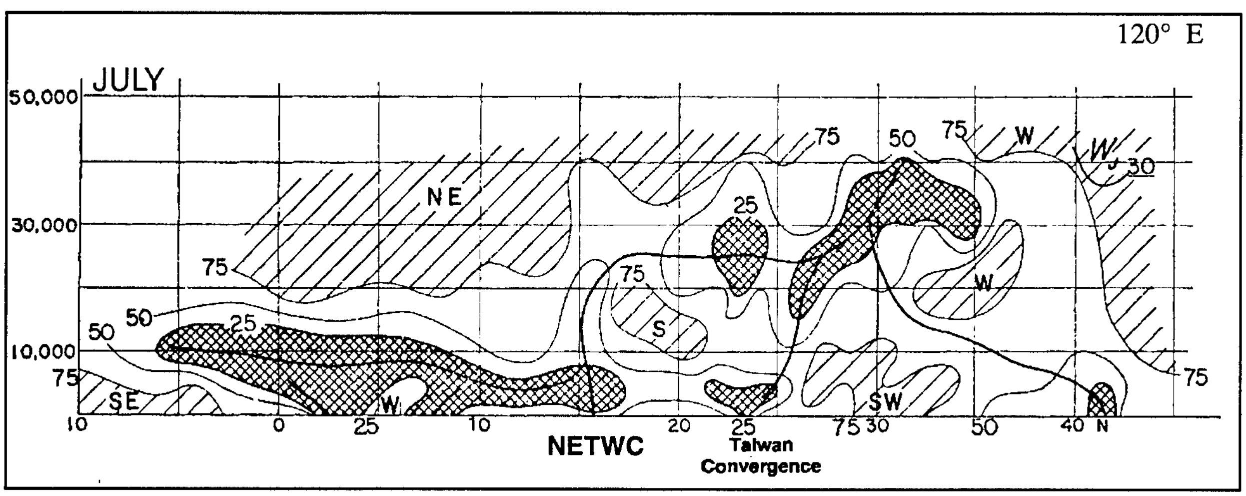


Figure 2-11. July Vertical Cross Section along 120° E. Striped areas indicate wind direction is steady. W_J indicates westerly jet axis; W indicates westerly, S indicates southerly, etc. Underlined values indicate wind speeds. Cross hatched areas indicate variable wind directions or a shear zone. Thin lines are isopleths of wind steadiness (25, 50, 75 percent of the time). Heavy lines (steadiness-minimum lines) indicate the point at which winds are minimally steady before becoming variable.

When the summer monsoon has finally been established, it will consist of the following components:

- Australian high
- Cross-equatorial flow (from the Southern Hemisphere)
- NETWC
- Tropical easterly jet
- Western Pacific high
- Mei-yu front
- Mid-latitude disturbances

A schematic diagram of the summer monsoon and its components is seen in Figure 2-12.

Two air mass sources create the two branches of the summer monsoon. One is the cross-equatorial flow from the Southern Hemisphere that creates a low-level southwesterly wind flow. The other is a southeasterly flow that originates on the southern flank of the western Pacific subtropical high. The southeasterly component is stronger, extends further into the region, and maintains itself longer.

The establishment of the summer monsoon ushers in the rainy season for eastern Asia. Precipitation data from many locations indicate that a significant percentage of the annual precipitation falls during this period. The monsoon rains are not steady. They come in pulses that last anywhere from 2 to 10 days, followed by periods of calm weather. Rainfall amounts are usually heavy and rain events generally cover a large area. Flooding is a frequent problem in the region. The heavy rainfalls common to the East Asian region are attributed to its mountainous terrain. Most heavy rainfalls in mountain or hilly areas occur on the windward slopes.

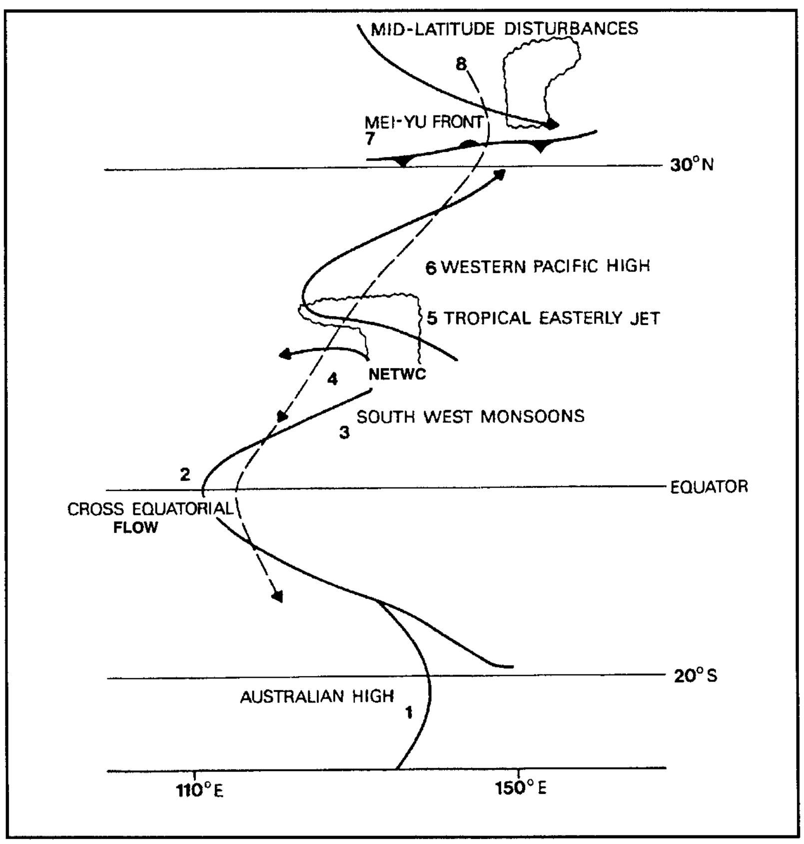


Figure 2-12. Summer Monsoon Components. The figure shows a schematic diagram of summer monsoon with its eight components.

The number of typhoons affecting China and Korea increases during the summer. As the subtropical ridge moves northward, the NETWC moves northward with the western extension as it moves into the South China Sea. The wind flows on both sides of the NETWC are also enhanced, the westerlies on the equatorial side due to cold surges from the southern hemisphere, and the easterlies on the poleward side due to the intensification of the subtropical ridge. Movement of the NETWC away from the equator and the enhancement of the flow on either side of the NETWC increases the low-level relative vorticity and makes conditions for typhoon genesis more favorable.

The retreat of the summer monsoon in East Asia is a rather straightforward, yet quick process that takes about a month. It is closely connected to the southward migration of the subtropical ridge. The ridge usually begins its southward movement by early September. By mid-September the low-level circulation pattern over the continent suddenly changes from a cyclonic to an anticyclonic pressure pattern, which allows the polar front, with its colder and drier air masses, to move south. By early to mid-October, the ridge moves south of 20° N, and allows the polar front to move into the South China Sea to complete the winter monsoon transition.

Monsoon Breaks. Monsoon breaks are defined as disruptions in the normal summer monsoon patterns of cloudiness and rainfall. This results in generally good weather over a large area. These breaks are classified as minor or major. A minor monsoon break typically lasts 2 or 3 days and is generally associated with a typhoon moving into the region. It is accompanied by good weather ahead of the storm. The monsoon pattern returns after the typhoon has dissipated or moved out of the region. A major monsoon break, on the other hand, lasts 5 days or more and occurs with the establishment of anticyclonic flow patterns in the lower levels (850-500 mb) over a large area. These patterns develop with the northward movement of the equatorial anticyclone (sometimes called a buffer ridge). If the break is severe enough, it will be seen at the 500-mb level as a ridge intrusion from the North Pacific high. Sometimes the ridge is intensified when it is enhanced by a trough in the subtropical westerlies. When this happens, the monsoon break becomes severe, and leads to drought conditions on the mainland. The monsoon flow will return once a mid-latitude trough is able to move southward to break the ridge down and shift it eastward.

Taiwan Convergence. Taiwan Convergence is a wind shear line caused by the convergence of the southwesterly monsoon flow from southern Asia and the southeasterly flow from the North Pacific high. It usually produces little convective activity (see Figure 2-10).

Equatorial Westerlies. These westerlies are formed by the outflow of the southern Indian Ocean high, beginning along the African coast and extending eastward to 130° E. In summer, it is strengthened around 110° E by outflow from the Australian high. The westerly flow extends from the surface to 700 mb, but in July, its strongest month, it extends to 500 mb. These winds are a source of cool, subsiding air between the northern and southern monsoon boundaries. Eastward-moving waves form in this flow, but little is known about them.

Jet Streams. The following jet streams affect this region: the polar jet, the subtropical jet, the tropical easterly jet, and the low-level jet.

Polar Jet. The presence of the polar jet is most evident during the winter season when the westerlies are at their strongest and have shifted to their most southern point. During the winter, the Tibetan Plateau splits the westerlies into two branches. The northern branch becomes the polar jet. Movement of the polar jet varies widely between 45° and 70° N. It also merges with the subtropical jet in the vicinity of Japan to create a broad, deep band of very high wind speeds over eastern Asia. Wind speeds over the region have been measured at over 240 knots. During the summer, the polar jet shifts to the north and weakens. It is associated with the migratory lows and polar fronts. The mean storm tracks follow polar jet very closely.

Subtropical Jet. In winter, the subtropical jet is situated south of the Himalayas and stretches northeastward across south central China. It crosses the coast near Shanghai to merge with the polar jet in the vicinity of Japan. This confluence zone enhances cyclogenesis in the South China Sea. This jet marks the southern limit of the winter polar air. It shows 2-3 degrees of latitudinal variation from the time it makes its first appearance over southern China in October until mid-April when it begins to shift back to the north (a prerequisite for the start of the summer monsoon). In the summer, it is located north of the Tibetan Plateau. Figure 2-13 shows the mean position of the subtropical jet at different times of the years. Mean positions range from 22° N in January to 45° N in July. Mean heights and speeds of the jet over East Asia are shown in Figures 2-14a and 2-14b. These figures also denote the zones of the predominate storm tracks and the areas of maximum precipitation in the region.

Tropical Easterly Jet (TEJ). This Northern Hemisphere summer jet is one of the most important components of the summer monsoon system in the east Asian monsoon region. It is also one of the major circulation features in the tropical upper troposphere in the northern summer. Its establishment and activity are closely associated with the seasonal change in the upper troposphere of the Northern Hemisphere (specifically, the development of the Tibetan anticyclone). The entrance region for this jet is over the South China Sea or in the western Pacific Ocean as far east as Guam (about 140° E). The mean position lies about 15° N latitude, 4 to 5 degrees south of the surface monsoon trough, but it oscillates between 5° and 20° N (see Figure 2-15).

The tropical easterly jet has two branches over the region. The northern branch occurs at 10° to 20° N at 100 mb, and the southern branch occurs around 5° N at 150 mb (see Figure 2-16). The northern branch is generally the stronger of the two. The tropical easterly jet is very steady; the variability of its core position is rather small. It is most persistent during the summer.

The tropical easterly jet is one of the most important circulation features affecting the monsoon activities and precipitation in East Asia. The yearly variability of the monsoon precipitation appears to be associated with the variation of the strength of the jet. A 10-year study of rainfall data showed the years with many monsoon rainfalls tend to correspond with a tropical easterly jet of above-normal intensity (a more extensive region of easterly wind speeds that exceed 40 knots, a more northerly position of the jet axis, and a stronger jet core). The years with deficit monsoon rainfalls tended to correspond with a tropical easterly jet of below-normal intensity. The study also indicated a variability period of 2-3 years for the jet with a corresponding variability for the precipitation patterns.

Low-Level Jets. A low-level jet is defined as a maximum wind or jet streak with a wind speed greater than 24 knots in the 1,600 to 9,800-foot (500- to 3,000-meter) layer. Low-level jets can be described in the following categories:

Category	Wind Speed
Weak	< 32 knots
Moderate	32-40 knots
Strong	> 40 knots

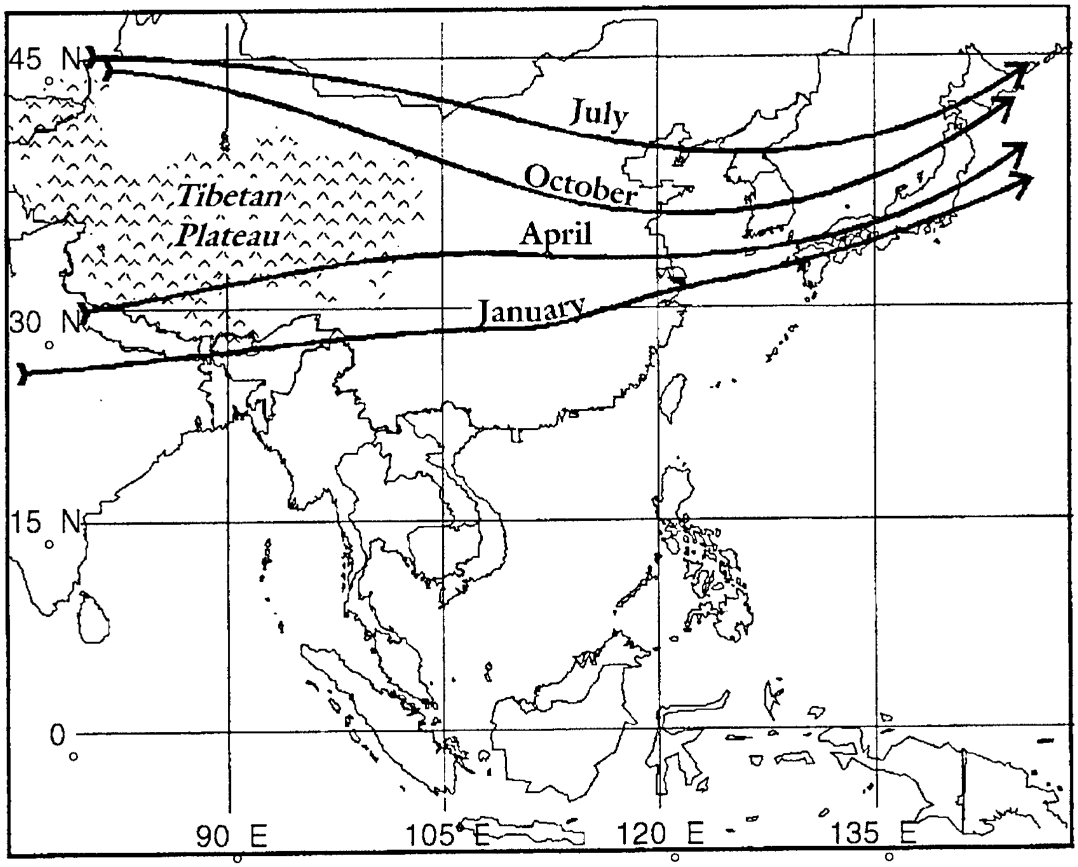


Figure 2-13. Mean January, April, July, and October Positions of the Subtropical Jet. Mean positions range from 22° N in January to 45° N in July.

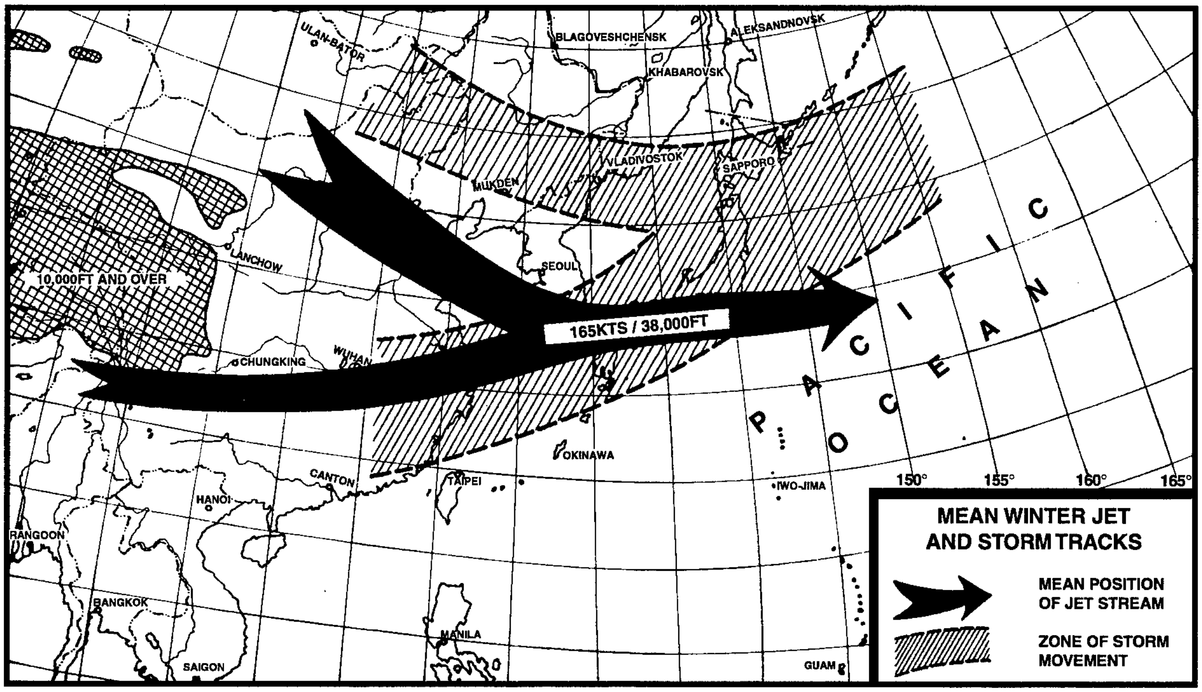


Figure 2-14a. Position of Axes of Maximum Winds Superimposed over Zones of Extratropical Cyclone Movement for Winter. Tibetan Plateau above 10,000 feet is shown by checked area.

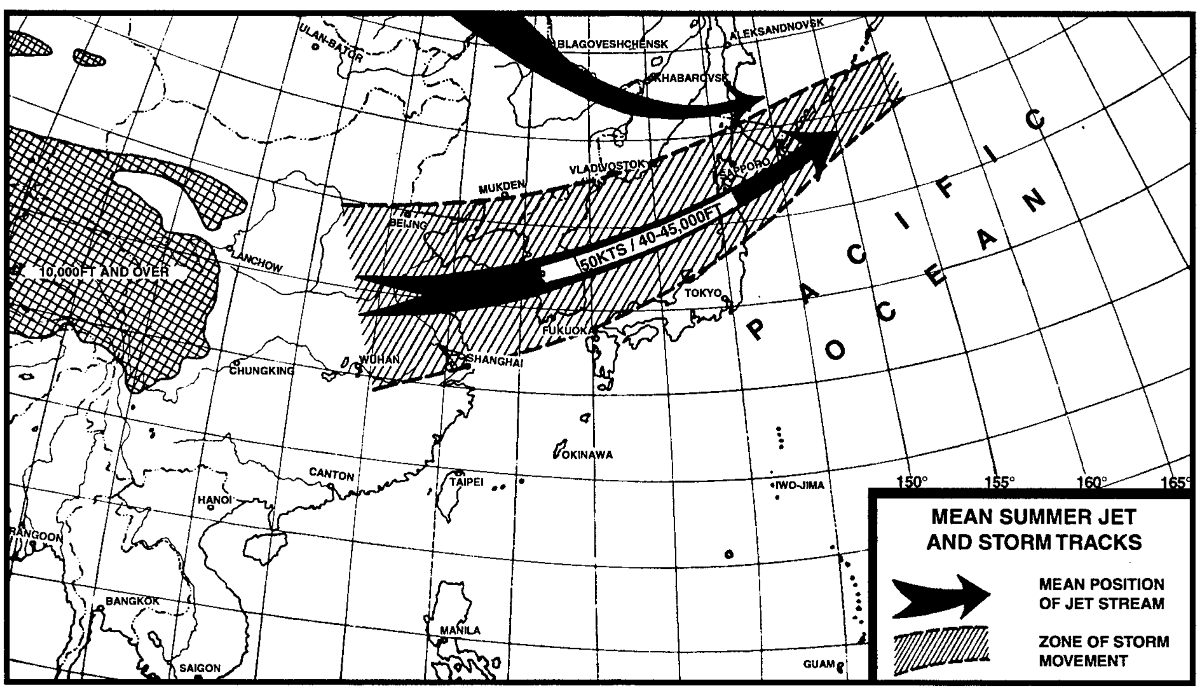


Figure 2-14b. Mean Position of Axes of Maximum Winds Superimposed over Zones of Extratropical Cyclone Movement for Summer. Tibetan Plateau above 10,000 feet is shown by checked area.

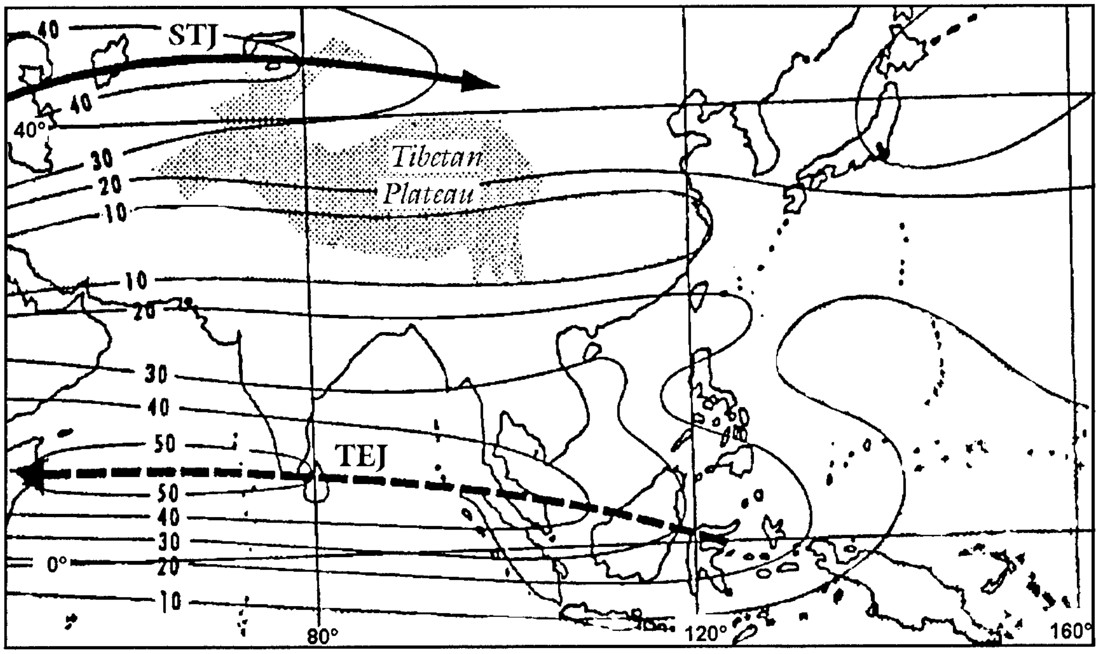


Figure 2-15. July Mean Position of the Tropical Easterly Jet. Wind speed in knots.

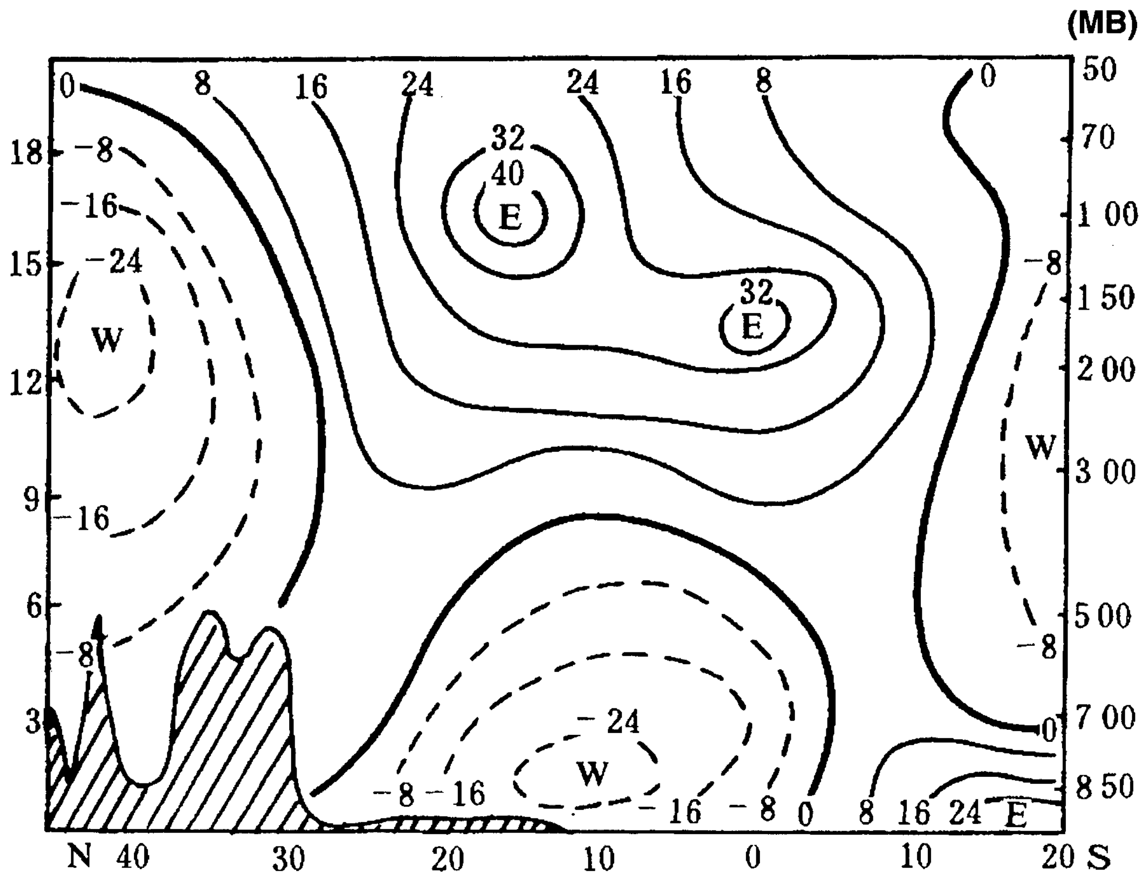


Figure 2-16. A Cross Section of the Mean Zonal Wind Components along 80° E for July. Solid (dashed) lines denote isotachs of easterly wind (westerly wind). Units: m s^{-1}.

Two low-level jets make their presence felt in East Asia during precipitation episodes. One is a prefrontal low-level jet, which has been observed during the southward intrusion of cold air. It is a significant factor in production of extensive heavy rains. The other is a low-level jet observed above the coastal areas of southern China and the northern South China Sea. This jet is associated with the monsoon surge, and it generates a region of persistent, heavy rains along the coastal areas of southern China. Heavy rainfall associated with the low-level jet is located in the left front sector of the jet where there is maximum convergence. Rainfall data indicates 80 percent of the heavy rainfall occurs this way.

The development of low-level jets is attributed to two synoptic processes. The first process is the intensification of the subtropical high and the development of low-pressure systems to the west of the jet. When the trough in the southern branch of the westerlies moves eastward to the east of the Tibetan Plateau, it may induce the genesis of a low vortex or low-level, low-pressure trough. As the system moves further eastward and deepens, the pressure gradient is enhanced. This generates the low-level jet (see Figure 2-17). The generation of this 850-mb jet was associated with the eastward movement of a southwest vortex from the Sichaun Province.

The second synoptic process is the enhancement of the summer monsoon over the Indochina peninsula and the northern part of the South China Sea. The wind maximum is first observed in the prevailing southwesterly monsoon airflow over Indochina, then it moves slowly northward until it influences the region of southern China (see Figure 2-18). This low-level jet type is relatively strong, has a larger scale, and is somewhat persistent.

The low-level jet is a very warm and moist high-speed air flow that may transport abundant moisture northward. Dew points have a marked positive anomaly along and to the left of the jet axis. The 700-mb level is the most moist. The warmest temperatures always lie along the jet zone. The low-level jet also has a marked diurnal variation of wind speed, which is very similar to that of the low-level jets of the Great Plains in the United States.

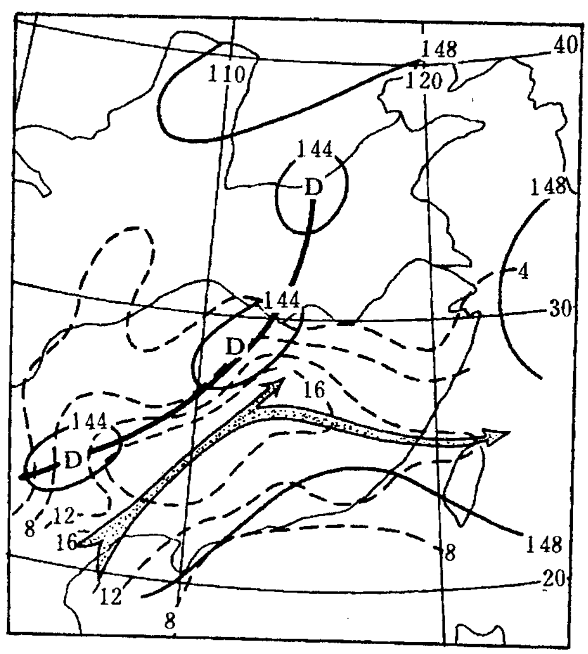


Figure 2-17. The 850 mb Weather Map at 0000 UTC, 16 May 1977. The solid lines are isopleths of geopotential height (decameters), the dashed lines isotachs, and the double arrow the jet axis. "D" indicates a disturbance.Units: m s^{-1}.

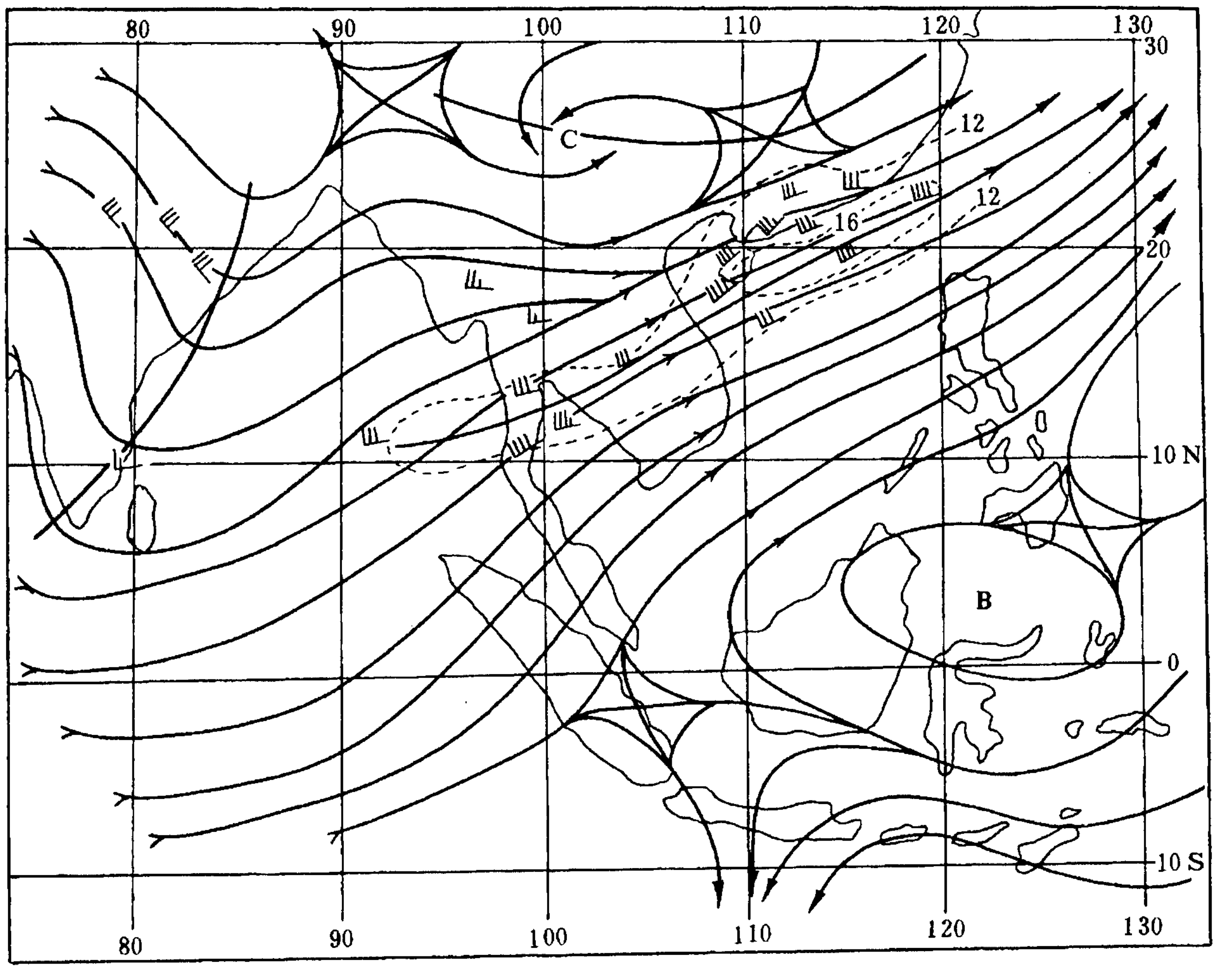


Figure 2-18. The Streamline Chart at 0000 UTC, 30 May 1977. The dashed line denotes isotach. "B" indicates a bubble high. Units: m s^{-1}.

Mid- and Upper-level Flow Patterns

Figures 2-19 through 2-22 show January, April, July and October mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels. Spacing of the vertical lines on these figures indicates elevation (tighter spacing for higher elevations).

High pressure dominates the region at the 850-mb level during January (Figure 2-19) with high-pressure centers located over Mongolia and off the southeast coast of China. The southerly winds situated to the west of the high off the coast of China pull warm air over southern China and induce a baroclinic zone. This zone causes the strong cold surges typical of the winter monsoon. A high-pressure ridge is present at 700 mb, while strong westerly winds dominate at the upper levels (500 and 200 mb). The subtropical ridge is located at its southernmost position.

By April, the transition to the summer monsoon is under way (Figure 2-20). There is a weakening in the high-pressure area over the mainland at the 850-mb level and the subtropical ridge has begun its northward movement. Strong westerly winds are still present at the upper levels, but they begin to recede to the north.

July's pattern (Figure 2-21) shows the summer monsoon has set up over the region. A southerly wind flow has established itself over the region in the lower levels. The subtropical ridge axis is located around 30° N through 500 mb. The upper-level westerlies have receded and weakened, while at 200 mb, the Tibetan high has set up along with the tropical easterly jet.

October's pattern (Figure 2-22) shows the beginning of the transition to the winter monsoon. High pressure begins to set up at the 850-mb level. The subtropical ridge axis has begun its southward movement. The upper-level westerlies are beginning to strengthen once again as they expand southward. At 200 mb, the Tibetan high has been displaced and the tropical easterly jet has dissipated.

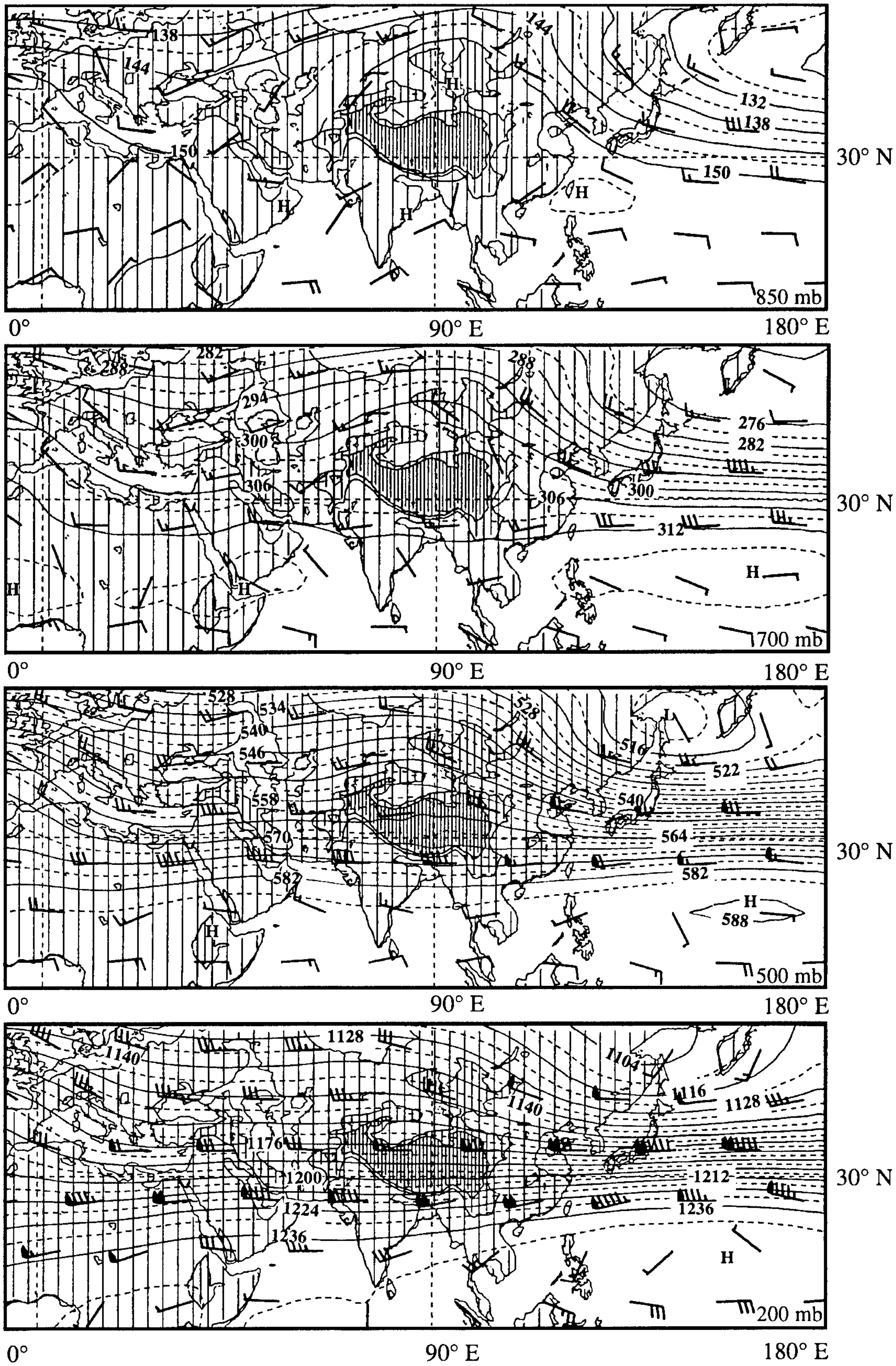


Figure 2-19. January Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

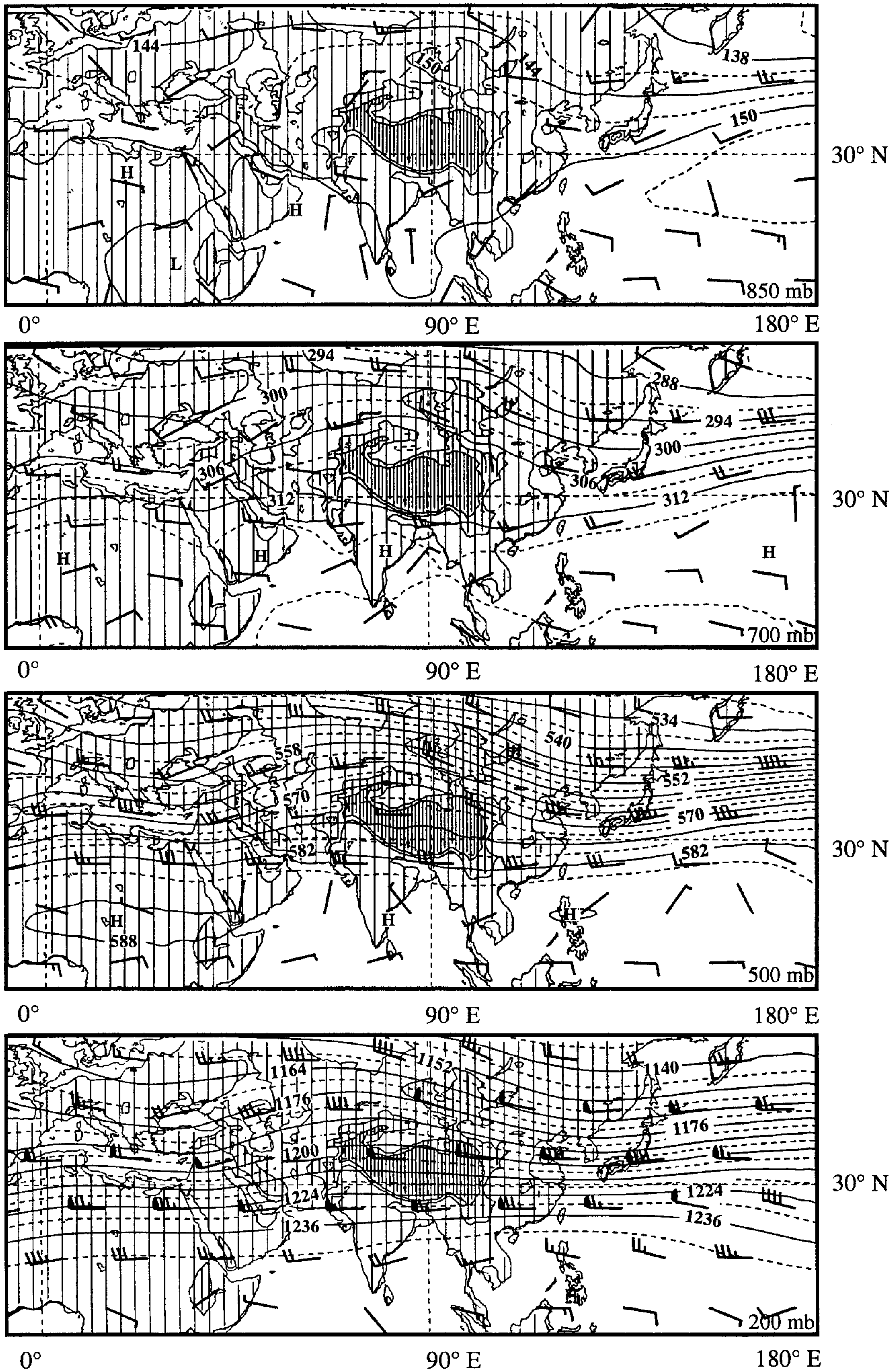


Figure 2-20. April Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

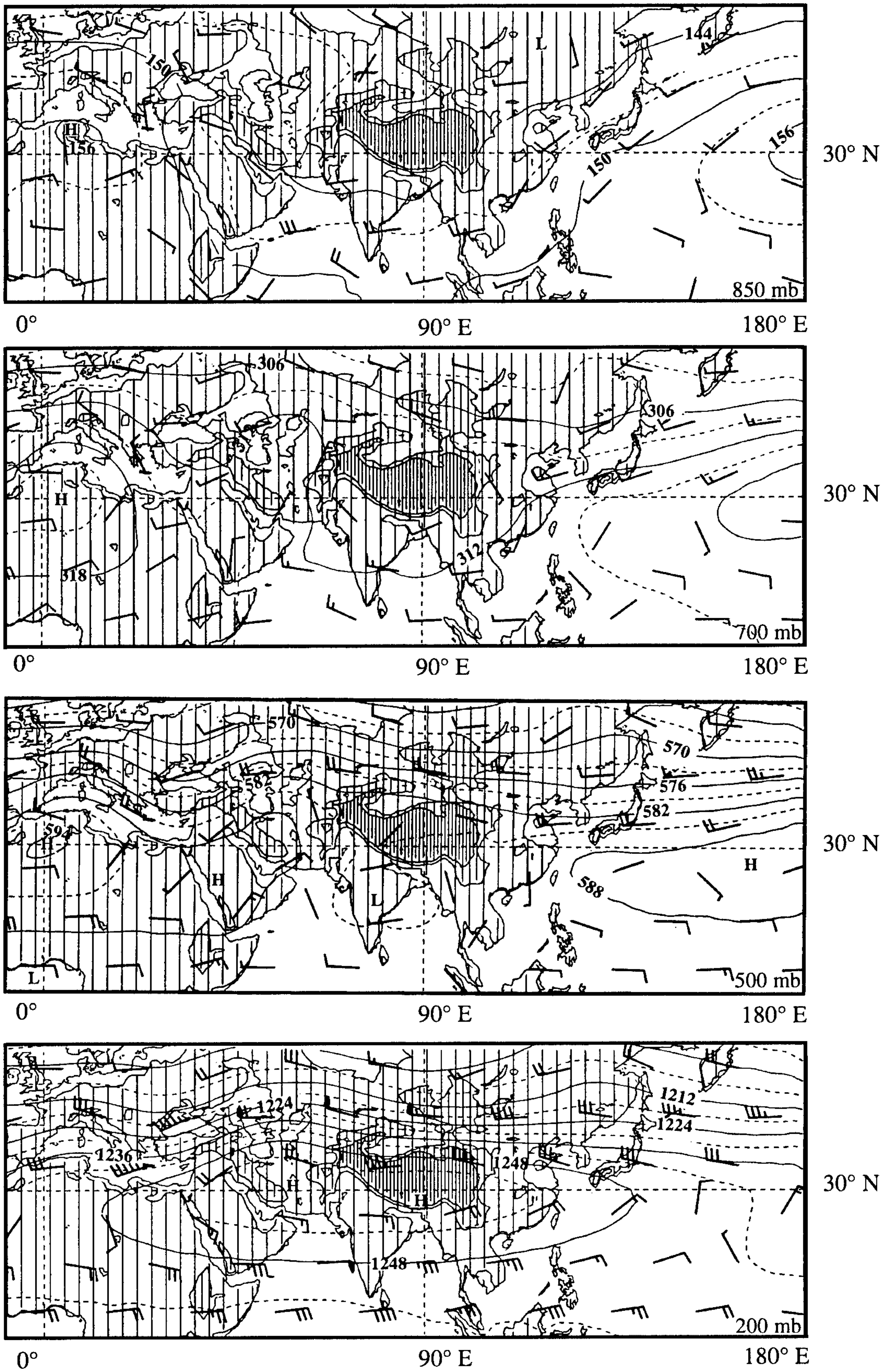


Figure 2-21. July Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

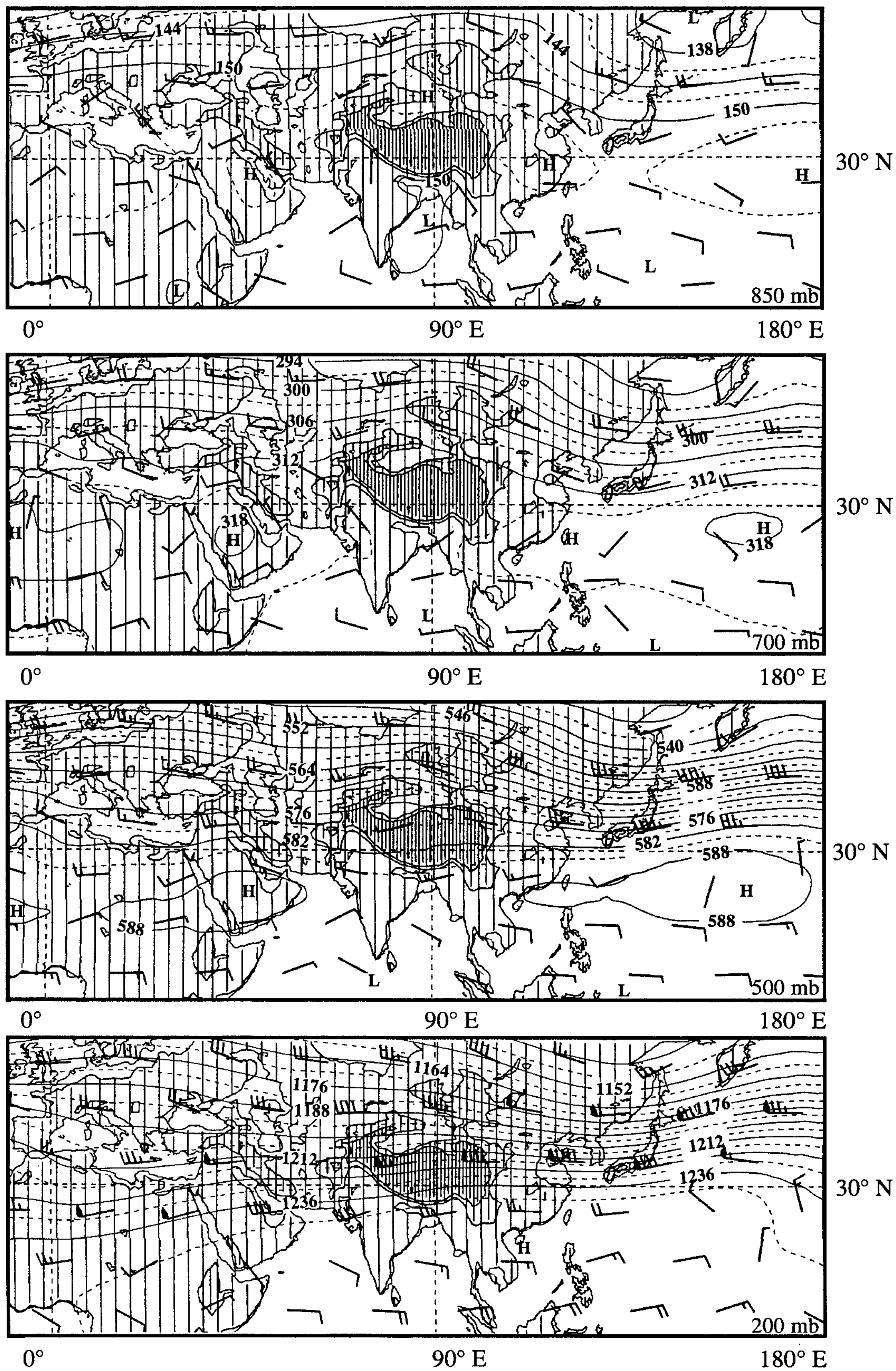


Figure 2-22. October Mean Upper-Air Climatology. The figure shows mean geopotential height (dkm) and vector mean wind (knots) data at the 850-, 700-, 500-, and 200-mb levels.

Subtropical Ridges. Subtropical ridges are upper-level features north and south of the equator with easterly flow between them. Mean annual positions are at 15° N and 10° S, centered at about 130° E, and these ridges move north-south together with the sun. The ridges are important as they provide outflow for the NETWC and tropical cyclone convection, and they provide a steering mechanism for tropical cyclone movement. Ridge movement is also one of the components needed for the transition between winter and summer monsoons (southward for winter, northward for summer). Ridge location can also impact rainfall during the summer monsoon. Studies have shown that droughts can occur over the Asian continent, particularly northern China, if the subtropical ridge positions itself farther west and/or to the south than normal. This abnormal movement cuts off the inflow of the moist, warm air into the region.

The subtropical ridge sometimes forms anticyclonic cells over the region, similar to the one seen in Figure 2-23 at 200 mb. The position and strength of these cells depend upon the strength and position of the tropical upper-tropospheric trough (TUTT).

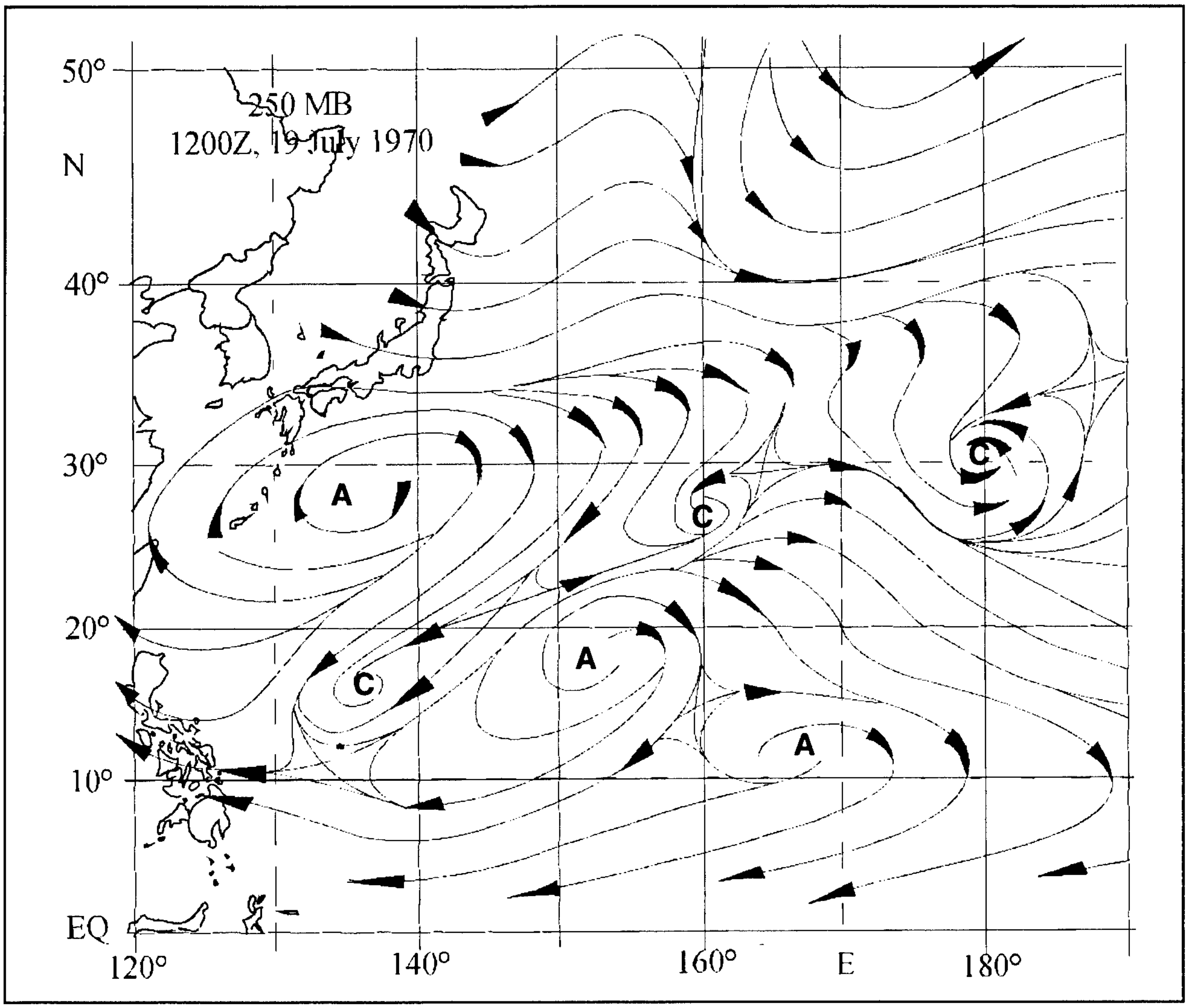


Figure 2-23. Streamline Analysis of the 200-mb winds for July. The figure shows an active TUTT. The "A" indicates an anticyclonic circulation and the "C" indicates a cyclonic circulation.

Tropical Upper-Tropospheric Trough (TUTT). The TUTT is a buffer zone between two cells of the subtropical ridge. The TUTT enhances the upper-level divergence needed for monsoon rains. It also enhances the development of typhoons by diverting the upper-level westerlies away from a developing system. An inactive TUTT has an east-west orientation, but takes on a southwest-northeast orientation when it becomes active (see Figure 2-23). When active, it is associated with extensive convective cloud systems. During active periods, two TUTTs tend to form in the Pacific. In the western Pacific, the active TUTT does not have a link with mid-latitude systems.

Tibetan High. The Tibetan high intensifies the easterlies to the south of the Himalayas, creates the tropical easterly jet, and provides the upper-air divergence needed for the summer monsoon rains. Normally found at the 200-100 mb level, it is formed in April when a high-pressure cell, formed over the South China Sea, migrates northwestward to the Tibetan Plateau. Figure 2-24 shows the mean positions in July and August. A heat low forms on the Tibetan Plateau's surface at about the 600-mb level, surrounded by a ring of highs along the plateau's rim. The high is maintained by the plateau's intense heating, latent heat release from the summer monsoon rains, and by dynamic interaction with the subtropical ridge that can cause its position to vary. If the Tibetan high's position shifts east of 90° E, severe drought over East Asia results. The Tibetan high appears to oscillate every 10-16 days.

The northwestward movement of the Tibetan high is one of the requirements for the establishment of the summer monsoon. A 1987 study of this movement shows an example of how the process works. The numbers in Figure 2-25 represent 5-day periods that start 16 April 1987 and end 4 July 1987. The abrupt northward movement during Period 6 (11-15 May) coincided with the onset of the summer monsoon. The establishment of the high over the Tibetan Plateau took place during Period 14 (20-25 June) which corresponded well with the rapid heating of the plateau. After this period, the path of the anticyclone splits. A portion retreats westward and a portion moves eastward By Period 16, the Tibetan high broke into two cells, one over central China, the other over northern Iran.

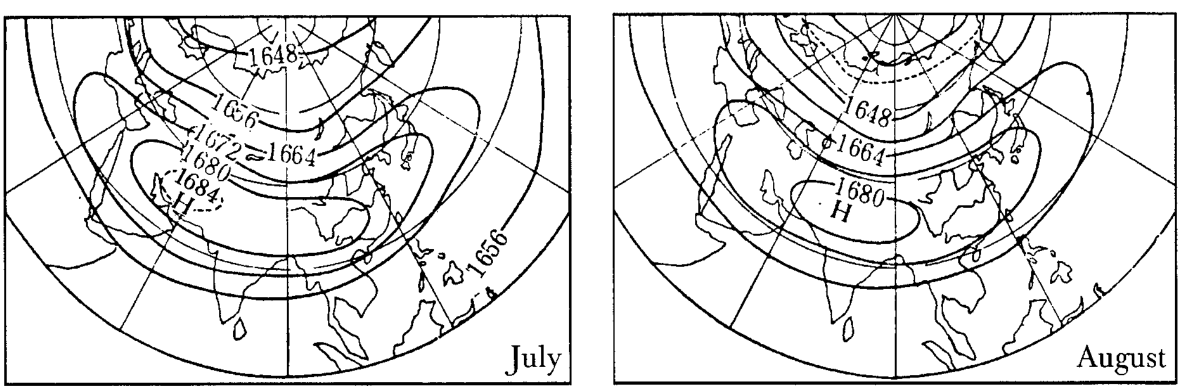


Figure 2-24. The monthly mean 100-mb charts in July-August, 1956-1970.

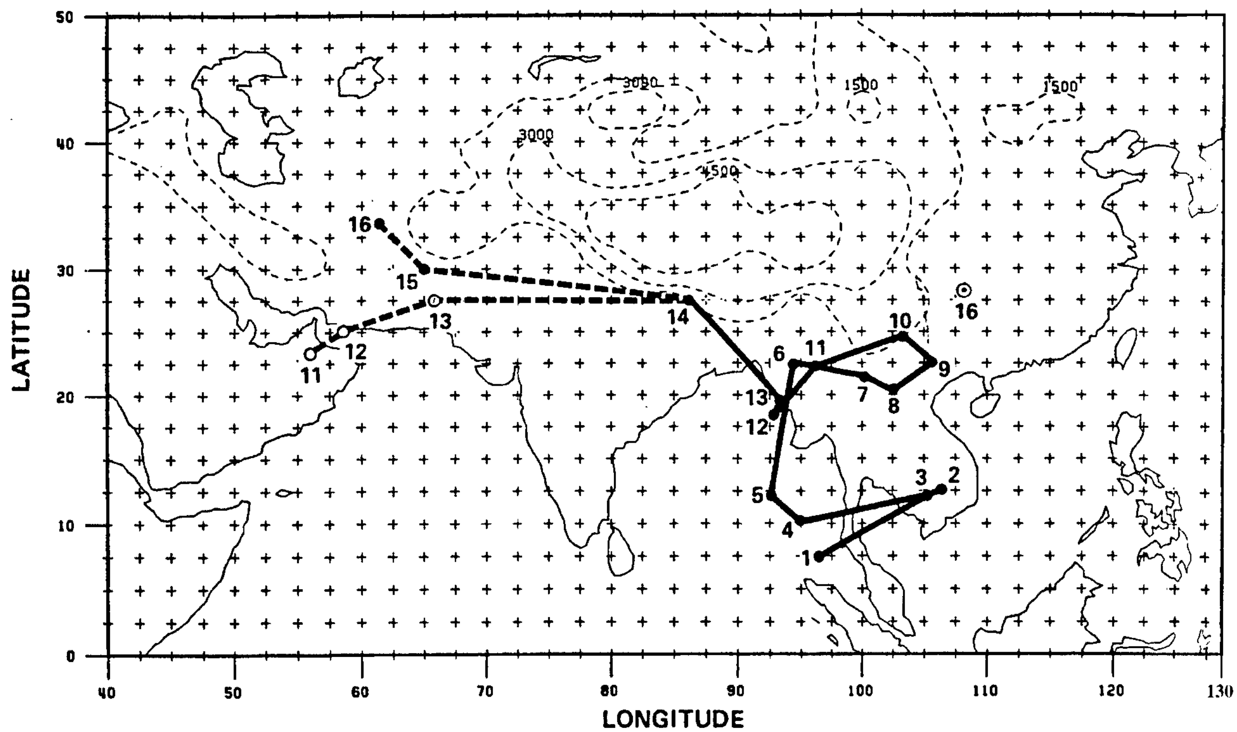


Figure 2-25. Mean Positions of the Tibetan Anticyclone at 200 mb 16 April-4 July, 1979. See Table 2-1 for meaning of numbers.

Table 2-1. Sequence of Events for Development of Tibetan High.

Period	Inclusive Dates	Action
1	16 April - 20 April	Tibetan High developed over southeastern Bay of Bengal.
2	21 April - 25 April	High moved northeastward to position over Vietnam.
3	26 April - 30 April	High remained over Vietnam.
4	1 May - 5 May	High moved westward over Bay of Bengal; low-level southwesterlies developed over Southeast Asia.
5	6 May - 10 May	Sudden temperature increase over eastern Tibetan Plateau; high drifted northwest.
6	11 May - 15 May	High abruplty moved northward to position over Myanmar; southwesterlies intensify; summer monsoon began.
7	16 May - 20 May	High shifted eastward to position over Indochina.
8	21 May - 25 May	High drifted southeastward.
9	26 May - 30 May	High drifted northeastward.
10	31 May - 4 June	High moved northwestward over southern China; 200 mb easterly wind flow developed over Indian Ocean.
11	5 June - 9 June	Western center developed over eastern Saudi Arabia; eastern center moved southwestward to position over Myanmar.
12	10 June - 14 June	Western center moved slowly northeast; eastern center moved to Bay of Bengal.
13	15 June - 19 June	Western center moved east to position over Iran; eastern center moved back over Bay of Bengal.
14	20 June - 24 June	East and west centers merge over northern India due to Tibetan Plateua heating
15	25 June - 29 June	High continued westward movement to position over Iran.
16	30 June - 4 July	Tibetan high splits into two cells - one over central China, the other over northen Iran. Tropical Easterly Jet is established.

Mid-Latitude Disturbances

Polar Front. Figures 2-26a and 2-26b show the mean position of the polar front in January and July. The polar front in January coincides with position of the subtropical westerly jet stream, which reaches very high wind speeds over eastern Asia in January. It also marks the southern boundary of the winter monsoon. During the summer, the polar front marks the northern boundary of the summer monsoon.

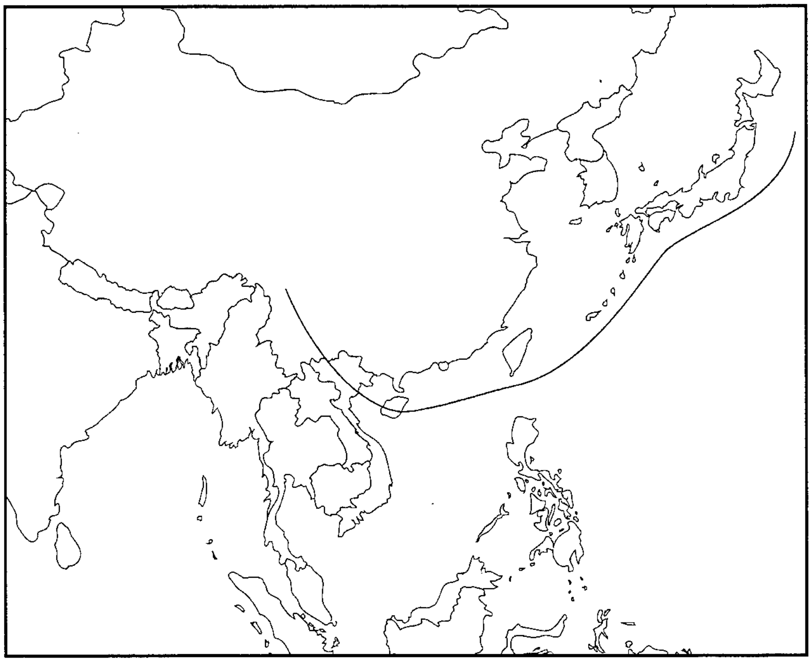


Figure 2-26a. Mean Polar Frontal Position in January.

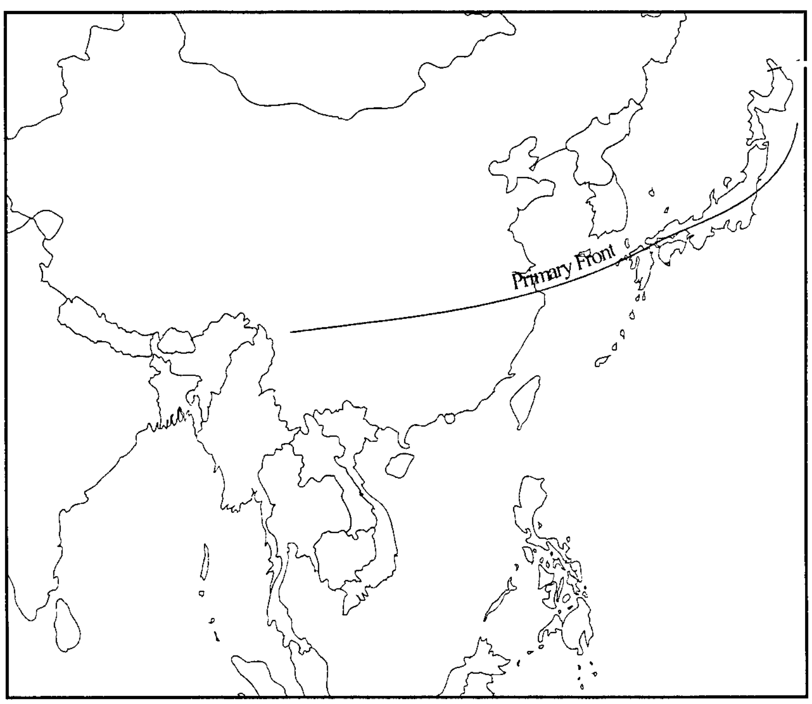


Figure 2-26b. Mean Polar Frontal Position in July.

Cyclogenesis/Storm Tracks. The low-pressure systems affecting the region have their origins on the lee side of the Tibetan Plateau over China and Mongolia. After formation, the upper-level westerlies tend to steer the lows eastward out of the region along one of four tracks, which are named for the low-pressure systems that frequent them (See Figure 2-27).

The lows are classified by their places of origin. Table 2-2 lists these four types of lows, their mean seasonal frequency of occurrence, and the corresponding track numbers for Figure 2-27. The different types of lows vary considerably, both annually and seasonally. The maximum number of lows occur in the spring, the minimum in winter as the strong Asiatic high often suppresses low pressure system development until the disturbances reach the coast. The northeast China lows, related to the upper westerly troughs in the polar jet stream, are most prevalent and account for 45 percent of the total cases. They originate near Lake Baykal, in Mongolia and Nei Mongol, or in northeast China. They move east-southeastward and usually reach their peak over northeast China. They tend to weaken and continue their eastward movement to the Sakhalin Island or the Sea of Okhotsk. The Huanghe River lows occur the least. They originate at the Great Bend, along the lower reaches of the Huanghe River or over the North China Plain. These lows move eastward across Korea into the Sea of Japan. A few move through Northeast China to Sakhalin Island. The Yangtze-Huaihe lows originate over the middle and lower reaches of the Yangtze-Huaihe rivers. Most of these lows move eastward to the East China Sea. A few move northeastward across Korea and the Sea of Japan. These lows are generally weak in the formative stage with only a frontal wave or 1-2 closed isobars when over the mainland. However, when they move out over the East China Sea, rapid intensification occurs, and they finally develop into active Aleutian low-

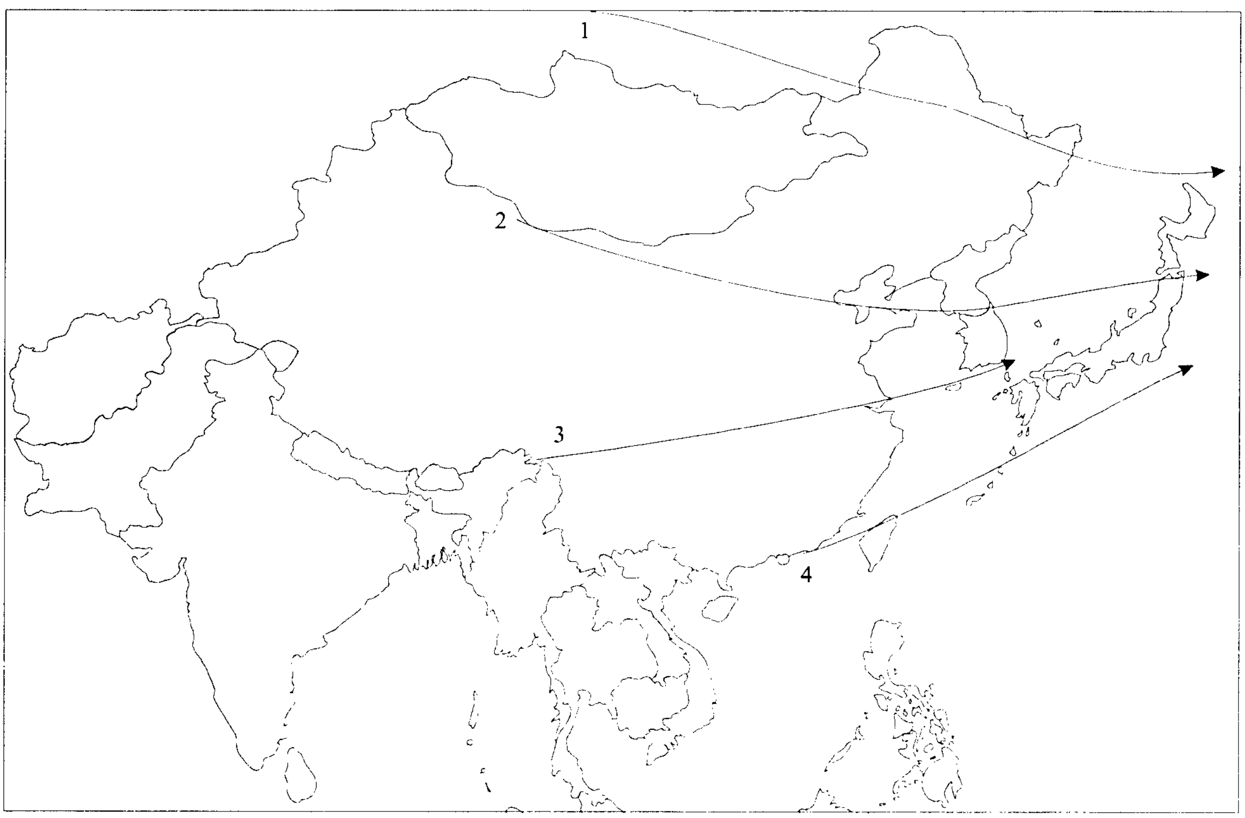


Figure 2-27. Main Storm Tracks Affecting Eastern Asia. 1. Northeast China, 2. Huanghe River, 3. Yangtze-Huaihe, 4. East China Sea

Table 2-2. Mean Seasonal Frequencies of Low-Pressure Systems.

Low Type	Spring	Summer	Autumn	Winter	Year
Northeast China	16	10	16	8	50
Huanghe River	1	4	2	2	9
Yangtze-Huaihe	10	8	4	5	27
East China Sea	9	1	6	8	24
Total:	36	23	28	23	110

pressure centers. Finally, the East China Sea lows are the most southerly. They originate in the Chinese mainland, and they track east-northeastward towards the southern coast of Japan.

Northeast China and Huanghe River low-pressure systems usually develop along a northern frontal zone while the Yangtze-Huaihe and East China Sea systems develop along a southern frontal zone. The northern and southern lows can develop alone or in pairs (see Figure 2-28).

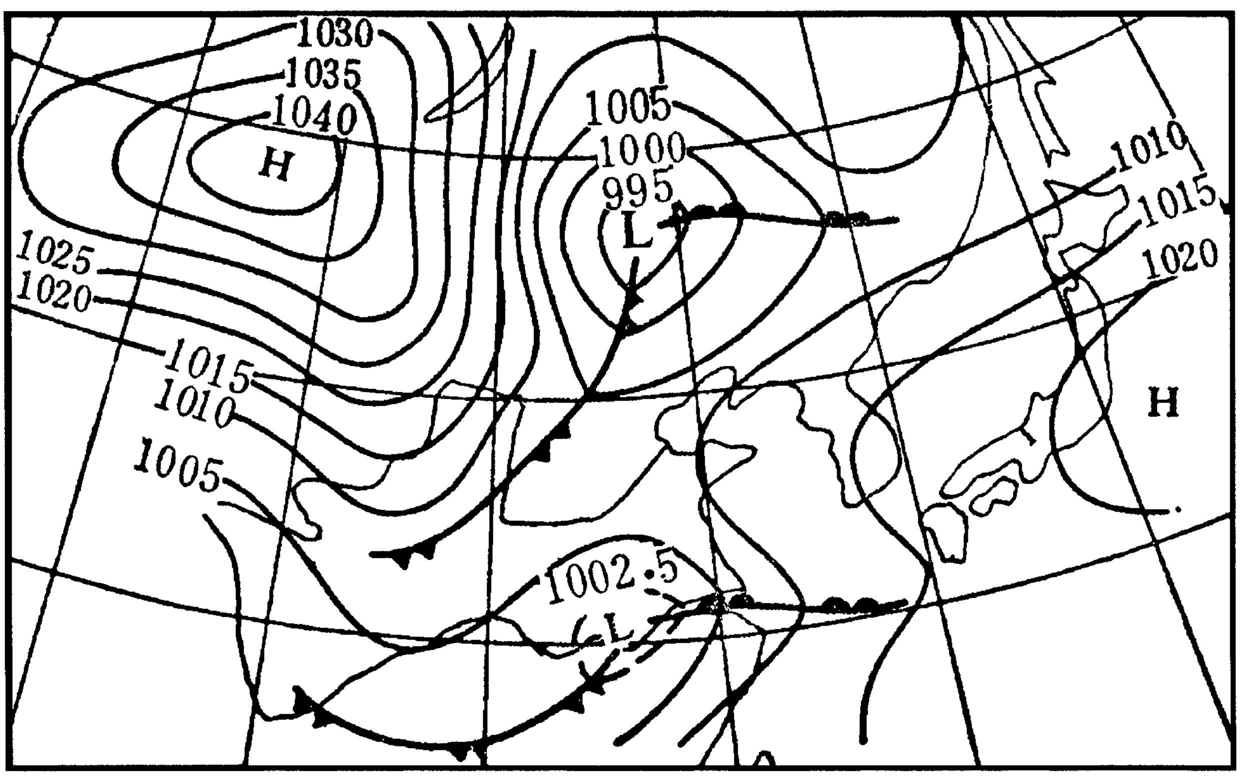


Figure 2-28. Surface Weather Map at 0000Z, 5 April 1958.

Explosive Cyclogenesis. Off the eastern coast of the Asian continent there often exists an explosively deepening low-pressure system. This type of system primarily occurs during the cold season, but it is capable of developing year-round. Known as a "meteorological bomb," this system is defined as a developing low with a deepening rate of at least 12 mb in 12 hours at 45° N. At the same time, the low's wind speed rapidly increases to 60 knots or greater. A pronounced frequency maxima of explosively deepening lows occur in the westernmost portion of the Pacific Ocean within and just to the north of the Kuroshio warm water current.

A study on explosive cyclogenesis indicated a relationship between the intensity of an explosive deepening low and latitude (see Figure 2-29). The lows which undergo the greatest explosive cyclogenesis tend to be centered around 40° N, where there is a strong confluent upper-level jet.

The numbers within the bars on the graph is a bergeron number, which is a measure of the amount of deepening a low-pressure system undergoes in a 24-hour period. One bergeron is equivalent to a pressure drop of 24 mb per 24 hours at 60° N. Since the bergeron value is a function of latitude, Φ, you must multiply the bergeron value by (sin Φ /sin 60°) in order to obtain the geostrophically equivalent rate for different latitudes. Table 2-2 converts the bergeron numbers in the figure to pressure values in mb/24 hrs. Included is the 1 bergeron value for the specified latitude.

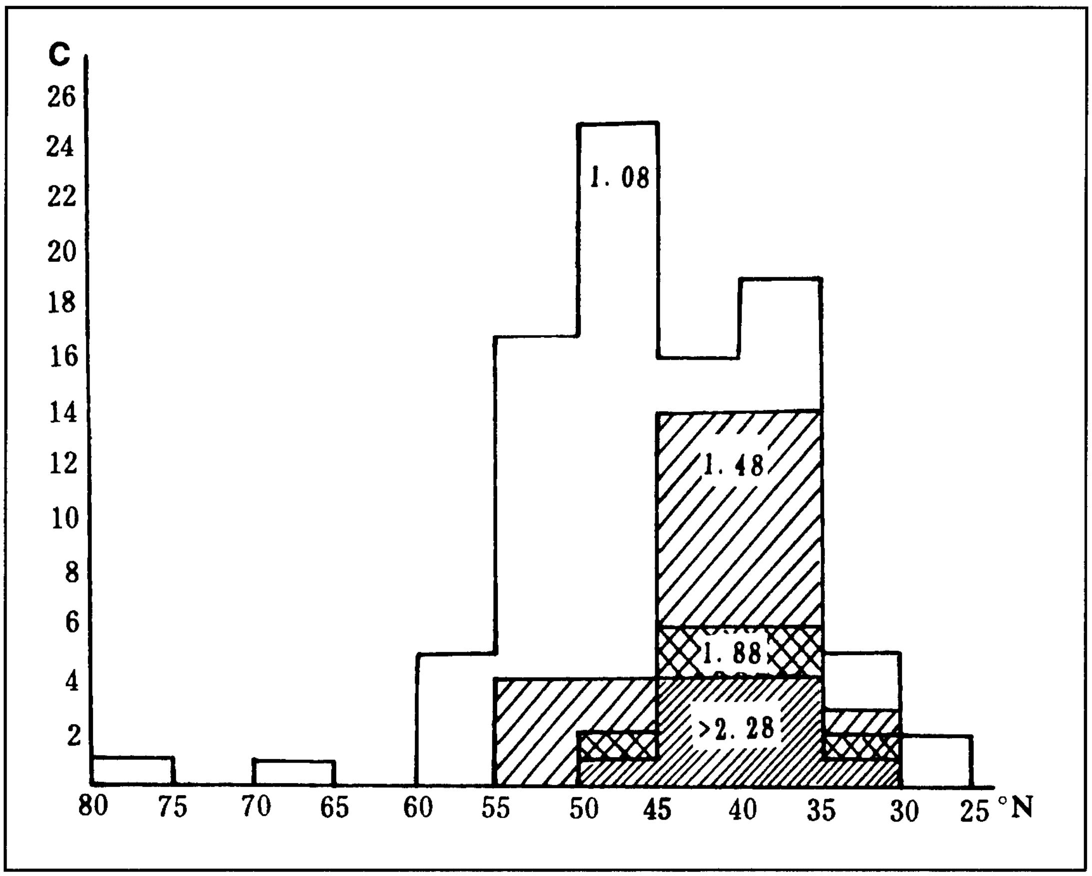


Figure 2-29. The Relationship between the Intensity of the Explosive Marine Cyclone and Latitude. The relationships are valued for the study area. C = number of cyclones.

Table 2-3. Bergeron to Pressure Drop (mb/24 hr) Conversion Chart for Figure 2-29.

	25 N	30 N	35 N	40 N	45 N	50 N	55 N	60 N	65 N	70 N	75 N	80 N
1	12	14	16	18	20	21	23	24	25	26	27	27
1.08	13	15	17	19	21	23	25	26	27	28	29	29
1.48		21	24	26	29	31	34					
1.88		26	30	33	37	40						
2.28		32	36	41	45	48						

Example: At 40° N, Figure 2-29 indicates that an average of four low-pressure systems per year will undergo a rapid deepening greater than 2.28 bergeron. Table 2-3 indicates this is equivalent to a deepening of 41 mb in a 24-hour period.

Explosive cyclogenesis is usually found about 400 nautical miles downstream from a 500-mb trough, which typically moves across the upwind continent for several days before triggering the surface event. The explosive cyclogenesis almost always occurs north of the main belt of westerlies and within or ahead of the planetary scale trough. Other criteria for explosive cyclogenesis includes the following:

- An intense baroclinic zone;
- An adequate supply of warm, moist air;
- The presence of a low-level jet; and
- An area of strong sea-surface temperature gradient.

The ocean area adjacent to the Asian mainland meets these criteria. It is highly baroclinic as it has a large vertical wind shear due to the strong wintertime jet maximum and frequent outbreaks of cold, arctic air. The western flank of the western Pacific subtropical high provides the moisture and the presence of a low-level jet with a mean intensity of 40 knots. The Kuroshio Current, situated south of Japan, is a warm water current that provides the strong sea-surface temperature gradient, the final ingredient.

Kunming Quasi-Stationary Frontal Zone. A common feature during the winter in China's eastern Sichuan Province, the Kunming frontal zone develops when cold air from the Asiatic high is blocked by the north slope of the Nanling Mountains, the Yunnan Plateau, and the east slope of the Qinghai-Tibet Plateau. The front separates the northeast Asian cloudy, wet, and cold polar air from the warm, dry west-southwesterly southwestern Asia air flow. Predominately northeast low-level winds occur on the east side of the front, and the winds veer to the west-southwest with altitude. Winds to the west of the front are predominately from the west-southwest at all levels. Figure 2-30 represents a typical location for the Kunming quasi-stationary frontal zone.

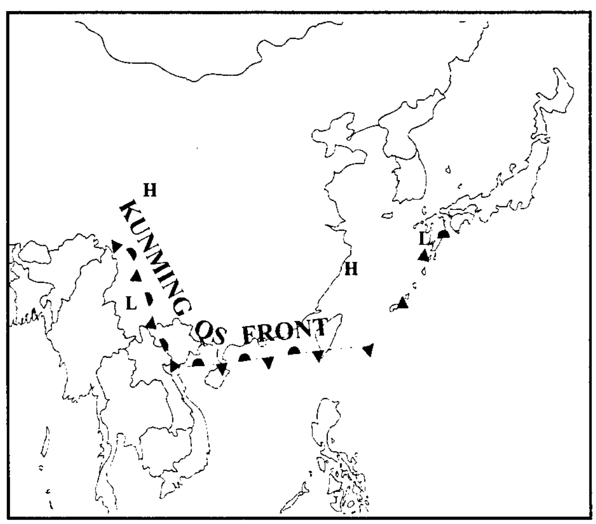


Figure 2-30. Typical Location for the Kunming Quasi-Stationary Frontal Zone.

Cold Surges. Cold surges are the most prevalent weather events that occur over East Asia during the winter monsoon. They occur at intervals of 4 to 20 days. Cold surges bring extremely dry and cold weather over Mongolia, China, and Korea. The associated weather includes high winds, abrupt temperature drops, severe frost, freezing rain, heavy snow, and even sandstorms.

A close relationship exists between the intensity of the Asiatic high and the severity of the cold air surges. One can generally expect a cold air outbreak when the Asiatic high builds up to considerable intensity. A study found that cold air outbreaks were likely to occur if the surface pressure of the high exceeded the mean surface pressure by at least 10 mb. Table 2-4 contains the statistics of the Asiatic high's central sea level pressure for a 22 year period, collected from a region bounded by 45-55° N and 90-105° E. The data shows that cold surges are most common from November to January when the Asiatic high is most intense.

Since cold surges are most prevalent in the shallow layer below 700 mb, their movement is dictated, in part, by the topography of the continent. Despite this, the key to the initiation of the cold air surge is an event that takes place in the upper-level westerlies. It begins with the establishment of a northwesterly flow over the Lake Baykal region. A short upper-tropospheric trough moves eastward towards the longwave trough along East Asia's coast. As the shortwave trough passes through the longwave trough position, it intensifies and initiates surface cyclogenesis over the East China Sea. The cyclogenesis, through thermal advection, begins to intensify the Siberian high. As the surface low intensifies, the pressure gradient between the low and the Asiatic high increases and initiates a cold surge. A strong cold front develops ahead of the surge and pushes southward. The front is accompanied by a steep rise of surface pressure, a sharp temperature drop, and a strengthening of the northerly winds. Winds associated with the fronts can reach speeds in excess of 40 knots. As the cold front moves beneath the jet stream, it generates a lot of weather. Since the jet seldom shifts southward with the front, the front quickly dries out when it reaches the subsident region south of the jet.

When the cold surge begins, the centers of the highs

Table 2-4. The Statistics of Central Sea-Level Pressure of the Asiatic High for Period 1958-1979.

Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Mean SLP (mb)	1036	1045	1051	1052	1049	1041	1032
Max SLP (mb)	1057	1075	1087	1085	1081	1074	1076
Mean # Days > 1050 mb	0.8	4.9	9	10.6	7.6	2.6	0.5
Mean # Days > 1060 mb	0	1.4	4.3	4.4	2.7	0.5	0.1
Mean # Days > 1070 mb	0	0.1	1.1	1.1	0.6	<0.1	<0.1
Mean # Cold Surges **	NA	4	4.6	4.3	3.1	1.4	NA

Notes: ** denotes data period of 1978-1985; NA denotes data not available.

tend to move along one of three main tracks (see Figure 2-31). Each of these tracks first show a southward movement then an eastward turn towards Japan. Cold air, branching off of the tracks, pushes the cold front southward along the eastern periphery of the Tibetan Plateau. These surges quite often reach the South China Sea. Early in the winter monsoon, these surges can generate considerable convective activity (associated with the cold air moving out over the still warm ocean). Otherwise, the cold surge tends to enhance the northeast trade winds for about 3 to 4 days after the onset of the surge. As a result, convection occurs over the western Pacific Ocean.

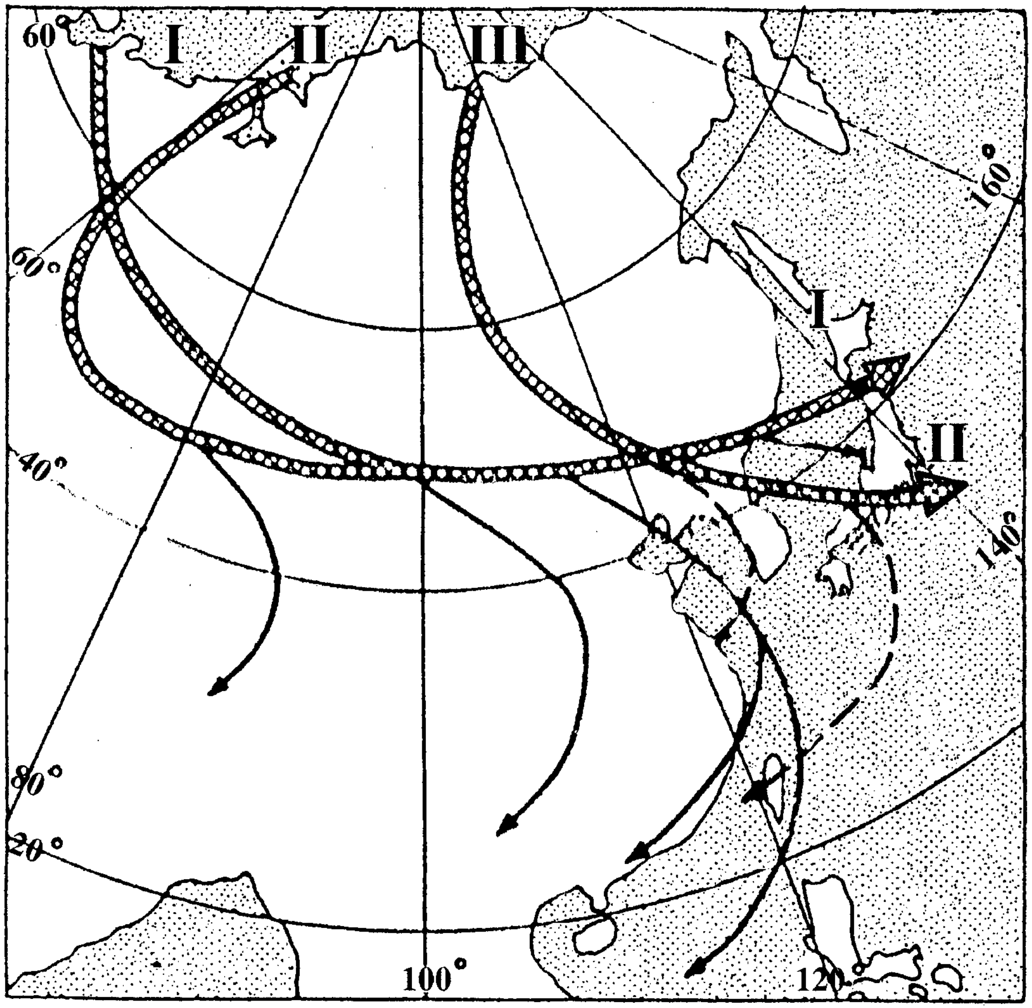


Figure 2-31. Main Tracks of Cold Surges. Large arrows show the primary tracks of the centers of high pressure associated with cold surges. The smaller arrows show cold air branching off of the main tracks.

Subtropical Disturbances

Mei-yu. The mei-yu (also called the mei-yu front) is a quasi-stationary belt of heavy rainfall that begins over southern China and moves slowly northward during the transition from the winter monsoon to the summer monsoon. The rain belt generally lasts in a stationary location for a month or less before moving slowly northward to another location. It usually begins over southern China during May, moves over Taiwan from May 15 to June 15, then moves over the Yangtze River valley in central China from June 10 to July 10 where it is given the name "mei-yu." The rain belt stretches eastward and extends toward Japan. It is associated with a quasi-stationary front whose cloud band extends from northeast to southwest. Rainfall develops along the front. The front is formed when the warm, moist monsoon air intersects with cold air being advected southward by eastward moving mid-latitude disturbances north of the region.

The characteristics of the mei-yu include heavy rain with periods of extremely heavy rain, high relative humidity, considerable cloudiness, and weak winds. Most of the rain falls on the warm side of the front. The rainfall is not only continuous, but it is also convective, with thunderstorms that can be huge, persistent, and stationary on the front. The thunderstorms are sustained by a combination of the upper-tropospheric divergence and lower-tropospheric convergence of the summer monsoon.

As mentioned earlier, the mei-yu occurs during the transition to the summer monsoon. Its movement is determined, in part, by the movement of the axis of the subtropical ridge. Before the onset of the transition, the subtropical ridge axis is situated south of 16° N. In early May, the ridge axis moves to 18° N. A heat low establishes itself on the continent and the cross-equatorial flow intensifies at 105° E. At 200 mb, the tropical easterlies appear over the northern portion of the South China Sea, while the southwesterly monsoon and a low-level jet prevails over the South China Sea at the lower levels. Rainfall suddenly begins over South China.

By mid-June, the ridge axis advances northward to 20-25° N. The quasi-stationary front over southern China moves northward in response to the ridge axis movement and sets up over the Yangtze River valley in central China, bringing heavy rain to that region. As the quasi-stationary rain belt moves north, the heavy rainfall over southern China ends abruptly. Also, at 200 mb, stable easterlies set up over Hong Kong, which is a criteria for the termination of heavy rain for southern China.

By mid-July, the subtropical ridge axis moves north of 25° N; it pushes the leading edge of the summer monsoon to 30° N. The heavy rain belt over the Yangtze River valley moves north of the Yellow River. It initiates the heavy rain period for northern China and signals the end of the mei-yu for central China.

When the mei-yu front is above the Yangtze River valley, mesoscale cyclonic vortices, which originate over western China, periodically move eastward along the front. These vortices bring thunderstorms and heavy rainfall to the valley. Although these vortices are very difficult to detect in surface pressure fields, they are very pronounced in the wind fields. The strong convection and the heavy rainfall is usually found in the southeastern quadrant of the vortices. Also, the temperature contrast across the front is small, but there is a marked moisture tongue near the frontal zone.

South of the front, a strong ageostrophic low-level jet situated between 1.5 and 3 km often exits (see Figure 2-32). This jet, which represents the wind maximum in the southwesterly monsoon, is an important mechanism in the occurrence of heavy rainfall along the front. Studies have shown that this jet has an excellent relationship with the heavy rainfall (a positive correlation coefficient of 0.8). The heaviest rain can be found in the left-front quadrant of the jet axis. The jet transports the needed momentum, heat, and moisture into the region for the heavy rainfall to occur.

There appears to be a relationship between the intensity of the summer monsoon and the amount of rainfall in the Yangtze River valley of central China. A study was done to calculate the correlation coefficients of this relationship and found that the correlation in regions to the north of the Huai River and in southern China were negative. In other words, if there is a strong monsoon, the rain belt would quickly move from southern to northern China and not remain over the Yangtze River valley. This scenario would lead to a below normal rain event for the valley and possibly lead to a drought. On the other hand, if the monsoon is weak, the mei-yu will remain over the Yangtze River valley for a longer than normal time period and lead to above normal rainfall. Table 2-5 contains a summary of 27 years of rainfall data for Nanjing, China, which is located north of the Yangtze River valley. The data was analyzed for the beginning and end of the mei-yu. The data in the table supports a correlation between the intensity of the summer monsoon and the amount of rainfall. The longer the mei-yu persists over the region, the greater the amount of rainfall. This is critical as the region depends upon the mei-yu for it summer rainfall needs.

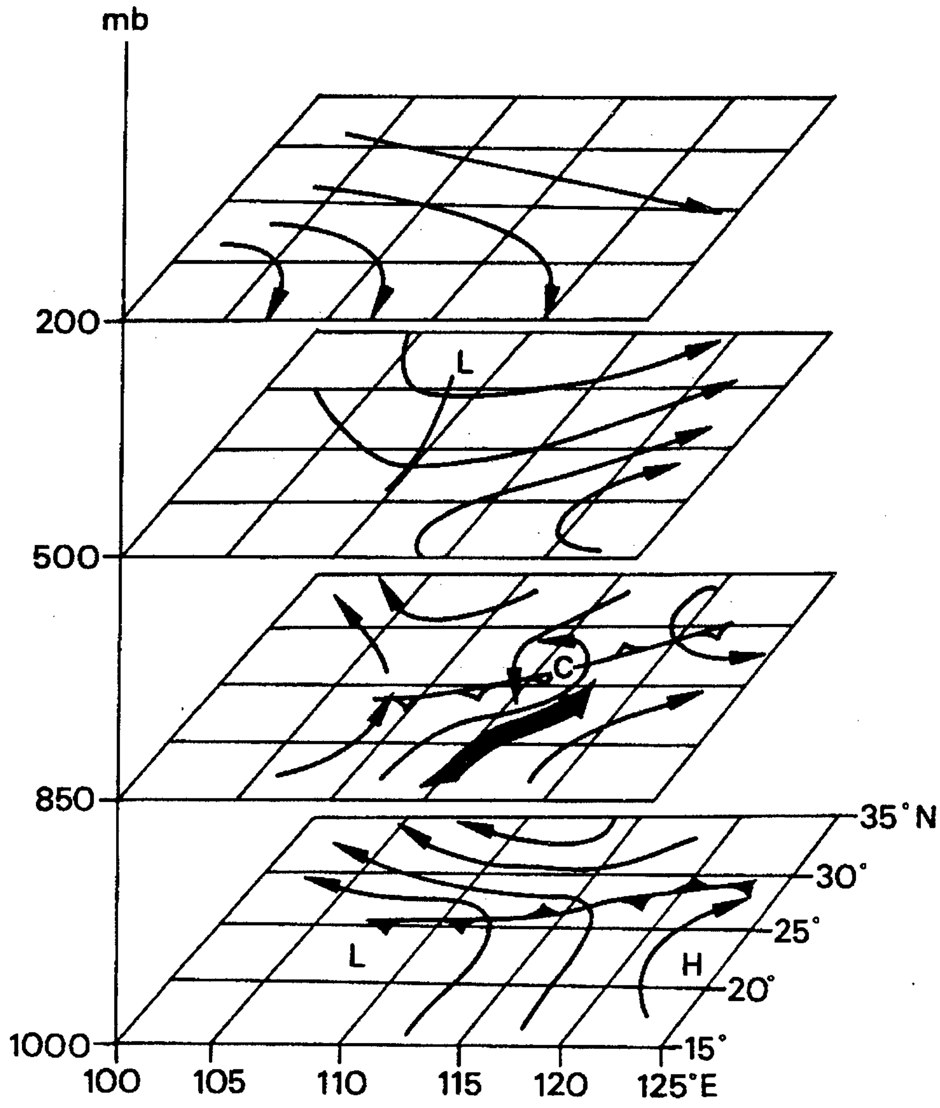


Figure 2-32. Schematic Flow Pattern during Heavy Rainfall in South China in May and June. Thick arrows show the jet stream.

Table 2-5. The Mei-yu Features in Nanjing, China (32° N, 118.47° E).

Year	Start Date	End Date	Duration (Days)	Total Rainfall	Total Rainfall June-July (in)	Year	Start Date	End Date	Duration (Days)	Total Rainfall	Total Rainfall June-July (in)
1954	June 23	July 30	38	24.54	29.67	1968	June 24	July 20	27	8.21	9.04
1955	June 23	July 13	21	7.53	9.93	1969	June 30	July 18	19	23.37	25.8
1956	June 3	July 19	47	19.39	19.49	1970	June 17	July 20	26	9.9	12.19
1957	June 30	July 12	13	5.89	18.61	1971	June 9	July 26	18	9.02	18.87
1958	June 26	July 29	4	2.33	6.88	1972	June 20	July 4	15	16.13	19.02
1959	June 27	July 6	10	4.15	9.71	1973	June 16	July 29	14	4.96	13.57
1960	June 18	July 29	12	4.11	10.06	1974	June 9	July 18	16	10.58	22.92
1961	June 6	July 17	12	6.1	8.97	1975	June 16	July 18	33	19.04	22.15
1962	June 16	July 9	24	13.07	15.14	1976	June 16	July 15	30	10.45	13.5
1963	June 22	July 29	8	4.45	12.55	1977	June 28	July 21	24	5.74	7.95
1964	June 24	July 1	8	4.91	10.52	1978	June 24	July 26	3	0.95	4.97
1965	June 30	July 24	25	4.54	7.14	1979	June 19	July 23	35	13.39	16.83
1966	June 28	July 13	16	5.22	5.94	1980	June 9	July 21	43	18.01	21.03
1967	June 24	July 5	12	5.02	7.4	Mean	June 20	July 10	21	9.67	14.07

Subtropical Cyclone. The subtropical cyclone, also known as the "middle layer cyclone," is a middle-tropospheric disturbance that usually occurs at the subtropical latitudes (15° N-35° N). This phenomena occurs over the South China Sea region at the rate of about three per year, mainly between the months of May and September. About two-thirds (68 percent) occur between July and August. They occasionally move over southern China and Taiwan where they can trigger significant rain events. The average life cycle of a South China Sea subtropical cyclone is 5 days, but some have been known to last between 2 and 11 days. Subtropical cyclones have strong cyclonic circulation between 700 mb and 500 mb, but are hardly detectable at the surface. There is maximum convergence between 400 mb and 600 mb, which is also the zone of greatest pressure gradients and strongest winds. Wind speeds up to 40 knots are detected at 600 mb. These cyclones have a cold core at the low levels with a warm core above. Trade winds prevail at the surface away from the center. A subsidence inversion overlays the trade winds. Trade wind flow is disrupted at the surface closer to the center. The cyclone may or may not develop a surface low.

Subtropical cyclones can produce heavy rainfall with the heaviest bands and the strongest surface winds located hundreds of kilometers from the center. Thunderstorm activity will occur only outside the main circulation. Latent heat released through deep convection may provide sufficient warming to give the subtropical cyclone the appearance of being a typhoon. If given enough time, subtropical cyclones can change into typhoons. Figure 2-33 shows a vertical cross section of a subtropical cyclone.

The development of subtropical cyclones over the South China Sea region can be classified in one of four processes:

- The NETWC-type cyclone, the most frequent type, occurs about 43 per cent of the time. In July and August, the subtropical high lies at its northernmost position while a strong, active NETWC is observed near 15-20° N. The tropical easterlies and the equatorial westerlies are both strong and so is the lower level convergence. There always appears to be a subtropical cyclone near the large horizontal shear or the negative height fall center on the NETWC, the eastern end of the monsoon trough, or at the tail end of the typhoon trough. If the NETWC-type subtropical cyclones form, most would move westward along the NETWC or northward with it. They tend to dissipate as the NETWC dissipates. A few of them could make their way to the Bay of Bengal and transform into a tropical cyclone.

• The cutoff vortex-type cyclone represents about 27 percent of the total. It forms when a eastward moving longwave trough deepens and extends into the low latitudes. The southern part of the trough is then cut off into a low vortex due to cold advection west of the trough before it develops further into a subtropical cyclone. This process generally develops downward from the upper level. It usually dissipates over the continent as very few develop into a frontal low. A few, however, can develop into a tropical depression or a typhoon once they move out over the warm seas.

• The easterly disturbance-type cyclone represents about 21 percent of the total. A steady easterly air current south of the subtropical high prevails at the middle and upper troposphere over the South China Sea during the summer and fall. An easterly disturbance is commonly associated with it. The disturbance moves toward the west. If the equatorial westerlies begin to intensify and propagate eastward because the NETWC is extended eastward, or if the equatorial anticyclone moves northward, the westerly current interacts with the easterly disturbance and causes it to develop into a subtropical cyclone. This type of subtropical cyclone generally moves into the NETWC and dissipates, or moves westward into the Bay of Bengal to merge into a depression. Very few develop into a tropical cyclone.

• The monsoon disturbance-type cyclone is the least frequent type, occurring only 9 percent of the time. During the summer, a low trough region exists from the Bay of Bengal eastward into the South China Sea. When the summer monsoon strengthens and propagates eastward (if a disturbance exists in the low trough region), the lower-level convergence could intensify it into a subtropical cyclone. Sometimes it continues to develop into a tropical cyclone.

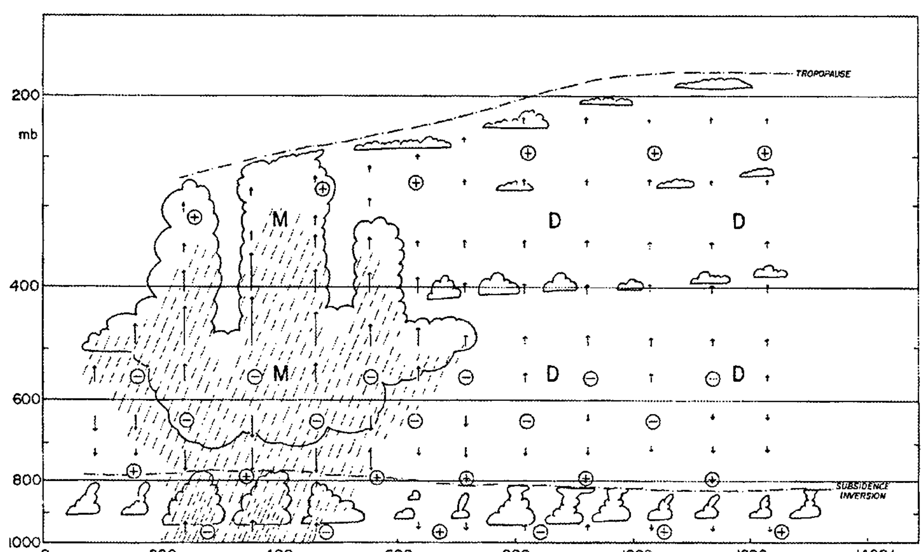


Figure 2-33. Vertical Cross Section of a Subtropical Cyclone. Divergence is indicated by plus signs, convergence by minus signs. Regions of vertically moving air undergoing dry adiabatic temperature changes are denoted by a "D"; regions undergoing moist adiabatic temperature changes are denoted by an "M."

Tropical Disturbances

Tropical Cyclones. Tropical cyclones pose a major threat to most of eastern Asia. An analysis of 33 years of tropical cyclone data shows that about 85 percent of them develop in the NETWC in the western Pacific Ocean east of the Philippines. The rest develop in the South China Sea. Tropical cyclones are synoptic-scale cyclones that develop over tropical waters and have well-organized circulations. They are warm core systems; the center temperature exceeds that of the surrounding environment. Strongest winds are near the surface and decrease with height. In the western Pacific, tropical cyclones fall into three categories depending upon their intensities: tropical depressions, tropical storms, or typhoons.

Tropical depressions are the weakest of the three, with sustained wind speeds near the center less than 34 knots. Wind damage is usually minimal, but heavy rainfall can lead to flooding.

Tropical storms are the next category of tropical cyclones, with sustained wind speeds near the center between 34 and 63 knots. Expect significant wind damage to poorly designed or constructed structures, and major flooding due to heavy rainfall. About 89 percent of the tropical depressions in the western Pacific Ocean develop into tropical storms.

Typhoons are the tropics' most impressive phenomena, and they are known for the destructive potential of their high winds, rain, and storm tides. Sustained wind speeds near the center are at least 64 knots, but some typhoons have attained sustained wind speeds exceeding 150 knots. Typhoons attaining sustained wind speeds of at least 130 knots are called "super typhoons." Widespread and catastrophic wind damage is likely. Damage depends upon the typhoon's intensity upon landfall. Ocean going vessels have reported severe structural damage when caught in a typhoon. Small vessels have capsized due to the heavy seas. Extensive flooding occurs due to the heavy rains and the high storm tides. About 57 percent of the tropical storms in the western Pacific Ocean develop into typhoons.

The western Pacific Ocean is the world's most active tropical cyclone region, annually accounting for over one-third of the world's total. A review of 33 years of tropical cyclone data provided by the Joint Typhoon Warning Center (JTWC), Guam, indicated that the region could expect about 31 tropical cyclones per year. Of those, 28 develop into tropical storms, and 18 develop into typhoons. Of the land areas comprising the East Asian region, China is most affected by tropical cyclones, followed by Taiwan and Korea, in that order (see Table 2-6).

Table 2-6. Mean Number of Tropical Cyclones Affecting the Northwest Pacific Ocean and Selected Locations from 1961 to 1993. Data source: JTWC Annual Tropical Cyclone Reports.

	WESTPAC			CHINA			TAIWAN			KOREA		
		TOT			TOT			TOT			TOT	
	TY	TS	TD	TY	TS	TD	TY	TS	TD	TY	TS	TD
JAN		0.6			0			0			0	
	0.3	0.3	0	0	0	0	0	0	0	0	0	0
FEB		0.4			0			0			0	
	0.1	0.2	0.1	0	0	0	0	0	0	0	0	0
MAR		0.6			0			0			0	
	0.2	0.3	0.1	0	0	0	0	0	0	0	0	0
APR		0.7			0			0			0	
	0.4	0.2	0.1	0	0	0	0	0	0	0	0	0
MAY		1.3			0.2			0.2			0.1	
	0.7	0.4	0.2	0.1	0.1	0	0.1	0.1	0	0	0.1	0
JUN		2.1			0.7			0.3			0.1	
	1.1	0.7	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0	0
JUL		4.6			2			0.3			0.4	
	2.8	1.4	0.4	0.7	1.2	0.1	0.3	0.2	0.1	0.1	0.2	0.1
AUG		6.2			1.7			0.6			0.6	
	3.2	2.1	0.9	0.4	1	0.3	0.3	0.2	0.1	0.1	0.4	0.1
SEP		5.5			1.8			0.7			0.2	
	3.4	1.6	0.5	0.8	0.9	0.1	0.5	0.1	0.1	0	0.1	0.1
OCT		4.8			0.8			0.1			0	
	3.2	1.1	0.5	0.3	0.3	0.2	0.1	0	0	0	0	0
NOV		3			0.2			0.1			0	
	1.8	1	0.2	0	0.1	0.1	0.1	0	0	0	0	0
DEC		1.4			0.2			0			0	
	0.7	0.5	0.2	0	0.1	0.1	0	0	0	0	0	0
YR		31.2			7.6			2.6			1.4	
	17.9	9.8	3.5	2.5	4	1.1	1.5	0.7	0.4	0.3	0.8	0.3

TOT = Average Number of Tropical Cyclones
TY = Average Number of Typhoons (Winds: 64 kts+)
TS = Average Number of Tropical Storms (Winds: 34-63 kts)
TD = Average Number of Tropical Depressions (Winds: <34 kts)

Figure 2-34 is a graphical presentation of mean monthly totals for tropical cyclones. Although tropical cyclones occur at any time of the year, the ones that affect the East Asian countries tend to occur only between the months of May to December, with peak months from July to September. Decreased tropical cyclone activity in East Asia can be attributed to two factors:

The first factor is based on the position of the subtropical ridge axis. Tropical cyclone development can only occur on the equator side of the ridge axis. During the first four months of the year, the ridge axis is situated south of 18° N. Any tropical cyclone activity will be short lived and movement will be generally westward towards the Philippines along the southern periphery of the ridge, though northern movement is possible if there is a weakness in the ridge.

The second factor occurs when the winter monsoon is in full force with its dominant northeasterly flow pushing colder and drier air into the Pacific Ocean. Tropical cyclones require warm sea surface temperatures and the influx of warm, moist air to maintain themselves. Any tropical cyclone, which is able to move north, will be moving over cooler water and will entrain the cold, dry air of the monsoon. When that happens they either dissipate over the water or undergo transition to a cold core low pressure system. The tropical cyclone can also be absorbed into one of the polar cold fronts that push southward and eastward off the continent. In either case, they are not likely to reach land as tropical systems.

Figures 2-35 and 2-36 show the typical paths of tropical cyclones during the course of the year. Movement of tropical cyclones is greatly influenced by the position and the intensity of the subtropical ridge. Most tropical cyclones move from east to west along the ridge's southern periphery. Tropical cyclones help maintain or intensify the ridge by transporting large amounts of latent heat of condensation to the middle and upper troposphere. This inflates the isobaric surfaces northwest of the center, and it enhances the ridge and propagates it westward. Northward movement occurs in reaction to a weakness in the ridge, induced by the eastward movement of mid-latitude troughs north of the ridge. Once a tropical cyclone moves north of the ridge axis, the upper-level westerlies influences its movement, and recurvature and acceleration to the northeast is likely.

Tropical cyclones can have a profound effect on eastern Asia's weather even if it does not make landfall. A typhoon moving into the South China Sea can induce a minor monsoon break over China by drawing the moisture flow away from China. This generally lasts about 2 or 3 days until the storm moves out of the region and allows the monsoon moisture flow to reestablish itself.

Tropical Waves. A wavelike disturbance in the easterly flow south of the subtropical ridge can develop off the east coast of China and move westward over southern China. This disturbance can bring extensive cloudiness and heavy rainfall to the region. It does not have to develop in the

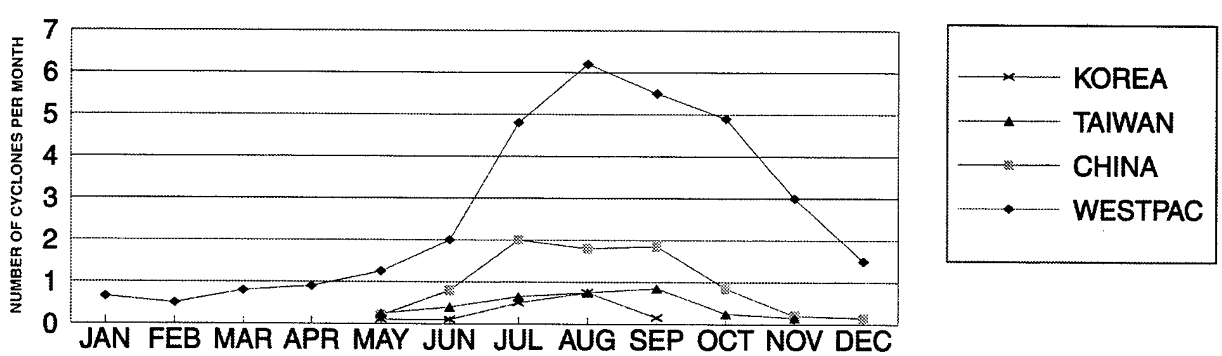


Figure 2-34. Monthly Mean Number Tropical Cyclones for the Western Pacific Ocean. The figure shows the mean number of tropical cyclones that occurred at selected locations between 1961 and 1993.

deep and steady basic easterly current. Development of this disturbance occurs when the subtropical ridge over the western North Pacific intensifies and expands westward towards the Chinese mainland. This intensification and expansion is due to a different cause, for example, a typhoon moving north. Once this happens, an extensive strong east to southeast wind occurs at the lower levels. This induces a strong positive vorticity and vorticity advection region. In this situation, a wavelike disturbance is likely to develop in the easterly flow near the East China coast, intensify, and move westward to affect a large area.

Equatorial Anticyclone. Also known as a "buffer high," these vortices form south of 10° N about 8 times a year in the western Pacific Ocean or the South China Sea. They are most prevalent between June and September and last from 4 to 9 days. Some last as long as 16 days. Equatorial anticyclones are strongest when the Australian high is very strong, which generally occurs when a Southern Hemispheric cold front reinforces the high. Once they develop, equatorial anticyclones tend to move north, sometimes as far as southern China. They are often associated with major monsoon breaks over southern China as they help establish an anticyclonic flow pattern in the lower levels over the region. They may also have a steering effect on the movement of typhoons. Case studies of several typhoons indicate that the presence of a strong northward moving equatorial anticyclone over the western Pacific Ocean or the South China Sea will induce a westward moving typhoon to reverse its course and move eastward or northward.

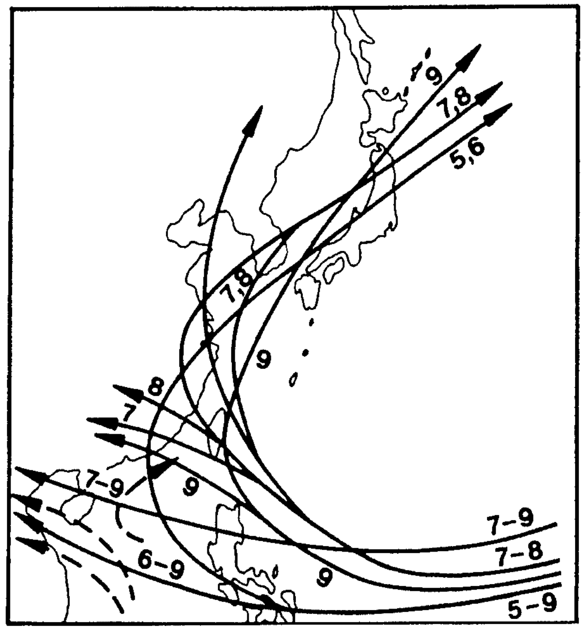


Figure 2-35. Tropical Cyclone Paths from May (5) to September (9). The figure shows the potential tracks of tropical cyclones that may affect East Asia during late spring to early fall.

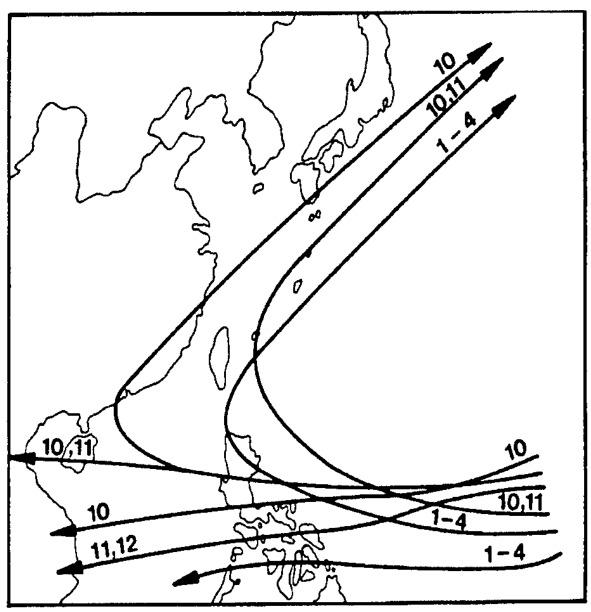


Figure 2-36. Tropical Cyclone Paths from October (10) to April (4). The figure shows the potential tracks for the limited tropical cyclones that affect East Asia during late fall to early spring.

Southwest China Vortex. The southwest China vortex is a mesoscale, low-level depression that develops in response to distortions imposed upon certain circulation types by the Tibetan Plateau. Table 2-7 is a summary of a 5-year study on the southwest China vortex. It shows that the vortex usually occurs between April and September and is most common in May and June. Forty-one percent of the vortices which develop dissipate in their location of origin. The rest intensify and move out toward the east.

For the southwest China vortex to form in the spring, a trough is needed in the south branch of the 500-mb westerlies over India and the Bay of Bengal. The warm, moist air current passes over the southeastern portion of the Tibetan Plateau and induces a low-level vortex over southwestern China. During the summer, a vortex usually develops over the eastern portion of the Tibetan Plateau when the subtropical high retreats eastward from the plateau. A vortex will also develop over southwestern China when a zonal shear line appears over the Tibetan Plateau or a monsoon depression is over India.

Once a vortex forms over southwestern China, any intensification and movement eastward will induce extensive heavy rain over eastern and northeastern China. Since around 41 percent of the vortices dissipate where they are formed, the forecaster must determine whether the synoptic situation favors eastward movement or dissipation. The synoptic situation favoring movement and intensification follows:

- •Strong low-level southwesterly current south of the vortex.
- •An appreciable negative height change area around the vortex at least from 850-500 mb.
- •Moisture increases near the vortex.

If the vortex is moving out east of a 500-mb trough associated with warm advection and upward motion, the rear of the vortex lies beneath the rear of the trough associated with cold advection and descending motion. For the vortex to dissipate, opposite synoptic conditions are needed.

Once the southwest China vortex begins to move out, it normally moves eastward on one of three routes. Figure 2-37 shows the expected region of vortex development and the likely routes of movement if the vortex does not dissipate.

Table 2-7. Frequency of Southwest China Vortex Occurrences and Tracks in 1970-1974.

Month	Apr	May	Jun	Jul	Aug	Sep	Total
Mean #:	8.8	11.2	10	7	3.2	8.3	48.5
Dissipated:	36%	25%	44%	49%	50%	55%	41%
Moved E:	38%	60%	36%	23%	6%	30%	38%
Moved NE:	16%	13%	12%	11%	31%	15%	14%
Moved SE:	9%	2%	8%	17%	13%	0%	7%

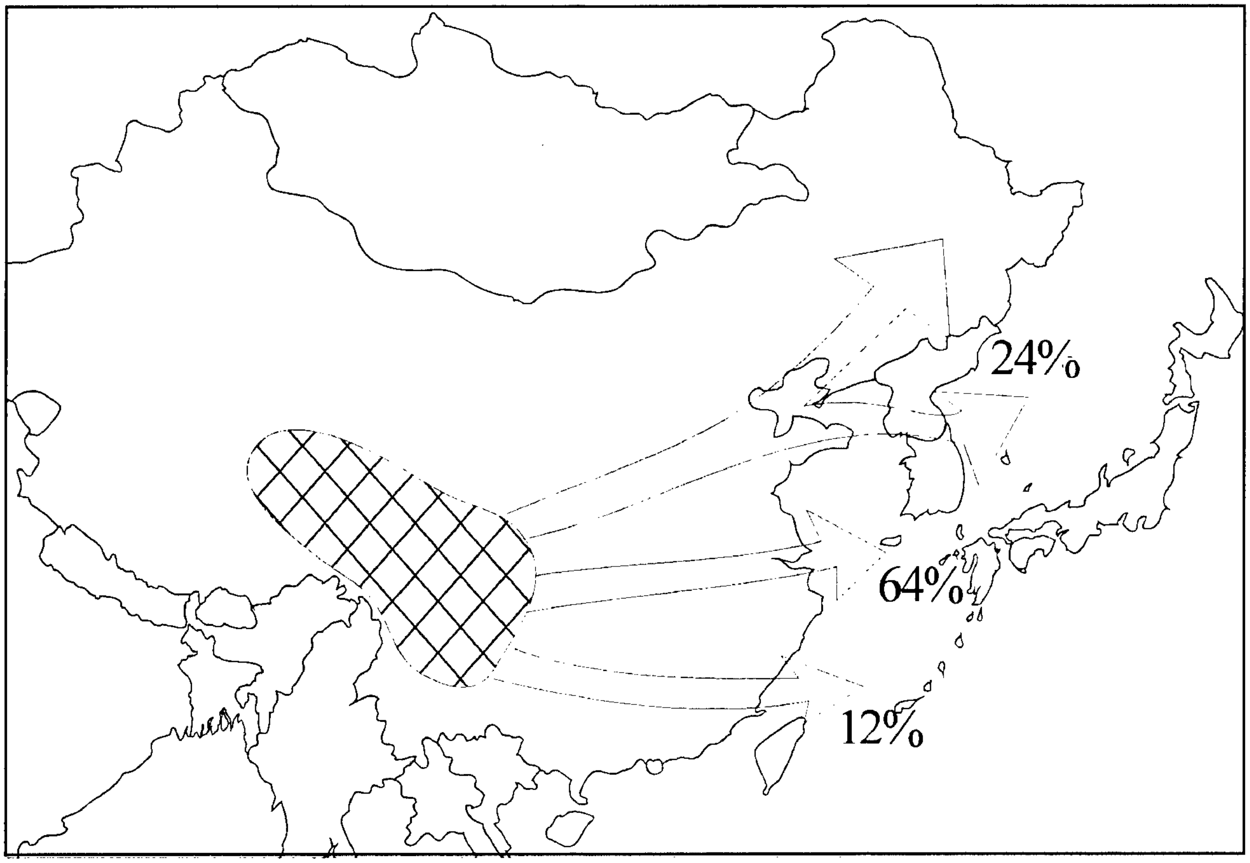


Figure 2-37. Southwest China Vortex. Figure shows the area of development (crosshatched area) and primary tracks between 1971-1974.

Cloud Features.

Cloud Clusters. Cloud clusters are unorganized convective cloud masses that generate very heavy rainfall. These cloud clusters are not associated with any recognized circulation system on any weather map. They are mesoscale phenomena, contain widespread stratiform cloud decks, and they are capped by cirrus shields. Rainfall is concentrated in embedded convection or in small regions of rain. Cloud clusters appear in satellite photographs as solid white masses due to the large cirrus canopies usually associated with them. These canopies are produced by outflow from and remnants of cumulonimbus clouds. The triggering mechanisms for cloud clusters are low-level convergence of wind and moisture fields and orographic forcing. Key development factors are the presence of a low-level jet and the monsoon cloud swell. Cloud clusters can last from a few hours to a couple of days and can be 180 to 620 miles (300 to 1,000 km) in diameter. They can also act as mesoscale disturbances and create or intensify the synoptic systems with which they interact.

Crachin. Crachin is a winter, low-level stratus phenomenon that generally occurs between December and late March (or early April). Crachin is confined to the coastal region of south China and northern Indochina. It is a prolonged period of drizzle and light rain accompanied by stratus and fog. These periods normally last 3 to 5 days, but some have lasted as long as 22 days. Development may occur in one of the following ways:

First, mixing of two nearly saturated air masses along a frontal boundary. This mixing occurs only during or after a cold frontal passage and raises the cloud base to near the top of the cold air, which is usually far from saturated. The lifting of the warm air may result in precipitation and some lowering of ceilings and visibility. The effect is generally short-lived and weak.

The second method of crachin formation is by the surface cooling of a warm, moist air mass. During the winter monsoon, a narrow band of cold water flows southwestward along the coast of China. This band of cold water plays a significant role in developing the worst and most persistent crachin under two different sequences.

The first sequence occurs when a polar continental high-pressure system moves off the mainland. The air on its eastern side modifies as it follows a track across the warm waters to the south of Japan before swinging westward to cross the cold waters along the Chinese coast.

It is over the colder waters where the rapid cooling and turbulent mixing of the air leads to crachin development. First, a stratus layer forms below the turbulence inversion. Then, as the moisture content of the incoming air increases, the stratus builds downward, drizzle sets in, and eventually sea fog forms. If the center of the high-pressure system becomes nearly stationary to the south of Japan, an intense and persistent crachin will develop, and it will require a fresh surge of the winter monsoon to disperse it.

The second sequence generally takes place as spring approaches. When a flat pressure gradient over the mainland and a wedge of the Pacific high extends across the Philippines to China, tropical maritime air advects over the region. The temperature contrast between the advected air and the coastal zone is sharp, and the crachin often takes the form of a dense sea fog. Clearing generally occurs with the sharp ridging that follows the passage of another monsoon surge.

Duststorms/Sandstorms. Given the right conditions, duststorms are dominant features in and near the deserts of the region. Duststorms carry suspended particles over long distances and often reduce visibility to less than 10 meters. Season of occurrence, wind direction, amount of particulate matter, and duration all vary by locality. Large-scale duststorms often persist for 1 or 2 days before a frontal passage or with a synoptic-scale squall line. Mesoscale squall lines may reduce visibility to less than 1,000 meters for several minutes to an hour. Sandstorms differ from duststorms only in the size of the suspended particles. Sand, being heavier, is seldom raised to more than 3-6 feet (1-2 meters) above the ground; the particles settle quickly.

Winds of 15-20 knots are sufficient to lift dust and sand. The mean threshold value is 17 knots, but speeds as low as 10-12 knots can produce duststorms. A pressure gradient of 6 mb per 10 degrees of latitude produces widespread duststorms 50 percent of the time. A 4 mb per 10 degrees of latitude surface pressure gradient is necessary to generate dust-laden surface winds.

Dust devils resemble miniature tornadoes, but their wind speeds are generally only between 10 and 25 knots. They can get strong enough to flatten huts. They form in clear skies and are set off by intense, summer daytime heating and local turbulence. Diameters range from 10 to 295 feet (3 to 90 meters) but average around 69 feet (21 meters). Most reach 246 feet (75 meters) high, but dust has been observed at 2,950 feet (900 meters). Dust devils move at about 10 knots and last for 1 to 5 minutes. Visibility is near zero in the vortex.

The origin and nature of duststorms depend upon general synoptic conditions, local surface conditions, seasonal considerations, and diurnal considerations.

General Synoptic Conditions.

- Active cold fronts. Sandstorms/duststorms can develop with frontal passages. Strong fronts increase the size of the area affected considerably and can produce a "wall of sand."

- Convective activity. Convective downdrafts commonly reach speeds needed to produce duststorms and sandstorms. Visibility can be greatly reduced within minutes.

Local Surface Conditions. Soil type and condition control the amount of particulate matter that can be raised into the atmosphere. Dry sand or silt, for example, is easily lifted by 10-15 knot winds. Haze is a persistent feature of sandy deserts. Fine dust, salt, or silt can be suspended for weeks and travel hundreds, even thousands, of kilometers from the source. Vehicles crossing the sand break through the crust easily; even very light winds can raise dust.

Seasonal Considerations.

• Winter. Large areas of dust/haze develop when a cold air surge from the Asiatic high moves into the region. Most duststorms develop along frontal boundaries. Synoptic-scale winds of only 10 to 15 knots can lower visibility to less than 3 miles (4,800) meters over large areas for up to 12 hours.

• Summer. Convection produces most duststorms, but late-spring frontal systems also produce them. Duststorms are more frequent in summer than in the winter. Local visibility is below 5,000 meters in areas where the soil is dry.

Diurnal Considerations.

• Daytime. The lowest visibility occurs shortly after the inversion breaks and turbulent surface mixing raises dust. Distant tree tops can be visible at this time, but their bases are obscured by the dust/haze. Daytime heating produces turbulent mixing in the lowest layers. Hot, dry winds transport dust aloft to the base of the large-scale subsidence inversion. Persistent dryness allows dust to reach 9,800 feet (3,000 meters) AGL where it can remain suspended for days or weeks.

• Nighttime. Cooler surface temperatures create stable conditions in the surface layer. Turbulent mixing is minimized; visibility improves during the night and is best between 2000L and 0600L as the temperature inversion produces light surface winds. Dust settles beneath the inversion layer throughout the night; visibility improves to between 6,000 and 10,000 meters.

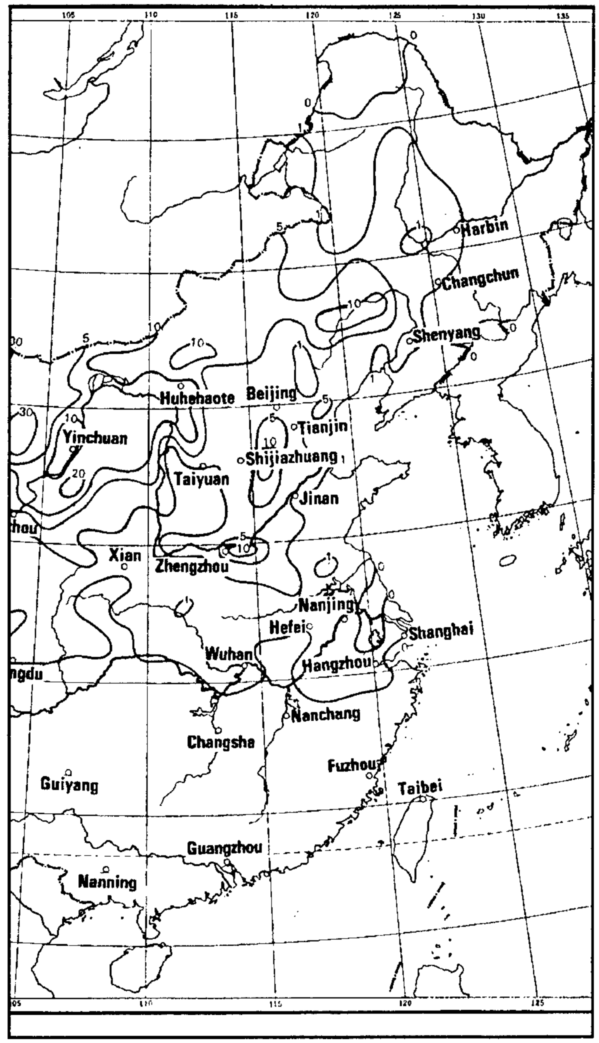


Figure 2-38. Mean Annual Number of Days with Sandstorms. The number of sandstorms decreases towards the southeast.

Figure 2-38 shows the distribution of sandstorm activity over China. Spring or early summer has the highest number of sandstorms.

Diurnal Circulations

Land/Sea Breezes. Differential surface heating generates this diurnal phenomenon along most of East Asia's coastline. These breezes can overwhelm changes that accompany synoptic or mesoscale weather systems. For example, they play an important role, along the South China coast, on the diurnal change of precipitation and extremely heavy rain events. Both promote the development of mesoscale disturbances, which bring heavy rainfall to areas along the coast. Location of the heavy rainfall concentration areas are dependent upon which windflow is in effect. Land breezes tend to concentrate the heavy rainfall along the coast, while the sea breezes concentrate it further inland. Normally, the marine boundary layer rarely extends above 3,000 feet (915 meters) AGL or more than 20 miles (30 km) inland unless modified by synoptic flow. There are two types of land/sea breezes—"common" and "frontal."

"Common" land/sea breezes affect all coastal areas of eastern Asia. Sea breezes are least likely to occur during the winter monsoon in those coastal regions directly affected by the sustained northerly wind flow from the Asiatic high. The northerly winds tend to mask all diurnal variations. Sea breeze activity still occurs along the Chinese coastline that borders the South China Sea. This pushes the weather associated with crachin inland. Figure 2-39 illustrates the "common" land/sea breeze circulation under calm conditions with no topographic influences and a uniform coastline. Onshore (A) and offshore (B) flow intensifies in proportion to daily heat exchanges between land and water. Common land/sea breezes normally reverse at dawn and dusk.

"Frontal" land/sea breezes are often linked to low-level jets, shown as arrows in Figure 2-40. Strong offshore gradient flow produces the frontal land breeze and enhances it while weakening the sea breeze. It delays the onset of the sea breeze by 1 to 4 hours as gradient flow prevents the sea breeze boundary layer (or "front") from moving ashore. When it does move onshore, it sometimes sustains 20-knot winds for 15-45 minutes. The strongest land breeze is usually present between midnight and morning.

High terrain near the coastline modifies the land/sea breeze in several ways. Orographic lifting produces sea breeze-stratiform/cumuliform cloudiness and deflects surface winds, while the mesoscale mountain circulation accelerates the land breeze over water. Elevated coastal topography produces steep nighttime temperature gradients.

Onshore gradient flow accelerates orographic lifting by day and produces localized convergence over open water during the early morning.

Coastal configuration also has an affect on land/sea breezes. Coastlines perpendicular to landward synoptic flow maximize sea breeze penetration while coastlines parallel to the flow minimize them.

Land/Lake Breezes. Several localized variations of the land/sea breeze circulation are caused by differential heating over large lakes. This circulation occurs in the absence of strong synoptic flow; it has a vertical depth ranging from 650 to 1,650 feet (200 to 500 meters) AGL. Figure 2-41 shows a land/lake circulation and cloud pattern with no synoptic flow. In late afternoon, a cloud-free lake is surrounded by a ring of convection some 12 to 25 miles (20 to 40 km) inland from shore. By early morning, the flow reverses and localized convergence occurs over open water.

Mountain/Valley and Slope Winds. Mountain/valley and slope winds develop under fair skies with light and variable synoptic flow. Mountain/valley winds, like land/sea breezes, dominate the weather in the absence of defined synoptic flow. There are two types of terrain-induced winds: valley winds and slope winds. They are shown in Figure 2-42. Valley winds tend to be stronger than slope winds and can override their influence.

Valley winds are produced in response to a pressure gradient between a mountain valley and a plain outside the valley. Air within the valley heats and cools faster than air over the plain. Daytime up-valley winds are strongest, averaging 10-15 knots between 700 and 1,300 feet (200 and 400 meters) AGL. Nighttime down-valley winds average only 3-7 knots at the same level. Peak winds occur at the valley exit. Deep valleys develop more nocturnal cloud cover than shallow valleys because nocturnal airflow convergence is stronger. The mesoscale mountain-valley circulation, which has a maximum vertical extent of 6,600 (2,000 meters), is determined by valley depth and width, prevailing wind strength in the mid-troposphere (stronger winds producing a more shallow circulation), and the breadth of microscale slope winds. The return flow aloft is much weaker and broader since it isn't confined to a narrow valley.

Slope winds develop along the surface boundary layer 0 to 500 feet (0 to 150 meters AGL) of mountains and large hills. Mean daytime upslope wind speeds are 6-8 knots; mean nighttime downslope wind speeds are 4-6 knots. Steep slopes can produce higher speeds, but these speeds are found at elevations no higher than 130 feet (40 meters) AGL. Downslope winds are strongest during the season with the greatest cooling while upslope winds are strongest during the season of greatest heating. Upslope winds are strongest on the slope facing the sun. Winds from a larger mountain can disrupt the winds of a smaller mountain. In some locations, cold air can be dammed up on a plateau or in a narrow valley. When sufficient air accumulates, it can spill over in an "air avalanche" of strong winds.

Figure 2-43 shows the life cycle of a typical mountain-valley and slope wind circulation. Mountain inversions develop when cold air builds up along wide valley floors. Cold air descends from slopes above the valley at 8-12 knots, but loses momentum when it spreads out over the valley floor. Wind speeds average only 2-4 knots by the time the downslope flow from both slopes converge. The cold air replaces warm, moist valley air at the surface and produces a thin smoke and fog layer near the base of the inversion. First light initiates upslope winds by warming the cold air trapped on the valley floor. Warming of the entire boundary layer begins near the 500-foot (150-meter) level AGL.

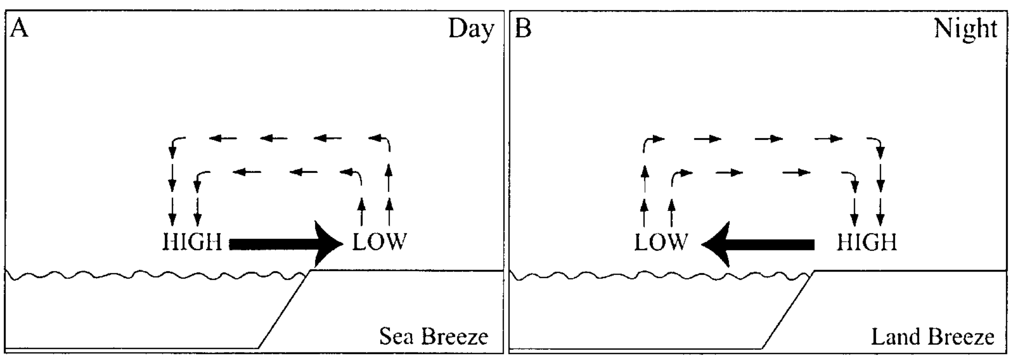


Figure 2-39. The "Common" Sea (A) and Land (B) Breezes. Thick arrows depict the surface flow.

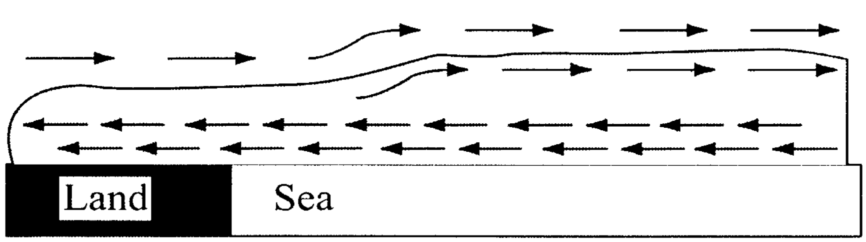


Figure 2-40. A Fully Formed "Frontal" Sea Breeze. Arrows depict wind flow; grey-shaded area is the marine air mass.

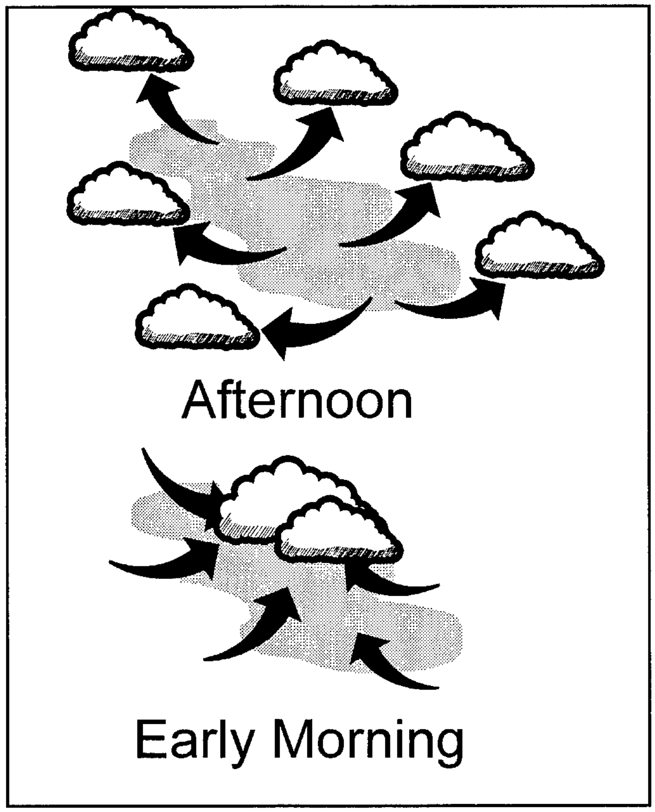


Figure 2-41. Idealized Land/Lake Breezes with Cloud Pattern. The figure shows a land/lake circulation and cloud pattern with no synoptic flow.

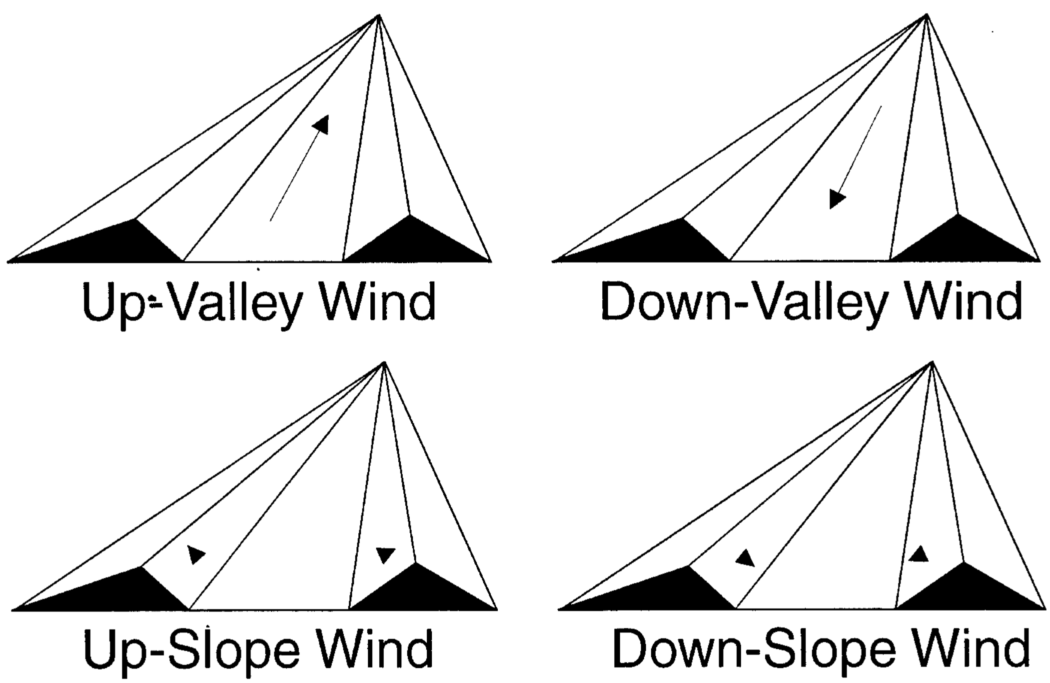
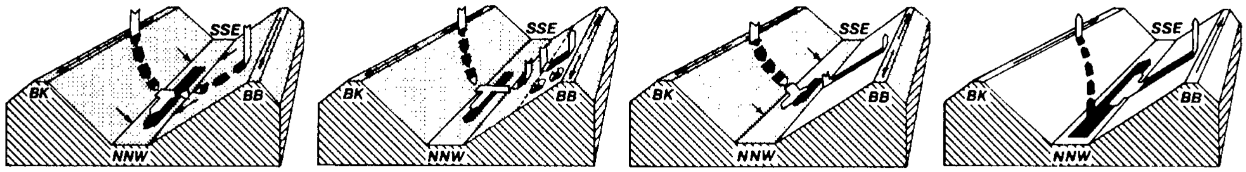


Figure 2-42. Mountain-Valley and Slope Winds. The figure shows the two types of terrain-induced wind.



Midnight to Sunrise

Downslope winds feed the mountain circulation.

Sunrise on the Upper East Slope

Sunrise almost immediately generates an upslope wind on the east slope

Whole East Slope in Sunlight

Upslope wind strengthens on the sunlit side; the down-valley wind weakens

Whole Valley in Sunlight

Upslope and up-valley winds support each other.

East-facing slopes begin to cool, weakening the upslope wind

Sun Shining on West Slope

Downslope wind begins on the east slope with colder air under-cutting the up-valley wind.

Sunlight Parallel to East Slope

Down-valley winds form; east slope winds extend cross-valley, feeding west's upslope winds.

Sunset East Slope and Valley Floor

Down-valley and downslope winds are present except tops of sunlit peaks.

After Sunset on the Lower West Slope

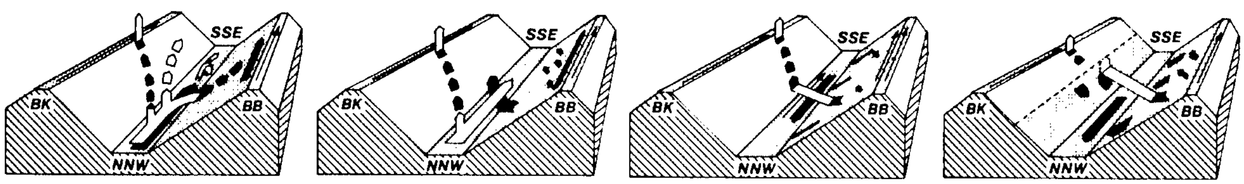


Figure 2-43. Diurnal Variation of Slope and Valley Winds. Both valley and slope winds are shown in relation to two ridges (BK and BB) oriented north-northwest to south-southeast. The dark arrows show the flow near the ground; the light arrows show movement of the air above the ground.

Local Wind Systems

Mountain Waves. These waves develop when air at lower levels is forced up over the windward side of the ridge. Criteria for mountain wave formation include sustained winds of 15-25 knots, winds that increase with height, and flow oriented within 30 degrees of perpendicular to the ridge.

Wavelength amplitude is dependent on wind speed and lapse rate above the ridge. Light winds follow the contour of the ridge with little displacement above and rapid damping beyond. Stronger winds displace air above the stable inversion layer; upward displacement of air can reach the tropopause. Downstream, the wave propagates for an average distance of 50 times the ridge height. Rotor clouds form when there is a core of strong wind moving over the ridge, but the elevation of the core does not exceed 1.5 times the ridge height. Rotor clouds produce the strongest turbulence. The clouds may not always be visible in dry regions. Figure 2-44 is an illustration of a fully developed lee-side wave.

Foehns. Hot, dry winds produced when air is forced over mountains are called foehns. They become hot and dry by adiabatic warming as they descend the leeward slope. Climatic parameters for these winds are defined as a daily maximum temperature of 86° F (30° C), a relative humidity of 30 percent, and a wind speed greater than 6 knots. Favorite locations for the formation of foehns are along the northeast coast of Korea during the winter, northern and northeastern China from mid-May to late June, and downwind of mountain ranges when conditions are favorable.

Gap Winds. Gap, "jet-effect," or venturi winds occur on the downward sides of narrow mountain passes under strong gradient conditions induced by the funneling of the wind. These winds are almost always "supergradient" with speeds as much as 35 to 45 knots higher than otherwise expected. The most common locations are mountain passes along the Sino-Russian border where winds speeds exceed 97 knots with maximum gusts of 136 knots. The Taiwan Strait, with its north-northeast to south-

southwest orientation, also acts as a wind funnel during the winter monsoon. Wind speeds exceed 35 knots for over 90 days a year.

Gulf of Tonkin Eddy. After the surge in the winter monsoon begins to weaken, a narrow band of southeasterlies from the South China Sea is deflected around Hainan Island. This forms cyclonic eddies or shearlines in the Gulf of Tonkin to the southwest. The eddies are 100-200 km wide and usually move to the north. The resultant southwesterly flow may attain 30 knots. Ceilings lift and the clouds become less overcast on the eastern side of the eddy.

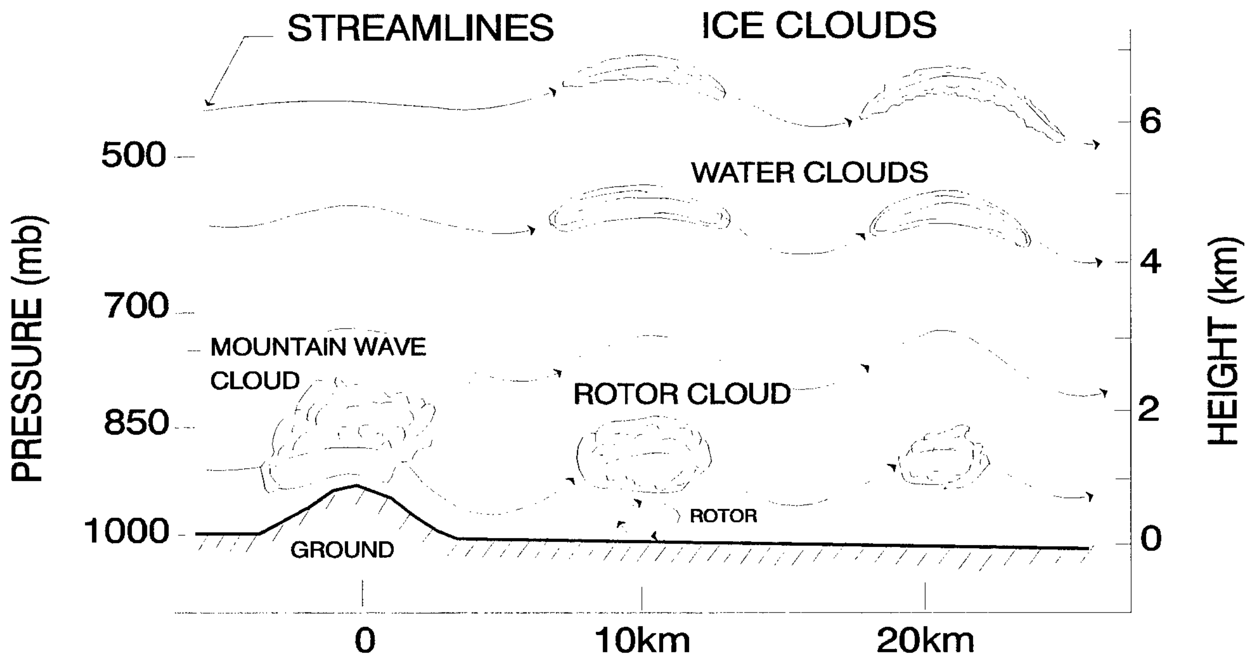


Figure 2-44. Fully Developed Lee Wave System. The figure depicts the features associated with mountain waves including the hazardous rotor cloud located downstream from the wave.

Effects of the Tibetan Plateau. The Tibetan Plateau is the tallest highland in the world; it is known as the "Roof of the World." It covers a geographical region from 30° to 38° N, 70° to 100° E, with an average elevation greater than 14,763 feet (4,500 meters). The plateau is home to many mountains whose peaks exceed 19,685 feet (6,000 meters) including the world's tallest, Mt. Everest, at 29,028 feet (8,848 meters). The presence of such a huge land feature in the western portion of the region obviously affects the weather patterns for the region. In this section, discussion of the Tibetan Plateau will be limited to the dominant jet streams of the region and the Asiatic (or Siberian/ Mongolia) high.

Jet Streams. During fall, winter, and spring, the Tibetan Plateau acts as a high-level radiation heat source. The associated rising surface pressures diminish the south-to-north temperature gradient and reduce the strength of the subtropical jet to the south of the plateau. Air subsides just to the east of the plateau and is further warmed by adiabatic heating. This air flows alongside very cold air that moves around the northern edge of the plateau over central China and induces an extremely large temperature gradient. This temperature gradient produces an extremely strong jet stream over East Asia, especially during winter, with wind speeds as high as 240 knots.

During the summer, the central and southeastern portions of the plateau continue to act as a heat source. Condensation from the Himalayas powerfully aids the effects of radiation. The subtropical ridge aloft lies over the southern portion of the plateau, and any adiabatic heating produced by mechanical subsidence is negligible. As a result, the surface pressure is higher at Lhasa, in southern Tibet, than in areas to the east or west. Instead of weakening the south-to-north temperature gradient as seen in the winter, the heating increases the north-to-south temperature gradient of the summer monsoon and produces a speed maximum in the upper-tropospheric easterlies south of India. These winds possess some jet stream characteristics and are collectively known as the tropical easterly jet.

Without the Tibetan Plateau, it is very likely that the jet streams would not be as strong as they are because the strong temperature gradients, which the plateau induces, would not exist. It is also possible that the tropical easterly jet would not exist. This would remove one of the most important circulation features of the summer monsoon and would change precipitation patterns in the East Asian region.

Asiatic High. As discussed earlier, intense anticyclogenesis, supported by radiational cooling, leads to the development of the Asiatic high in the Lake Baykal region of Siberia. Cold surges break away from the high to reinforce the winter monsoon and sweep out to affect southern China, the China Seas, and Korea. During numerical modeling of the global atmospheric circulation, researchers found that the Tibetan Plateau was needed to reproduce the Asiatic high. When the high terrain of the plateau and the Himalayan Mountains were removed from the model, the Asiatic high did not appear on the surface map. Analysis of the results of this modeling effort indicated that without the plateau and the mountains, an active baroclinic zone would exist between the radiatively cooling air over wintertime Siberia and the convectively heated air over the Indian Ocean region. Heat would be transported northward by baroclinic wave cyclones to counteract the radiative cooling. Simply put, without the "orographic dam" (the Tibetan Plateau and the Himalayan Mountains) to significantly diminish the northward advection of heat during the winter, the Asiatic high would not exist. If it did exist, it would not be as strong, and the winters over East Asia would be warmer.

The impact of the Tibetan Plateau on the climate of East Asia was demonstrated by the examples given above. Only by understanding how the plateau influences the development of these important climatic features will one truly appreciate its effect.

Wet-Bulb Globe Temperature (WBGT)

The WBGT heat stress index provides values that can be used to calculate the effects of heat stress on individuals. WBGT is computed using the formula:

WBGT = 0.7WB + 0.2BG + 0.1DB,

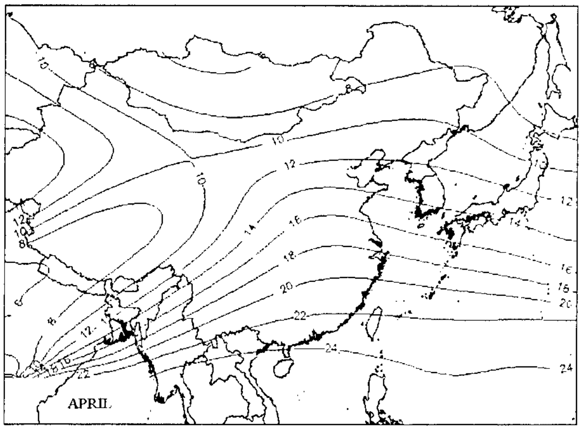
where: WB = wet-bulb temperature
BG = Vernon black-globe temperature
DB = dry-bulb temperature

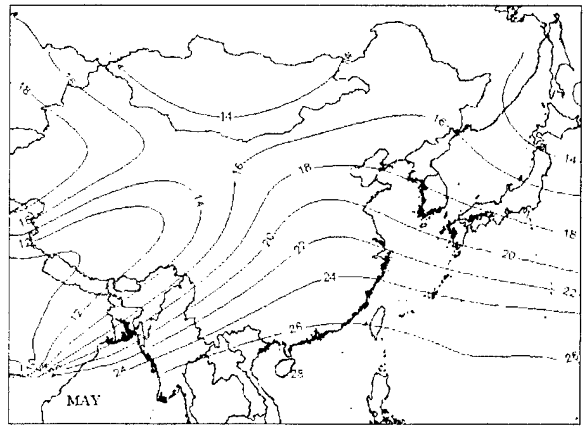
A complete description of the WBGT heat stress index and the apparatus used to derive it is given in Appendix A of TB MED 507, *Prevention, Treatment and Control of Heat Injury*, July 1980, published by the Army, Navy and Air Force. The physical activity guidelines shown in Figure 2-45 are based on those used by the three services.

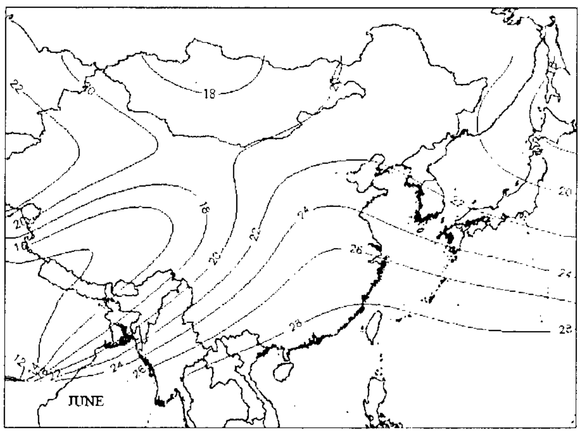
Figure 2-46 gives average maximum WGBTs for the months of April through October. For more information, see USAFETAC/TN-90/005, *Wet Bulb Globe Temperature, A Global Climatology*.

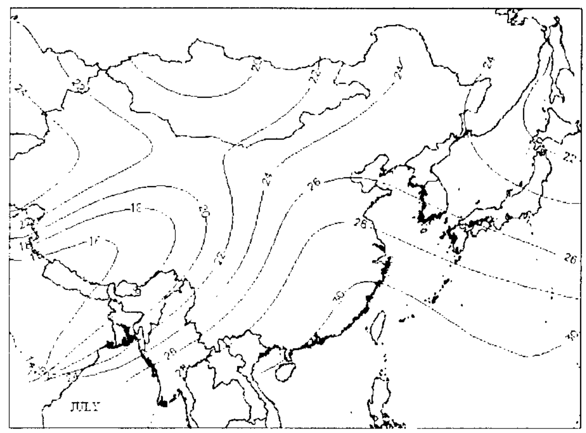
WBGT (° C)	Water Requirement	Work/rest Interval	Activity Restrictions
32-up	**2 quarts/hour**	**20/40**	**Suspend all strenuous exercise.**
31-32	**1.5-2 quarts/hour**	**30/30**	**No heavy exercise for troops with less than 12 weeks hot weather training.**
29-31	**1-1.5 quarts/hour**	**45/15**	**No heavy exercise for unacclimated troops, no classes in sun, continuous moderate training 3rd week.**
28-29	**.5-1 quart/hour**	**50/10**	**Use discretion in planning heavy exercise for unacclimated personnel.**
24-28	**.5 quart/hour**	**50/10**	**Caution: Extremely intense exertion may cause heat injury.**

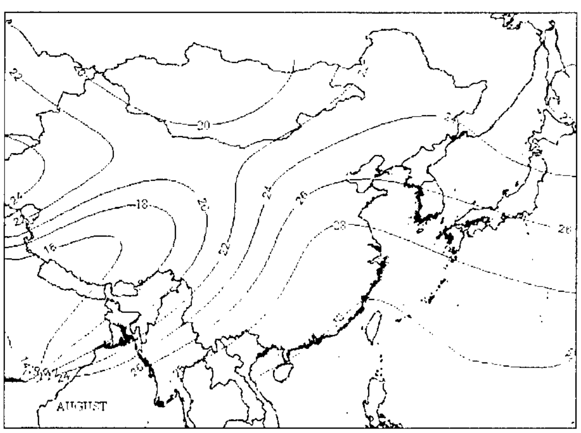
Figure 2-45. WBGT Heat Stress Index Activity Guidelines. Note that the wear of body armor or NBC gear adds 6° C to the WBGT, and activity should be adjusted accordingly.

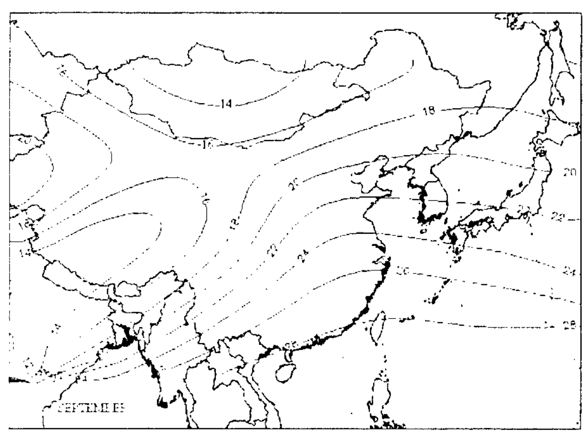












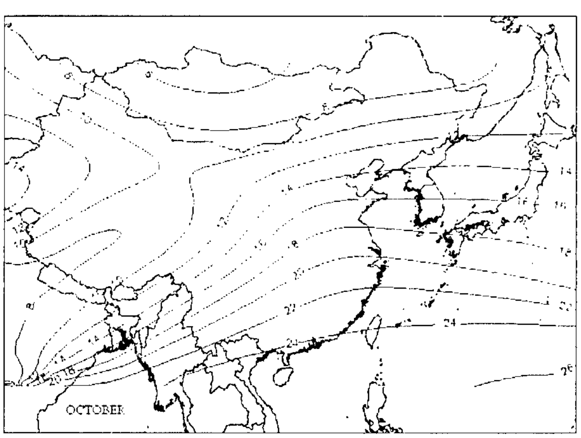
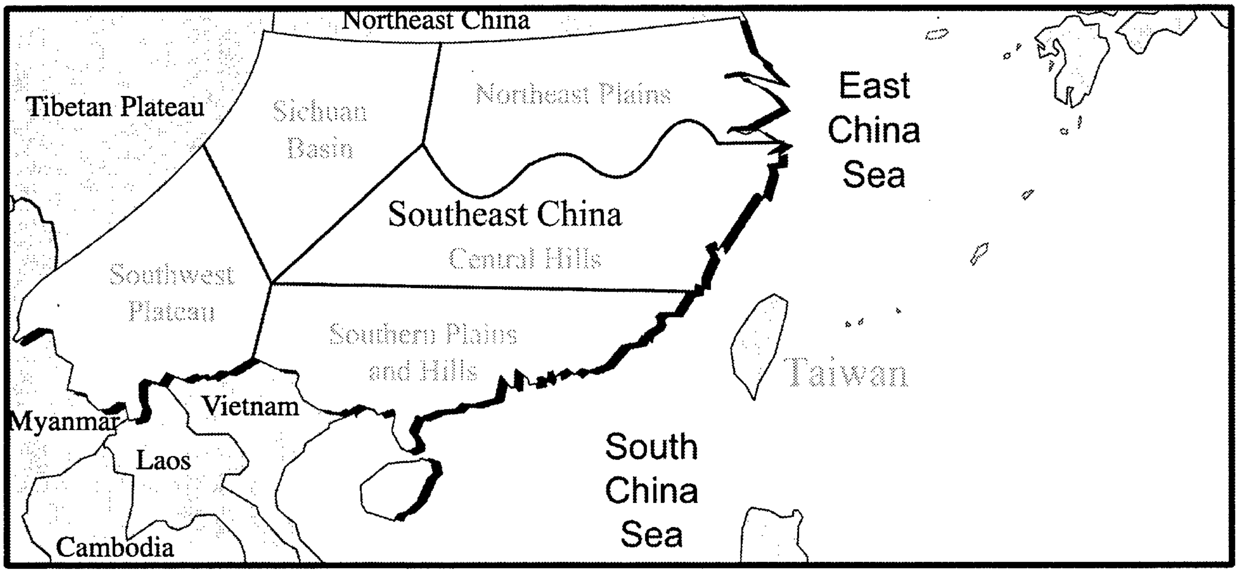


Figure 2-46. Mean Maximum WBGT. The figure shows the mean maximum WBGT for the months when WBGT may impact operations.

Chapter 3

SOUTHEAST CHINA

This chapter describes the geography, major climatic controls, special climatic features, and general weather by season for southeast China in East Asia. This area includes southeastern mainland China plus the islands of Hong Kong, Macau, and Hainan.



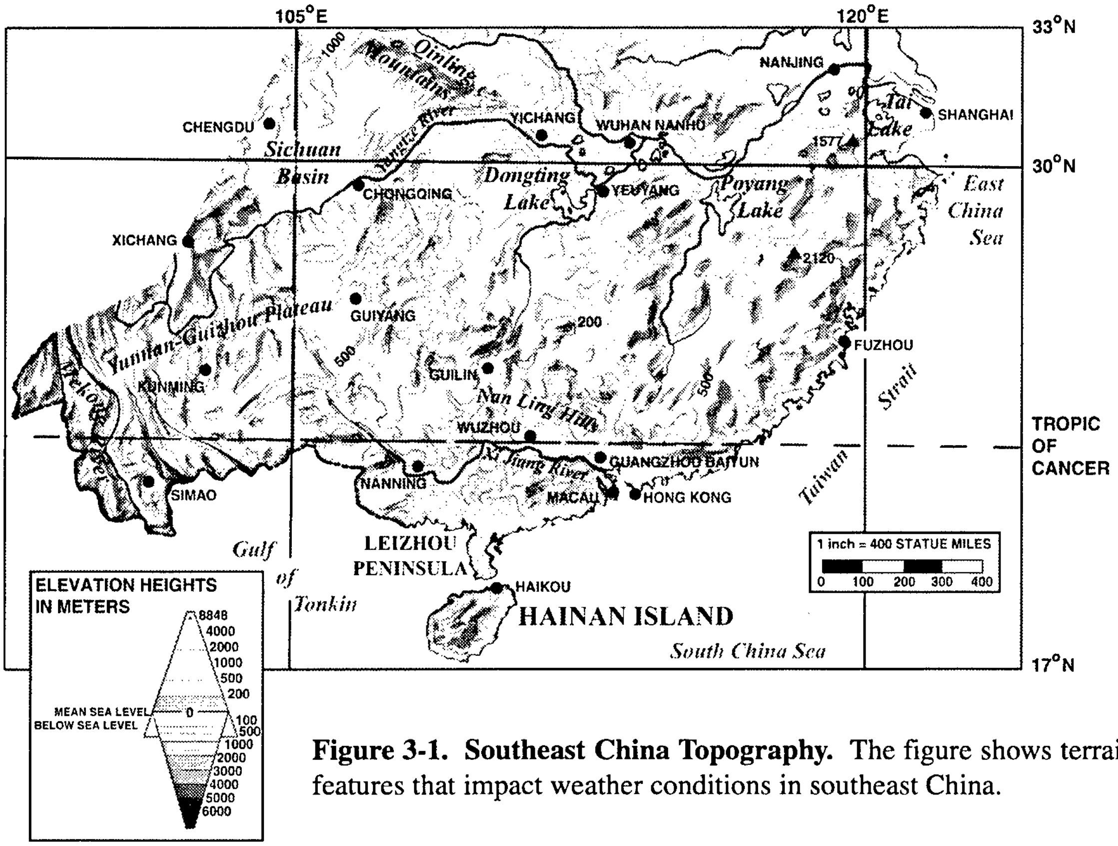


Figure 3-1. Southeast China Topography. The figure shows terrain features that impact weather conditions in southeast China.

Boundaries. Southeast China's border with the remainder of mainland China approximates the long-term 800-mm average annual precipitation isopleth. The eastern portion and part of the southern boundary consists of coastline bordering the East China Sea, the Taiwan Strait, the South China Sea, and the Gulf of Tonkin. The borders between China and Vietnam, Laos, and Myanmar define the rest of the southern border. In the west, southeast China's border on the eastern edge of the Tibetan Plateau coincides with the 2,000-meter elevation contour. All offshore islands along the coast of southeast China, including Hong Kong, Macau, and Hainan Island, are part of southeast China.

Major Terrain Features. In general, the terrain descends from the high mountains in the west and northwest to the low plains of the northeast and the coast (see Figure 3-1). For purposes of this study, southeast China is divided into five regions: Sichuan Basin, northeast plains, southwest plateau, central hills, and southern plains and hills (see map on page 3-1). Each region is discussed separately each season in this chapter.

Sichuan Basin. The Sichuan Basin is located in the northwest. It is surrounded by the high Qinling Mountains to the north, high mountains to the west, lower mountains to the east, and high plateau to the south. Elevations range from 1,000 feet (300 meters) to about 3,300 feet (1,000 meters). Northwest of the Sichuan Basin, just outside of southeast China, snow-covered mountains extend to more than 16,000 feet (5,000 meters) above sea level.

Northeast Plains. The northeast plains, east of the Sichuan Basin, consist of the Yangtze River valley, with its river and series of lakes and basins, and plains that surround the valley. The plains are mostly less than 160 feet (50 meters) above sea level except for a few rolling hills that average below 3,300 feet (1,000 meters).

Flooding occurs nearly every summer when the Yangtze River rises dramatically. The lakes and manmade basins act as overflow reservoirs to lessen the impact of the flooding.

Southwest Plateau. The southwest plateau is an intermediate step down in altitude between the high Tibetan Plateau and the lowlands to the east. This area contains the eastern edge of the Tibetan Plateau and the Yunnan-Guizhou Plateau. These mountains are separated by deep gorges. In eastern Guizhou, elevations range between 3,300 feet (1,000 meters) in the east and 6,600 feet (2,000 meters) in the west.

Central Hills. The central hills extend eastward from the Sichuan Basin and southward from the northeast plains to the southern plains and hills. This region has many rolling hills, small plains, several narrow mountain ranges rising above 3,000 feet (900 meters), and a few mountain peaks above 5,900 feet (1,800 meters). It includes numerous offshore islands.

Southern Plains and Hills. The southern plains and hills extend east from the southwest plateau to the east coast of China and north from the southern coast to the central hills. Just to the east of the southwestern plateau, hills dominate the topography. Farther east, the rugged southeastern highlands border the coast, with its bays and numerous offshore islands. The Xi Jiang Basin, with its hills and infertile soil, lies south of the Nan Ling hills.

Rivers and Drainage Systems.

The Yangtze River or "long river" is one of the three major rivers in China, the longest river in Asia, and the third longest river in the world. It extends 3,900 miles (6,300 km) from its origin in the mountains of southwest China to the East China Sea at Shanghai (see Figure 3-1).

The Yangtze is a major transportation artery in southeast China. Approximately the first 1,600 km inland from the sea are navigable for oceangoing vessels. Smaller vessels can go as far as Chongqing, about 1,500 miles (2,400 km) up the river. Some of the most important lakes in China lie along the Yangtze River. Lakes in the middle portion of the river, the Dongting and Poyang, serve as reservoirs for excess river water. During the rainy season, they increase to two to three times their dry season size. There are several lakes in the delta region of the Yangtze River. The largest one is Lake Tai.

The Xi Jiang is the next most important river system in southeast China. Its origin is in the southwest plateau southeast of Kunming. It rises in the mountains and flows more than 1,200 miles (2,000 km) before it empties into the South China Sea.

Ocean Currents/Sea Surface Conditions. The Kuroshio and Tsushima Currents play a major role in the climate of southeast China. Figure 2-1 shows these currents in January and July. During winter, under the influence of the northeasterly flow in the boundary layer, the Kuroshio Counter Current draws cold water southward along the coast of southeast China. Sea-surface temperatures vary from about 68°F (20°C) near Hainan to 43°F (6°C) in the Yellow Sea near northern southeast China. Cold water near the coast results in a strong temperature gradient in the South China Sea—part of the warm, Northeast Equatorial Current is also diverted into the South China Sea.

During summer, the southwest winds form the Tsushima Current, a warm, southwesterly current that flows northward along the coast of southeast China. Sea-surface temperatures are warm. They vary from a high of about 84°F (29°C) near Hainan to about 75°F (24°C) in northern southeast China.

MAJOR CLIMATIC CONTROLS

General Climate. The climate of southeast China varies from tropical on offshore islands in the south to warm temperate in the north. Between these extremes, most of southeast China has a subtropical climate. Although much of southeast China (north of 25° N) is outside of the region defined as having a monsoon climate, it does have a monsoon-like climate. The wind direction changes approximately 180 degrees between winter and summer.

Asiatic High. This cold, shallow, continental pressure feature dominates most of the Asian continent during winter. Although cold, dry air is associated with the Asiatic high, the strong northeasterly flow over southeast China is cold and moist because of its long trajectory over water. This moisture, coupled with the stable atmospheric conditions associated with the high, causes extensive cloudiness and fog.

Aleutian Low. This is a winter feature. Since it is strongest at the same time that the Asiatic high is strongest, the tight gradient between the two pressure centers causes strong northeasterly flow over southeast China.

Asiatic Low. This thermal low combines with the North Pacific high to drive the summer southwesterly wind flow.

North Pacific High. The position of this subtropical high affects the winter and summer circulation over southeast China. In summer, it combines with the Asiatic low to bring in southwesterly flow. When the North Pacific high is farther north and west than normal, an active summer weather season can be expected. Conversely, when the subtropical high's position is farther south and east than normal, an inactive season can be expected. The North Pacific high also affects winter weather over southeast China. The high fluctuates between a shallow and a deep flow pattern (each lasts about 10 days) and causes fluctuations in the northeast flow over China.

El Niño/La Niña. When the El Niño appears in the eastern Pacific, the North Pacific high shifts southward. This results in below normal convective activity over the South China Sea and a drought over much of southeast China, except for the northeast plains where flooding occurs in the area north of the Yangtze River. As El Niño decays, the North Pacific high shifts northward and convective activity returns to the South China Sea. At the same time, a drought may affect the northeast plains north of the Yangtze River. During El Niño years, cold surges occur less frequently during winter, and there are fewer typhoons. More cyclogenesis occurs over the East China Sea during the El Niño. The La Niña portion of the cycle has less impact on this region than El Niño. It boosts precipitation amounts in the summer months, but not enough to bring the numbers above the normal range.

Subtropical Jet. The upper-air westerlies are strongest during winter and are at their southernmost position where the Tibetan Plateau splits the flow into two components, northern and southern. The northern component goes north of southeast China. Its position defines the southern extent of the polar air intrusion into southeast China from October until mid-April. Then it moves northward (Figure 2-14a), which signals the beginning of the northward migration of the southwest monsoon. The southern branch crosses southeast China. It skirts south of the Himalayas and crosses southeast China from southwest to northeast to Shanghai where it exits Asia.

Cold Surges. Intense intrusions of cold, dry air from the Asiatic high move southward over southeast China at 4-20 day intervals. They are most frequent from November to January. A strong cold front develops ahead of the cold surge and pushes southward. Winds can gust to more than 40 knots during a cold surge. In addition, sharp temperature drops accompany the front. Dust and sandstorms accompany cold surges but are limited to the northeast plains. Freezing temperatures can extend through most of southeast China. When a cold surge reaches the South China Sea, it can generate considerable convective activity early in winter when the ocean temperatures are still warm. There are fewer cold surges during an El Niño.

East China Sea Low. This low develops over the East China Sea mainly in fall through spring. The strong temperature gradient between the ocean currents flowing along southeast China's coast during winter enhances cyclogenesis in this area. It only occasionally develops during summer; about

24 per year. It normally moves away from the coast, steered by the upper-level westerlies. The coastal areas and the islands along the coast can be affected with low cloudiness, rain, and strong winds associated with these lows. Flash flooding is possible. Cyclogenesis increases in the East China Sea as much as 20 percent during an El Niño year.

Equatorial Anticyclones. These occur about eight times per year, most frequently between June and September, and last for 4-9 days (sometimes as long as 16 days). They are strongest when the Australian high is strongest and sometimes reach southeast China. These may affect the path of typhoons. See Chapter 2 for a complete explanation.

Kunming Quasi-Stationary Front. This front separates the cloudy, rainy, and cold polar air mass that covers most of southeast China during winter from the warmer, drier, south-southwesterly flow that originates in southwest Asia. It normally affects the southwest plateau, the Sichuan Basin, and Hainan Island. Flying weather in this vicinity is extremely poor as a result.

Low-Level Jet. This feature manifests itself as a jet streak or maximum wind greater than 25 knots in the layer between 1,600 and 9,800 feet (500 and 3,000 meters). Generally, there are two types of low-level jets that show up during heavy precipitation episodes. One low-level jet precedes cold air intrusions. Warm and moist, it contributes to extensive heavy rains. The second type of low-level jet is caused by a surge in the southwest flow during summer. It produces heavy, persistent rain in the coastal areas. Figures 2-17 and 2-18 show examples of these two low-level jets.

Polar Front. During winter, the polar front marks the southern boundary of the northeast flow and the position of the subtropical westerly jet. Its mean position in January places it south of most of southeast China. During summer, the polar front marks the northern boundary of the southwest flow. In July, the mean position of the primary polar front crosses northeast China and Korea.

Southwest China Vortex. These develop each year between April and September, mainly in May and June. The Sichuan Basin is in the favored area for formation of this vortex. About half remain stationary and dissipate in their area of origin; most of the rest move eastward and affect the northeast lowlands, and only a few move southeastward across the central hills. See Chapter 2 for a complete explanation.

Subtropical Cyclones. These "middle-level cyclones" affect southeast China from May through September at a rate of about three per year. Most occur in July and August. Occasionally, they move over southeast China and produce heavy rain. The life cycle is about 5 days, but can be anywhere between 2 and 11 days. A surface low may not develop with the cyclone. See Chapter 2 for details.

Tropical Cyclones. These storms pose a major threat to southeast China (see Chapter 2, Table 2-6). During May and June, storms tend to curve northeastward after crossing the Philippines and cross the eastern coastal area on a path north and northeast. During the summer, the tracks also take the storms inland to move westward across the central hills and southern plains and hills areas. In October and November, storms usually cross Hainan Island or curve northeastward across the east coast of southeast China. Their high winds, heavy rainfall, and storm surges cause widespread flooding and property damage. In an El Niño year, there are fewer typhoons during summer, especially between July and November.

Tropical Waves. These disturbances in the easterly flow south of the subtropical ridge develop off the east coast of China and move westward over southeast China. They can bring extensive cloudiness and rainfall to the region. Although these tropical waves are rare, they can affect the area for extended periods and cause heavy rain.

Yangtze-Huaihe Lows. These lows are most common during April-June (4-5 per month). About 27 occur per year. Most of the lows affect the middle to lower reaches of the Yangtze River valley from Yichang to the mouth of the river. These lows result in heavy precipitation in the Yangtze River valley.

Cloud Clusters. Clusters occur during summer.

These cumulonimbus cloud masses are capped by cirrus shields with widespread stratiform cloud decks. Cloud clusters generate heavy rainfall and cause flash flooding. They can extend from 185 to 620 miles (300 to 1,000 km) in diameter, and they can last from a few hours to a couple of days.

Crachin. This low-level fog and stratus with drizzle and light rain usually starts in December or January, about the time of the annual temperature minimum. It occurs until spring, sometimes as late as mid-April, along the coast of southeast China. Crachin develops in two ways. See Chapter 2 for a detailed description of the types of crachin that occur here.

Duststorms/Sandstorms. The only area that experiences these storms is north of 30° N (the northeast plains) where up to one storm per year is average. These storms usually occur in spring to early summer before the rainy season. Dust or sandstorms reduce visibility to less than 1 km.

Foehn. These winds occur in the western part of southeast China. While they can occur at any time of the year, they are most prevalent during the winter monsoon when strong westerly winds blow across the north-south oriented mountains. These winds bring in short-term higher winter temperatures in the Sichuan Basin and in the southwest plateau.

Land/Lake Breeze. Dongting Lake, the largest lake along the Yangtze River, is large enough to have a lake breeze when the general circulation pattern is weak. The land breeze starts at about 1800L, earlier in the winter and later in the summer. The lake breeze tends to start around 1100L, sooner in summer and later in winter. While the Dongting Lake breezes occur year-round, they occur more frequently in spring and summer than in fall and winter. The land/lake circulation can extend to an altitude of about 900 meters.

Land/Sea Breeze. The entire coastline experiences land/sea breezes, but the South China Sea coast is most affected by these diurnal winds. These occur year-round but are strongest during summer. In winter, the strong northeasterly flow effectively masks any sea breeze except along the South China Sea, where the sea breeze moves crachin inland and reduces the ceiling and visibility at coastal and near-coastal locations. The winter land breeze displaces crachin offshore.

Mesoscale Convective Complexes (MCC). These summer weather systems peak in June when an average of 16 occur; about 80 occur yearly. China and the South China Sea are favored areas for MCC development. Over land, MCCs form on the lee side of mountain ranges, where low-level jets are frequent, and upslope flow provides the instability. Low-level flow with a long fetch over warm water brings the moisture needed for formation.

Mountain Waves. The Sichuan Basin and the southwest plateau areas are the most vulnerable areas. Severe-to-extreme turbulence is possible downwind from the ridge line to a distance equal to 50 times the ridge height. Because the air is dry, rotor clouds that indicate areas of the most severe turbulence may not be visible. Mountain waves are most pronounced from fall through spring.

General Weather. During winter, cold, moist air delivered by strong northeast flow dominates most of southeast China. Because of the long, over water fetch, cloudy and damp conditions with drizzle and fog occurs in many places. The western southwest plateau, western Sichuan Basin, and Hainan Island receive warmer, drier, southwesterly flow from southwest Asia. This flow is separated from the cold, moist northeasterly flow by the Kunming quasi-stationary front. Although precipitation amounts are the lowest of the year, frequent, light precipitation occurs often in southeast China.

The pressure gradient between the Aleutian low and the Asiatic high causes strong northeasterly flow over southeast China. The northeast flow gradually gains strength from October through December. It peaks in January when the systems reach their peak strength. The flow decreases from February through March as warmer air weakens the Asiatic high.

Cold surges from the Asiatic high are among the most common features of winter weather in southeast China. They occur when the Asiatic high's central pressure increases to at least 10 mb higher than its mean central pressure. Cold surges usually occur at intervals of 4 to 20 days per month during November through January. In February, they decrease slightly in frequency as the Asiatic high weakens. By March, only 1-2 cold bursts occur.

Since cold surges from the Asiatic high are a shallow phenomenon, usually below 700 mb, topography plays an important role in how they affect the weather. The surge propagates as a strong, cold front that can reach throughout southeast China. The Sichuan Basin and the southwest plateau are protected by higher terrain from the shallow cold intrusions. January temperatures there are 3-5 Celsius degrees warmer than other locations in China at the same latitude. The southern plains and hills experience frost in late December or early January and mean last frost in late January or early February. Hainan Island and the Leizhou peninsula rarely, if ever, experience frost.

Strong surface winds in excess of 40 knots can accompany a strong cold surge. These winds produce sandstorms in northern China and occasionally in the northeast plains of southeast China. A dust layer can reach as high as the top of the northeast circulation layer, about 700 mb, and extend over southeast China. The dust reduces visibility aloft to the top of the layer. Above that, westerly winds prevail and carry any dust at that level eastward away from southeast China.

Crachin forms along the coast of southeast China, except for Hainan Island, between December and March as the result of a cold frontal passage or warm, moist air tracking from the vicinity of Japan across the cold Kuroshio Counter Current flowing along the coast of southeast China. As the Kuroshio Counter Current flows southward along the coast, warmer water from the North Equatorial Current mixes with the colder water south of 25° N. Part of the North Equatorial Current flows around the north end of Taiwan and joins the Kuroshio Counter Current. Additional warm water of the North Equatorial Current reaches the Kuroshio Counter Current from the strait between Luzon and Taiwan. It then mixes with the colder water. As the mixing warms the cold current, crachin becomes less prevalent, so that by the time the currents reach Hainan Island, crachin is nonexistent. Cold front-induced crachin is short lived, but the second type is more persistent and can last 3-5 days to 3 weeks. The stratus, fog, drizzle, and rain associated with the crachin can extend seaward from the coast 60-100 miles (100-160 km). Crachin can also affect locations near the coast as the northeast flow can push it up to 60 miles (100 km) inland. It clears when a cold surge pushes across southeast China.

The Kunming quasi-stationary front typically lies across northern Hainan Island and along the borders that divide the southwest plateau from the southern plains and hills and the Sichuan Basin. Since this divides the moist, cool, cloudy, and drizzly northeastern air mass from the warmer, drier southwestern air mass, the southwest plateau and the southwest Sichuan Basin enjoy warmer temperatures, less cloudiness, and less precipitation than the rest of southeast China. Yunnan Province covers most of the southwest plateau, and its name means "south of the cloud." On the other hand, the Sichuan Basin and Guizhou provinces earn the epithet, "It never clears for 3 days in a row."

Sky Cover. It is cloudy in winter because the northeast flow advects moist air from the adjacent ocean. In fact, southeast China is the cloudiest part of China (see Figure 3-2). These clouds are usually stratiform, but thunderstorms develop near the end of the season as the strong northeast flow weakens. The widely varied terrain causes great variation in cloud cover; windward slopes are cloudier than lee side slopes due to orographic lifting of the moist air. In the following discussion, percent sky cover or percent cloud cover refer to the percentage of the sky covered with clouds.

Sichuan Basin. This region is the cloudiest area of southeast China. It is cloudy throughout the year, on average 55-90 percent sky cover. This varies by season and location. In the northwest, sky cover averages 20-65 percent. Cloud cover averages 70-90 percent elsewhere. Winter cloud ceilings at any altitude average 80-100 percent during the day and 70-80 percent at night with the lower frequency in the northwest. Ceilings less than 3,000 feet occur under 20 percent of the time at the northwestern locations and 20-50 percent of the time at other locations above 600 meters.

Southwest Plateau. This part of southeast China experiences the greatest seasonal variation in cloudiness. The western part is shielded from the moist, shallow, northeast monsoonal flow by high mountains. Also, dry air from the Tibetan highlands often dominates the area. As a result, the west is less cloudy than the east. Annual sky cover averages from 40-60 percent in the west to 55-80 percent in the east. Lowlands in the southeast are cloudier at 70-95 percent (annual). Diurnal variation in cloud amount is 5-40 percent and is the greatest during the winter. The frequency of ceilings at any altitude reflects this diurnal variation. Ceilings vary from 30-40 percent at night to 30-70 percent in the afternoon. Morning ceilings are even more frequent.

Northeast Plains. Most of the time in this area, cloud cover averages 55-70 percent the year-round, although it is cloudier in winter and spring than in summer and fall. There is less cloudiness north of the Yangtze River than south of it. Ceilings at any altitude occur 50-70 percent of the time during the day and only slightly less often at night. Cloudiness increases throughout the season as the polar front and the northeast monsoon affect the weather. Towards the end of the season as the northeast monsoon weakens, late February through March, the front begins to migrate northward. This brings an increase in cloudiness in this region. The highest frequency of ceilings below 3,000 feet occurs in March along the coast at more than 40 percent of the time. Elsewhere, these ceilings occur 20-30 percent of the time in March and less frequently in the other months.

Central Hills. This area has extensive cloud cover year-round (60 to 85 percent) due to the moist, northeast flow. Ceilings at any altitude are most extensive during the day at 70-80 percent and less so at 60-70 percent at night. Ceilings less than 3,000 feet are not as extensive during December and January; they occur less than 20 percent of the time in most places. They occur more frequently at the end of the season when they occur as much as 40 percent of the time.

Southern Plains and Hills. Cloudiness is extensive throughout the year. During winter, ceilings at any altitude occur 50-70 percent of the time during the day and 40-60 percent at night. The western part of the area is the cloudiest. Occurrence of ceilings less than 3,000 feet is quite variable. On Hainan Island, these ceilings occur more frequently on the coasts that are exposed to the northeast flow (from less than 20 percent to about 35 percent) than along the western part of the island which is sheltered by the topography (less than 10 percent).

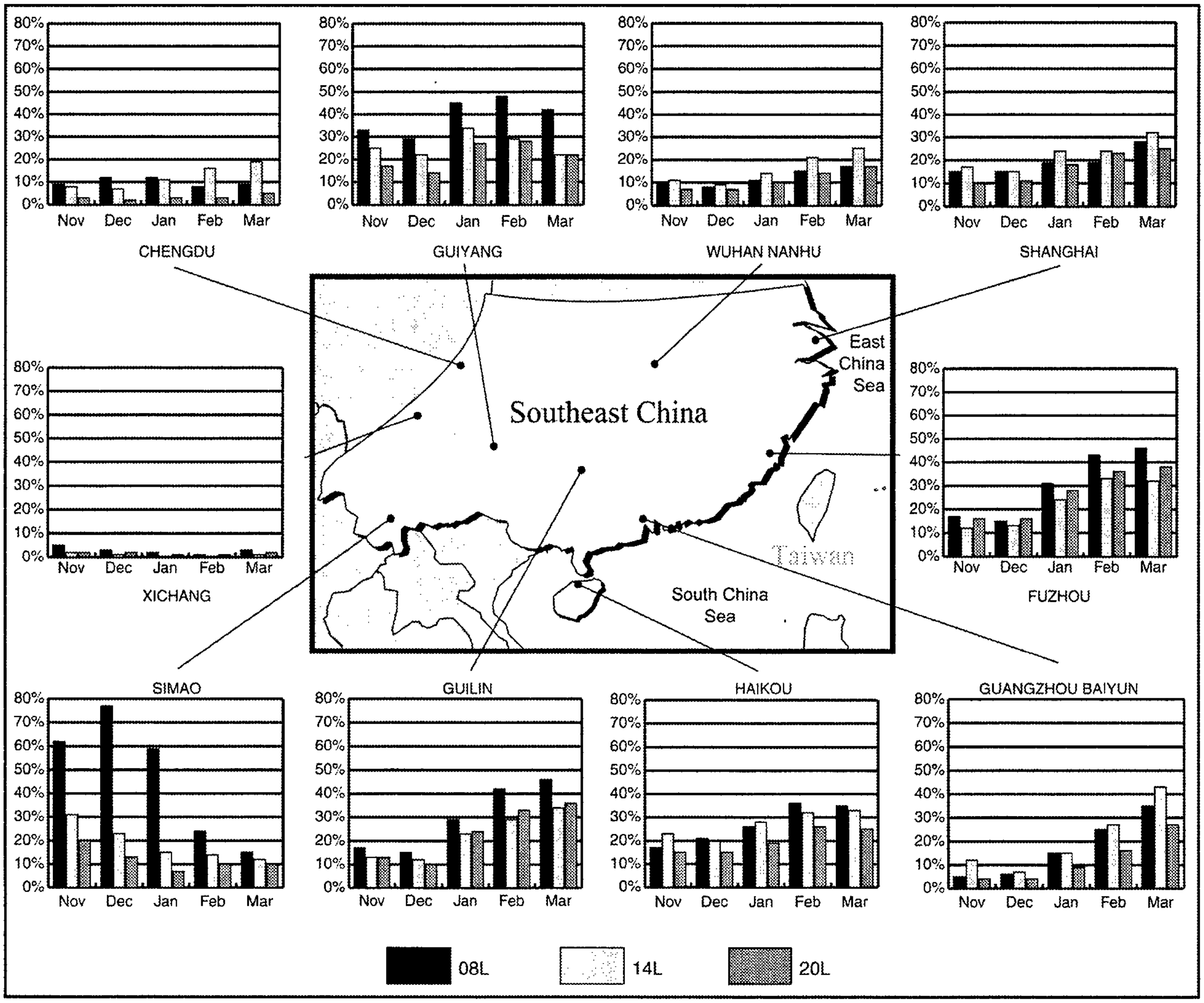


Figure 3-2. Winter Ceilings Below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. The moist, cool, and stable air associated with the northeast flow provides conditions favorable for the formation of fog or mist. Usually, this occurs most in the morning and the visibility improves to a degree by afternoon (see Figure 3-3). Offshore, over the cold Kuroshio Counter Current, crachin can persist for long periods and affect the visibility on the coastal islands and inland where the prevailing winds carry it. In general, northern southeast China experiences the most fog. This includes the Sichuan Basin, the northeast plains south of the Yangtze River, and the northern central hills.

A duststorm or sandstorm in the northeast plains, caused by gusting winds associated with a cold surge, can temporarily reduce visibility to less than 1,000 meters. Shanghai has experienced only one sandstorm every 10 years in January (based upon 20 years of record). One day per year with a sandstorm in the northeast plains would be the most that would be expected while the rest of southeast China would rarely, if ever, experience a sandstorm. Only a severe drought produces conditions for sandstorms on the surface. Visibility aloft can be reduced by dust that results from sand and duststorms in northeast China. The strong winds associated with cold surges can carry the dust or sand aloft to the top of the northeast circulation layer, normally about 700 mb.

Sichuan Basin. The surrounding mountains shelter the basin from the full force of the winter northerly to northeasterly flow. This results in a high percentage of calm winds in the Sichuan Basin and poor visibility due to the stagnant, cold, moist, stable conditions. Below 600 meters elevation, visibility below 4,800 meters occurs up to 80 percent of the time in the morning due to fog and mist. By afternoon, the visibility is still restricted to less than 4,800 meters 50-60 percent of the time in December and January. At the higher elevations, above 600 meters, the visibility is much better. There, less than 4,800 meters occurs only 10 percent of the time or less.

Southwest Plateau. Visibility is generally good in this area except at Simao where morning fog and mist reduce the visibility to less than 4,800 meters 50-60 percent of the time in December and January. Visibility improves to more than 4,800 meters by afternoon most of the time.

Northeast Plains. Locations along the Yangtze River experience the highest frequency of visibility less than 4,800 meters in the morning. Restrictions occur 40-60 percent of the time in December and January due to fog and mist, but less frequently later in the season. By afternoon, visibility improves significantly. Then, visibility less than 4,800 meters occurs 20-30 percent of the time or less frequently at many locations away from the river. A rare duststorm or sandstorm caused by a cold surge from the Asiatic high can reduce the visibility to less than 1,000 meters for short periods (less than a day in most cases).

Central Hills. Fog and mist occur more frequently in the northern part of the area where the northeast flow carries moisture from the ocean and the Yangtze River. In January, fog occurs more than 20 days in this area. Fog decreases in frequency to the south except at some locations near the coast. Visibility less than 4,800 meters in fog occurs up to 60 percent of the time in the morning. By midafternoon, the frequency drops to 10 percent or less at most locations.

Southern Plains and Hills. Visibility is mostly good with only some locations experiencing morning fog that reduces the visibility to less than 4,800 meters 20-30 percent of the time. By afternoon, visibility improves. Visibility below 4,800 meters occurs, on average, less than 10 percent of the time.

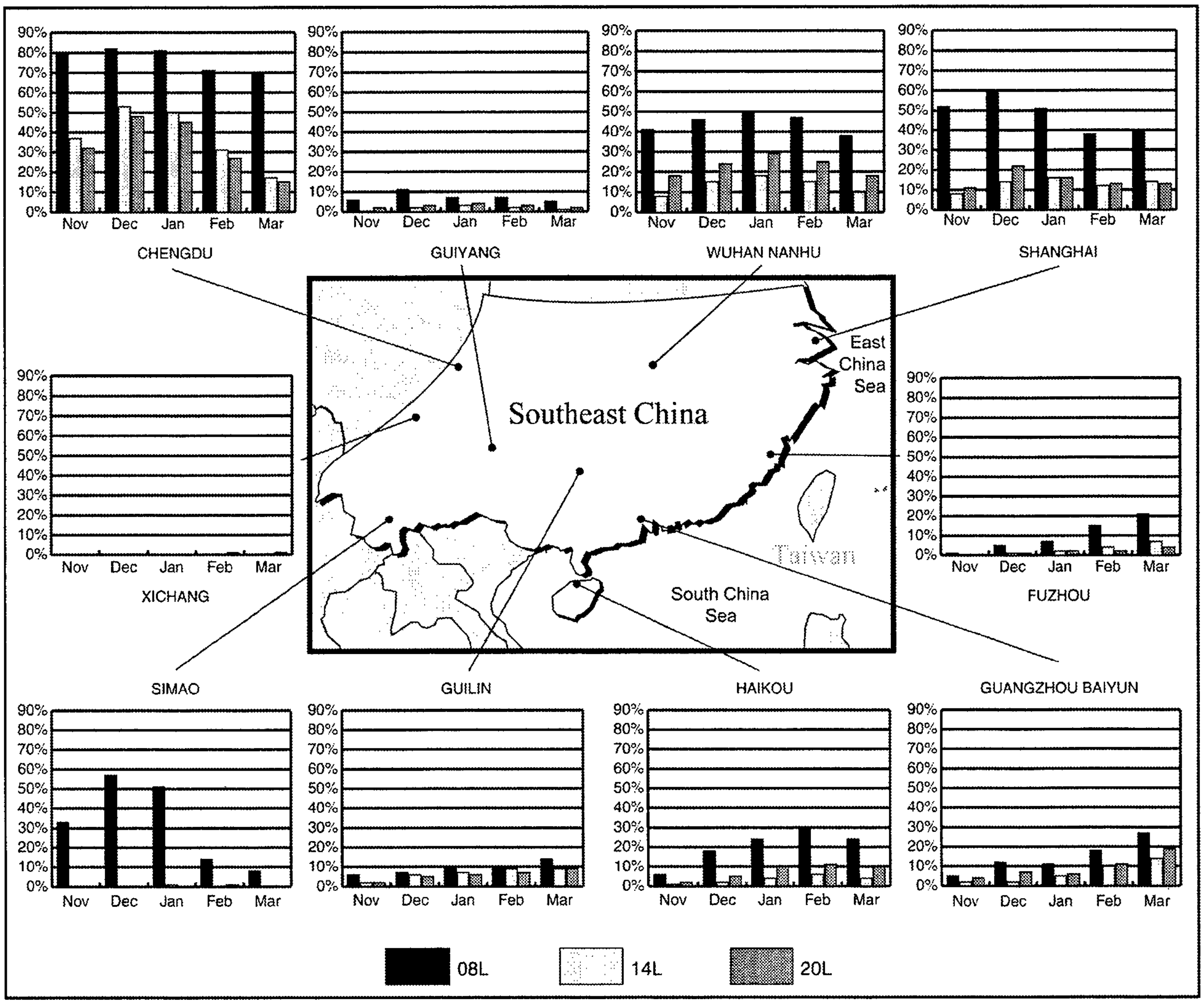


Figure 3-3. Winter Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. The northeast flow is the primary control on the direction and speed of the surface winds, but the variable terrain of southeast China causes local variations in the flow. Consistently strong surface winds occur on the offshore islands and along the east coast because the winds travel unobstructed over the ocean. Higher elevations experience foehn and bora winds caused by cold surges from theAsiatic high. Locations at very high elevations in the mountains experience high winds because of the nearness of upper-air jets. The Taiwan Strait has strong winds because northeasterly winds are funneled through the strait. The lightest surface winds occur in southern southeast China and in sheltered valleys and basins. For example, calm winds are frequent, especially at night, in the Sichuan Basin and in the valleys of the southwest plateau. See Figure 3-4 for January wind roses.

Sichuan Basin. This protected basin has frequent calm conditions, especially at night when calms occur up to 60 percent of the time at elevations below 600 meters. Above that height, calms are less frequent. During the day, light northeast winds of 5 knots or less prevail with speeds up to 15 knots possible. Extreme winds of 25-45 knots occur on rare occasions.

Southwest Plateau. Surface winds on the plateau (elevation about 1,300 meters) do not show the northeast flow. Rather, they are often calm at night and south to southwest during the afternoon, approximately the same as the 850-mb winds. Wind speeds are mostly below 15 knots, but they increase to as high as 25 knots at higher locations. Extreme high winds of 50 knots are possible.

Northeast Plains. Surface winds are stronger near the coast where northeast winds have traveled unobstructed over the ocean. Winds are calm at night 30-50 percent of time except near the coast where Shanghai winds are calm only 13 percent of the time at night. Prevailing winds are generally from the north or northeast at speeds up to 15 knots with some winds up to 25 knots at Shanghai. A land/lake breeze at Dongting Lake is possible during winter periods of weak circulation, or about 7-8 days per month. The lake breeze starts about noon and ends in the early evening. Extreme winds up to 55 knots are possible with an especially strong cold surge in the northeast monsoon.

Central Hills. All locations in this area show brisk north to northeast winds with little diurnal change. Calm winds at night occur 25 percent of the time or less at most locations. Wind speeds of 6-15 knots are common. Speeds up to 25 knots occur 10 percent of the time at some locations. Extreme winds of about 65 knots have occurred near the coast and on islands along the coast. This is caused by an intense cold surge that bursts through the Nanling barrier and drives the Kunming front well south of its usual position in the lee of the Kunming and Nanling Mountains. Passage of the frontal boundary produces high winds, but the intensely cold air mass pushing it south is quickly warmed (which loosens the temperature gradient) when it reaches the South China Sea and the winds die down rapidly. Fuzhou, near the coast shows a diurnal change in the winds from north at night to southeast during the day. This appears to be the result of a land/sea breeze that is present even in January.

Southern Plains and Hills. Surface winds in the southern hills and plains are northerly to easterly with calm winds only a small percent of the time near the coast. Inland winds are often calm at night. Winds of 6-15 knots are common with speeds up to 25 knots only a small percentage of the time near the coast and on Hainan Island. Exposed locations near the coast and on Hainan Island can get winds up to about 55 knots with an intense cold surge in the northeast monsoon (see the explanation in the central hills section immediately above).

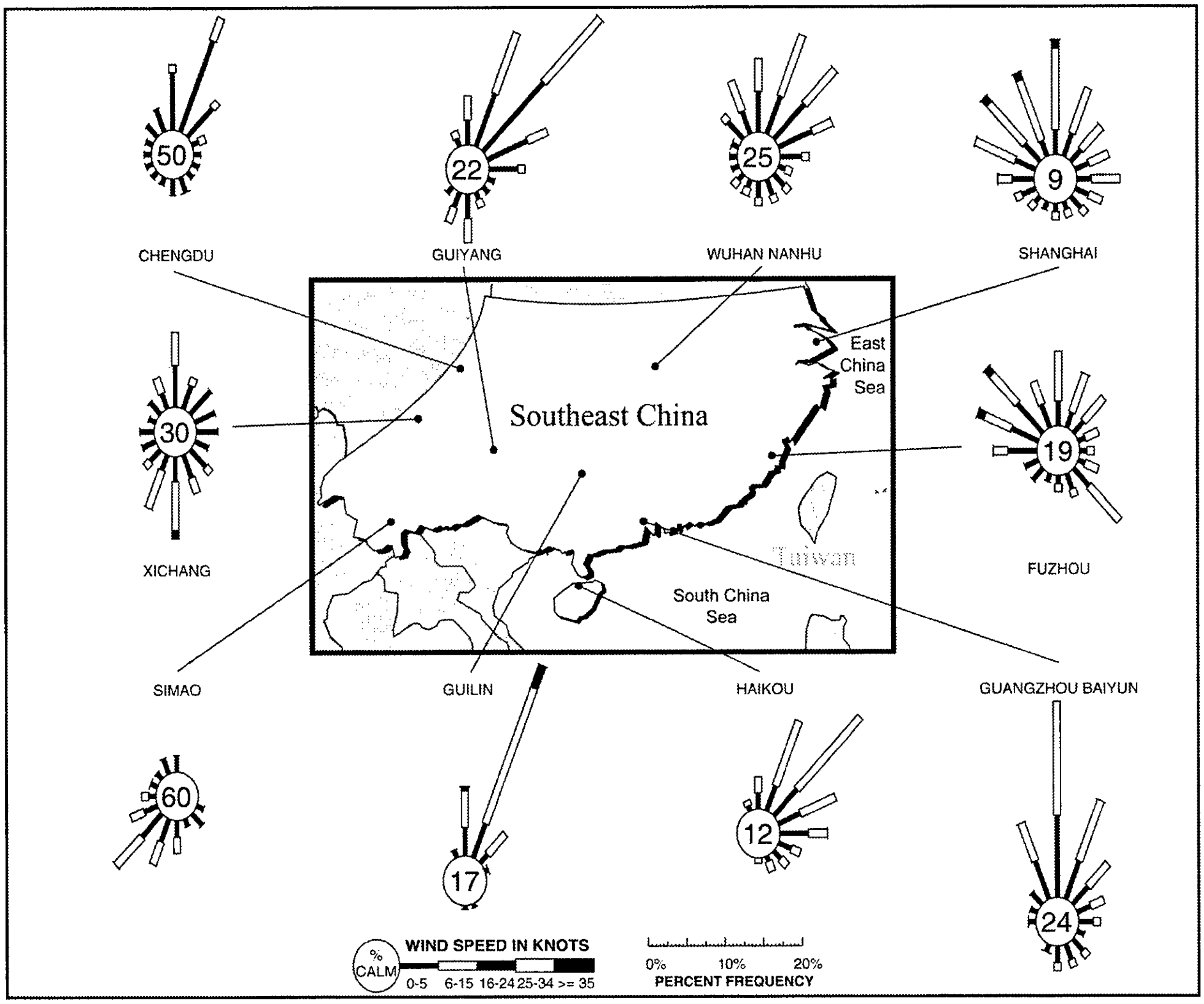


Figure 3-4. January Surface Wind Roses. The figure shows the prevailing wind directions and range of speeds based on frequency and location.

Winds Aloft. Westerlies prevail above the boundary layer (see Figure 3-5). The shallow northeast monsoon is confined to the lower layers of the atmosphere. Even at the 850-mb level, the northeast monsoon is not very evident in the south and west. The subtropical jet crosses southeast China from southwest to northeast during winter. The January mean freezing level varies from about 3,000 feet at Shanghai to 13,000 feet at Haikou.

Sichuan Basin. The January 850-mb winds are southerly with winds up to 45 knots. Westerly winds at speeds up to 60 knots occur at 700 mb, up to 100 knots at 500 mb, and up to 120 knots at 300 mb.

Southwest Plateau. Light southerly winds dominate at 850 mb. Although winds of up to 30 knots occur, speeds are usually 15 knots or less. Westerly winds at speeds up to 60 knots occur at 700 mb, up to 100 knots at 500 mb, and up to 120 knots at 300 mb.

Northeast Plains. Northwesterly winds with speeds up to 45 knots occur below the 700-mb level. Westerlies prevail with speeds up to 60 knots at 700 mb and up to 100 knots at 500 mb. The subtropical jet is indicated by winds up to 120 knots (35 percent of the time in January) at 300 mb.

Central Hills. Winds at 850 mb are variable with mean northerly winds at speeds up to 30 knots. A low-level, southwesterly jet may be evident as winds with speeds up to 45 knots occur from that direction. Westerlies prevail with speeds up to 60 knots at 700 mb, up to 100 knots at 500 mb, and occasionally more than 120 knots at 300 mb.

Southern Plains and Hills. On Hainan Island, westerly winds are not as strong as those to the north. At 850 mb, southwesterly winds at speeds up to 30 knots prevail. These dry, warm winds cause the mild weather that occurs here. Westerlies prevail with speeds up to 40 knots at 700 mb, up to 75 knots at 500 mb, and occasionally 90 knots at 300 mb.

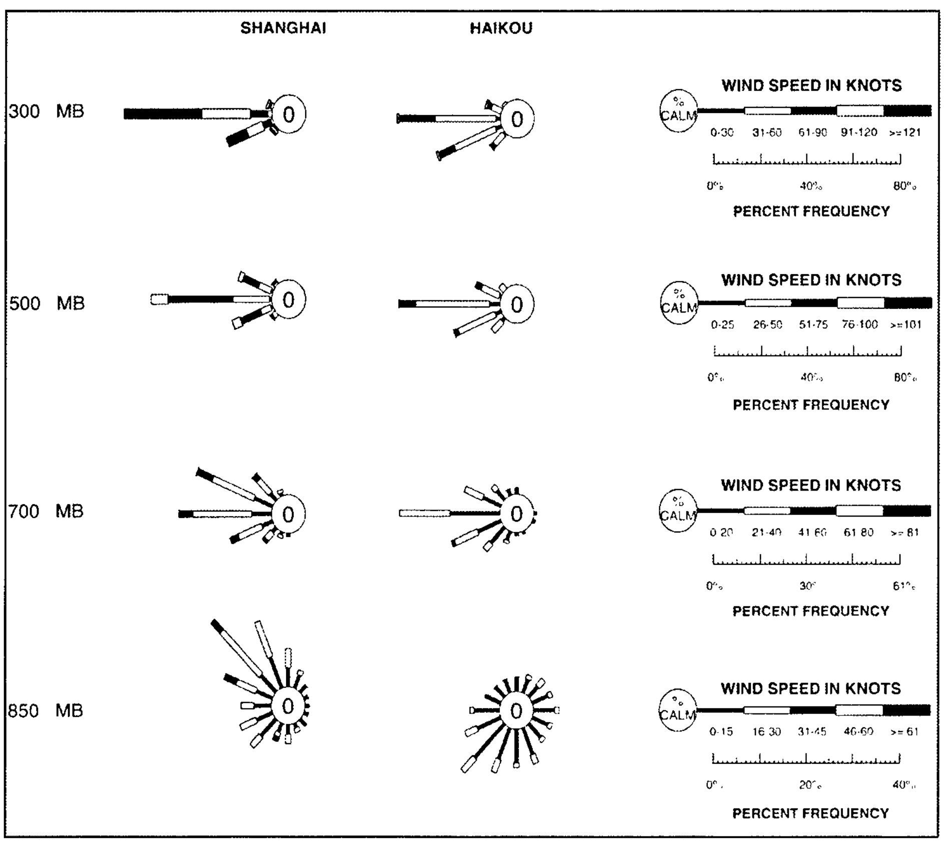


Figure 3-5. January Upper-Air Wind Roses. The wind roses depict 1200 UTC wind speed and direction for standard pressure surfaces between 850 and 300 mb.

Precipitation. Winter is generally the season with the least precipitation (see Figure 3-6). January, the month with the strongest northeasterly flow, has the lowest monthly average at most locations. Typically, all of southeast China averages from 10 mm to more than 70 mm during January. Precipitation is lowest in the west and north and highest in the east where the northerly to northeasterly flow crosses the ocean before reaching the area. The highest mean precipitation in January (70-80 mm) is in the northeast plains and central hills, between the Yangtze River valley and the Nanling Mountains. Terrain is a factor in producing the higher amounts due to orographic lifting. Cold bursts from the north lift warm, moist air aloft. A string of surface low-pressure centers develops as a result, and they move eastward under the westerly upper-air flow. The cold fronts associated with these lows often become stagnant on the northern slopes of the Nanling Mountains and cause low clouds and precipitation south of the Yangtze River (see Figure 3-6).

The central hills north of 25° N, Sichuan Basin, and the northeast plains and hills are vulnerable to freezing rain and drizzle. The rest of southeast China is too warm. Warm, moisture-laden air is advected onshore and overlays frigid surface air. Stratiform clouds settle over this cold layer and rain falls through the subfreezing air. In the Sichuan Basin, freezing precipitation occurs 20-30 days a year in the mountains and 2-7 days a year at lower elevations. In the northeast hills and plains, freezing precipitation occurs between 1 and 5 days a year, but it is rare on the coast. Once on the ground, glaze ice lasts longest in the mountains and disappears much more quickly at lower elevations.

Thunderstorms are not as common during winter as they are in spring and summer due to the cold, stable conditions over most of southeast China. They can occur following anomalous warm conditions or during a persistent rainy situation. As the Asiatic high weakens in February, thunderstorms appear at most locations and increase in frequency in March. Over the Yangtze River valley, thunderstorms have been observed about once every 2 to 3 years at the height of winter.

Sichuan Basin. Precipitation amounts are small in January. The area receives an average of only 10-30 mm, but rain or drizzle falls during 20-25 days of the month at elevations above 600 meters and 15-20 days of the month at lower elevations. Therefore, while it rains often, amounts are small. Snowfall also occurs more frequently at the higher elevations. It peaks in January and occurs during nearly 10 days; below 600 meters the snow falls during 5 days or less per month. Snow depth averages 5 cm. Freezing rain or drizzle occurs (in warm, overrunning situations) 20-30 days per year in the mountains and 2 to 7 days per year at lower elevations. At lower elevations, glaze ice on the ground melts away within a day in most cases; it takes longer in the mountains and may remain on the ground for 35-50 days at a time. At the highest elevations, it can stay on the ground as long as 135 days at a time.

Thunderstorms are more likely to occur in areas above 600 meters and then they are more likely toward the end of the winter (they occur five to eight times during March). Below 600 meters thunderstorms are extremely rare, but increase in frequency toward the end of winter when they occur five times or less per month.

Southwest Plateau. This area receives an average of 10-20 mm over 5-22 days in January. Amount and duration depend on orientation to the northeast monsoon. Windward slopes receive more rainfall. Those locations also receive more snowfall, 8 days in January compared to only 1-2 days at other locations. Maximum depth of snow cover is more than 10 cm in the northwestern part of the area.

Thunderstorms are rare in winter, but one or two per month can occur every month except December. Thunderstorm frequency increases in March to five per month at some locations.

Northeast Plains. January's mean precipitation of 20-40 mm falls on 10-15 days of the month. The northeast flow weakens toward the end of winter as the Asiatic high weakens. Thunderstorms increase in frequency to a maximum of 5 per month in March. Snowfall occurs through the end of the season. It peaks at 5-7 days per month and drops to one or two days in March. Maximum depth of snow cover is higher in this part of southeast China. It averages 20-40 cm in the eastern part of the region. This area is vulnerable to freezing precipitation in situations where warm, moist air overruns frigid surface air, about 1 to 5 days per year. The glaze ice produced by freezing precipitation causes damage to trees and power lines. Coastal areas see freezing precipitation more rarely; Shanghai records freezing rain only once every 10 years.

Thunderstorms are rare from December to through January, the period of the strongest northeast flow. The first thunderstorms arrive in February, and they increase in frequency through March. They occur four times per month or less during those months.

Central Hills. Precipitation in January (30 to more than 70 mm) falls on an average of 15-20 days. Rainfall is lowest during November and December, but increases through the rest of the season so, by March, rainfall occurs on 20-25 days. Snow occurs through the end of the season. Maximum depth of snow cover is more than 40 cm in the northeast. The area North of 25° N is vulnerable to freezing precipitation on about 1-5 days per year. This occurs during overrunning situations.

Thunderstorms are rare in November through January, but increase in frequency to as many as 9 days with thunderstorms during March.

Southern Plains and Hills. Winter rainfall is heaviest in the east along the coast where the northeast flow first reaches land after it traverses the water of the South China Sea. Average amounts decrease from about 50 mm there to about 20 mm in the west. Hainan Island receives most of its rainfall on its windward side. Precipitation decreases from east to west from more than 40 mm to less than 10 mm in January. The number of days with rainfall increases throughout the season from 10 days or less in December to 20 days or more in March. Snowfall is extremely rare in this region. By March, thunderstorms occur about 5 days as the northeast monsoon weakens.

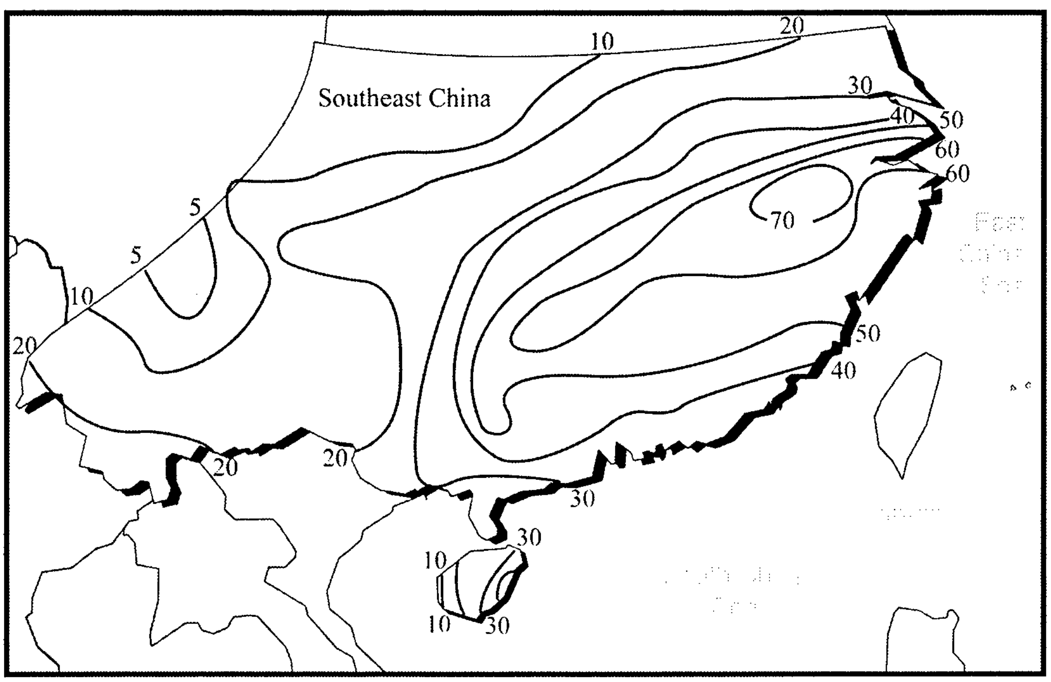


Figure 3-6. January Mean Precipitation (mm). The figure shows mean water equivalent amounts that occur in southeast China when winter is at its peak.

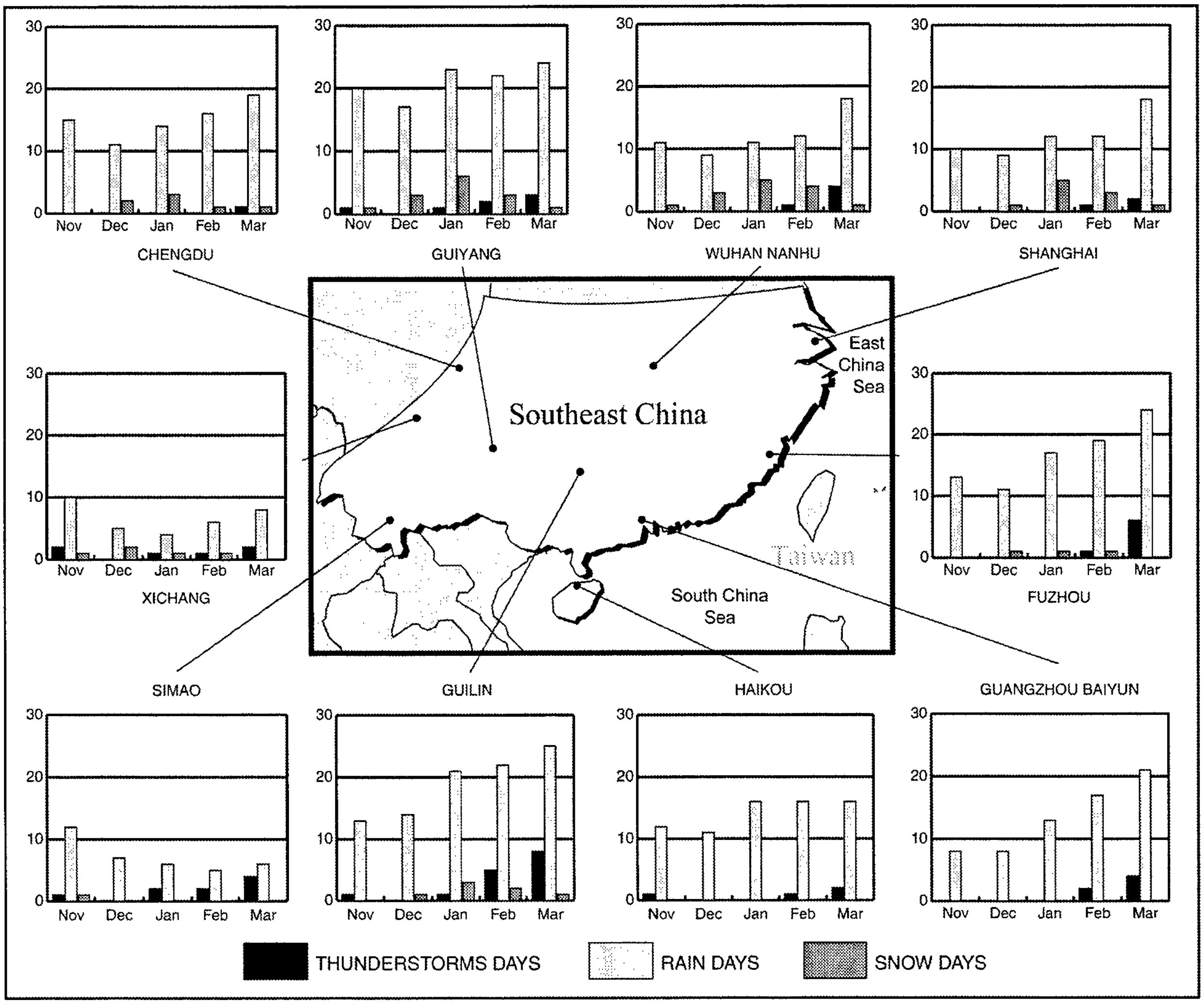


Figure 3-7. Winter Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average winter occurrences of rain, thunderstorm, and snow days for representative locations in southeast China.

Temperatures. Compared to other locations at the same latitude, China is much colder in winter due to the strong, cold Asiatic high. The temperature pattern is zonal. Isotherms are parallel to the latitude lines, and the temperature gradient is the strongest of the year.

The coldest temperatures occur north of the Yangtze River valley in the northeast plains where means close to 32°F (0°C) prevail. Temperatures are warmest along the southern coast and Hainan Island where mean daily maximum temperatures average 59° to 77°F (15° to 25°C) in January (Figure 3-8) and mean daily minimum temperatures average 50° to 68°F (10° to 20°C) (Figure 3-9).

The Sichuan Basin is also warmer than surrounding areas with average January temperatures about 9°F (5°C) warmer than areas around it because surrounding high terrain protects the basin from the cold surges from the Asiatic high.

Temperature fluctuations are larger during November and March, the start and end of the winter season, when the cold and warm air alternate over southeast China. From December to February, temperatures are uniformly low with little variation. Extreme low temperatures follow the same zonal pattern of colder in the north and warmer in the south. They are usually caused by cold bursts from the Asiatic high.

Sichuan Basin. In the Sichuan Basin, winter temperatures are more moderate than in other areas of southeast China. Absolute minimum temperatures range from 10° to 28°F (-12° to -2°C) while the average minimums range between 32° and 50°F (0° and 10°C). Maximum temperatures average 45° to 57°F (7° to 14°C) and extreme maximums can reach as high as 90°F (32°C) in late March.

Southwest Plateau. Mean maximum temperatures in January are 50° to 68°F (10° to 20°C) and mean minimums are 32° to 50°F (0° to 10°C). Extreme minimums go as low as 14°F (-10°C) and extreme highs as high as 100°F (38°C) are possible near the end of the season.

Northeast Plains. Mean temperatures range between 32°F and 46°F (0° and 8°C). The lower reaches of the Yangtze River are colder than the warm upper reaches. Extreme low temperatures range between 0° and 14°F (-18°C and -10°C).

Central Hills. Average high temperatures in January range between 46° and 59°F (8° and 15°C) while average lows are between 32° and 50°F (0° and 10°C). Extreme minimums reach as low as 10°F (-12°C) during the coldest months and extreme highs can reach 100°F (38°C) by the end of March.

Southern Plains and Hills. Extreme minimum temperatures rarely go below 32°F (0°C) and extreme highs reach 104°F (40°C) by the end of March. Mean maximum temperatures in January of 59° to 77°F (15° to 25°C) and mean minimums of 50° to 68°F (10° to 20°C) indicate that this region of China never really gets cold. The mean maximum temperatures greater than 68°F (20°C) are mostly confined to the Leizhou Peninsula, Hainan Island, and the islands in the South China Sea.

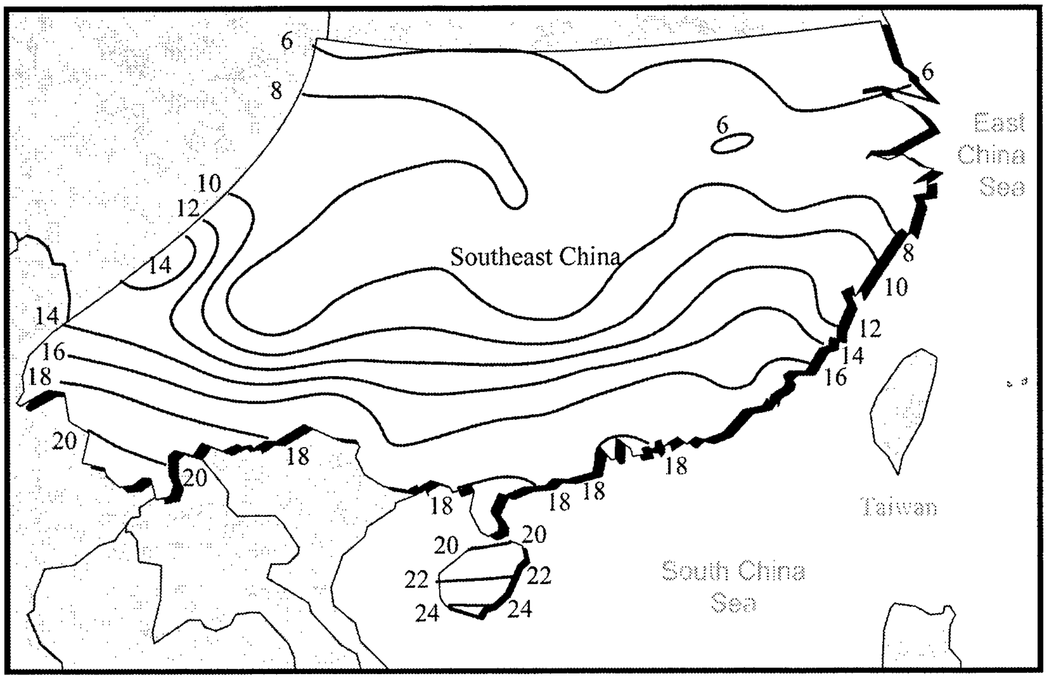


Figure 3-8. January Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for the coldest month of winter. Mean maximum temperatures during other winter months may be higher, especially at the beginning and end of winter.

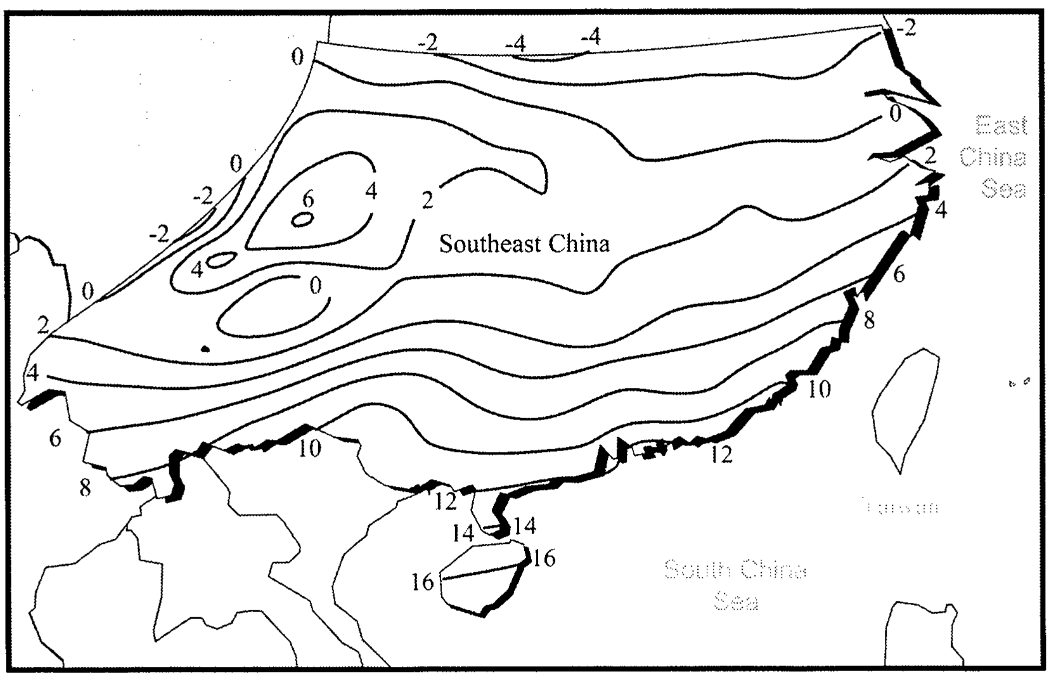


Figure 3-9. January Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the coldest month of winter. Mean minimum temperatures during other winter months may be higher, especially at the beginning and ending of the winter season.

Hazards.

Aircraft Icing. Predominant stratiform clouds and cold temperatures aloft make aircraft icing less likely than during other seasons. In the north, light rime icing in clouds is possible from about 3,000 feet (900 meters) to 20,000 feet (6 km). In the south, it is most likely from 4 km to about 8.5 km. In areas where freezing precipitation is occurring, severe icing will be present in cloud from the surface to the top of the freezing layer.

Freezing Precipitation. Winter, especially January and February, is when the most freezing precipitation occurs in southeast China. The northeast plains, the central hills north of 25° N, and the mountains in the Sichuan Basin are susceptible to this condition; the rest of southeast China is too warm. Freezing rain or drizzle causes dangerous glaze or rime ice (supercooled raindrops freeze in a clear or semitransparent coat on power lines, tree limbs, vehicles, buildings, and the ground at near freezing temperatures). The weight of the ice brings down the power lines and trees and makes ground travel extremely difficult. In the Sichuan Basin, freezing precipitation occurs anywhere from 20-30 days per year at mountain stations in the Yangtze River valley and 2-7 days per year elsewhere. The incidence in the northeast plains and central hills is lower, about 1-5 days per year, and nearer the coast it occurs even less frequently. Shanghai experiences freezing precipitation only about once in 10 years. Once formed, glaze ice persists the longest at mountain stations where it has lasted as long as 135 days. On the plains, the longest periods of glaze occur between 28° N and 35° N where it can persist for 100 hours or more. The maximum duration of glaze at Shanghai, however, has been about 9 hours.

Tropical Cyclones. Although the storm season usually ends in fall, a tropical depression or tropical storm may still cross Hainan Island or curve northeast along the east coast in November or December about once every 5 years. Tropical depressions, with winds between 34 and 63 knots, can wreak havoc along the east coast.

Turbulence. Strong westerly winds aloft and the rugged terrain of southeast China, especially in the Sichuan Basin and the southwest plateau, make conditions favorable for mountain-wave turbulence downwind from these mountains to altitudes well above 20,000 feet (6 km). This turbulence can be severe, depending on the wind velocity.

Trafficability. China is a country of very diverse topography and soil types. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine grained, and consist of clays and silts. The soil type range, however, extends to and includes some sizable areas of sand and gravel. In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows, especially if frozen, and some valley bottoms.

On the plains, slopes vary from nearly level to about 20 percent. The soils are predominantly medium to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the dry season, movement conditions are fair to good except where restricted by marshy areas, steep-banked water courses, irrigation canals, forests, and very rugged terrain. In the southern part of the plains, rice cultivation limits movement when paddies are flooded.

Within this basin are low mountains, hills, and many streams and terraces. Soils are mostly fine grained. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas.

General Weather. Spring heralds the transition from the stable, cold, northeast flow to the warm, moist, unstable southwest flow. The weather fluctuates more rapidly in spring than during winter as most weather systems are migratory rather than stationary and are usually not as strong as in winter. Gradually and unevenly, temperatures increase over the area.

These changes are directly related to changes in the semipermanent meteorological features. The Asiatic thermal low develops rapidly in May and the Asiatic thermal high weakens. In addition, the ridge line of the North Pacific high advances northward. These changes in the weather pattern intensify the cross-equatorial flow. Southwest flow prevails in the South China Sea with a low-level jet. These changes all contribute to the rapid increase in rainfall in southern southeast China.

Cold surges still occur during April, but the cold air warms quickly as it moves southward, and low temperatures don't last more than 2-3 days. Consequently, the last frost in the northeast plains is usually in late March to early April, while the remainder experiences its last frost before April.

The first of two rainy seasons south of the Yangtze River—the mei-yu— starts in April and lasts through May. It is associated with small depressions that move eastward along the quasi-stationary mei-yu front. This front usually lies between the Yangtze River and the southern coast and migrates northward as the season progresses. Rainfall associated with the front lasts 1 month or less over any locality. The heaviest rain occurs south of the front, usually during May south of the Yangtze River.

Extratropical cyclones are most frequent during spring and contribute to the persistent spring rains and cloudiness. Yangtze-Huaihe lows develop over the Yangtze River valley along frontal zones most frequently during spring. They move east or northeast and cause heavy rainfall along their path. Four to five of these occur each month in spring, but as many as seven per month are possible. East China Sea lows form farther east along a frontal zone than the Yangtze River-Huaihe lows but have about the same frequency (four to five per month). Their track is usually the same as the Yangtze River-Huaihe lows.

Persistent rainy periods are characteristic of spring weather from the Yangtze River valley southward. During a persistent rainy period, stratiform precipitation occurs. Precipitation amounts seldom exceed 100 mm, but the totals are normally above 20 mm. The precipitation can cover vast areas. As many as five persistent rainy periods can occur in one location, but two is average. Average duration is 5-7 days but have lasted as long as 18 days.

Two circulation patterns are known to cause persistent rainy periods—a blocking high near the Ural Mountains in Siberia, and a large low-pressure area over the middle and high latitudes of Eurasia.

Sky Cover. It is cloudy over most of southeast China during spring, except in the southwest plateau where the Kunming quasi-stationary front continues to divide the cloudy, northeasterly flow from the drier flow from southwest Asia (see Figure 3-10). As spring progresses, cloudier conditions arrive in the southwest plateau with warm, moist air masses of maritime origin. Most cloudiness is associated with the heavy precipitation area of the first rainy season that moves northward over the area with the mei-yu front. It first starts at the south coast in the southern plains and hills and moves northward into the central hills where it remains for about a month before moving northward again. The Sichuan Basin remains one of the cloudiest areas due to the topography; ceilings occur 70-80 percent of the time with little diurnal variation. The least cloudiness occurs north of the Yangtze River valley and at the southern coast of southeastern China. This is because the rainy period, or mei-yu season, rapidly moves northward from the southern plains and hills, but it remains over the central hills for much of spring. Ceilings occur 50-70 percent of the time with the lower occurrences at the south coast and north of the Yangtze River.

Sichuan Basin. Ceilings occur 70-80 percent of the time with little diurnal variation. While it is cloudy over the basin, low clouds contribute only a small part as cloud ceilings less than 3,000 feet occur less than 20 percent of the time at most locations. At the higher elevations, above 2,000 feet (600 meters), these ceilings are more frequent (20-40 percent). Diurnal variation is small, but it depends on elevation. Lower locations experience more low clouds in the morning and higher elevations experience them more in the afternoon as the cloud bases rise with daytime heating.

Southwest Plateau. Ceilings are quite variable over this region due to the terrain. In general, the east and northeast, where the Kunming quasi-stationary front may still exist early in the season, have the most clouds. Ceilings vary from about 60 percent at night in the east to 70 percent during the day. In the west, they vary from 30 to 40 percent. Ceilings less than 3,000 feet follow the same pattern. In the northwest they occur less than 10 percent of the time, while in the east they occur up to 60 percent of the time.

Northeast Plains. Ceilings occur about 60-70 percent of the time, with the most cloudiness south of the Yangtze River and the least to the north. There is little variation from day to night. Ceilings less than 3,000 feet are more frequent near the coast and on islands along the coast, where they occur up to 40 percent of the time. In the west, they occur 20 percent of the time or less. The Yangtze-Huaihe lows are most frequent in spring, when four to five per month occur. These lows affect the middle to lower reaches of the Yangtze River valley. They are responsible for the higher frequency of low ceilings in that area.

Central Hills. This area has extensive cloud cover during the transition from winter to summer as the first rainy season starts its migration northward and stays over the central hills for about 30 days. Ceilings occur 70 percent of the time at night and 80 percent of the time during the day. Ceilings less than 3,000 feet occur up to 40 percent of the time near the coast and on the offshore islands and mostly less than that inland. Nocturnal rain causes the highest frequency of ceilings less than 3,000 feet in the morning; the lowest frequency is usually in the late afternoon to evening.

Southern Plains and Hills. Southern Hainan Island generally has the least cloudiness. At night, ceilings occur about 50 percent of the time on southern Hainan, but they occur about 70 percent of the time in the rest of the southern plains and hills. During the day, the frequency increases to 70 percent on southern Hainan Island and to 80 percent in the rest of the region. Ceilings less than 3,000 feet occur as much as 60 percent of the time with the rain belt that moves northward.

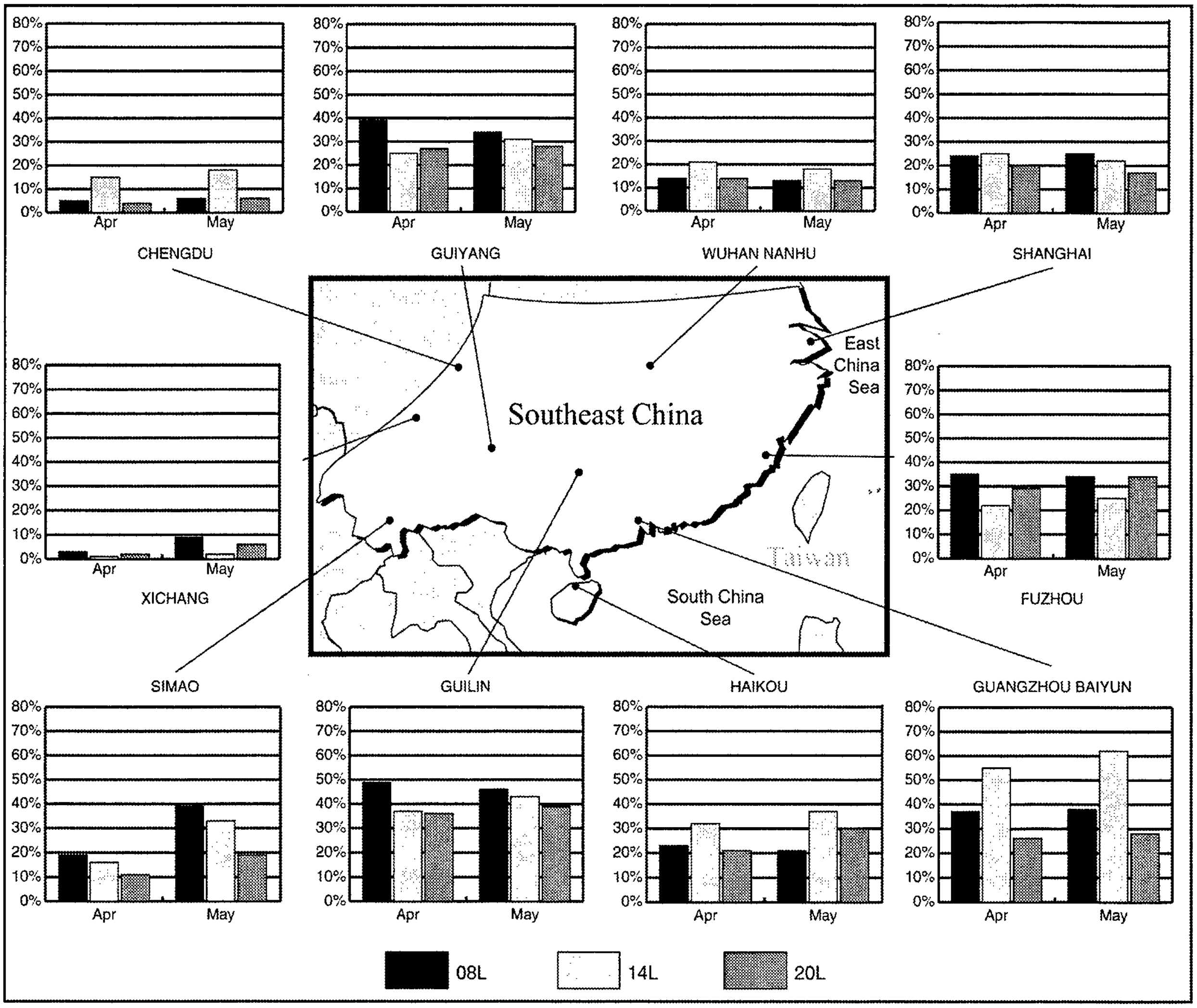


Figure 3-10. Spring Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Fog and mist persist in the spring as long as northeast flow persists. Fog is the primary restriction to visibility (see Figure 3-11). Crachin and its associated sea fog and drizzle can restrict visibility along the coast and at the coastal islands until mid-April.

Most sandstorms or duststorms occur in spring, particularly in April before the rainy season starts, but they mostly occur in northwest China. The northeast plains experience on average only 1 day with duststorms per year. South of 30° N, sandstorms and duststorms are extremely rare. However, an El Niño causes drought conditions over most of southeast China except for the northeast plains. During an El Niño year duststorms may occur south of 30° N, but they would not generally occur in the northeast plains because an El Niño event causes flooding there. Sandstorms and duststorms normally reduce the visibility to less than 1,000 meters.

As the mei-yu front progresses northward over southeast China, persistent rainy periods along and to the south of this front cause reduced visibility due to the rain and rain-induced fog.

Sichuan Basin. The visibility is usually good except in the morning when it is restricted to less than 4,800 meters as often as 60 percent of the time due to fog and mist. Actual frequency of occurrence varies by location. Higher stations such as Guiyang, have visibility less than 4,800 meters less than 10 percent of the time there. Fog with visibility 9,000 meters or less occurs more than 15-27 days per month. At sites above 600 meters, it is 6-10 days.

Southwest Plateau. Good visibility prevails; there are isolated locations where restrictions drop visibility below 4,800 meters. These restrictions occur mostly in the morning due to fog. Fog with visibility 9,000 meters or less occurs 3-7 days per month in the east and up to 2 days in the west.

Northeast Plains. The highest frequency of visibility less than 4,800 meters is along the Yangtze River, where rain and fog restrict the visibility 30-40 percent of the time in the mornings. By afternoon the frequency drops to 10 percent or less. Visibility of 9,000 meters or less with fog occurs 14-25 days per month, but only about 10 days per month near the coast. Duststorms and sandstorms are most frequent during spring, but they are still rare. Shanghai experiences sandstorms once every 5 years, on average, during April. Duststorms or sandstorms reduce the visibility to less than 1,000 meters.

Central Hills. The northeastern part of the area has the highest frequency of visibility less than 4,800 meters. The restricted visibility occurs up to 40 percent of the time in the morning and improves by afternoon except at offshore islands, where fog and mist continue to restrict visibility the remainder of the day. Elsewhere, visibility is generally good.

Southern Plains and Hills. Visibility is mostly good near the coast. Lower visibility inland occurs 20 percent of the time in the morning due to fog and precipitation. Visibility of 9,000 meters or less due to fog and mist occurs up to 23 days per month near the coast, but rarely on Hainan Island.

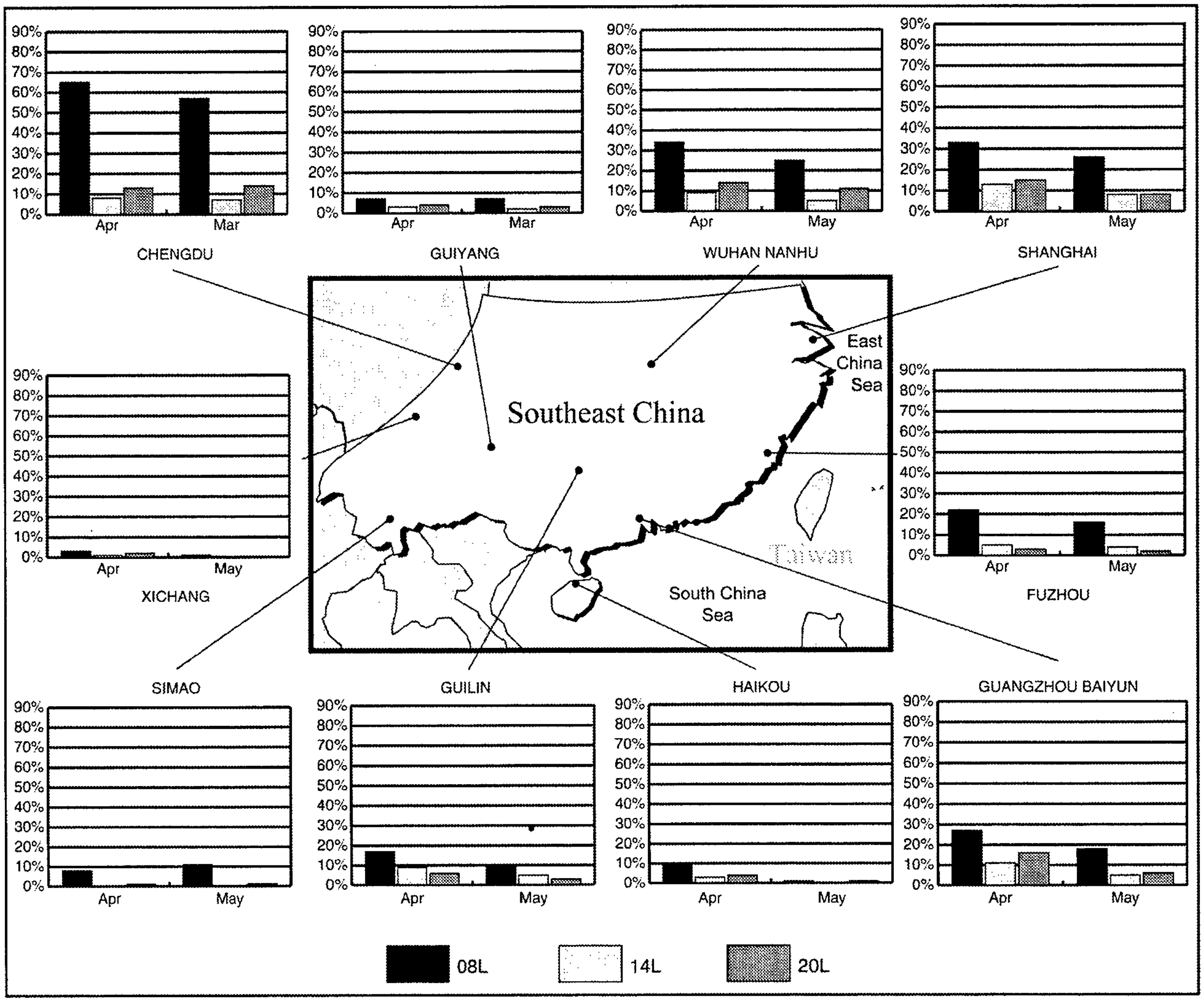


Figure 3-11. Spring Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. During the transition from winter to summer, surface wind directions vary between northeasterly and southwesterly. As the summer flow arrives from the south and the winter flow retreats northward, the wind direction changes to a southerly direction. Wind speeds in summer are generally lower than in winter. Coastal areas and higher elevations have the strongest winds. Winds along the southeast coast average 8-10 knots. In the south they average 2-6 knots (see Figure 3-12).

Sichuan Basin. Northeast winds still prevail in the Sichuan Basin. Nighttime winds are calm up to 50 percent of the time. During the day, winds are light from the north to northeast at most locations. Guiyang, which is an exception, averages strong, southerly winds at 6-15 knots during the day. Guiyang had extreme winds of 64 knots (thunderstorm related) during May.

Southwest Plateau. Calm winds are frequent at night in valleys and protected locations. At Simao, southwesterly winds dominate. These winds are usually 15 knots or less, but at Kunming, which is nearly 2,000 feet (600 meters) higher than Simao, wind speeds in the afternoon can be up to 25 knots. At Xichang, a mountain and valley breeze is evident. Winds blow from the north at night with speeds up to 15 knots and from the south during the afternoon at speeds up to 25 knots.

Northeast Plains. Calm winds occur at night over one-third of the time except at locations near the coast. For example, Shanghai's winds in April are southeasterly day and night with speeds mostly 6-15 knots, but speeds up to 25 knots occur in the afternoon. Shanghai has a very small percentage of calm winds. Extreme winds of about 60 knots have occurred at the coastal islands (caused by early season tropical storms). A land/lake breeze along the shores of Dongting Lake occurs during periods of weak general circulation, about 12 days per month. The lake breeze starts before noon and the land breeze starts in the early evening. The lake breeze keeps afternoon temperatures slightly lower near the lake.

Central Hills. Summer southwest flow returns to the coastal areas. Calm winds occur during the night about 30 percent of the time or more depending on location. Near the coast, prevailing winds are southerly to southeasterly. During the afternoon, a sea breeze may strengthen the southeasterly winds at Fuzhou. Mean winds are mostly 6-15 knots, but speeds can be up to 25 knots. Locations farther west in the central hills still show northeasterly flow during April at speeds up to 25 knots. The strongest winds occur on the offshore islands and near the coast where maximum winds have been about 50 knots during spring.

Southern Plains and Hills. Calm winds occur 35-45 percent of the time at night except near the coast and on Hainan Island. An afternoon sea breeze from the east to northeast blows at 6-15 knots and up to 25 knots along the South China Sea coast. Elsewhere, winds are generally from the southeast at 6-15 knots and sometimes up to 25 knots. Extreme winds of 60 knots have occurred on Hainan Island during thunderstorms or an early season tropical storm or typhoon.

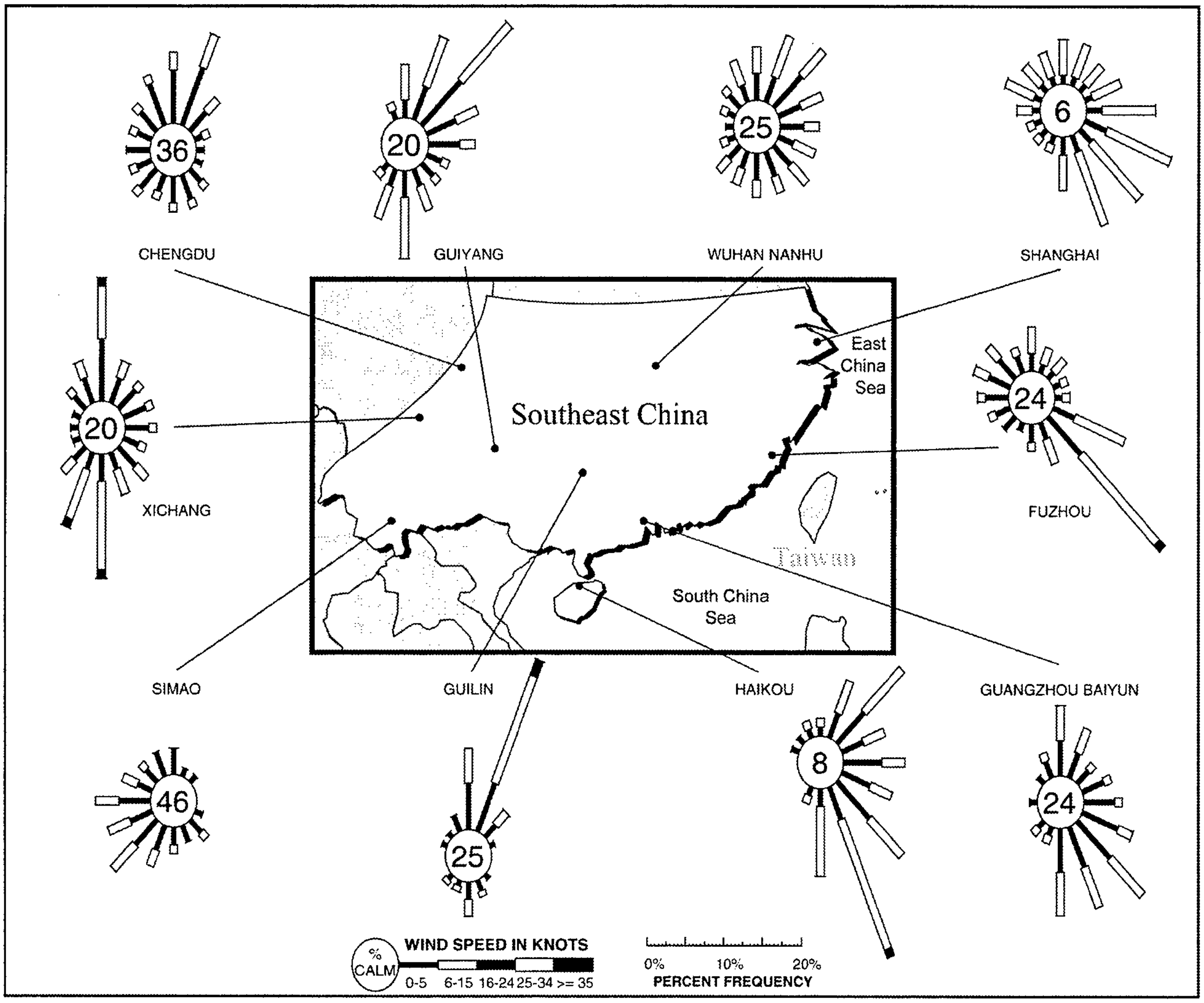


Figure 3-12. April Surface Wind Roses. The figure shows the prevailing wind directions and range of speeds based on frequency and location.

Winds Aloft. Westerlies still prevail above 700 mb (see Figure 3-13), but they decrease slightly in intensity as the polar jet begins its shift northward in advance of the southwest flow; its mean position is across northern southeast China. The tropical easterly jet appears in the South China Sea in early May with speeds greater than 40 knots. The freezing level aloft varies from about 12,000 feet at Shanghai to 16,000 feet at Haikou during April.

Sichuan Basin. April winds are southerly up to 30 knots at 850 mb and southwesterly up to 60 knots at 700 mb. At 500 and 300 mb, westerly winds prevail with speeds up to 75 and 120 knots, respectively.

Southwest Plateau. Prevailing April winds are southerly through westerly at speeds up to 30 knots at 850 mb. At 700, 500, and 300 mb, westerly winds prevail with maximum speeds of 60, 75, and 120 knots, respectively.

Northeast Plains. Shanghai's prevailing 850-mb winds remain northwesterly with speeds up to 45 knots, an indication of lingering winter. Westerlies prevail above 850 mb with speeds up to 60 knots at 700 mb, 100 knots at 500 mb, and more than 120 knots at 300 mb. The mean position of the subtropical jet has moved northward.

Central Hills. The arrival of summer low-level southwesterly flow shows at 850 mb where prevailing winds are southwest at up to 45 knots during April. Westerlies prevail above 850 mb with speeds up to 60 knots at 700 mb, 75 knots at 500 mb, and 120 knots at 300 mb.

Southern Plains and Hills. Wind speeds at 500 and 300 mb decrease between January and April as the subtropical jet shifts northward. At Haikou, southwesterly winds up to 30 knots prevail at 850 mb during April. Westerlies and southwesterly winds prevail with speeds up to 40 knots at 700 mb, 50 knots at 500 mb, and 90 knots at 300 mb.

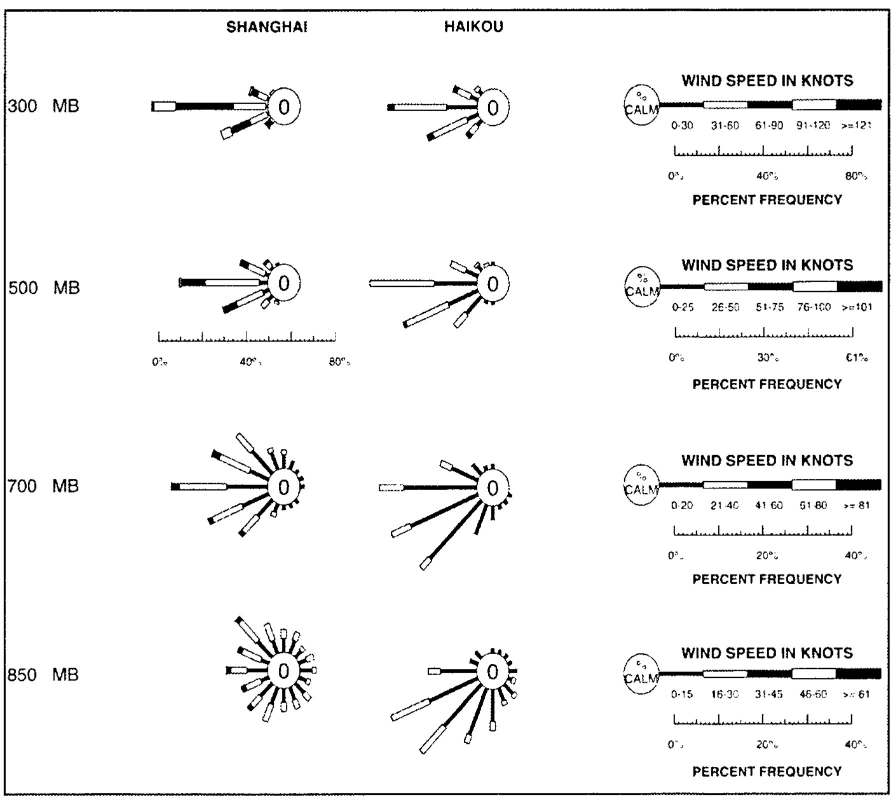


Figure 3-13. April Upper-Air Wind Roses. The wind roses depict the 1200 UTC wind speed and direction for standard pressure surfaces between 850 and 300 mb. Levels with different percent frequency are so indicated.

Precipitation. Rainfall increases everywhere during spring as the air warms and the moisture content increases. April mean precipitation ranges from 50 mm in the north and west to more than 250 mm south of the Yangtze River in the northeast plains and in the northeastern central hills (Figure 3-14). The first rainy season begins south of the Yangtze River in April when cold frontal passages trigger the rainfall. After the onset of the southwest flow in mid-May, both the amount of rainfall and the number of days of rainfall double when compared to April (see Figure 3-15). In May, heavy rainfall associated with the quasi-stationary mei-yu front moves slowly northward over the area south of the Yangtze River. Divergence in the upper troposphere and convergence in the lower troposphere initiate and sustain persistent, large, stationary thunderstorms that last up to 12 hours near the South China Sea.

Most thunderstorms occur during summer over southeast China, but spring sees an increase in thunderstorm activity with the onset of southwesterly flow. More thunderstorms occur over land than over the ocean. Consequently, fewer thunderstorms occur on the offshore islands and near the coast than inland. This is because the sea surface is cooler than the air over it in the afternoon, which results in more stable conditions over the water. On the other hand, the land is hotter than the ocean due to solar heating, and it is also warmer than the air over it. This causes unstable conditions. On an annual basis, the south has more thunderstorms days than the north, but in midwinter and midsummer, the difference is small. The southern plains and hills area, especially in the mountains on central Hainan Island and on the southwest plateau, has the highest annual frequency of thunderstorms.

Hail is not as frequent as it is in other areas of China, and it is a localized phenomena. It is more frequent over the mountains than over the plains, and it is more frequent on the windward slopes than the leeward slopes. The southwest plateau, Sichuan Basin, and the western central hills receive the most hail, an average of 1-3 days per year. The rest averages 1 day or less per year with hail. The coastal regions in the south are almost hail-free. The 15,000-foot freezing level limits icing incloud to light intensity above the freezing level.

Hong Kong has experienced hail 25 times in 20 years, about 1 day per year, and 80 percent of the time the hail occurs in March and April. A case in April 1995 exhibited all the characteristics of a mid-latitude super-cell storm. The storm was accompanied by a gust front and 66 mm of rain in 1 hour.

Sichuan Basin. Rain or drizzle occur on more than 20 days each month, but amounts are not usually great. Snow can still occur in April at the higher elevations, but snow cover is short lived, lasting only a day or so. Accumulations range from 50 to 150 mm with the higher amounts in the east and the lowest amounts in the west. Thunderstorms occur 5-10 days per month. The higher stations have the most thunderstorm days (8-10 days per month), while the remainder of the area has 3-7 thunderstorm days per month.

Southwest Plateau. Rainfall increases each month during spring from 9-22 days with rain in April to 15-25 days in May. The highest location, Weining, which is located at 7,336 feet (2,236 meters), has the largest number of days with rain and snow. It can still snow in April and May, but the snow cover lasts no more than a day. Accumulations range from less than 25 mm in the northwest to approximately 75 mm in the east. Thunderstorm days range from 6 to 11 per month and generally increase in frequency in May

Northeast Plains. This area experiences frequent, persistent light to moderate rain during spring. This rain is continuous rather than convective, and it is caused by cold fronts that become stationary along the Nanling Mountains. Waves and lows, which move eastward along the frontal zone, trigger the precipitation. The rainfall days are fairly constant in April and May at 15-21 days. Accumulations range from 50 mm in the north to 150 mm in the southeast. Thunderstorm days are fewest near the coast, where the cool ocean waters limit thunderstorm development. Shanghai averages 2-3 thunderstorm days per month. Cloudiness over the area also limits thunderstorm development by limiting heat-induced convective currents. Warm, moist, unstable southwesterly flow does not arrive here until later which further restricts thunderstorm activity. Farther inland from the coast, 4-8 thunderstorm days per month are average.

Central Hills. The mei-yu front triggers persistent rains when it remains over the region for about 30 days before moving northward. It rains on 21-24 days per month. Accumulations range from 100 mm in the south to more than 250 mm in the northeast, where orographic lifting in the rugged terrain causes increased rainfall. Along the east coast, the cooler ocean stabilizes the atmosphere, and precipitation amounts average less than 100 mm. Thunderstorm days are fewest offshore. In general, the thunderstorm days decrease slightly from April to May in this region. There are 6-12 thunderstorm days in April and 5-11 in May. The highest frequency of thunderstorms is in the west and the lowest is in the east near the coast. This slight decrease indicates the area of rainfall associated with the mei-yu front has moved northward in May, and the typhoon rainy season has not started yet.

Southern Plains and Hills. The rainfall days increase slightly from April to May and average 15-21 days. The southern coast of Hainan Island gets the least rainfall, with 8-11 days per month. Accumulations range from 75 mm in the west to between 200 and 250 mm in the central part of the area. The east coast gets less than 100 mm. Thunderstorm development near the coast is limited by the cool ocean currents. Coastal locations have 5-9 thunderstorm days per month, but inland locations have 7-15 days per month with May having more than April. Hainan Island thunderstorm days double at Haikou from April to May.

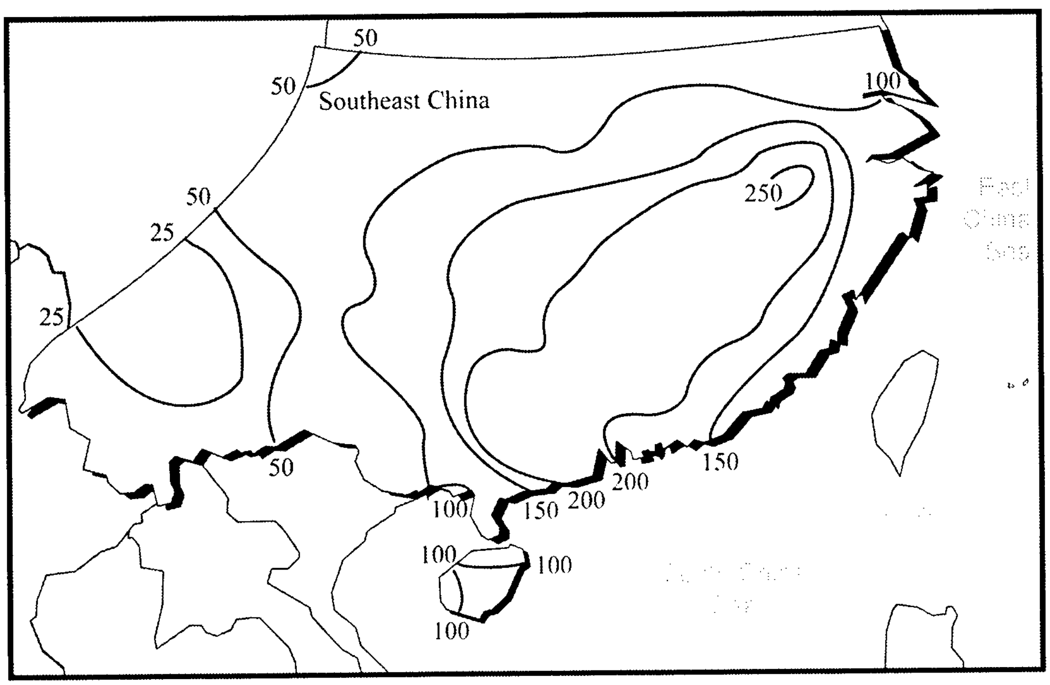


Figure 3-14. April Mean Precipitation (mm). The figure shows mean water equivalent amounts that occur in southeast China during the transition from winter to summer.

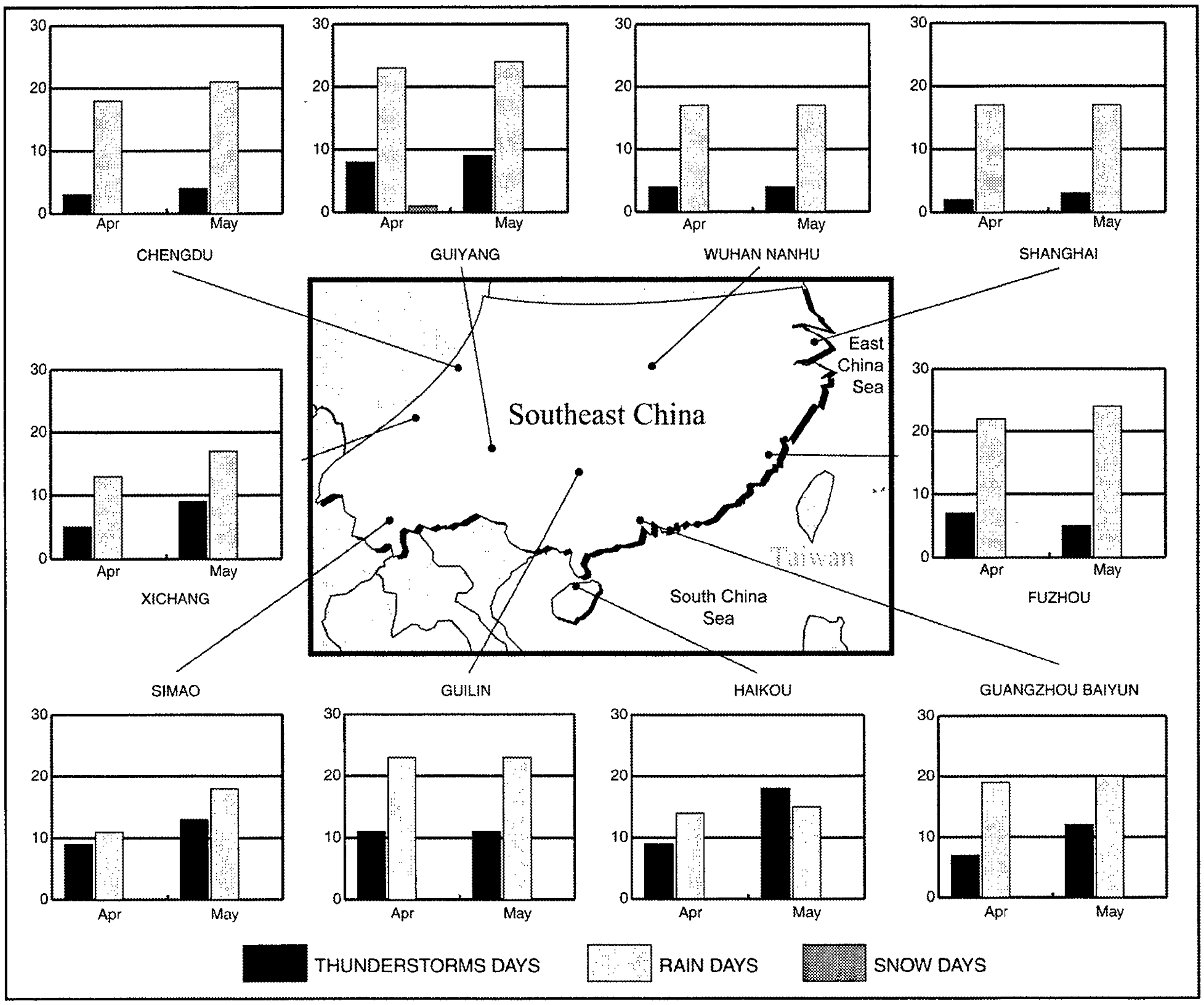


Figure 3-15. Spring Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average spring occurrences of rain, thunderstorm, and snow days for representative locations.

Temperatures. Between January and April, temperatures rise 14-21 Fahrenheit (8-12 Celsius) degrees south of the Yangtze River so that April temperatures are above freezing nearly everywhere. However, temperatures rise slowly and unevenly. Due to the extensive cloud cover and rainfall south of the Yangtze River, temperatures don't rise as rapidly as in other areas of China. Mean temperatures range from 59°F (15°C) in the north to 77°F (25°C) in the south. Mean maximum temperatures in April range from 64°F (18°C) in the north to 86°F (30°C) on southern Hainan Island (Figure 3-16). Southeast China is still slightly cooler in spring than other countries at the same latitude, but the difference is not as marked as in winter. In general, mean minimum temperatures range from 50°F (10°C) in the north to 77°F (25°C) on southern Hainan Island (Figure 3-17). At maritime and coastal locations, the mean monthly temperatures are 4° to 5°F (2° to 3°C) cooler than at inland stations at the same latitude due to the influence of the cool ocean waters. For example, Shanghai's mean April temperature is 5°F (3°C) cooler than Wuhan Nanhu's.

Sichuan Basin. Below freezing temperatures disappear with the passing of winter. Mean minimum temperatures between 54° and 61°F (12° and 16°C) and extreme minimums between 34° and 45°F (2° and 7°C) reflect the warming that takes place as the Asiatic high weakens and the warmer southwesterly flow establishes itself. Mean maximum temperatures of 68° to 77°F (20° to 25°C) also reflect this. Extreme high temperatures can reach 104°F (40°C). At the higher elevations, above 600 meters, mean maximums are slightly lower, 66° to 73°F (19° to 23°C), and extreme maximums reach 95°F (35°C).

Southwest Plateau. Because of the higher elevation of this region, it can experience extreme low temperatures as low as 28°F (-2°C) in April, but May extreme lows are above freezing. April mean minimum temperatures are 45° to 68°F (7° to 20°C) while mean maximums are 63° to 81°F (17° to 27°C). Extreme maximums can reach from 82°F (28°C) to as high as 109°F (43°C) due to less cloudiness over much of the area.

Northeast Plains. Cloudiness and precipitation prevent large increases in temperatures from January to April. Cold outbreaks from the Asiatic high are possible in April, but are short-lived. Mean maximum temperatures are 59° to 77°F (15° to 25°C) and mean minimum temperatures are about 50° to 68°F (10° to 20°C). Extreme lows of 30°F (-1°C) can occur in April with a cold surge, but minimum temperatures are mostly above freezing. Extreme highs inland can reach 108°F (42°C) in May inland, but near the coast the maritime effects keep temperatures slightly lower.

Central Hills. Cloudiness and precipitation prevent large increases in temperatures from January to April. Average high temperatures vary from about 59°F (15°C) in the north to near 86°F (30°C) in the south with higher temperatures in May. Average lows vary from 54°F (12°C) in the north to 72°F (22°C) in the south. The colder temperatures associated with cold surges from the Asiatic high are still possible in early April. Extreme low temperatures can go below freezing, 30°F (-1°C), in the north, while in the south, they may only get as low as 55°F (13°C) because the cold surges are weaker than in winter and are moderated as they move southward.

Southern Plains and Hills. Temperatures increases are small from January to April because this area is mild during winter. Mean maximum temperatures range between 72° and 88°F (22° and 31°C) and mean minimums range between 63° and 79°F (17° and 26°C) with the higher temperatures in the south and on Hainan Island. Extreme maximum temperatures range from 93° to 111°F (34° to 44°C).

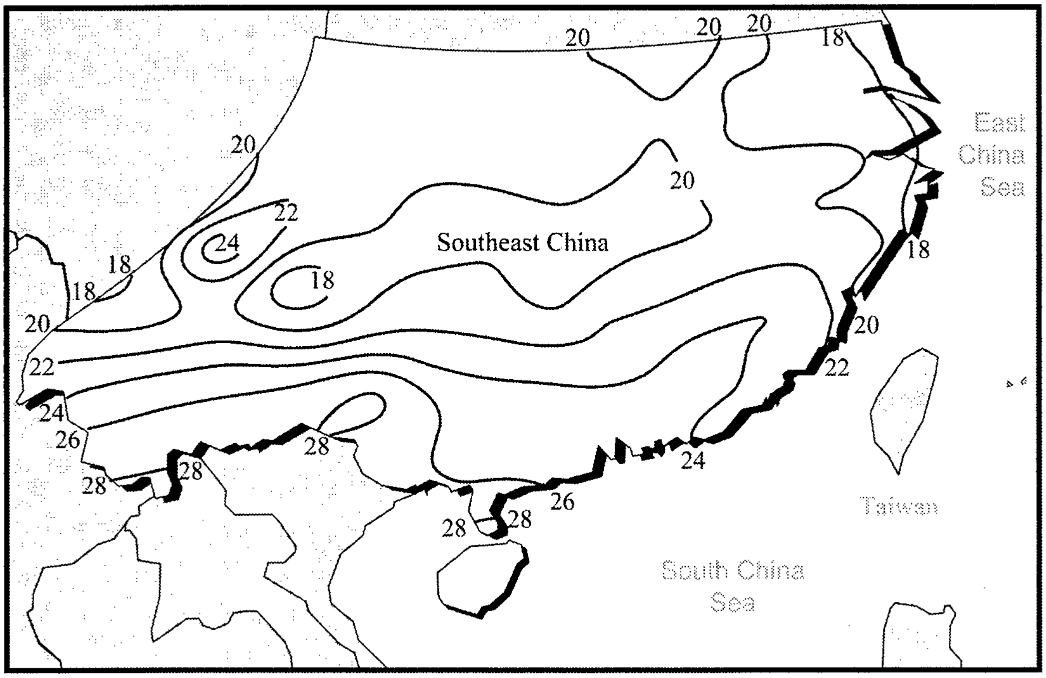


Figure 3-16. April Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for a representative spring month. Mean maximum temperatures during other spring months may also be higher.

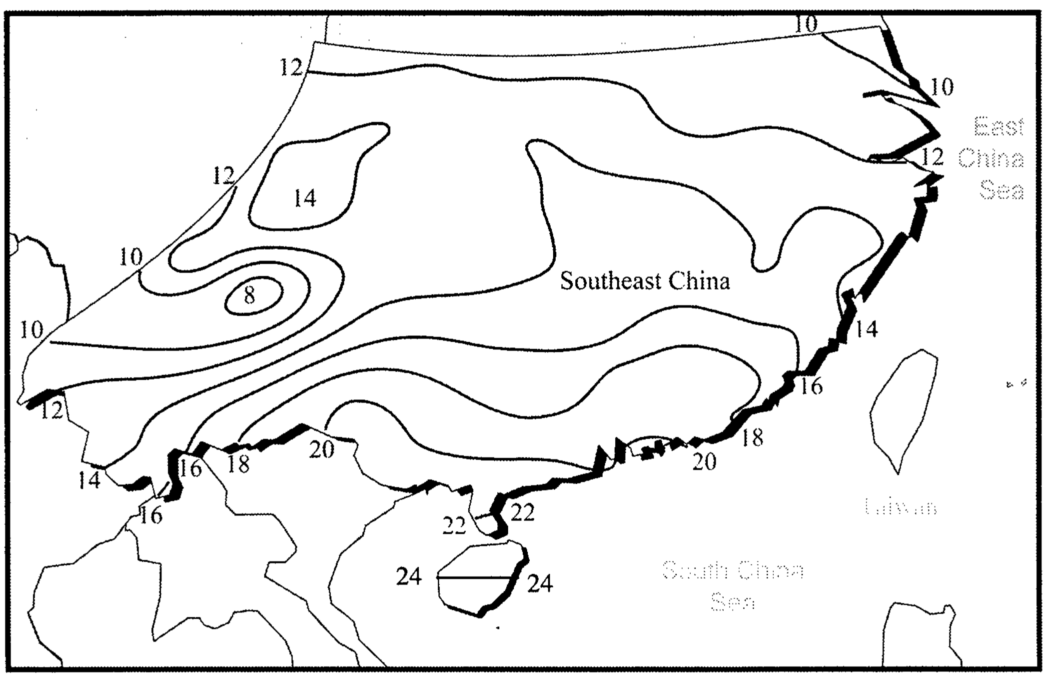


Figure 3-17. April Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for a representative month of spring. Mean minimum temperatures during other spring months may be higher, especially at the end of the spring season.

Hazards.

Flooding. The increased rainfall due to thunderstorms and persistent rainy periods cause devastating spring floods in southeast China.

Aircraft Icing. Icing is most hazardous during spring because increased convective cloud development and increased temperatures aloft make icing more probable than in winter. Also, convective clouds are embedded in large stratiform cloud areas during spring. In the north, light rime icing is possible in stratiform clouds from about 12,000 to 25,000 feet (3,700 to 7,600 meters). In the south, it is most likely from 16,000 to 28,000 feet (4,900 to 8,500 meters). In convective clouds, more hazardous moderate-to-heavy clear icing occurs at the same elevations.

Tropical Cyclones. May is usually the beginning of the season for tropical storms and typhoons, although southeast China should only be affected by one of each every 10 years.

Turbulence. Strong westerly winds aloft and the rugged terrain of southeast China, especially in the west in the Sichuan Basin and the southwest plateau, make conditions favorable for mountain-wave turbulence downwind from these mountains to altitudes well above 10,800 feet (6,000 meters). This turbulence can be severe. Severity depends on the wind velocity.

Trafficability. China is a country of very diverse topography and soil types. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppes, deserts, wide and narrow valleys, deep gorges, alpine meadows, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained, and consist of clays and silts. The soil type range, however, extends to and includes some sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows, especially if frozen, and some valley bottoms. During he wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

On the plains, slopes vary from nearly level to about 20 percent. The soils are predominantly medium- to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the wet season, movement conditions are good to poor. Condition depends on soil type. During this time, coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near the river mouths become soft and muddy. They often stop or severely restrict movement.

Within the Sichuan Basin are low mountains, hills, and many streams and terraces. Soils are mostly fine-grained. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. During the wet season, conditions are poor to unsuitable in most places.

General Weather. Summer is usually considered the rainy season in southeast China. The weather is cloudy, hot, and wet. However, spring with its persistent rainy periods usually has more rainfall than summer with its convective precipitation. The first rainy phase of spring, the mei-yu season, continues its northward movement, while the second rainy season, sometimes called the typhoon rainy season, begins in southern southeast China. The onset of the southwest summer flow occurs first along the southeastern coast about mid-May. By mid-July, the southwest monsoon has usually reached northward to about 30° N (about the same latitude as the Yangtze River valley).

The mei-yu season continues into summer in the northeast plains as the front is pushed farther north by the advancing southwest monsoon. In the Yangtze River valley, the heavy precipitation associated with this front usually occurs from about June 10 to July 10. At the same time, the first rainy season abruptly ends in the south. The second rainy season, the typhoon rainy season, with its heavy rains starts in July. These heavy rains are from several sources, among them thunderstorms, migratory lows, tropical disturbances, tropical storms, and occasional typhoons.

Changes in the semipermanent meteorological features that herald the arrival of summer include strengthening of the Asiatic low, continued northward movement of the ridge line of the North Pacific high, the northward migration of the subtropical jet, and the appearance of stable easterlies over Hong Kong at 200 mb. The thermal Asiatic low reaches its maximum strength in July. The ridge line of the North Pacific high continues its northward movement to 20-25° N by mid-June. By July, the subtropical jet has usually moved north of southeast China. Easterlies over Hong Kong are necessary for the end of heavy rainfall in the south.

Sky Cover. Once the mei-yu season ends in the northeast plains, cloudiness decreases (see Figure 3-18). The lower Yangtze River valley has the least cloudiness of the year from late summer to early fall. Cloudiness in the Sichuan Basin also decreases in summer. With the onset of southwesterly flow, the southwest plateau experiences an increase in cloudiness. Low clouds move into southwest Sichuan Basin and the southwest plateau. From a maximum there, low clouds decrease north and east. The lower Yangtze River valley experiences a period of drought once the mei-yu ends.

The clouds in summer are predominantly convective and show some diurnal variation in their amount. This is most evident in the summer when cloud amounts over water are higher at night than during the day, and cloud amounts over land peak in the midafternoon. In the mountains, clouds peak in the afternoon, but in the valleys, there are more clouds during the night.

Over land, convective clouds reach their maximum coverage in the midafternoon. Strong convection during the day lifts the moisture and clouds to higher elevations in the mountains. Offshore the opposite is true. During the day, the ocean surface is cooler than the air above it. This condition stabilizes the atmosphere near the ocean surface and stifles convective cloud development during the day. At night, the ocean is warmer than the air above it. The air over water is now warmer than that over land, a land breeze begins, and clouds form over the water. The offshore islands experience more clouds at night and in the morning than in the afternoon. Cloudiness in the valleys is slightly higher at night than during the afternoon due to nocturnal orographic rain during summer.

The frequency of ceilings at any height over southeast China varies at night from 40-50 percent in the northeast plains, central hills, and southern plains and hills to 80 percent or more in the southwest plateau. The Sichuan Basin has ceilings at night about 60 percent of the time as does the western part of the central hills and the southern plains and hills. By afternoon, it increases to 60-80 percent nearly everywhere with the least cloudiness in the northeast and the most cloudiness in the southwest.

Sichuan Basin. Although cloudy year-round, this area has less low cloud in summer than in winter or spring, except for the southern part of the region. Guiyang has more low clouds than Chengdu during all seasons. Ceilings less than 3,000 feet reach their maximum in the afternoon at less than 20 percent of the time except at higher locations like Guiyang. Ceilings less than 3,000 feet occur more than 25 percent of the time there. The summer southwesterly flow brings more moisture and unstable conditions than in winter. This makes convective clouds more likely than stratiform clouds.

Southwest Plateau. Summer is the cloudy season due to the southwest flow that advects moisture into the region. Topography causes some variation in the cloudiness. Windward slopes are cloudier than lee-side slopes due to orographic lifting. Ceilings less than 3,000 feet occur 40-70 percent of the time in the morning at most locations and 50-60 percent of the time at most locations in the afternoon.

Northeast Plains. Through the mei-yu season in June to early July, the lower Yangtze River valley is cloudy, but as the mei-yu front moves northward to northeast China, cloudiness decreases. The convective clouds associated with the mei-yu front produce heavy rainfall. Compared to winter, the plains area has less cloud during the mei-yu season, but much heavier rainfall. For the remainder of summer the area enjoys low cloudiness but also suffers drought conditions. It is cloudier along and near the coast. Ceilings less than 3,000 feet occur as much as 50 percent of the time in the morning.

Central Hills. It is cloudier in the west and on the coastal islands than in the interior of the central hills. Ceilings less than 3,000 feet occur up to 50 percent of the time in the west during the afternoon when maximum cumuliform clouds occur.

Southern Plains and Hills. Total cloudiness does not vary much from winter and spring, but low clouds decrease during summer. This happens even though precipitation is at its maximum during summer due to thunderstorms, tropical cyclones of varying strength, and typhoons. The rainfall is heavy and short in duration rather than light with long periods of low clouds a in winter or spring. Haikou, has the least low clouds in July through August while mainland locations have the least low clouds in fall.

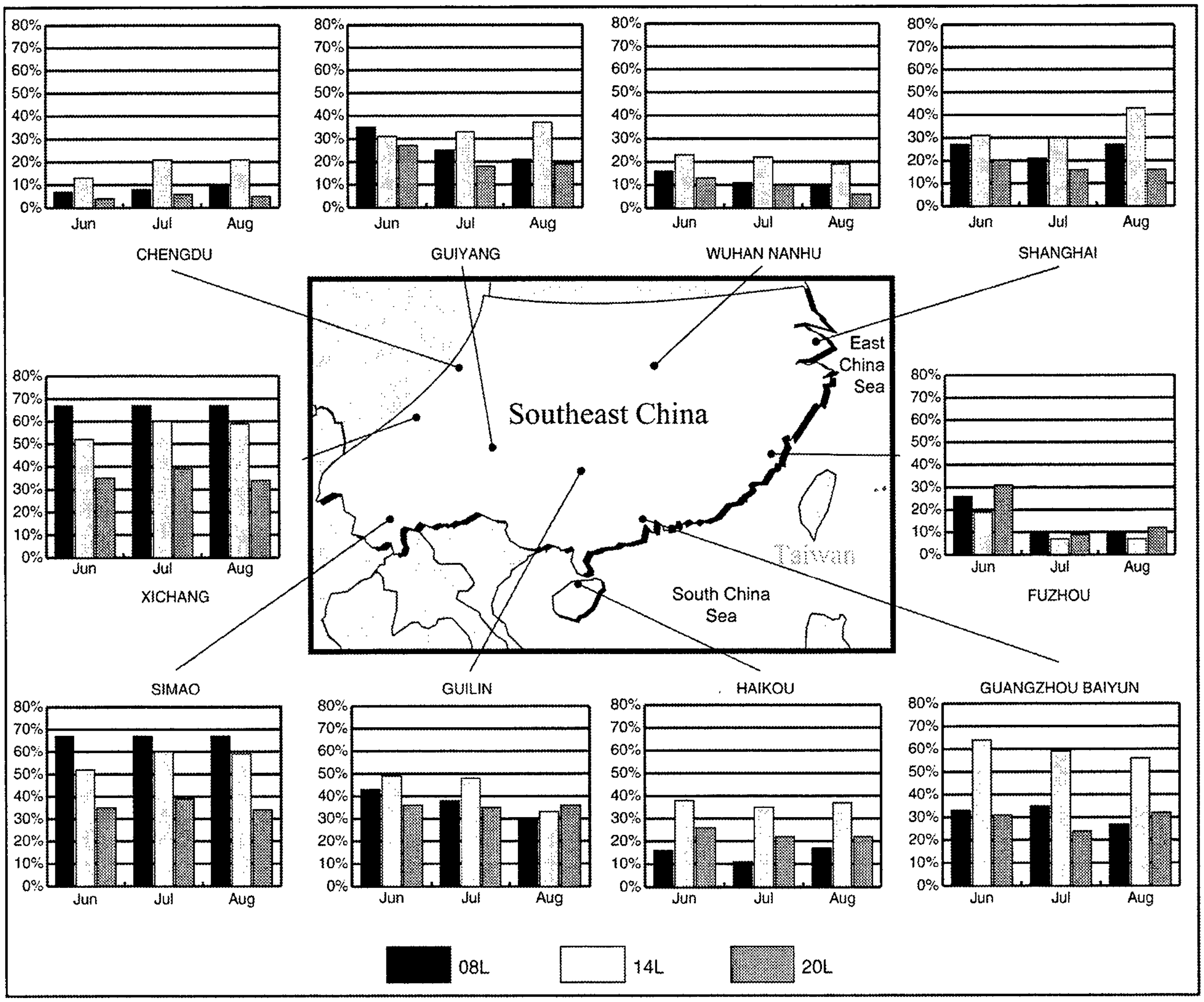


Figure 3-18. Summer Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Summer visibility is generally good nearly everywhere (see Figure 3-19). Fog is less widespread than during winter and spring, except at some higher locations and the northeast plains. Heavy rains caused by the mei-yu front in the northeast plains lower visibility in rain and fog. The front normally remains over the area until about July 10 before it moves northward into northeast China. The second rainy season begins in July. It's convective precipitation reduces the visibility for shorter periods than the persistent rains of spring.

Sichuan Basin. Locations at higher elevations experience visibility less than 4,800 meters up to 10 percent of the time in the morning. These locations rarely have restrictions at other times of the day. At the lower, more protected locations in the basin, morning visibility is less than 4,800 meters about 40 percent of the time in June. Restricted visibility decreases in July and August as the more unstable air masses make their way into the basin. Chengdu, which is located in a river valley, gets both river fog and advection fog as much as 62 percent of early morning hours. Fog and mist restrict visibility to 9,000 meters or less 9-28 days per month with the least number of fog days at the higher elevations.

Southwest Plateau. The visibility is generally good. The eastern part of the region has morning visibility less than 4,800 meters up to 10 percent f the time. However by afternoon, restrictions drop to 1 percent or less. The same percentages apply at all hours in the rest of the southwest plateau. Fog that restricts the visibility to 9,000 meters or less occurs only 1-3 days per month in the west and 3-10 days per month in the east.

Northeast Plains. Rain and fog reduce the visibility to less than 4,800 meters up to 30 percent of the time in the morning, but generally 10 percent or less at other times. Visibility restrictions in fog or mist of 9,000 meters or less occur inland up to 26 days per month but only about 6 days per month at the coast. Although rare during summer, duststorms and sandstorms are possible during a prolonged drought. Shanghai experiences sandstorms less than 1 day during July, an average based on 20 years of record. Duststorms or sandstorms can reduce the visibility to less than 1,000 meters.

Central Hills. Offshore islands have the highest rate of visibility less than 4,800 meters at nearly 40 percent of the time in the morning and over 20 percent of the time in the afternoon and evening in June. Up to 22 days per month have visibility of 9,000 meters or less due to fog. The rate of occurrence decreases throughout July and August. Most other locations experience lower visibility less than 20 percent of the time in the morning and rarely at other times of the day.

Southern Plains and Hills. The visibility is good. Only a couple of locations have visibility less than 4,800 meters more than 10 percent of the time. This occurs in the morning due to fog, and by afternoon, the visibility is rarely less than 4,800 meters.

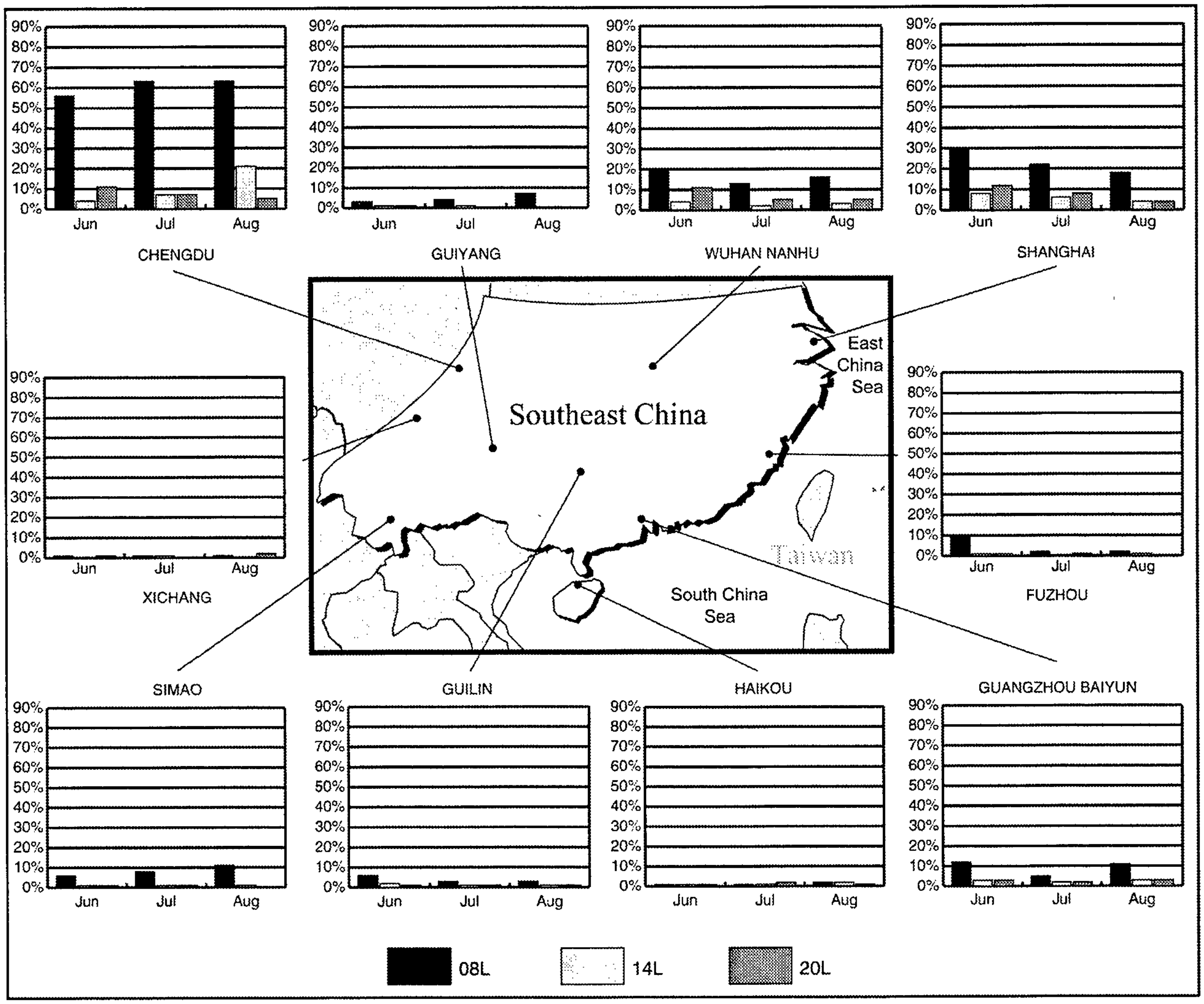


Figure 3-19. Summer Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Summer surface winds are generally southwesterly to southeasterly unless topography or a local circulation overcomes the southwesterly flow (see Figure 3-20). Average wind speeds are less than in winter or spring. Along the southeast coast, average speeds are about 8 knots, but elsewhere 6 knots or less is average. In basins, valleys, and other locations sheltered from the wind, calm and light winds that average 1-3 knots are frequent.

Except for typhoons, summer winds are generally not as strong as winter or spring winds. While typhoons can cause wind gusts greater than 80 knots along the east coast and more than 100 knots in the offshore islands south of 30° N, only 1.3 typhoons usually affect southeast China during the whole summer. On average, three tropical storms can affect the area during summer and cause winds greater than 34 knots. In the Taiwan Strait, winds of 34-63 knots occur on up to 5 days during summer.

Sichuan Basin. Night winds are calm 40-60 percent of the time, depending on location. During the afternoon, calm winds occur 15 percent of the time or less. Thunderstorms can cause maximum winds of 35-45 knots.

Southwest Plateau. Surface winds are often calm at night, 40-75 percent of the time. During the afternoon, winds are from the south to southwest mostly under 5 knots except at Kunming, where 6-15 knots is more likely. Thunderstorms can cause winds up to 55 knots.

Northeast Plains. Near the coast, brisk southeasterly winds blow nearly all of the time with an average speed of 6-15 knots. Speeds top 25 knots in the afternoon when the sea breeze may augment the prevailing wind. Winds in the middle and upper reaches of the Yangtze River valley are calm at night up to half the time and southeasterly to southwesterly during the afternoon at 6-15 knots (some gusts up to 25 knots). Extreme maximum winds during the summer of 66 knots have occurred at the coastal islands and were probably due to a typhoon or tropical storm.

Dongting Lake is large enough to produce the land/lake breeze that is similar to the sea breeze at the coast. Data from Yueyang, located on the eastern shore of Dongting Lake, indicates the land/lake breeze occurs 10-11 days per month during the summer in periods of weak general circulation. The lake breeze starts around midmorning during the summer, and the start of the land breeze may be delayed until midevening. The lake breeze tends to make afternoon temperatures at locations near the lake about 2 Fahrenheit (1 Celsius degree) degrees lower than at locations farther from the lake.

Central Hills. Southeasterly winds near the coast are 6-15 knots during the afternoon with speeds up to 25 knots possible. Elsewhere, southwesterly winds prevail with afternoon speeds of 6-15 knots. Nighttime calm winds occur about 25-35 percent of the time, except at Guilin, where calm winds at night occur almost 60 percent of the time. Maximum winds of nearly 70 knots have occurred at offshore islands due to a typhoon or tropical storm.

Southern Plains and Hills. Nighttime winds are calm 35-50 percent of the time at most locations except on Hainan Island, where calm winds at night are less frequent. Southeasterly to southwesterly winds at 6-15 knots prevail during the afternoon. Typhoons or tropical storms have caused winds greater than 60 knots on Hainan Island.

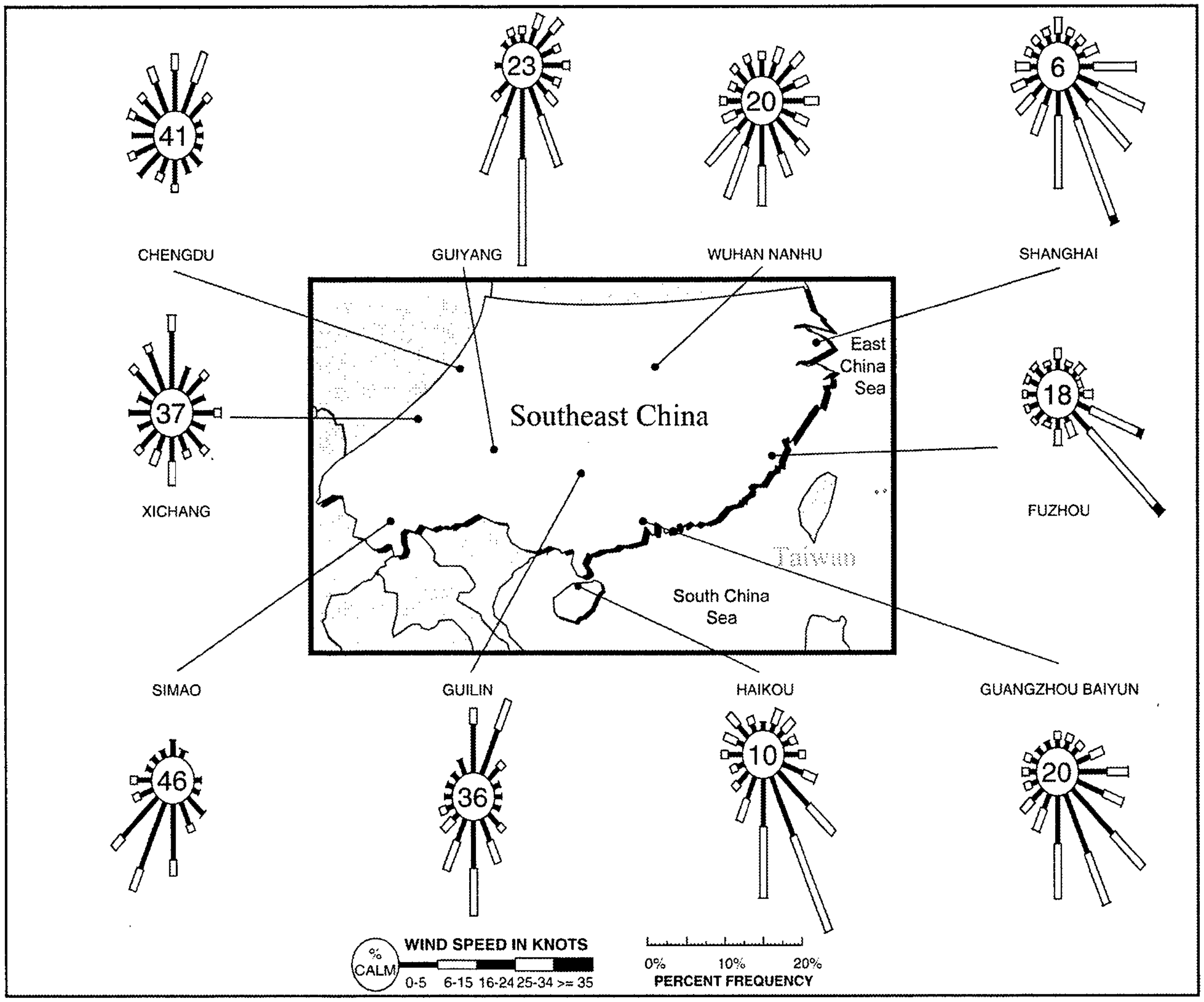


Figure 3-20. July Surface Wind Roses. The figure shows the prevailing wind directions and range of speeds based on frequency and location.

Winds Aloft. The subtropical jet is north of southeastern China for most of the summer (see Figure 2-21). Upper-air winds are light over southeast China during the summer with southerly to southwesterly winds at lower levels. In the north, westerlies prevail at the higher elevations, but light easterlies prevail at the 300-mb level over the rest of the region. These easterlies indicate the presence of the tropical easterly jet to the south in the South China Sea and the development of the Tibetan high. While the tropical easterly jet is usually south of southeast China, it oscillates between 5° N and 20° N and sometimes comes across the southern part of southeast China, especially Hainan Island. If the tropical easterly jet intensifies (it oscillates northward towards southeast China, the jet core becomes stronger than normal, and the area of wind speeds greater than 40 knots expands), summer rainfall will be above normal. Conversely, a weak tropical easterly jet results in less rainfall than normal. The mean freezing level is at about 18,000 feet during summer.

Sichuan Basin. Normally, low-level southerly winds prevail at up to 30 knots (850 mb) and 40 knots (700 mb). Winds are usually less than 25 knots at 500 mb and 30 knots at 300 mb.

Southwest Plateau. Winds aloft are generally weak at 15 knots or less from the south at 850 mb.

Northeast Plains. Westerlies occur at 700 mb and above with southwesterlies almost equally probable. At 850 mb, southwesterly winds with speeds up to 45 knots occur, although 30 knots or less are normal.

Central Hills. Southwesterlies prevail from the surface through the 500-mb level. Winds are fairly light at all altitudes. At 300 mb, weak easterly winds prevail with speeds mostly 30 knots or less.

Southern Plains and Hills. July's average winds are light from the southeast through southwest at 850, 700, and 500 mb. At 300 mb, light easterly winds prevail.

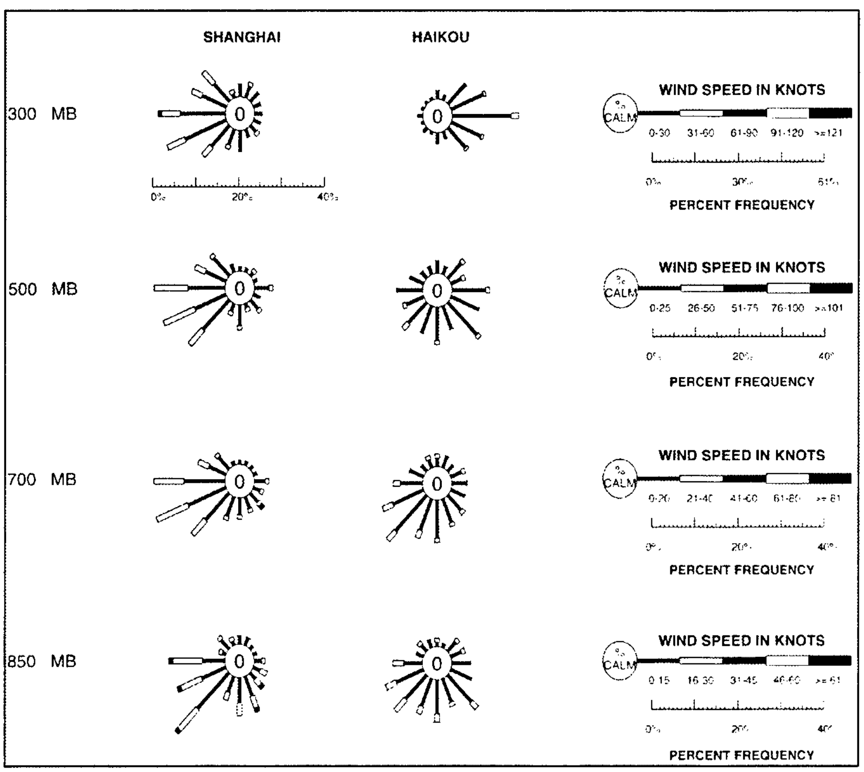


Figure 3-21. July Upper-Air Wind Roses. The wind roses depict the 1200 UTC wind speed and direction for standard pressure surfaces between 850 and 300 mb. Levels with different percent frequency are so indicated.

Precipitation. During the summer, rainfall generally decreases from south to north and east to west. Figure 3-22 shows the mean precipitation amounts for July in southeast China. Extremely heavy rainfalls of 400 mm or more in 24 hours have occurred at numerous places across southeast China, although less numerous in the west. Isolated instances of 24-hour rainfalls of 800 mm or more have occurred. Most of the rainfall occurs in short spurts during the May-July flood season (see Figure 3-23). For example, from the south coast to about 27° N, about 50 percent of the rainfall along 115° E for the 3 month period occurs in May. Further north, southeast China gets about 50-70 percent of the total precipitation for summer between mid-June and mid-July due to the mei-yu. Episodes of heavy precipitation triggered by the presence of an unusually strong tropical easterly jet have caused extensive flooding in the southern parts of southeast China. In one memorable season, 1,200 mm of rain fell in a single 5-day period in the lower and middle Yangtze River valley. This caused devastating flooding, destroyed crops, and took many lives.

Most thunderstorms occur during summer over southeast China because of warm, moist flow. More occur over land than over the ocean because of orographic lifting. Consequently, fewer thunderstorms occur on the offshore islands and near the coast. The cooler sea-surface temperature provides an additional stabilizing factor during the afternoon. On the other hand, the land is hotter than the ocean due to solar heating, and it is also warmer than the air over it. This results in unstable conditions. On an annual basis, the south has more thunderstorm days than the north, but in the summer the moist, unstable air penetrates throughout southeast China. There is little difference in thunderstorm occurrence between south and north China in midsummer. The southern plains and hills, especially the mountains on central Hainan Island, and the southwest plateau have the highest annual occurrence of thunderstorms in southeast China.

Hail is not as frequent as it is in other areas of China and it is a localized phenomena. It is more frequent over the mountains than over the plains and more frequent on the windward slopes than the leeward slopes. The southwest plateau, Sichuan Basin, and the western central hills are the areas that receive the most hail, an average of 1-3 days per year. The rest averages less than 1 day per year with hail, and the coastal regions in the south are almost hail free. The high freezing level causes most hail to melt before reaching the ground. Most hail occurs in summer when mesoscale convective complexes occur.

Sichuan Basin. This is the only area that has large-scale nocturnal rain following overcast skies during the day. Mean precipitation in July is 150-200 mm. The number of days with rain is fairly consistent all summer; the number of thunderstorm days peaks in July and August. This indicates the transition from slow, persistent rain to shorter, heavier, convective precipitation. Rain falls an average of 18-22 days a month from June to August. Thunderstorms occur 4-8 days in June and 6-9 days in July and August.

Southwest Plateau. Most of the rain falls in the southwest near the border with Laos and Myanmar and along the western border due to the topography and the moist southwesterly flow. Mean precipitation amounts in July average 200 mm to more than 300 mm. The eastern part of the southwest plateau averages less, 150-200 mm in July. All of the southwest plateau experiences rainfall during 20 or more days per month, and the areas that receive the most rainfall average 22-28 days during July. Higher locations experience snowfall that is short-lived. They can average 1 day of snow fall in June and July. Thunderstorm activity peaks in July and August when 7-14 and 12-18 thunderstorms days occur, respectively.

Northeast Plains. The mei-yu front lies stationary over the Yangtze River valley from mid-June to mid-July and produces heavy rains. From 1954-1980, the average beginning date of the mei-yu at Nanjing was 20 June and the average ending date was 10 July, although it began as early as 3 June and ended as late as 30 July. The average June-July rainfall during the same years was 357 mm. An average of about 246 mm (or 69 percent) of the total fell during the average 21-day period of the mei-yu. Rainfall during the mei-yu, generally east of 110° E, is continuous and heavy (extremely heavy at times).

The average precipitation in the area for July is 150-250 mm. The number of days with rainfall generally decreases from June through August as the mei-yu front moves northward into northeast China. In June, the area experiences 18-21 days with rain. In August, the rainfall days average 11-16. Thunderstorms are often imbedded in the extensive clouds associated with the mei-yu. Fewer thunderstorms occur here than farther south. Thunderstorm activity peaks in July because the mei-yu front has thunderstorms embedded in the stratiform clouds and it usually moves north about mid-July. July averages 6-11 thunderstorm days.

Central Hills. Mean July precipitation is generally 150 to 200 mm. Rainfall days generally decrease from June and July from 18-21 to 11-20 days. In the south, rainfall days increase again in August. This coincides with the second rainy period that usually starts in July-August Fewer thunderstorms occur on the coastal islands than at sites inland from the coast. Inland areas average 7-13 thunderstorm days per month.

Southern Plains and Hills. This region receives the most rainfall during summer. July average rainfall along the coast of the South China Sea ranges from 200 mm to upwards of 350 mm. Northern Hainan Island receives 200 mm or more. Most of this rainfall comes from thunderstorms. The topography along the south coast causes orographic lifting of the moist, warm air, and this produces the convective clouds and precipitation. Near the southern coast and on northern Hainan Island, where the region receives most of its rainfall, thunderstorm days average 15-19 days per month. Inland to the north, thunderstorm days average 12-16 days per month. On the east coast, thunderstorm days average only 6-12 days per month because the ocean temperature is relatively cooler than the air above, especially in the afternoon when thunderstorms typically develop.

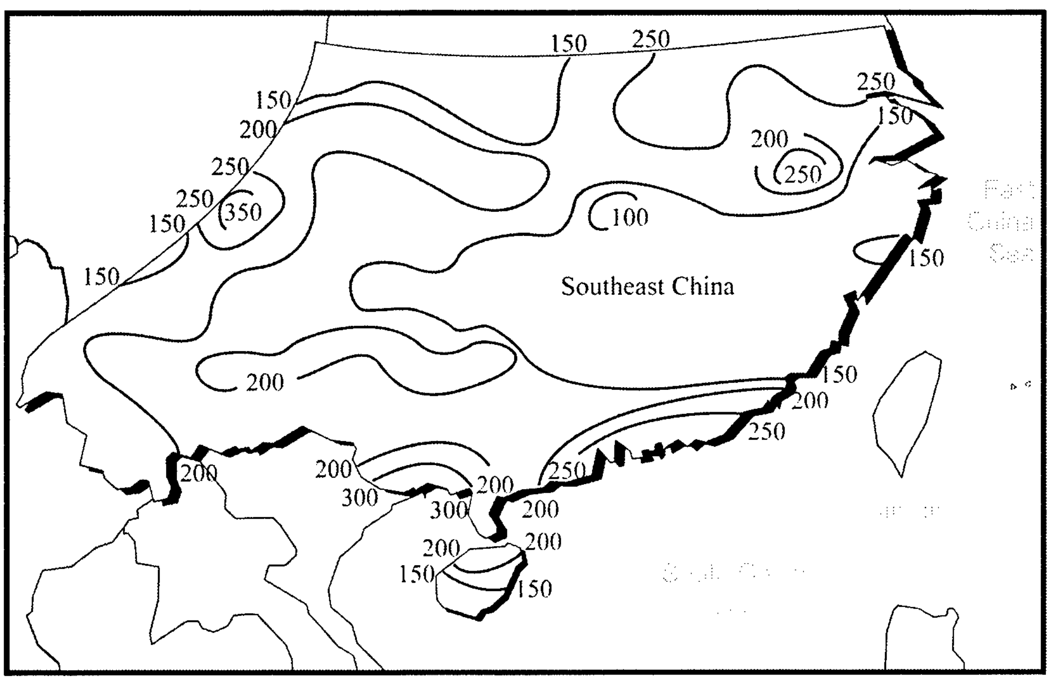


Figure 3-22. July Mean Precipitation (mm). The figure shows mean water equivalent amounts that occur in southeast China when summer is at its peak.

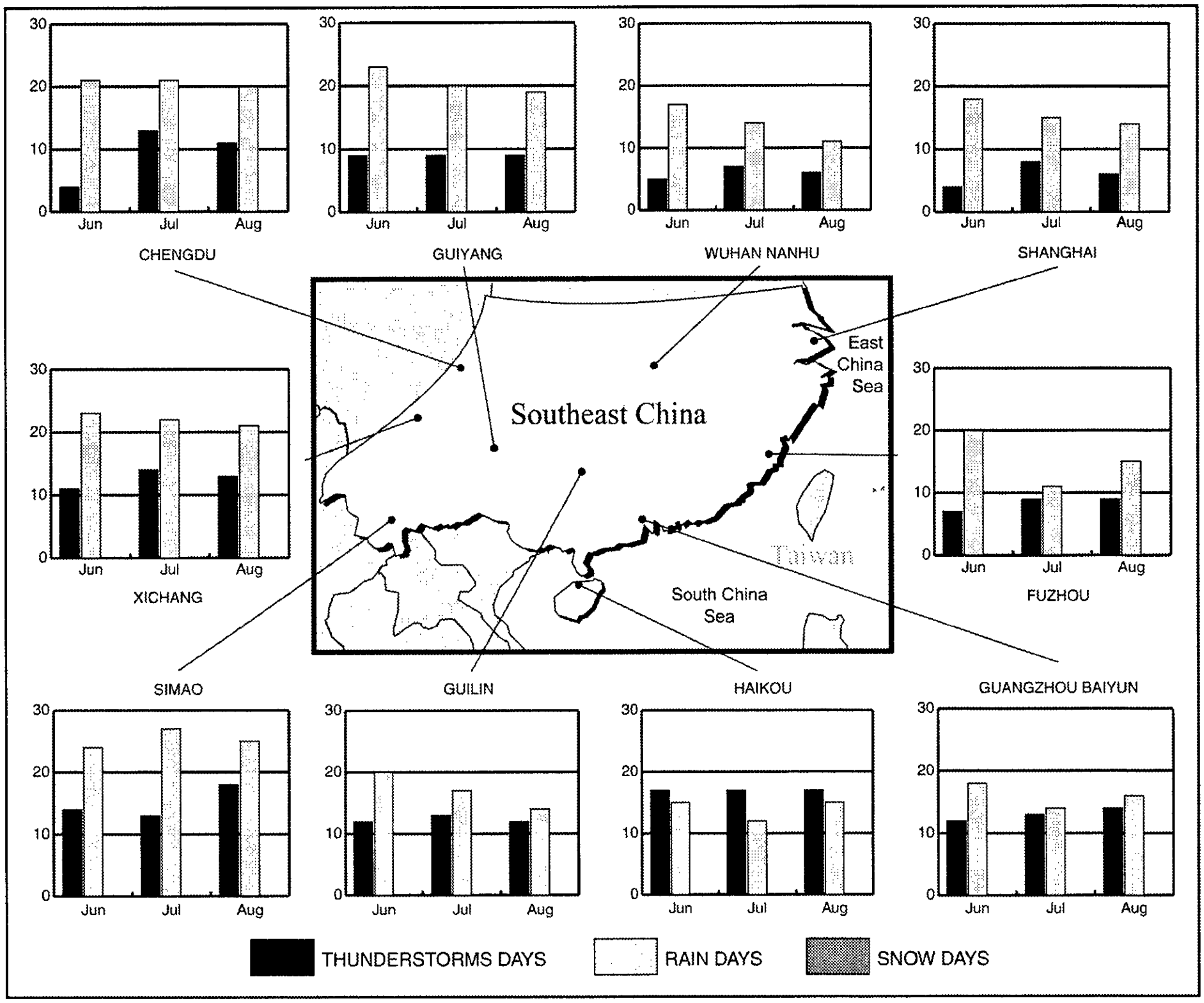


Figure 3-23. Summer Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average summer occurrences of rain, thunderstorm, and snow days for representative locations.

Temperatures. July is usually the warmest month of the year. It is warmer than other locations at the same latitude due to the massive Asian landmass. The temperature pattern during summer is quite different than during winter. The zonal winter pattern changes to a meridional pattern in summer, with weaker temperature gradients. Isotherms parallel the coast, and the hottest temperatures occur inland, away from the moderating ocean affect.

Mean temperatures of 82° to 86°F (28° to 30°C) in July cover the whole area, with means of 86°F (30°C) or more in the mid-Yangtze River valley. Along the coast mean temperatures of 82°F (28°C), or slightly less, prevail from Shanghai to Taiwan. See Figure 3-24 for mean maximum temperatures in July. Mean maximums range from about 73° to 95°F (23° to 35°C). The coolest temperatures occur along the coast in the northeast plains, northern central hills, western Sichuan Basin, and the southwest plateau. See Figure 3-25 for mean minimum temperatures in July. Mean minimums range from about 59°F (15°C) at the western border of the southwest plateau to 77°F (25°C) or more in the rest of the region.

Sichuan Basin. Extreme maximum temperatures can reach 109°F (43°C), while average maximums are 77° to 86°F (25° to 30°C). Average minimum temperatures are 66° to 70°F (19° to 21°C), and extreme minimums are 46° to 55°F (8° to 13°C).

Southwest Plateau. Extreme maximums are greater than 104°F (40°C) and extreme minimums are 36° to 54°F (2° to 12°C). Mean maximums are 68° to 81°F (20° to 27°C) and mean minimums are 55° to 68°F (13° to 20°C).

Northeast Plains. Extreme maximums of 104° to 108°F (40° to 42°C) can occur in the upper- and middle-Yangtze River valley, but near the coast temperatures of 95° to 104°F (35° to 40°C) are more likely. Extreme minimums are 48° to 68°F (9° to 20°C). Mean maximum temperatures range from 75° to 90°F (24° to 32°C) and mean minimums range from 68° to 79°F (20° to 26°C) with cooler temperatures near the coast.

Central Hills. Extremes high temperatures range from 100°F (38°C) in south and east to 104°F (40°C) west and north. Extreme low temperatures from 50° to 68°F (10°C to 20°C). Mean highs are 75° to 93°F (24° to 34°C) and mean lows are 70° to 79°F (21°C to 26°C) with the lower temperatures in the east and south.

Southern Plains and Hills. Extreme maximums range from 100°F (38°C) (or less along the coast) to 104°F (40°C) in the west. Extreme minimums range from 50° to 72°F (10°C to 22°C). Mean maximums range from 84°F (29°C) along the coast to 91°F (33°C) in the west.

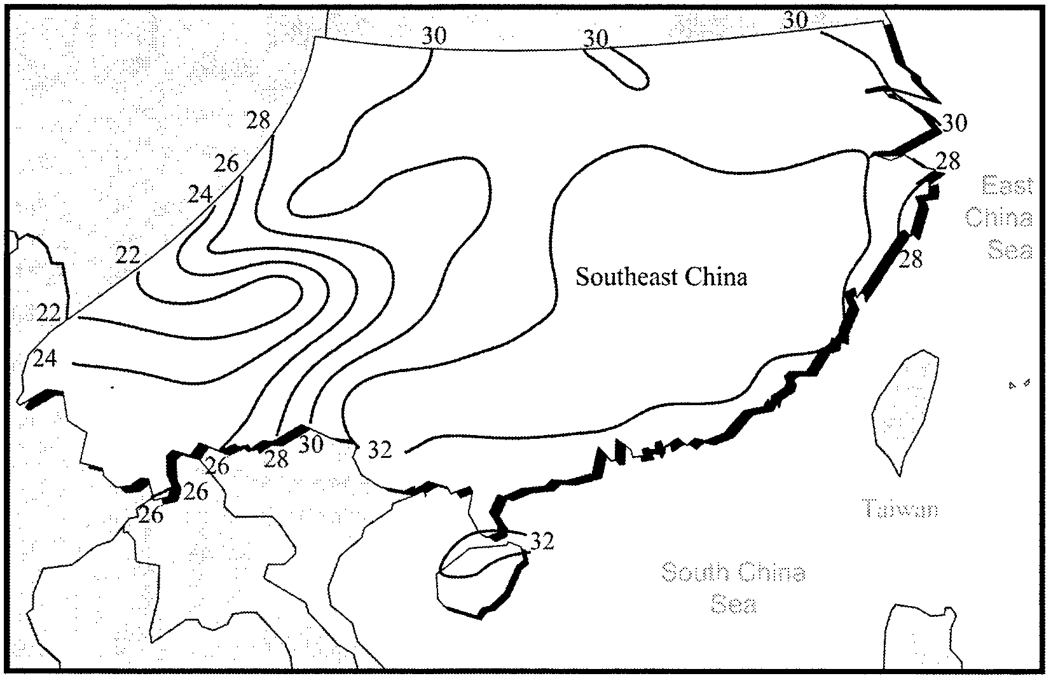


Figure 3-24. July Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for the warmest month of summer. Mean maximum temperatures during other summer months may be lower, especially at the beginning and ending of the summer season.

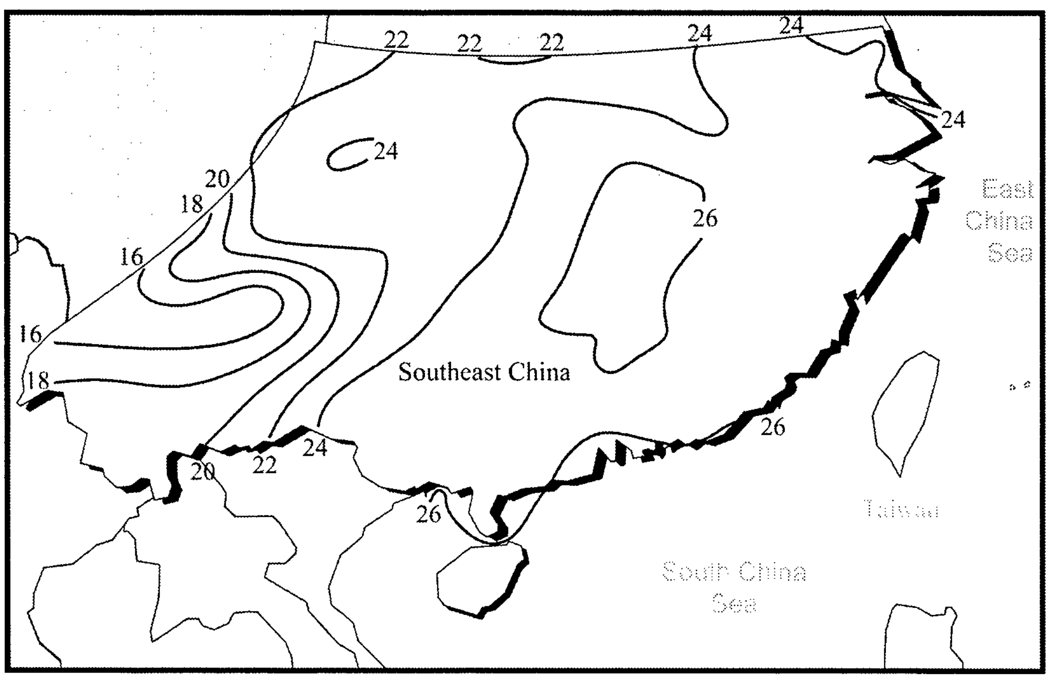


Figure 3-25. July Mean Minimum Temperatures (°C). These temperatures represent the average of all low temperatures for the warmest month during summer. Mean minimum temperatures may be lower, especially at the beginning and ending of the summer season.

Hazards.

Aircraft Icing. The increase in moisture aloft that arrives with summer coupled with the warmer temperatures aloft make icing probable in clouds. The atmosphere aloft is much the same, north and south, in summer so that icing in clouds is possible from about 18,000 to 29,000 feet (5,500 to 8,800 meters) everywhere over southeast China during July. In convective clouds, moderate-to-heavy clear icing occurs between those heights.

Floods. Floods occur every year in southeast China. The months of May through July usually have the worst floods in southeast China, although flash floods are possible at any time during the two rainy seasons. During this time, extremely heavy 24-hour rainfalls lead to flash floods.

During the mei-yu period in the Yangtze River valley, usually mid-June to mid-July, damaging floods occur there. Devastating floods have occurred in the middle and lower valley on a couple of occasions. For example, more than 1,200 mm of rain has fallen in the upper valley during a 5-day period.

Typhoons. China has one of the highest occurrence rates for typhoons in eastAsia. Damaging typhoons occur virtually every year in this area of China, especially near the coast. They cause flash flooding and damage from strong winds. About five typhoons per year affect the coastal areas of southeast China, mainly from July through September. Typhoons affect all coastal areas and as far as 300 miles (500 km) inland.

Trafficability. China is a country of very diverse topography and soil types. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppes, deserts, wide and narrow valleys, deep gorges, alpine meadows, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained, and consist of clays and silts. The soil type range includes some sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows and some valley bottoms. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

On the plains, slopes vary from nearly level to about a 20 percent incline. The soils are predominantly medium- to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the wet season, movement conditions are good to poor. Condition depends on soil type. During this time, coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near the river mouths become soft and muddy. They often stop or severely restrict movement.

Within the Sichuan Basin are low mountains, hills, and many streams and terraces. Soils are mostly fine grained. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas. During the wet season, conditions are poor to unsuitable in most places.

General Weather. Fall is usually the period of the least cloudiness with moderate temperatures and gentle breezes. The Chinese refer to fall as the period with crisp air and clear skies. These conditions make it the most comfortable time of the year. This weather is very similar to the North American "Indian summer," and it occurs because the rainfall, rainfall days, and cloud amounts in September and October are less than in August and November. This type of weather usually is confined to the area along and south of the Yangtze River or the area between 25° N and 32° N (this includes the central hills and northeast plains regions). It is caused by a cold, dry, high-pressure area that moves rapidly over southeast China from the north. The remainder usually experiences the least cloudiness of the year in fall, but the early winter months have less rainfall and fewer rainfall days.

The areas to the east and west of the high-pressure system are subject to weather systems to the east and west. These cause two types of rainy periods during fall. One occurs in the east where Indian summer prevails and the other occurs in the west where it does not. The first period of rain usually coincides with the period of Indian summer in the rest of southeast China. A surface trough extends from the Yunnan-Guizho Plateau (southwest plateau) north to the Sichuan Basin. This trough produces the rainy period in those areas. The second area that experiences a rainy period includes the coast from Shanghai to Taiwan. Tropical cyclones (typhoons, tropical storms, and tropical depressions) and topography cause increased rainfall in this area. The transition from summer weather to winter weather is rapid. It takes only about 45 days between early September and mid-October. During the first 10 days of September, the summer flow usually retreats to the Yangtze River valley. By the end of September, the winter northeast flow has usually moved southward through all of southeast China east of 105° E. The summer southwest flow retreats south before the winter northeast flow to the coastal areas of southeast China. During the first ten days of October, the winter flow penetrates the coastal areas and finally, after 10 October, Hainan.

The abrupt transition over southeast China is caused by an equally abrupt change in the general circulation pattern over the area caused mainly by the huge land mass of Asia. Cooling of the land causes the Asiatic thermal low to dissipate rapidly and the Asiatic thermal high to build. The Tibetan Plateau also has a dynamic affect on the weather. While it keeps cold air from the plateau itself, it directs cold air around its eastern edge into southeast China, which allows cold surface highs to reach the northeast plains and the central hills. These highs produce Indian summer in those areas. The rainy period in the Sichuan Basin and southwest plateau starts about the time the upper-air easterlies are replace by the westerlies, but before the westerly jet prevails in the area.

These rapid changes in the synoptic or surface weather conditions are followed by a slower southward shift in the upper-level weather patterns. The movement of the upper ridge lags behind the southward movement of the surface trough.

Sky Cover. Although southeast China is cloudy year-round, the eastern part of the area usually has the least cloudiness of the year during fall (see Figure 3-26). By October, however, winter weather patterns begin to return. The Sichuan Basin again becomes one of the cloudiest locations in China. Low clouds are frequent there also. The lower Yangtze River valley has very little low cloudiness.

Sichuan Basin. Some locations experience the least cloudiness of the year in September. By October, cloudiness returns and sky cover averages 45-75 percent depending on location. Ceilings occur 60-80 percent of the time at night and 70-80 percent or more during the day. There are fewer clouds in the east where the Yangtze River flows eastward from the basin and low-cloud ceilings are far less frequent. Ceilings less than 3,000 feet occur more frequently at the higher elevations such as Guiyang (above 600 meters) where they occur 25-35 percent of the time in the morning and 25-30 percent of the time in the afternoon. Elsewhere, ceilings below 3,000 feet occur less frequently. The diurnal variation is about 10-15 percent.

Southwest Plateau. This part experiences the greatest seasonal variation in cloudiness. The western part is shielded from the moist, shallow northeast monsoonal flow by high mountains. Dry air from the Tibetan highlands often dominates the area. As a result, it is less cloudy in the western part of this area than in the eastern part, and cloudiness decreases through fall as the winter monsoon establishes itself. Lowlands in the southeast are cloudier. Afternoon ceilings occur 70 percent of the time or more in the east and central part of the region and 50-60 percent in the west. Night ceilings occur about 50-60 percent of the time. Due to the terrain, ceilings less than 3,000 feet are quite variable, 20-60 percent in the morning and 10-55 percent in the afternoon and evening.

Northeast Plains. Indian summer usually prevails in this region so cloudiness is the lowest of the year. Typhoons and other tropical cyclones can cause extensive cloudiness in the region, mostly near the coast and in the lowerYangtze valley. Ceilings occur 50-65 percent of the time during the afternoon and 40-60 percent of the time at night. The upper Yangtze valley, which adjoins the Sichuan Basin, has the highest frequency of ceilings, but not low cloud ceilings. Ceilings below 3,000 feet occur less than 20 percent of the time with very little diurnal variation. At the coast and on coastal islands, ceilings below 3,000 feet occur more frequently due to tropical features. Low ceilings occur 20-40 percent in the morning with a slight increase in the afternoon before decreasing in the evening. The coast south of Shanghai receives the most low clouds.

Central Hills. Indian summer usually affects this region also. However, the western part of the region, adjoining the Sichuan Basin, has the most clouds. Ceilings occur there an average of 60-70 percent of the time in the afternoon and about 50-60 percent at night. The coast has ceilings 60 percent of the time or more during the afternoon and 50-60 percent at night. The central part of the region averages ceilings 50-60 percent of the time with little diurnal variation. Because of the terrain, low cloud ceilings can be quite variable, but ceilings less than 3,000 feet generally occur 25 percent of the time or less. It depends on location and time of day. Coastal islands have morning low ceilings up to 40 percent of the time.

Southern Plains and Hills. September and October have the least cloudiness as the winter northwest flow usually doesn't reach the southern plains and hills until sometime in October. Afternoon ceilings occur 50-60 percent of the time in the east and 60-70 percent in the west areas that adjoin the southwest plateau. At night, ceilings decrease in frequency along the coast to 50 percent or less of the time and in the west to 50-60 percent of the time. Ceilings less than 3,000 feet occur more often in the afternoon than at other times of the day. This cumuliform cloud layer still develops in this region because the more stable winter conditions have not yet penetrated this far south. Afternoon ceilings less than 3,000 feet occur 15-45 percent of the time in September, but only 5-35 percent in October.

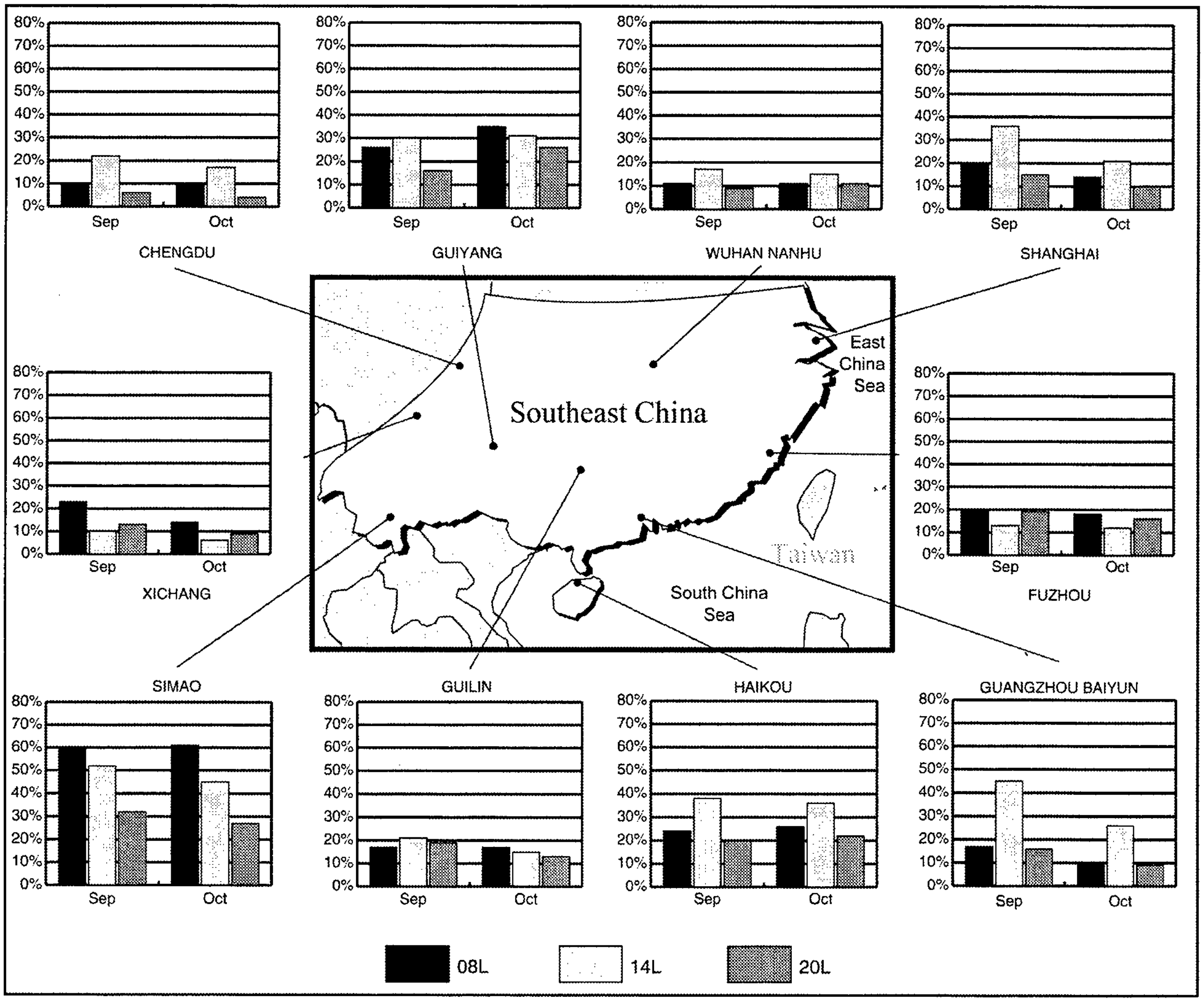


Figure 3-26. Fall Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Generally, the visibility in the fall is good. As the winter circulation pattern returns to the region with its cold, stable conditions, visibility decreases (see Figure 3-27).

Sichuan Basin. The higher locations have good visibility. Visibility below 4,800 meters occurs only 6-12 percent of the time in the morning; low visibility is rare in the afternoon. Elsewhere in the basin, nocturnal rains and fog restrict the visibility to less than 4,800 meters 40 to 70 percent of the time. In the afternoon and evening, visibility below 4,800 meters occurs about 10-20 percent of the time.

Southwest Plateau. The visibility is uniformly good. Simao has morning visibility less than 4,800 meters about 20 percent of the time in October.

Northeast Plains. The visibility is generally good. In Shanghai, morning visibility less than 4,800 meters occurs 30 and 40 percent of the time in September and October, respectively. By afternoon, visibility less than 4,800 meters occurs about 5 percent of the time. Other locations along the Yangtze River experience morning fog 20-40 percent of the time. It clears in the afternoon but reforms in the evening.

Central Hills. A few locations have morning visibility less than 4,800 meters up to 40 percent of the time. By afternoon only 5 percent or less occurs.

Southern Plains and Hills. Good visibility prevails. Only a few locations have morning visibilities less than 4,800 meters.

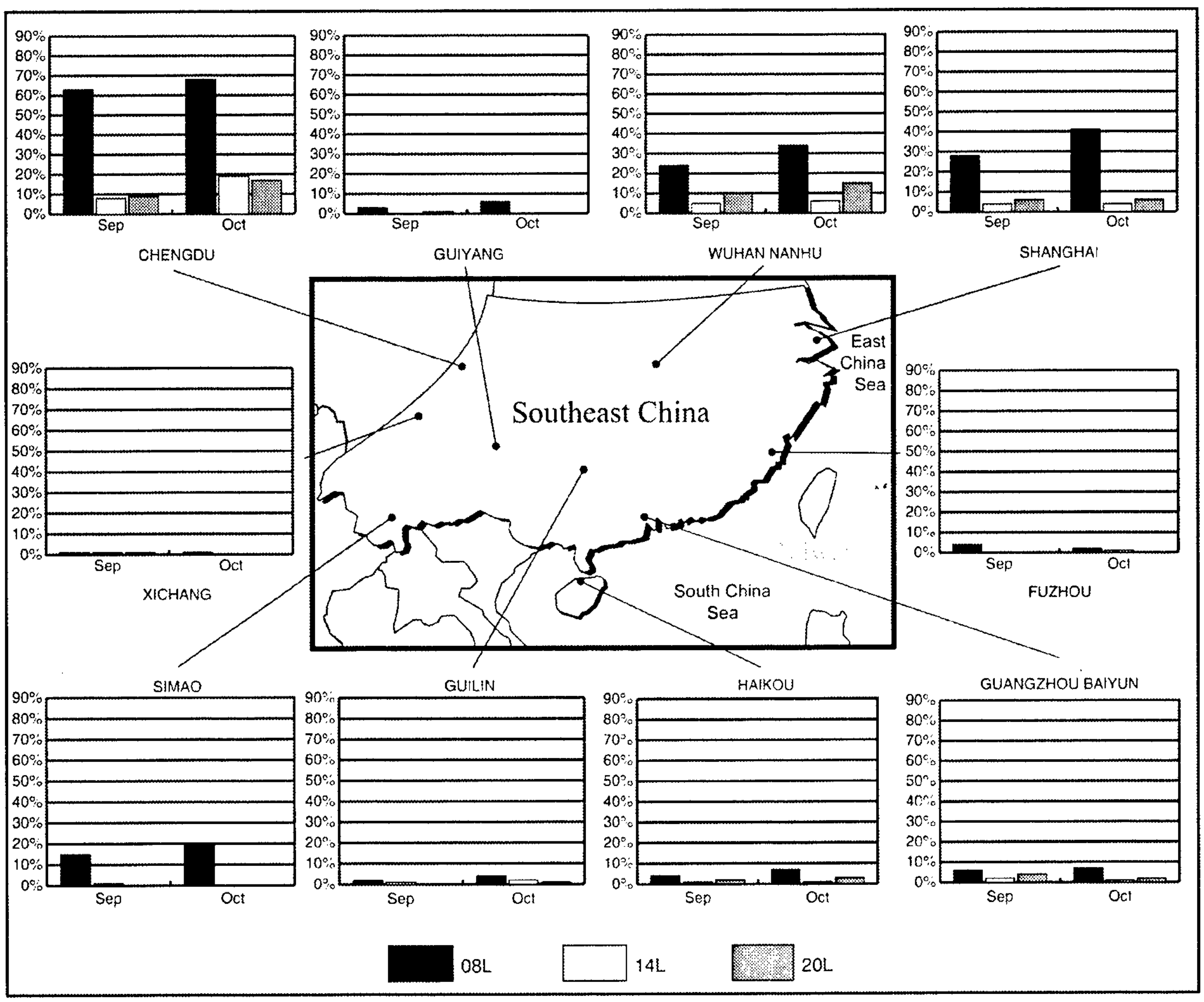


Figure 3-27. October Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percentage of ceilings below 3,000 feet based on location and diurnal influences.

Surface Winds. Fall has frequent calm days with gentle to moderate breezes in most areas before the winter northeasterly flow establishes itself about mid-October (see Figure 3-28). Average speeds of 4-8 knots prevail except in the southwest plateau where calm or light and variable winds occur, especially in the valleys. Tropical storms and typhoons with their winds of 34-63 knots and greater than 64 knots, respectively, are still possible through fall. September has the most activity, about one of each storm type occurs on average. By October, tropical storms and typhoons are still possible, but only about once every 3 years. Winds more than 34 knots increase in frequency as the northeast flow strengthens. The Taiwan Strait experiences these winds more than 10 days in October due to funneling of the wind through the strait.

Sichuan Basin. Calm winds occur 40-60 percent of the time at night and are generally 5 knots or less when they are not calm. Even in the afternoon, calm winds occur about 20 percent of the time. In the afternoon, winds are mostly light from the north to northeast at 5 knots or less. At the higher elevations, afternoon wind speeds are usually 6-15 knots. Maximum winds of 45 knots can occur there with an especially strong early cold surge.

Southwest Plateau. Winds remain south to southwest in this region with calm to light and variable winds at night. During the afternoon, winds are light southerly to southwesterly at 5 knots or less, but occasionally up to 15 knots. Winds are stronger at the higher elevations. Afternoon speeds are usually 6-15 knots. Extreme winds of about 50 knots can occur at the higher locations.

Northeast Plains. Northeasterly flow arrives in October in the northeast plains. Winds are northerly to northeasterly except at some locations in the Yangtze River valley appears to funnel the winds from the southeast. Calm winds at night are frequent at locations in the upper Yangtze River valley (35-50 percent of the time), but less frequent near the coast (Shanghai). Afternoon wind speeds are stronger near the coast also; winds are usually 6-15 knots, but occasionally rise to 25 knots. A typhoon or tropical storm can cause extreme winds on the coastal islands (greater than 60 knots). The land/lake breeze at Dongting Lake occurs about 6-9 days of the month during periods of weak general circulation. The lake breeze starts in late morning, and the land breeze begins in the early evening.

Central Hills. Northeasterly to northwesterly winds prevail with speeds of 6-15 knots and occasionally up to 25 knots day and night. Some protected locations have calm winds at night. One station, Fuzhou, shows a sea breeze in the afternoon when the prevailing wind is from the southeast at 6-15 knots. The sea breeze only prevails in periods of weak circulation; northerly winds prevail otherwise. In September, strong winds are most likely caused by a tropical storm or typhoon, but in October, strong winds are most likely the result of strong northeasterly flow.

Southern Plains and Hills. Winds at and near the coast are stronger than those farther inland. On the coast opposite Taiwan, northeasterly to easterly winds prevail day and night, normally at speeds of 6-15 knots with some stronger winds to 25 knots. Funneling of winds in the Taiwan Strait can occasionally produce even stronger winds during October. Extreme winds of 58 knots in September were caused by a tropical storm or typhoon while winds of about 45 knots in October were probably due to the funneling of the winds. Inland, calm night winds occur from 45 to more than 60 percent of the time. Light winds prevail there during the day.

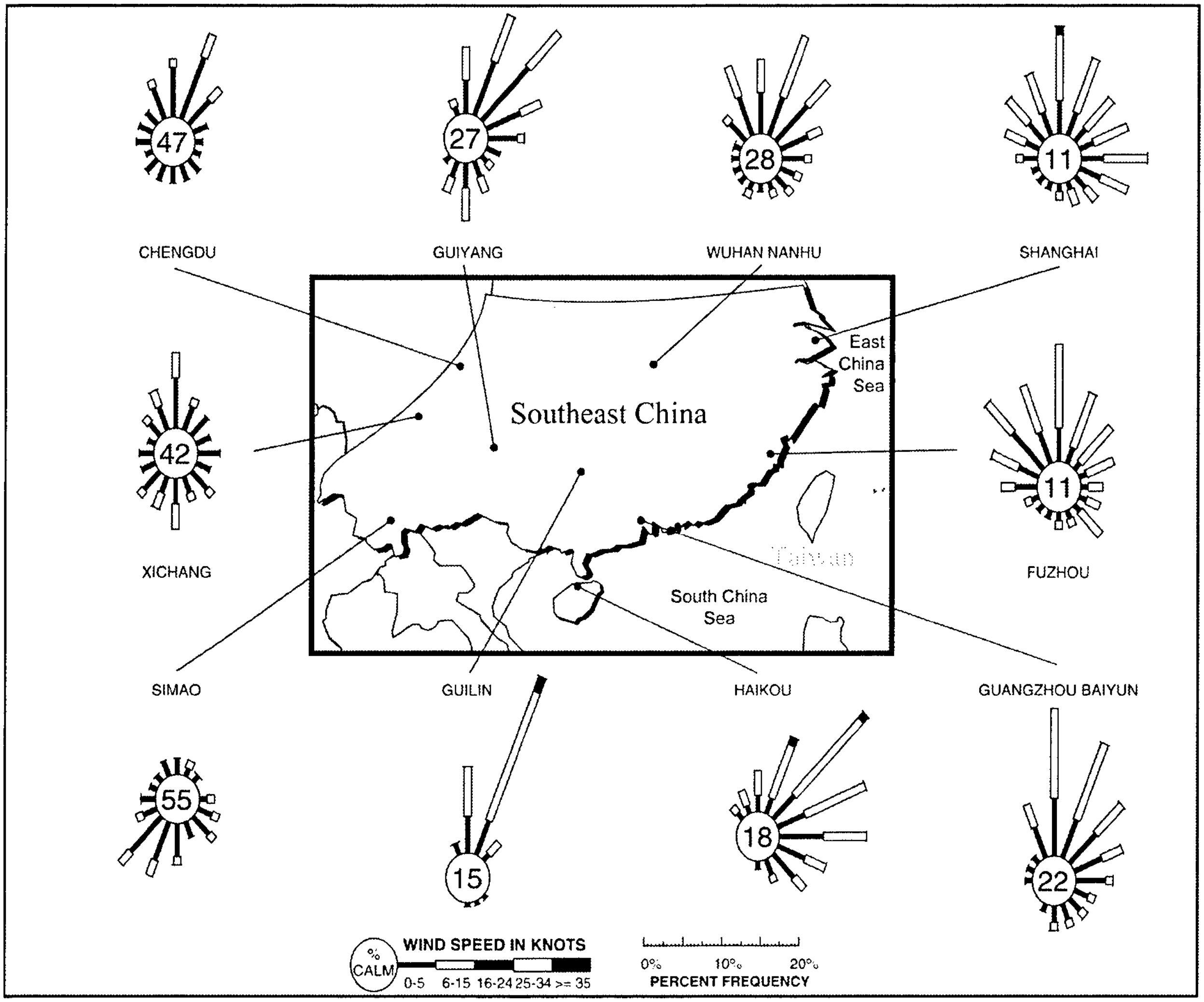


Figure 3-28. October Surface Wind Roses. The figure shows the prevailing wind directions and range of speeds based on frequency and location.

Winds Aloft. The transition to the winter circulation pattern begins in fall (see Figure 3-29). At 850 mb, high pressure develops over southeast China, while at 500 mb and above, westerlies expand southward over most of southeast China. The subtropical and polar jets remain north of southeast China. The Tibetan high moves southeastward, and the tropical easterly jet dissipates. The easterlies, which were present aloft during summer, move southward. The freezing level in the north occurs about 14,800 feet (4,500 meters) in October, and in the south, it occurs about 17,000 feet (5,200 meters).

Sichuan Basin. Southerly to southwesterly flow prevails up to 700 mb. At 500 mb and above, westerlies prevail. The 500-mb winds are occasionally as strong as 75 knots; at 300 mb they reach up to 120 knots.

Southwest Plateau. Weak southerly winds below 700 mb become weak westerlies at 700 mb, where the predominant speed is 0-20 knots. Westerlies at 500 mb and 300 mb are also fairly weak with the most frequent speed of 0-30 knots.

Northeast Plains. Shanghai's 850-mb winds prevail from the north, usually at speeds up to 15 knots. Speeds up to 45 knots occur with cold surges from the developing Asiatic high. Westerly winds prevail above 700 mb, with speeds of 120 knots at 300 mb.

Central Hills and Southern Plains and Hills. Fairly strong 850-mb winds from the northeast (speeds up to 45 knots) are possible. Westerlies prevail at 700, 500, and 300 mb. They are weak at 700 mb, but become moderate at 500 and 300 mb. These winds indicate that the winter northeast flow reaches the southern extreme in October.

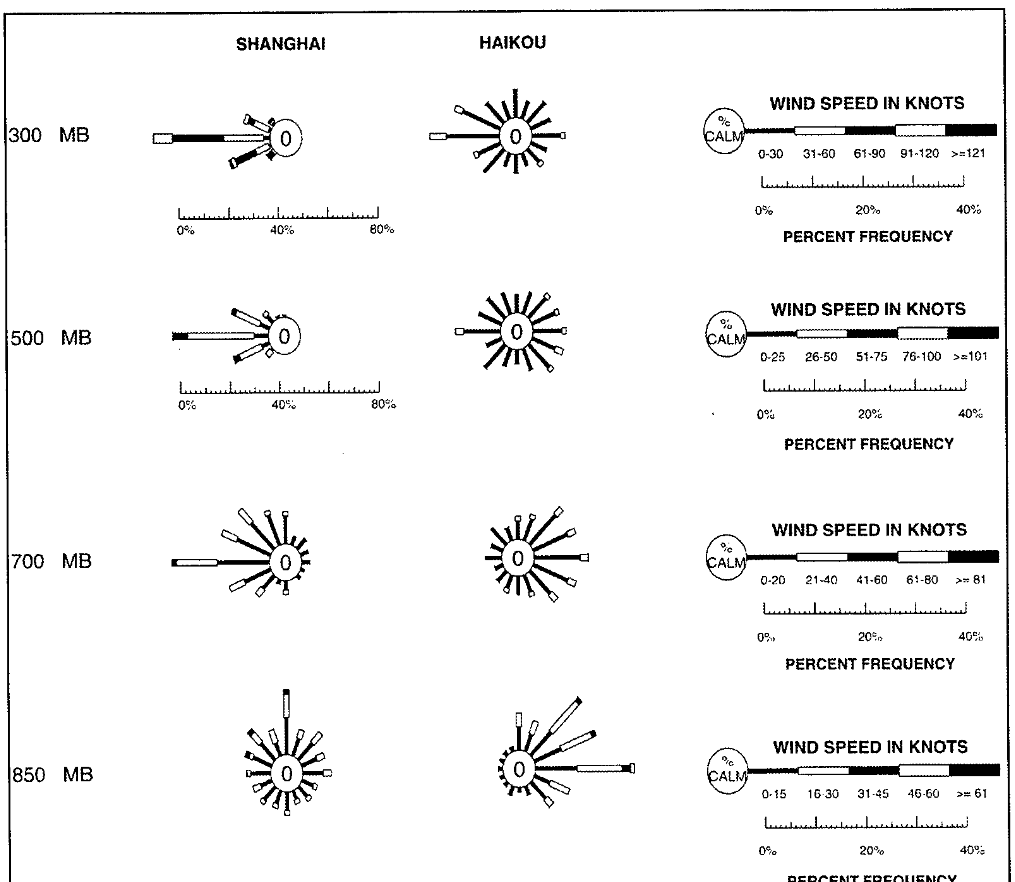


Figure 3-29. October Upper-Air Wind Roses. The wind roses depict the 1200 UTC wind speed and direction for standard pressure surfaces between 850 and 300 mb. Note: Some levels have different percent frequency scales.

Precipitation. Mean precipitation patterns are oriented north-south during this season. See Figure 3-30 for the distribution of mean precipitation in October over southeast China. While Indian summer prevails over much of southeast China during fall, some areas experience one of two kinds of rainy periods. The Sichuan Basin and the southwest plateau experience one of these. This period of rain, known as "unceasing fall rains," is triggered by a surface trough extending over the Yunnan-Guizhou plateau northward to the Sichuan Basin. Cold air at the surface is fed into the trough by a surface high-pressure ridge, which moves southward across southeast China. While the high causes fine weather in some of southeast China, its cold air enhances the trough and produces the rainy period in other areas. The second area that experiences a rainy period includes the coast from Shanghai to Taiwan. Typhoons and topography cause increased rainfall in this area. The areas that receive the most rainfall in October are the Sichuan Basin, the southwest plateau, and Hainan Island (see Figure 3-31).

Thunderstorms decrease in frequency in fall as the unstable, warm, moist southwesterly flow is replaced by the cold, dry, stable northeasterly flow. That means thunderstorm activity decreases first in the north and last in the south. Thunderstorms still occur in the south during October while they become rare in the north. The southwest plateau and the southern plains and hills are two regions where the thunderstorms continue through fall (see Figure 3-33.).

Sichuan Basin. Most of the basin averages 100-150 mm of precipitation in October. Rainfall days average 17-23 days. One day with snow occurs in October at Guiyang, one of the highest locations. Most of the precipitation is steady rather than convective. Thunderstorm activity decreases through fall as the stable winter conditions move into the basin. Thunderstorm days decrease from 2-3 days in September to only 1-2 days in October.

Southwest Plateau. The western part of the region has the highest mean precipitation of this area from 100 mm to more than 150 mm. The eastern part of the region receives an average of 50-100 mm. Rainfall days decrease at most locations from September to October; September averages 19-23 days and October averages 15-21. Snowfall occurs in October at the highest elevations in the plateau on 1 day of the month. Thunderstorms continue through fall, although there are fewer in October than in September. Thunderstorm days range from 7 to 13 during September and 2-5 days in October.

Northeast Plains. This is one of the areas that experiences Indian summer. Mean precipitation is 50-100 mm in October. Rainfall days decrease slightly from September to October in the lower Yangtze River valley from 14-19 days to 12-16 days. In the upper valley, the rainfall averages about 13-16 days for both months. Only a few thunderstorms occur during fall. September averages 2-4 thunderstorm days and October has only 1 day.

Central Hills. Mean precipitation averages 50-100 mm in most of the region with more precipitation in the west near the Sichuan Basin. Rainfall days decrease in the east from 14-16 days in September to 13-14 days in October, while they increase in the west from 11-15 days in September to 14-19 days in October. Thunderstorms decrease in frequency through the fall from 2-8 days in September to 1-3 days in October.

Southern Plains and Hills. Hainan Island receives the most rainfall in October due to its topography. The eastern coast of the island averages 250 mm or more, and it decreases westward to 100 mm or less. The island averages 15-17 days per month with rainfall. On the mainland, 50-100 mm is average. It rains there during 10-15 days in September and 9-16 days in October. Thunderstorms decrease in frequency through fall. Hainan Island and the southern coast of the mainland have 14-17 thunderstorm days in September and 4-6 days in October. The mainland has 7-8 thunderstorm days in September and 1-3 days in October.

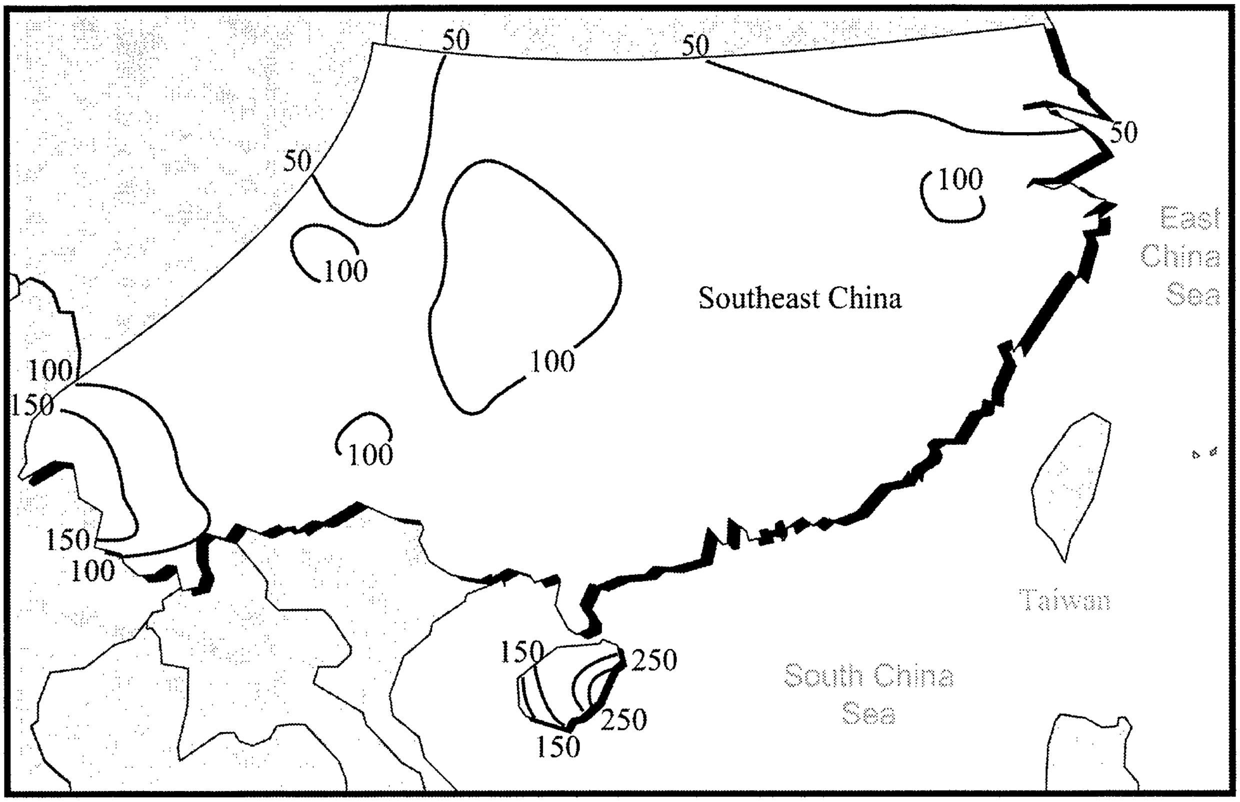


Figure 3-30. October Mean Precipitation (mm). The figure shows mean water equivalent amounts that occur in southeast China during the transition from summer to winter.

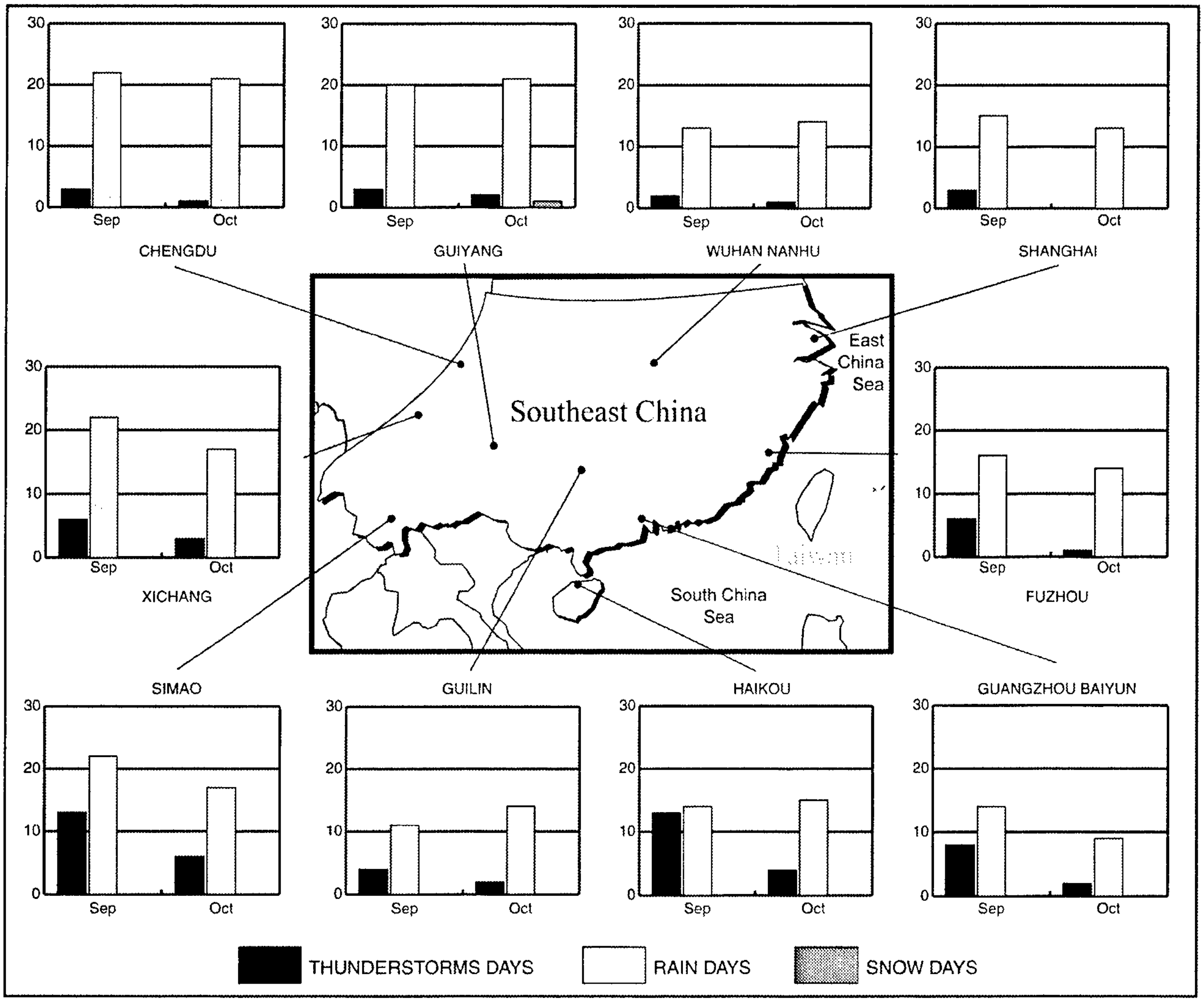


Figure 3-31. Fall Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average occurrences of rain, thunderstorm, and snow days for representative locations.

Temperatures. With rapid cooling of the Asian continent that starts in September, temperatures begin to drop, and the isotherm pattern changes to the zonal temperature pattern characteristic of winter. Cold surges from the developing Asiatic high begin in October and cause periods of abnormally low temperatures at some locations in southeast China, especially in the northern part of the region. Islands in the South China Sea are the warmest places in fall with mean temperatures greater than 77°F (25°C) due to warm ocean currents in the region. The southern plains and hills and southern central hills remain relatively warm in fall with mean temperatures of 68°F (20°C) or more. Cold surges from the Asiatic high do not usually reach this far south until the Asiatic high is stronger. Figure 3-32 shows the mean maximum temperatures for October and Figure 3-33 shows the mean minimum temperatures.

Sichuan Basin. Mean maximum temperatures range from 68° to 77°F (20° to 25°C) and mean minimums range from 55° to 64°F (13° to 18°C). Extreme low temperatures can get as low as 39°F (4°C). Extreme high temperatures over 86°F (30°C) are possible before the winter is firmly established.
Southwest Plateau. Mean maximum temperatures range from 68° to 81°F (20° to 27°C) and mean minimums range from 57° to 68°F (14° to 20°C). Extreme low temperatures can reach 30°F (-1°C) at the higher elevations in October. Extreme highs can reach 102°F (39°C) in September.

Northeast Plains. Mean maximum temperatures range from 68° to 81°F (20° to 27°C) and mean minimums range from 54° to 72°F (12° to 22°C). Extreme lows can reach 30°F (-1°C) in October and extreme highs can reach as high as 104°F (40°C) during Indian summer in September.

Central Hills. Mean maximum temperatures range from 70° to 88°F (21° to 31°C) and mean minimums range from 57° to 73°F (14° to 23°C). Extreme lows can reach near freezing in the north during October and extreme highs can reach as high as 108°F (42°C) during September.

Southern Plains and Hills. Mean maximum temperatures range from 81° to 88°F (27° to 31°C) and mean minimums range from 66° to 77° (19° to 25°C). Extreme lows can reach 4°F (2°C) in October, and extreme highs can reach 108°F (42°C) in September.

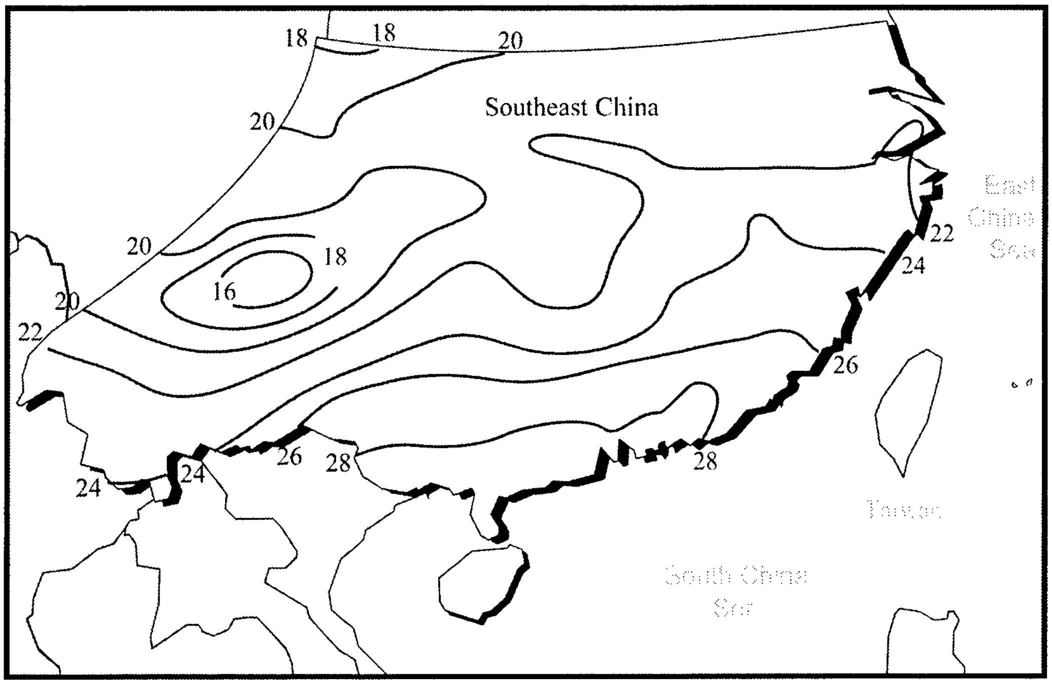


Figure 3-32. October Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for a representative month of fall. Mean maximum temperatures during other fall months may be lower, especially at the end of the fall season.

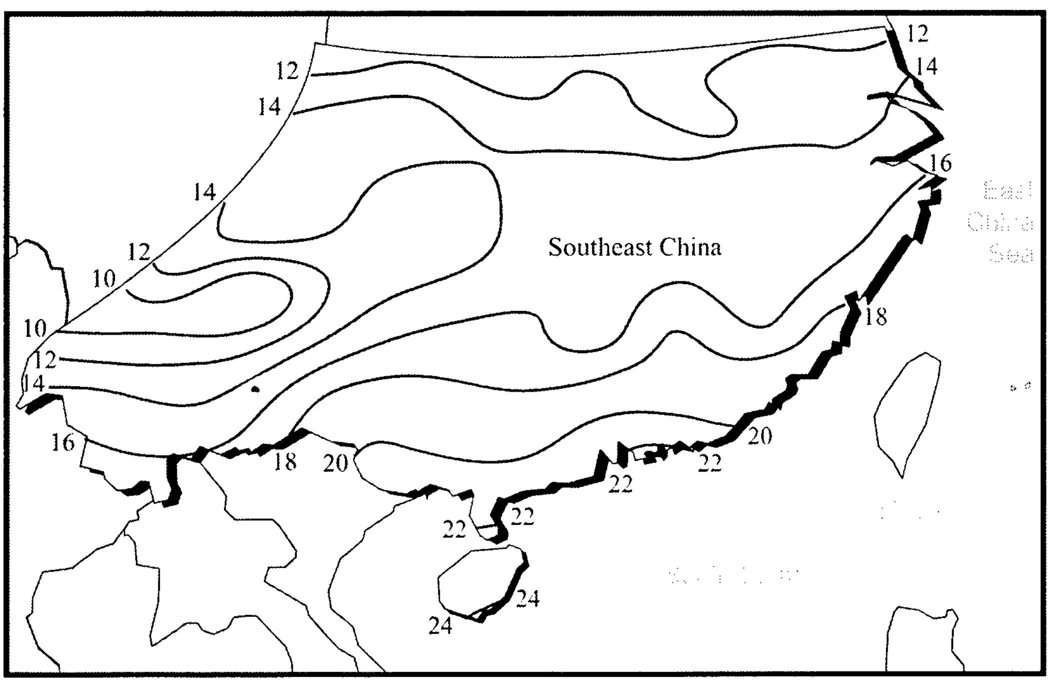


Figure 3-33. October Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for a representative month of fall. Mean minimum temperatures during other fall months may be higher, especially at the beginning of the fall season.

Hazards.

Aircraft Icing. In general, fall has less cloud cover, so icing is less of a problem. High-altitude temperatures are warm enough (warmer than -20°C) for icing to occur in convective clouds. The stratiform clouds that are typical of winter are not yet extensive in fall. In the north, light rime icing in stratiform clouds is possible from about 14,800 to 25,000 feet (4,500 to 7,600 meters). In the south, it is most likely from 17,000 to 28,800 feet (5,200 to 8,500 meters) during October. In convective clouds, the more hazardous moderate to heavy clear icing occurs at the same elevations.

Turbulence. Although strong westerlies usually have not developed over southeast China during the fall, they can occur in October. Strong westerly winds aloft and the rugged terrain of southeast China, especially in the west in the Sichuan Basin and the southwest plateau, make conditions favorable for mountain-wave turbulence downwind from these mountains. This turbulence occurs to altitudes well above 20,000 feet (6,000 meters), and it can be severe (depends on wind velocity).

Typhoons. Damaging typhoons occur virtually every year in this area of China, especially near the coast. They cause flash flooding and damage from strong winds. About five typhoons affect the coastal areas every year, mainly from July through September. Typhoons affect all coastal areas and as far as 300 miles (500 km) inland.

Trafficability. China is a country of very diverse topography and soil types. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppes, deserts, wide and narrow valleys, deep gorges, alpine meadows, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained, and consist of clays and silts. The soil type range includes some sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during he dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows, especially if frozen, and some valley bottoms. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

On the plains, slopes vary from nearly level to about 20 percent grade. The soils are predominantly medium- to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the dry season, movement conditions are fair to good except where restricted by marshy areas, steep-banked water courses, irrigation canals, forests, and dissected areas (very rugged terrain). In the southern part of the plains, rice cultivation limits movement when paddies are flooded. During the wet season, movement conditions are good to poor. Condition depends on soil type. During this time, coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near the river mouths become soft and muddy. They often stop or severely restrict movement.

Within the Sichuan Basin are low mountains, hills, and many streams and terraces. Soils are mostly fine-grained. In the mountains, conditions for movement are poor to unsuitable at times because of steep slopes. In the dry season, conditions in the hills and plains are poor to good. Conditions depend on local agricultural practices. Movement conditions are unsuitable in flooded rice paddies and in highly terraced areas. During the wet season, conditions are poor to unsuitable in most places.

Chapter 4

NORTHEAST CHINA

This chapter describes the geography, major climatic controls, special climatic features, and general weather by season for the northeast region of China.

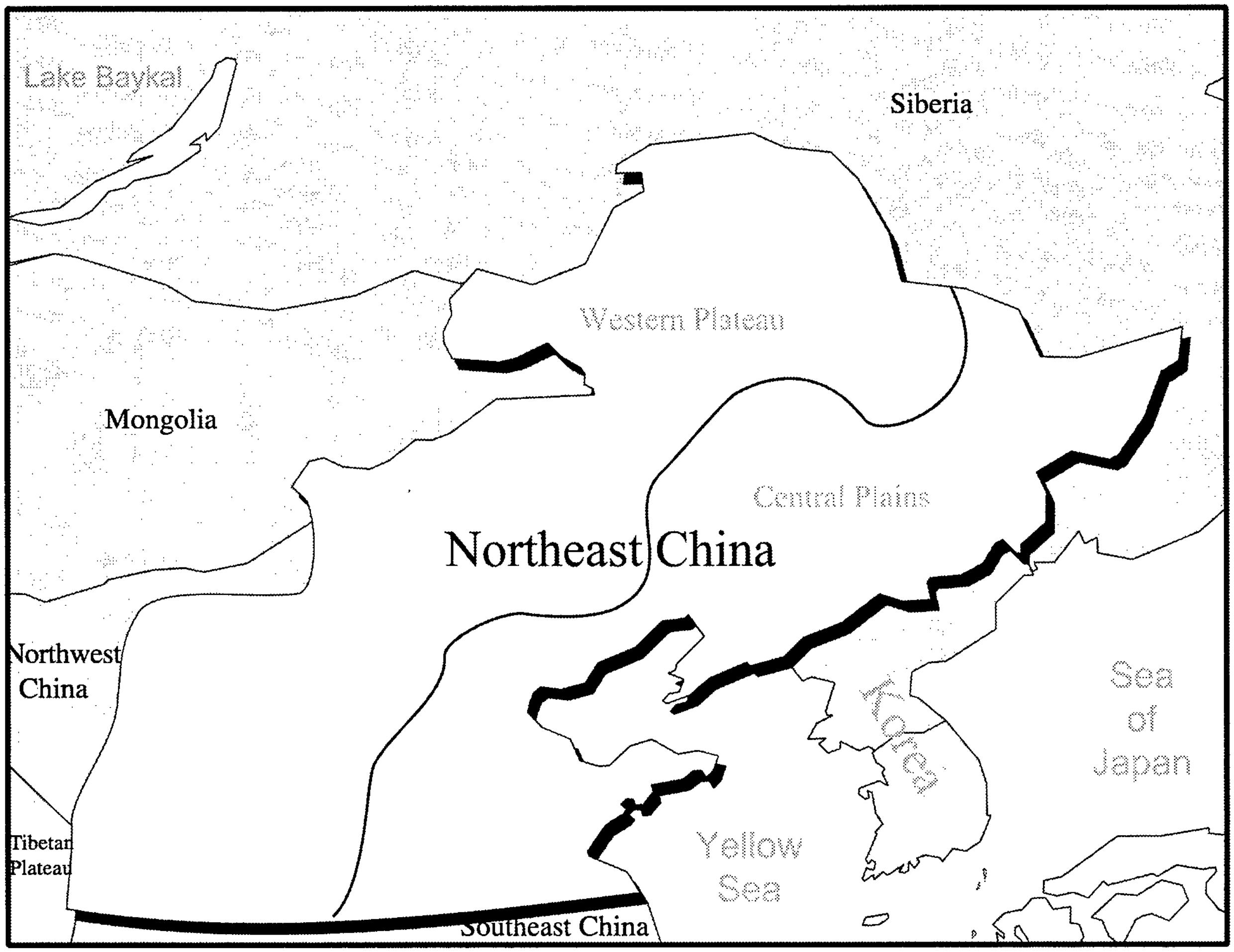


Figure 4-1. Northeast China Topography. This map shows major place names, rivers, and terrain features for the area of interest.

Boundaries. Siberia borders this region to the north and northeast. The eastern part is bordered by North Korea and the Yellow Sea. The southern border extends approximately east to west until it reaches the southwest border near 33° N, 105° E. The western border extends northward to the border of Mongolia. Much of the western border follows the edge of the eastern Gobi Desert. The remaining northwestern border is the China-Mongolia border.

Major Terrain Features. The topography of the northeastern China region has mountains, hills, plateaus, and plains with a general northeast to southwest orientation. The region is basically divided by a series of mountains and hills into an eastern lowland plains area and a western plateau. The Manchurian and North China Plains dominate the eastern half of the area. The western half is mostly the Loess and Inner Mongolian Plateaus.

The Central Plains. The Manchurian Plain lies at an elevation generally below 1,640 feet (500 meters); much of it is below 650 feet (200 meters). This rolling plain is split into northern and southern parts by a low divide, which is 500-850 feet (150-260 meters) high. The divide extends northwestward across the plain.

Except for the southern portion, which opens up to the Yellow Sea, the Manchurian Plain is nearly surrounded by mountains and hills. The Da Hinggan Range lies to the west and north. Elevations rise above 3,000 feet (900 meters) with numerous peaks above 4,000 feet (1,200 meters) and some above

5,000 feet (1,500 meters). In the extreme north, Mt. Fengshui, the highest peak, is 5,260 feet (1,603 meters). The Xian Hinggan Range borders the plain to the northeast. Elevations are typically 2,000 feet (600 meters) or less with peaks between 3,000-4,000 feet (900-1,200 meters). On the North Korea border, elevations are between 1,500-3,000 feet (450-900 meters). Peak elevations rise between 4,000-5,000 feet (1,200-1,500 meters).

The North China Plain is similar in size to the Manchurian Plain. It lies east and southeast of the Taihang Mountains, from Beijing to nearly the Yangtze River. Elevations in the Taihang Mountains rise to over 6,500 feet (2,000 meters). The flat plain has mean elevations under 650 feet (200 meters).

The plain is broken by hills and mountains (Shantung Hills), which lie near the east-central section of the plain. Elevations rise to around 1,500 feet (450 meters) with a few peaks above 3,000 feet (900 meters). Mt. Tai is the highest point in this area at an elevation of 5,090 feet (1,524 meters). On the Shantung Peninsula, isolated peaks with mean heights between 2,000-3,000 feet (600-900 meters) dot the landscape. The highest point on the peninsula is Mt. Lao at 3,800 feet (1,158 meters).

Elevations here rise to well over 3,000 feet (900 meters) with several peaks above 6,000 feet (1,800 meters). The highest point in this region is Mt. Wutai at 10,106 feet (3,058 meters).

Along the western part of the southern border lies the Qinling Mountains. These mountains are oriented west to east and extend into the North China Plain. Elevations vary from 3,000-10,000 feet (900-3,000 meters) with the western portion higher. Mt. Taibai is the highest peak at 12,500 feet (3,767 meters). These mountains are a series of parallel ridges. Canyon walls often rise abruptly to 1,000 feet (300 meters) above valley streams.

The Western Plateau. A unique plateau region of loess-clad hills and barren mountains lies in southwestern northeast China. This region, known as the Loess Plateau, is between the North China Plain and the desert regions of the west. The average height of the plateau is around 4,000-5,000 feet (1,200-1,500 meters), but individual ranges reach near 9,300 feet (2,800 meters). Ravines cover approximately 50 percent of the Loess Plateau region. Erosion cuts gullies to depths of 300 to 650 feet (90 to 200 meters). The Mu Us Desert, lies north of the Loess Plateau. Elevations are about 4,000-5,000 feet (1,200-1,500 meters).

The Inner Mongolian Plateau lies northeast of the Yin Mountains and Ordos Plateau. This region borders the extreme eastern part of the Gobi Desert. Elevations are predominately between 3,000-4,000 feet (900-1,200 meters).

Major Water Bodies. The Yellow, East China, and South China Seas border the region.

Rivers and Drainage Systems. The Yellow River (Huang Ho) originates in Tibet and winds its way around the Mu Us Desert before it flows from southwest to northeast into the Yellow Sea. The Manchurian Plain is drained in the north by the Songhua River and its tributaries, and in the south by the Liao River.

The Amur River marks the boundary between China and Siberia. Much of the Amur remains frozen an average of 183 days each year.

Ocean Currents/Sea-Surface Conditions. Figure 2-1 shows the two major ocean currents that affect the region and the mean sea-surface temperatures. During winter, persistent northeast winds result in a cold current, the Kuroshiro Counter Current, which flows north to south along the coast of mainland China. Sea-surface temperatures (SSTs) begin to fall rapidly in October. By January, SSTs drop to 0°C in Bo Hai Bay, where broken ice frequently extends 60-100 miles (100-150 km) offshore. Ice occasionally extends into the Korea Bay. South of the Shantung Peninsula, SSTs increase to near 10°C. SSTs along the coast are generally a few degrees warmer than the air above them.

Asiatic High. As shown in Figure 2-5, the Asiatic high dominates the weather from late September through April and reaches its maximum intensity in January. Outflow from the high creates northwesterly to northeasterly surface wind flow. When northwesterly flow is interrupted, winds tend to follow local pressure differences and terrain features. Cold fronts associated with these cold surges sweep southeastward across the North China Plain about once every 5-6 days during winter.

North Pacific High. Figure 2-2 shows the mean position of the subtropical high during January and July. The seasonal shift in the position of the North Pacific high's ridge axis is closely linked to the advance and retreat of major rain belts in East Asia. Summer rainfall amounts over northeastern China are likely to be higher than normal when the North Pacific high is north of its mean position. Drought may occur when it is farther south and east of its normal summer position.

Aleutian Low. This low works with the Asiatic high to create a strong pressure gradient over East Asia during winter. This pressure gradient results in the predominantly northwesterly to northeasterly surface flow of winter. Fluctuations in its strength can affect the strength of the flow over the region. Eastward moving low-pressure systems are drawn to this area, especially in winter.

Asiatic Low. The Asiatic low, a large-scale thermal low, dominates the Asian landmass during summer. It acts with the North Pacific high to produce the southerly surface flow of summer.

Extratropical Cyclones. Northeast China and Huanghe River lows influence the climate of northeast China throughout the year (see Table 2-2). Storms are most frequent during summer over the northern interior. The northeast China lows typically track from southern Siberia, across Lake Baykal, then into the North Pacific Ocean. Huanghe River lows develop in western China, south of the Mongolian border. They usually track eastward, across the southern part of northeast China. They cross into the Yellow Sea. Figure 2-27 shows their typical tracks.

These lows normally bring cloudy conditions and precipitation at regular intervals from late spring to early autumn, when moist air dominates north China. Well-developed lows are infrequent over the northern interior during winter as the polar front lies south of the region over the South China Sea. Winter cyclones often result in stronger winds with little cloudiness.

Both types of lows can bring extensive duststorms during winter and early spring. These duststorms can lower visibility to 4,800 meters or less for 1-2 days. Lows passing near the coast may intensify as they interact with the warmer water, bringing strong winds and rain or snow to coastal areas.

Migratory Highs. Most migrating highs move generally southeastward before turning eastward south of the Shantung Peninsula. During winter, migratory highs occasionally break away from the Asiatic high and drift southeastward to bring clear skies and very cold temperatures. In summer, they bring sunny skies and relatively cool, dry weather.

Typhoons. July through September are the peak months for typhoon activity. Typhoons generally recurve and move off the mainland before reaching northeast China (see Figure 2-35). The Shantung Peninsula and southern coastal sections are most likely to be affected. Storms that approach from the southwest lose much of their destructive intensity over land, however, heavy rains can still affect the region and cause flooding. Those moving northward over the Yellow Sea lose much of their force in the mountains of the Shantung Peninsula. Typhoons that approach directly from the Yellow Sea may strike the Liaotung Peninsula. Although the storms are weakened by friction over land, they bring high tides and torrential rains. Severe flooding is possible whenever these storms move inland or pass close enough to the coast to bring heavy rains.

Mei-yu Front/Season. Although the mei-yu front does not reach northeastern China, its position and movement is directly related to the advance of the summer season. When the mei-yu rain belt moves north of the Yellow River, generally around mid-July, it indicates the start of the heavy rainfall period.

Strong summer wind flow shortens the mei-yu season. The rain belt moves rapidly northward and brings early rains. In years with weak summer wind flow, the mei-yu front stagnates in the Yangtze River valley. The stationary heavy precipitation causes widespread and persistent flooding. The polar front stalls along with the mei-yu front. This causes a late arrival of summer moisture. Drought conditions occur even as the Yangtze River valley floods.

Cold Surges and Cold Fronts. Figure 2-31 shows the main tracks of cold surges across northern and northeastern China. Cold surges are marked by a sharp drop in air temperature of at least 18 Fahrenheit (10 Celsius) degrees within 24-48 hours. Temperature drops of 68 Fahrenheit (38 Celsius) degrees or more can occur. Strong cold outbreaks normally last between 4 and 6 days. In the winter, successive cold fronts march across the region about once per week. Precipitation seldom occurs with these fronts. The progression of cold fronts depends largely on topography.

Cold fronts are sometimes accompanied by gales that persist for up to a week in exposed areas. Waves occasionally develop along the front in the southern part of the region. These waves move eastward or northeastward and can produce significant snowfall.

Southwest China Vortex. This low-level vortex forms during the spring transition and summer seasons. It is most common during May and June. Of those systems that move out of their Tibetan source regions, nearly one-quarter move northeast and bring widespread, heavy precipitation.

Duststorms. Sources of dust are the Loess Plateau, the deserts of Mongolia, and the western sections of the region. Duststorms may occur at any time of the year, but are most frequent in the winter and spring, when the ground is usually dry. They are most intense when a low-pressure system and its associated cold front cross the area. Duststorms may persist for several hours and reduce visibility to hundreds of yards. Their vertical extent may reach several thousand feet.

General Weather.

During the winter, northeast China is under the dominating influence of the strong, intensely cold Asiatic high. This leaves the entire area in a cold, polar, continental air mass. The polar front is well south of the area, at about 20° to 25° N latitude. Southward moving cold surges from the Asiatic high occur frequently and create cold northwesterly winds and extremely low temperatures, particularly in northern sections. Typically, before the arrival of a cold wave, the southerly current of air brings warmer temperatures and more cloudiness. Light snow and occasional periods of rain (in the more southern locations) develop. Strong gusty winds, an abrupt decrease in temperature, and gradually clearing skies are characteristics that follow a cold wave. The lowest temperature occurs after the winds decrease in intensity. These cold snaps are very sporadic and there are periods when the winds follow local pressure differences. Winters are much colder than at similar latitudes in North America. Temperatures during the coldest months, December through early February, drop between -4° to -13°F (-20° to -25°C). The area experiences little cloudiness during the long, cold winter, and it generally has unrestricted visibility. Occasional migratory systems move through the area from west to east and bring brief periods of cloudiness. Surface winds are light with calm conditions about 25 percent of the time. Snow falls on only 5 to 10 days, with just a few inches accumulation.

Sky Cover.

Western Plateau. During winter, cloud cover is generally sparse in the western mountain region due to the dry, continental air mass that dominates the area. However, cloud cover occurs because of residual moisture that becomes trapped in some of the valleys. Also, the few migratory systems that cross the region bring in cloudiness from the west. Mean monthly cloudiness varies from 30 to 40 percent in the north to about 55 to 65 percent in the south. Drier conditions exist in the north due to the strong effects of the Asiatic high. Low clouds are rare, with ceilings below 3,000 feet occurring less than 15 percent of the time. In the south, ceilings less than 3,000 feet occur with higher frequency in the mornings (as stratus). In the north and in mountains, ceilings less than 3,000 feet occur most frequently in the afternoon (as stratocumulus). Low cloudiness occurs least in January. Wutai Shan, which has an elevation of 9,507 feet (2,898 meters), receives more ceilings below 3,000 feet (during any season) than any other station in northeast China. Ceilings less than 1,000 feet are rare and occur less than 5 percent of the time nearly everywhere except Wutai Shan, where ceilings less than 1,000 feet occur 20 to 25 percent of the time.

Central Plains. Mean sky cover is scattered during most of the winter months. Up to about 70 percent of the time, the sky is clear. Ceilings below 3,000 feet occur infrequently, generally 6 percent or less of the time, as shown in Figure 4-2. Ceilings below 1,000 feet occur only 1-2 percent of the time. The least amount of sky cover occurs in the northern part of the area, with increasing cloudiness at stations in southern areas of the North China Plain. Coastal stations also report slightly more sky cover than the overall averages, but these stations still have mostly clear or scattered skies.

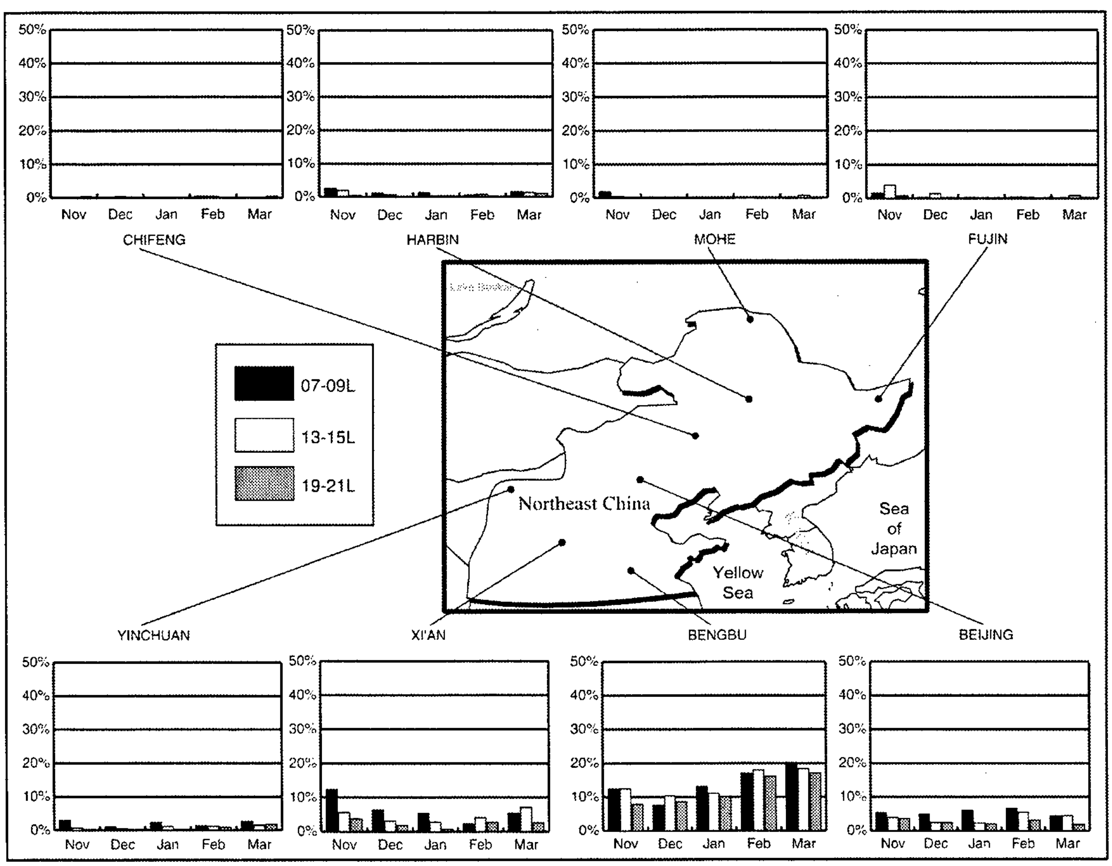


Figure 4-2. Winter Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Western Plateau. Fog and blowing sand are the primary causes of restriction to visibility in the region. The two most likely locations for fog are in the extreme north and in the river valleys to the south. The highest frequency of low visibility normally occurs in December and January. During intense, cold outbreaks, radiation fog often develops under the shallow inversions that form. Smoke and haze often restrict visibility during the early morning hours in industrialized regions. Fronts that pass through the area commonly cause strong winds with periods of reduced visibility due to blowing sand, but they seldom bring significant precipitation.

The deserts of Mongolia, northwestern China, and the Loess Plateau are the most favorable source regions for dust. Typically, after frontal passage, the lowest visibility of a mile or less lasts only for a few hours. Dust from the Loess Plateau may lift into a fine, yellow dust that will linger for 1 to 2 days. Under extremely turbulent conditions, the dust may persist for 3 to 4 days. The visibility will gradually improve at the surface, but the dust will lift several thousand feet into what is called a "yellow haze." This normally occurs after approximately 2 days. Visibility below 4,800 meters occurs in the mornings 15 to 75 percent of the time in the north and southern river valleys.

The highest frequency of low visibility occurs at Hailun in January, where visibility below 4,800 meters occurs 75 percent of the time due to radiation fog that forms in the valley. Elsewhere, reduced visibility usually occurs less than 15 percent of the time. In the afternoon, visibility less than 4,800 meters occurs less than 15 percent of the time at nearly every location. Xi'an, which is located in the southern portion of this region, has visibility below 4,800 meters more than 30 percent of the time because of haze and blowing sand during the afternoon.

Visibility below 800 meters occurs infrequently. Most locations have visibility below 800 meters less than 5 percent of the time. A few locations near river valleys have 800-meter visibility in fog 15 to 24 percent of the time. These locations are in river valleys where ready moisture sources exists. These periods of low visibility occur due to the ready moisture sources, and they only last from shortly before sunrise until midmorning. There are many rivers that help add moisture to the southern sections of the area, and the Da Hinggan Mountains help protect the north from the dry, Siberian air.

Fog occurs only 1 to 2 days a month in central portions of the region, where southwest winds bring in dry air from the west. Blowing sand occurs 1 to 8 days per month; maximum amounts occur at Yanchi (15 days per month). Most occurrences of blowing sand are in late winter and early spring, when the ground is drier as a result of the low amount of precipitation received throughout the winter.

Central Plains. Lowest visibility generally occurs in the early morning hours, when the wind is frequently calm. Radiation fog and pollutants in the more industrial areas, will restrict visibility to less than 4,800 meters (see Figure 4-3) up to 50 percent of the time. This fog is short-lived and usually dissipates shortly after sunrise.

Visibility will also be restricted during periods of snowfall (usually 5 to 10 days) during the season. How much snow restricts visibility depends on wind and fall rate. Under light winds, visibility will be better than under stronger winds. Heavy snow falls will restrict visibility much more than lighter falls.

During periods of calm surface winds (about 25 percent of the time), strong inversions develop. These inversions trap pollutants in industrialized areas and restrict surface visibility.

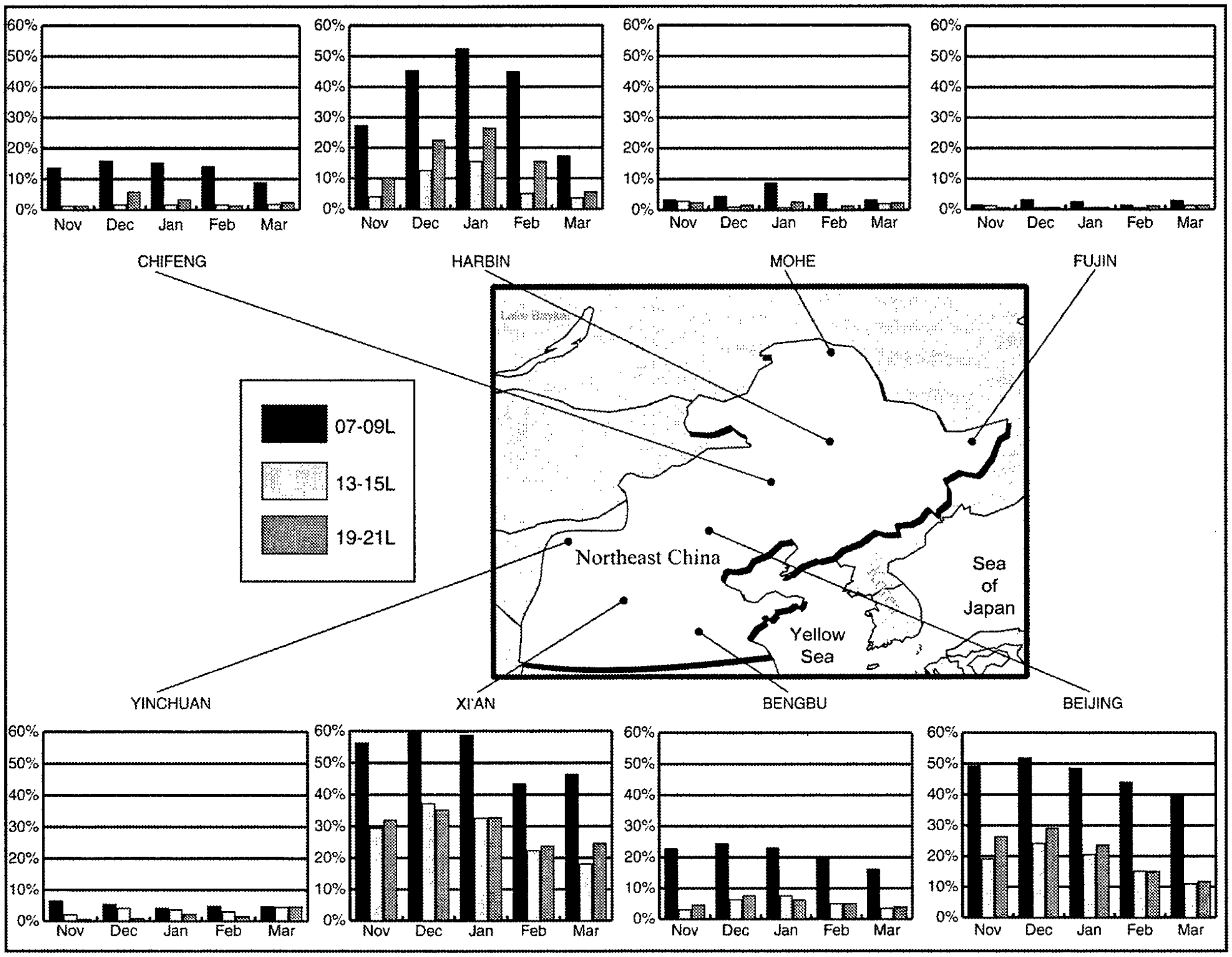


Figure 4-3. Winter Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Western Plateau. The Asiatic high, migratory systems, and topography affect surface wind direction and speed. Normal flow within the region should be out of the north or northeast; however, due to terrain, local wind regimes affect nearly every section of the region. Winds are primarily northerly in the western sections of the region, and westerly or southwesterly in the east. This is due to some of the mountain ranges to the west that deflect the northerly winds to a westerly direction. In many areas, mountains act as blocking mechanisms that keep out the cold, northerly winds. In the north, this seems to be the case at both Hailar and Nenjiang; both stations report a dominant southerly wind. Hailar is located on the north end of a valley and receives funneling from the south. A mountain range to the north protects it from the northerly flow. Wind speed depends greatly on the topography and the general wind direction. Wind directions that are predominantly out of a westerly or northerly direction usually average 6 to 15 knots. However, winds that blow from the south offset the general flow and only average 1 to 5 knots. Calm winds occur quite frequently, up to 45 percent of the time. The Asiatic high causes strong winds during the passage of cold surges. Winds as high as 40 to 50 knots often occur with these cold outbreaks. Wutai Shan, located in southern portion of the western plateau, records the highest winds for the region; they receive 70-knot winds quite frequently during the winter. Their elevation is 5,248 feet (2,898 meters); the highest of any place in the region and they occasionally receive the effects of the low-level jet stream.

Central Plains. Surface winds are generally light, at speeds of 7-10 knots. Calm winds are frequent, with most locations reporting calm about 25 percent of the time. The prevailing wind direction is northwest to northeast. Winds are stronger along coastal areas and during the passage of strong cold surges from the intensely cold Asiatic high. These surges occur every 6-8 days, and bring winds as high as 40 knots, as well as sharp and rapid drops in temperature. Terrain features occasionally disrupt the prevailing wind flow throughout the area, but two stations in the east-central area of the Manchurian Plain demonstrate rare wind conditions (see Figure 4-4). Both Harbin and Changchun record more than 50 percent of winds at all hours from the southeast, south, or southwest. Both stations are nestled in valleys surrounded to the northeast-southwest by ridges and peaks averaging about 1,000-1,600 feet (300-500 meters). The prevailing surface winds from the north are deflected to a southerly or southwesterly direction by these ridges. Winds recorded during the afternoon at both locations show a more frequent northwesterly direction, although the prevailing direction is still southerly. Winds during the early morning hours show a more pronounced southwesterly direction. Under frequently clear skies, radiational cooling on the surrounding slopes enhances the southerly flow as air moves down the slopes toward the slightly warmer air in the valleys.

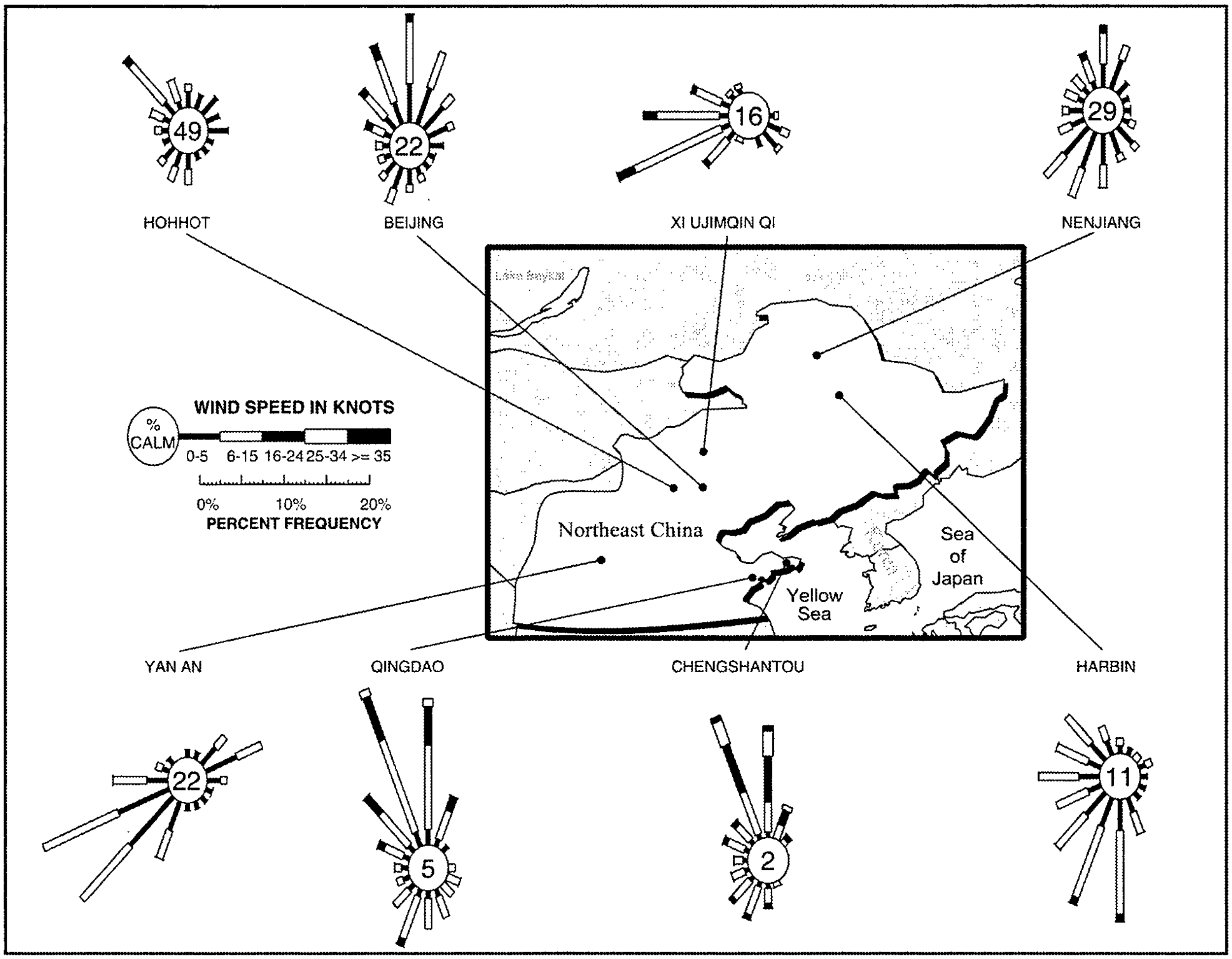


Figure 4-4. January Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds.

Northeast China lies under the belt of prevailing westerlies (see Figure 4-5). These westerlies extend from the surface to at least the 100-mb level, located near 52,000 feet (16 km). Winds below about 10,000 feet (3 km) can be terrain-influenced, especially over the Inner Mongolia Plateau where elevations range from about 3,000 to 4,900 feet (1-2 km) and over many of the mountain ranges within the area. During winter, they also strongly resemble the prevailing flow of the cold northeast winds. Little evidence of this shows at 700 mb where winds are westerly or northwesterly throughout the entire region. Winter is the season of strongest winds at all levels over the area. The axis of the polar jet stream lies well to the south of the region near the 35th parallel. Mean wind speeds range from 15 to 40 knots through 700 mb and increase to 70 to 100 knots at 200 mb. At the 200-mb level, southern sections of the area experience wind speeds exceeding 100 knots about 35 to 40 percent of the time. Average tropopause height is 35,000 in the north to 45,000 feet (11 to 14 km) in the south; this is where the strongest winds associated with the jet are located.

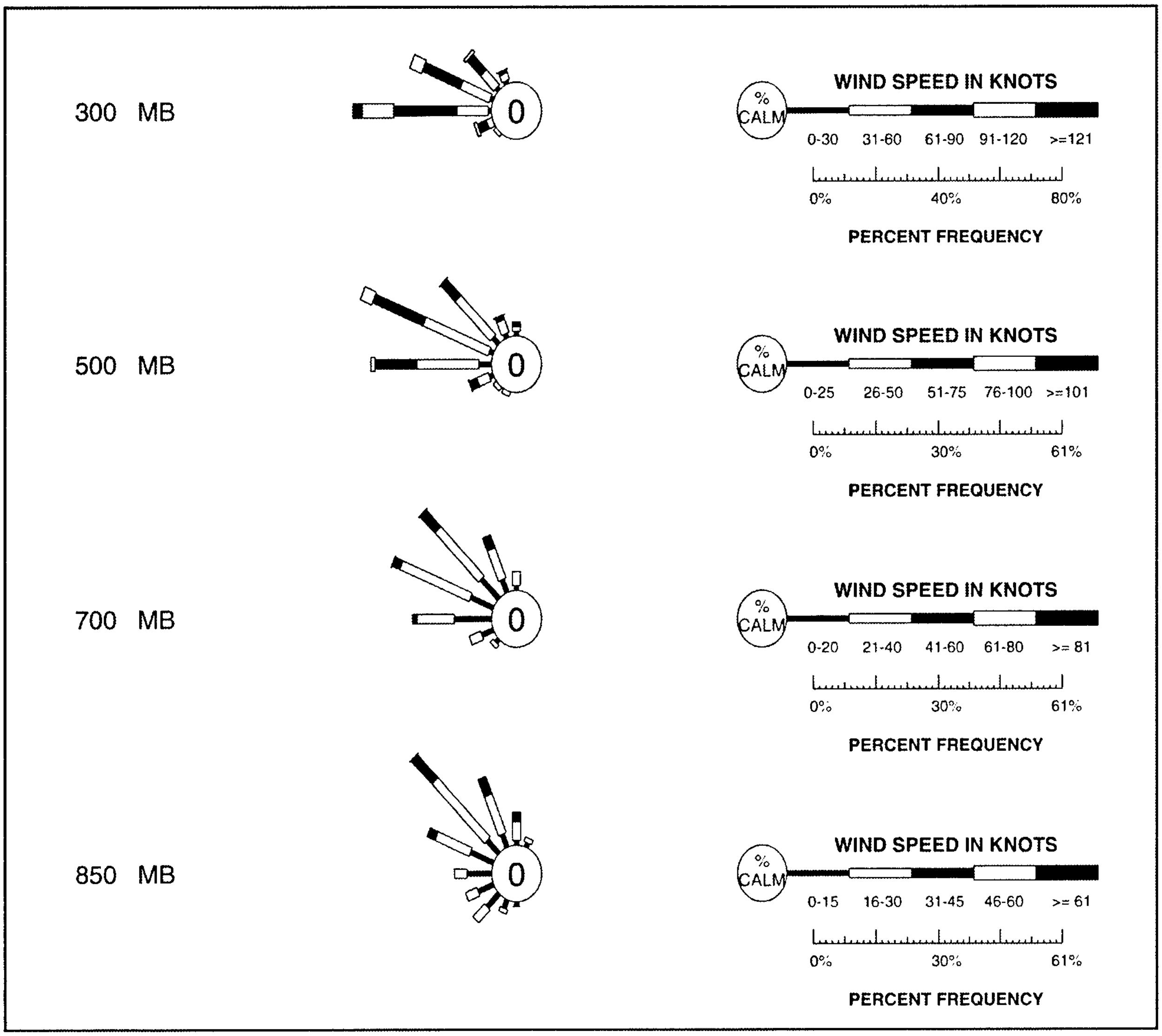


Figure 4-5. January Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Beijing, China.

Precipitation/Thunderstorms.

Western Plateau. Winter is the dry season since the cold continental air mass of the Asiatic high dominates the region. Frontal systems associated with cold surges that come from the west and northwest cause the majority of the precipitation. These systems normally move very rapidly to the east southeast and normally last less than a day. They have little moisture and yield meager amounts of precipitation (see Figure 4-6). Generally, precipitation decreases from about 25 mm in the south to 5 mm in the north. Topography strongly influences precipitation even during the winter.

Although light snow or snow flurries can continue through the entire day with only small accumulations, heavy snows can occur in some of the mountain passes and on the windward side of slopes. Northern sections of the region receive between 10 and 20 days a month of snowfall; southern sections of the region receive less than 5 days per month (see Figure 4-7). Although northern sections receive more snow days, the dryness of the air mass mainly allows only for snow flurries. Arxan, located in a valley in the northern sections of the region, received a maximum of 24 days with snowfall in December.

Snow cover varies in depth from one location to another, but usually lasts from October to April. Although snow occurs quite frequently, the amounts are generally light. Also, because of the dryness of the air and the high frequency of sunny days, much of the snow sublimates. The ground is usually lightly covered much of the time. Average snow depths range from 25 cm to 115 cm. The greatest snow depths have been observed on the windward side of mountains, in the northern sections, and some isolated mountain locations in the south. Snow depths are generally small, but deep snow depths can occur in high mountain passes.

Because of the length of winter, rainfall can occur during this season. Normally, rainfall amounts are also meager due to the lack of available moisture. Rain usually occurs at the start and end of winter. Mean days with rainfall occur from 1 to 2 days in the north to as much as 16 days in the extreme south. Normally, freezing precipitation is not reported within the region. Because of rain and snow occurring within the region, there is a probability of freezing rain, freezing drizzle, and sleet throughout the area, particularly in the south, where air-mass modification is at its greatest and temperatures are warmer.

Thunderstorms are rare during the winter months. The few thunderstorms that form are frequently caused by passage of frontal systems. They usually occur in October and April in scattered locations throughout the region. Mean thunderstorm days are 1 to 2 during winter months. Severe thunderstorms do not normally form because of lack of heating, the lack of strong vertical lift that is available during the summer, and the strong subsidence inversion that caps convection. Thunderstorm tops average 25,000 to 30,000 feet (8 to 9 km) and are frequently embedded in stratiform clouds, particularly in the south, where there is a high moisture content.

Central Plains. Very little precipitation falls during the winter months. Most stations record precipitation on only 5-10 days during the season. In the far south, precipitation may reach 25 mm per month. In the northern areas, the amounts rarely exceed 5 mm except for isolated areas in the far east that have moisture available from marshy areas and river valleys. The ground in most areas is snow covered on only 10-15 days, with snow depths of 10-13 mm, and rarely 30 mm or more. During the passage of a cold surge from the Asiatic high, snowstorms can occur if adequate moisture is available. Cyclonic flow from the Yellow Sea or East China Sea can supply enough moisture to produce intense snowstorms.

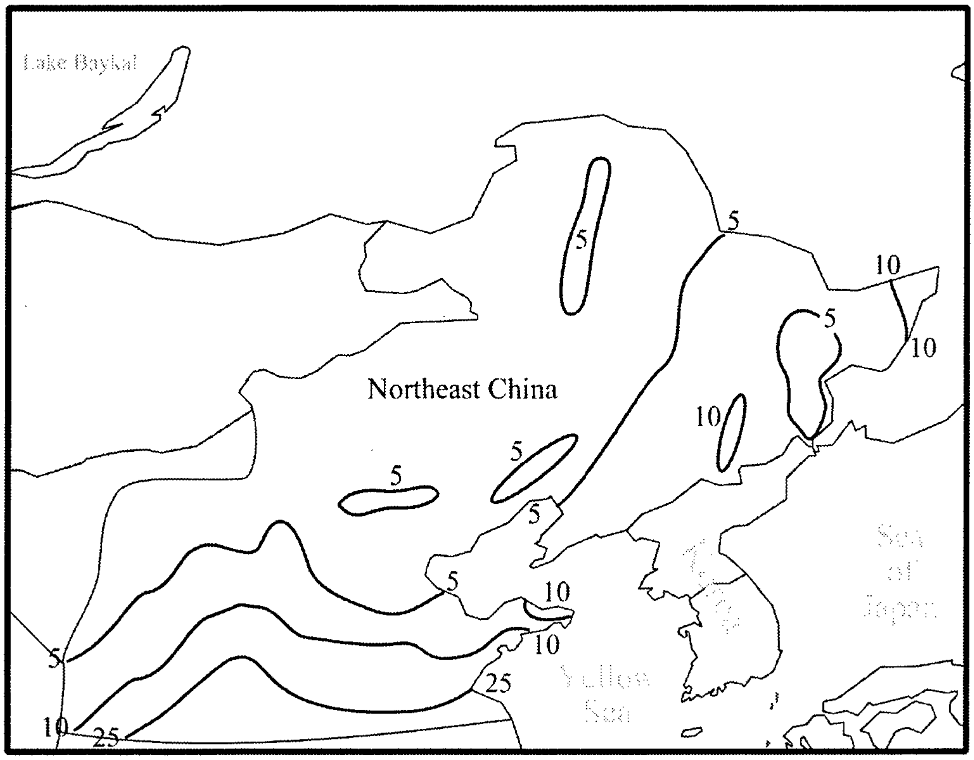


Figure 4-6. January Mean Precipitation (mm). The isopleths depict the water equivalent of the limited precipitation received during the winter season.

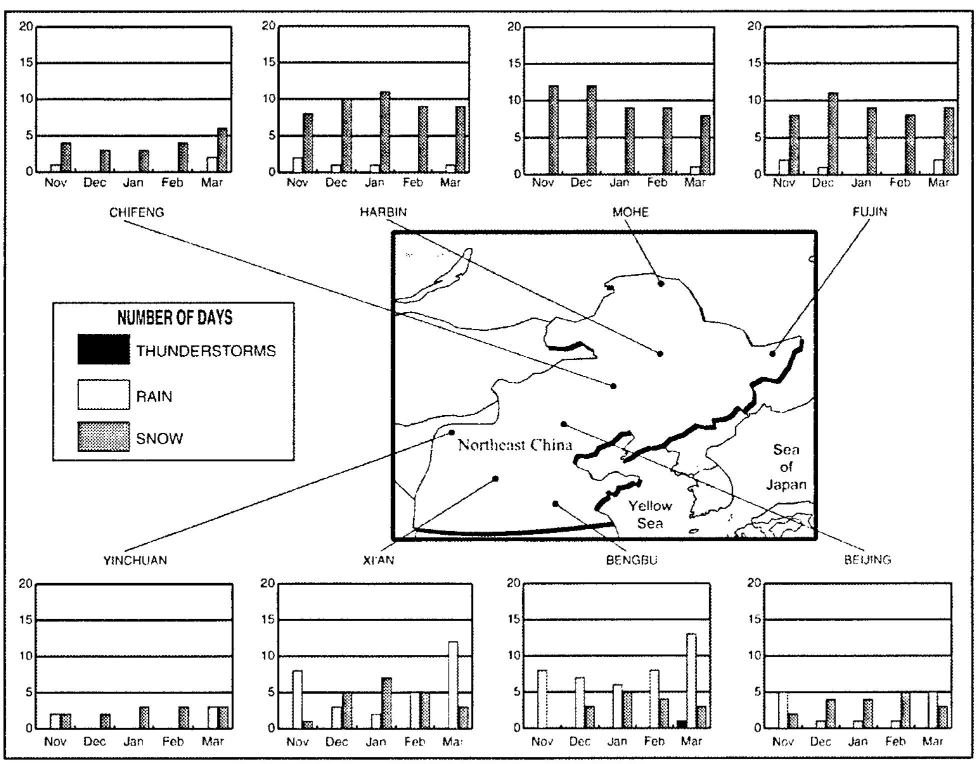


Figure 4-7. Winter Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain and snow days for representative locations in the region.

Temperatures.

Western Plateau. Latitude plays a significant role in temperatures, more so than topography. Temperatures get extremely cold during the winter with increasing north latitude. Topography also plays a role in temperatures. North-south oriented mountain ranges, such as the Da Hinggan Mountains, shield many locations from the cold Siberian air.

The coldest months are November through February. They are much colder than those experienced at equivalent latitudes of North America because of the strength of the Asiatic high and its proximity to the region. Nearly half the zone has extreme minimum temperatures less than -31°F (-35°C). Temperature ranges are greater than coastal locations to the east because they are inland and do not feel the effects of the warm coastal waters.

During January, the coldest month, mean maximum temperatures can vary as much as 54°F (30°C) (see figure 4-8). Mohe, located the farthest north, is the coldest location in the region and has an mean maximum temperature during January of -8°F (-22°C). Ankang, in the south, has a mean maximum of 45°F (7°C). Temperatures decrease significantly from south to north. Mean maximum temperatures range from 32° to 50°F (0° to 10°C) in the south to 5° to -8°F (-15° to -22°C) in the north. Mean minimum temperature range from 23° to 5°F (-5° to -15°C) in the south to -13° to -33°F (-25° to -36°C) in the north (see Figure 4-9). The extreme minimum for the whole area was -56°F (-49°C) at Mohe in January.

Central Plains. Temperatures of 5° to -13°F (-15° to -25°C) during December and January characterize the winter season in the northern part of the area (generally the Manchurian Plain). In the southern area (North China Plain) temperatures are not as severe. They generally range from about 23° to 50 °F (-5° to -10°C).

About every 6-8 days, a strong cold surge from the Asiatic high crosses the region and brings stronger winds and sharp temperature drops. These cold surges are characterized by 24-48 hour temperature drops of at least 18°F (10°C). Temperature drops of 36°F (20°C) or more can occur. In addition to strong winds and rapid temperature falls, the surges can bring severe frost, heavy snow, and if there is little moisture available, dust or sandstorms on the plateau areas. The very cold temperatures can be significantly lowered by the light winds that usually prevail. Windchill temperatures can be lowered to dangerous levels by the stronger winds that occur during cold surges.

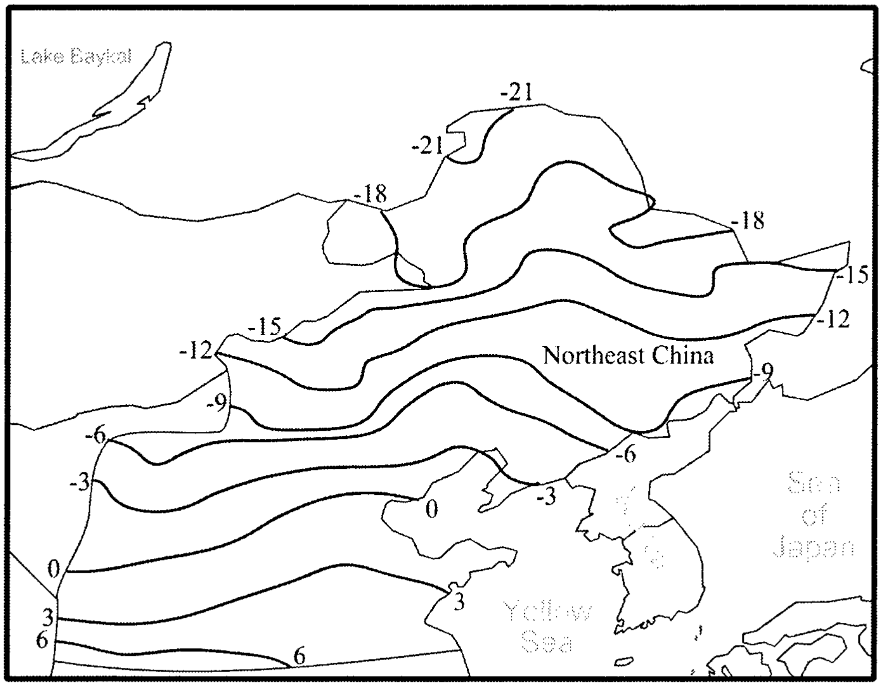


Figure 4-8. January Mean Maximum Temperatures (°C). Temperatures represent the average of all high temperatures for the coldest month of winter. Mean maximum temperatures during other winter months may be higher, especially at the beginning and ending of the winter season.

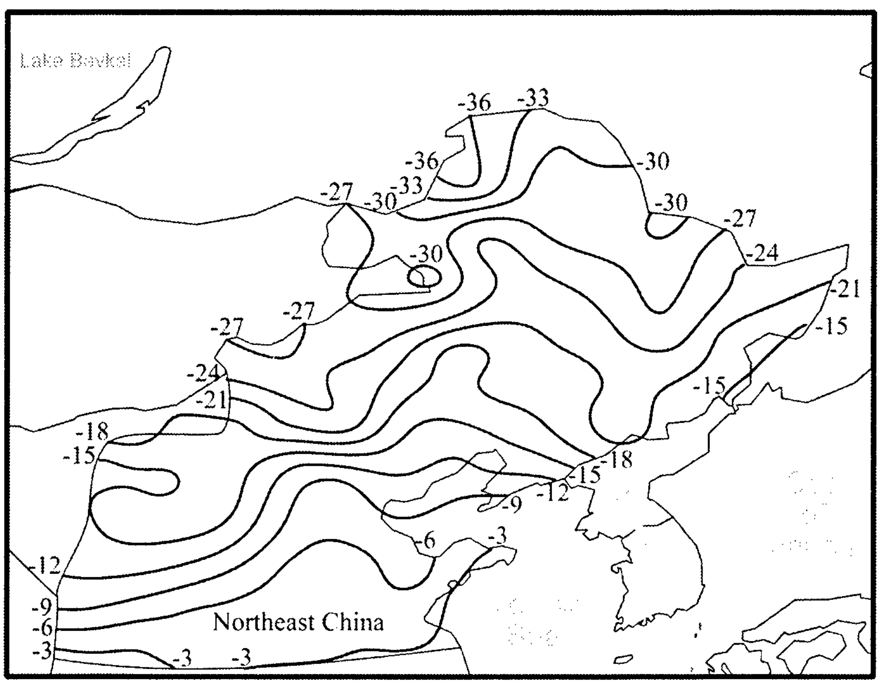


Figure 4-9. January Mean Minimum Temperatures (°C). Temperatures represent the average of all low temperatures for the coldest month of winter. Mean minimum temperatures during other winter months may be higher, especially at the beginning and ending of the winter season.

Hazards.

Aircraft Icing. During winter icing conditions are at a minimum due to lack of moisture and clouds. The best chance for icing is in the south where there is a higher moisture content. The average height of the freezing level is at the surface and the average height of the -20°C is 15,000 feet (5 km). Since winter cloudiness is frequently stratiform, rime icing is possible up to 15,000 feet (5 km). The greatest threat is in the lower 3,000 to 6,500 feet (1 to 2 km) where the temperatures are only a few degrees Celsius below freezing. When migratory low-pressure systems cross the area and cloudiness increases, the potential for ice accretion is greater.

Turbulence. Cold surges moving across the area can cause widespread turbulence along and behind a winter cold front. The turbulence can extend up to approximately 10,000 feet (3 km); although usually light, it may reach the moderate category over the rugged terrain and mountains of the western border of the central plains, and in the western plateaus region, Da Hinggan, Hua Shan, and Daba Shan Mountains. Its intensity is directly related to the strength of the wind, and it may become severe when winds attain high speeds in the layers 2,000 to 3,000 feet (500 to 900 meters) above the surface. Clear air turbulence is likely with the jet stream and can occur anywhere within the region. Normally, the strongest winds are near the tropopause. As mentioned earlier, the average tropopause is at 35,000 feet (11 km) in the north and 45,000 feet (14 km) in the south. The strongest turbulence will be located near these heights. The strength of the turbulence is directly proportional to the speed of the jet; normally expect moderate.

Wind Chill. Wind chill is a significant problem, particularly in the northern sections of the region where temperatures are extremely cold. The mean minimum temperature of -31°F (-35°C) at Mohe, combined with a wind of 15 knots, creates a -71°F (-57°C) wind chill factor; that is very near the great danger category. On the other hand, in the south where the mean minimum is closer to 32°F (0°C), adding a 15 knot wind would produce a wind chill of approximately 12°F (-11°C). Wind chills can get much colder than this during strong cold surges from the Asiatic high.

Trafficability. China is a country of very diverse topography and soil types. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadows, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained, and consist of clays and silts. The range of soil types includes some sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes; dense forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows, especially if frozen, and in some valley bottoms.

On the plains, slopes vary from nearly level to about a 20 percent incline. The soils are predominantly medium to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the dry season, movement conditions are fair-to-good except where restricted by marshy areas, steep-banked water courses, irrigation canals, forests, and dissected areas (very rugged terrain).

General.

During the spring transition (generally April and May), the strong, intensely cold Asiatic high begins to decay. At the same time, the North Pacific high begins to move north and intensify. The polar front begins to move north from a mean January position at about 20° to 25° N latitude. Lows form on the frontal boundary and travel northeast to provide much precipitation to the southern part of the area. The southwest China vortex can occasionally track through the area and can cause huge amounts of cloudiness and increased precipitation to the western plateau. Spring has the highest frequency of migratory lows that bring in massive influxes of moisture off the Yellow and the East China Seas. These lows normally track in from a westerly or southwesterly direction and usually originate in northwest Siberia, Mongolia, or the western part of north China. They usually move in an easterly direction and most weaken and carry very little moisture before crossing northeast China. Some lows slow down and can bring in massive amounts of moisture, cloudiness, and precipitation from the Bo Hai Bay and the Yellow Sea. Normally, 12 to 16 lows occur in the spring in the area. Heavy snows, heavy rain, and thunderstorms occur with greater frequency in the spring. Although much of the area is still influenced by the cold, polar, continental air mass, temperatures are moderating. Snow falls in April on about 1-2 days in the southern and central areas, with 3-4 snow days in the far north areas. Snow is very rare in May throughout the entire area.

Sky Cover.

Western Plateau. The northward migration of the polar front, along with an influx of moisture, brings increased cloud cover from the south. Cloudiness ranges from 50 to 60 percent of the time in the north to 60 to 70 percent of the time in the south. Low ceilings have a wide range of variability due to terrain features. Ceilings less than 3,000 feet average less than 10 percent of the time in the east to less than 5 percent in the west (see Figure 4-10). Mountain stations, which have the most ceilings, are more likely to see lower ceilings in the afternoon. Low ceilings in valleys and in the southern portions of the region occur during the morning. Wutai Shan receives ceilings below 3,000 feet 20 percent of the time in May; Hailun, in the northeast section of the region, has the lowest frequency (1 percent of the time). Ceilings less than 1,000 feet occur less than 5 percent of the time at nearly every location. The exception is Wutai Shan, where ceilings less than 1,000 feet occur 20 percent of the time.

Central Plains. Scattered to broken average sky cover occurs in April and May. About 20-25 percent of the time, the sky is clear. Ceilings below about 3,000 feet occur infrequently, generally 10-15 percent of the time, mainly with the passage of a transitory low system. Ceilings below 1,000 feet are even more rare. They occur on an average of 1-2 percent of the time. The least amount of sky cover occurs in the northern part of the area, with increasing cloudiness at stations in southern areas of the North China Plain.

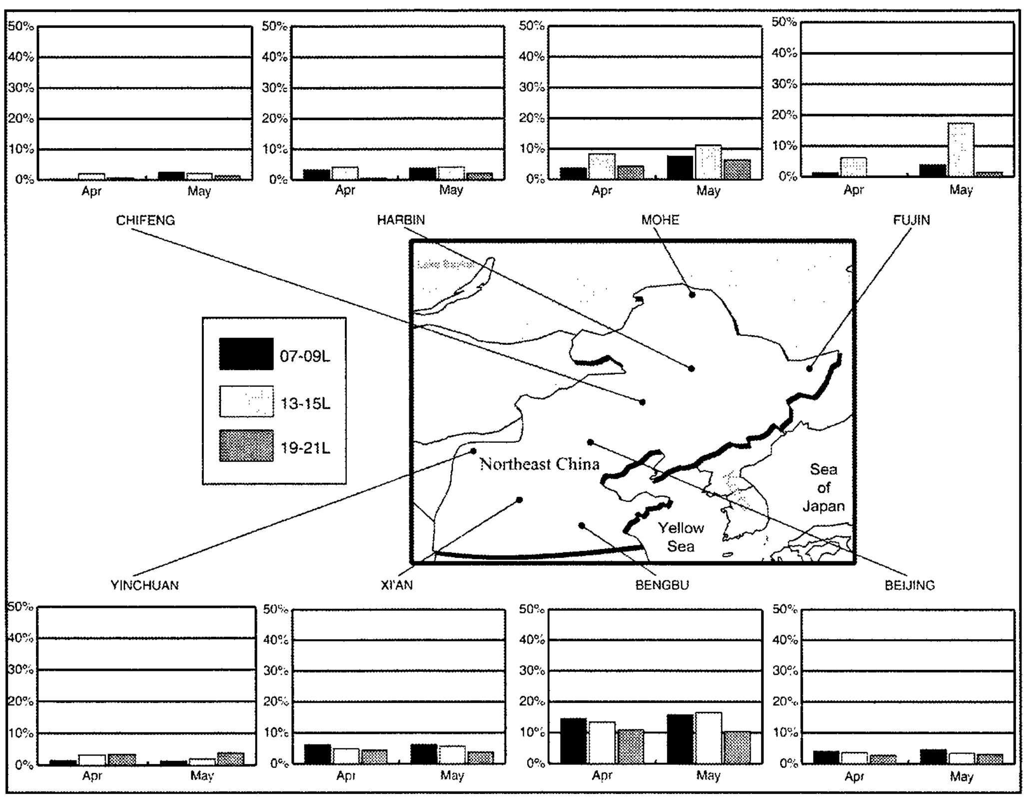


Figure 4-10. Spring Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Western Plateau. Visibility greatly improves during spring. Increased migratory features and cloud cover decrease the chances for fog. Fog normally occurs 1 to 2 days per month except for the southern river valleys that have between 15-20 days per month. Visibility below 4,800 meters normally occurs less than 10 percent of the time. Xi'an has the maximum frequency of visibility below 4,800 meters (44 percent of the time). Visibility below 800 meters occurs less than 5 percent of the time except for Wutai Shan, which has visibility below 800 meters 23 percent of the time in March.

Blowing sand occurs with greater frequency in the central part of the region due to low rainfall in the source region (Gobi Desert), periodically stronger winds, and convectively unstable air. Blowing sand occurs from 5 to 8 days per month, and it is most intense during spring. This is when the soil is dry and cold surges from the Asiatic high still pass through the region. Normally these sandstorms last only a few hours, but visibility problems can occur over several days if the dust gets transported several thousand feet in the air. The sand storm sometimes reduces visibility to several hundred yards. Lowest visibility occurs in the afternoon during the period of maximum instability.

Central Plains. Calm winds during the early morning hours cause radiation fog that restricts visibility to less than 4,800 meters 5-15 percent of the time (see Figure 4-11). Visibility less than 800 meters occurs 1 percent of the time. This fog is short-lived and usually dissipates shortly after sunrise. Calm wind conditions favor the development of a temperature inversion, which traps pollutants and further restricts visibility in the more populated and industrial areas.

Occasionally, the winds carry fine dust from the plateau areas of Mongolia and north China to this region. These duststorms can lower the visibility to 1,600 meters or less. After a storm passes, the yellow haze may restrict visibility for a few days.

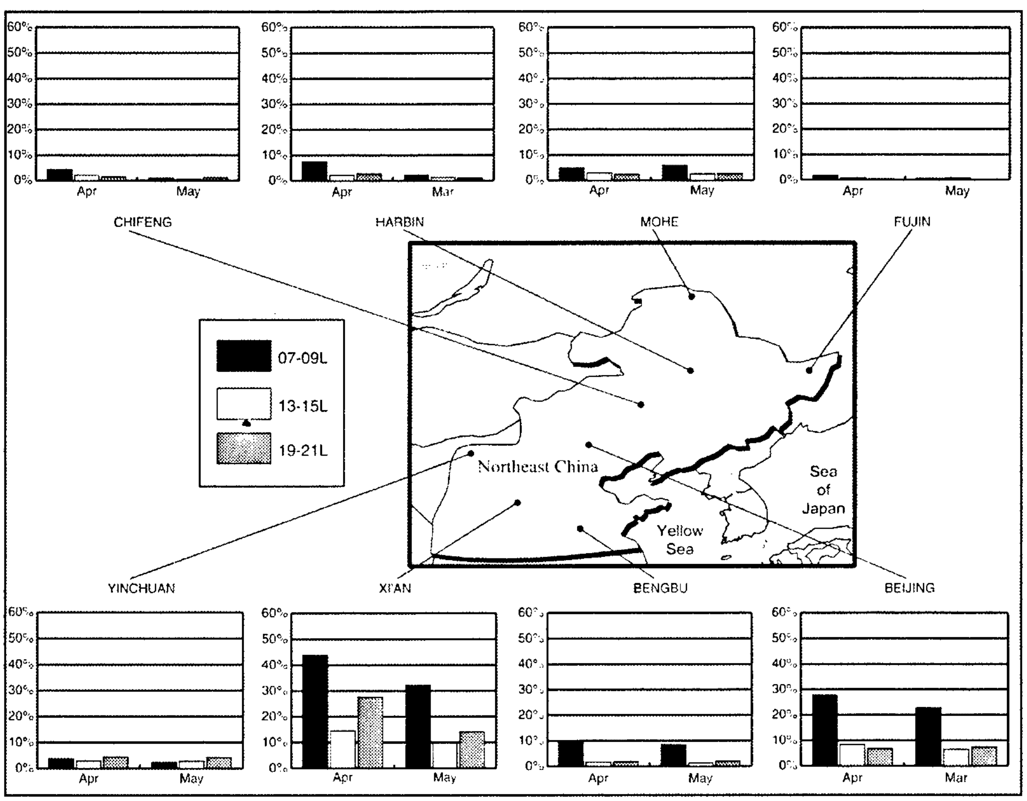


Figure 4-11. Spring Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Western Plateau. The Asiatic high weakens, but continues to influence wind directions (west to northwest) until the end of April (see Figure 4-12). By May, the Asiatic high dissipates. The southern sections of the region start to receive southerly winds as the polar front begins its migration to the north. Migratory lows move from east to west and kick up southerly winds ahead of and northwest winds behind them. Normally, wind speed increases around midmorning and decreases after sunset. Wind speeds are often a little stronger during this season; average winds are from 6 to 15 knots. Calm winds occur less frequently during spring than any other season; they occur from 2 to 27 percent of the time. As would be expected, most calm winds occur from night to mid morning. Extreme maximum winds in thunderstorms can reach greater than 50 knots. The extreme maximum winds for the region are caused by the high elevation of Wutai Shan. They are close to 10,000 feet (3 km), where the wind speed is strong compared to the surface. Wind speeds as high as 70 knots in April and 66 knots in May have been experienced there. Elsewhere, extreme maximum winds usually fall between 40 to 50 knots.

Central Plains. Surface winds are generally light, at speeds of 7-10 knots, with frequent calm winds. The prevailing wind direction is still northwest to northeast. In the southern and central areas however, southeast-southwest winds are reported 10-15 percent of the time. In the northern Manchurian Plain, winds are northerly, with the exception of Harbin and Changchun (discussed in the winter winds section).

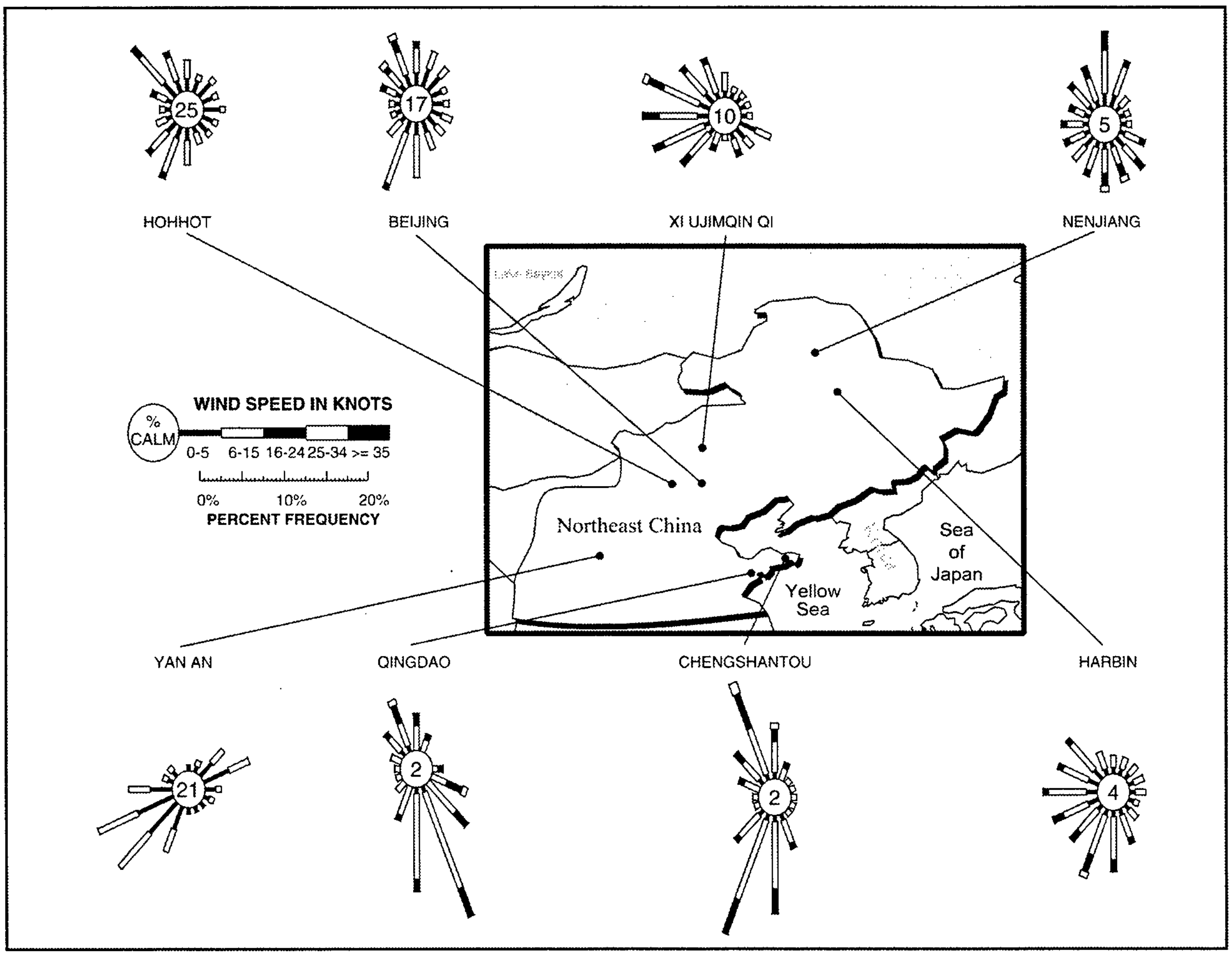


Figure 4-12. April Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds.

Upper-air winds over northeast China are westerly during all seasons. These westerlies extend from the surface to at least the 100-mb level or near 52,000 feet (16 km). Winds below 10,000 feet (3 km) can be terrain-influenced, especially over the Inner Mongolian Plateau where elevations range from 3,000 to 4,900 feet (1 to 2 km). Above the 10,000 feet (3 km) level the westerlies are well established. The polar jet begins to weaken and migrate northward. Although it weakens, it remains present in the north, but begins to dissipate in the south. The subtropical jet starts to make its appearance in the south in April, but not in the north during spring. As the polar front begins to migrate north, southerly winds replace the northerly winds of winter below 850 mb. Cold surges continue to bring occasional wind shifts to the northwest, but are less frequent than in winter. Mean wind speeds are about 20 to 30 knots in the lower 700 mb increasing to 70 to 80 knots at 200 mb. Winds in excess of 100 knots at 200 mb occur less than 15 percent of the time during spring. The mean tropopause height increases from 40,000 (12 km) in the north to 48,000 (15 km) in the south, where the maximum wind speeds most frequently occur.

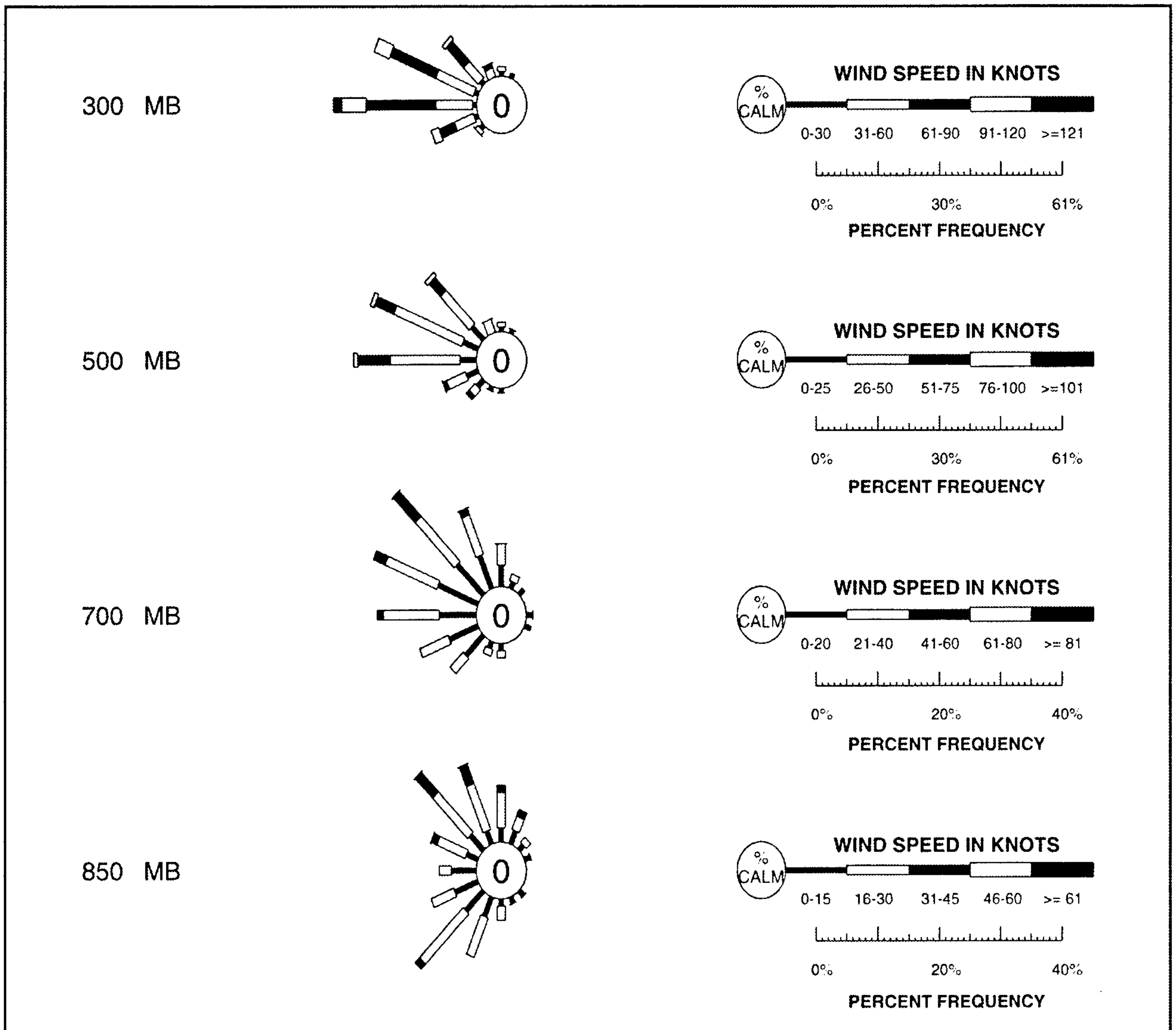


Figure 4-13. April Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Beijing, China.

Precipitation/Thunderstorms.

Western Plateau. Spring receives both snowfall and rainfall. As warm, moist air works its way northward, precipitation amounts increase. Due to increased moisture, showers begin to replace the very light precipitation of winter. Precipitation amounts average 25 mm in the north and central regions and up to 50 mm in the south, where the warm, moist air begins to make its presence first felt (see Figure 4-14). Most stations that receive snowfall usually only average 2 to 3 days with snow during May, a decrease from an average of 10 days in April. Because of the increase in temperatures, most snow melts in the lower elevations. A few locations in higher elevations above 5,000 feet (2 km) or in the north where cold outbreaks still occur, may see accumulations through April. In the south, where warm intrusions regularly occur, snow is rare during any part of spring. By May, only the higher mountain areas have snow cover. Rainfall occurs an average of 10 to 15 days both in the north and south; a few valley locations in the south receive 17 to 18 days with rainfall. For example, Hanzhong, which is located in a river valley, receives 18 days of rainfall per month.

Thunderstorms do not occur with great frequency during the spring because the moisture content is still low, but they do increase in frequency as the warm air moves north. Generally, thunderstorms occur in April in the south and in May in the north. Thunderstorms average 1 to 2 days in April and increase to an average of 4 days by May (see Figure 4-15). As in winter, severe thunderstorms do not normally occur. Tops of thunderstorms range from 25,000 to 30,000 feet (8 to 9 km).

Central Plains. Precipitation days and amounts increase from the winter minimums. Most stations record precipitation between 4 to 10 days. With the winds beginning to shift to the south, the stations in the southern areas receive increased moisture (25 to 50 mm) and cloudy conditions. An occasional migratory low brings increased clouds and precipitation. Stations report up to 50 mm in April and up to 75 mm in May. In the north, about 25 mm of precipitation is reported each month.

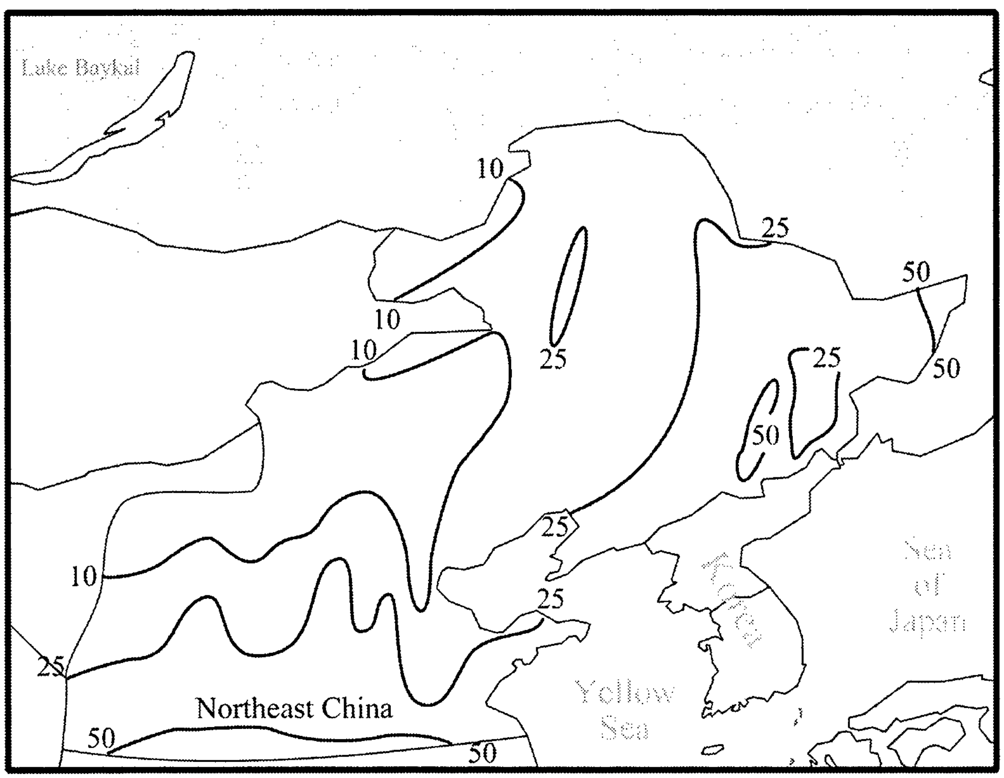


Figure 4-14. April Mean Precipitation (mm). The isopleths depict the increased water equivalent of precipitation received during the spring season.

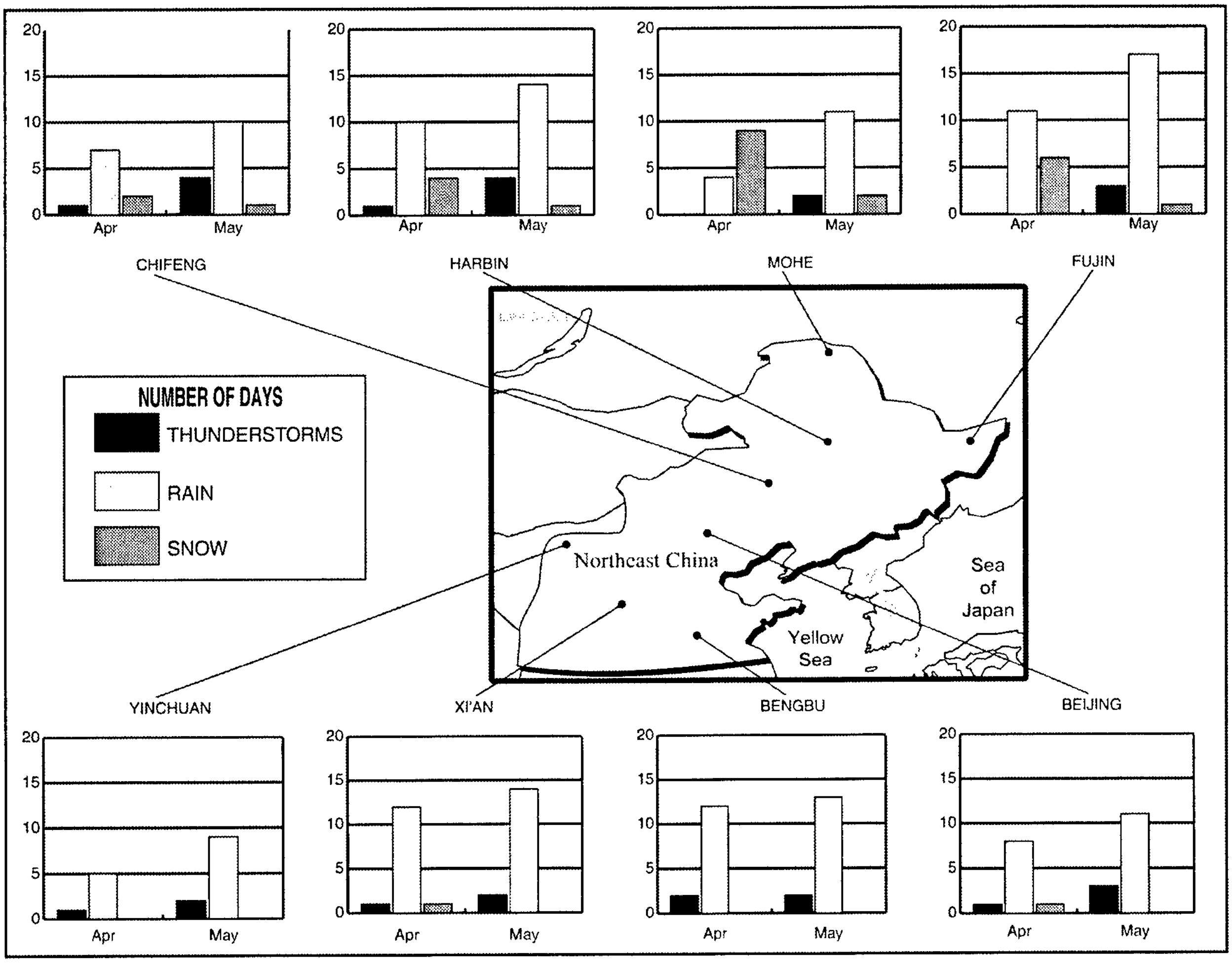


Figure 4-15. Spring Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for representative locations in the region.

Temperatures.

Western Plateau. Temperatures begin to increase due to weakening of the Asiatic high and increasing insolation. The mean last frost dates occur from early April in the south to early June in the extreme north. Mean temperatures below 32°F (0°C) occur until April. Mean maximum temperatures range from 45° to 64°F (7° to 18°C) in the north to 64° to 75°F (18° to 24°C) in the south (see Figure 4-16). Mean minimum temperatures range from 19° to 45°F (-7° to 7°C) in the north to 30° to 61°F (-1° to 16°C) in the south (see Figure 4-17). Mohe reported the extreme minimum with a -18°F (-28°C) temperature in April. Yuncheng reported an extreme maximum temperature of 102°F (39°C) in May.

Central Plains. In the North China Plain, temperatures range between 52° to 63°F (11° to 17°C), with mean minimums of 32° to 41°F (0° to 5°C), and mean maximums of 59° to 68°F (15° to 20°C). Further north, the temperature range is about 41° to 46°F (5° to 8°C). Mean minimums are 23° to 32°F (-5° to 0°C), and mean maximums are in the 32° to 50°F (0° to 10°C) range. Although weakening, the Asiatic high still occasionally sends a strong cold surge across the region. When it does, stronger winds and sharp temperature drops accompany the surge. Temperature drops of 18°F (10°C) can occur. Temperatures as low as -4°F (-20°C) have been reported in the northern areas, with 32° to 23°F (0° to -5°C) reported in the southern North China Plain.

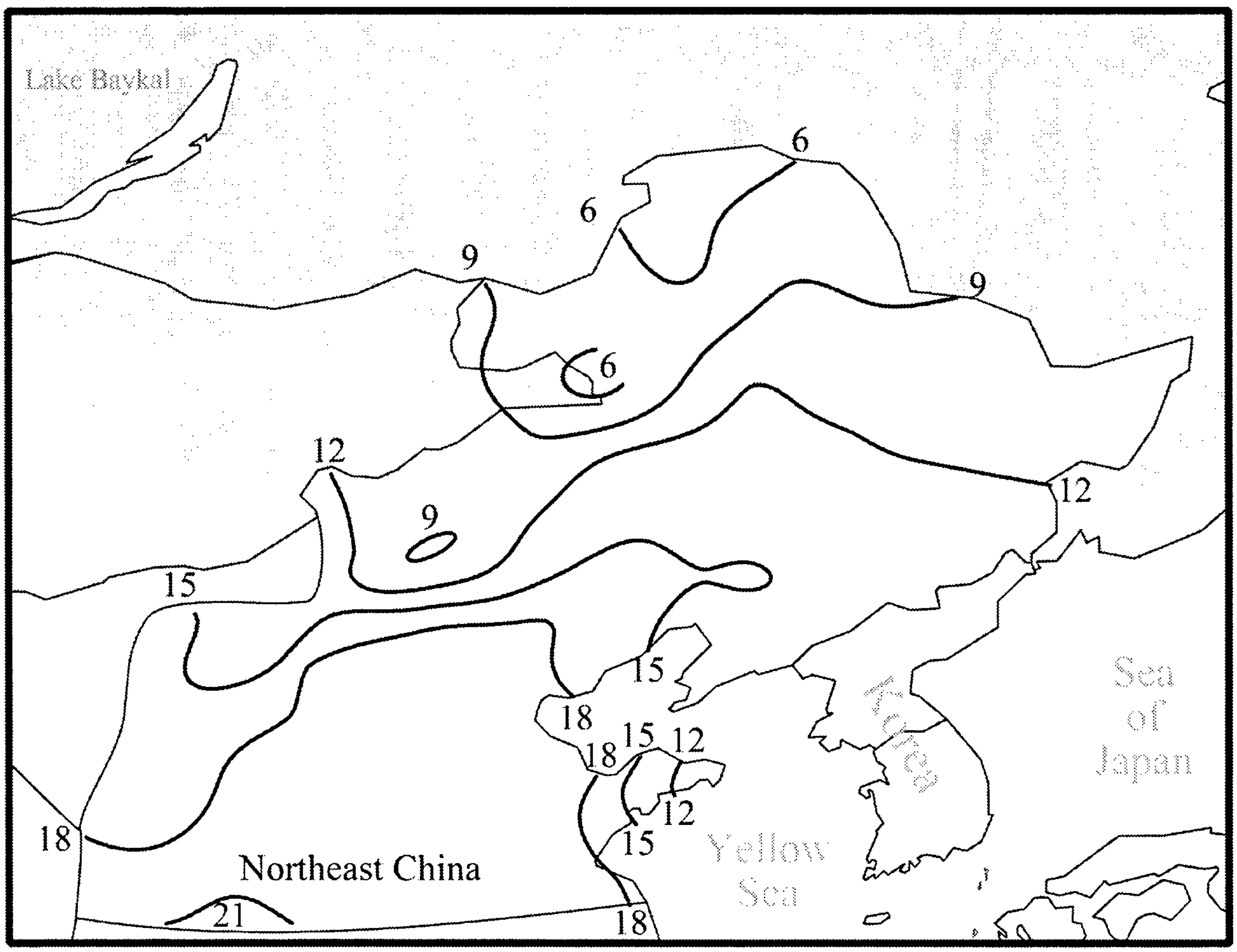


Figure 4-16. April Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for a representative month of spring. Mean maximum temperatures during other spring months may be higher, especially at the end of the spring season.

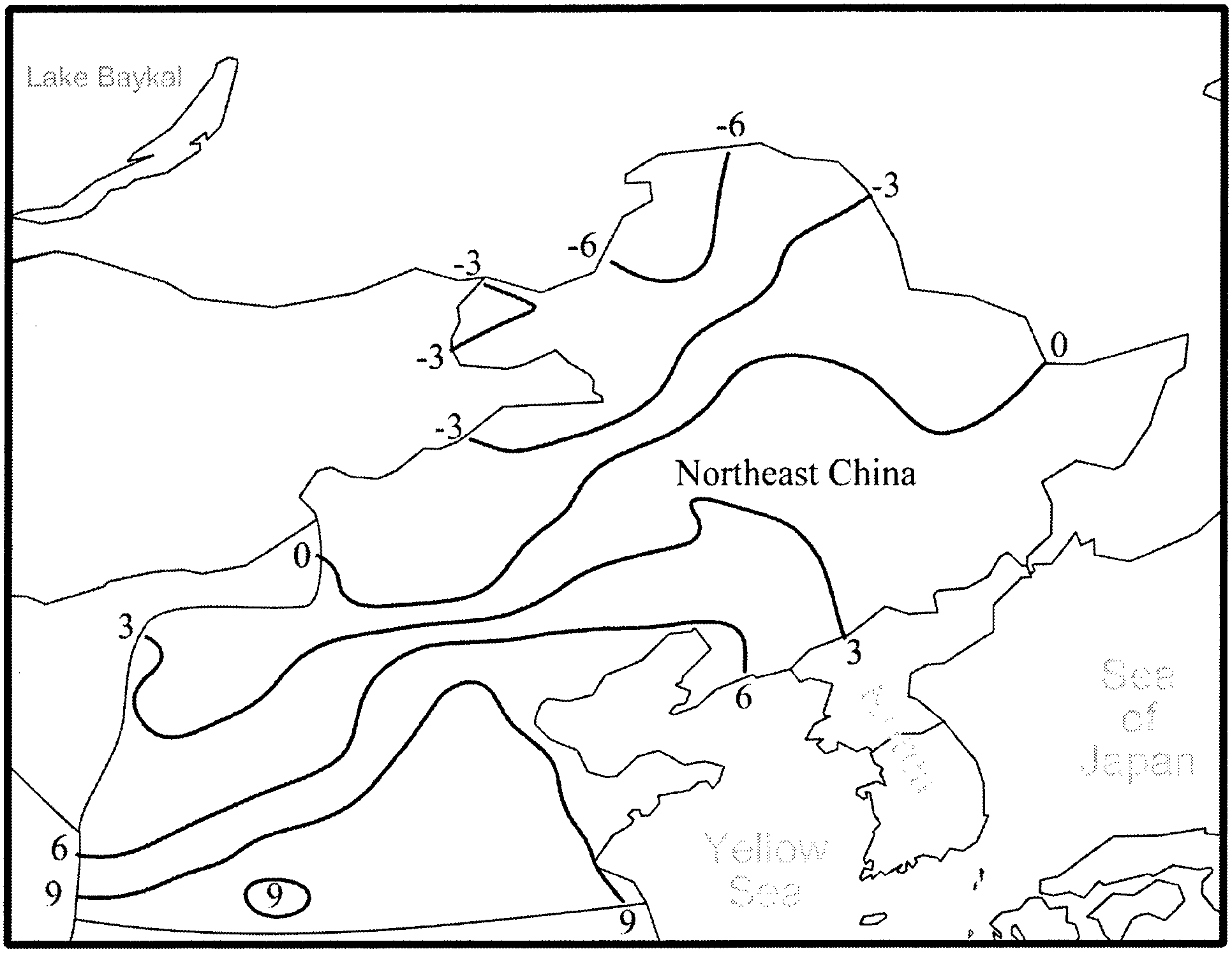


Figure 4-17. April Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the coldest month of spring. Mean minimum temperatures during other spring months may be higher, especially at the end of the spring season.

Hazards.

Aircraft Icing. The potential for aircraft icing increases during the spring transition. The polar front is retreating, the Asiatic high is beginning its decay, and the North Pacific high is becoming stronger. Warm, moist, maritime air advances northward, bringing increased clouds. The mean freezing level is at about 6,000 feet (2 km) throughout the transition period. The most likely levels for icing are between 6,000 and 25,000 feet (2 and 8 km). Both rime and clear icing are possible since both cumuliform and stratiform clouds are present in the spring. During thunderstorms, severe icing is possible near the freezing level. Icing is most likely to occur in cloud decks associated with migratory lows moving through the area. The lows bring colder air from the north and lower the freezing level to at or near the surface. The heaviest icing occurs near the front behind the lows.

Turbulence. Cold surges often create widespread turbulent conditions along and behind a cold front. This usually occurs below 5,000 feet (1 km). Turbulence may be quite strong and extend to several thousand feet. Thunderstorms begin to occur in April, most commonly in the southern parts of the region. These storms can produce violent updrafts, heavy rain showers, lightning, hail, and turbulence. Although not common during the transition, thunderstorms do occur an average of 2-3 times each month. The turbulence in and near these storms may become severe and pose a significant threat to air operations. Turbulence is likely in and near the center of migratory lows and along the cold front to the rear of the low. Also, expect turbulence over mountain ridges and through passes when the surface and lower level winds exceed 20-25 knots. Orographic turbulence is possible below 10,000 feet (3 km) over rough terrain, particularly over the Da Hinggan, Hua Shan, and Daba Shan Mountains. Turbulence intensity is directly related to the strength of the wind, and the strength may occasionally become severe when winds associated with the low-level jet attain high speeds in the layers below 3,000 feet (900 meters) above the surface. Terrain-induced turbulence may extend as much as 50 miles downwind of the ridges and peaks. With increased moisture in the atmosphere, rotor clouds may form over the ridges. These clouds are positive indicators of turbulence. Clear air turbulence is likely with the jet stream and can occur nearly anywhere within the region. Normally, the strongest winds are near the tropopause. The average tropopause is at 40,000 feet (12 km) in the north and 48,000 feet (15 km) in the south. The strongest turbulence will be located near these heights. The strength of the turbulence is directly proportional to the speed of the jet; normally, moderate turbulence can be expected

Wind Chill. Minimum temperatures at night can still drop below 39°F (4°C), which can cause wind chill factors to drop to dangerous levels. In the north, where temperatures stay cold through spring, the wind chill temperature can drop to -4°F (-20°C) with 15 knots of wind.

Trafficability. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadows, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained and consist of clays and silts, but sizable areas of sand and gravel exist. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms with coarse-grained soils.

On the plains, slopes vary from nearly level to about a 20 percent incline. The soils are predominantly medium- to fine-grained; however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. In the southern part of the plains, rice cultivation limits movement when paddies are flooded.

During the wet season, movement conditions are good to poor. The quality of trafficability depends on soil type. Coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near river mouths become soft and muddy. They often stop or severely restrict movement.

General Weather.

The summer wind flow from the southwest advances northward into southeast China as the Asiatic high collapses. The North Pacific high intensifies and moves north, and the polar front shifts northward from its winter mean position. The Aleutian low and the tight pressure gradient between it and the Asiatic high weakens. Warm, moist air invades the region and brings increasing cloudiness, precipitation in the form of steady rain, rainshowers from thunderstorm activity, and much warmer temperatures.

This warmer air has two primary sources. The most significant is the flow northward from the west side of the intensifying North Pacific high. A secondary source is the cross-equatorial flow from the Australian high. This air is dry when it leaves its source region, but picks up significant moisture as it makes its long trek across the warm ocean waters. There is another possible source of moisture that originates well outside of this region, especially during the transition period. The southwest China vortex will occasionally generate weak lows that move east across the southern part of the region into the East China and Yellow Seas. These lows send warmer moist air into the region across Bo Hai Bay into the plains, the lowlands of the Manchurian Plain, and southern sections of the western plateau. As mentioned earlier in this chapter and detailed in Chapter 2, the mei-yu front has an influence on northeast China. This quasi-stationary front forms and dictates the weather in the Yangtze River valley, south of this region. Most of the precipitation occurs in the warm air south of the front, but the precipitation north of the front affects the extreme southern area of northeast China. Also, the shift of the polar front may be delayed as it can be stalled by this front when it reaches the Yangtze River valley. A typhoon very rarely enters northeast China. When one does, it usually weakens dramatically. These storms can bring brief strong winds, heavy precipitation, and much cloudiness to the coastal regions, and the interior mountain region.

Sky Cover.

Western Plateau. Summer has more low cloudiness than any other season because the southeast winds advect moisture. Generally, cloud cover occurs about 70 percent of the time, except for the area east of the Badain Jaran Desert. This area has cloud cover 40 to 60 percent of the time. The upper-level winds are primarily westerly, which keeps this area cloudless much of the time. Terrain strongly influences low ceiling times; they occur primarily in the afternoons at mountain locations, and in the early morning hours in the valleys. Ceilings below 3,000 feet occur on average less than 20 percent in the whole region (see Figure 4-18). Migratory storms produce higher frequencies of ceilings below 3,000 feet. Ceilings below 1,000 feet occur less than 10 percent of the time nearly everywhere. The exception is in the central part of the area, where moisture is funneled into the Dongbei Pingyuan valley and the windward slopes of the Wutai Shan Mountains. Ceilings below 1,000 feet occur 28 to 37 percent of the time in the valley and 44 percent of the time at Wutai Shan. Higher elevations are frequently cloaked by cloud layers.

Central Plains. Increased sky cover reflects the influence of the warmer, moist air that invades the region. Scattered-to-broken sky cover amounts occur in the northernmost areas with broken-to-overcast amounts in the southern areas. Stations along the coasts report more cloudy conditions than those inland, especially during the afternoon hours when a sea breeze lifts moist air over the ridges along the coasts and sea breeze fronts develop. Clear skies are reported about 5-12 percent of the time during summer. Ceilings below 3,000 feet occur up to 25 percent of the time. Ceilings below 1,000 feet occur 2-6 percent of time. The southerly flow loses some of its moisture as it travels northward across the ridges and mountains of the central plains. This is reflected in the decreasing cloud amounts as the moisture decreases to the north.

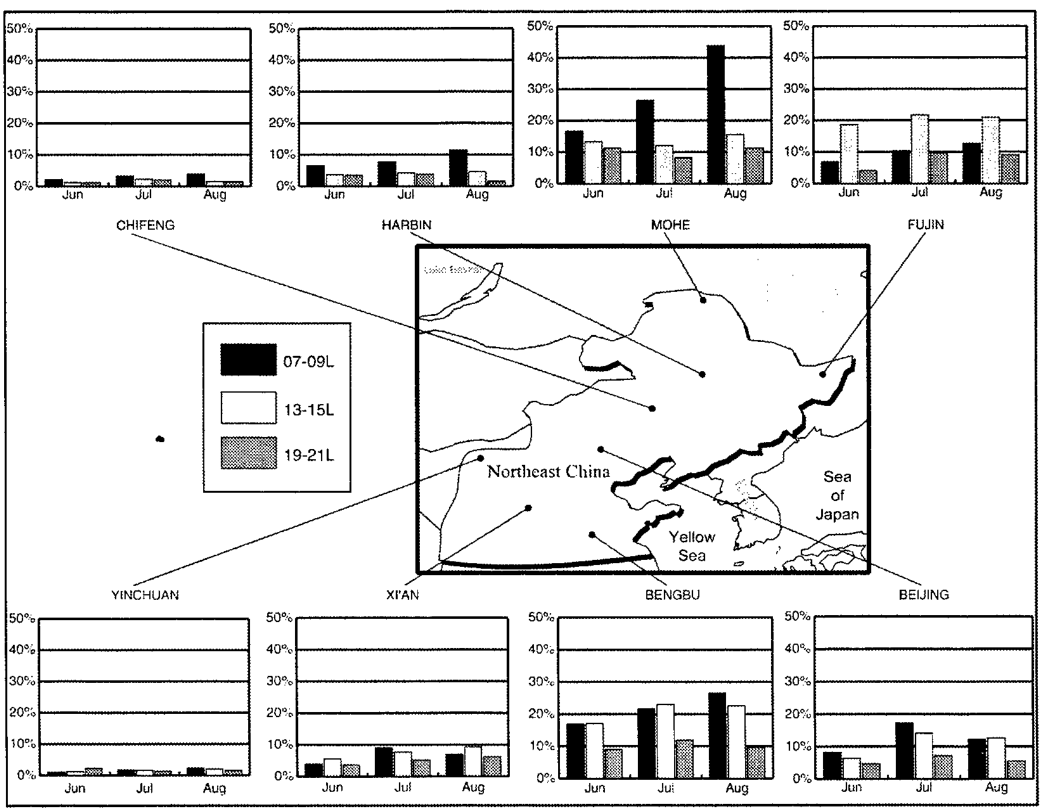


Figure 4-18. Summer Ceilings below 3,000. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Western Plateau. Instability in the region keeps visibility problems to a minimum at most locations. Thunderstorms and rainshowers are at a maximum and cause short-term visibility problems. Haze and smoke are least likely to occur during this season.

Visibility below 4,800 meters occurs less than 10 percent of the time at most places. In the northern portion of the region, visibility restrictions increase toward the end of summer due to weak radiation fog. Visibility less than 4,800 meters occurs up to 28 percent of the time in the far north and in the southern part of the area. Beijing reports visibility less than 4,800 meters as much as 48 percent of the time during morning hours because of industrial pollution. Visibility less than 800 meters occurs up to 25 percent of the time during morning hours in the north and in isolated mountain locations (see Figure 4-19). Elsewhere, visibility below 800 meters rarely occurs. Dry southwesterly wind limits fog days in portions of the western region. Increased precipitation during the summer decreases blowing sand restrictions. Most blowing sand occurs in May and June; by August, it tapers off as the summer rains peak. Normally, the greatest restrictions occur in the afternoon due to diurnal instability. Visibility improves again after sunset when the atmosphere begins to stabilize and winds decrease. Blowing sand occurs 1 to 2 days per month at most locations except the Gobi Desert, where it occurs as much as 5 to 10 days per month.

Central Plains. Visibility is generally good during the summer months. During heavy rains, visibility is severely limited. Visibility less than 4,800 meters occurs 3-6 percent of the time. Visibility less than 800 meters is rarely reported. Sea fog along the coasts may reduce visibility, especially south of the Shantung Peninsula, where warm moist air flows over the colder coastal waters. These sea fogs are widespread and extend several miles inland. North of the Shantung Peninsula, the fogs are less frequent and less extensive. Duststorms are possible, but they become less likely as the season progresses.

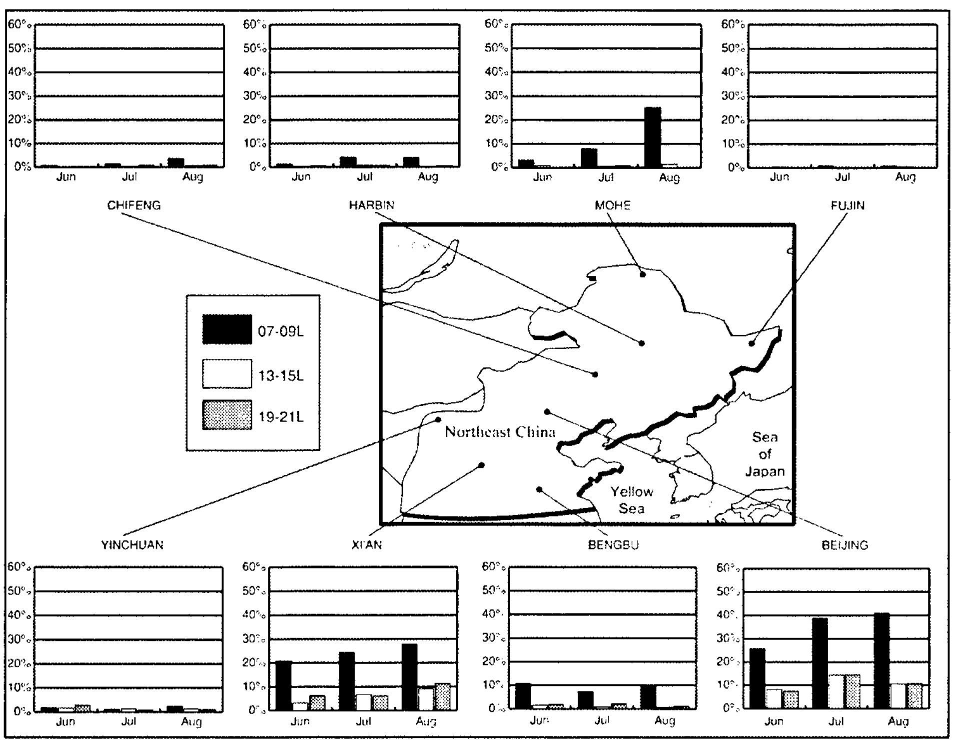


Figure 4-19. Summer Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Western Plateau. Surface winds are from the southeast to southwest at most locations. Topography plays a greater role in summer than in any other season. Local wind regimes develop as a result of mountain/valley breezes that enhance wind speed and deflect wind direction. Arxan, which is located in a northeast-southwest oriented valley, has a weak southeast daytime valley breeze, but at night, the wind reverses to a steady mountain wind.

Wind speeds average 5 knots or less at night and roughly 6 to 15 knots during the day (see Figure 4-20). Calm winds occur from 5 to 35 percent of the time, mostly at night. Summer has the lowest extreme maximum winds. Extreme gusts usually occur from thunderstorms, but gusts associated with topography are more common. Summer has the highest number of thunderstorms; associated downrush gusts as high as 40 to 50 knots occur. The extreme maximum winds for the region (52 knots) occur at Wutai Shan, which is located at an elevation of 10,000 feet (3 km). These strong westerly winds are due to the station's elevation.

Central Plains. Surface winds are generally light during the summer. The prevailing direction throughout the area is south-southwest, at speeds of about 6-10 knots. Calms occur 8-30 percent of time at most locations except coastal stations. The prevailing wind direction at these stations is southeast, and wind speeds during the afternoon are about 8-15 knots. A sea breeze frequently begins at midmorning and adds a few knots of speed to the prevailing wind. Its effect is strongest in the middle of the afternoon. By sunset, the sea breeze subsides, and a weak land breeze begins.

Terrain strongly affects the seasonal prevailing winds. Some locations report wind directions nearly opposite to the expected directions. Yanji, which is located in a deep river valley near the eastern end of the China-North Korea border, provides a graphic example. The southwest-northeast-oriented ridges surrounding Yanji are between 1,600 to 2,600 feet (500 to 800 meters). The southern ridge blocks the southerly winds, but a pass a few hundred meters east of Yanji allows the winds to blow through. The winds deflect off the northern ridges and cause a prevailing northeasterly wind throughout summer.

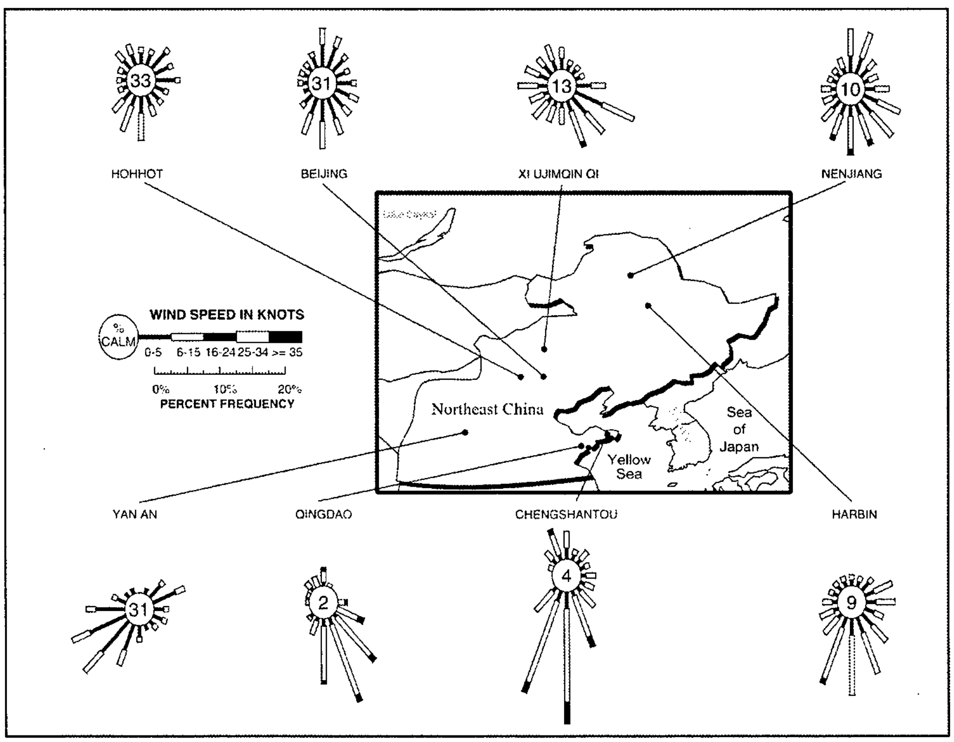


Figure 4-20. July Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds.

Summer upper-level winds throughout the region are generally westerly, but at lower speeds than during the winter months (see Figure 4-21). Also, wind directions are more variable in the lower levels. Southerly winds are apparent to the 850-mb level, with weak northwesterly winds at 700 mb. At about 19,000 feet (6 km), the westerlies prevail. A very weak polar jet crosses northern sections of the region. The subtropical jet is fully developed and flows in a west-east ribbon between 40° and 45° N. During summer, winds are light and variable to a greater height. Terrain influences the direction, particularly in the western section of the region and over many of the mountains. The wind speeds generally increase with height up to about 40,000 feet (12 km), then they decrease. Speeds range from 15-20 knots at about 10,000 feet (3 km) to 60-75 knots at 40,000 feet (12 km). Above that level, they decrease to average 35-40 knots at about 50,000 feet (15 km). Winds greater than 100 knots occur less than 5 percent of the time. The tropopause is at its greatest height. It ranges from 50,000 feet (15 km) in the north to 55,000 feet (17 km) in the south.

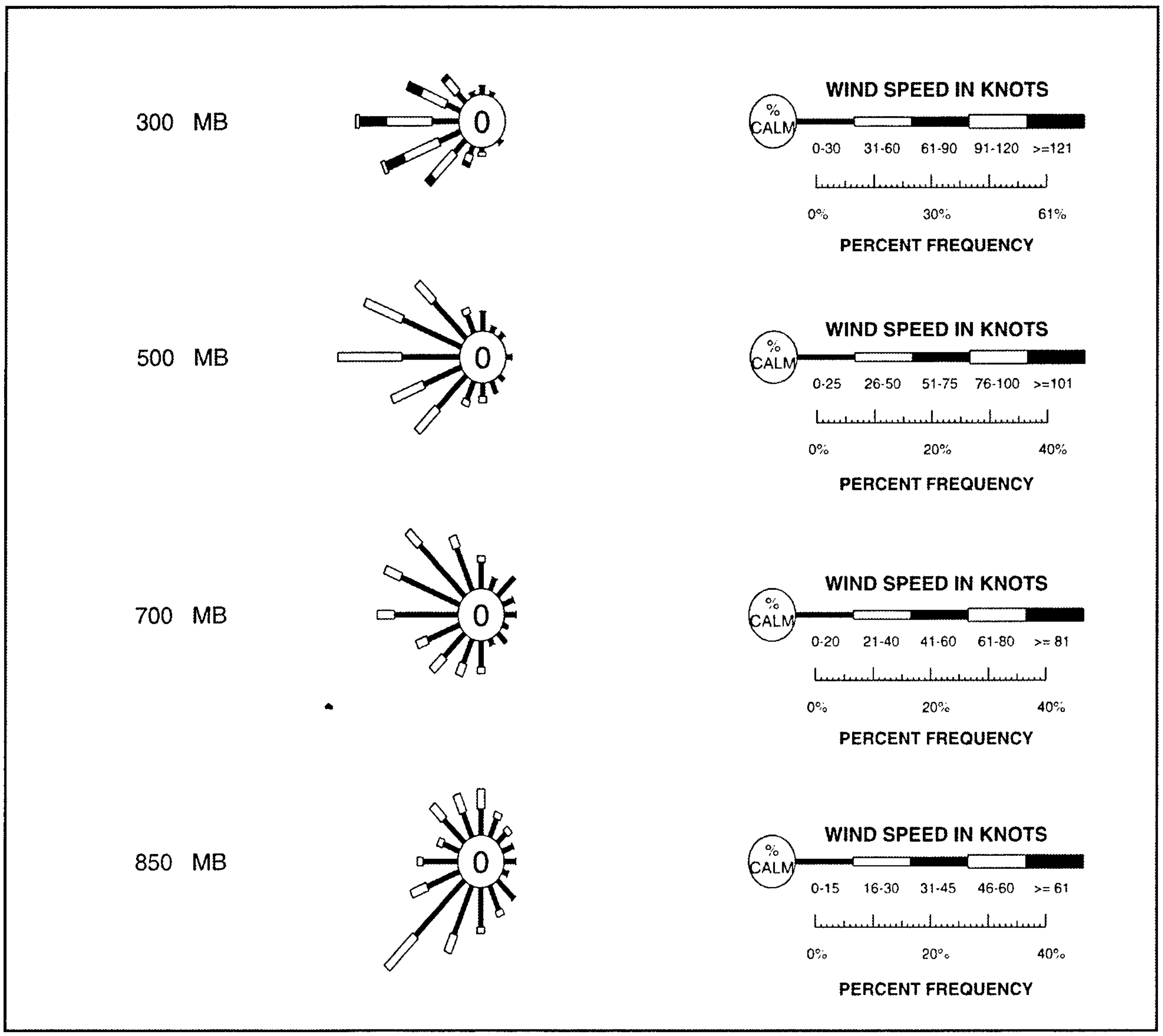


Figure 4-21. July Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Beijing, China.

Precipitation/Thunderstorms.

Western Plateau. Summer is known for its abundant rains that are sharply different from the meager precipitation of winter. The region receives 60 to 70 percent of its annual precipitation in the summer. The rains are associated with migratory lows that cross the area. The southwest vortex can bring in an overabundance of precipitation as it crosses the region from southwest to northeast.

Summer rains can be steady or showery with heavy rain and thunderstorms. Steady rains normally occur in the morning when cloudiness is most likely to be stratified. This is the time of day when the atmosphere is most stable. The showers normally occur in the afternoon when the atmosphere is convectively unstable.

Precipitation over the region is highly erratic from year to year. It often varies between drought and flood conditions. Mean precipitation amounts vary from 100 mm in the north to 150 mm in the south, where there is a higher amount of moisture (see Figure 4-22).

Topography plays a key role in precipitation. Many of the mountains impede flow of the warm, southerly current of moisture from the southeast. Orographic lift removes much of the moisture. Windward mountain slopes receive the bulk of regional rainfall. Maritime air masses that succeed in traversing the mountains are modified to much drier conditions before they reach the western part of the region. The western sections of the region near the Badain Jaran and Tengger Deserts receive a scant 50 mm of precipitation. This is due to the loss of moisture of the maritime air mass as well as the southwesterly low-level flow coming off the desert regions.

Summer sees an average of 10 to 20 days of precipitation all season (see Figure 4-23). In northern sections, peak frequency for rain occurs in July and August. In southern sections, peak frequencies occur early in July when the polar front is farthest north. Typhoons normally only affect coastal regions. On rare occasions, a typhoon may move inland during July or August, but these usually weaken rapidly. These systems can cause heavy rains and flooding, particularly in some of the river valleys of the south.

Snow is not widespread, but can occur in higher elevations and in the northernmost sections of the region. Mean number of days is usually 1 to 2 days per month, mainly in May and June. Wutai Shan receives snow every month of the year except in August. Still, snow accumulation is unlikely, since the freezing level is at roughly 10,000 to 15,000 feet.

Summer is the season when thunderstorms occur with the greatest frequency and the strongest intensity because of abundant moisture advected from the southeast. Thunderstorm activity is normally caused by orographic lift. A very few are caused by migratory lows and fronts. Most mountain thunderstorms occur with great regularity in the afternoon as a result of huge amounts of solar heating. With the moist and unstable air masses of summer, afternoon convection is an important lifting agent over plateaus and flat plains. Valley locations frequently receive thunderstorms late in the evening as the storms move down out of the mountains.

Although tops of thunderstorms only average 30,000 to 35,000 feet (9 to 11 km), they can occasionally become severe with violent updrafts, frequent lightning, and occasional hail. Hail is highly localized and exists in a very small column of a thunderstorm. Generally, it cuts a narrow swath along the storm's path. Because of uneven heating and moisture, the worst hail conditions are most likely to be on the windward side of mountains. Hail occurs less than 5 days per year (usually during summer). Wutai Shan, because of its high elevation, receives hail an average of only twice per year.

Thunderstorms occur with the greatest frequency during July and August. Most locations record an average of 5 to 8 days of thunderstorms per month for July and August.

Central Plains. As the summer season in northeast China progresses, a sharp increase in cloudiness brings a significant increase in precipitation from the winter minimums. In the southern areas of the region in early summer, rain and rainshowers formed north of the mei-yu front over the Yangtze River valley can bring heavy rains. Warm, moist air invades the region as the polar front retreats northward. Widespread clouds and orographically induced thunderstorms associated with the front produce periods of heavy rain.

On average, precipitation falls on about 6-20 days each month. Thunderstorms occur at the beginning of the season, but most activity takes place in July with a monthly average of 8 storms. Stations in the northern areas receive at least 75 mm of rain in early summer with a maximum in July, when most stations report at least 100 mm. Harbin, in the central Manchurian Plain, reports a mean amount of 161 mm during July. In the central areas of the central plains, more than 170 mm of precipitation is reported. Rain falls on about 15 days during the summer, and thunderstorms occur on about 6 days. Farther south, most stations record a mean monthly precipitation amount of 200 mm. Xuzhou reports 250 mm during July. Precipitation falls throughout the southern areas on 9-19 days during summer, and most stations report 6-10 thunderstorms each month. Northeast China receives 50 to 70 percent of its yearly precipitation during the months of June, July and August.

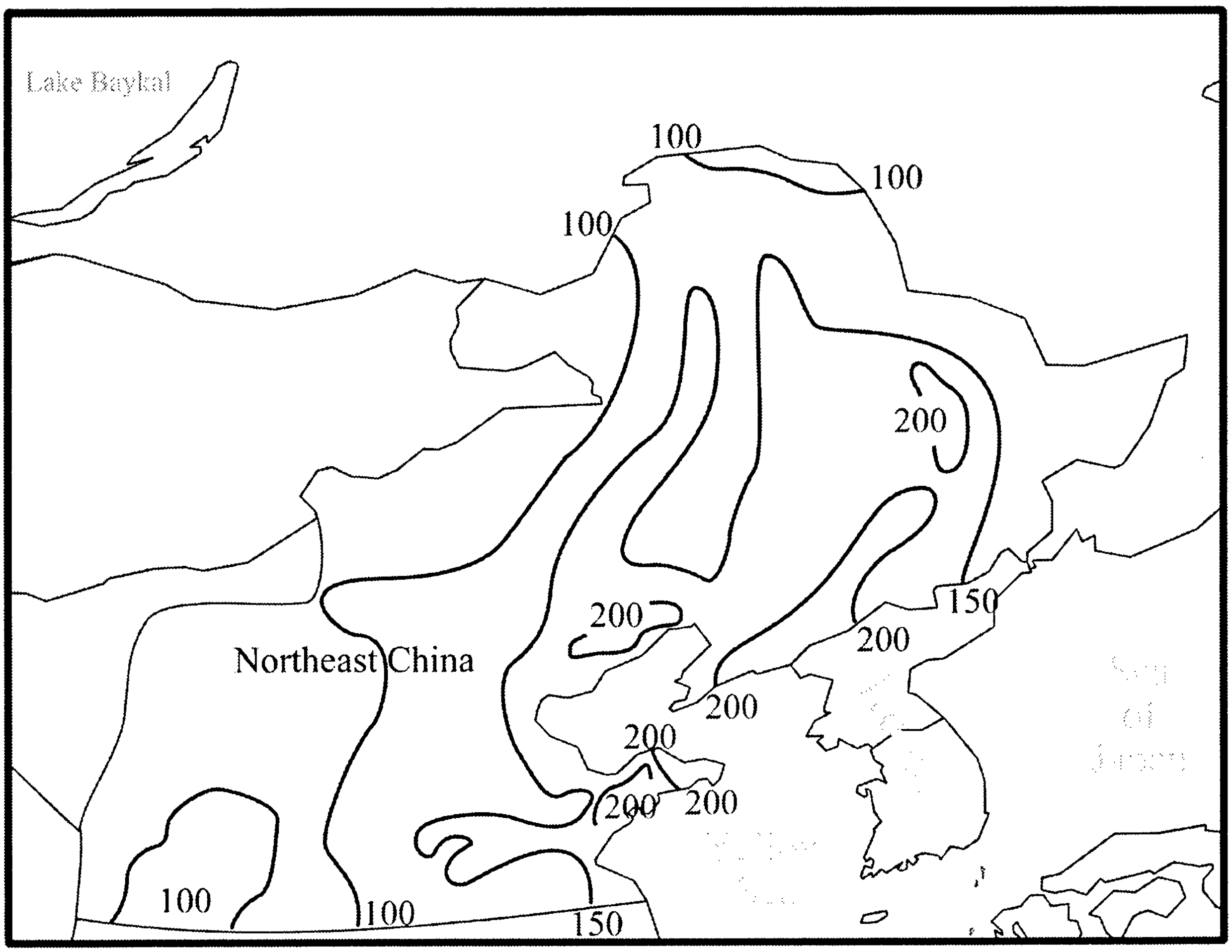


Figure 4-22. July Mean Precipitation (mm). The figure shows mean precipitation amounts in the region.

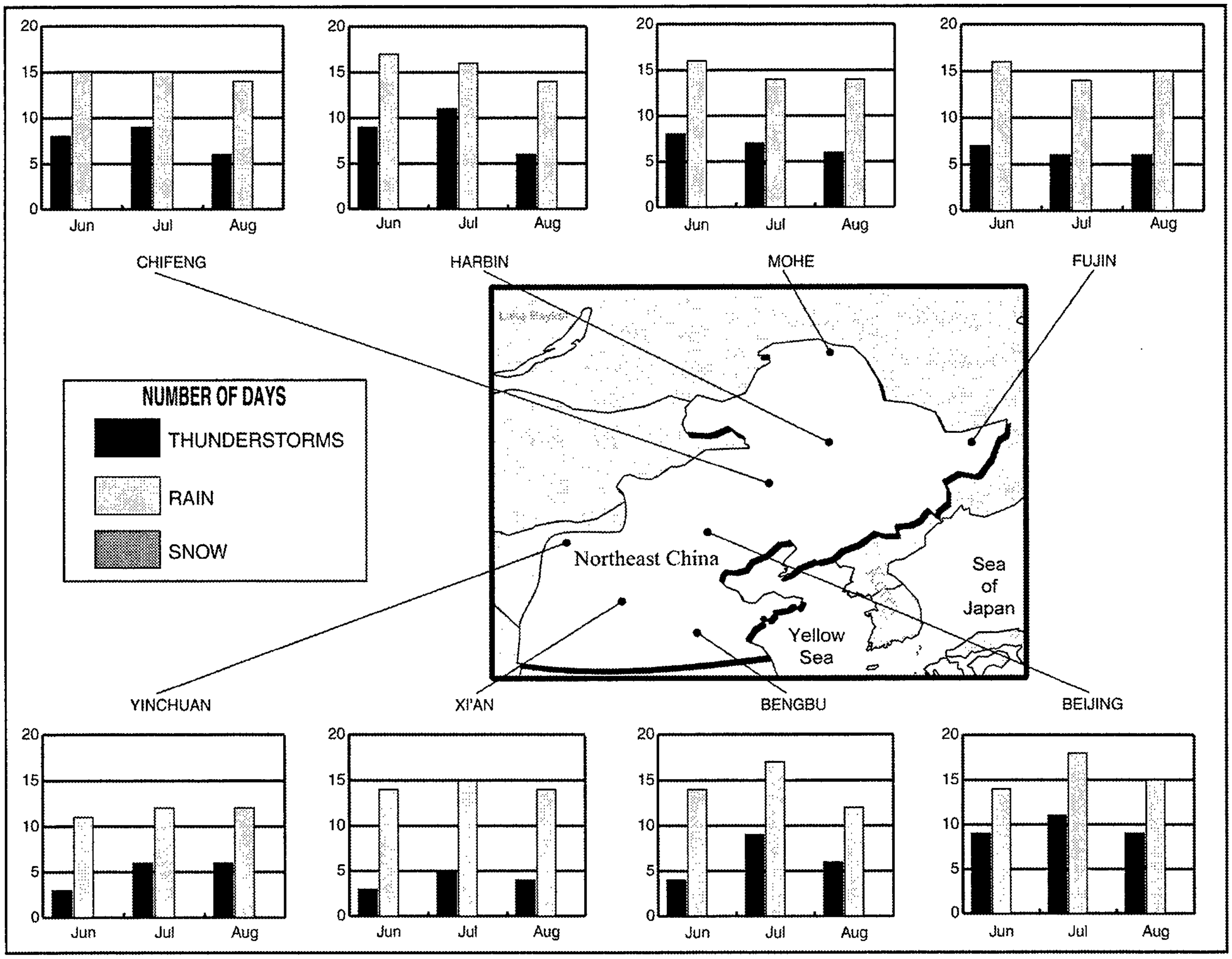


Figure 4-23. Summer Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for representative locations in the region.

Temperatures.

Western Plateau. For the most part, the region experiences a continental air mass. There are warm summer days and much cooler nights because of radiational cooling. This is typical of areas with very dry climates. July is normally the warmest month nearly everywhere within the region. Topography also plays a role in temperature contrast. Temperatures tend to drop with higher elevations. For example, Wutai Shan has a mean maximum temperature of 54°F (12°C) in July and the nearby station of Taiyuan, which has a much lower elevation, has a mean maximum temperature of 82°F (28°C) during the same month. Mean maximum temperatures range from 68° to 77°F (20° to 25°C) in the north to 77° to 86°F (25° to 30°C) in the south (see Figure 4-24). Mean minimum temperatures range from 50° to 59° (10° to 15°C) in the north to 59° to 79°F (15° to 26°C) in the south (see Figure 4-25). The extreme maximum temperature of 102°F (39°C) occurred at Yuncheng in August. The extreme minimum temperature for the region, 14°F (-17°C), occurred at Wutai Shan.

Central Plains. Summer temperatures in northeast China range from mean minimums in the north of 61°F (16°C) to 77°F (25°C) in the southern areas. Mean maximum temperatures follow the same trend; highs are several degrees warmer in the south. Highs range from 77° to 88°F (25° to 31°C). Fujin recorded a temperature of 28°F (-2°C) in May, the last month of the transition and beginning of the summer season. In the far south, Bengbu recorded absolute maximums of 108°F (42°C) in both July and August. Unusually low temperatures may occur when the summer wind flow in southeast China is weak and the polar front, with its trailing warm air, is late in arriving in northeast China. If the summer wind flow in southeast China is strong, the front will move quickly north. This allows warm, moist air to invade the region earlier than usual, and it will get unusually hot.

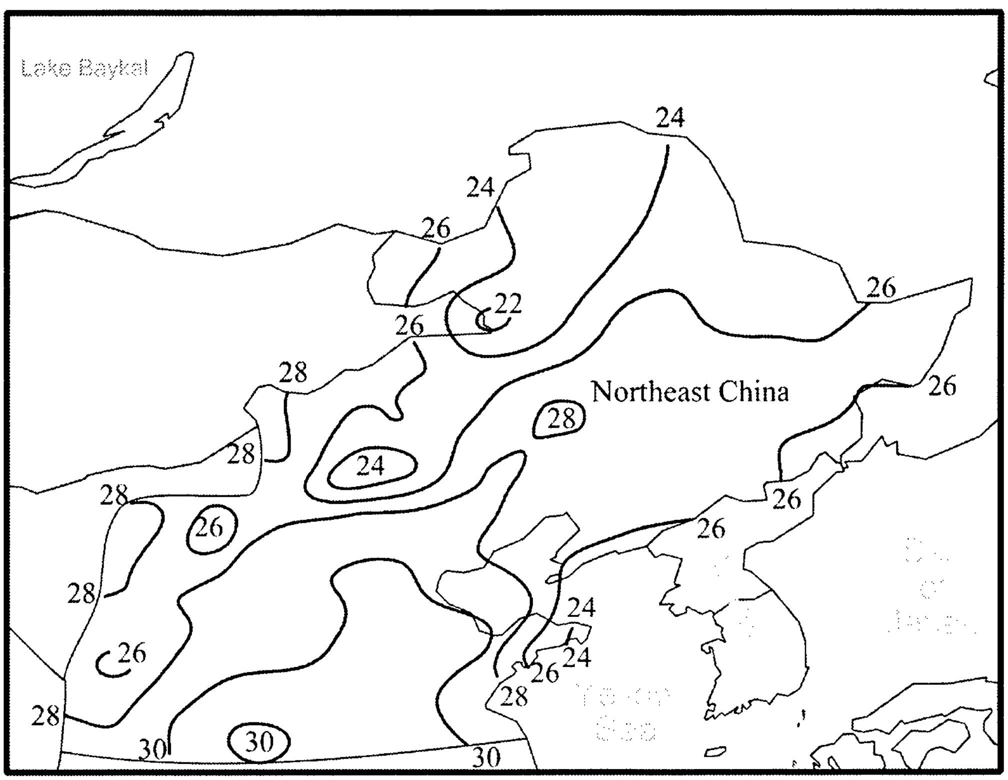


Figure 4-24. July Mean Maximum Temperatures (°C). Temperatures represent the average of all high temperatures for the warmest month of summer. Mean maximum temperatures during other summer months may be lower, especially at the beginning and ending of the summer season.

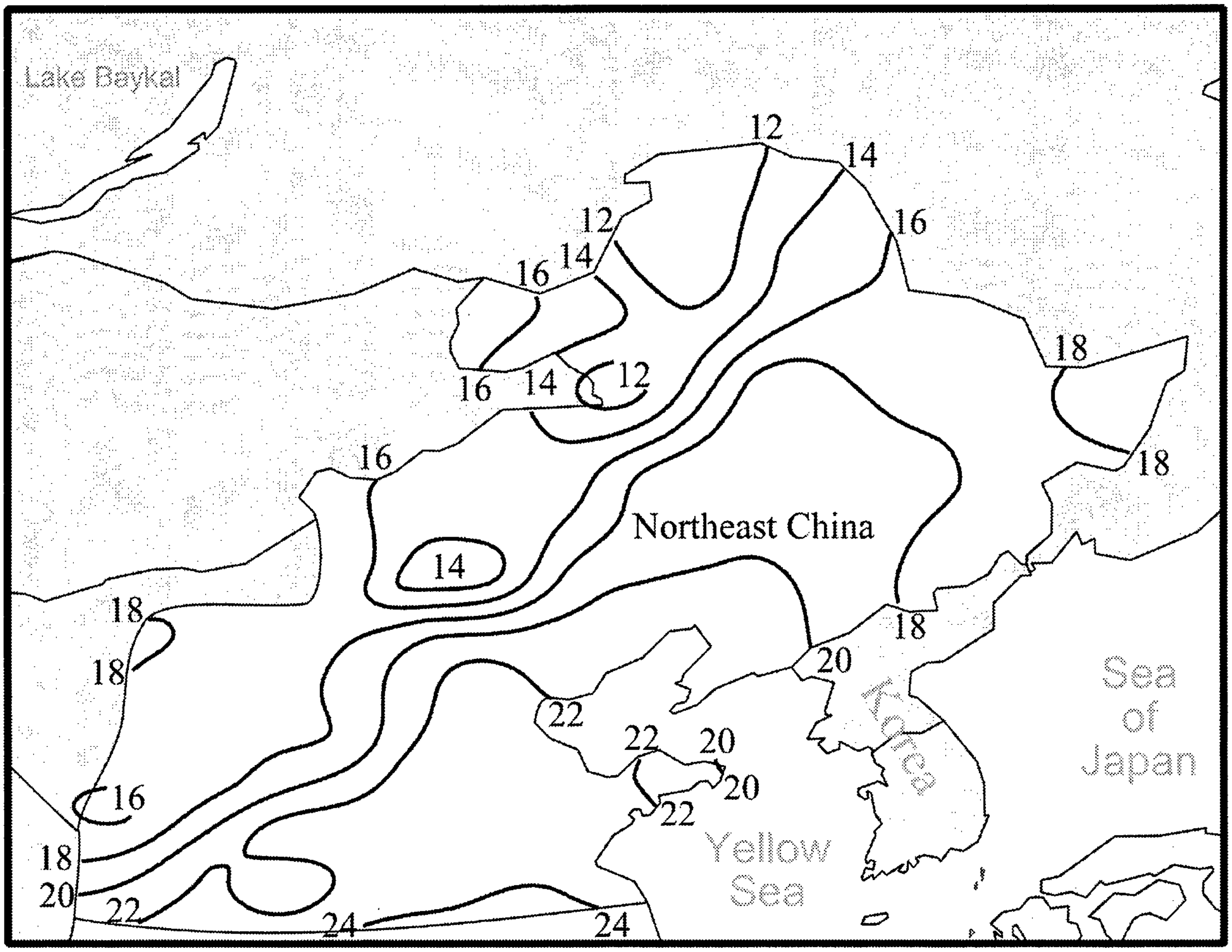


Figure 4-25. July Mean Minimum Temperatures (°C). Temperatures represent the average of all low temperatures for the warmest month of summer. Mean minimum temperatures during other summer months may be lower, especially at the beginning and ending of the summer season.

Hazards.

Flooding. Flooding is most likely in areas of flat terrain and valleys. Heavy rains associated with the moist, southerly winds of summer and the occasional torrential rains of typhoons can cause severe flooding. Loss of life and property is the immediate problem, but famine often follows the flood due to damaged or destroyed crops. Heavy rains, associated with migratory lows and their associated fronts, are the greatest cause of flooding. Most floods are the result of excessive runoff or dike failures. The latter is especially serious, since many dikes are built above the level of the countryside. When dikes break, rivers spread out over the countryside. On flat plains, floods can spread out for miles and persist for months. In the western plateau, the southern river valleys and plains receive most of the flooding. Occasional flash floods occur from heavy thunderstorms everywhere in the western plateau. The eastern plains are especially susceptible to flooding during heavy, prolonged rains associated with typhoons.

Drought. Drought can be worse than flooding because it affects both mountains and plains. Prolonged airflow from the deserts of the west produces conditions that favor drought. At times, drought has been known to last for several years and can mean the loss of many lives. In this region, droughts can be expected just about anywhere. Annual or even monthly amounts of rainfall can be deceiving. The critical factors include not only total rainfall, but also sufficient rainfall when vegetation needs the precipitation. The year-round aridity of the northwest is conducive to drought.

Typhoons. The northwest Pacific Ocean is a fertile breeding ground for typhoons, with about 36 percent of the world's tropical cyclones developing in this area. About 32 percent of the typhoons that develop here hit mainland China coastal areas along the South China Sea and East China Sea. June through November is the official typhoon season; most activity occurs in July-October. The threat to northeast China from typhoons is significantly lower than to the more southern coastal areas along the South China and East China Seas. Occasionally a typhoon will skirt the southeast China coast, move into the Yellow Sea, and hit the Shantung Peninsula full force. Torrential rains, destructive winds, and widespread flooding occurs. Typhoons lose much of their strength while crossing the mountainous peninsula, but they can still bring heavy rain northward into the Manchurian Plain. Typhoons that do not make landfall on mainland China may still impact China's weather. Storms in the South China Sea can draw in moisture that normally feeds the summer monsoon in southeast China. This causes a minor monsoon break that lasts 2-3 days. After the passage of the storm, the summer monsoon reestablishes itself and typical southwest monsoon weather continues.

Aircraft Icing. With the arrival of warm, moist air and increased cloudiness, the threat of icing increases significantly. The freezing level is between 10,000 feet (3 km) to 15,000 feet (5 km). Upper-air temperatures do not cool to below -20°C until about 20,000-25,000 feet (6-8 km). Between these altitudes, icing is likely. The predominant cloud type is stratiform, so the potential for rime icing is strong. Near the freezing level, heavy clear icing occurs in and near cumuliform clouds.

Turbulence. Because much of northeast China is mountainous, turbulence is always a threat. With winds of 20 to 25 knots or more, mechanical turbulence occurs above and as much as 50 miles downwind of ridges and peaks. Stronger winds can produce severe turbulence. Thunderstorms occur throughout the summer season as a result of both orographic lift and migratory lows and their associated fronts. In the center of the lows, along the front, and in and near thunderstorms, turbulence poses a significant threat to air operations. Thermal turbulence caused by the extensive solar heating occurs quite frequently in the region. Elevation, character of the underlying surface, amount of surface heating, and the stability of the air mass all influence how high turbulence extends. At times, thermal turbulence can exist in a broad column several thousand feet high. Clear air turbulence is likely with the jet stream and can occur nearly anywhere within the region, however, the jet stream is not normally strong during summer. Normally, the strongest winds are near the tropopause. The average tropopause is near 40,000 feet (12 km) in the north and 48,000 feet (15 km) in the south. The strongest turbulence will be near these heights. The strength of the turbulence is directly proportional to the speed of the jet; normally, light-to-moderate turbulence can be expected.

Trafficability. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine-grained, and consist of clays and silts. The soil type range, however, extends to and includes some sizable areas of sand and gravel. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

On the plains, slopes vary from nearly level to about a 20 percent incline. The soils are predominantly medium- to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. In the southern part of the plains, rice cultivation limits movement when paddies are flooded. During the wet season, movement conditions are good to poor. Condition depends on soil type. During this time, coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near the river mouths become soft and muddy. They often stop or severely restrict movement.

General Weather. Fall, the transition from summer to winter, is remarkably brief. The transition usually takes place in about 6 weeks, during September and October. The wind circulation pattern abruptly reverses as the warm, moist, maritime air of summer retreats to the Yangtze River valley along with the polar front. The Asiatic high builds strength while the Aleutian low deepens. The pressure gradient between the two systems tightens, and cold, dry, continental air begins to invade the area. Surface winds exhibit a northerly direction, clouds decrease, and temperatures become much lower. By late October, the winter season is established throughout most of northeast China.

Sky Cover.

Western Plateau. Because the polar front is south of most of the region, cloudiness increases from north to south, from 30 to 50 percent of the time in the north to 60 to 70 percent of the time in southern sections of the region. By the end of fall, all low ceilings decrease in the region, but a few pockets of cloudiness persist in southern river valleys. Ceilings less than 3,000 feet vary widely because of terrain. High elevation locations have ceilings below 3,000 feet as much as 48 percent of the time. Low elevation locations have them as little as 3-4 percent of the time (see Figure 4-26). Isolated locations in the southern part of the region have their yearly maximum cloud cover during September. Yan An, Hanzhong, and Ankang all receive ceilings below 3,000 feet 17 to 27 percent of the time. Ceilings less than 1,000 feet occur less than 5 percent of the time. Wutai Shan has the greatest frequency of ceilings less than 1,000 feet, about 30 percent of the time.

Central Plains. Mean cloudiness decreases from its summer maximum. Most stations report scattered-to-broken sky cover. In the far south, broken sky cover occurs most of the time. This reflects the proximity of the retreating warm, maritime air located just south of this area. By mid-October, cloudiness transitions to the pattern of the winter season, with scattered sky cover at most locations. In the north and central areas of the central plains, ceilings are less than 3,000 feet 3-6 percent of the time. Farther south, stations report ceilings less than 3,000 feet 10-22 percent of time. Ceilings less than 1,000 feet occur less than 2 percent of the time, except in the far south where they occur during 3-4 percent of the time.

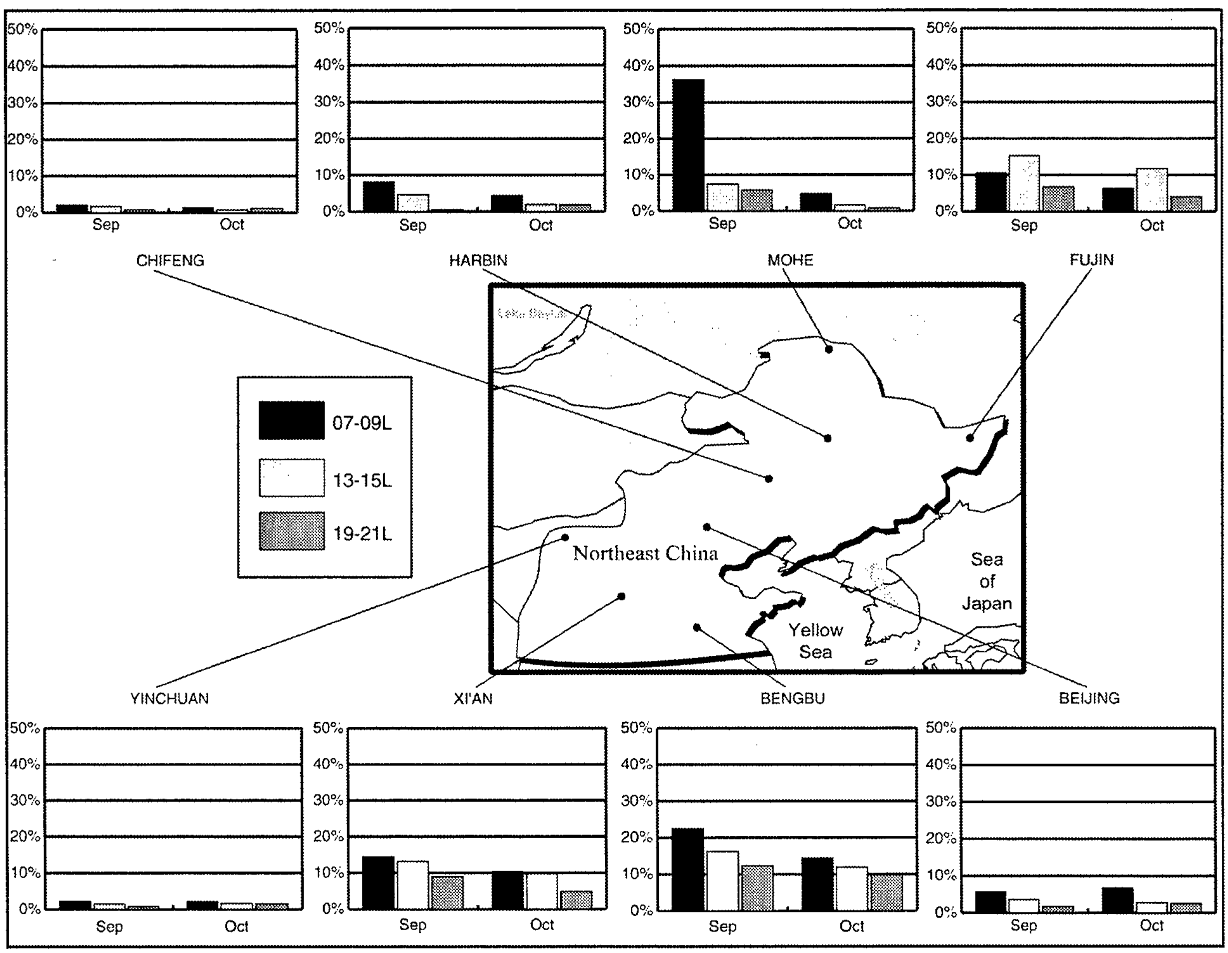


Figure 4-26. Fall Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Western Plateau. Normally, an increase in fog begins in the fall, although visibility restrictions do not cause a significant problem to operations. Most locations have visibility less than 4,800 meters less than 10 percent of the time (see Figure 4-27). As the polar front migrates south, cool air begins to spread south, and visibility problems begin to occur under developing inversions in the river valleys to the south. Xi'an shows an increase in occurrence of visibility below 4,800 meters from 28 percent of the time in the summer to 43 percent of the time in the fall. In the north, low visibility occurs from 14 to 30 percent of the time. Visibility below 800 meters is infrequent. It occurs less than 5 percent of the time. A few locations in the north, and some mountains and river valleys to the south, have visibility below 800 meters 8 to 22 percent of the time. Most locations have fog from 1 to 10 days per month; a few isolated parts of the region in the southern river valleys and the north have fog from 10 to 25 days per month. Summer rains dampen the ground, so blowing sand only occurs 1 to 2 days during the month.

Central Plains. Visibility is restricted less as cold air replaces the warm, moist air of summer. Most stations report visibility greater than 4,800 meters nearly 90 percent of the time. Northern stations report visibility less than 4,800 meters and less than 800 meters about 1 percent of the time. Most central stations and southern stations report these restrictions only 3-4 percent of the time. Beijing is an exception. It is a large, heavily populated city with many industrial and heavy manufacturing plants. Pollution from these industries reduces visibility in and near this city throughout the year. In September, Beijing reports visibility less than 4,800 meters about 17 percent of the time. Visibility is less than 800 meters less than 1 percent of the time.

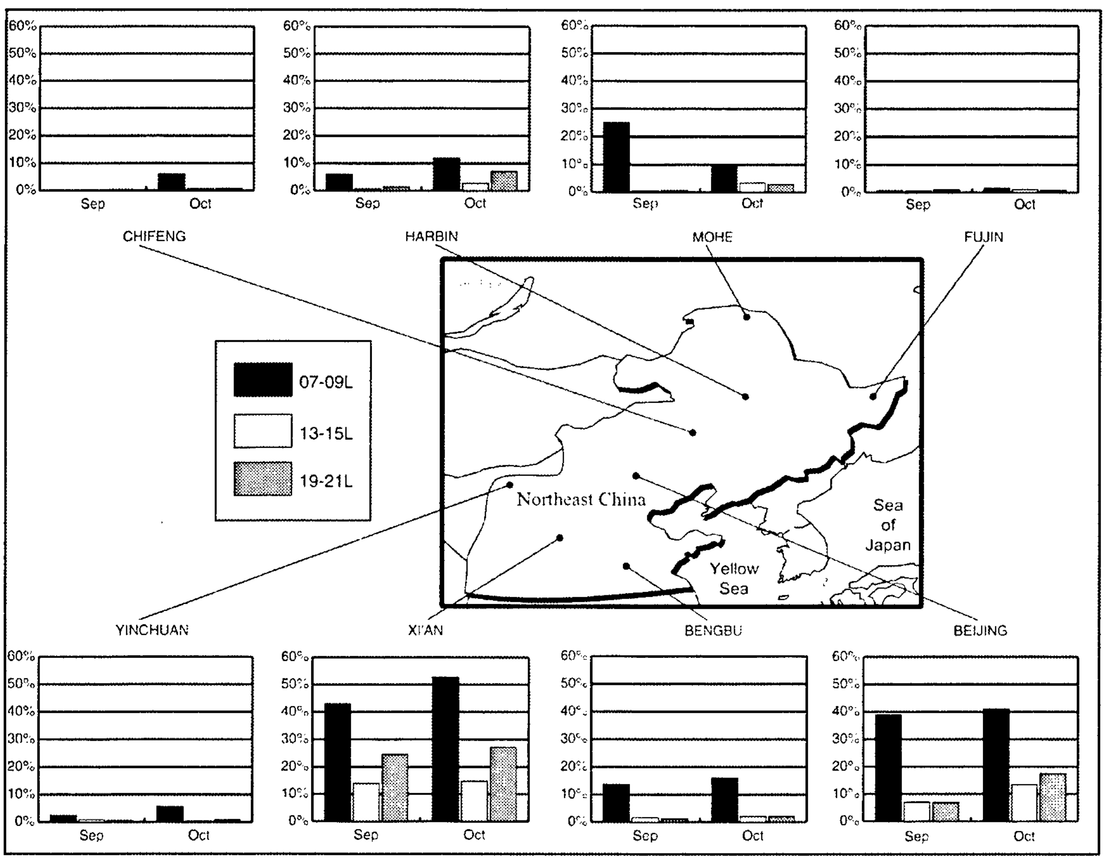


Figure 4-27. Fall Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Western Plateau. During fall, southerly flow shifts to the northwest or west and, in some cases, southwest (see Figure 4-28). Local circulations continue to influence winds. Some locations get a southerly wind direction, which is directly opposite of prevailing flow. Speeds vary widely due to topography and locations; some places get 1 to 5 knots of wind, while others have average speeds of 6 to 15 knots. Calms occur 10 - 40 percent of the time, mostly in the early morning hours. Extreme maximum winds (66 knots) occurred at Wutai Shan. These extreme maximum winds are due to the high elevation of Wutai Shan.

Central Plains. The advancing cool air from the north is reflected in the surface wind directions. Stations in most of the region report winds from a northerly direction. Terrain has a significant influence on northeast China's winds in all seasons. The directions often reflect the orientation of mountain ridges and passes more than the general flow. Speeds are light, generally 5-10 knots. During fall, the incidence of calm winds begins to increase, especially in the early morning hours. The afternoon sea breeze is less likely to occur north of the Shangtung Peninsula; however, the sea breeze may produce southeasterly or southerly winds farther south. Thunderstorm activity decreases, so there are fewer incidents of stronger winds and gusts.

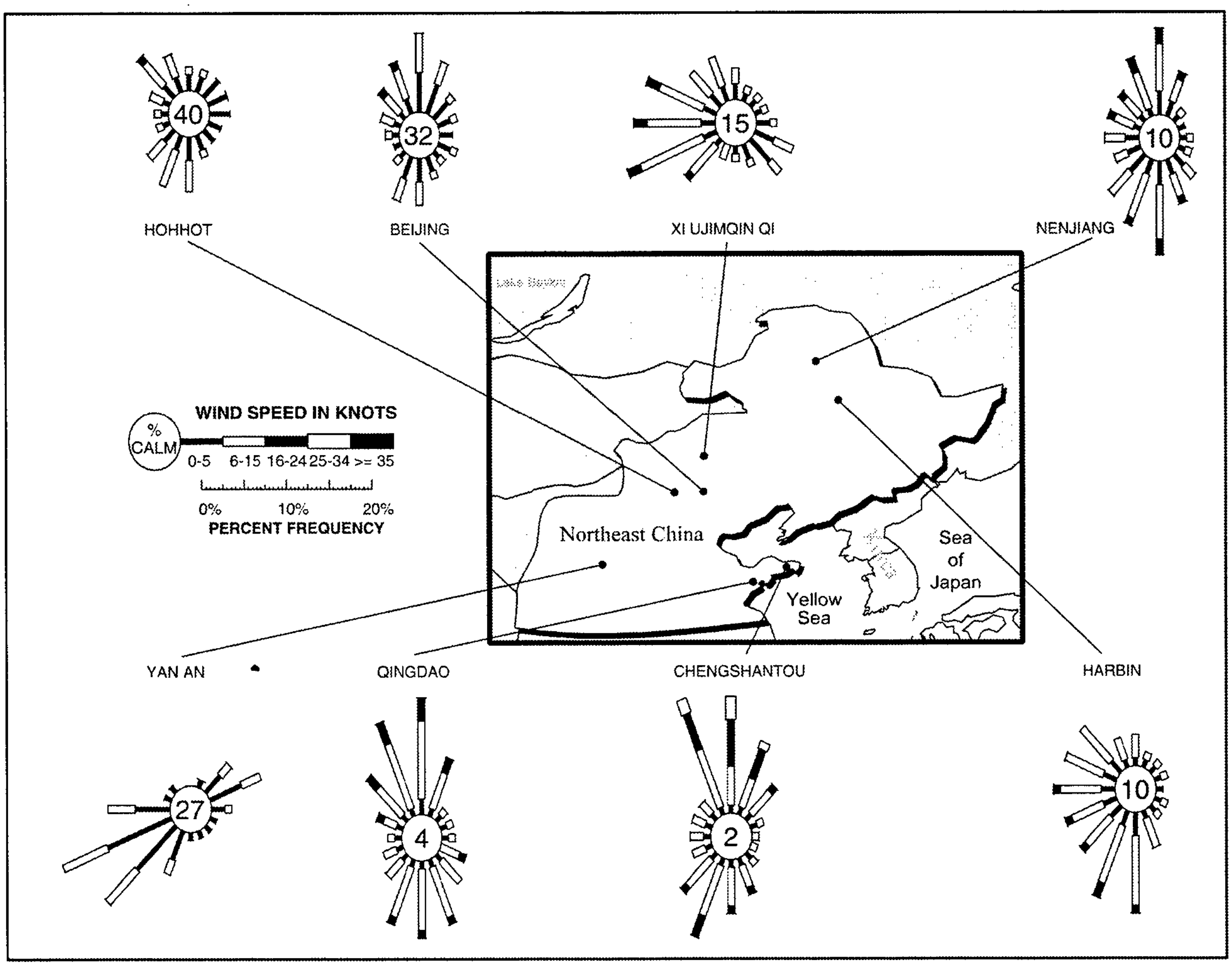


Figure 4-28. October Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds. Upper-level winds are generally westerly, as in all seasons in this region (see Figure 4-29). The polar jet begins to strengthen and migrate southward, and the subtropical jet begins to decrease in intensity. Winds up to about 10,000 feet (3,000 meters) are somewhat variable, but are generally southwest-northwest. Westerlies prevail at about 19,000 feet (6 km). Terrain influences the winds in the lower levels over the plateaus in western northeast China. Speeds do not change significantly from the summer speeds. They range from 15-20 knots at 10,000 feet (3 km) to about 60-75 knots at about 40,000 feet (12 km). Speeds decrease above that level. They average 30-45 knots at 50,000 feet (15 km). Winds in excess of 100 knots occur approximately 10 percent of the time. The tropopause drops to between 45,000 and 50,000 feet (14 and 15 km) by the end of the fall season.

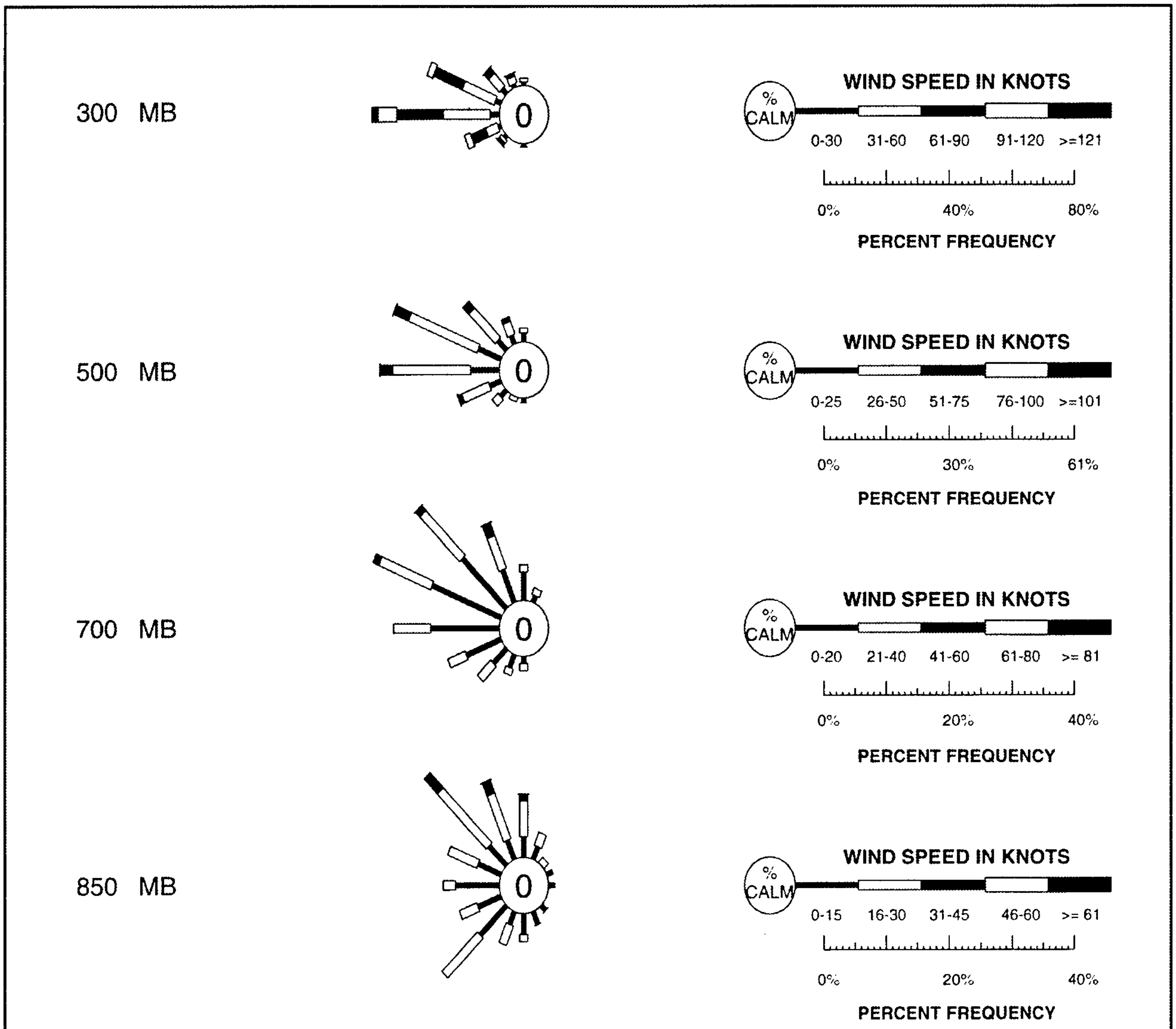


Figure 4-29. October Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Beijing, China.

Precipitation/Thunderstorms.

Western Plateau. Precipitation rapidly decreases in the transition from the rainy summer season to the dry winter season. Precipitation decreases to 10 mm around the western desert regions and to 50 to 75 mm in the north and south (see Figure 4-30). Most precipitation is still liquid since rain days average between 16 and 29 during fall (see Figure 4-31). The highest frequency of days with rain occurs in the river valleys of the southeast near the polar front. The lowest number of days with rain occurs in the west due to the upper westerly winds which bring dry air.

Northern parts of the region and locations at higher elevations receive their first snowfalls by the end of September. This is due to early cold outbreaks that occur there. Mean snow days average 1 to 8 days per season. Since snowfall is just beginning, snow cover is not likely to be a factor.

Thunderstorm activity decreases rapidly due to loss of heating and moisture. The polar front drops south, and convection declines over the plateau regions. In the first half of September, lingering summer heat lifts thunderstorm tops to between 25,000 35,000 feet, but by late in the month that heat collapses and so do the thunderstorms. Thunderstorms occur 1 to 3 days during fall. Severe thunderstorms rarely occur because of the lack of strong vertical lift.

Central Plains. Although most stations still report significant amounts of precipitation, total precipitation decreases. In the far north, rain falls about 20 days during fall. About 66 mm usually accumulates during this period. Precipitation falls 19 days in the central area. Amounts range from 58 mm to about 75 mm. Farther south, rain occurs about 24 days; amounts range from 76 mm to 90 mm. Thunderstorms occur about 5 days in the central area, but the southern portion of the central plains only have 1 thunderstorm day. Snow occurs at the northern areas during October.

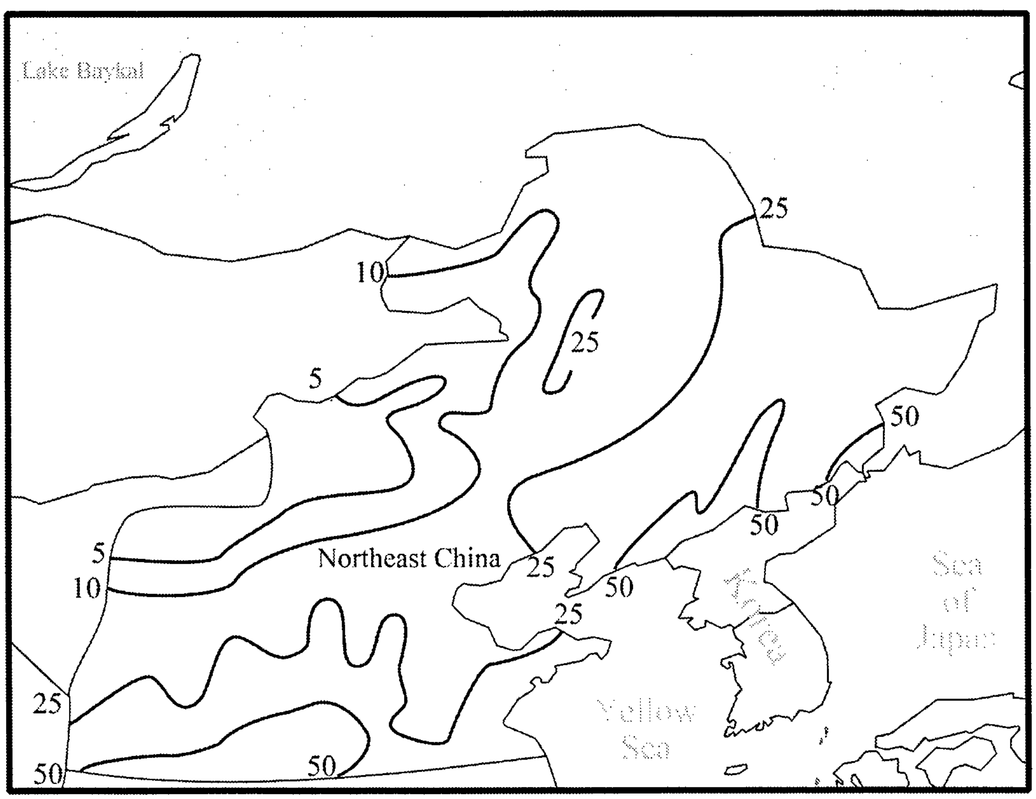


Figure 4-30. October Mean Precipitation (mm). The isopleths depict the water equivalent of precipitation received during October.

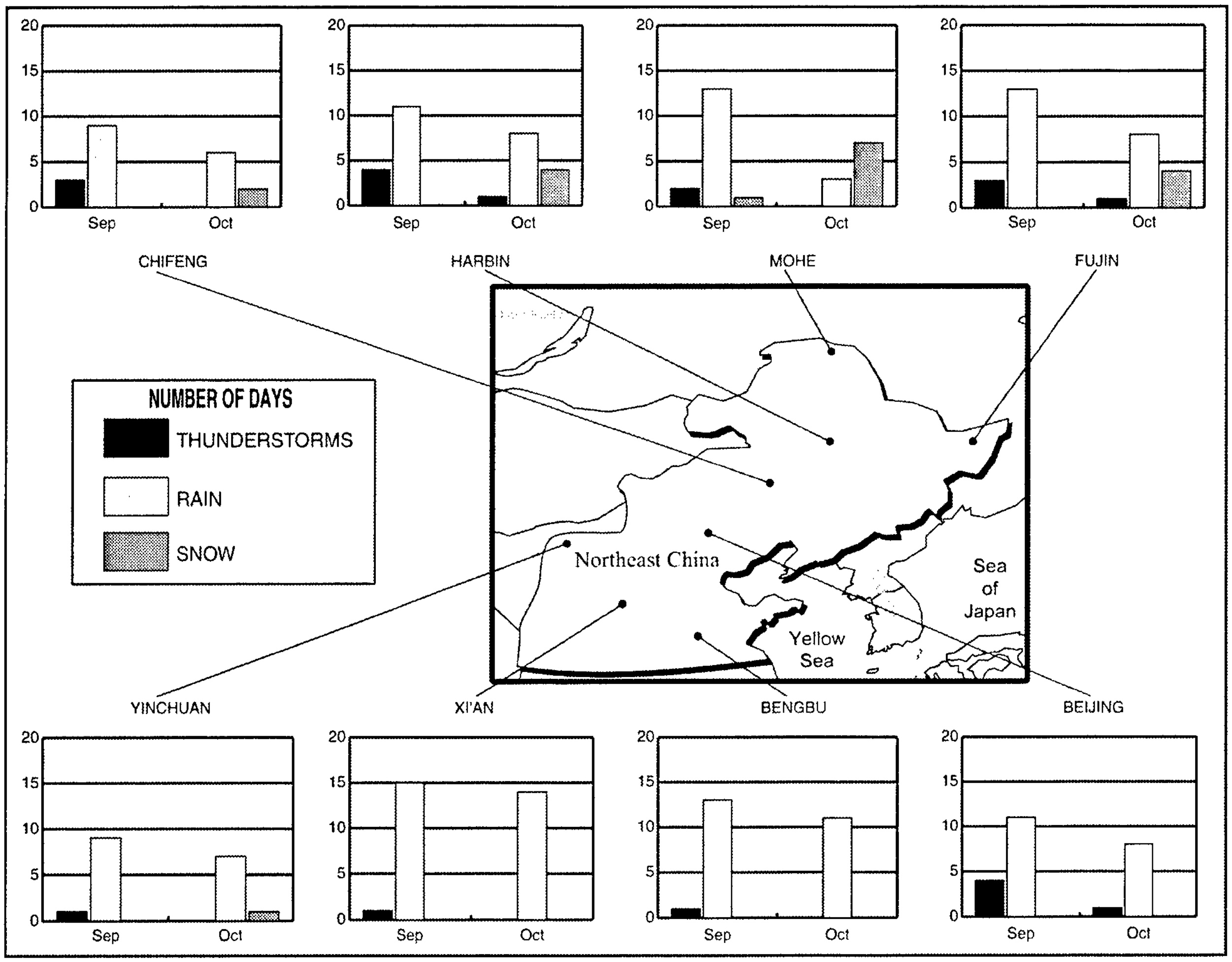


Figure 4-31. Fall Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for representative locations in the region.

Temperatures.

Western Plateau. As the Asiatic high strengthens, days become shorter, and the nights get longer, temperatures drop rapidly. Occasional cold surges move in from the northwest and can drop temperatures much lower than the means. Mean maximum temperatures range from 41°F (5°C) in the north to 64°F (18°C) in the south (see Figure 4-32). Mean minimum temperatures average range from 16° to 32°F (-9° to 0°C) in the north to 64°F (18°C) in the south (see Figure 4-33). The region experienced an extreme high of 102°F (39°C) at Lushi, possibly as a result of foehn winds, and an extreme minimum of 7°F (-14° C) at Tultihe, probably caused by a cold surge.

Central Plains. During the fall transition, temperatures cool considerably from the summer maximums as a reflection of the advance of the continental air from the Asiatic high. Mean maximum temperatures range from 43°F (6°C) in the north to 64°F (18°C) in the south. Mean minimum temperatures range from 32°F (0°C) in the north to 66°F (19°C) in the south. The absolute maximum temperature, 99°F (37° C), occurred in September at Bengbu. Fujin reported an extreme minimum of 28°F (-2°C).

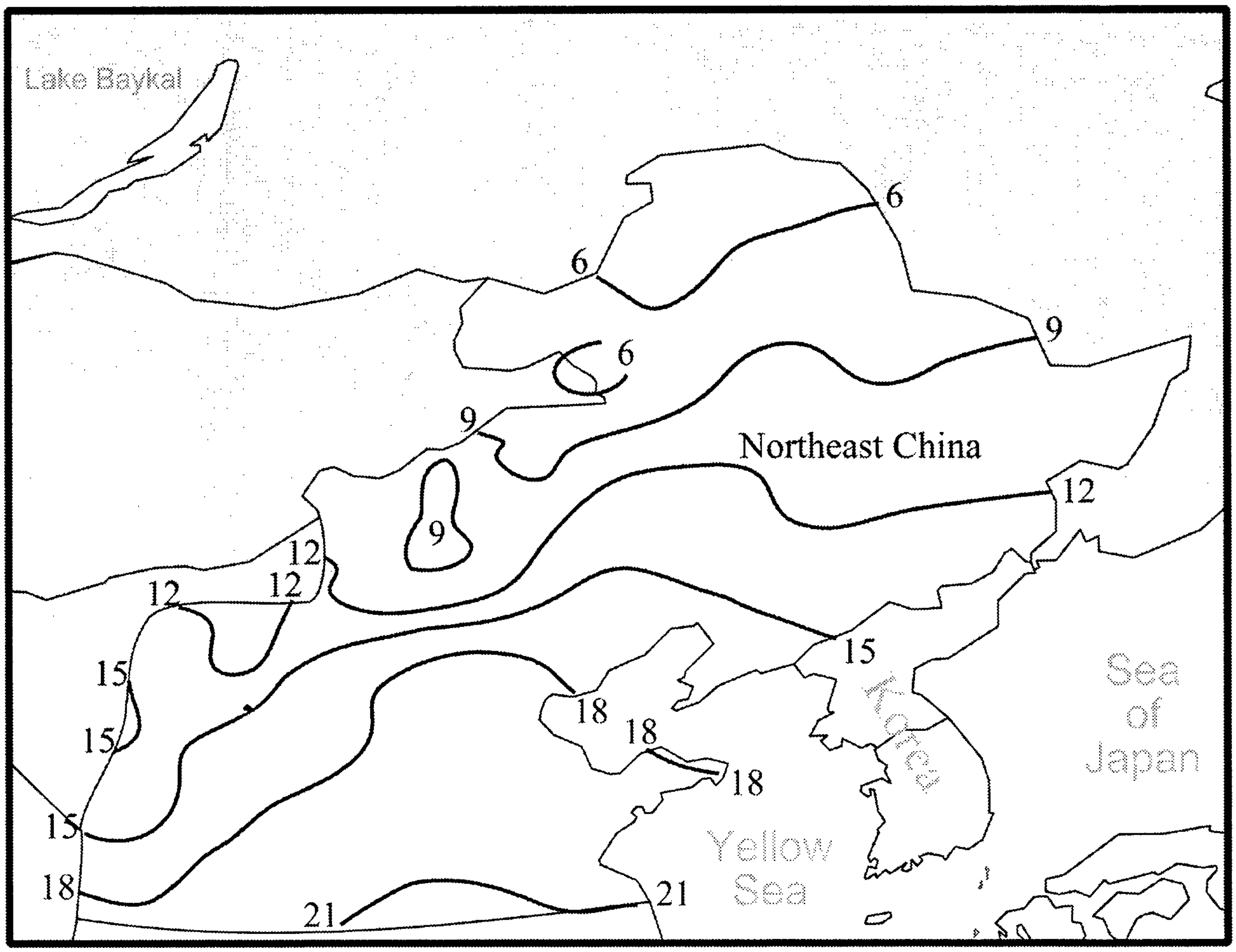


Figure 4-32. October Mean Maximum Temperatures (°C). Temperatures represent the average of all high temperatures for fall. Mean maximum temperatures during September are warmer, especially at the beginning of the month.

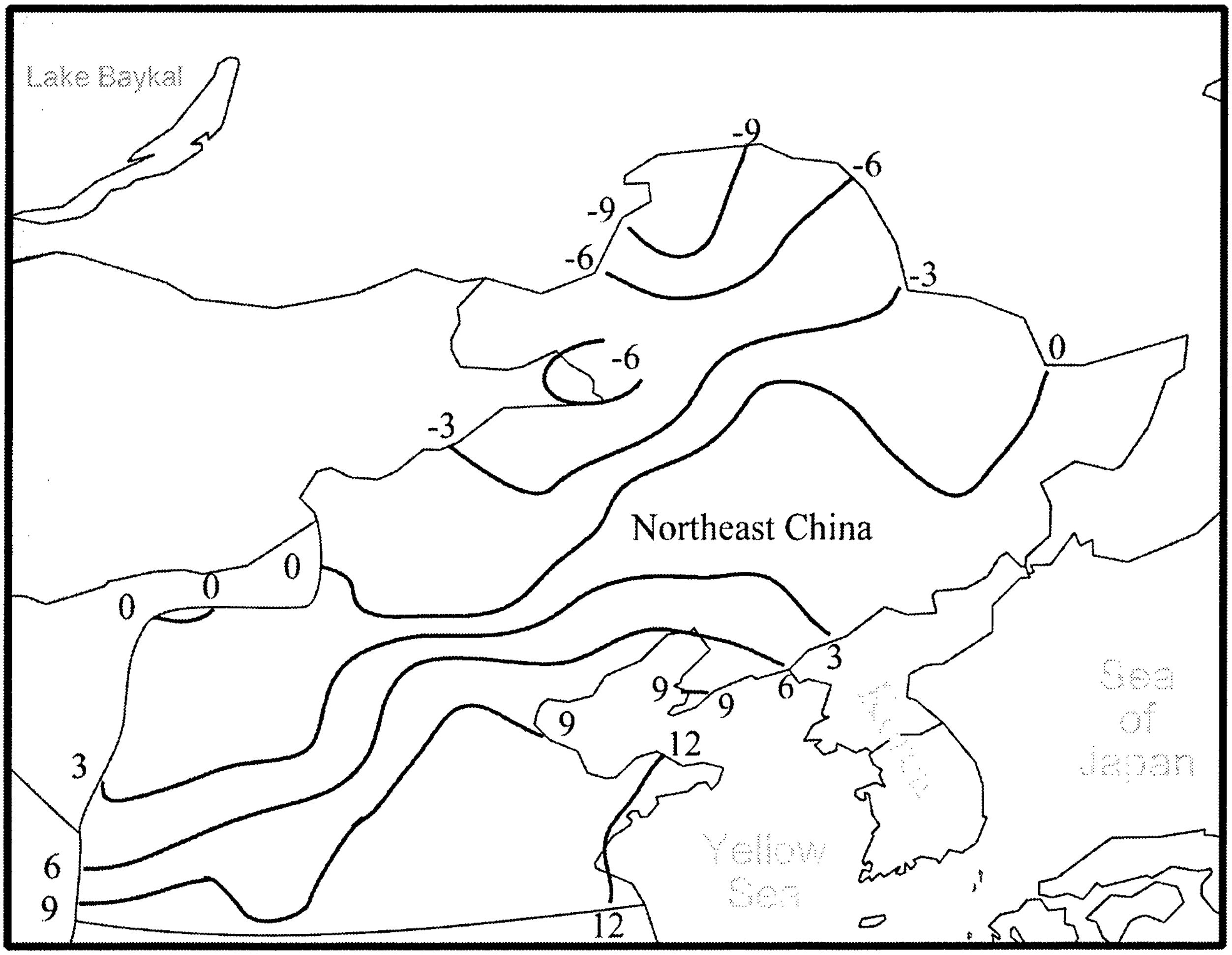


Figure 4-33. October Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the fall. Mean minimum temperatures during September are warmer, especially at the beginning of the month.

Hazards.

Flooding. Flooding is most likely in areas of flat terrain and in valleys. Heavy rains associated with the moist, southerly winds of summer and the occasional torrential rains of typhoons can cause severe flooding with loss of life and property. Famine often follows flooding conditions due to destruction and damage of crops. Heavy rains associated with migratory lows and their associated fronts are the cause of flooding. Most floods are the result of excessive runoff or dike failures. The latter is especially serious, since many dikes are built above the level of the countryside. When dikes break, rivers spread out over the countryside. On flat plains, floods can spread out for miles and persist for months. In the western plateau, the southern river valleys and plains receive most of the flooding. Occasional flash floods occur from heavy thunderstorms just about anywhere in the western plateau. In northeast China, the eastern plains are especially susceptible to flooding. Heavy, prolonged rains during passage of typhoons pose the greatest threat.

Drought. Drought can be worse than flooding because it affects both mountains and plains. Prolonged airflow from the deserts of the west produces conditions that favor drought. At times, drought has been known to last for several years, and can mean the loss of many lives. In this region, droughts can be expected just about anywhere. Annual or even monthly amounts of rainfall can be deceiving. The critical factors include not only total rainfall, but also sufficient rainfall when vegetation needs the precipitation. The year-round aridity of the northwest is conducive to drought.

Typhoons. The northwest Pacific Ocean is a fertile breeding ground for typhoons, with about 36 percent of the world's tropical cyclones developing in this area. The threat to northeast China from typhoons is significantly lower than to the more southern coastal areas along the South China and East China Seas. Occasionally a typhoon will skirt the southeast China coast, move into the Yellow Sea, and hit the Shantung Peninsula full force. Torrential rains, destructive winds, and widespread flooding occurs. Typhoons lose much of their strength while crossing the mountainous peninsula, but they can still bring heavy rain northward into the Manchurian Plain. Typhoons that do not make landfall on mainland China may still impact China's weather. Storms in the South China Sea can draw in moisture that normally feeds the summer monsoon in southeast China. This causes a minor monsoon break that lasts 2-3 days. After the passage of the storm, the summer monsoon reestablishes itself and typical southwest monsoon weather continues.

Aircraft Icing. During fall, moisture decreases rapidly and clouds start to flatten into a more stratiform type. The mean freezing level decreases to between 7,000 and 8,000 feet (2 and 3 km). The most likely levels for icing are between 8,000 and 25,000 feet (2 and 8 km). Both rime and clear icing are possible since both cumuliform and stratiform clouds are present in the fall. During thunderstorms, severe clear icing is possible near the freezing level. Aircraft icing is also likely in cloud decks that accompany migratory lows. The freezing level may drop to the surface at times as cold air works its way in fromSiberia.

Turbulence. Cold surges often create widespread turbulent conditions along and behind a cold front. This usually occurs below 5,000 feet (1 km). Turbulence may be quite strong and extend to several thousand feet. Orographic turbulence is possible below 10,000 feet (3 km) over rough terrain, particularly over the Da Hinggan, Hua Shan, and Daba Shan Mountains. The intensity is directly related to the strength of the wind, and may become severe when winds attain high speeds in the layers below 3,000 feet (900 meters) above the surface. Clear air turbulence is likely with the jet stream and can occur anywhere within the region. Normally, the strongest winds are near the tropopause. The average tropopause is at 45,000 feet (14 km) in the north and 50,000 feet (15 km) in the south. These heights are where the strongest turbulence is located. The strength of the turbulence is directly proportional to the speed of the jet; the jet normally begins to strengthen in fall and moderate turbulence begins to occur with greater frequency.

Trafficability. Topography ranges from nearly level plains to steep, rugged mountains. Included in this range are basins, hills, high plateaus, upland steppe, desert, wide and narrow valleys, deep gorges, alpine meadow, very intensely terraced hills, and permanent snowfields. The soils of the country are predominantly fine grained, and consist of clays and silts. The soil type range, however, extends to and includes some sizable areas of sand and gravel.

In the mountains and hills, conditions for off-road movement during the dry season are mostly poor to unsuitable due to steep, rugged slopes, forests, and very intensive, manmade terracing. Conditions are fair to good in some alpine meadows, especially if frozen, and some valley bottoms. During the wet season, movement is virtually impossible except along established routes and locally in valley bottoms where coarse-grained soils may exist.

On the plains, slopes vary from nearly level to about a 20 percent incline. The soils are predominantly medium to fine-grained, however, some areas of coarser soil are in the north and some areas of highly organic soils are in the far northeast. During the dry season, movement conditions are fair to good except where restricted by marshy areas, steep-banked water courses, irrigation canals, forests, and dissected areas (very rugged terrain). In the southern part of the plains, rice cultivation limits movement when paddies are flooded. During the wet season, movement conditions are good to poor. Condition depends on soil type. During this time, coarse soil allows much better movement conditions than fine-grained soils. Fine-grained lower terrace and flood plain soils near the river mouths become soft and muddy. They often stop or severely restrict movement.

Chapter 5

TAIWAN

This chapter describes the geography, major climatic controls, special climatic features, and general weather (by season) for Taiwan. The regions Taiwan encompasses include the following: the northern coastal plains, the western coastal plains, the central and eastern highlands, and the Pescadores Islands, as shown below.

TAIWAN GEOGRAPHY

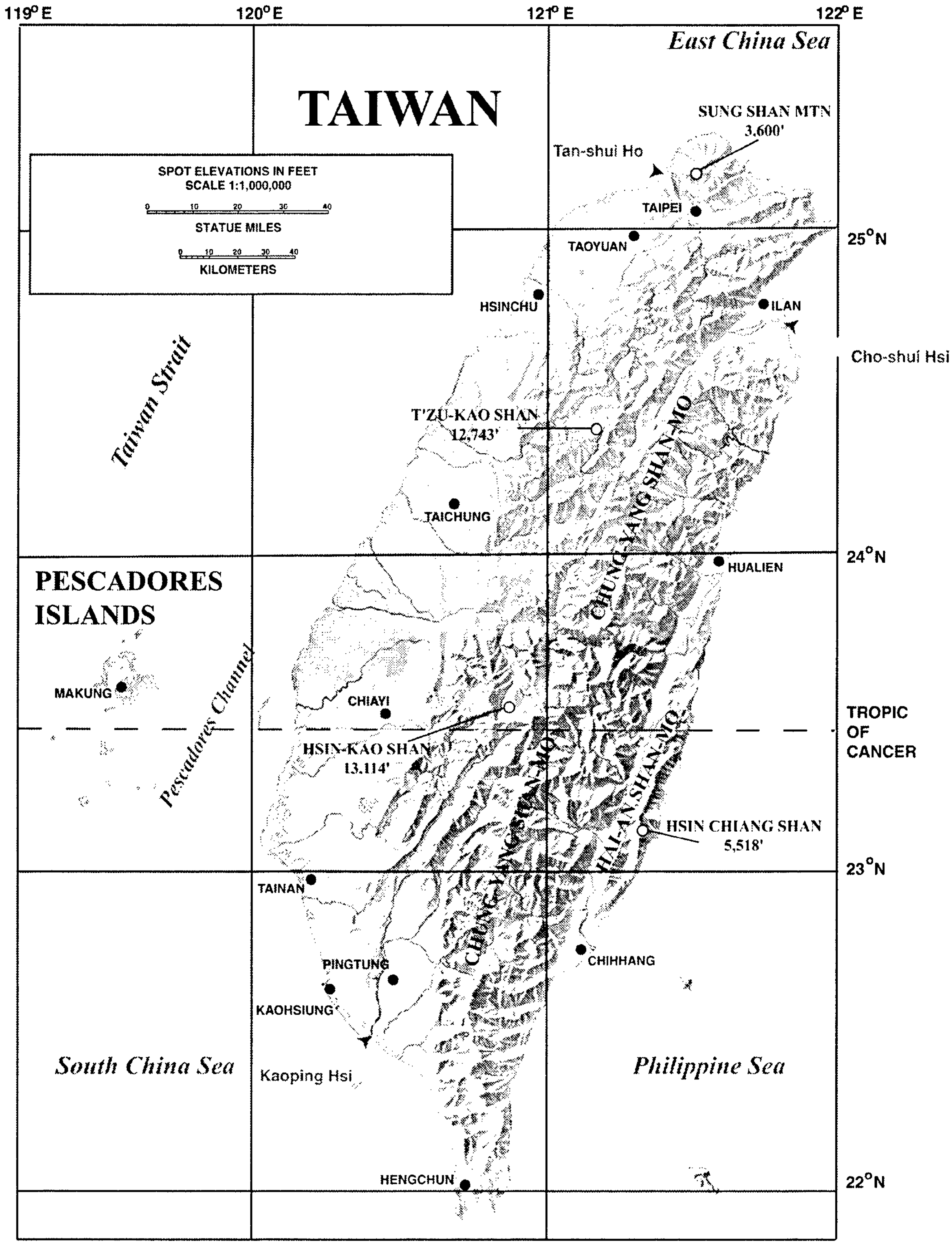


Figure 5-1. Taiwan Topography. This map shows major place names and terrain features for the area of interest.

Boundaries. Taiwan is a mountainous island, oriented north-northeast to south-southwest, about 100 miles (161 km) off the southeast coast of China. It is approximately 245 miles (395 km) long and 90 miles (145 km) across its widest point. The island is surrounded by the East China Sea to the north, the Philippine Sea and Pacific Ocean to the east, the South China Sea to the south, and the Pescadores Channel and the Taiwan Strait to the west. Several small islands lie off the coast of Taiwan; the largest group is the Pescadores Islands.

Major Terrain Features.

Northern Coastal Plains. This plain is 12 to 19 miles (20 to 30 km) wide and has small, rolling hills that average less than 1,000 feet (300 meters) in elevation. The highest point is at Sung Shan, a small mountain just north of Taipei with an elevation of 3,600 feet (1,100 meters). An area of marshlands, forests, and small lakes resides between Hsinchu and Taipei. Ilan is surrounded with marshlands and several small rivers.

Western Coastal Plains. This is a mostly flat coastline strip, 10 to 30 miles (16 to 48 km) wide, interspersed with lagoons, low sand dunes, and low rolling hills that seldom rise over 300 feet (90 meters). A small area of marshlands lies north of Taichung. A rather large area of the Chung-yang Shan-mo foothills, with a peak elevation near 1,000 feet (300 meters), extends southwestward between Tainan and Pingtung.

Central and Eastern Highlands. The most significant feature is a rugged mountain range, called Chung-yang Shan-mo. It lies east of and parallel to the island's axis. This range, which extends the entire length of the island, is tilted to the west and covers about two-thirds of Taiwan. The average peaks rise to about 8,900 feet (2,700 meters). The highest peak, Hsin-kao Shan, with an elevation of 13,114 feet (3,997 meters), is in the south central part of the island. There are more than 60 peaks above 10,000 feet (3,050 meters). The east coast has the steepest slopes; elsewhere, a more gradual incline exists from the numerous independent hills and small mountains found around the range. A smaller range, Hai-an Shan-mo, with a peak elevation of more than 5,250 feet (1,600 meters), lies parallel to the east coast. The Taitung River valley lies between these two ranges. It extends from the eastern coastal cities of Hualien to Taitung (near Chihhang). A very narrow eastern coast strip, in many places less than 1 mile (1.6 km) wide, lies at the eastern foot of Hai-an Shan-mo.

Pescadores Islands. The Pescadores Islands are about 25 miles (40 km) off the west coast of Taiwan. The islands consist of 64 flat, windswept islands. The highest elevations on the two largest islands, Penghu Tao and Yuweng Tao, are 72 feet (22 meters) and 200 feet (60 meters), respectively.

Rivers and Drainage. Most of the numerous rivers throughout Taiwan, nearly all of which originate in the Chung-yang Shan-mo, are short and subject to extreme seasonal variation in flow. Principal rivers are the Tan-shui Ho (flowing northward just west of Taipei) and the Cho-shui Hsi (flowing westward into the Taiwan Strait between the cities of Taichung and Chiayi). Another major river, the Kaoping Hsi, flows southward near Pingtung. A relatively large river, also named Cho-shui Hsi, and several smaller rivers lie just south of Ilan in northeast Taiwan.

Ocean Currents/Sea Surface Conditions. Figure 2-1 shows the major ocean currents that affect Taiwan, with corresponding mean sea-surface temperatures. During the winter monsoon, a branch of the North Equatorial Current is diverted southward along Taiwan's west coast and into the South China Sea. This warm current flows adjacent to the cold, southward-flowing Kuroshio Counter Current near China's east coast. In January, coastal water temperatures range from 62° to 70° F (17° to 21°C), off the northern to southern coasts, respectively. July's coastal water temperature is near 82°F (28°C).

MAJOR CLIMATIC CONTROLS

Asiatic High and Aleutian Low. The strong, cold, and shallow Asiatic high dominates much of Asia from September to late April. This high acts with the Aleutian low to establish a strong pressure gradient over the East China Sea. The strength of the pressure gradient, which is at a maximum in January, is directly related to the strength of the northeast monsoonal flow over Taiwan.

Asiatic Low and North Pacific High. During May, the cold Asiatic high is replaced by the Asiatic low. This thermal low acts with the northwestward expanding North Pacific high, which displaces the Aleutian Low north and east to establish a summer monsoonal flow over the South China Sea and Taiwan. The farther northwest this high is positioned, the more active the summer monsoon.

Polar Front and Taiwan Low. During the winter monsoon, the passage of deep upper trough in the mid-latitudes often triggers intense anticyclogenesis over central China and cyclogenesis over the East China Sea. As the pressure gradient across the East China coast tightens, cold air bursts out of the continent towards the South China Sea, and a "cold surge" is initiated. The polar front associated with the surge can not normally be followed southward of about 25° N. However, the polar front occasionally stagnates over southern Taiwan and brings periods of considerable low cloudiness. The cold surge freshens the monsoonal flow and intensifies the precipitation. The mean position of the polar front in January is just south of Taiwan. During winter, an average of seven migratory lows develop along the polar front in southern parts of the East China Sea. The most favorable areas of development are the eastern or northern sectors of Taiwan, usually from January to March. These cyclones tend to develop when the winter monsoon weakens and an upper-level trough is over northern China. This setup causes warm, moist, upper-level southwesterly winds over northern Taiwan. Taiwan lows usually spread low ceilings, poor visibility, and continuous precipitation over northern Taiwan before moving rapidly towards Okinawa a few hours after cyclogenesis.

East China Sea Low. These lows develop along a southern frontal zone over southeast China's mainland during the winter monsoon. Their track is east-northeast, and occasionally they cross northern Taiwan before heading toward the southern coast of Japan. The approaching low causes a breakdown of the northeast monsoonal flow. This brings a short period of fine weather to northeastern Taiwan because of the downslope trajectory of the induced southerly wind. Passage of the low brings the return of the monsoonal flow and its associated low clouds, and continuous light rain to northern Taiwan.

Monsoon Trough. The monsoonal trough, otherwise known as the Near Equatorial Trade Wind Convergence (NETWC), lies in a transition zone between the west or southwesterly winds to the south and the easterly or northeasterly trade winds to the north. An active trough, with large areas of cloud clusters, normally causes weather 5 to 10 degrees of latitude south of Taiwan; however, the trough can bring rainshowers to southern Taiwan when it reaches its most northern position in July and August. This trough is a major source region for tropical cyclones that periodically affect Taiwanese weather.

Subtropical Jet. As this jet shifts southward during the winter monsoon, it greatly influences storm tracks and helps create favorable areas of cyclogenesis as it merges with the polar jet over the East China Sea. Taiwan's weather is influenced by this jet when the jet is in its southernmost position in December through February.

Tropical Easterly Jet. The intensity and mean position of this jet is directly related to the activity of the summer monsoon. The mean position lies at about 15° N, four to five degrees south of the surface NETWC, but it oscillates between 5° and 20°N. A stronger and more northerly positioned jet can intensify convective activity in southern Taiwan.

Mei-yu. The mei-yu is a quasi-stationary belt of heavy rainfall that begins over South China during the month of May. It slowly moves northward and extends eastward over Taiwan from mid-May to mid-June. It then continues moving northward into central China and stretching eastward to Japan, where it is called the bai-u. This front forms when warm, moist, conditionally unstable, monsoonal air intersects with cold air advected southward by eastward moving mid-latitude disturbances north of the region. The most intense precipitation normally occurs in the deep convective cells at the leading edge of the front; however, prefrontal convective rainbands can produce heavy rainfall amounts in a short periods of time. Widespread precipitation, both convective and stable, normally accompanies frontal passage. Movement of the mei-yu front is irregular. It sometimes becomes stationary or moves southward for a short period before it jumps northward again. Although the front is characterized by a smaller horizontal temperature gradient than is found in typical polar fronts, it is accompanied by a strong moisture gradient and horizontal wind shear. Flooding and/or flash flooding is often associated with the mei-yu front.

Taiwan Convergence. Convergence of the southwesterly monsoonal flow from SoutheastAsia and the southeasterly flow from the North Pacific high produces this wind shear line off the east coast of Taiwan. The convergence results in little convective activity.

Tropical Cyclones. Typhoons affecting Taiwan generally occur from May through December, but are most frequent in July, August, and September. During the winter monsoon, typhoons usually develop only when the North Pacific high is intense with a strong 200-mb ridge to provide outflow and a steering mechanism for typhoons. Typhoons approaching Taiwan during this season are weakened by the cold, dry air entrainment at lower levels and by vertical shearing from the upper-level westerlies. An average of three or four typhoons affect the area, while two or three actually cross Taiwan in a year. There is a general tendency for cyclones to develop and track progressively farther north as the season progresses. Typhoons normally approach from the southeast and bring heavy rain, flooding, and wind damage to the east coast. They lose intensity as they cross the rugged eastern and central highlands. Typhoons approaching from the southwest, normally late in the year, move over the relatively warm Taiwan Strait and cause torrential rainshowers, flooding, and wind damage to the western coastal plains. Regardless of their trajectory, very intense and massive typhoons can have devastating effects throughout Taiwan.

Venturi Winds. The north-northeast to south-southwest orientation of Taiwan Strait acts as a wind tunnel between the Chinese mainland and Taiwan during the winter monsoon. Wind speeds over the strait exceed 35 knots better than 90 days of the year. These winds are also evident during the summer monsoon, but to a much lesser extent. This kind of wind is also found over the Cho-shui Hsi River valley, the Taitung River valley, and in other valleys between mountains orientated northeast to southwest.

Land/Sea Breeze. These diurnal breezes dominate surface wind direction in coastal Taiwan and in the Pescadores Islands when the monsoonal flow is weak or during the transitional seasons. However, low-level convergence between the sea breeze and monsoonal flow can produce large afternoon or early evening thunderstorms on either coast.

Mountain/Valley and Slope Winds. These local winds are most noticeable during the transition seasons or when monsoonal flow is weak. They augment the land/sea breeze on the eastern coast.

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General Weather. The major contributor to the winter monsoon is the intense Asiatic high. Augmented by the northeasterly flow from the strong and persistent Aleutian low, this high produces a shallow, north-northeasterly flow from Japan to the Indochina peninsula. This cold, dry, polar, continental air mass is modified at low levels as it passes over the relatively warm waters of the East China Sea. Northeasterly winds prevail 70 percent of the time and bring unstable low-level maritime air masses to the region as far south as Hsinchu. In the western coastal plains, northerly low-level winds prevail 70 percent of the time. Above the shallow, northeast monsoonal flow, westerlies prevail. A shallow inversion is usually found between 5,250 feet (1,600 meters) and 7,000 feet (2,100 meters). Polar frontal passage can produce significant amounts of precipitation, mainly in northern Taiwan.

This is the dry season for most of Taiwan; however, maximum cloudiness and almost continuous light rain, drizzle, and fog are observed on most days in the northern coastal plains and neighboring windward slopes. In the western coastal plains, northerly flow allows only a limited amount of rainfall, mainly in the northern sections. Cold monsoonal flow above the warm, southward flowing branch of the North Equatorial Current produces morning advection fog along Taiwan's west coast. Downslope winds on the lee side of mountains contribute to less cloudiness and little precipitation in the central and southern areas of the highlands. Mountain valley visibility is often restricted by morning fog, drizzle, and stratiform clouds that can extend to the ground. Along the east coast, fog is virtually nonexistent because of the strong, unrestricted windflow. Abundant cloudiness, little rain, and strong winds are normal for the Pescadores Islands. Temperatures are mild in the lowlands and in the islands; however, quite cold temperatures are found at the highest elevations with wet snow possible from December through February.

An average of three or four typhoons affect the area, while two or three actually cross Taiwan annually. Typhoons affecting the region from November through April, although possible, are very unlikely. October typhoons that approach from the southeast over the warm Philippine Sea bring heavy rain, flooding, and wind damage to the east coast. They quickly lose intensity as they cross the rugged, thickly forested eastern and central highlands. Typhoons approaching from the southwest move over the relatively warm Taiwan Strait and cause torrential rainshowers, flooding, and wind damage to the western coastal plains and the Pescadores Islands.

Sky Cover. At most locations, there is little diurnal variation in the occurrence of low ceilings (see figure 5-2). There is a gradual increase in low cloudiness at most locations as the season progresses. In the event of a typhoon, areas in its track will experience widespread low cloudiness.

Northern Coastal Plain. Abundant low, mainly stratocumulus, clouds form in the unstable maritime air over the East China Sea. Strong, northeast monsoonal flow advects these low clouds onshore, which contributes greatly to the overcast sky conditions seen throughout much of the day in the plains. Ceilings occur 80 percent of the time at local noon in January. Ceilings below 3,000 feet occur more than 60 percent of the time at most locations. A 30 to 50 percent frequency of ceilings less than 1,000 feet is common. Taipei, blocked from monsoonal flow by the Sung Shan (mountain) to the north, experiences less low cloudiness. Other locations which are similarly shielded from monsoonal flow also have less cloud cover.

Western Coastal Plains. Northerly monsoonal flow around the northwest extension of the Chung-yang Shan-mo and over the Taiwan Strait advects low cloudiness to the northern areas. Downslope winds over the southwestern foothills of the Chung-yang Shan-mo result in considerably less low cloudiness south of Pingtung. The polar front occasionally stagnates for days over southern Taiwan, bringing periods of low ceilings to the south. Ceilings below 3,000 feet occur less than 40 percent of the time, while ceilings below 1,000 feet seldom occur in the plains.

Central and Eastern Highlands. Strong, northeast monsoonal flow advects low clouds from the plains onto the windward mountain slopes. Additional low cloudiness on the northern slopes, which can extend to the ground, is provided by upslope moisture advection. Morning low cloudiness is often found in the mountain and river valleys. At elevations above the monsoonal flow, less cloudiness is observed as the drier westerlies prevail. Considerably less low cloudiness is found on the lee sides of mountains. This is particularly true on the lee side of the Chung-yang Shan-mo, where downsloping leads to adiabatic warming and drying of the air. Ceilings below 3,000 feet occur less frequently, north to south, along the eastern coast.

Pescadores Islands. The north-northeasterly flow (because it picks up moisture over the Taiwan Strait) produces abundant low cloudiness throughout most of the season. The percent frequency of ceilings below 3,000 feet is normally over 60 percent in the islands. By the end of the season, Makung Air Base averages ceilings below 1,000 feet about 50 percent of the time.

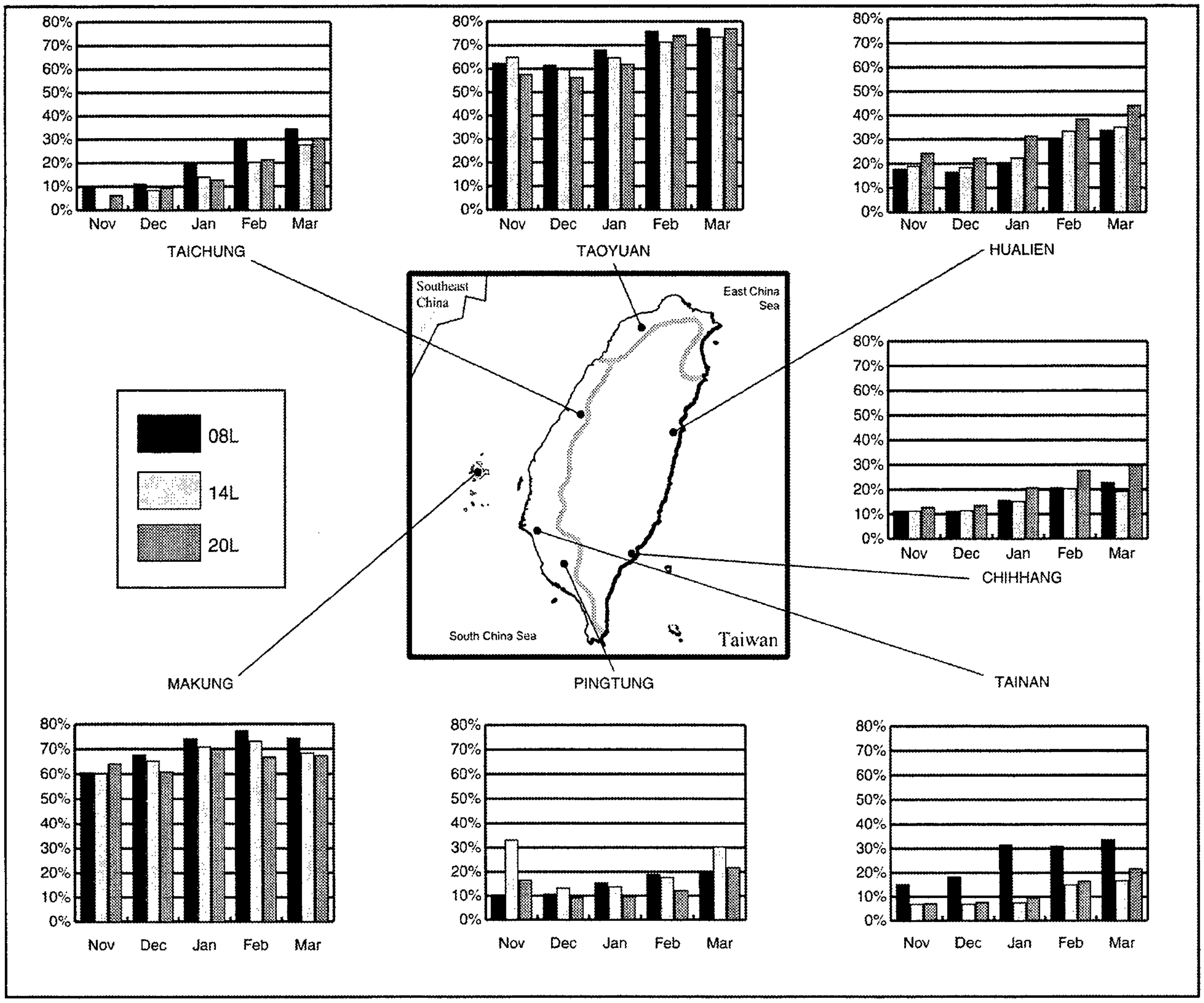


Figure 5-2. Winter Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent ceilings below 3,000 feet based on location and diurnal influences.

Visibility. Low visibility increases in the plains and highlands as the season progresses, regardless of the time of day (see Figure 5-3).

Northern Coastal Plains. The combination of advection fog, rain, and drizzle generally keeps visibility below 4,800 meters 25 to 45 percent of time during the morning hours and about 20 percent of the time in the afternoon and evening. The lowest visibility is normally found in less exposed areas of the forest and marshlands because the still air keeps moisture available. Visibility can be greatly reduced when a Taiwan low develops over the northern plains.

Western Coastal Plains. Early morning visibility is often reduced to less than 4,800 meters, primarily by advection fog. This low morning visibility may occur more than 60 percent of the time at some isolated locations. With the aid of the normally present shallow inversion, afternoon and evening haze restricts visibility about 30 to 50 percent of the time in the industrial cities. Visibility below 4,800 meters in haze, blowing dust (which occurs mainly in the northern sections), and smoke occurs about 10 to 20 percent of the time.

Central and Eastern Highlands. Terrain plays an important role in determining visibility in the highlands. The northern windward slopes commonly have visibility below 4,800 meters in fog and rain, where cloud bases at ground level often produce visibility below 1,600 meters. Radiation and/or advection fog contributes to the low morning visibility found in the mountain and river valleys. On the lee of mountains, especially in the south, and in the eastern coastal cities, visibility is seldom below 4,800 meters. At the east coast city of Taidong, no fog has been reported in the 20 years since the weather station opened in 1977, primarily because of unrestricted exposure to strong monsoonal flow.

Pescadores Islands. The strong north-northeasterly winds across Taiwan Strait primarily account for the 90 percent occurrence of unrestricted visibility this season. Rain and morning fog occasionally obscure visibility.

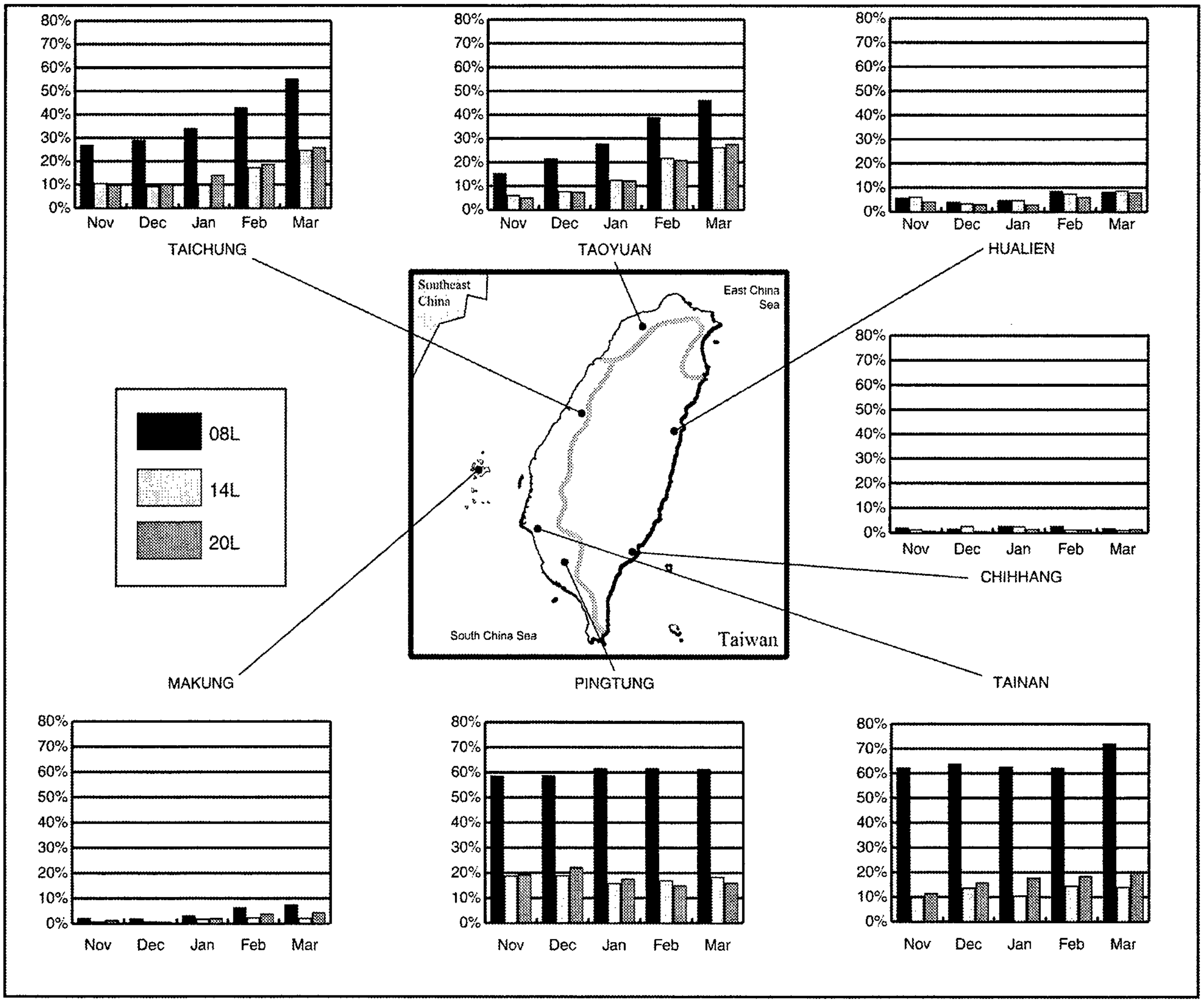


Figure 5-3. Winter Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Most areas exposed to the monsoonal flow at night, with the exception of the east coast, experience a lighter, northerly wind. Typhoons bring destructive winds of 64 knots or greater as they move onshore. Figure 5-4 shows the effects of the northeast monsoonal flow in January for selected coastal cities.

Northern Coastal Plains. Winds are generally northeast at 10 to 15 knots and gusty in the plains. Taoyuan Air Base experiences winds greater than 15 knots about 30 percent of the time. At Taipei, on the lee side of the Sung Shan Mountains, a light, easterly wind is observed.

Western Coastal Plains/Pescadores Islands. The Taiwan Strait has its wind maximum in winter because the prevailing wind direction causes a funneling effect between China's coastline and Taiwan. Strong, northerly surface winds prevail along the west coast, while even stronger north-northeasterly winds are found on the islands. There is a 30 percent frequency of winds greater than 25 knots at Makung Air Base. Except over Taiwan Strait, or anywhere during the passage of a tropical cyclones, surface wind speeds in excess of 35 knots are seldom reported.

Central and Eastern Highlands. A rather strong northeasterly wind occurs on the windward slopes, while a lighter, terrain-deflected wind is observed below 6,000 feet (1,800 meters) in the central and southern highlands. Funneling winds between parallel northeast-southwest oriented mountains often reach speeds in excess of 25 knots. One area where funneling occurs is over the Cho-shui Hsi River valley in northeast Taiwan. Above 6,000 feet (1,800 meters), the northeast monsoonal flow loses identity, and the upper-level westerlies prevail at speeds of 15 to 30 knots. Because of the steep slopes along the eastern coast, land/sea breezes, augmented by mountain/valley breezes, influence wind direction during the day, and often dictate direction at night.

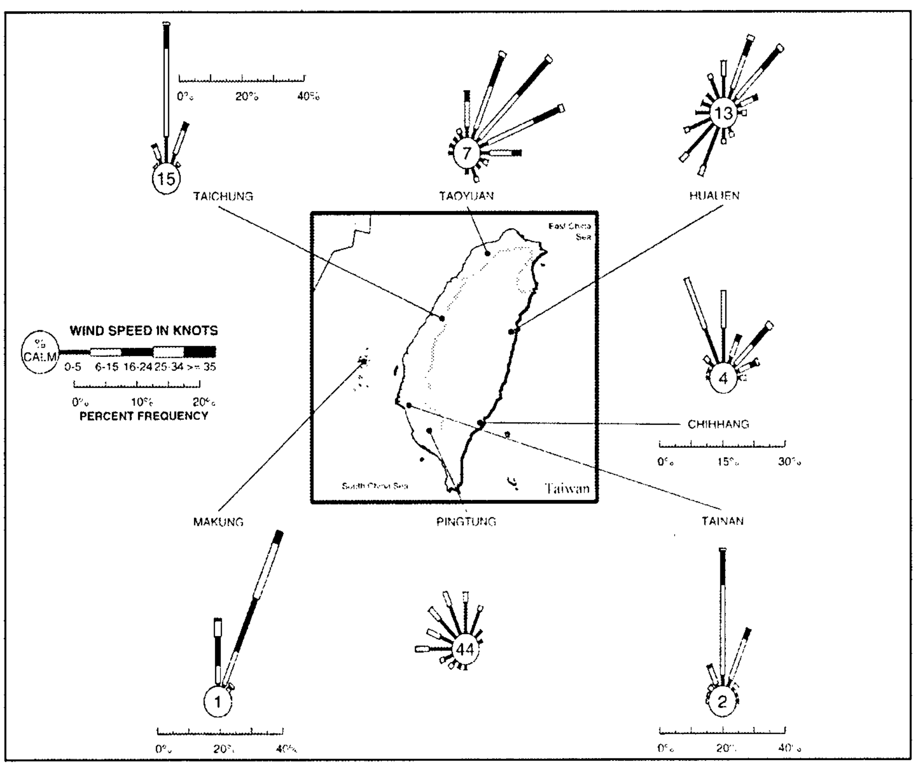


Figure 5-4. January Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location. Separate pecent frequency scales are given for locations that differ from the main legend.

Upper-Air Winds. North-northeast monsoonal winds, averaging less than 20 knots, reach heights of 6,000 to 8,000 feet (1,800 to 2,400 meters) at the beginning of the season. These winds diminish in vertical extent as the season progresses. They reach only 2,000 to 6,000 feet (570 to 1,800 meters) by March. West-southwest winds prevail from 700 mb to 300 mb and increase in speed with height. The west-southwest to east-northeast subtropical jet progresses southward to as close as 5° N from December through February. Figure 5-5 shows 300-mb winds in excess of 90 knots occur 30 percent of the time in January over Makung. Over northern Taiwan, 300-mb wind increase to more than 120 knots about 10 percent of the time. The frequency of strong winds at all levels decreases southward through Taiwan. Winds are variable at 10 to 30 knots above 100 mb.

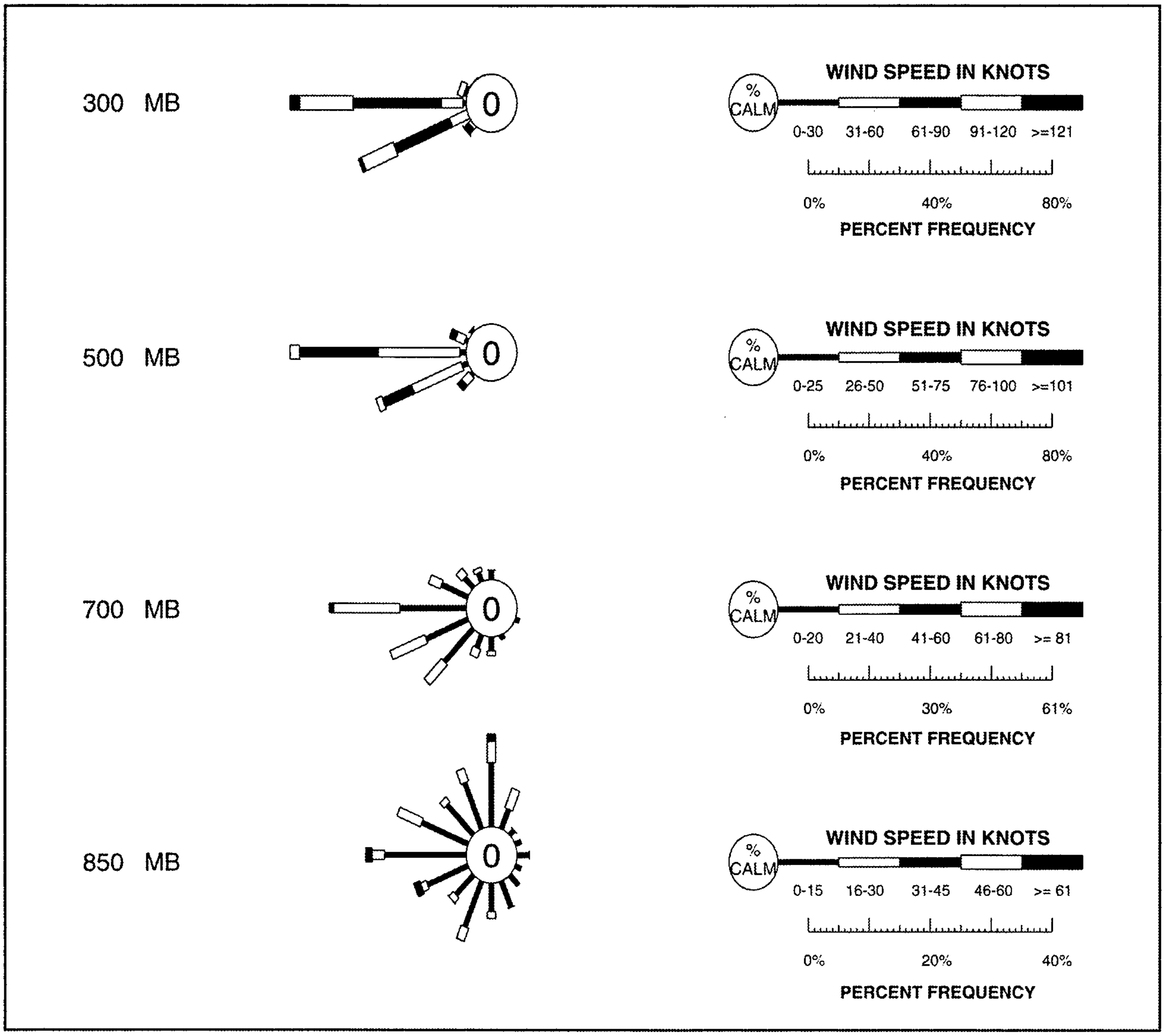


Figure 5-5. January Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 at Makung AB, Taiwan. Note: Each wind rose has a tailored legend.

Precipitation. Significant amounts of rainfall occur on the windward mountain slopes during polar frontal passage (see Figure 5-6). Orographic lifting increases the extent and duration of precipitation on the windward slopes and may induce convective activity. The number of days with rainfall at most coastal stations tends to increase as the season progresses (see Figure 5-7). By March, the number of days per month with rainfall range from more than 20 in the northeast to only about 5 along the southwestern coast. In the unlikely event of a typhoon this season, mean rainfall amounts range from 150 to 500 mm.

Although thunderstorms can occur in any region throughout the year, they are less frequent this season. Thunderstorm formation in Taiwan is normally a product of surface heating and/or orographic lifting; formation is rarely induced by the polar front. The shallow inversion above the monsoonal flow limits the amount of convective activity. Thunderstorms are more likely to occur during the early and later months of the season when surface heating is stronger.

Northern Coastal Plains. Exposure to northeast monsoonal flow leads to generally light, continuous precipitation from advected stratiform clouds. Taiwan lows periodically bring continuous rainfall to the plain. January's mean rainfall amounts are in excess of 400 mm on the windward slopes near Chilung. In contrast, the nearby city of Taipei, which is not exposed to monsoonal flow, averages only 87.8 mm in January.

Western Coastal Plains. The intensity of precipitation diminishes as the northerly monsoonal flow deposits its moisture inland. Downslope winds over the southwest foothills of the Chung-yang Shan-mo lead to almost negligible rainfall amounts south of Pingtung. January's mean precipitation decreases from about 50 mm to less than 25 mm from north to south.

Central and Eastern Highlands. Winter rains are enhanced by topographic lifting on the northern slopes. Most of the moisture in the air is precipitated out on these slopes. This makes for minimum rainfall amounts on the lee side of the central and southern highlands. Snowfall is commonly seen on the highest mountain peaks from December to February, but rarely seen below 4,000 feet (1,200 meters).

Pescadores Islands. This is the dry season for these relatively flat islands. They usually receive only light rain from advected stratocumulus clouds.

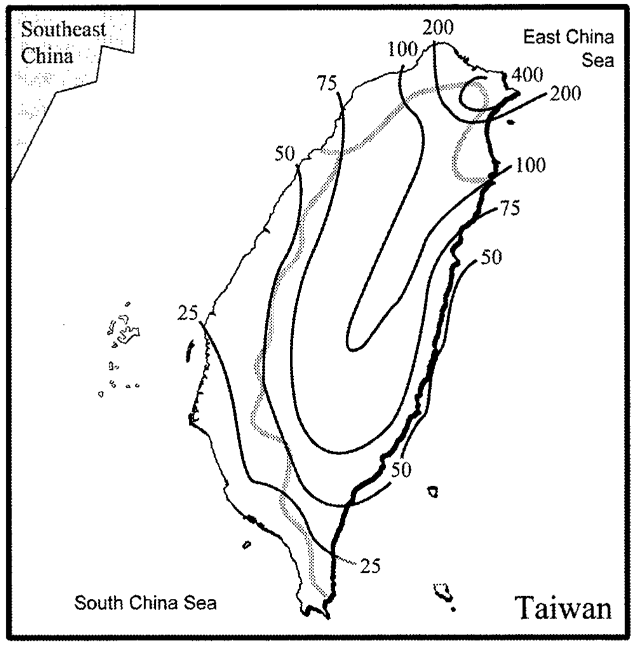


Figure 5-6. January Mean Precipitation (mm). The figure shows mean precipitable water amounts in the region.

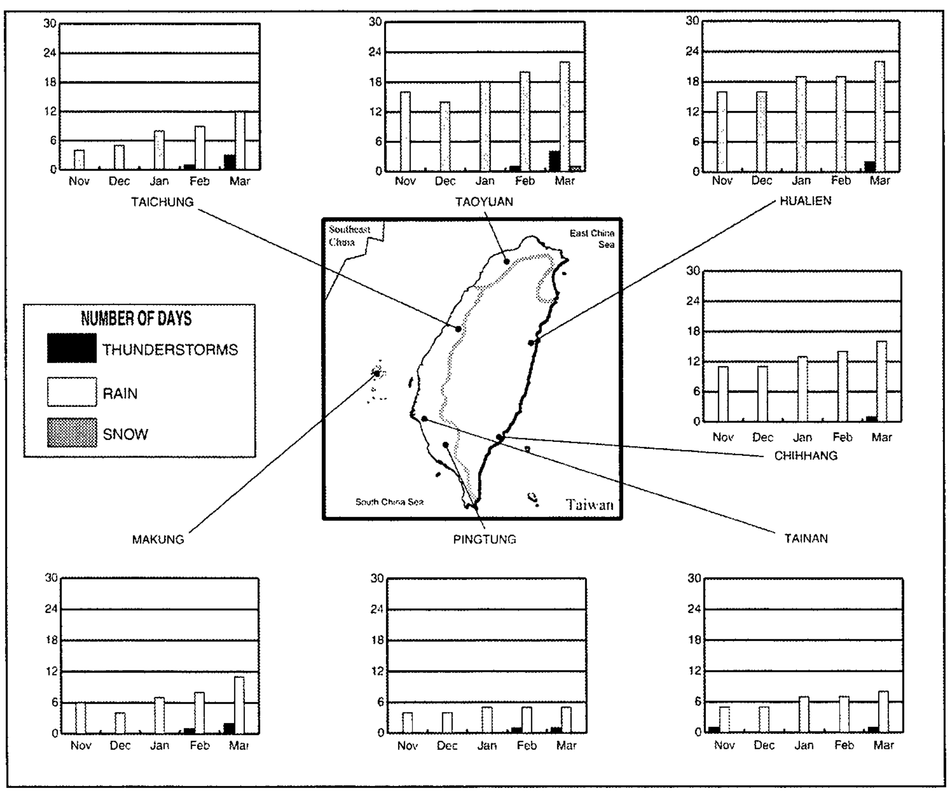


Figure 5-7. Winter Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for representative locations in the region.

Temperatures. Temperatures during this season vary regionally, depending primarily on elevation, latitude, proximity to China's mainland, and the surrounding water temperatures. Mean temperatures in the lower elevations are generally 9° to 18°F (5° to 10°C) warmer at the beginning then at the end of the season. Extreme minimum temperatures in January range from about 50°F (10°C) on the southern coast to a minus 5°F (15°C) at the highest elevations.

Northern and Western Coastal Plains/Pescadores Islands. Modification of the cold, polar continental air by the surrounding waters, combined with long daytime hours at these low latitudes, leads to mild temperatures along the coastal plains and neighboring islands. January's mean maximum temperatures range from around 59° to 77°F (15° to 25°C) from the northern to southern coasts (see Figure 5-8). The moderating influences of the surrounding waters contribute to mean minimum coastal temperatures of only 53° to 64°F (12° to 18°C) from north to south (see Figure 5-9). Because the Pescadores Islands are located closer to China's mainland, and the surrounding water temperatures are slightly cooler than Taiwan's adjacent west coast, temperatures are normally 5° to 9°F (3° to 5°C) lower.

Central and Eastern Highlands. The coldest mean maximum temperatures, around 39°F (4°C), occur in January and February at the highest elevations of the central highlands. Slope temperatures are generally warmer on the lee side of mountains. Temperatures normally decrease with elevation at a rate slightly greater than the moist adiabatic lapse rate, as the shallow inversion is less noticeable over the highlands. Part of this is also because air cools dry adiabatically in the drier air above the inversion.

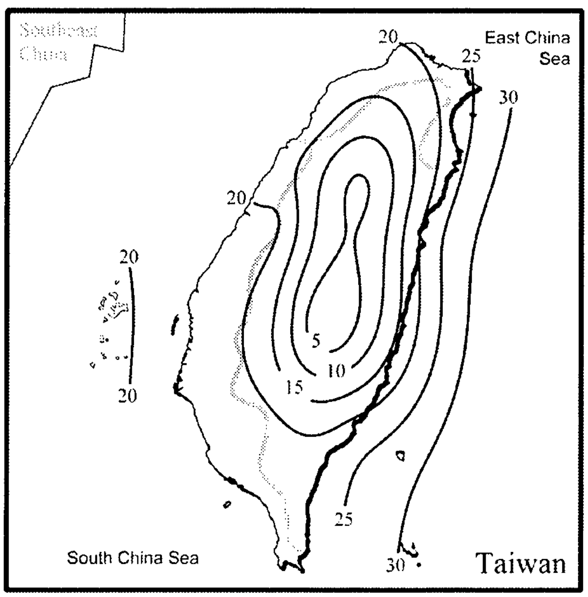


Figure 5-8. January Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for the coolest month of the winter. Mean maximum temperatures during other winter months may be higher, especially at the beginning and ending of the winter season.

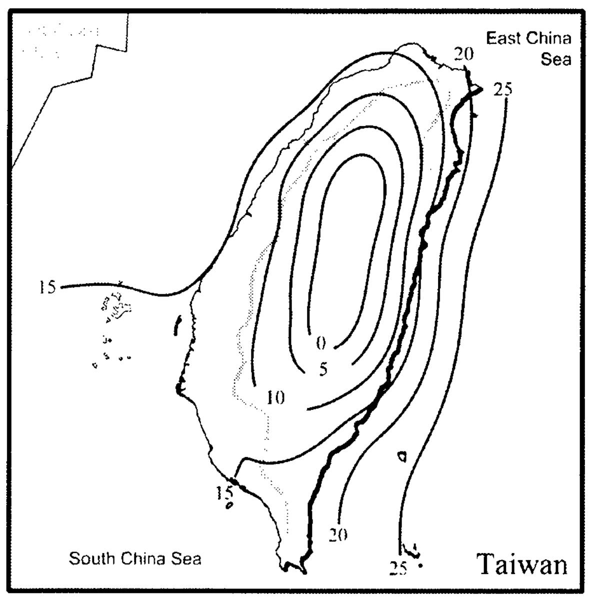


Figure 5-9. January Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the coolest month of winter. Mean minimum temperatures during other winter months may be higher, especially at the beginning and ending of the winter season.

Hazards. Although rare, typhoons still represent a very serious hazard to Taiwan. They can approach from either the southeast or southwest, late in the year. All regions in Taiwan need to remain on alert for the destructive winds and torrential rains accompanying these huge storms.

In January, the freezing level over northern Taiwan is at or below 5,250 feet (1,600 meters) about 10 percent of the time. On rare occasions, it is found as low as 2,000 feet (600 meters). During these situations, expect light rime icing in clouds and moderate clear icing in precipitation. Under normal conditions, expect rime icing in clouds from about 11,000 feet (3,500 meters) up to 26,000 feet (8,000 meters) during the midseason.

Moderate-to-severe turbulence can occur over the mountain ranges and at low levels over the Taiwan Strait.

Local flooding, including flash flooding, is most likely to occur in low-lying areas in the extreme northeast.

Trafficability. About three-fourths of Taiwan consists of rough, rugged mountain ranges. The rest of Taiwan has flat, rolling plains and hills. Included in the plains and hills are some terraces and heavily dissected areas. The soils of the mountainous areas are shallow and coarse-grained. The soil consists of gravels and sands with rock outcroppings. Movement conditions are unsuitable at all times due to steep slopes and forests.

In the plains and hills, the slopes range from level to moderately steep. Soils are predominantly fine-grained, but some sizable areas of coarse- and fine-grain mixtures exist, especially in the southwest. Movement conditions in these areas range from fair to unsuitable during the dry season. Movement is restricted mainly by stream banks, some marshy areas, agricultural practices (mainly rice paddies), forests, and severely dissected terrain.

General Weather. A gradual change in weather occurs during this transition season from the winter to the summer monsoon. In late April, the Asiatic high begins to weaken with the coming of warmer weather. The upper-level subtropical ridge expands westward as it moves northward. The mei-yu front tracks slowly northward, in response to the northern movement of the axis of the subtropical ridge. This front brings periods of continuous rain and occasional intense convective activity to southern Taiwan by mid-May. By the end of the season, the last vestiges of the winter monsoon are gradually replaced by the increasing surges of the summer monsoon in all areas except northern Taiwan. The increasing pressure gradient between the developing Asiatic low over Pakistan and the strengthening North Pacific high creates a southwesterly low-level jet over northern portions of the South China Sea late in the season. This jet normally strengthens portions of the mei-yu front, and eventually transports additional moisture to southern Taiwan. Northern Taiwan experiences continuous low cloudiness and light rain throughout most of the season. Surface wind speeds gradually decrease as the winter monsoon weakens. The strengthening summer monsoon replaces the winter monsoon in central and southern Taiwan by June. The instability and low-level convergence associated with the mei-yu front provides considerable cloudiness and heavy rainfall to southern and central areas late in the season. The southwest monsoonal surges bring warm, moist, unstable air to the south and provides additional rainfall.

An average of two or three typhoons cross Taiwan in a year. Typhoons are unlikely to affect the region in April. Typhoons in May normally approach from the southeast over the warm Philippine Sea. They bring heavy rain, flooding, and wind damage to the east coast but lose intensity as they cross the rugged, thickly forested eastern and central highlands. Typhoons approaching from the southwest move over the relatively warm Taiwan Strait and cause torrential rainshowers, flooding, and wind damage to the western coastal plains and the Pescadores Islands.

Sky Cover. In the event of a typhoon, areas in its track will experience widespread low cloudiness.

Northern Coastal Plains. Continual abundant cloudiness, with little diurnal change, occurs throughout the season. The weakening northeast monsoonal flow advects mainly stratocumulus clouds onshore, although daytime surface heating allows cumulus clouds to build as the shallow inversion breaks. Daytime ceilings below 3,000 feet occur about 60 percent of the time, while ceilings below 1,000 feet occur about 30 percent of the time. Sites less exposed to monsoonal flow, like Taipei, have less low cloudiness (see Figure 5-10).

Western Coastal Plains. The northern areas report ceilings below 3,000 feet about 30 percent of the time throughout the day. Ceilings below 1,000 feet occur less than 5 percent of the time. As moist, unstable, southwesterly monsoonal surges replace the northeasterly flow in southern Taiwan, the frequency of ceilings below 3,000 feet increases. This increase is even more evident by mid-May, as passage of the mei-yu front tends to lower ceilings. Little change in diurnal cloudiness occurs except along the southwestern coast where most low ceilings occur in the afternoon due to enhanced low-level convergence provided by the sea breeze.

Central and Eastern Highlands. Although the northeast monsoonal flow weakens, the exposed northern slopes continue to experience considerable low cloudiness. Upslope moisture advection often produces ceilings below 1,000 feet in these areas. Cumulus clouds build on the windward slopes of the central mountains, while much less cloudiness is observed on the lee side. Low cloudiness normally remains well after passage of the slow, northward moving mei-yu front. By late season, lower ceilings occur more frequently on the southern slopes because of the upslope moisture advection provided by the strengthening summer monsoon. Primarily in response to an early afternoon sea breeze on the east coast, lower ceilings occur more frequently in the late afternoon or evening.

Pescadores Islands. The rather strong, northeast monsoonal flow continues to advect stratocumulus clouds onshore throughout most of the season. The frequency of ceilings below 3,000 feet is normally greater than 50 percent throughout the day. Ceilings below 1,000 feet are reported about 30 percent of the time. Ceilings remain low during and well after passage of the mei-yu front, regardless of the late season wind shift.

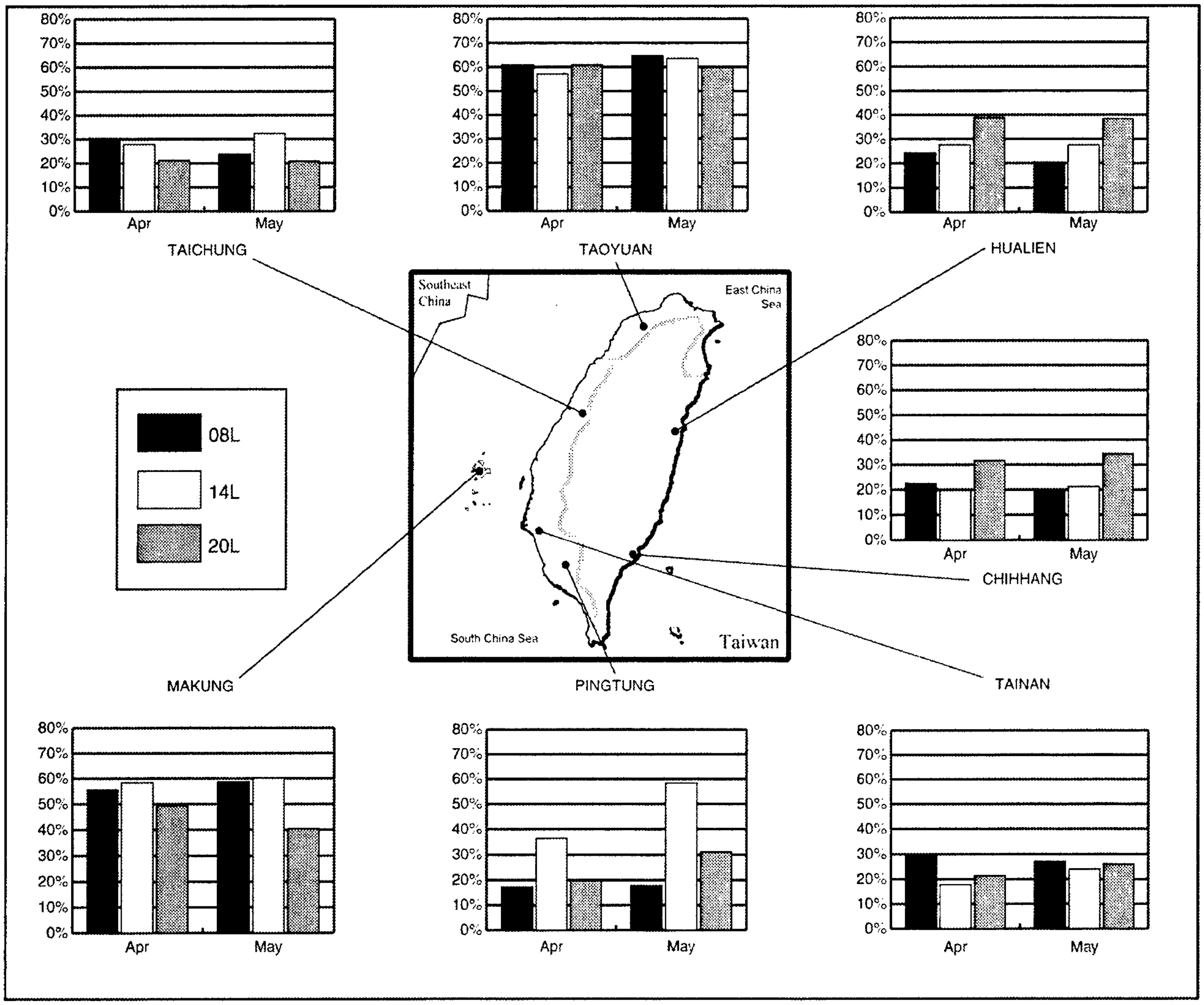


Figure 5-10. Spring Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northern Coastal Plains. Visibility below 4,800 meters occurs 30 to 50 percent of the time in the morning and 10 to 30 percent of the time in the afternoon and evening (see Figure 5-11). Although rain restricts visibility less this season, the somewhat lighter breezes enhance fog formation, especially over the marshlands.

Western Coastal Plains. Advection fog, haze, and smoke in the industrial cities continue to restrict visibility. After the first good spring rainshower, visibility usually improves. The lowest visibility occurs in the morning at most locations. Visibility improves in May as the shallow inversion associated with the winter monsoon lifts. Heavy rainshowers associated with the mei-yu front restrict visibility for short periods of time.

Central and Eastern Highlands. Fog, rain, and low clouds frequently reduce visibility below 4,800 meters along the northern slopes and in the mountain and river valleys. Heavy rainshowers restrict visibility as the mei-yu front progresses northward. In the eastern coastal cities, visibility below 4,800 meters occurs less than 10 percent of the time.

Pescadores Islands. Except during periods of rain, or on the occasional foggy mornings, the relatively strong surface winds keep visibility unrestricted.

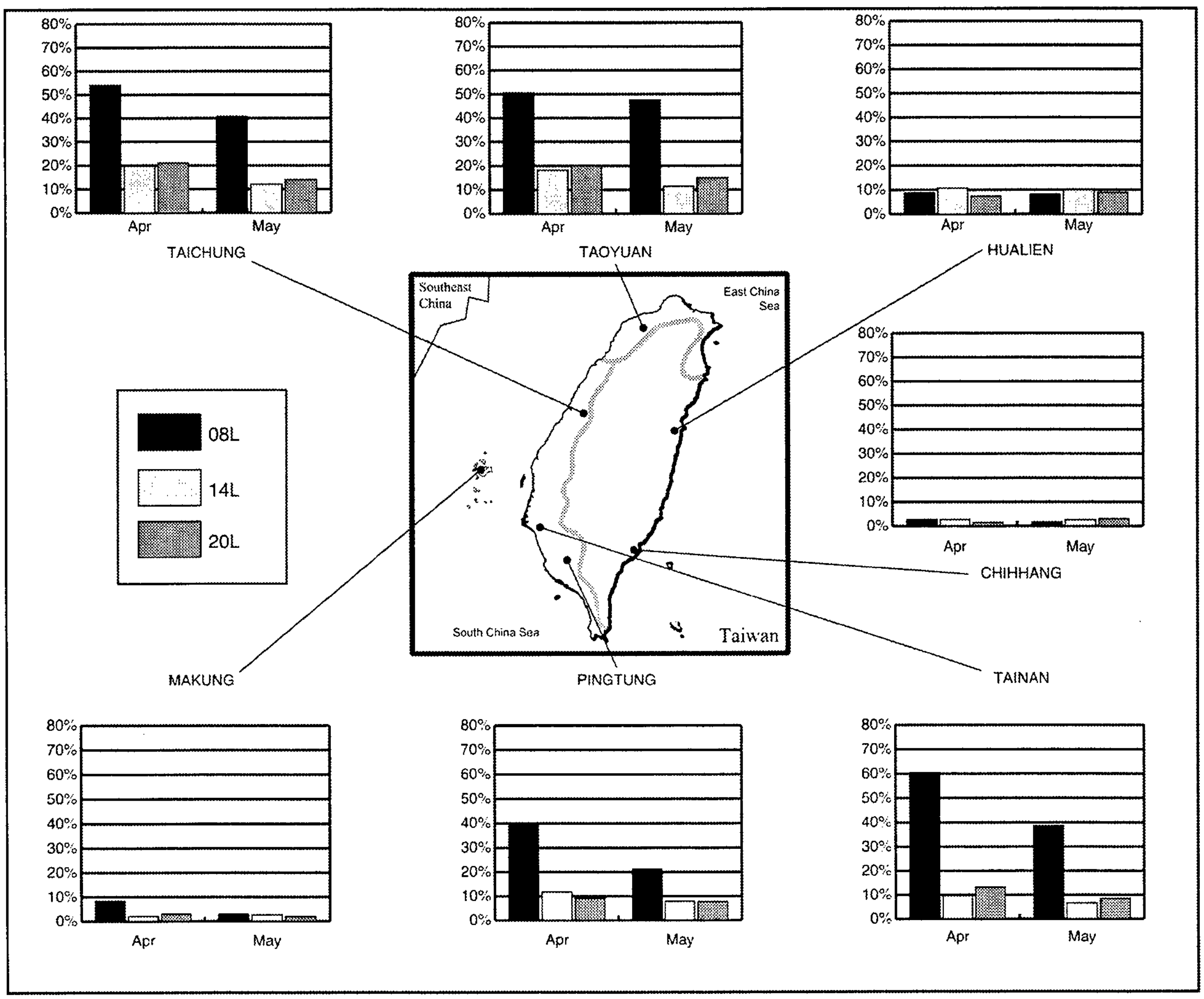


Figure 5-11. Spring Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibilities below 4,800 meters bases on location and diurnal influences.

Surface Winds. As the eastern extension of the mei-yu front meanders northward through the southern and central portions of Taiwan late in the season, surface wind direction and speed vary accordingly (see Figure 5-12). Most locations have lighter winds at night. Only very intense typhoons can maintain their full force after crossing the mountains.

Northern Coastal Plains. Gusty, northeasterly winds at about 10 knots prevail throughout most of the day into early May. A lighter, northeasterly wind of 6 to 10 knots occurs for the rest of the month. A light, normally northeasterly breeze occurs at night.

Western Coastal Plains. Northerly winds at less than 10 knots occur from April to early May. Lighter winds occur in the south. By the middle to end of May, most inland stations in the south have a light, southwest monsoonal surge. Land/sea breezes dictate wind flow along the coast.

Central and Eastern Highlands. Northeasterly winds prevail on the northern slopes throughout most of the season. Variable winds occur at lower elevations in the central areas because of local topography deflections and the changing monsoonal surges. West-southwest winds at less than 15 knots occur at elevations above 6,000 feet (1,800 meters). The southern slopes experience a moderate southwesterly flow by mid-May, as the low-level jet strengthens. In the eastern coastal cities, northeasterly winds prevail during the day. A light mountain breeze often dictates direction at night.

Pescadores Islands. Funneling of the monsoon flow through the Taiwan Strait keeps wind speeds relatively strong over the islands. Speeds in excess of 25 knots occur less than 10 percent of the time in April. They are seldom reported in May because the winter monsoon loses identity. By the end of May, a moderate southerly component wind begins after passage of the mei-yu front.

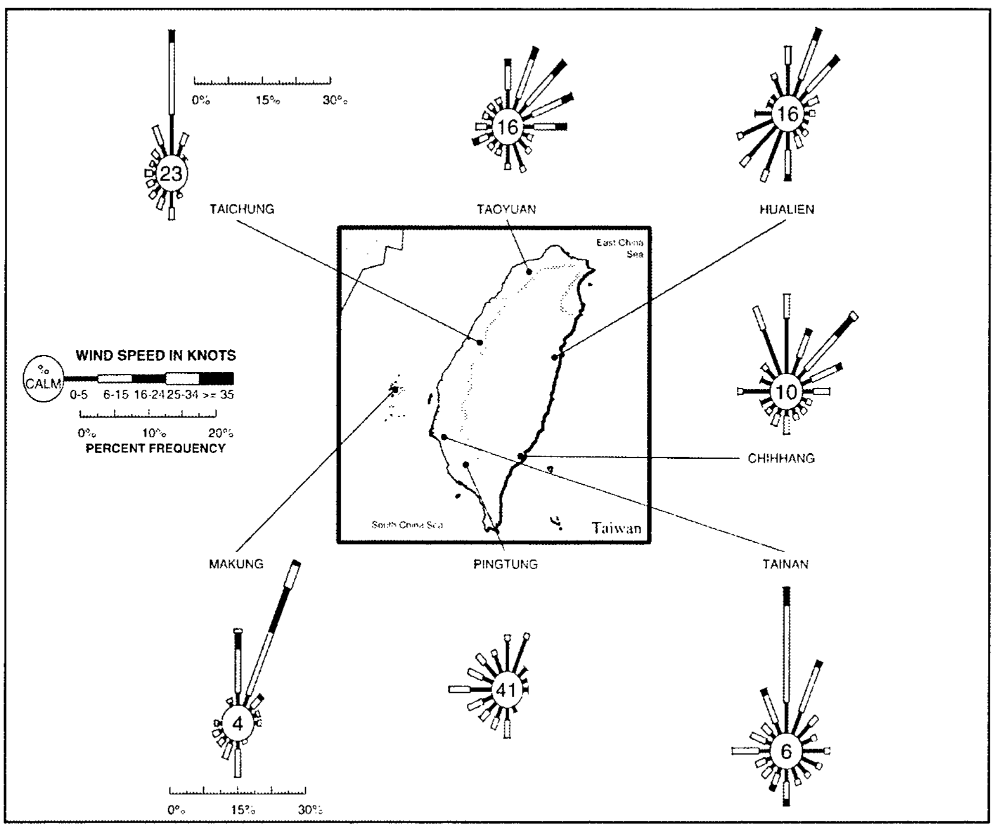


Figure 5-12. April Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location. Separate percent frequency scales are given for locations that differ from the main legend.

Upper-Air Winds. April's 850-mb winds are south-southwesterly 10 to 20 knots. By mid-May, the southwesterly low-level jet increases speeds to 25 knots. As the subtropical jet migrates northward, upper-level west-southwest winds diminish somewhat. Wind speeds in excess of 60 knots occur 30 percent of the time over Makung AB at 300 mb (see Figure 5-13). Northern Taiwan's winds are 10 to 15 knots stronger at this level. Above 60,000 feet (19 km), winds are predominantly easterly at 10 to 30 knots.

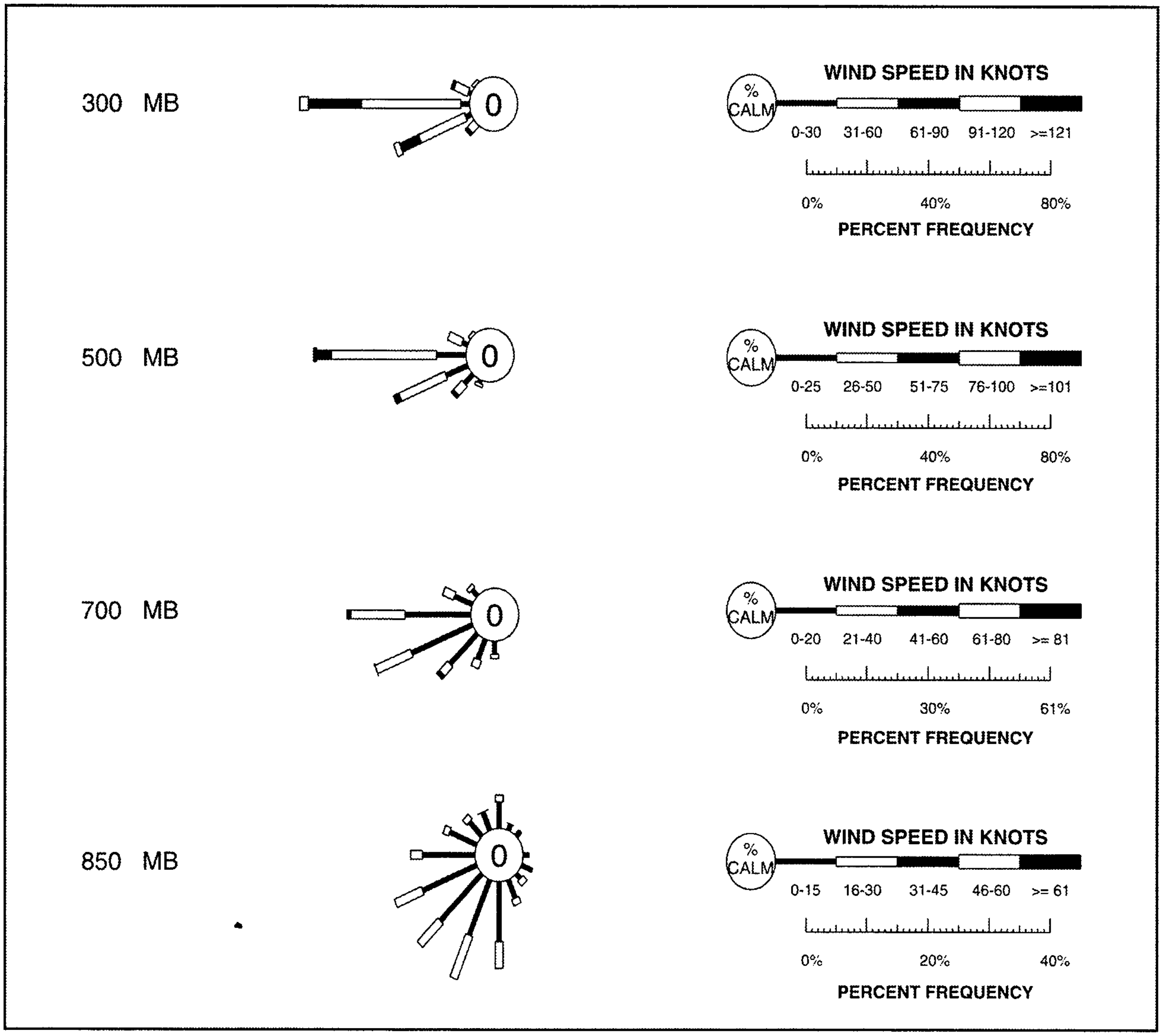


Figure 5-13. April Upper-Air Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Makung AB, Taiwan. Note: Each wind rose has a tailored legend.

Precipitation. A widespread precipitation pattern occurs in the spring season (see Figure 5-14). For all but the northeast tip of Taiwan, higher rainfall amounts occur during April than monthly amounts in the previous season. Rainfall reaches at least 75 to 100 mm at most coastal locations. Zhaori, which is located on the western slope of Mt. Nenggao, receives the greatest amount (438 mm) in April. Batongguan, on the western slope of Mt. Yushan, averages 396 mm for the month of April. In the event of a typhoon, mean rainfall amounts from the storm range from 150 to 500 mm. Intense embedded thunderstorms often accompany typhoons.

Northern Coastal Plains. Low-level instability, established by the cool breezes of the winter monsoon over the relatively warm East China Sea, produces almost continuous light rain and drizzle until midseason.

Less than 5 thunderstorm days occur on average in April and May. In April, polar frontal activity triggers these storms. In May, daytime surface heating in combination with orographic lifting induces convective activity. May's mean precipitation increases to over 200 mm throughout the plain.

Western Coastal Plains. In northern areas, northerly flow over the relatively warm Taiwan Strait creates enough atmospheric instability to produce light rain 10 to 15 days each month. In the south, mean precipitation in May is about twice that of April. Heavy rainshowers and continuous rain accompany the mei-yu front in May.

Thunderstorms in April through mid-May are mainly a product of surface heating and low-level convergence of the sea breeze and monsoonal flow. The deep, convective cells at the leading edge of the mei-yu front, and/or convective activity before and after frontal passage, contribute to the increasing frequency of thunderstorms as the season progresses in the southern and central areas of the plains (see Figure 5-15).

Central and Eastern Highlands. April's largest precipitation totals are found in the central highlands.

Showers and thunderstorms are common on the northern slopes due to the lifting of stratocumulus clouds advected onshore by the northeast monsoon. Orographic lifting of the mei-yu front and upslope advection of the succeeding warm, unstable monsoonal flow on the southern slopes accounts for the more than 400 mm of rainfall in May.

Pescadores Islands. The islands receive about 10 to 15 days of rainfall each month. Precipitation amounts tend to be greater in May, especially when the mei-yu front passes through late in the season. Thunderstorms associated with the mei-yu front can reach the islands late in the season.

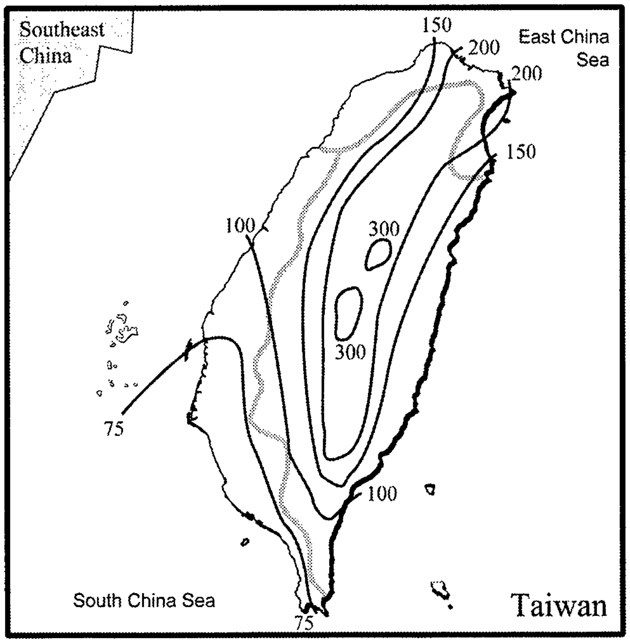


Figure 5-14 April Mean Precipitation (mm). The figure shows mean precipitable water amounts in the region.

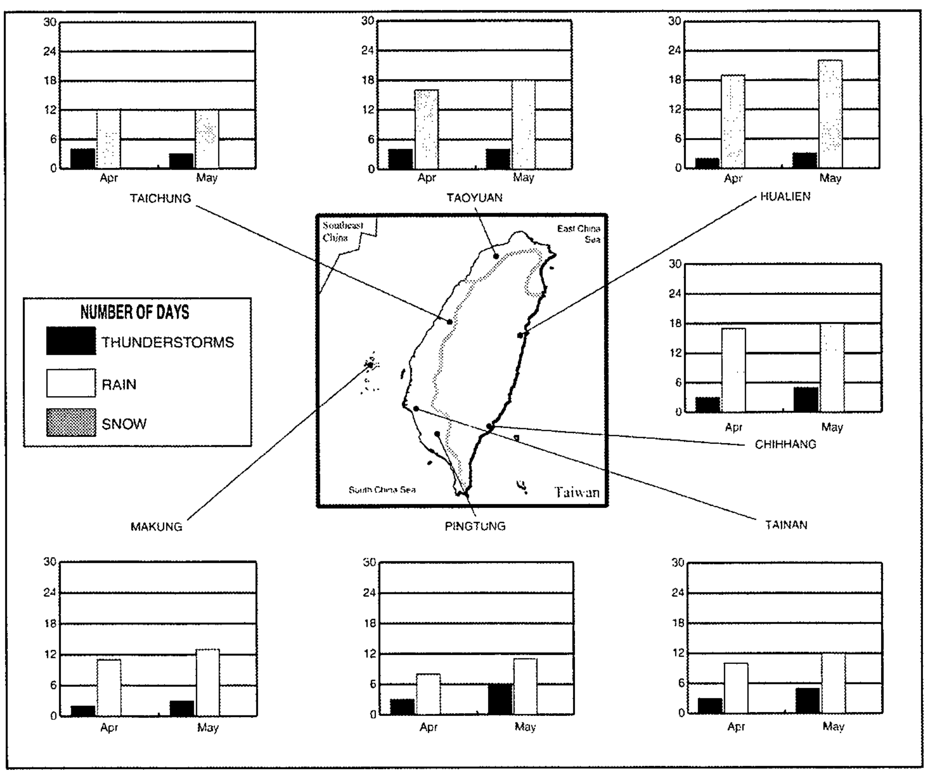


Figure 5-15 Spring Mean Monthly Precipitation and Thunderstorms Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for representative locations in the region.

Temperatures. The spring transition season brings a slight warming trend to Taiwan. In May, temperatures at most locations are generally 2° to 5°F (1° to 3°C) higher than those in April (see Figures 5-16 and 5-17).

Northern and Western Coastal Plains. Mean maximum temperatures range from about 71°F (22°C) in the north to near 86°F (30°C) in the south. Mean minimum temperatures are generally near 68°F (20°C).

Central and Eastern Highlands. Mean maximum temperatures in April decrease with elevation to near 50°F (10°C) at the highest peaks. The mean low temperatures at these peaks usually remain above freezing.

Pescadores Islands. The islands remain slightly cooler than the adjacent Taiwan coast. The mean maximum temperature is about 75°F (24°C), while the mean minimum temperature is near 68°F (20°C).

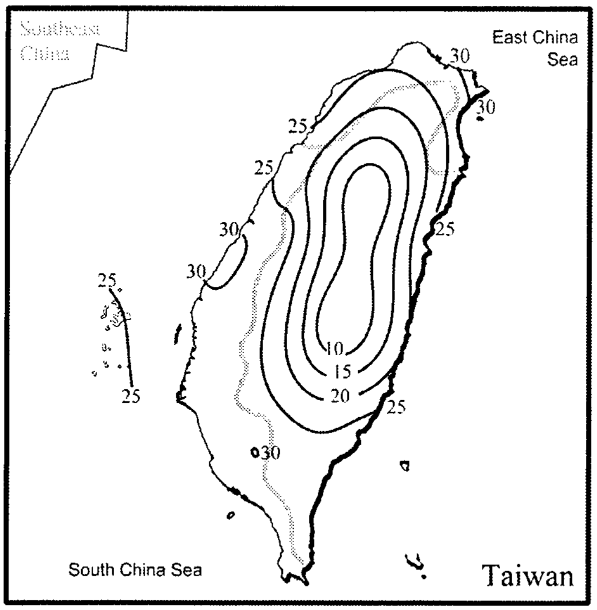


Figure 5-16. April Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for the coolest month of spring. Mean maximum temperatures in May will be slightly higher.

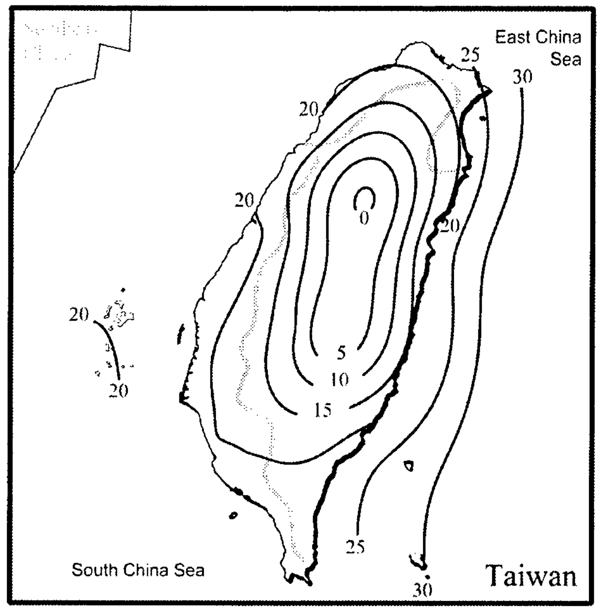


Figure 5-17. April Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the coolest month of spring. Mean minimum temperatures in May will be slightly higher.

Hazards. The destructive winds and torrential rains accompanying typhoons are a very significant hazard to Taiwan. An average of three per year pass over, or very close to the island. They usually approach from the southeast in May. All regions need to be on the alert for typhoons.

Heavy rainfall associated with the mei-yu front can cause flooding and flash flooding anywhere along the frontal zone. Low-lying areas in the southwestern foothills and near rivers in the southwestern plains are most vulnerable to flooding during this season.

Trafficability. About three-fourths of Taiwan consists of rough, rugged mountain ranges. The rest of Taiwan has flat, rolling plains and hills. Included in the plains and hills are some terraces and heavily dissected areas. The soils of the mountainous areas are mostly shallow and coarse-grained. The soil consists of gravels and sands with many rock outcroppings. Movement conditions are unsuitable at all times because of steep slopes and forests.

In the plains and hills, the slopes range from level to moderately steep. Soils are predominantly fine-grained, but some sizable areas of coarse and fine-grain mixtures exist, especially in the southwest. Movement conditions in these areas range from fair to unsuitable during the dry season. Movement is restricted mainly by stream banks, some marshy areas, agricultural practices (mainly rice paddies), forests, and severely dissected terrain.

General Weather. By June, the Asiatic thermal low is centered over south central Asia. The low acts with the northwestward expanding North Pacific high to strengthen the southwest monsoonal flow. By early to mid-June, the slow-moving mei-yu front has already dumped significant precipitation on northern Taiwan, and is now tracking towards Japan. A southwesterly low-level jet over the South China Sea transports additional moisture to southern Taiwan.

In this maritime tropical air, huge cumulonimbus clouds develop over the western coastal plains and neighboring windward slopes. Roughly two-thirds of Taiwan's annual precipitation falls during this season. The southwestern slopes receive some of the heaviest rainfall in the Far East. Although the mean position of the NETWC is 5 to 10 degrees south of Taiwan in July, it periodically meanders northward to bring heavy rains to the southwestern plains and windward slopes in July and August. The Taiwan convergence zone extends from the NETWC as it makes its most northern appearance in July. This zone triggers some convective activity east of Taiwan. Temperatures in the plains are quite hot; more comfortable conditions exist at the higher elevations. Mountain valley visibility is often restricted by morning fog.

Typhoons are most likely to affect the region during this season. Typhoons approaching from the southeast over the warm Philippine Sea bring heavy rain, flooding, and wind damage to the east coast before losing intensity as they cross the rugged, thickly forested eastern and central highlands. Typhoons approaching from the southwest move over the relatively warm Taiwan Strait and cause torrential rainshowers, flooding, and wind damage to the western coastal plains and the Pescadores Islands.

Sky Cover. Coastal land and sea breezes, along with local mountain and valley breezes, have their greatest influence on sky cover during this season. In the event of a typhoon, areas in its track will experience widespread low cloudiness.

Northern Coastal Plains/Central and Eastern Highlands. Before passage of the mei-yu front through northern Taiwan, stratocumulus clouds advected onshore keep ceilings low most of the day. Low cloudiness usually remains well after passage of the slow moving front. Upslope moisture advection produces huge cumulonimbus clouds on the southwestern slopes. Low ceilings are less common on the east coast as the season progresses, mainly due to increased downsloping by the strengthening southwest monsoonal flow in July and August. On the northern and eastern coasts, ceilings below 3,000 feet are more likely in the late afternoon and evening, as downslope winds delay the arrival of the sea breeze front.

Western Coastal Plains. Diurnal changes in sky cover are most noticeable on the west coast. After the late morning sea breeze, a marked increase in low ceilings occurs in the early to midafternoon. As the season progresses, surface heating becomes stronger and the southwest monsoonal flow strengthens as it converges with the local sea breeze. The combination increases the occurrence of ceilings below 3,000 feet (see Figure 5-18).

Pescadores Islands. Cooler water temperatures make the air more stable during daytime over the sea. This causes the diurnal variation of sky cover over the smaller islands to be opposite of that over Taiwan. Sky cover over the smaller islands is usually less at 1400L than at 0800L.

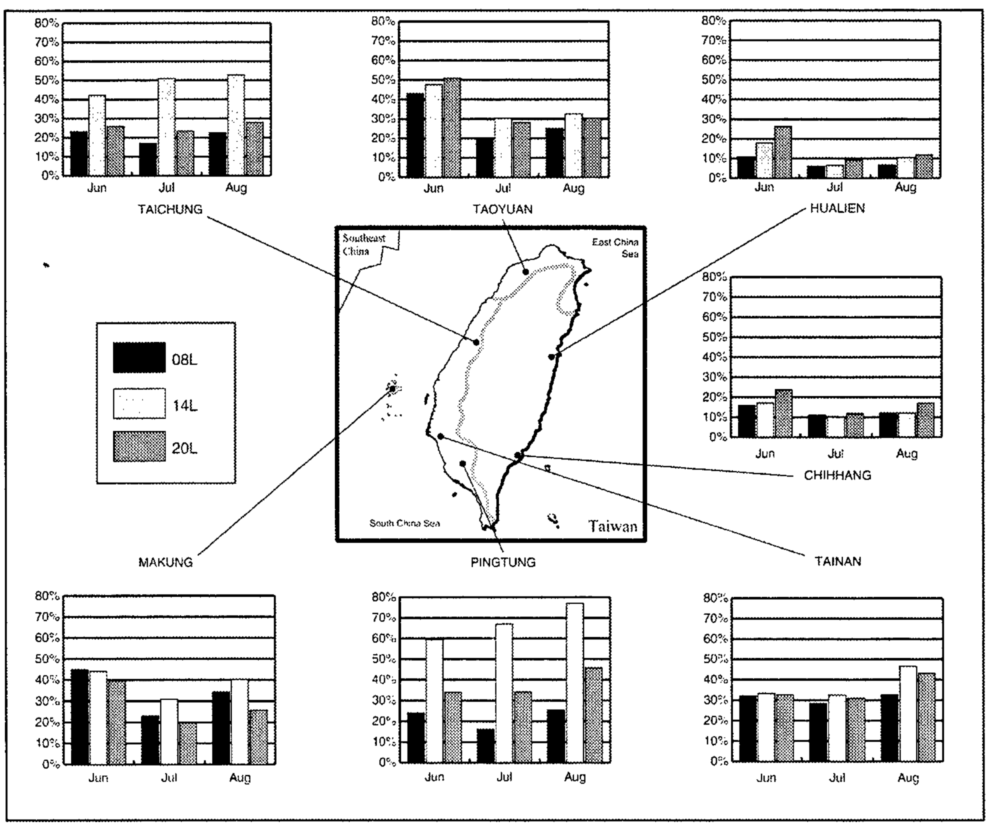


Figure 5-18. Summer Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northern and Western Coastal Plains. Visibility less than 4,800 meters occurs less than 20 percent of the time in most coastal cities during this season (see Figure 5-19). Restricted visibility is common in June as the mei-yu front passes through the region. Light rain, drizzle, or advection fog restricts visibility during the morning hours. Haze or rainshowers obscures visibility in the afternoon and evening. Smoke occasionally reduces visibility below 8,000 meters in the industrial cities.

Central and Eastern Highlands. Before passage of the mei-yu, visibility on the exposed northern slopes is frequently below 4,800 meters in light rain and fog. As the season progresses, visibility becomes less restricted on the northern slopes. Throughout the season, morning radiation fog or low stratus reduces visibility below 1,600 meters in the mountain valleys. Visibility less than 1,600 meters in heavy rainshowers and fog, frequently occurs on the southwest slopes. In the eastern coastal cities, visibility less than 4,800 meters occurs less than 10 percent of the time.

Pescadores Islands. Visibility is usually unrestricted in the relatively flat islands because of the strong winds.

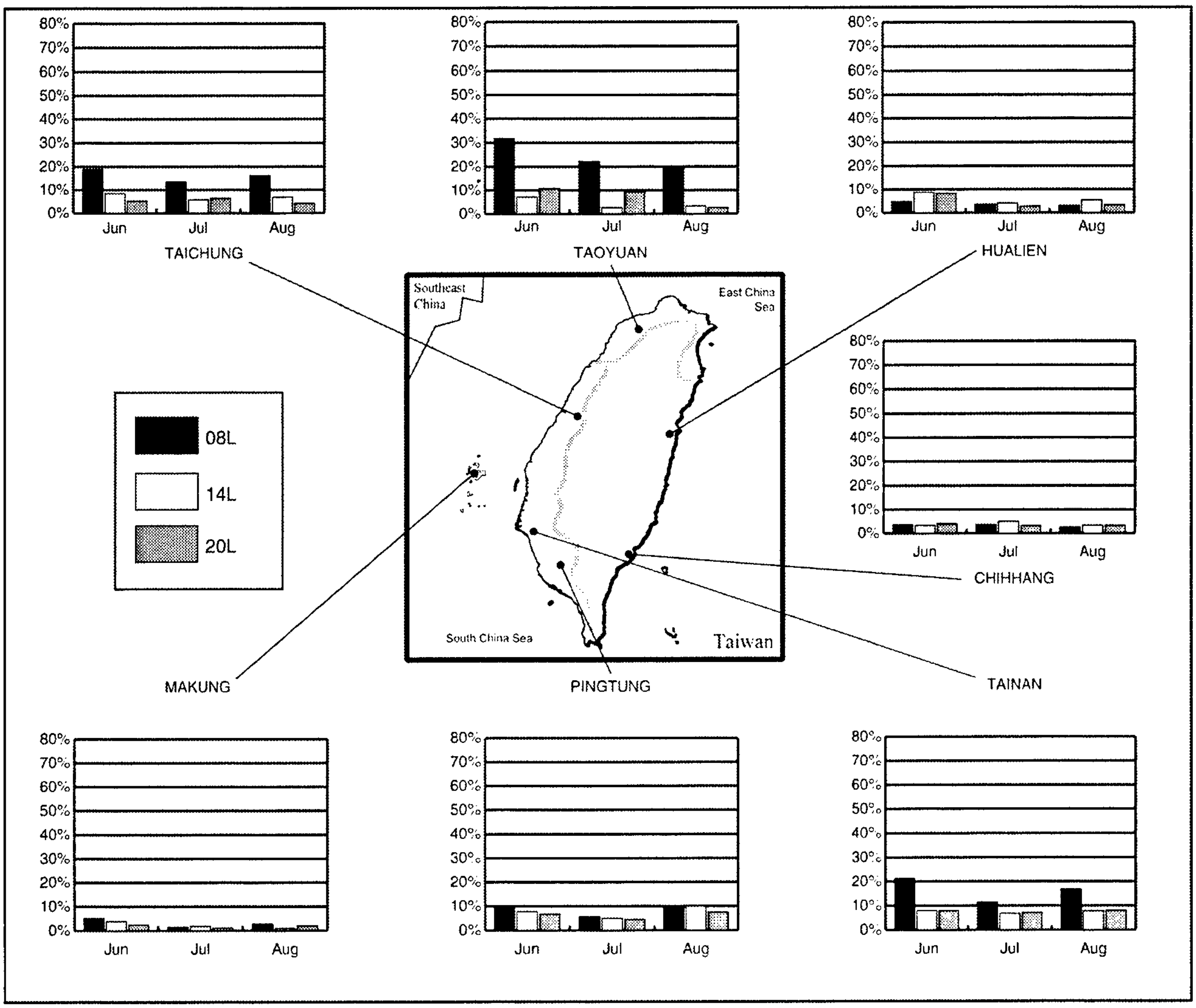


Figure 5-19. Summer Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Summer is the most likely time for typhoons to occur. Maximum gusts of up to 175 knots have been estimated off the coast of Taiwan. Otherwise, gusts in excess of 25 knots occasionally accompany thunderstorms (see Figure 5-20).

Northern and Western Coastal Plains. After passage of the mei-yu front early in the season, the summer monsoon influences surface winds on the coastal plains. The southwest monsoonal flow, however, is not as strong or as persistent as its northeast counterpart. This allows land and sea breezes to influence, and often dictate, wind speed and direction. A late morning sea breeze adds a westerly component to the monsoonal flow on the west coast.

Central and Eastern Highlands. Winds in the mountains are highly dependent on local topographical deflection of the summer monsoon. The southwesterly low-level jet brings 20-knot winds to the southern and western slopes of the highlands. An early afternoon sea breeze on the east coast, augmented by the valley breeze, results in a southeasterly flow of about 6 to 15 knots. At night, winds are either calm or consist of a light offshore flow.

Pescadores Islands. A southwest monsoonal flow of 10 to 15 knots is typical during the day, while a lighter southerly wind is common at night over the islands.

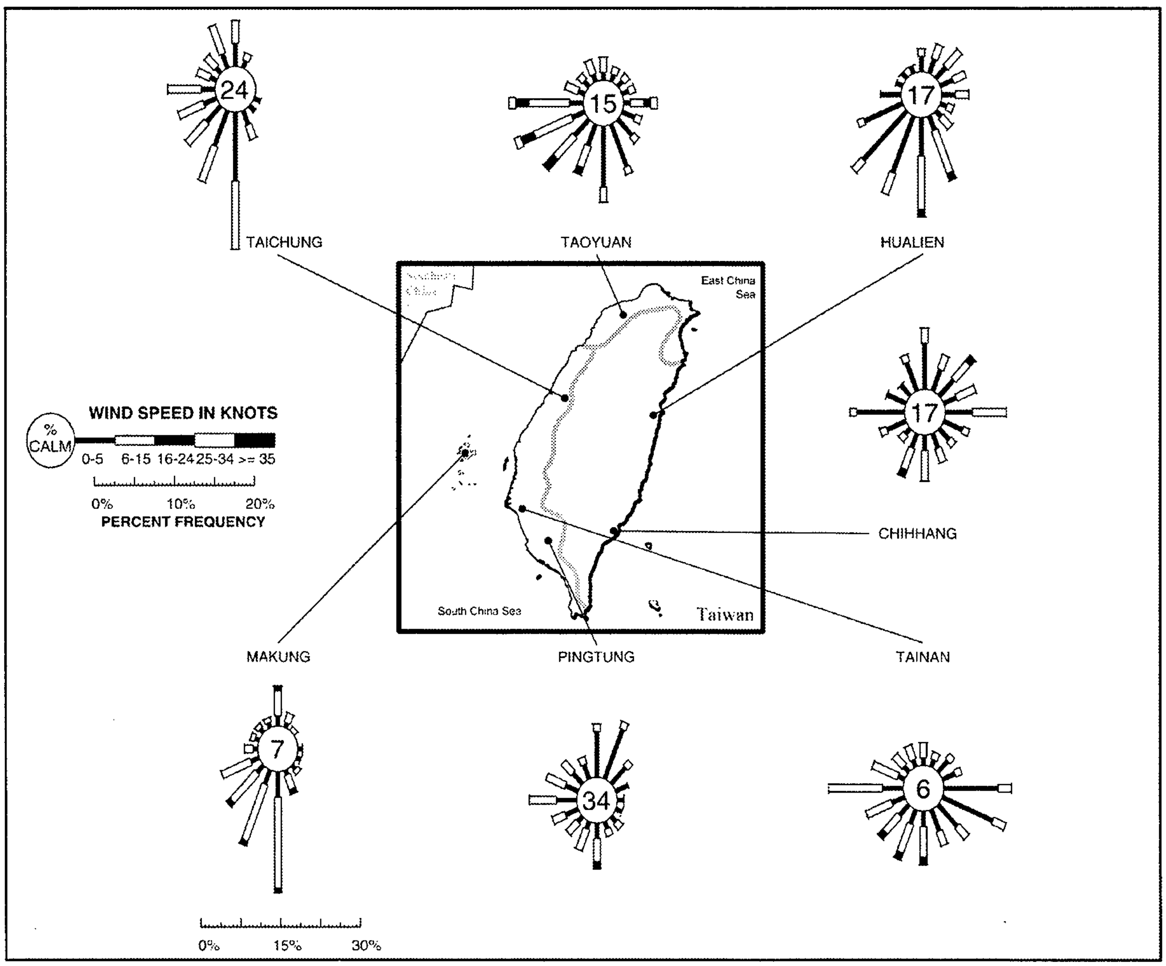


Figure 5-20. July Surface Wind Roses. The figure shows the prevailing wind direction and range of speed based on frequency and location. Separate percent frequency scales are given for locations that differ from the main legend.

Upper-Air Winds. July's strongest upper-level winds occur at the 850-mb level due to the close proximity of the southwesterly low-level jet (see Figure 5-21). South-southwesterly monsoonal flow occurs up to about 700 mb. These winds are generally not as strong or as persistent as their northeast counterparts, and they diminish somewhat over central and northern Taiwan. The tropical easterly jet has its greatest influence on upper-level winds this season. Easterly winds of 20 to 40 knots exist above 300 mb. The strongest winds at all levels will normally be found over southern Taiwan.

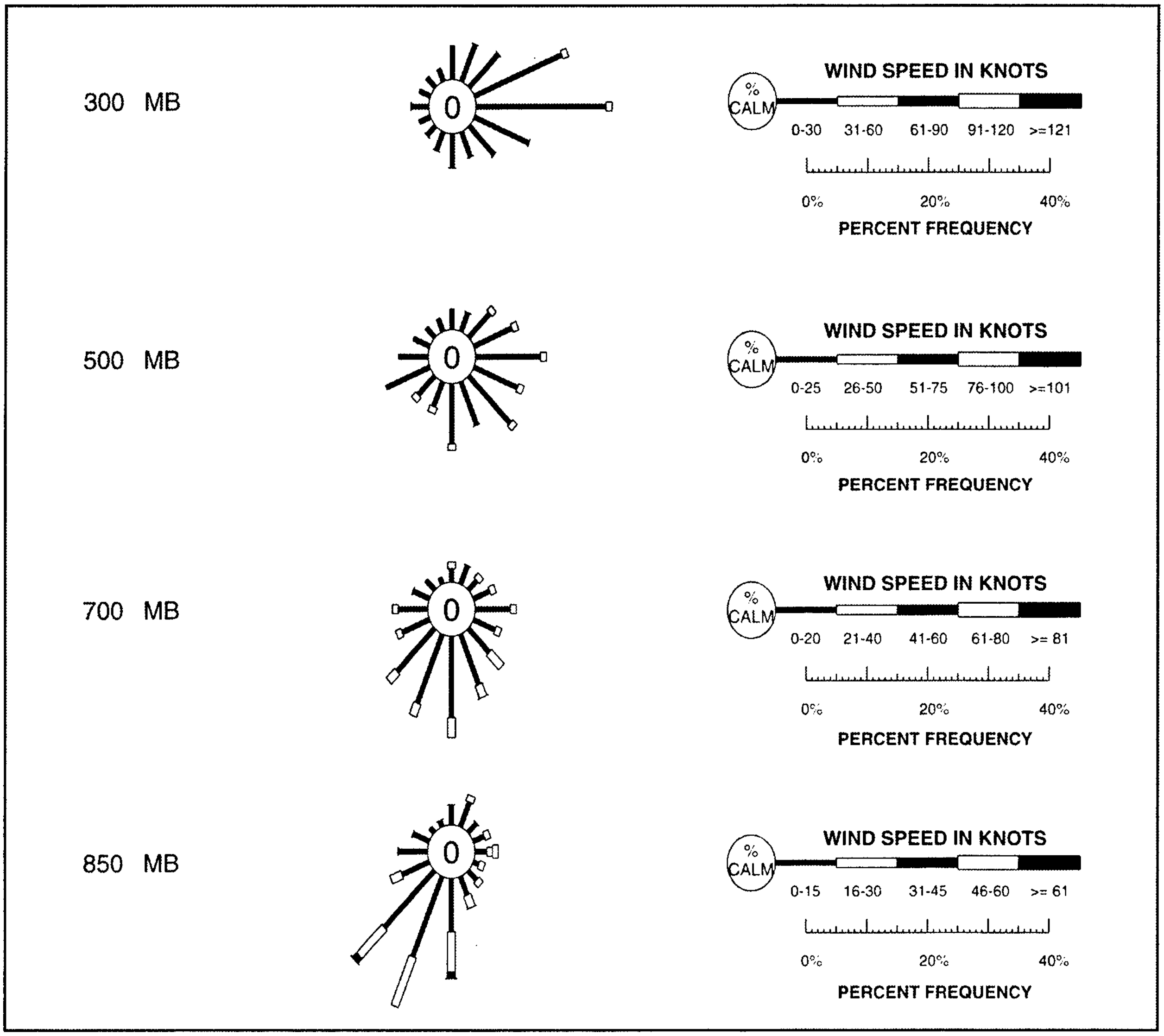


Figure 5-21. July Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Makung AB, Taiwan. Note: Each wind rose has a tailored legend.

Precipitation. Summer brings the wet season to southern Taiwan (see Figure 5-22). Torrential rains accompanying typhoons produce mean precipitation totals ranging from 150-500 mm. The NETWC periodically moves northward in July and August and brings additional convective activity to southern Taiwan. Intense embedded thunderstorms often accompany typhoons.

Northern and Western Coastal Plain/Pescadores Islands. Early in the season, significant rainfall can occur in northern Taiwan as the mei-yu front passes through the area. Rainfall occurs 15 to 20 days per month in the western plains and 10 days per month in the northern plains and on the islands. July's mean precipitation amounts range from less than 200 mm in the islands, to over 400 mm in the southwestern plains. After passage of mei-yu front, coastal showers and thunderstorms form at any time of the day; however, afternoon or early evening is the normal time of occurrence. Strong surface heating and low-level convergence between the monsoonal flow and the daily sea breeze induces convective activity along the coasts and in the islands. Thunderstorm activity increases as the season progresses and the monsoonal flow strengthens (see Figure 5-23).

Central and Eastern Highlands. Orographic lifting of the warm, moist, monsoonal flow on the windward slopes of the Chung-yangShan-Mo produces huge cumulonimbus clouds, often in excess of 50,000 feet. These intense thunderstorms can produce hail, and they contain strong updrafts and dangerous downdrafts. The tropopause is at about 55,000 feet year-round. Almost daily rainfall produces extreme amounts of precipitation, with some areas reporting monthly rainfall totals in excess of 1,000 mm. Amounts less than 300 mm are usually found on the lee side of the range and along the east coast.

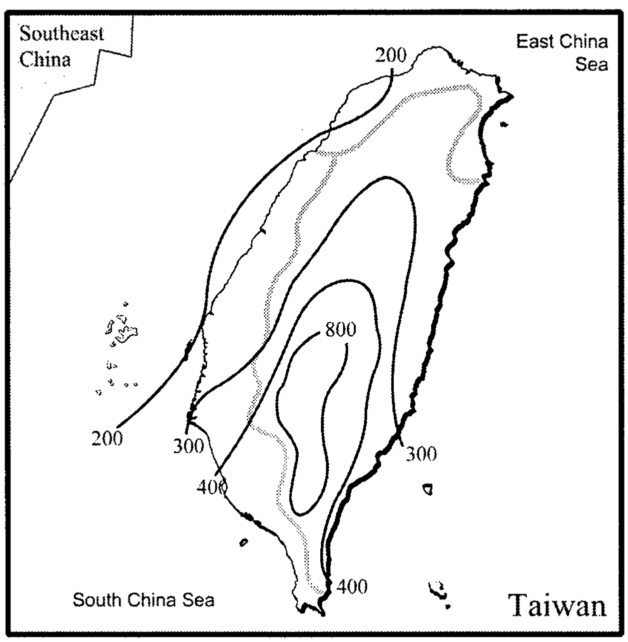


Figure 5-22. July Mean Precipitation (mm). The figure shows mean precipitation amounts in the region.

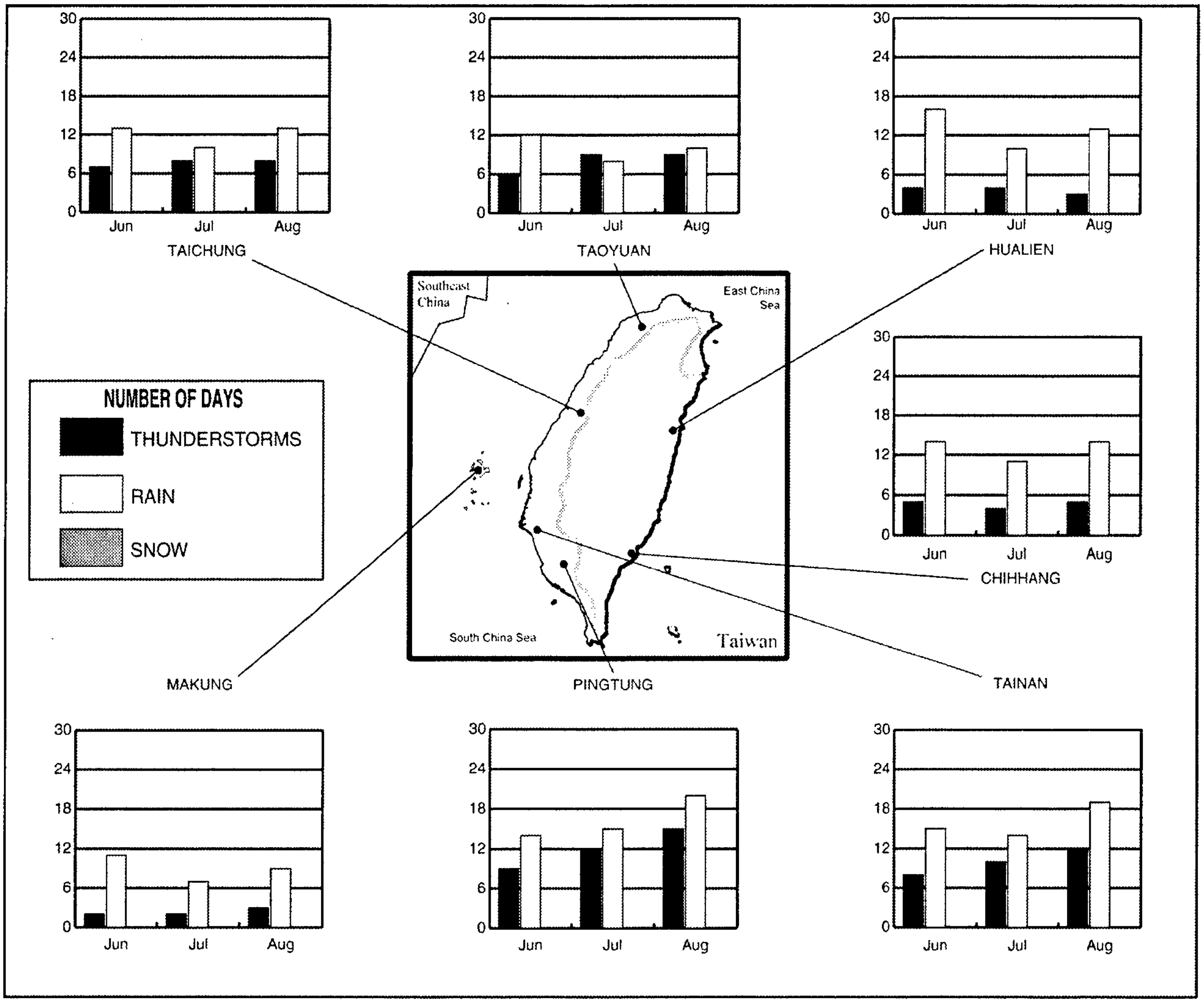


Figure 5-23. Summer Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average seasonal occurrences of rain, thunderstorm, and snow days for the representative locations in the region.

Temperatures. In a place where annual temperature changes are fairly small, this is the hot season. Temperatures in June and August vary only slightly from the July means listed below.

Northern and Western Coastal Plains. July's mean maximum temperatures are generally 86° to 94°F (30° to 35°C) along the entire coast (see Figure 5-24). Mean minimum temperature is near 77°F (25°C) along the coast (see Figure 5-25).

Central and Eastern Highlands. Extreme maximum temperatures, usually reached in July or August along the coast and September at the higher elevations, range from 66° to 102°F (19° to 39°C). Mean minimum temperatures in the highlands range from about 68°F (20°C) at 4,000 feet (1,200 meters) to less than 50°F (10°C) at the highest elevations.

Pescadores Islands. Cooler temperatures are reported on the islands because of the moderating influences of the surrounding waters. Mean maximum temperatures are near 86°F (30°C), while July's mean minimum temperatures are about 77°F (25°C).

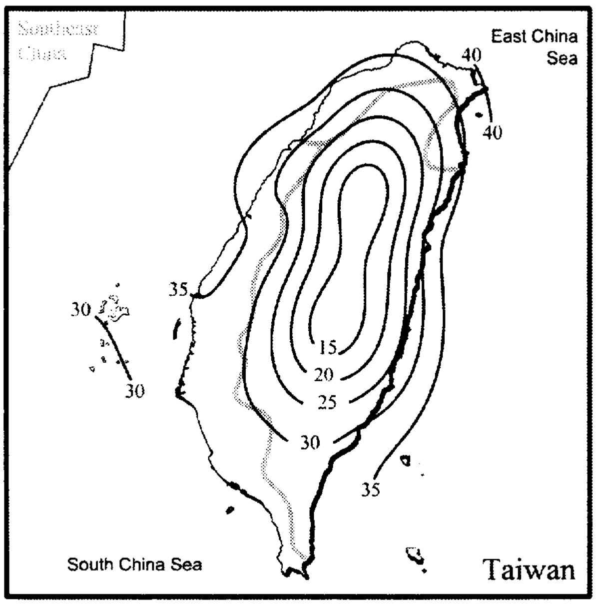


Figure 5-24. July Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for the warmest month of summer. Mean maximum temperatures during other summer months may be lower, especially at the beginning and ending of the summer season.

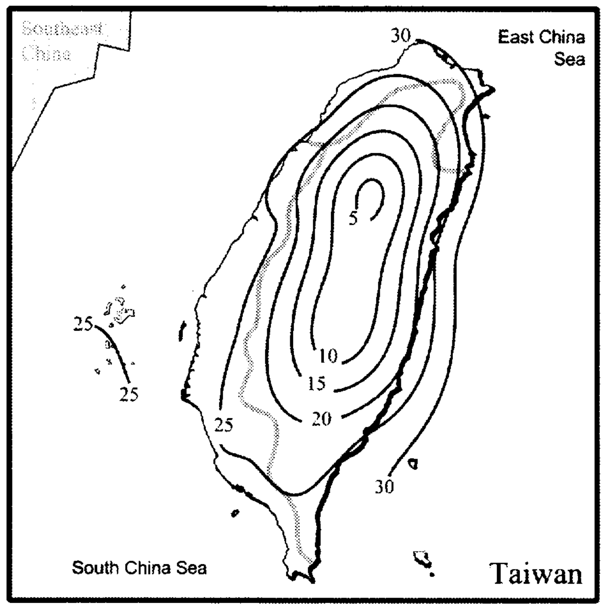


Figure 5-25. July Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for the warmest month of summer. Mean minimum temperatures during other summer months may be lower, especially at the beginning and ending of the summer season.

Hazards.

This is the major season for typhoons. An average of three per year pass over or near Taiwan. They usually approach from the southeast during this monsoon season, which makes eastern coastal cities extremely vulnerable. However, all regions in Taiwan need to be on the alert for these extremely dangerous storms. The greatest danger to life with typhoons is related to the quality of buildings. The evacuation of aircraft and personnel to safe havens may be necessary.

Extensive flooding often accompanies typhoons. Heavy daily rainfall in low-lying areas in the Chung-yang Shan-Mo and along streams in the neighboring plains often results in flooding. Huge thunderstorms produces localized flash flooding that frequently washes out roads.

Turbulence. Moderate-to-severe turbulence can be found in and around thunderstorms. Light-to-moderate low-level turbulence is found over the strait and the highlands.

Aircraft Icing. Light, clear icing is possible in cumuliform clouds above 15,000 feet.

Trafficability. About three-fourths of Taiwan consists of rough, rugged mountain ranges. The rest of Taiwan has flat, rolling plains and hills. Included in the plains and hills are some terraces and heavily dissected areas. The soils of the mountainous areas are mostly shallow and coarse-grained. The soil consists of gravels and sands with many rock outcroppings. Movement conditions are unsuitable at all times because of steep slopes and forests.

In the plains and hills, the slopes range from level to moderately steep. Soils are predominantly fine-grained, but some sizable areas of coarse- and fine-grained mixtures exist, especially in the southwest. Movement conditions in these areas range from fair to unsuitable during the dry season. Movement is restricted mainly by stream banks, some marshy areas, agricultural practices (mainly rice paddies), forests, and severely dissected terrain.

General Weather. A southerly descent of the axis of the upper-level ridge prevents any further creation of weather by the NETWC. At the same time, thermally induced high pressure sets up over eastern China at 850 mb and below. This high is primarily responsible for the early northeast monsoonal surges as the weaker southwest monsoonal flow subsides. This is not a smooth transition of low-level airflow, but a rather abrupt change, characterized by several back and forth exchanges of monsoonal surges. Because the winter monsoon is stronger and more persistent than its summer counterpart, the fall transition season is shorter than that of spring and normally ends by mid-October. By season's end, a shallow inversion sets up at about 7,000 feet (2,100 meters) in northeast Taiwan.

Little change in weather occurs through September. Although the warmer, southwest monsoonal flow eventually subsides, surface temperatures remain quite hot. The strengthening Asiatic high allows the northeast monsoonal surges to dictate low-level flow in October. This seasonal reversal in wind direction is usually completed in northern Taiwan by mid-to-late September and in southern Taiwan by early to mid-October. October brings a pattern of increasing low cloudiness to the northeast and decreasing low cloudiness to the southwest. In the northern coastal plain, mean temperatures in October are about 4 to 6 Fahrenheit degrees (3 to 4 Celsius degrees) lower than those in September. Only a small drop in mean temperature occurs in the western coastal plain. Cold monsoonal flow over the relatively warm, southward-flowing branch of the North Equatorial Current provides morning advection fog along Taiwan's west coast. Convective activity is still present throughout Taiwan, although the frequency and intensity of thunderstorms lessens significantly in October.

Typhoons that approach from the southeast over the warm Philippine Sea, bring heavy rain, flooding, and wind damage to the east coast. Most lose intensity as they cross the rugged, thickly forested eastern and central highlands. Typhoons approaching from the southwest move over the relatively warm Taiwan Strait and cause torrential rainshowers, flooding, and wind damage to the western coastal plains and the Pescadores Islands.

Sky Cover.

Northern Coastal Plains/Pescadores Islands. Strong, onshore monsoonal flow advects stratiform clouds over the plains early in the season, particularly along the northeastern coast. The freshening northeast monsoon advects stratocumulus clouds over the islands by mid-to-late September. Ceilings below 3,000 feet occur 30 to 50 percent of the time (see Figure 5-26).

Western Coastal Plains. Little change in low cloudiness occurs in September. Continued strong, daytime heating and low-level wind convergence (associated with sea breezes) commonly cause low "afternoon" ceilings. In October, downslope winds provided by the dominate northeast monsoon decreases the occurrence of low ceilings. Diurnal variance in low cloudiness becomes negligible in northern and central portions of the western plains.

Central and Eastern Highlands. Mean cloudiness decreases on the western slopes of the Chung-yang Shan-mo. This indicates drying of the air due to the downslope trajectory of the developing northeast monsoon. As the low-level wind changes direction, so will the location of cumuliform clouds, especially on the freshly windward slopes in the north. Ceilings below 3,000 feet occur 30 to 60 percent of the time on the windward slopes and 10 to 30 percent of the time on the lee slopes.

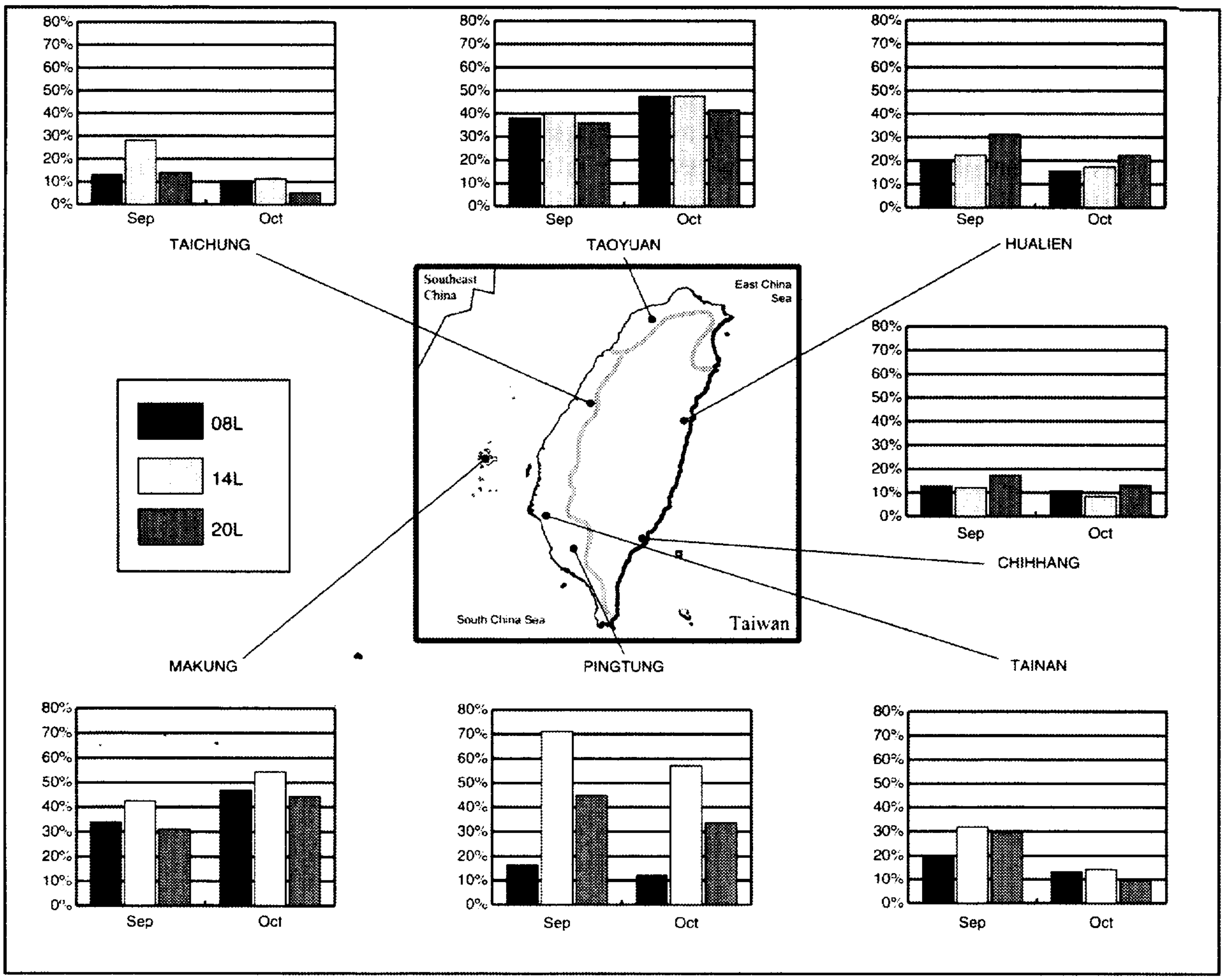


Figure 5-26. Fall Ceilings below 3,000 Feet. The graphs show a monthly breakdown of the percent of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northern Coastal Plains. Throughout the coastal plains, rain and fog reduce visibility below 4,800 meters about 10 to 30 percent of the time (see Figure 5-27). The lowest visibility occurs in the morning. In industrial cities, visibility typically drops below 8,000 meters in smoke and haze during the day.

Western Coastal Plains. Along the western plain, the occurrence of low visibility increases. In October, morning visibility below 4,800 meters occurs 40 to 60 percent of the time. Afternoon visibility in the industrial cities normally improves to between 4,800 and 8,000 meters in smoke and haze.

Central and Eastern Highlands. Restricted visibility in the highlands and valleys continues, but to a lesser extent than in the previous season. Restricted visibility occurs when cloud bases lower to ground level on the windward slopes. Mountain slopes abruptly change from windward slopes to lee slopes because the winds are unstable in the transition season between summer and winter monsoonal flow. In the eastern coastal cities, rain or haze reduce visibility below 4,800 meters less than 10 percent of the time.

Pescadores Island. Visibility continues to be good in the islands. Visibility at or below 9,000 meters occurs less than 10 percent of the time.

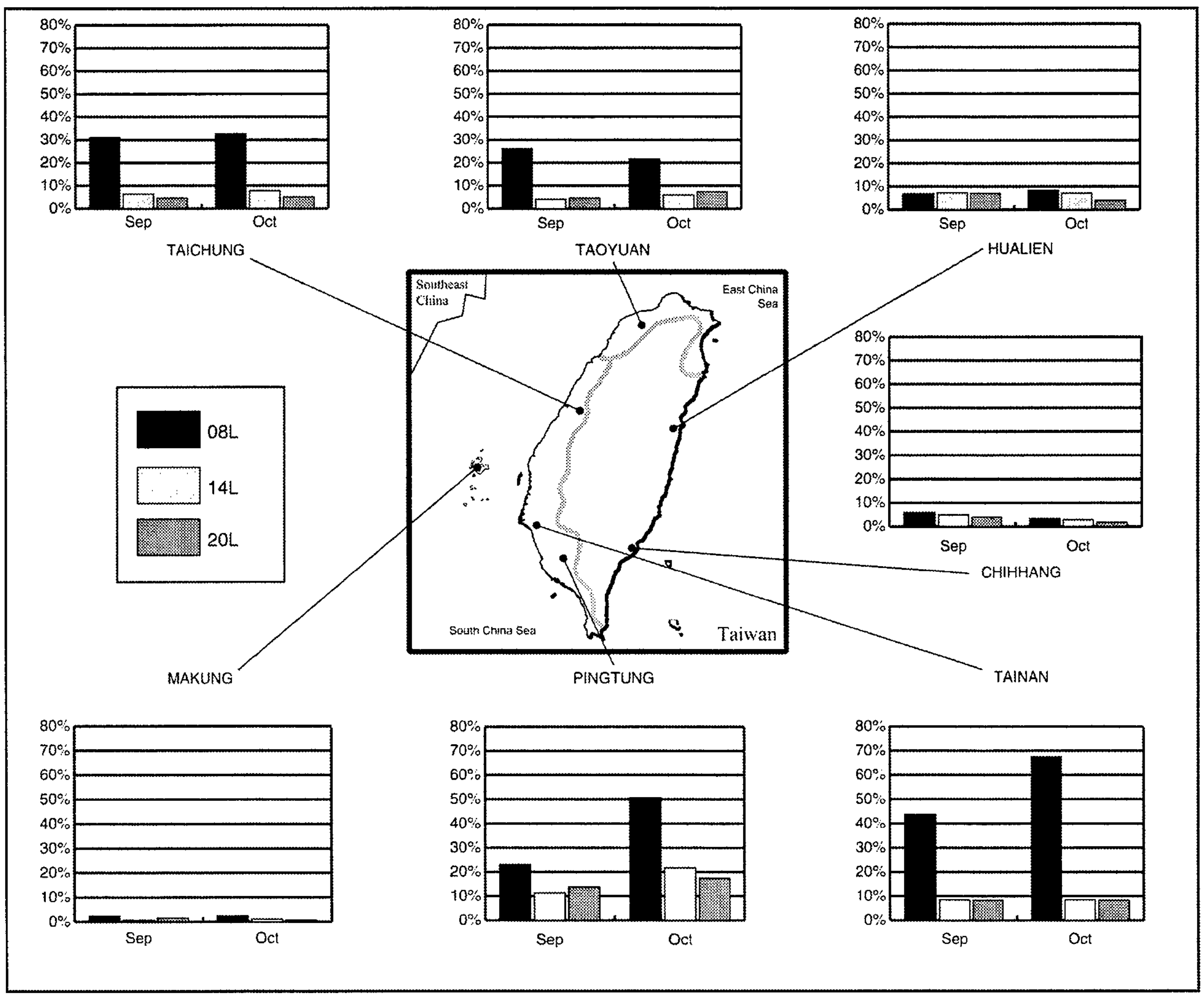


Figure 5-27. Fall Visibility below 4,800 Meters. The graphs show a monthly breakdown of the percent of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds. Typhoons, packing wind speeds in excess of 100 knots, are always possible in September. By October, the winter monsoon winds are largely dominant.

Northern Coastal Plains/Pescadores Islands. Figure 5-28 shows the dominance of the strengthening northeast monsoonal surges and the weakening southwest monsoonal flow. Winds become predominately northeasterly by mid-to-late September. Winds in the plains will generally be at 10 to 15 knots, and will be gusty. Wind speeds of 15 knots with gusts to 25 knots are common in the islands.

Western Coastal Pains. Although land and sea breezes influence winds in the northern areas, the winter monsoonal surges more often dictate wind direction. Winds frequently contain a northerly component of about 10 knots by midseason. In the southern areas of the plains, land and sea breezes continue to dictate wind directions and speeds in September. By early to mid-October, a freshening northerly component wind dominates as the transition season ends. At Pingtung, and in other isolated areas, winds are generally light and variable during the day and mostly calm at night.

Central and Eastern Highlands. Except on slopes exposed to the northeast monsoonal surges, winds in the highlands are generally variable at 10 to 15 knots at all elevations. Northeast monsoonal surges also influence winds along the east coast, however, the daily land and sea breezes, augmented by mountain and valley breezes, primarily determine wind direction and speed during this transition season. At the coastal cities of Hualien and Taitung, daytime winds are generally northeast at 6 to 10 knots and gusty. At night, an offshore flow at about 6 knots is common.

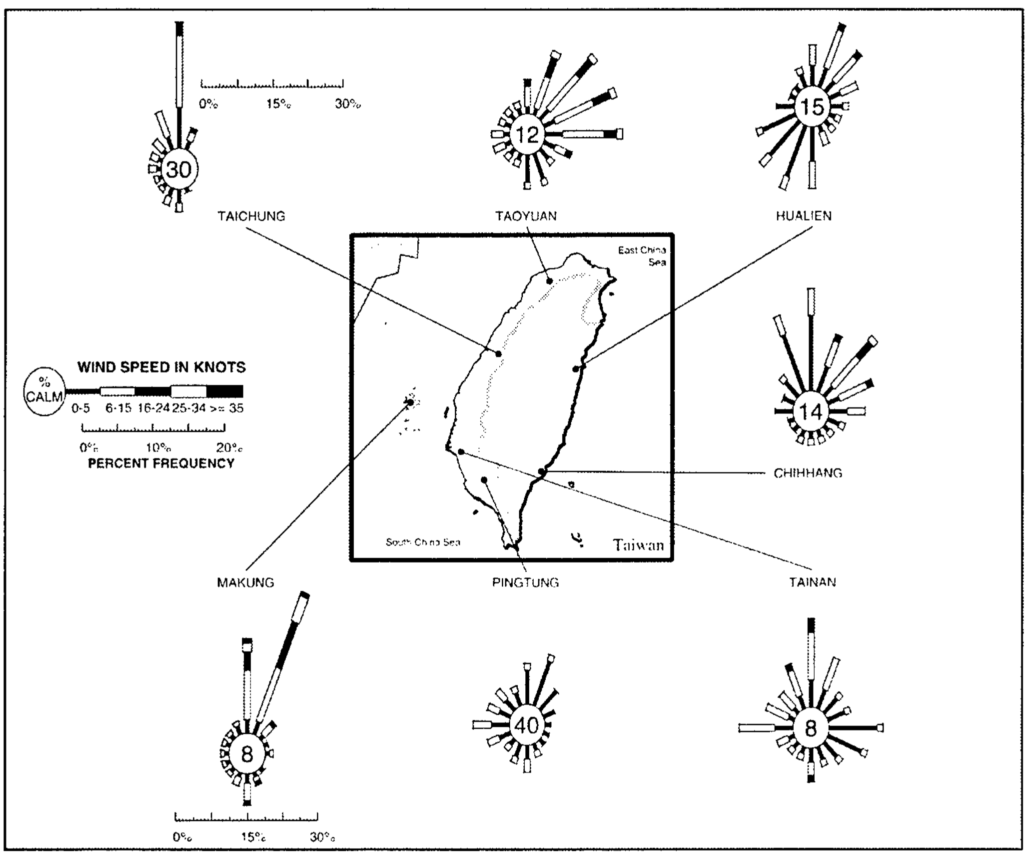


Figure 5-28. September Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location. Separate percent frequency scales are given for locations that differ from the main legend.

Upper-Air Winds. By mid-September, the weakened southwesterly low-level jet at 850 mb is replaced by northeasterly winds at 12 to 20 knots. Figure 5-29 shows variable winds at less than 20 knots at both 700 and 500 mb over Makung AB. These variable winds are present throughout Taiwan. A southward shifting tropical easterly jet is apparent at 300 mb over Makung AB. North of Taiwan, westerlies at 300 mb begin moving southward this season.

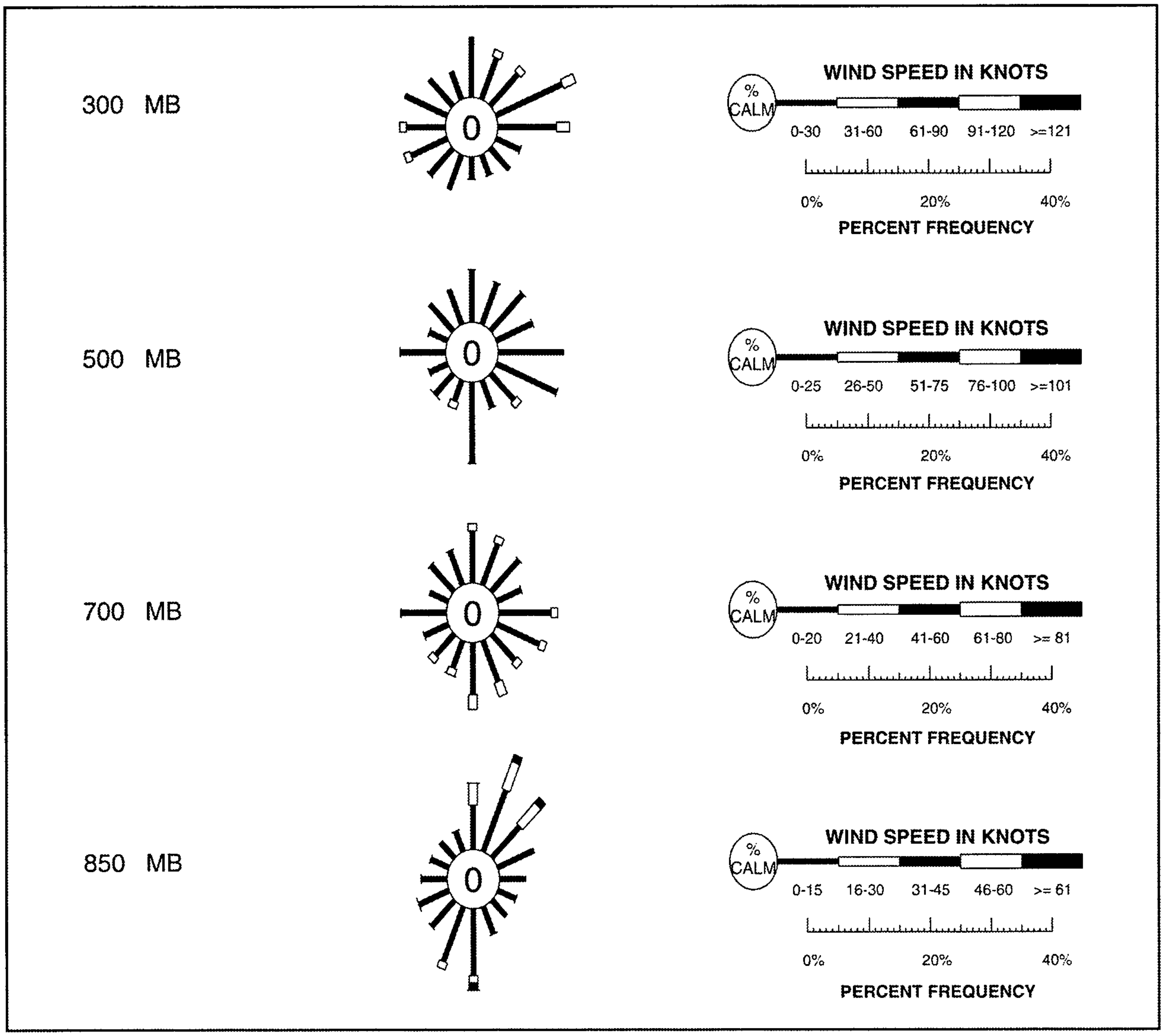


Figure 5-29. September Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Makung AB, Taiwan. Note: Each wind rose has a tailored legend.

Precipitation. As surface heating decreases towards the end of September, so does convective activity. The number of thunderstorm days in September, when compared to August, decreases in Taiwan. Intense embedded thunderstorms often accompany typhoons. Torrential rains accompanying typhoons produce mean precipitation totals ranging from 150-500 mm.

Northern Coastal Plains. Although the mean number of days of precipitation increases as the season progresses in northeast Taiwan, the actual amount of precipitation is usually lower as rainfall intensity weakens due to reduced convective activity (see Figures 5-30 and 5-31). October's mean number of precipitation days ranges from about 7 days in the northwest to 15 days in parts of the northeast.

Late in the season, convective activity becomes limited as the inversion sets up in the northeast at about 7,000 feet (2,100 meters). Convective activity decreases in western areas as a slightly cooler, low-level northeasterly breeze increases atmospheric stability. Taichung averages less than 5 days of thunderstorms in September. The northeast monsoon brings light rain and drizzle to the plains.

Western Coastal Plains. A weakening southwesterly monsoonal flow decreases convective activity in the south, although some areas in the southwest still have thunderstorms 10 to 15 days in September. This convective activity occurs due to instability produced by surface heating and low-level wind convergence. It still produces significant amounts of rainfall although the precipitation totals lesson somewhat by early September. The mean number of days of precipitation in September, when compared to August, decreases slightly in the south and west. Lower precipitation amounts are observed to the north. September's mean precipitation in the coastal plains ranges from 120 mm along the west coast, to about 300 mm in low-lying areas near Pingtung. The mean number of days with precipitation steadily decreases throughout the season.

Central and Eastern Highlands. Although northeast monsoonal flow increases upslope moisture advection in the northern highlands, little change in rainfall amount occurs. Less convective activity occurs as the atmosphere becomes more stable aloft. By the end of the season, a shallow inversion exists above the northeast monsoon, causing the clouds to become increasingly stratified. Continued warm temperatures induce convective activity on the windward slopes in the central mountains. Rainfall amounts stay about the same; however, location of cumulus buildups on the windward slope varies as wind direction changes this season. Downsloping of the northeasterly winds limits rainfall on the western slopes late in the season. As the southwest monsoon weakens and is ultimately taken over by the northeast monsoon, the intensity and frequency of rainfall decreases on the southwestern slopes of the Chung-yang Shan-mo.

Pescadores Islands. The strong northeasterly winds almost eliminate the possibility of thunderstorms late in the season. Precipitation occurs about 4 to 8 days per month this season. September's rainfall amounts average 120 mm for the month.

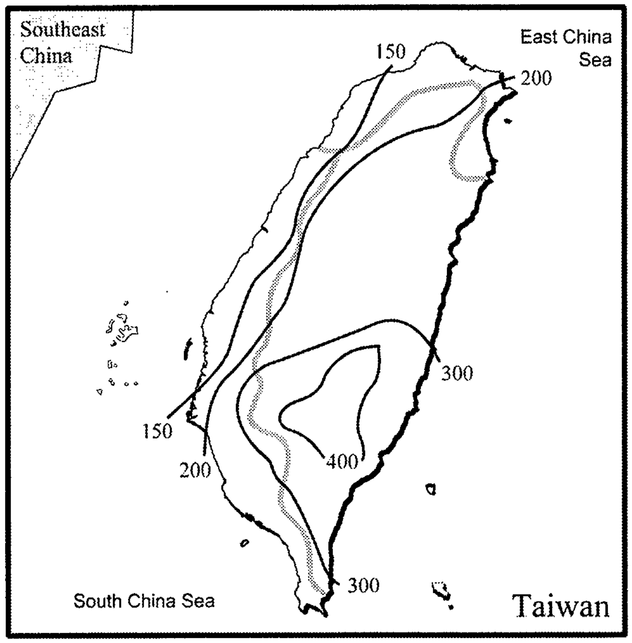


Figure 5-30. September Mean Precipitation (mm). The figure shows mean precipitation amounts in the region.

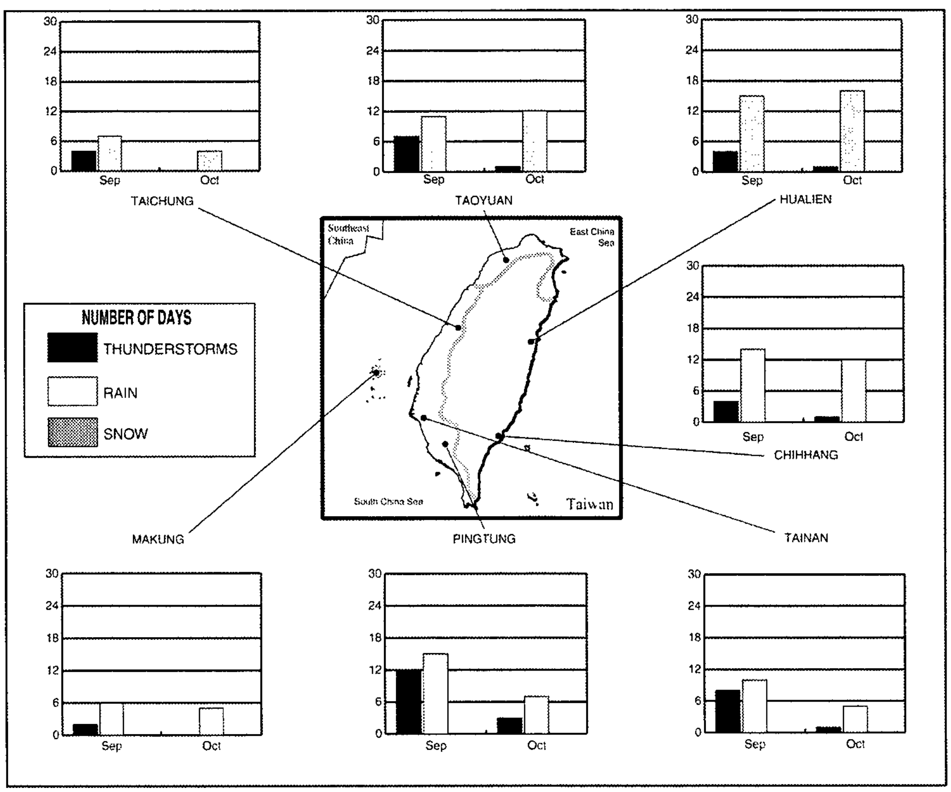


Figure 5-31. Fall Mean Monthly Precipitation and Thunderstorm Days. The graphs show the average occurrence of precipitation and thunderstorms for selected cities in Taiwan.

Temperatures. September mean maximum temperatures, when compared to those in July, are only 2 to 4 Fahrenheit (1 to 2 Celsius) degrees cooler along the coasts. The temperatures are a few degrees warmer in the highlands. October's mean temperatures in northern Taiwan are generally 4 to 6 Fahrenheit (3 to 4 Celsius) degrees lower than those in September. In southern Taiwan, October's mean temperatures are about 2 to 4 Fahrenheit (1 to 3 Celsius) degrees lower than those in September.

Figure 5-32 shows September's mean maximum temperatures are near 86°F (30°C) in the northern coastal plains and the Pescadores Islands. Temperatures stay at about 86° to 90°F (30° to 32°C) on the western coastal plains. Mean maximum temperatures in the highlands decrease with increasing elevation to about 61°F (16°C) at the highest peaks.

September's mean low temperatures range from about 77°F (25°C) at the coast to about 50°F (10°C) at the highest elevations (see Figure 5-33). Radiational cooling on calm, clear nights in the valleys provides lower temperatures than at more exposed higher elevations.

Figure 5-32. September Mean Minimum Temperatures (°C). Mean minimum temperatures represent the average of all low temperatures for September. Daily low temperatures are often lower than the mean.

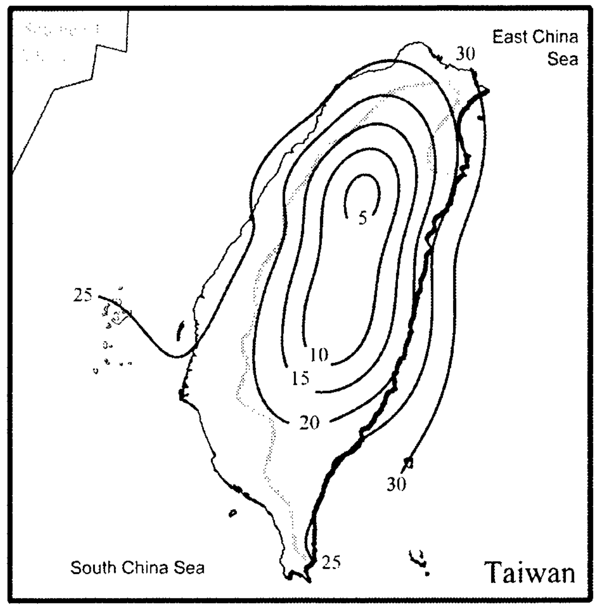


Figure 5-33. September Mean Maximum Temperatures (°C). Mean maximum temperatures represent the average of all high temperatures for September. Daily high temperatures are often higher than the mean.

Hazards. Always be on the lookout for the destructive winds and torrential rains that accompany typhoons. The Northern Hemisphere's record 24-hour period rainfall, 49 inches (1,250 mm), occurred at Paishih, Taiwan, on 10-11 September, 1963. Evacuation of aircraft and personnel to safe havens may be necessary.

Icing. Light, clear icing is possible in cumulonimbus clouds above 15,000 feet.

Turbulence. Moderate-to-severe turbulence in and around thunderstorms is always possible. Generally, light turbulence can be expected at low levels over the islands and mountains.

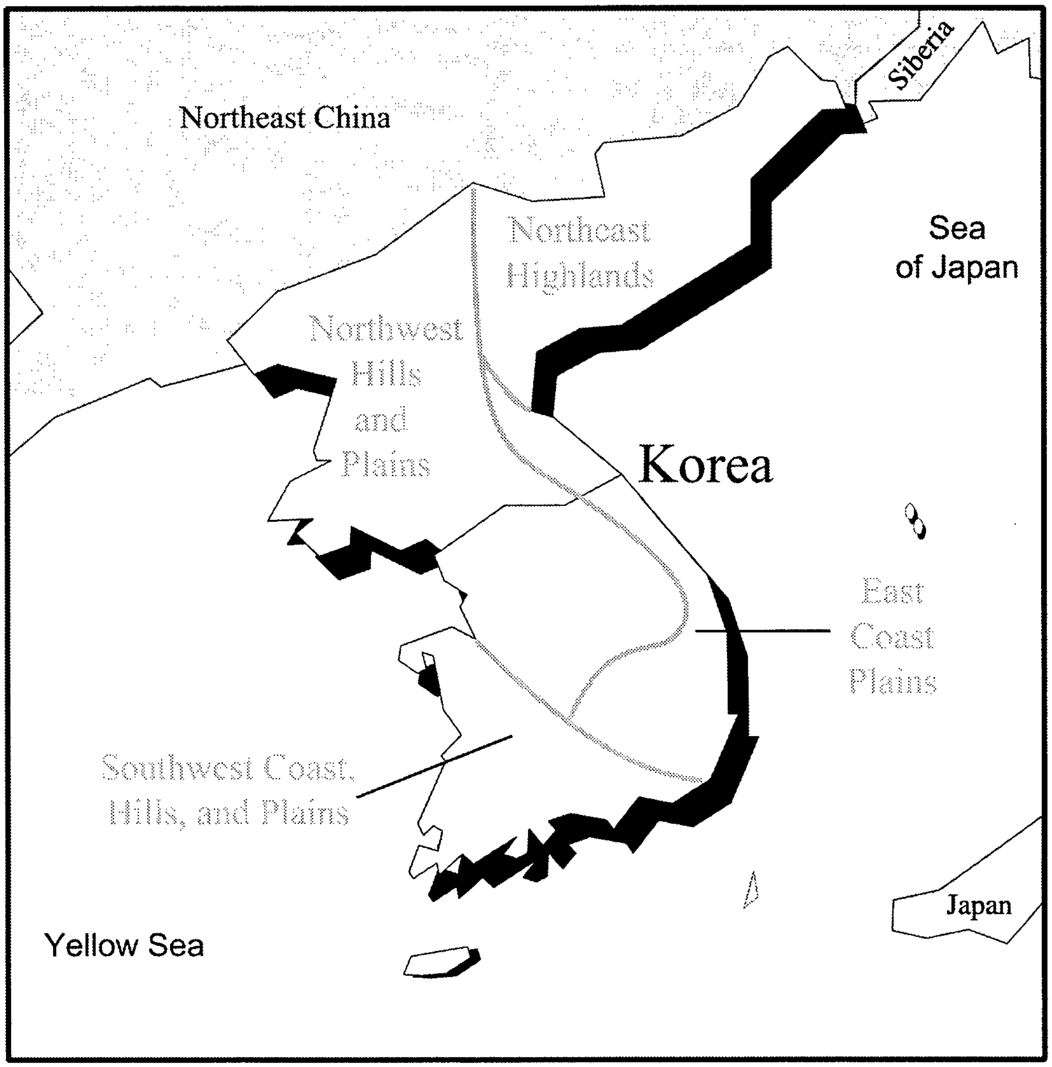
Trafficability. About three-fourths of Taiwan consists of rough, rugged mountain ranges. The rest of Taiwan has flat, rolling plains and hills. Included in the plains and hills are some terraces and heavily dissected areas. The soils of the mountainous areas are mostly shallow and coarse-grained. The soil consists of gravels and sands with many rock outcroppings. Movement conditions are unsuitable at all times because of steep slopes and forests.

In the plains and hills, the slopes range from level to moderately steep. Soils are predominantly fine-grained, but some sizable areas of coarse- and fine-grained mixtures exist, especially in the southwest. Movement conditions in these areas range from fair to unsuitable during the dry season. Movement is restricted mainly by stream banks, some marshy areas, agricultural practices (mainly rice paddies), forests, and severely dissected terrain.

Chapter 6

THE KOREAN PENINSULA

This chapter describes the geography, major climatic controls, and general weather (by season) of Korea. For the purpose of this study, Korea has been divided into four climatic subzones: the northeast highland, the northwest hills and plains, the east coast, and the southwest hills and coastal plain (includes Cheju Island).



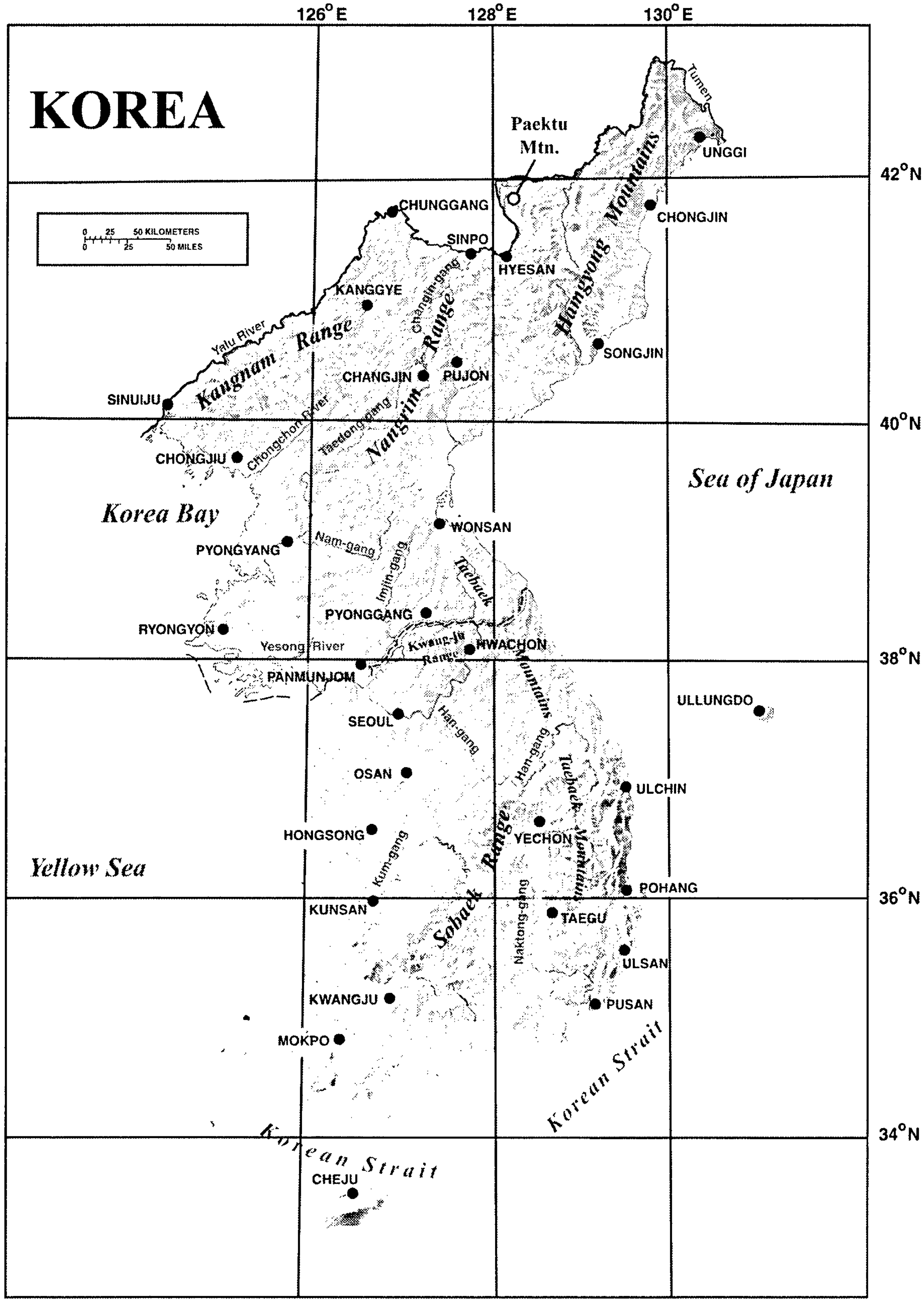


Figure 6-1. Korean Peninsula Topography. The figure shows terrain features that impact weather conditions on the Korean peninsula.

Boundaries. Korea is at the juncture of the Asian continent and the Japanese archipelago. It is bordered to the north by China and Siberia. The west coast is bordered by the Yellow Sea (Korea Bay). The east coast is bordered by the Sea of Japan (East Sea). The Korean Strait lies along a line that extends southwest from Mokpo at the peninsula's southwestern tip. The strait is 174 miles (280 km) in length and has a breadth of 124 miles (200 km). There are 3,579 islands adjacent to the Korean peninsula. Cheju, the largest of the islands, lies 60 miles (96 km) off the southwest coast of the peninsula.

General Topography. Hills and mountains cover about 75 percent of Korea. The remainder is covered by scattered lowlands. Most of the rivers are short, swift, and shallow. There are eight major rivers in Korea: the Yalu, Tumen, Chongchon, and Yesong in the Democratic Peoples Republic of Korea (DPRK), and the Hangdang, Naktong, Han, and Kum in the Republic of Korea (ROK).

Climatic Zones of Korea. For this study, the Korean climatic region has been further divided into four areas primarily because of topographical influences on climate. Each area will be discussed separately each season.

Northeast Highlands. The Nangrim, Hamgyong, and Kangnam Ranges make up the Kaema plateau. The Kaema plateau has an average elevation of 3,300 feet (1,000 meters). Paektu Mountain is the highest mountain in the DPRK; it rises 9,003 feet (2,744 meters) along the northern edge of the Kaema plateau. The Nangrim Range runs from north to south through the middle of the country. Large river plains exist between the western mountains and merge along a narrow, irregular coastal plain on the west coast. The Hamgyong Range, which extends northeast from the Nangrim Mountains, forms a steep slope between the Kaema plateau and the Sea of Japan.

Numerous valleys have small rivers or streams. Many flow into the Tumen River. The Tumen River is the only large river in the DPRK that empties into the Sea of Japan. Navigable for roughly 53 miles (85 km), it begins at Paektu Mountain and flows northeastward to the Sea of Japan.

Numerous small lakes and reservoirs are scattered throughout the area. There are two large lakes, the Changjin Reservoir, oriented north to south in the valley north of the city of Changjin, and the Pujon Reservoir, oriented north to south 17 miles (28 km) east of Changjin Reservoir.

Northwest Hills and Plains. This zone is a series of parallel mountain chains oriented northeast to southwest. They branch off the Taebaek and Nangrim ranges. The area includes a series of river valleys and the island of Paengnyoung-do. The mountain range farthest to the north is the Kangnam Range. This range lies along the Chinese border. The Kwangju Range, an offshoot of the Taebaek Mountains, extends southwest to Seoul. The range separates the Paju plain in the Imjin drainage from the Han. The majority of the mountain tops in this region are less than 4,900 feet (1,500 meters) in height. The western lowland plains and river basins are interspersed with hills and low mountains.

All the rivers in this region drain westward to the Yellow Sea. The Yalu River is the longest river in Korea. The Yalu rises at Paektu Mountain and flows southwestward for 790 km (491 miles) to the mouth of Korea Bay. Only the lower reaches of the Yalu are navigable. During the winter months, the Yalu is frozen from November to March.

There are many small lakes and reservoirs in the northwest hills and plains. Two main reservoirs within this region are the Hwachon Reservoir and the reservoir on the Yalu River. The Yalu is dammed northeast of Chunma and forms the largest reservoir in DPRK. The Hwachon Reservoir is 4 miles (6 km) east of Hwachon.

East Coast Plain. The east coast plain is a narrow, ragged plain with short rivers, sandy beaches, inlets, and lowlands parallel to the southern half of the east coast of Korea and the offshore island of Ullungdo. The Taebaek Mountains are less than 4,000 feet (1,200 meters) in height and extend the entire length of the western boundary. The east coast plain is approximately 12 miles (20 km) in width. There are some areas where mountains terminate at the coast. Ullungdo is 8 miles (13 km) across and rises to a height of 2,953 feet (900 meters) at Mt. Saningbong.

Southwest Hills and Plains. This area, which includes Cheju Island, consist of mountains and plains. The low mountains and hills are the dominant features with most peaks below 5,000 feet (1,500 meters).

The Sobaek Mountains dominate the southern mountain and valley region, which extends southwestward from the southern end of the Taebaek range. The Sobaek Mountains form an interior divide that separates the northwest area and Seoul from the southeast area and Pusan. In the south, the Sobaek Range terminates in the great Chiri Massif, which rises to 6,342 feet (1,933 meters). The Sobaek Range has a mean elevation of 3,500 feet (1,000 meters). The Noryong Range is an offshoot of the Sobaek and also extends southwest. These mountains rise only 2,500 feet (760 meters) and form a natural boundary between the Honam Plain and the Yongsan River basin.

Major rivers and streams occupy the valleys between the mountain ranges. The Naktong, on the south coast, is 325 miles (525 km) long and enters the sea through a multi-channeled delta. The Naktong is just west of the city of Pusan and flows to the Korean Strait. The Kum River flows northward between the Sobaik and Charyong, then turns southwest to empty into the Yellow Sea; the total length is 250 miles (402 km). Other major rivers in the southwest region are the Mangyong, Somjin, and Yongsan Rivers. These rivers empty into the Yellow Sea. There are many small lakes, reservoirs and marshes. The majority of these rivers have developed large river basins along the coastal plains. Cheju Island lies 60 miles (96 km) off the southwest coast. Mt. Halla, the central peak, dominates the entire island; it rises 6,500 feet (2,000 meters). There are numerous streams that flow rapidly away from the center of the island.

Ocean Currents and Temperatures. There are four main sea currents that affect Korea.

The Kuroshio Current. This is a warm current that flows northward from the East China Sea into the Korea Strait. Water temperatures in the Kuroshio are about 61°F (16°C) in winter and 77°F (25°C) in summer.

The Tsushima Current. This warm current flows along the southeast coast of Korea into the Sea of Japan. The Tsushima current flows northeastward. Sea-surface temperatures along the southeast coast of Korea range from 43°F (6°C) to 52°F (11°C) in January to 75°F (24°C) in August.

The Liman Current. This is a cold countercurrent that flows southwest along the northeastern coast of Korea. The Liman is strongest in winter when the strong, northerly atmospheric circulation helps push the cold water south. In summer, the Liman continues to bring cold water along the northeast coast, but the flow is weaker because it is no longer reinforced by a strong circulation pattern. Sea-surface temperatures along the shoreline of the Sea of Japan north of 38° N range from 30°F (-1°C) to 43°F (6°C) in January and from 70°F (21°C) to 73°F (23°C) in August.

The Yellow Sea Current. This current changes directions with the seasons. In winter, it flows southward, driven by the strong, northwesterly atmospheric flow. In February, offshore sea-surface temperatures range from 34°F (1°C) to 48°F (9°C). In summer, without the reinforcement of the northerly flow, the current changes direction to flow northward along the west coast and brings warmer water to the coast. Mean sea-surface temperatures in August are 73°F (23°C) along the immediate shoreline.

North Pacific High. This system strengthens and moves northward during the summer. Extending across the Pacific to the Asian coast, it provides the Asian east coast with a steady, southeasterly flow of moist, warm air. During the fall, the cell weakens and moves southeast.

Asiatic High. This thermal high reaches maximum strength in December and January, then dissipates in spring. The mean position of the lobe nearest Korea is just south of Lake Baykal. The cold air produced in this system is very dry and results in frequent clear skies and little precipitation for the peninsula. The southeast and southwest coasts of Korea experience more precipitation than other areas because of migratory low-pressure systems that move in from the adjacent seas. The polar front, at the leading edge of the Asiatic high, is well south of Korea throughout the winter.

Asiatic Low. This is a summer feature that forms in late spring as the Asian landmass heats. This thermally-induced low enhances an onshore flow of warm, moist air. This air mass produces rainy, hot, and humid conditions for much of Korea and helps pull the polar front northward.

Aleutian Low. The Aleutian low is strongest in winter. This low, in conjunction with the vast Asiatic high, creates the strong, cold, offshore winds and dry weather that dominate all of Asia. Changes in its position alter the primary storm tracks. When it builds west, the storm tracks move west and affect Korean weather more.

Migratory Cyclones. Migratory low-pressure systems have a major impact on Korea's weather conditions. These systems, which are named for their source regions, are shown in Figure 6-2.

Shanghai Low. The Mongolian and Takla Makan lows are parent systems for Shanghai lows. They move through the Shanghai area and intensify as they move out over the water. The Shanghai low is the most important low for Korean precipitation. It generally develops along a stagnant, decaying frontal system and regenerates the front.

Yellow Sea Low. Takla Makan, Honan, Lung Chiong, and Mongolian lows are parent systems for this low. The lows move out of China and intensify over the Yellow Sea in the area between Shanghai and Osan AB and track over Korea. Associated weather includes strong, gusty, surface winds and showery precipitation. The Yellow Sea low generally occurs from late February through late April. The wind is primarily southerly.

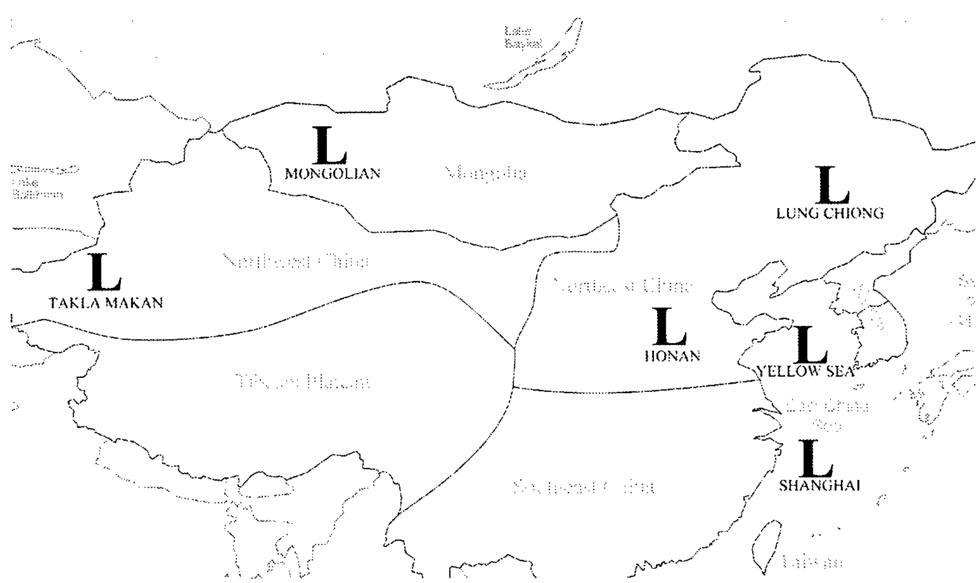


Figure 6-2. Migratory Low-Pressure Systems. The figure shows the source regions for migratory low-pressure systems that impact Korea's weather.

SPECIAL CLIMATIC CONTROLS

Bai-U Front. During May, the bai-u front, which is located over the ocean south of Japan, forms between the relatively persistent, cool, moist northeasterly flow of the Okhotsk high, and the warm, moist southwesterly flow from the Pacific High. The mean position of the polar front is between Ogasawara and the south side of Okinawa. As the Asiatic high begins to slowly weaken in June, the warm Pacific high expands to the north and west and pushes the bai-u front to the north. The rainy season associated with the bai-u front begins around the middle of June on Cheju-do and slowly progresses northward over the course of about one month. These intense rainshowers are called "plum rains." The plum rains normally begin in the south during June and continue northward for about 2-4 weeks to affect northern regions by July. By the latter part of July, the bai-u front weakens. At that time, the front is located on a line from southern Sakhalin Island to northern Korea and the Shantung Peninsula area. These areas experience a brief rainy season.

The associated weather north of and along the bai-u front mainly consists of fair weather with prevailing easterly winds associated with the Okhotsk high. Along the west coast, morning fog, persistent cloudiness, and steady light rain or drizzle occur. Heavy rainshowers will occur with the approach of a cyclonic disturbance that moves out of the Shantung Peninsula. To the south of the frontal boundary, thunderstorms and rainshowers frequently occur in the afternoon; stratus forms in the morning and burns off by noon. All along the frontal boundary, small, weak lows move through approximately 3 days apart. These tiny lows bring stratus, fog, and light rain on the northern side of the front. Conditions are marginally better on the southern side (ceilings below 1,500 feet and visibility below 4,800 meters remain as long as the low and front are in the area).

Typhoons. Typhoons affect Korea once to twice a year, on average. There have been extreme conditions where typhoons have affected Korea 4-5 times a year. Summer through early fall is the period when typhoons are usually most active. Typhoons are accompanied by torrential rains, low ceilings, and high wind speeds. Storm surges associated with typhoon winds may cause extensive damages along the coastal regions, especially along the south coast.

Yellow Wind. During late winter and early spring, dust from the Gobi Desert is carried south by active cold fronts that move from the northwest. The dust spreads over Korea and lowers visibility for as long as 24 hours. During the spring, when the northwesterly or westerly flow is strong, yellow dust can be carried as high as 15,000 feet. This restricts in-flight visibility.

General Weather. By mid-November, the Asiatic high reaches full strength. Skies clear, visibility becomes excellent, strong, gusty winds become common, and temperatures plummet. Extremely cold, dry air pushes southward from Siberia. The winds increase in strength throughout winter, with the peak strength in January. Winds blow steadily from the northwest to northeast.

The northern storm tracks become active during winter. Mongolian lows are the most common systems to affect the country. An occasional Shanghai low will spin out over the Yellow Sea, gather moisture, and move east. When that happens, the peninsula gets snow. At times, it is quite heavy at higher elevations because of uplifting. Low-pressure systems that develop on the polar front provide a secondary source of winter precipitation for southwest Korea. Sometimes these systems intensify enough to wrap moisture well north of their surface position. They affect Korea most in the early stages of winter while the polar front, although south of the peninsula, is still relatively close. These lows advect overcast conditions and steady precipitation (rain in low elevations and snow in higher elevations) into the southern portions of the Korean peninsula. Both systems are transitory and pass through in 1-3 days. Only migratory lows out of Manchuria or Yellow Sea lows bring extensive, layered clouds and snow. These lows skirt the southern edge of the powerful Asiatic high.

By November, the polar front moves well south of Korea. It is farthest south in February when it is located just north of the Philippines. Typhoon season officially ends in November, but 5 percent of storms that move through the western Pacific Ocean track over Korea in November. These storms are usually badly battered by the time they make landfall in Korea and do little more than dump large amounts of precipitation.

Sky Cover. This is the season of clear skies as the Asiatic high suppresses activity. Near the coasts, stratocumulus and stratus are often advected ashore. Locations at higher elevations have lower ceilings. A 3,000-foot ceiling on the coast will be on the ground in the mountains (see Figure 6-3).

Northeast Highlands. Except for clouds associated with migratory frontal lows, middle and high clouds are rarely present. A 2,000- to 3,000-foot ceiling occurs 25 to 30 percent of the time in November, especially in the early morning hours. January has the lowest amount of ceilings below 3,000 feet, with an average occurrence rate of 15 percent of the time. Ceilings can be a particular problem near the east coast as onshore winds bring moist, cold air inland. Multiple layers with frontal systems often extend from 1,000 feet to 30,000 feet. Under extremely cold conditions with little wind, ice fog may form near urban centers and airfields, or wherever water vapor is introduced into the atmosphere. Cloud tops associated with ice fog are below 500 feet AGL. Dissipation requires heat and a sharp reduction in pollution.

Northwest Hills and Plains. Little cloudiness occurs except with strong frontal passage. In January, ceilings less than 3,000 feet occur 15 percent of the time throughout most of the region, except along the coast of the Yellow Sea. In November through early January, Ryongyon and Pyonggang experience ceilings less than 3,000 feet more than 30 percent of the time due to onshore flow off the Yellow Sea. Thin cirrus occasionally marks the polar jet and altocumulus forms over the highlands with 7,000-foot bases and 12,000-foot tops. Layered cloud cover associated with frontal systems often extends from 1,000 feet to 30,000 feet. Under extremely cold, still conditions, ice fog may form near urban centers and airfields. Ice fog forms because the air is too cold to support the moisture released into the atmosphere by homes and industry. Cloud tops associated with ice fog are below 500 feet AGL. Dissipation requires heat and a sharp reduction in pollution.

East Coast Plain. Clear skies occur an average of 15-18 days a month all through the winter. The number of clear days increases in a progression from south to north. Most cloudiness occurs in the morning hours. Ceilings of 3,000 feet or above occur in the morning hours an average of 45 percent of the time at most mountain stations, but they occur much more rarely (well under 20 percent of the time) at lower elevations. Ceilings burn off quickly by midmorning and stay gone for the remainder of the day. Ceilings 1,500 feet or below rarely occur at any elevation.

Southwest Hills and Coastal Plain. Even along the coasts, mean cloud cover is only scattered, except in the early morning hours when the mean cover is broken an average of 30-40 percent of the time. In the hills, coasts and basins area, onshore flow from the relatively warm water nearby can create low stratus and stratocumulus ceilings inland, especially in higher elevations (uplifting). Ceilings tend not to persist past midmorning. Along the coasts, ceilings vary between 2,000 to 3,000 feet.

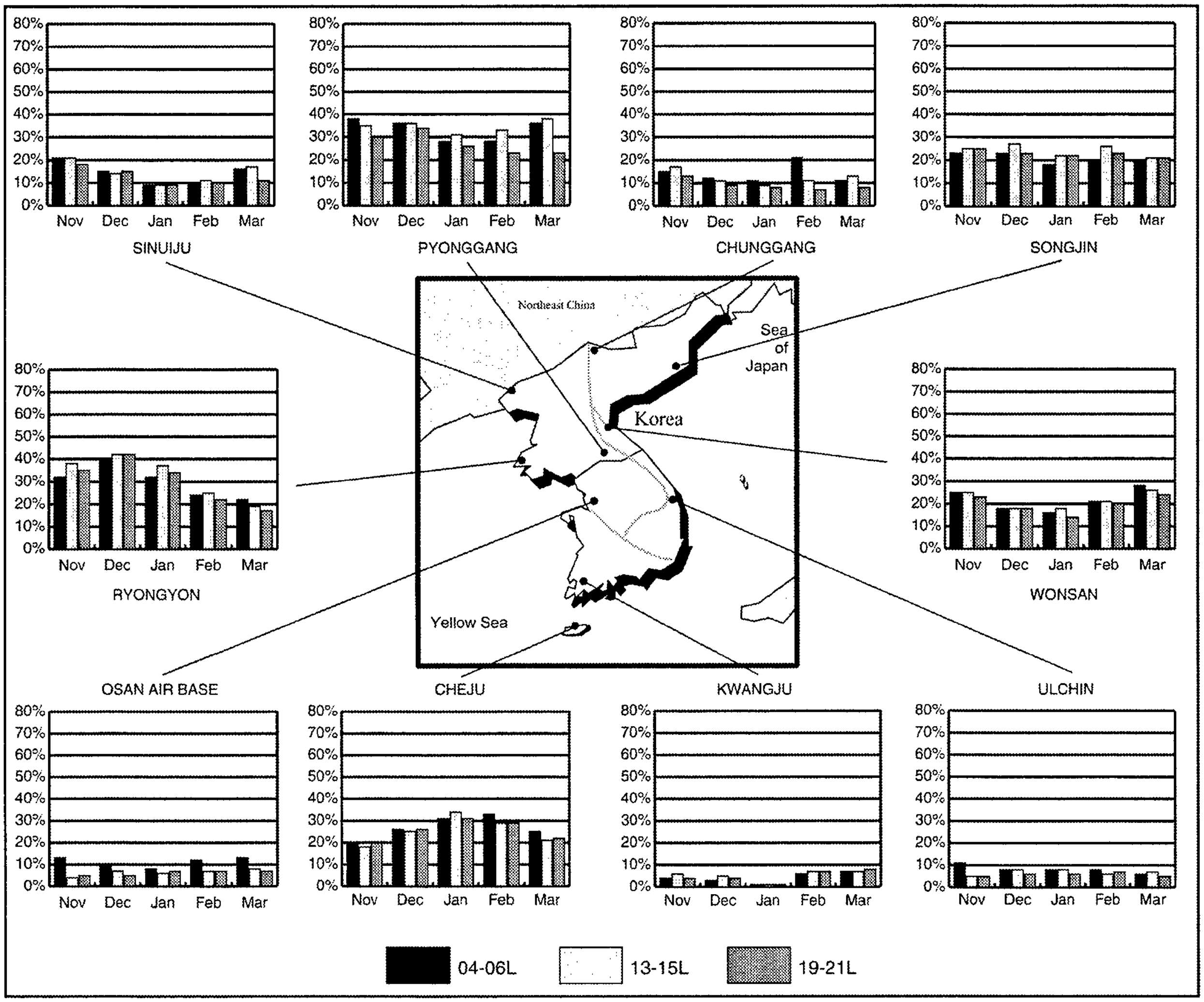


Figure 6-3. Winter Ceilings below 3,000 Feet. The graphs show a breakdown of ceilings below 3,000 feet based on location and diurnal influences.

Visibility. During winter, Korean stations report visibility greater than 9,000 meters 90-95 percent of the non-morning hours (see Figure 6-4).

Northeast Highlands. Visibility is generally excellent with exceptions. Late night and early morning ground fog commonly occurs when there is no wind, terrain is favorable, and a moisture source is available. In light or calm winds, urban visibility is restricted to below 4,800 meters just before and after dawn due to smoke. Visibility is less than 4,800 meters an average of 15 percent of the time from 0400L to 0600L. Some areas experience visibility less than 4,800 meters as much as 26 percent of the time in those hours. Afternoon visibility less than 4,800 meters occurs only 5-6 percent of the time at most locations. Snow can drop visibility to near zero, especially over higher terrain. Heavy snow showers along the coast can cause visibility to abruptly fall from unrestricted to 100 meters or less.

Northwest Hills and Plains. Visibility is generally excellent throughout the winter. The potential for visibility less than 4,800 meters in smoke and fog is greatest (10-12 percent of the time) at night and in early morning. Visibility generally increases to greater than 4,800 meters by late morning in most valleys. Visibility less than 4,800 meters occurs 4-6 percent of the time in the afternoon. In larger cities and around vast water sources, stagnant high-pressure systems can keep visibility below 4,800 meters most of the day. Snow can drop visibility to near zero, especially over higher terrain. Restricted visibility occurs more often in larger urban areas than elsewhere. Also, heavy snow showers off the coast reduces visibility to 100 meters.

East Coast Plain. The main visibility problem is manmade pollution. Wood smoke and industrial output reduce visibility, especially in valleys. Cold, drainage winds form inversions in valleys and trap pollutants beneath them. Outside of pollution, snow reduces visibility. Snow-related restrictions are variable. High-valley stations experience more fog than do those at lower elevations due to a combination of two factors. First, strong inversions created by cold drainage winds cap valleys. Pollution quickly drops visibility below 4,800 meters. Second, warm air moving in from over water creates an upslope condition and causes clouds to form. When the clouds form at station elevation, they are classified as fog. Despite this, restrictions to visibility are still unusual. Visibility under 4,800 meters occurs most during early morning hours, 40-65 percent of the time, and rarely after that.

Southwest Hills and Coastal Plain. The main visibility problem is pollution. Wood smoke and industrial output reduce visibility, especially in the valleys. Aside from pollution, snow reduces visibility. Snow-related restrictions are variable. In southern coastal areas and on Cheju-do, drizzle and rain reduce visibility more frequently than snow. Mountain stations experience more fog than those at lower elevations. Taegu experiences some type of visibility restriction more than 20 days per month. Despite this, restrictions to visibility are unusual. Visibility less than 4,800 meters occurs most during early morning, 40-65 percent of the time, and rarely after that.

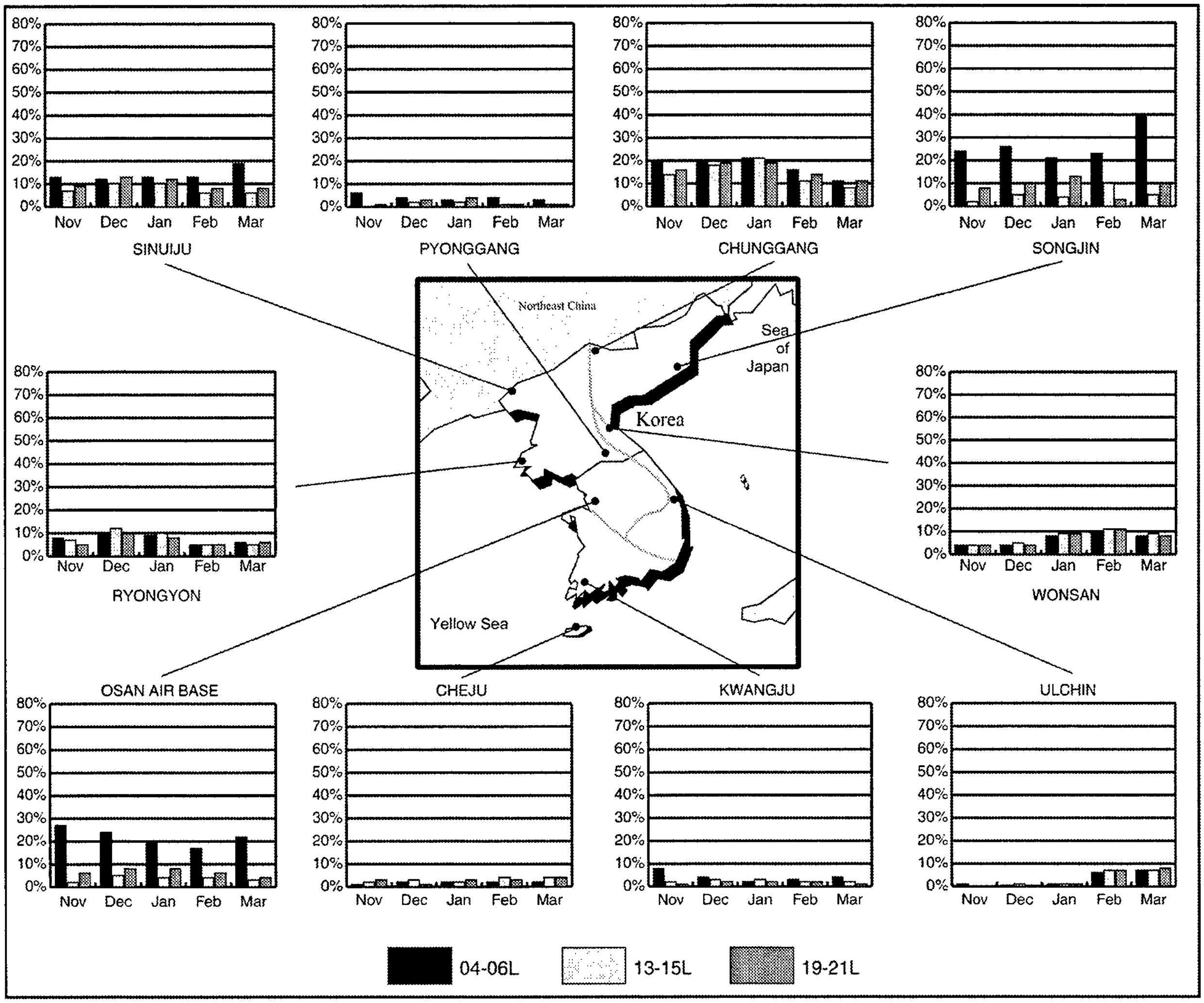


Figure 6-4. Winter Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds

Northeast Highlands. Surface winds, as shown in Figure 6-5, are northerly and strong, especially during a new Siberian outbreak. Gust speeds exceed 45 knots. Above ridges, where funneling takes place in passes and valleys, winds may exceed 65 knots. Foehn and bora winds occur throughout winter. Calm winds occur late at night and in the early morning when a strong subsidence inversion exists, particularly in protected mountain valleys.

Northwest Hills and Plains. When a blocking high sets up over Manchuria and spills extremely cold air over Korea, strong, northerly, surface winds occur. Wind gusts can exceed 45 knots; over ridges they can exceed 65 knots. Funneling, foehn, and bora winds are responsible for the highest speeds throughout the winter. Calm winds occur late at night and in the early morning when a strong subsidence inversion exists, particularly in protected mountain valleys.

East Coast Plain. General flow is from the north-northwest, but local winds and terrain influence both direction and speed. The mountain areas get boras, foehns, and funneling winds. Although far more common further north on the peninsula, bora winds occur in the southeast mountains during January and February, when winter cold is at its deepest. Funneling in mountain passes and canyons can increase wind speeds significantly. With winds already blustery, funneling can augment them enough to cause damage to buildings and equipment. Under the right conditions, stations at the foot of canyons or basins report steady winds in excess of 30-35 knots with gusts above 50 knots. Location relative to both the prevailing wind flow and to drainage features determines whether or not a site experiences funneling winds.

Southwest Hills and Coastal Plain (includes Cheju Island). General flow is from the north-northwest, but local winds and terrain influence both direction and speed. Mountainous areas get boras, foehns, and funneling winds. Although far more common further north on the peninsula, these winds do occur in the southwestern mountains during January and February when winter cold is at its deepest. Funneling in mountain passes and canyons can increase wind speeds significantly. For example, under northerly flow, Pusan has winds that often exceed twice the speeds Taegu experiences under the same regime. Taegu is at the head (top) of a basin while Pusan is at a mouth. Chinhae, just southwest of Pusan, has reported steady winds as high as 35 knots with gusts to 58 knots as a result of funneling.

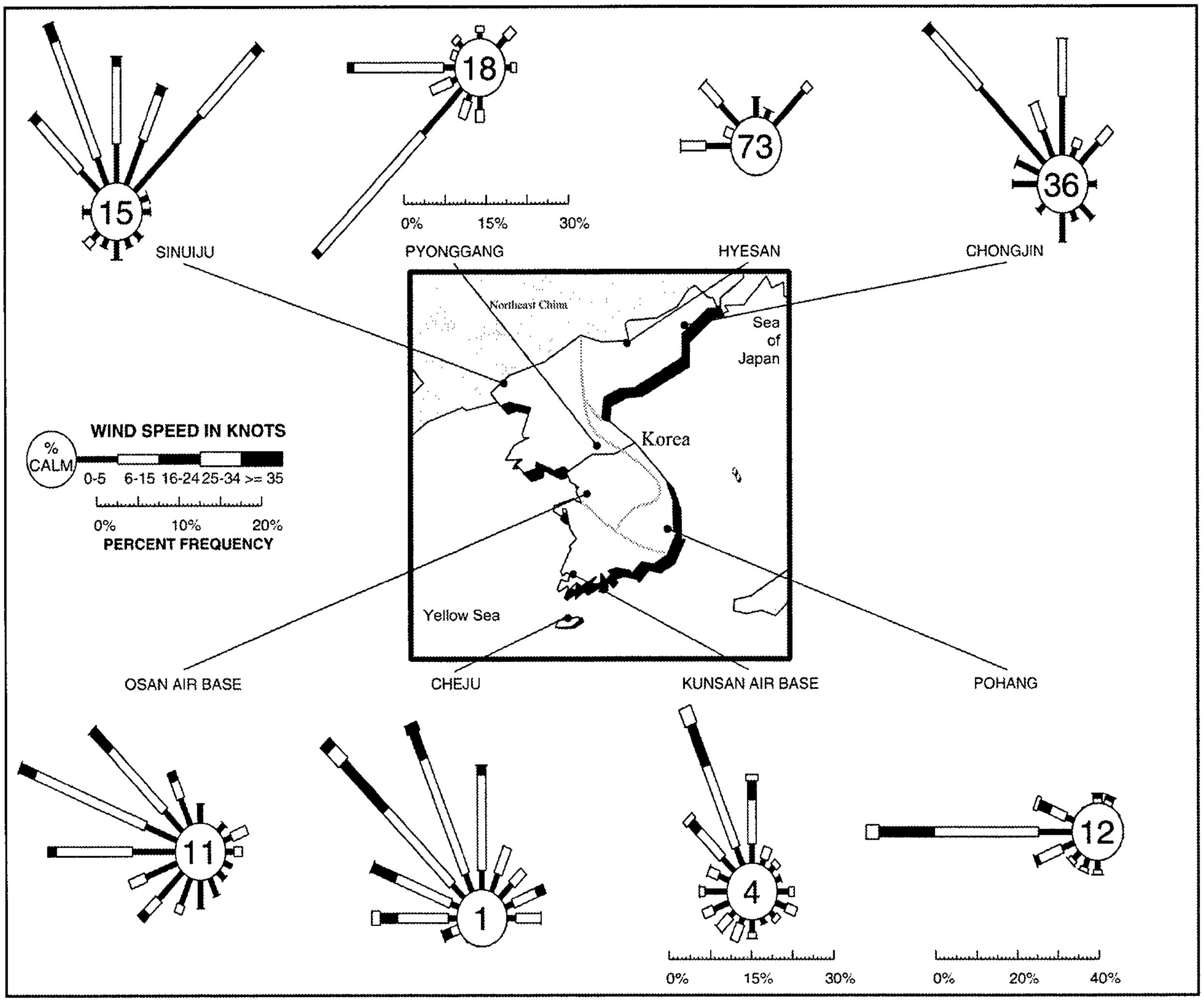


Figure 6-5. January Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location. Areas with a different percent frequency are so indicated.

Upper-Air Winds: The westerly jet is strongest in winter; speeds often exceed 100 knots (see Figure 6-6). The combined subtropical and polar jet, which splits into two separate branches during spring and summer, merges by December into a deep, powerful wind band. By January, the jet axis is over southern Korea at an average height of 35,000 to 40,000 feet and has an average wind speed of 80-105 knots. February is the month when the merged jet is at its strongest and furthest south, centered over Cheju-do. The axis lies just south of the peninsula and the mean winds are 90-120 knots. The relative position does not change in March, but the jet core widens and the speeds lower to a mean of 85-95 knots.

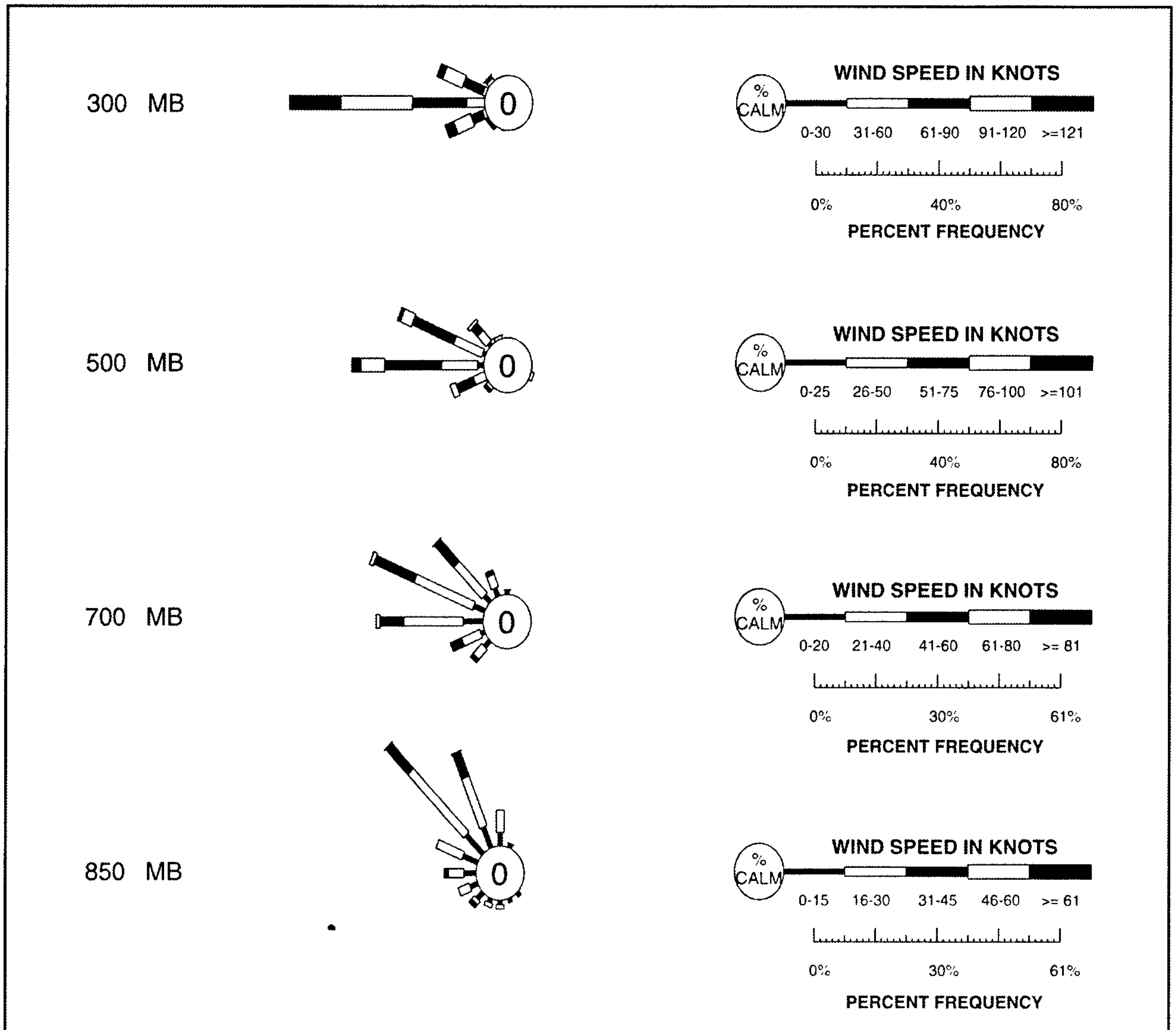


Figure 6-6. January Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Kwangju in southwest Korea. Note: Each wind rose has a tailored legend.

Precipitation.

Northeast Highlands. Precipitation (almost all snow) north of 40° N averages less than 10 mm per month. South of 40° N, mean monthly amounts jump to near 25 mm (see Figure 6-7) . Twenty-four hour extremes, however, have reached 3 inches (75 mm) in the Wonson area under strong onshore flow behind an east-moving frontal low. Almost all precipitation falls as snow from mid-December through late February. Some freezing rain may occur along the coasts. Precipitation days increase rapidly from south to north, a reflection of the increased activity along the northern storm tracks (see figure 6-8). Despite the higher number of precipitation days, actual amounts are lower in the north than in the south because there is less available moisture in the north. Thunderstorms are practically unknown in winter in this region. A very rare, cold air thunderstorm may occur with intense low-pressure systems. Thunderstorm tops are less than 25,000 feet.

Northwest Hills and Plains. Precipitation days increase rapidly from south to north. Despite this, precipitation (all snow) north of 40° N averages less than a 10 mm per month. South of 40° N, mean monthly amounts jump to 25 mm. The reason for this apparent anomaly is the availability of moisture. There is more moisture in the south than in the north, so even though the north has more precipitation days, the amounts are greater in the south. In the area of strong onshore flow behind an east-moving frontal low, 24-hour extremes have reached 75 mm in places. Almost all precipitation falls as snow from mid-December through late February. Some freezing rain may occur along the coast near Panmunjon. Thunderstorms are very rare and occur only with very intense storm systems.

East Coast Plain. Winter is a low precipitation period for all of Korea. Most eastern plain stations report between 25 and 50 mm of precipitation (water equivalent) per month. At higher elevations away from the moderating influence of water, precipitation falls as snow, but coastal stations get both rain and snow, with occasional episodes of freezing rain. Yellow Sea lows develop 12-24 hours after Honan lows form over China directly east of Korea, and they track across central Korea. East coast stations do not get much precipitation from this low until the circulation around the low reaches the Sea of Japan and brings moisture onshore under east or southeast flow. As the low continues eastward, the circulation around it shifts to northeast over the Korean east coast. This cuts off onshore moisture advection. Overall, this type of low drops relatively little precipitation on the east coast of Korea and passes through in 1-3 days. Thunderstorms are a very rare winter phenomenon.

Southwest Hills and Coastal Plain (includes Cheju Island). Winter is a low precipitation period, but the southwest does get more than the north. Yellow Sea lows bring onshore flow to the southwestern coasts. Shanghai lows and transitory lows, which move along the polar front and spin clouds and precipitation north of the polar front, also bring rain and snow to southwest Korea. Windward locations get more snow/rain than leeward sites (8-12 days per month in windward sites and 4-8 days per month for leeward sites) and accumulate snow throughout the winter. Even without an organized weather system, northwest winds blow stratocumulus ashore that develops in moist air over the Yellow Sea. The result is a dusting of snow along the coasts with more accumulation at higher elevations. Mean precipitation amounts range from 25-50 mm of precipitable water per month at most stations with 50-76 mm per month at southwest coastal stations. This area is more vulnerable to freezing rain than any other area of Korea because of the moderating influences of the nearby water. It warms cold surges from Siberia just enough to produce freezing rain in the leading edge of the cold air. Thunderstorms are rare winter phenomena, except for March. As winter starts to give way to spring, small weather systems spawned by the polar front track into the waters around the southern parts of the peninsula and have enough temperature differential to produce some thunderstorm activity as far north as Taegu.

Figure 6-7. January Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

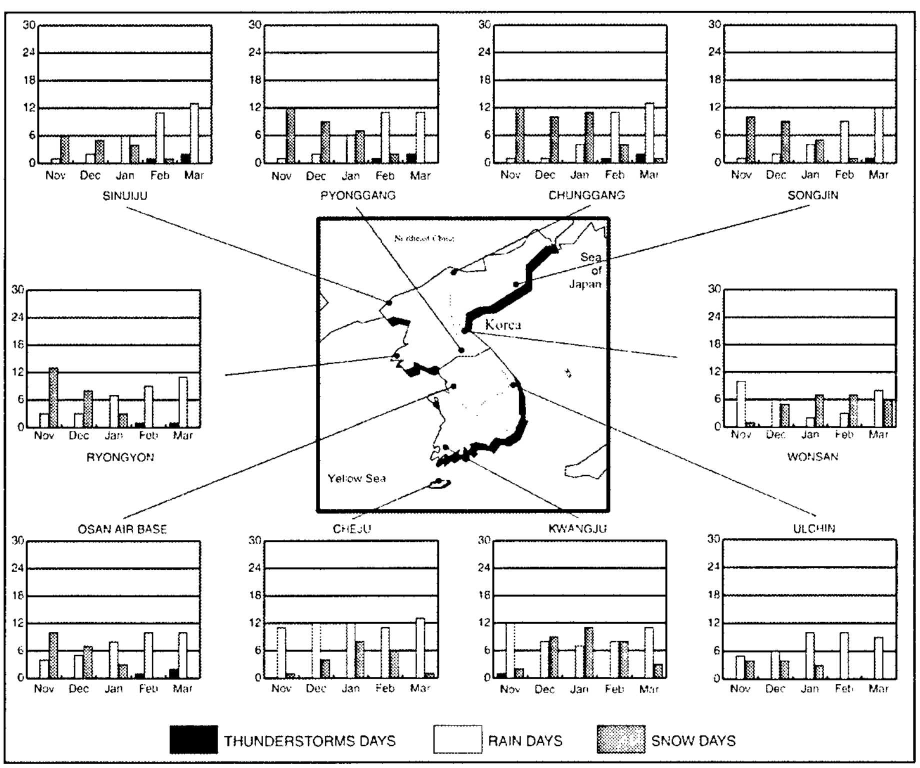


Figure 6-8. Winter Mean Monthly Precipitation and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at scattered locations within Korea.

Temperature.

Northeast Highlands. Bitterly cold weather with extreme wind chills and high frostbite risks are the rule. High temperatures average at or just above freezing only along the east coast south of 41° N; all other areas are well below freezing (see Figure 6-9). The Manchurian border averages from 12° to 15°F (-9° to -11°C); the Kaema plateau and the Hamgyong Mountains are both well below that. Lows average 10° to 15°F (-9° to -12°C) along the coast and drop to near -30°F (-34°C) along the eastern Manchurian border (see Figure 6-10). All of North Korea's ground freezes by early December; it does not thaw, in the north, until late March. Figure 6-11 shows these dates across the country. All but the large, deep rivers freeze right to the bottom (solid) by late December, and do not lose their ice until April.

Northwest Hills and Plains. Temperatures vary greatly from place to place in the winter, mainly because of latitude and elevation. Mean maximum temperatures in January range from 10° to 15°F (-10° to -12°C) in the northwest to 19° to 22°F (-6° to -7°C) in the central west. Mean minimum temperatures during January vary from -20°F (-29°C) in the north to about 20°F (-7°C) in the south. All of North Korea's ground freezes by early December; it does not thaw in the north until late March. Small rivers freeze solid by late December, and do not thaw until April.

East Coast Plain. There is considerable elevation variance in this region, which influences temperature. Low elevation stations, notably those along coasts, have warmer temperatures than high elevation stations. Regional mean high temperatures range from 25° to 42°F (-4° to 6°C) in high elevations to 35° to 52°F (2° to 11°C) along the coasts. The mean low temperatures range from 3° to 23°F (-16° to -5°C) at higher elevations to 31° to 41°F (0° to 5°C). At all stations, the coldest high and low temperatures occur in January and February, with the coldest temperatures in the north.

Southwest Hills and Coastal Plain (includes Cheju Island). There is considerable elevation variance in this region, which influences temperature. Low elevation stations have warmer temperatures than high elevation stations. Regional mean maximum temperatures range from 39° to 57°F (4° to 14°C). The mean minimum temperatures range from 23 to 41°F (-5° to 5°C). March temperatures average 9 Fahrenheit (2 to 3 Celsius) degrees warmer than those of February. The last frost date for the coastal areas falls in mid-March, but the stations at higher elevations have frosts as late as early April.

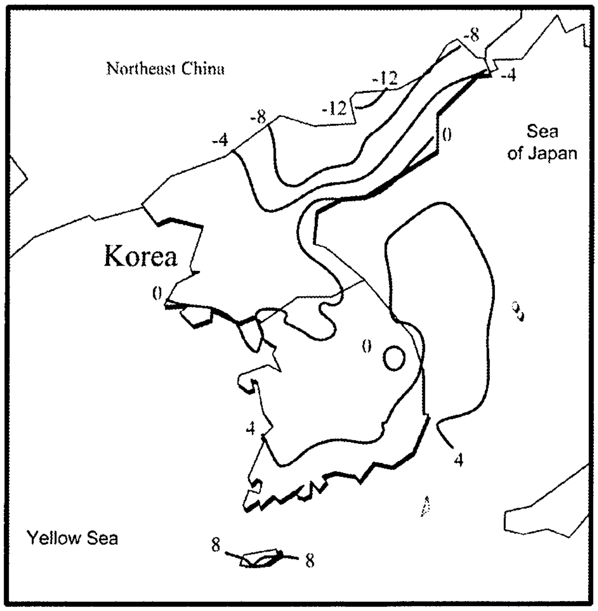


Figure 6-9. January Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for winter.

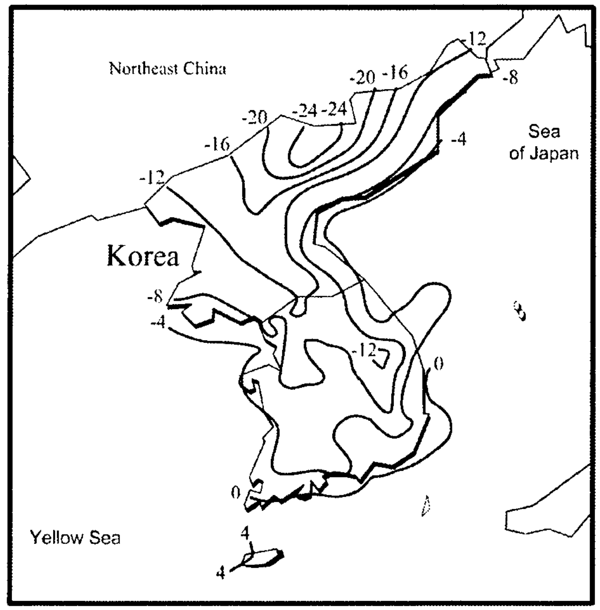


Figure 6-10. January Mean Minimum Temperatures (°C). These temperatures represent the average low temperatures for winter.

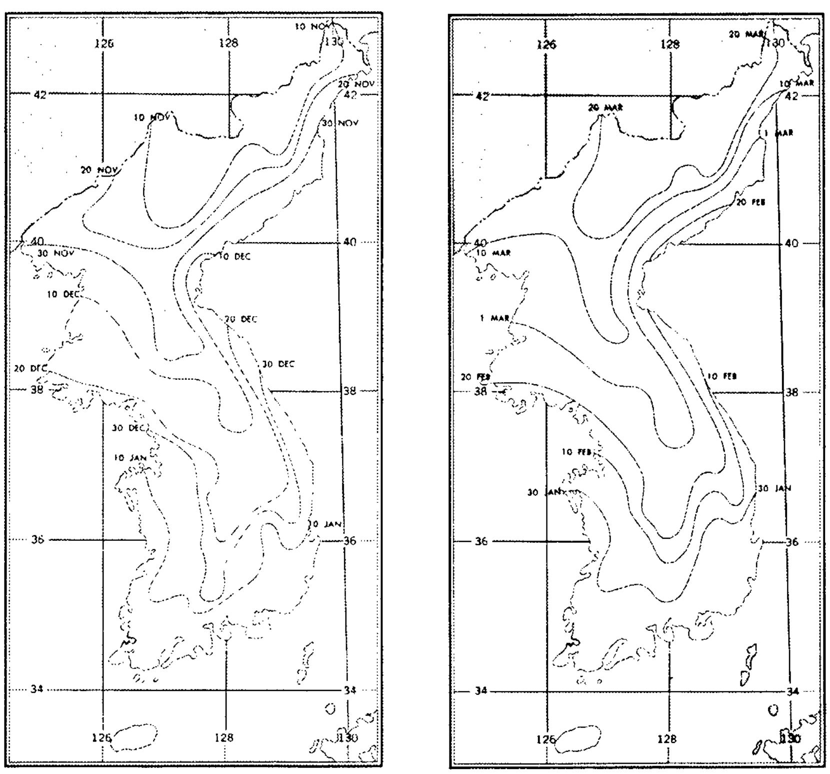


Figure 6-11. Mean Surface Soil Freeze and Thaw Dates.

Hazards. Water survival times of less than 15 minutes occur off the extreme northeast coast (Sea of Japan). Off the extreme northwest coast (Yellow Sea), they are under 45 minutes.

Aircraft in-cloud icing remains a problem along the coasts. Low ceilings and poor visibility are associated with major lows and restrict both air and ground traffic. Clouds will sometimes obscure mountain tops, ridges, and passes, and topographical awareness is a sound safety move.

Severe turbulence occurs over and downwind of mountain ridges under strong northerly flow. Because the air is so dry, there may be no visual cues (such as altocumulus standing lenticular clouds (ACSL) or roll clouds to warn of severe turbulence.

The ground freezes solid and creates problems for ground construction or artillery emplacement. Snow depths along the east coast can reach 2 feet (65 cm), and near 1 foot (30 cm) inland. Drifts can exceed 5 feet (1.5 meters). Structural icing is a problem for both communications towers and for ships operating offshore.

Wind chill and hypothermia are typical winter hazards. South Korea experiences mild wind chill problems, but North Korea gets much colder and experiences deadly wind chills in the deepest cold of winter (January and February).

Freezing rain can be highly dangerous to both ground and air operations. The precipitation freezes to surfaces on contact, which can both immobilize moving surfaces on aircraft and add a lot of weight very quickly. On the ground, it can bring down power lines and guy wires, encase equipment in a layer of ice, and render road travel all but impossible. Even walking can be dangerous.

Trafficability. About 75 percent of the Korean peninsula consists of steep, rugged mountains and hills. The rest consists of plains and lowlands, mostly along the west coast and in scattered inland areas. Soils of the peninsula are mainly mixed coarse and fine-grained. Shallow, coarse-grained soils cover most mountains and hills. The fine-grained soils occur mainly in coastal areas, on the flat plains, and in some hill areas. Most of these fine-grained soils are deep to very deep; some are highly plastic (high clay content) and some are highly organic. The more plastic a soil is, the stickier and slipperier it is when wet. The more organic it is, the less weight it can bear although it is less sticky or slippery than clay soil.

In the mountains and hills, movement conditions are unsuitable at all times because of forests and steep, rugged terrain. Movement is possible along established routes and corridors in valleys, but these are very limited. In the plains and lowlands where rice is grown, movement is unsuitable because of flooded fields and soft soils. Some movement is possible in winter across frozen rice fields. In other areas of the plains and in some low hills, mainly where dry crops are grown along the west and south coasts, movement conditions are fair in the dry season. Direction of travel is limited by stream banks, canals, forests, and rough, dissected terrain.

General Weather. The Asiatic high breaks down in the spring, and the Pacific high starts to push the polar front northward. Temperatures rise progressively higher, and low-pressure areas sweep ever closer to Korea as the polar front approaches. By April, the front is between Taiwan and Shanghai, and sweeping lows wrap extensive cloudiness and precipitation well into Korea. Associated thunderstorms occur as far north as Taegu. Cheju-do sees this situation as early as the first part of March and experiences the heaviest rain with it. The northerly flow around the Asiatic high-pressure cell over Siberia is no longer dominant; the mean winds become light and variable. Based on the mid-level and low-level trajectory, the overlying air mass is still continental. Depending on trajectory over land or water, the air mass may be either moist or dry. The average date of the last frost in spring occurs around April 20th in central Korea.

Spring is characterized by a pattern of weak and indefinite flow. When compared to April, the mean surface temperatures show an average increase of 10 Fahrenheit degrees (6 Celsius degrees). On the northeast coast and on the central western coast, there is a rapid increase in the incidence of dense fog as intrusions of warm, moist air from the south continue to occur. This moist air results in increasing cloudiness and precipitation during April. The increased precipitation, coupled with snow melt and thawing ground (particularly in the higher elevations) causes a substantial rise in river levels. A slight maximum in river stage heights usually occurs in April. Ordinarily, this increase in water levels is not sufficient to cause wide spread flooding. The ground surface is generally wet and muddy and the roads are in poor condition. Mud can get as deep as 18 to 30 inches (46 to 76 cm) along rivers and rice paddies. Typhoon activity does not reach the Korean peninsula in the spring.

Sky Cover.

Northeast Highlands. Cloudiness increases in spring as the Asiatic high weakens and the strong, northwesterly flow of dry, continental air decreases. The polar front occasionally migrates northward over Korea with warm, moist air and clouds. Scattered skies occur at night half the time; during daylight hours, clear-to-scattered skies occur only 10 days of the month. Broken-to-overcast skies occur on 10-14 days at night and 15-20 days of the month during the day. Ceilings less than 3,000 feet occur 26 percent of the time in April and increase to 31 percent of the time in May (see figure 6-12). Ceilings less than 3,000 feet occur most often between the hours of 0400L and 0600L, with an average of 29 percent of the time in April and 35 percent of the time in May.

Northwest Hills and Plains. Mean cloud cover increases as warm, maritime air replaces cold, dry, continental air. The polar front occasionally migrates northward over Korea when strong lows occlude on the front. These lows, which are fed by cold air off the land, spin up to become very strong systems. They wrap large amounts of moisture around themselves and spread warm, moist air and clouds across the region. Scattered-to-clear skies occur at night half the time and only about 10 days a month during daylight hours. Broken-to-overcast skies occur on 10-14 nights and 15-20 days of the month. Ceilings occur less than 3,000 feet 22 percent of the time in April, with a maximum occurrence of 26 percent of the time from 0400 to 0600L. In May, the probability of ceilings less than 3,000 feet increases slightly to 29 percent of the time. Pyonggang and Kanggye, which lie at the western base of the Nangrim mountain range, experience ceilings less than 3,000 feet greater than 40 percent of the time, due to upslope.

East Coast Plain. Clear, dry conditions give way before the onset of spring rains. Middle-to-high overcast conditions become widespread in Korea by the end of May. By the end of April, clear skies only occur 5-8 days of the month. Despite this, low ceilings are unusual for the plains. Outside of early morning hours, coastal stations see ceilings of 3,000 feet or less 10-20 percent of the time. Morning ceilings at 3,000 feet or below occur on the coast 30-40 percent of the time and burn off well before midday. Mountain stations, in a reflection of their higher elevation, report ceilings 3,000 feet or less 30-45 percent of the time in the mornings, then drop off to less than 15 percent of the time for the rest of the day. Ceilings below 1,500 feet rarely occur anywhere in the region. Mountainous areas are frequently cloaked in clouds.

Southwest Hills and Coastal Plain (includes Cheju Island). Middle-to-high overcast conditions become widespread in southwest Korea by the end of May. Outside of early morning fog and stratus, coastal stations see ceilings of 3,000 feet or less 10-20 percent of the time. Mountainous stations report ceilings 3,000 feet or less 30-45 percent of the time. Mountainous areas are frequently cloaked in clouds.

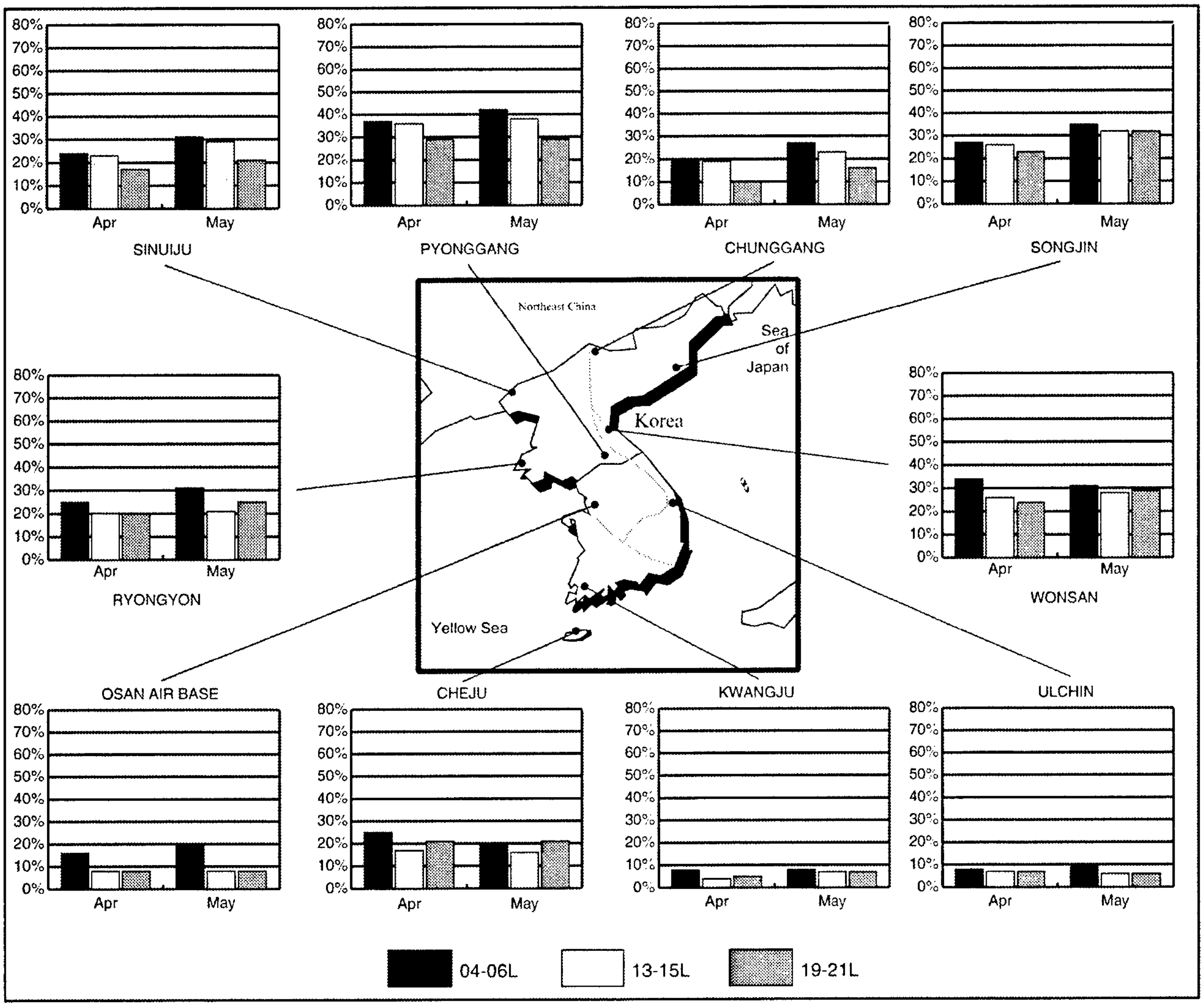


Figure 6-12. Spring Ceilings below 3,000 Feet. The graphs show a breakdown of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northeast Highlands. The main cause of low visibility during the spring is fog. Morning fog occurs 15 days a month in the western and southern regions of this area. Between 0400 and 0600L, visibility is generally 3,200-4,800 meters in fog 25-30 percent of the time. Visibility less than 1,600 meters occurs 5 percent of the time. There are 2 types of fog that affect northeast Korea—sea fog and radiation fog. Sea fog forms over the Sea of Japan when relatively warmer air passes over the cool water surface. An easterly wind advects the sea fog over the coast and inland, dams it up against the mountains, and fills in the valleys. This is very noticeable at Songjin and Chongjin where visibility less than 4,800 meters occurs 50-55 percent of the time in April and May between the hours of 0400L and 0600L. Radiation fog, which can reduce visibility to 3,200 meters, occurs most frequently along rivers and in mountain valleys. It usually dissipates by late morning. Smoke and haze often occur in large industrial areas.

Occasionally, the skies over the northern peninsula are colored by "yellow winds" or dust suspended in the atmosphere (caused by dust storms over Mongolia and northern China). Dust aloft can extend as high as 15,000 feet and reduce flight-level visibility to 3,200 meters. This occurs on average 1 to 2 days a month in the north. Visibility may be restricted for several days as strong, upper-level winds bring dust over from the Gobi Desert. Dust restricts visibility an average of 10 days a year. During the first couple of weeks in April, snowfall can reduce visibility in the mountains. Occasionally, a snowstorm will reduce visibility to near zero.

Northwest Hills and Plains. Fog is the major obstruction to visibility. Visibility will begin to decrease in the early morning hours with the worst conditions at sunrise. Visibility less than 1,600 meters occurs in early mornings near towns and cities because of pollution and calm winds. At these sites, visibility drops below 4,800 meters after midnight under calm winds and does not markedly improve until 1 to 2 hours after sunrise (see Figure 6-13). Visibility below 9,000 meters occurs on approximately 40 percent of spring mornings. Visibility below 4,800 meters occurs on 17 percent of May mornings. In low-lying areas and around water sources, visibility below 800 meters is not uncommon. Fog will linger through midmorning; denser fog will last through early afternoon. Osan AB and surrounding valleys experience visibility less than 4,800 meters more frequently—29 percent of the time in April and 33 percent of the time in May—due to the increase of pollutants in the atmosphere, which provide additional condensation nuclei for fog formation. During early spring, this area is also susceptible to "yellow winds" out of China. During yellow wind outbreaks, visibility may drop below 4,800 meters for 1 to 2 days at a time.

East Coast Plain. Spring burn-off adds to visibility problems as farmers who did not burn their fields in the fall take care of that chore now. Fog, rain, and pollution also contribute restrictions to visibility. Visibility obstructions due to wet haze start as the polar front moves closer and closer. Morning fog/haze restricts visibility to less than 4,800 meters an average of 30-40 percent of the time then burns off before midday. The rest of the day and night, visibility drops below 4,800 meters less than 10 percent of the time along the coasts and less than 20 percent of the time at higher elevations. With few exceptions, stations report visibility below 11,000 meters less than 10 days per month.

Southwest Hills and Coastal Plain (includes Cheju Island). Spring burn-off also adds to visibility problems in this area. Fog, rain, and pollution also contribute restrictions to visibility. Wet haze becomes a problem as the polar front moves closer and closer. Morning fog/haze restricts visibility to less than 4,800 meters an average of 30-40 percent of the time. The rest of the day and night, visibility drops below 4,800 meters less than 10 percent of the time along the coasts and less than 20 percent of the time at higher elevations.

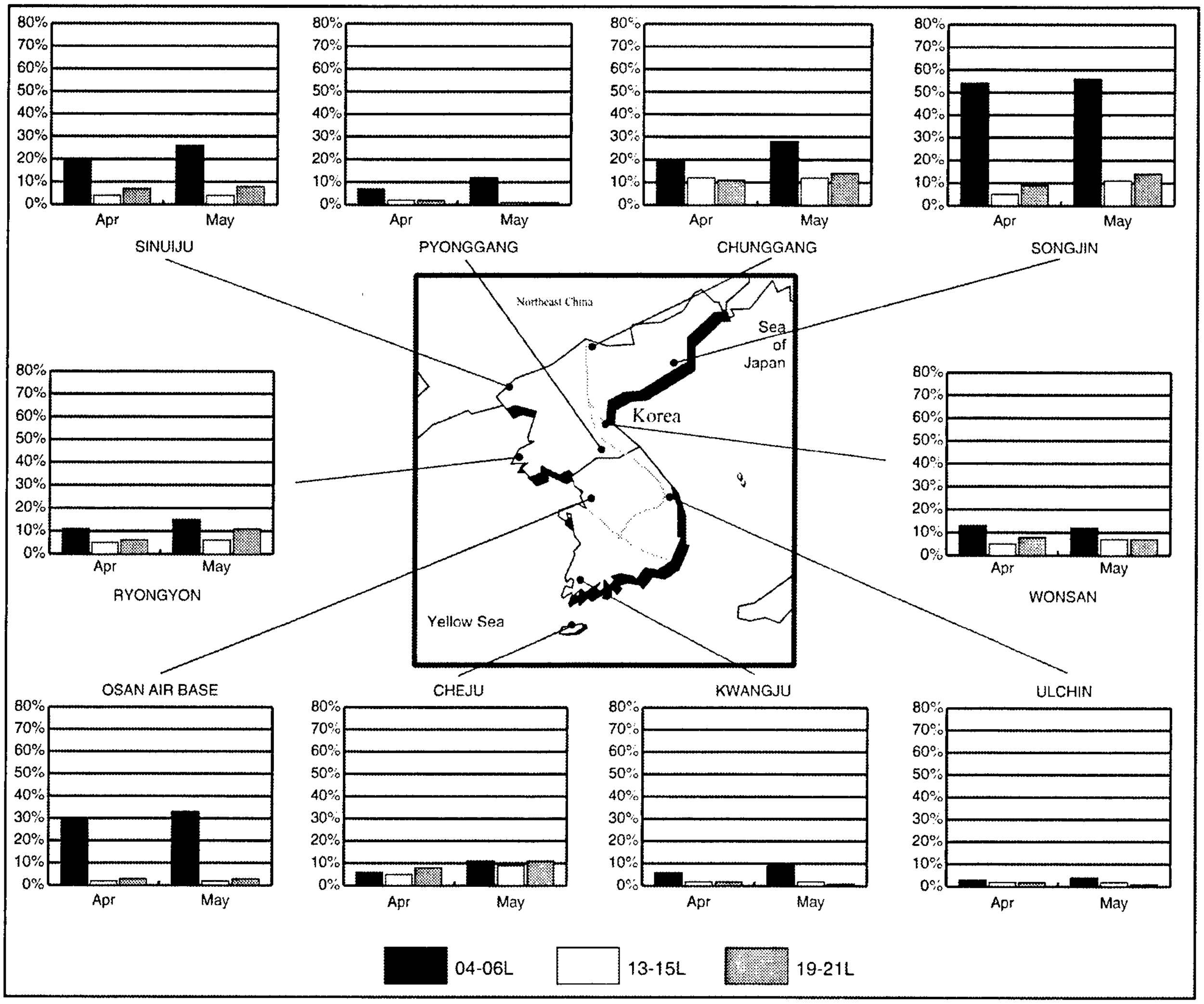


Figure 6-13. April Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Northeast Highlands. Winds become light and variable in spring as the Asiatic high weakens. The percentage of southerly winds increases due to weakening of the Asiatic high and to the increasing frequency of frontal passages (see Figure 6-14). Topography still plays an important role in both wind direction and intensity. Variations in the wind direction and speed are common due to the rugged terrain. Diurnal variations due to circulations like the land/sea breeze increase. Foehn winds occur on the west side of the mountains along the east coast in association with strong, easterly, onshore winds from Sea of Japan. Lows from China, which pass over the Korean peninsula, can produce these winds. Gale-force winds (greater than 27 knots) are not common, but the northeast highlands still have the highest frequency due to funneling. They occur on as many as 2-4 days a month, and the maximum speeds have reached as high as 80 knots.

Northwest Hills and Plains. Mean wind speeds are higher during spring than at any other time of the year. In late morning through afternoon, winds range from southwesterly to westerly at 8-16 knots. Night and early-morning winds are light and variable, but they can be northeasterly through southeasterly at 4-7 knots with mountain/valley breezes. Spring is often heralded by gusty winds, especially with frontal passage. As high pressure builds in behind the front, afternoon winds blow at 12 to 15 knots. Variations in the wind direction and speed due to the rugged terrain are common. Coastal diurnal variations due to land/sea breezes increase. Low-level winds above the boundary layer are more variable as fronts move through more often. Foehn winds, at speeds generally less than 15 knots, move down from the Myohyang Mountains to the east, particularly during early spring. Bora winds are associated with cold outbreaks and occur as late as early May in the northernmost area of the region.

East Coast Plain. Because this is the transition season between the winter and summer regimes, winds are variable. Prevailing winds at most stations under the lee of the mountains and not right on the coast are right out of the mountains to the west. As the polar front approaches, lows bring the winds around to a southeasterly or southerly direction to reflect their circulation. In times when the cold, dry winter regime holds, general north or northwest flow dominates, but local winds vary considerably because of terrain. Under winter-like conditions, jet-effect (funneling) winds can occur. The greater temperature gradient between higher and lower elevations during spring tends to enhance those winds. Under the right conditions, stations directly in the drainage path can get winds that blow steadily over 30 knots and gust over 50 knots. Overall, the prevailing winds are from the west, but local topography plays a significant part in both direction and speed.

Southwest Hills and Coastal Plain (includes Cheju Island). Spring winds are variable. As the polar front approaches, lows bring the winds around to a southeasterly or southerly direction to reflect their circulation. In times when the cold, dry winter regime holds, north or northwest flow dominates. Funneling winds occur under these conditions. In some cases, the effect is actually enhanced in spring by the greater temperature gradient between higher and lower elevations. Chinhae and Pusan are classic examples of this. Both have reported steady winds in excess of 30 knots with gusts over 50 knots under funneling winds from the north-northwest.

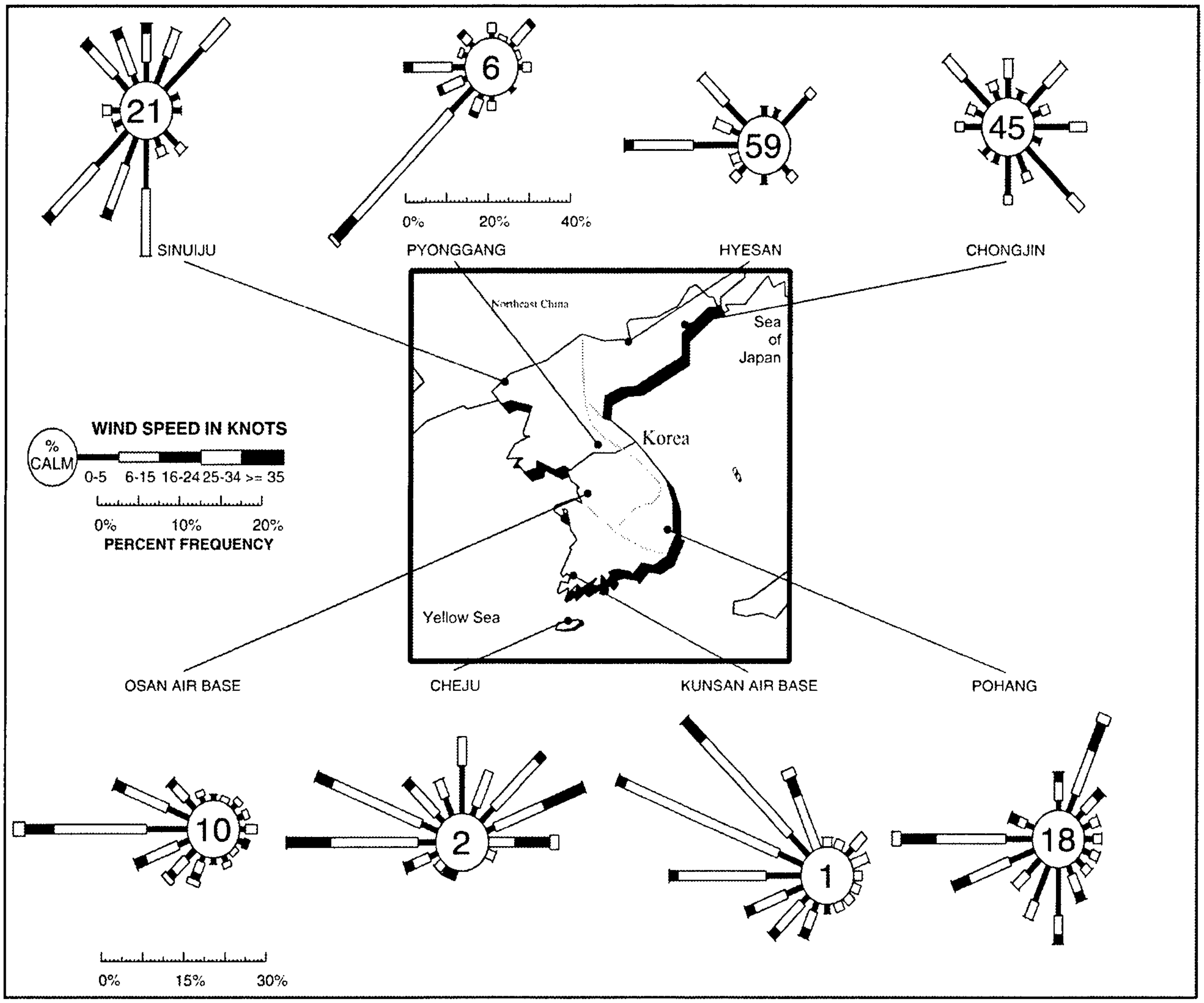


Figure 6-14. April Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds. The combined subtropical and polar jet stream slows and divides in spring. One axis lies across North Korea (polar jet) and the other (subtropical jet) lies across Shanghai and southern Japan. Upper-air winds are primarily westerly. Jet core speeds drop to an average of 65-75 knots above 25,000 feet and continue to slow into the summer (see Figure 6-15).

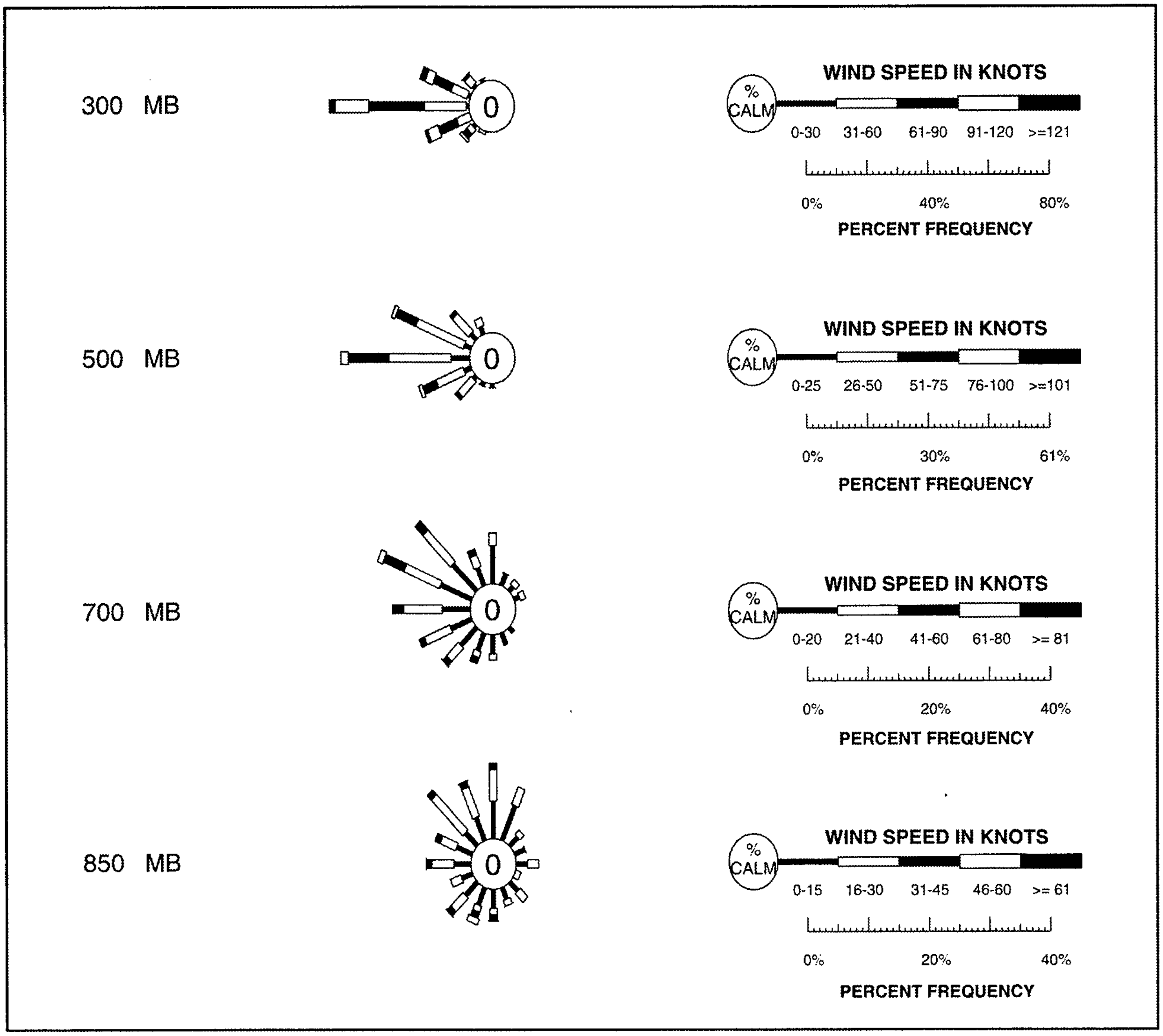


Figure 6-15. April Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Kwangju. Note: Each wind rose has a tailored legend.

Precipitation.

Northeast Highlands. Precipitation amounts continue to increase during April, but mean monthly totals remain below 50 mm (see Figure 6-16). Precipitation frequency for a particular location depends on the direction of the prevailing wind flow and the proximity to the mountain range. Windward stations experience 8-12 days of precipitation while leeward stations receive only 4-8 days. In April, snowfall occurs an average of 3-5 days, with snow cover that generally lasts 2-3 days. In May, the average is 1 day of snowfall in the higher elevations This snow melts quickly. Snowfall will not normally occur after early May.

Thunderstorms are still rare during the spring. Thunderstorms normally occur only over the highest mountains as a strong cold front or Yellow Sea low passes. Along the coasts, thunderstorms occur less than 1 day a month, as shown in Figure 6-17. Tops range from 30,000 to 35,000 feet.

Northwest Hills and Plains. Precipitation totals increase steadily as more low-pressure centers cross central Korea. On rare occasions, early April precipitation may still be snow, but the average last snowfall date is 30 March. Snow normally does not occur after early May, even in the higher northern elevations, except over the crests of the highest peaks. By late May, the polar front lies across the south end of the peninsula, and rain falls on 1 day out of 3. Average amounts increase to 89 mm in May. Twenty-four hour rainfall amounts have reached 43 mm.

Thunderstorms occur infrequently in spring. They are generally associated with strong fronts, and occur on an average of 1 day in April and 3 days in May. Bases for the thunderstorms are 1,500 feet AGL, with tops near 30,000 to 35,000 feet. Small hail may accompany some thunderstorms. With the large temperature differential in the spring, downrush gust speeds can easily be more than triple normal wind speeds. Downrush winds have exceeded 45 knots in places.

East Coast Plain. Small, low-pressure systems bring moisture as they move along the polar front every 3-5 days. As a result, rain sweeps through with lows. Speed of passage depends on the strength and speed of the parent system. Mean precipitation amounts rise from winter lows. An average of 50-127 mm of rain falls with most inland stations reporting in the low end of that range. Snow accumulation is unusual, but still possible at higher elevations and in the northern third of the plain. Late snows of 76-127 mm have been reported in early April. Thunderstorms occur less than 1 percent of the time throughout the eastern plain.

Southwest Hills and Coastal Plain (includes Cheju Island). Small, low-pressure systems move along the polar front through this area every 3-5 days. Rain sweeps through with the lows. Speed of passage depends on the strength and speed of the parent system. Mean precipitation amounts rise from winter lows. Southwest coastal stations get 101-152 mm per month while most others get 76-101 mm. Upslope convection causes most of the thunderstorm activity in the spring; frontal convection follows close behind. Although they only occur less than 1 percent of the time, thunderstorms are a threat that should be taken seriously when they do occur. These storms can produce damaging winds, hail and flash flooding because of heavy rain.

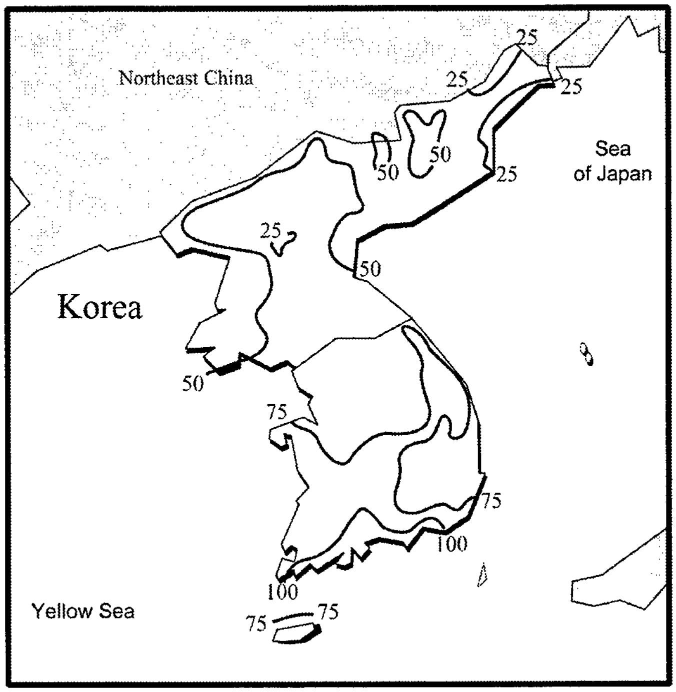


Figure 6-16. April Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

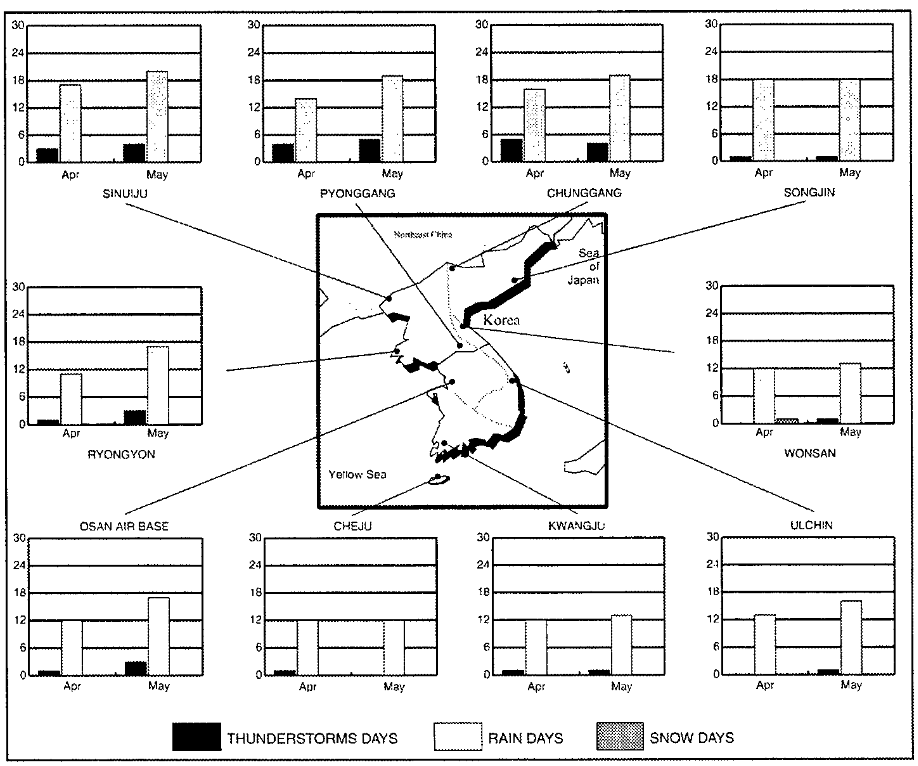


Figure 6-17. Spring Mean Monthly Precipitation and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at Korean locations.

Temperatures.

Northeast Highlands. April mean highs increase from near 60°F (15°C) along the North Korea/South Korea border to near 50°F (10°C) along the Siberian and Manchurian borders (see Figure 6-18). Mean lows range from slightly over 40°F (4°C) to below freezing along the Yalu River (see Figure 6-19). Temperatures over the higher mountains fall well below freezing. By May, mean highs range from near 60°F (15°C) along the Russian border to over 70°F (21°C) along the DMZ. Lows also rise; they are 39° to 44°F (4° to 7°C) along the northeast coast and 50° to 53°F (10° to 12°C) along the DMZ. Recorded extremes range from a record low of 1°F (-17°C) in the extreme north along the Manchurian border to a record high of 100°F (38°C) at Wonsan.

Northwest Hills and Plains. Temperatures warm steadily throughout the season. April mean high temperatures are near 60°F (15°C) in the central northwest hills and plains and near 50°F (10°C) along the northern borders of North Korea. Mean lows are slightly below freezing along the Yalu River. Temperatures in the higher mountains fall well below freezing. As the polar front moves northward, incursions of warm, moist air become more common. By May, mean highs range from near 60°F (15°C) along the northern borders to over 70°F (21°C) in the central northwest hills and plains. Recorded extremes range from a record low of 3°F (-16°C) in the extreme north along the Manchurian border to a record high of 95°F (35°C) in the northern interior. The mean date for the last frost is April 20, but freezing temperatures can occur as late as the first week in May, especially if a migratory high settles over Korea.

East Coast Plain. Winter's icy grip is broken in this season. Temperatures can still dip to freezing in the first half of April, but frost warnings are over by April 20. The mean last frost date varies by latitude and elevation. Mean last frost in the southern one third of the east plain is as early as 20 March. By 20April, even the most northerly stations and high elevation stations in the mountains facing the plains see no more frost. Mean high temperatures in April are in the 57° to 62°F (14° to 17 °C) range. By May, the highs range from the 62° to 73°F (17° to 23°C). Extreme high temperatures can top 100°F (38°C) by the end of May, but generally stay in the 93° to 96°F (34° to 36°C) range. April mean low temperatures are generally in the 44° to 48°F (7° to 9°C) range with high elevation exceptions, which dip into the 33° to 37°F (1° to 3°C) range. By May, mean lows are up into the 44° to 57°F (7° to 14°C) range. Extreme lows dip below freezing through the early days of May, but this generally happens in high elevations.

Southwest Hills and Coastal Plain (includes Cheju Island). Temperatures warm this season; they can still approach freezing, but frost warnings are over by April. Mean high temperatures in April range from 50° to 71°F (10° to 22°C). Temperatures depend on elevation. By May, the highs range from 64° to 78°F (18° to 26°C). Extreme high temperatures can top 90°F (32°C) by the end of May, but generally stay in the 84° to 89°F (29° to 32°C) range. April mean low temperatures range from 48 to 55°F (9° to 13°C). By May, lows rise to 57° to 60°F (14° to 16°C). Extreme lows approach, but don't quite drop to freezing, except in mountainous areas. Taegu shows an April extreme low of 18°F (-8°C), and that is fairly common for mountain stations.

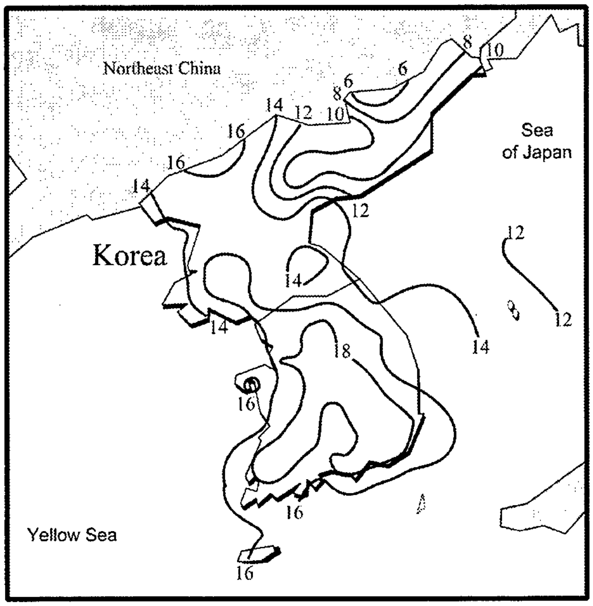


Figure 6-18. April Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for spring.

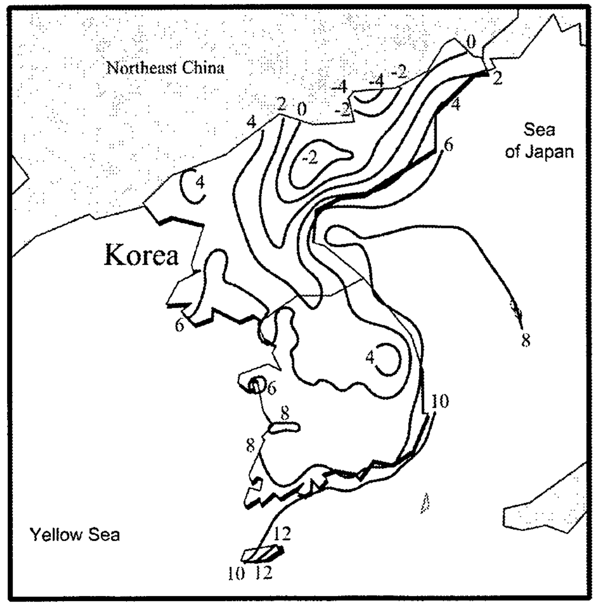


Figure 6-19. April Mean Minimum Temperatures (°C). These temperatures represent the average low temperatures for spring.

Hazards. Sea survival times increase to about 30 minutes off the northeast (Sea of Japan) coast. Off the northwest (Yellow Sea) coast, they increase to approximately 2 hours by the end of May.

Severe turbulence, severe mixed icing, strong wind shear, and strong surface winds occur with thunderstorms. Dust advected in from the Gobi Desert and from north China can cause a reduction in visibility from the surface to as high as 15,000 feet (4,600 meters). Low ceilings and visibility associated with major lows restrict both air and ground traffic. Sea fog occurs more frequently with the westerly winds. As the combined winter jet divides into two separate streams, turbulence problems decrease; however, turbulence is still significant, especially where the jets diverge. Moderate-to-heavy turbulence can be expected near the jet core. Severe turbulence over and downwind of mountain ridges can still be expected under strong, northerly flow. It will usually be signaled by the presence of ACSL and roll or rotor clouds.

The ground begins to thaw and produces deep mud conditions in low-lying areas. The average river depth is 7 feet (2 meters), with a maximum river depth of 23 feet (7 meters) along the Han River. Snow melt and increased precipitation result in rivers that rise to their deepest depth and fastest current speed.

Trafficability. About 75 percent of the Korean peninsula consists of steep, rugged mountains and hills. The rest consists of plains and lowlands, mostly along the west coast and in scattered inland areas. Soils of the peninsula are mainly mixed coarse- and fine-grained. Shallow coarse-grained soils cover most mountains and hills. The fine-grained soils occur mainly in coastal areas, on the flat plains, and in some hill areas. Most of these fine-grained soils are deep to very deep; some are highly plastic and some are highly organic. The more plastic a soil is, the stickier and slipperier it is when wet. The more organic it is, the less weight it can bear although it is less sticky or slippery than clay soil. In the mountains and hills, movement conditions are unsuitable at all times because of forests and steep, rugged terrain.

Movement is possible along established routes and corridors in valleys, but these are very limited. In the plains and lowlands where rice is grown, movement is unsuitable because of flooded fields and soft soils. Some movement is possible in winter across frozen rice fields. In other areas of the plains and in some low hills, mainly where dry crops are grown along the west and south coasts, movement conditions are fair in the dry season. Direction of travel is limited by stream banks, canals, forests, and rough, dissected terrain. In the wet season, conditions of movement are unsuitable in all but very localized areas.

General Weather. By July, the polar front is as far north as it will go, and the weather in all of Korea is hot and humid. Aside from activity on the unstable polar front, there are two main reasons for changes in weather. The well-established Asiatic low (a thermal low), which is located over the continental mainland, and the Bonin high (part of the stable subtropical ridge) expands westward into the East China Sea. The resultant flow off the sea brings in a continuous stream of warm, moist air. This produces regular rain, rainshowers, thunderstorms, and extensive cloudiness. Most of the rainfall for Korea comes in this season. Because it is so unstable, the polar front generates numerous small low-pressure systems that often stall in the Korea Strait. This occurs most often in July and brings large amounts of rain to all of Korea.

The east coast plain is relatively dry compared to the southwest portion of Korea. Much of the precipitation associated with lows along the polar front is rained out as the lows move over the mountains. After the lows move far enough east for onshore flow to begin on the east coast (circulation around the low), it is the advected moisture that actually produces most of the rain. More northern parts of the peninsula depend on this onshore flow for most of their precipitation as well. The southern third of the plains gets more wraparound rain from lows tracking along the polar front than the north. Shanghai lows and Yellow Sea lows that move across the peninsula lose much of their moisture in the mountains. They require onshore advection of moisture to precipitate on the east coast plains.

June begins the most active typhoon period for Korea. Before this, storms recurve and stay well south of the peninsula. Only 9-14 percent of all typhoons that develop in the western Pacific reach Korea between June and September, and these are usually considerably weakened by the time they arrive.

Sky Cover.

Northeast Highlands. The frequency of ceilings below 3,000 feet continues to steadily increase from the south to the north through July, a reflection of the northward movement of the polar front (see Figure 6-20). August has less cloud cover than other summer months. Mountains are routinely obscured above 1,000 feet within 100 miles (161 km) of the polar front or low-pressure centers. In these areas, layered clouds extend to well above 30,000 feet. Ceilings within 50 miles (80 km) of the front or low may drop well below 1,000 feet. Otherwise, low stratus gives way to late morning cumulus with isolated afternoon thunderstorms; there is rapid clearing after sunset. The average frequency of ceilings less than 3,000 feet in June is 54 percent of the time. Changjin has ceilings less than 3,000 feet 79 percent of the time from 0400 to 0600L in June. Sinpo experiences these same conditions 52 percent of the time. Overall, from 0400 to 0600L, ceilings occur less than 3,000 feet 64 percent of the time in June. In July, the frequency of these low ceilings reaches a maximum with an average rate of 71 percent of the time from 0400 to 0600L. It drops to 46 percent of the time from 1300 to 1500L. Changjin experiences ceilings less than 3,000 feet approximately 88 percent of the time from 0400 to 0600L in July.

Northwest Hills and Plains. The onset of southerly flow leads to significant cloudiness. Unlike the other seasons, there is very little diurnal variation in summer cloud cover. The mean cloud cover is broken. The predominantly low clouds have bases between 1,000 and 3,000 feet. Ceilings normally drop below 1,000 feet immediately after sunrise, but improve by midmorning. Such conditions occur on only 1 morning in 10, even in July, usually with strong southwesterly and southerly moist low-level flow. Clouds with bases below 200 feet are common in rainshowers, but are mostly associated with dense sea fog moving in from Korea Bay. The low cloud deck is often fairly solid to 10,000 feet with broken altocumulus decks above. Toward the end of the season, the heavy overcast decreases as the region transitions into fall. In June the average occurrence of ceilings is 34 percent of the time; in July the frequency increases to 49 percent of the time. These ceilings decrease to an average of 39 percent of the time in August. The maximum occurrence of ceilings below 3,000 feet occurs between the hours of 0400 and 0600L, with June at 41 percent of the time, July at 60 percent of the time, and August at 50 percent of the time. Pyonggang and Kanggye experience these low ceilings more frequently during the early morning hours, 73 and 78 percent of the time, respectively.

East Coast Plain. This is the cloudiest time of year as small lows sweep slowly across the peninsula an average of 4 times per month. Cloudy skies prevail better than 95 percent of the time. Clear skies only occur 1-3 days per month all summer. Ceilings 3,000 feet or below occur as much as 80 percent of the time in the morning at higher elevations and 40-70 percent of the time in the morning at lower elevations. By midday, low ceilings dissipate, and skies remain scattered the rest of the day. The southern third of the eastern plain is better off than the rest. It only sees ceilings below 3,000 feet 15-25 percent of the time in the mornings and rarely the rest of the day. Ceilings at or below 1,500 feet occur less than 15 percent of the time everywhere and usually result from morning fog that lifts out into temporary ceilings. Ceilings below that occur less than 5 percent of the time, mostly in direct association with morning fog.

Southwest Hills and Coastal Plain (includes Cheju Island). This is the cloudiest time of year as small lows sweep slowly across the peninsula an average of 4 times per month. Ceilings 3,000 feet or below occur anywhere from 15-35 percent of the time. Ceilings at or below 1,500 feet occur approximately 15 percent of the time. Ceilings below that occur less than 10 percent of the time, usually in the morning hours. The southwestern coastal area report the most cloudiness and the southeast coast report the least.

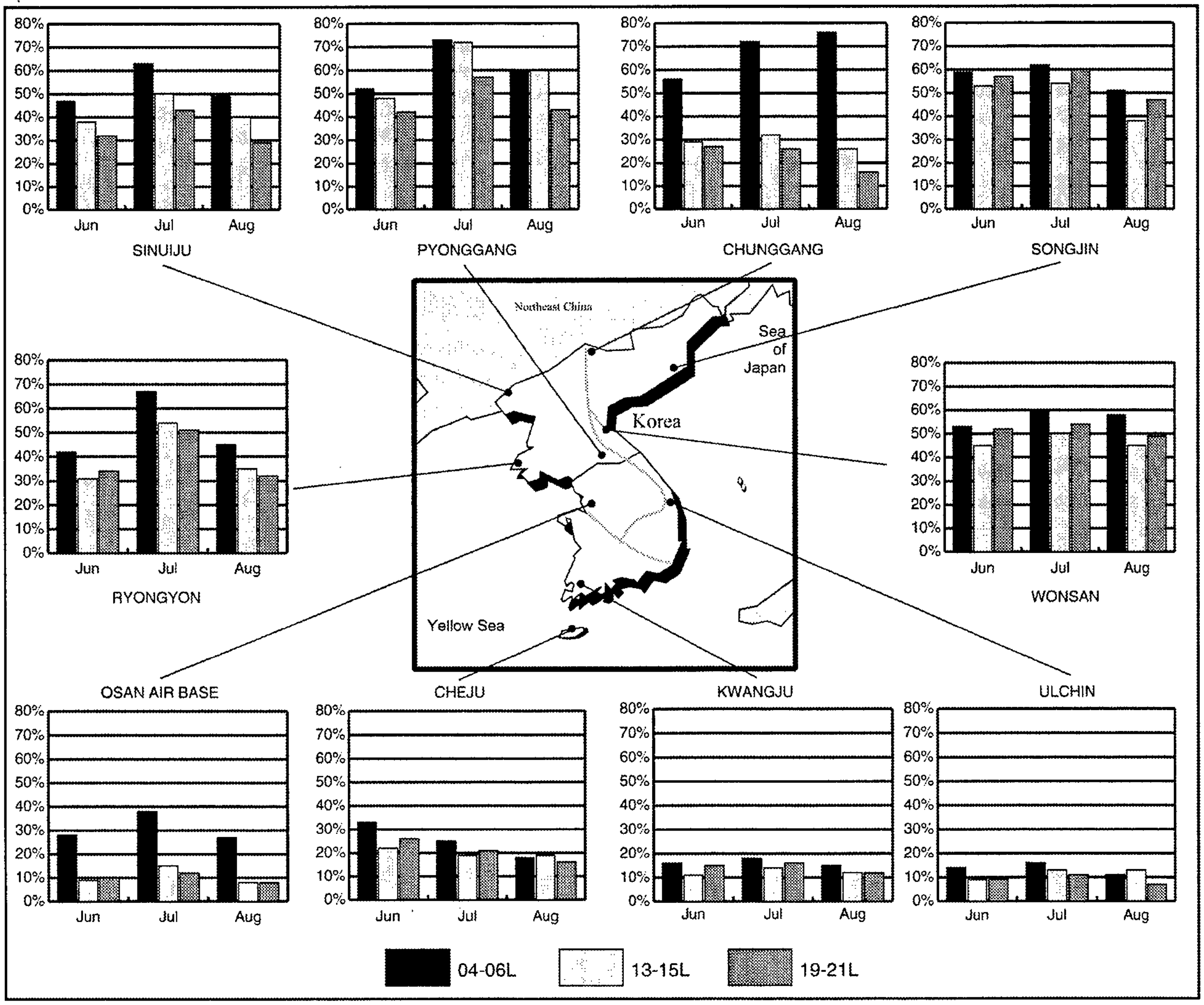


Figure 6-20. Summer Ceilings below 3,000 Feet. The graphs show a breakdown of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northeast Highlands. Fog is widespread along the northeastern coast and north of advancing frontal systems. Early morning visibility drops below 4,800 meters as much as 65 percent of the time in June and July, between 0400 and 0600L (see Figure 6-21). By late July, these poor conditions decrease; mean occurrence is 45 percent of the time at most locations by August. Early and midmorning visibility less than 1,600 meters occurs more than 40 percent of the time at locations along the coastlines. While the Sea of Japan warms, the Liman Current along the northeast coast continues to keep sea-surface temperatures relatively cold, so the prevailing winds (slightly onshore) ensure nocturnal fog and low clouds. Inland stations consistently see nocturnal radiational ground fog. During the afternoon, the inland areas of the northeast highlands experience visibility less than 4,800 meters less than 5 percent of the time. Many of the coastal regions have visibility less than 4,800 meters as much as 30 percent of the time in June and 25 percent of the time in July.

Northwest Hills and Plains. Low visibility is a greater problem during summer than at any other time of year. Moist southeasterly flow and high humidity combined with calm winds at night are quite conducive to fog formation. Radiation fog normally forms after midnight and lasts until late morning 11-15 days a month; it is most common (30-40 percent of the time) from 0400 to 0600L. Haze lasts throughout the day with a frequency of 30-40 percent of the time in the afternoon; it is less common at night. Visibility in fog is usually 3,200-4,800 meters, but fog obscures visibility to less than 1,600 meters up to 8 days a month. For the rest of the season, visibility less than 1,600 meters in fog can be expected on 6 days a month. At midsummer, fog may be thick enough to totally obscure the sky, but much of it is shallow; elevations above 500 feet (150 meters) are often above the fog. The bays occasionally have navigation problems due to fog banks. Similar problems affect air traffic. Afternoon visibility rises above 11,000 meters on only 1 day in 2. Rain also restricts visibility. Heavy rains can reduce visibility to less than 800 meters but generally only briefly. As mentioned in the previous season, the Osan AB vicinity experiences a higher occurrence of low visibility (44 percent of the time in June) due to pollution.

East Coast Plain. Summer is the haziest time of year. Visibility is restricted below 9,000 meters an average of 90 percent of the time, but restrictions under 4,800 meters are far less common. Morning fog is short-lived and drops visibility under 4,800 meters less than 15 percent of the time throughout the region.

Southwest Hills and Coastal Plain (includes Cheju Island). Summer is the haziest time of year. Visibility is restricted below 9,000 meters an average of 90 percent of the time, but restrictions under 4,800 meters are less common. Morning fog is short-lived and drops visibility under 4,800 meters less than 15 percent of the time throughout the region. Any station that faces direct onshore winds experiences more morning fog than stations leeward to the wind. Windward stations get morning fog an average 20-25 days of the month during the summer. Leeward stations only get morning fog on 5-8 days per month.

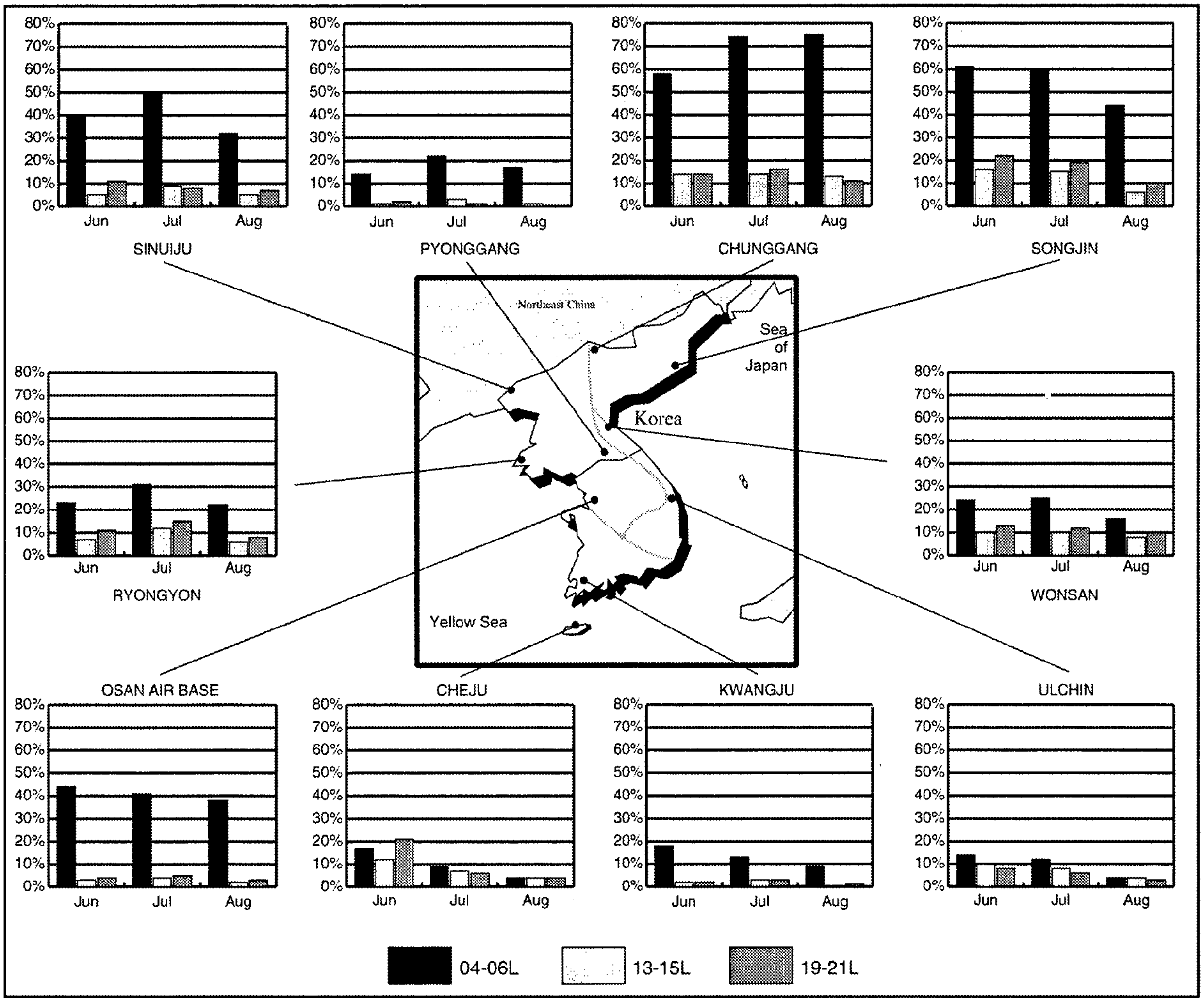


Figure 6-21. Summer Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Northeast Highlands. Coastal low-level winds tend to be southerly; east coast low-level winds reflect both the channeling by coastal mountains and the flow behind Shanghai and Yellow Sea lows that have crossed into the Sea of Japan (see Figure 6-22). Inland surface winds tend to have an overall southerly component, but local terrain influences alter the direction somewhat. Night and early morning winds are normally less than 3 knots; calms frequently occur. Land/sea breezes are common along the coast, as are mountain/valley winds in the interior and along the east coast. Except in thunderstorms and typhoons, speeds are usually well under 25 knots. Typhoon winds may exceed 90 knots—such rare winds are most likely on the exposed east coast after the typhoon recurves northeastward into the Sea of Japan.

Northwest Hills and Plains. Although the surface winds in Korea are influenced by a number of factors that cause considerable variability, they are primarily controlled by the large scale high- and low-pressure systems and by topography. Winds are northeasterly during the night and morning and southwesterly during the afternoon, with an average speed of 5 knots. A true land/sea breeze circulation is generally not established until late in the season. Winds over 25 knots occur rarely. These speeds may occur with an extratropical cyclone or a tropical cyclone. Winds as high as 45 knots have occurred during tropical storms, typhoons, or thunderstorms.

East Coast Plain. Summer winds are controlled as much by local factors as by the summer large-scale circulation. Outside of winds generated by low-pressure systems, land/sea breezes and mountain/valley breezes determine wind direction and speeds. This is the only season most stations get winds from a direction other than west. For 3 months, the prevailing wind shifts around to southeast to southwest with a few exceptions. An example of an exception is Wonsan, North Korea, which has east-northeast prevailing winds in summer. This happens because of topography. For Wonsan, general southeast flow travels over higher land prior to entering Yonghung-Man (an enclosed bay). This diverts the wind just enough to bring it around to the east-northeast. Obviously, local topography is an important factor in wind flow both for direction and for speed everywhere in the eastern plains.

Southwest Hills and Coastal Plain (includes Cheju Island). Summer winds are controlled as much by local factors as by large-scale circulation. Outside of winds generated by low-pressure systems, land/sea breezes and mountain/valley breezes determine most on wind direction and speeds. Winds are generally southwesterly, but local winds will depend on location relative to water and to higher terrain.

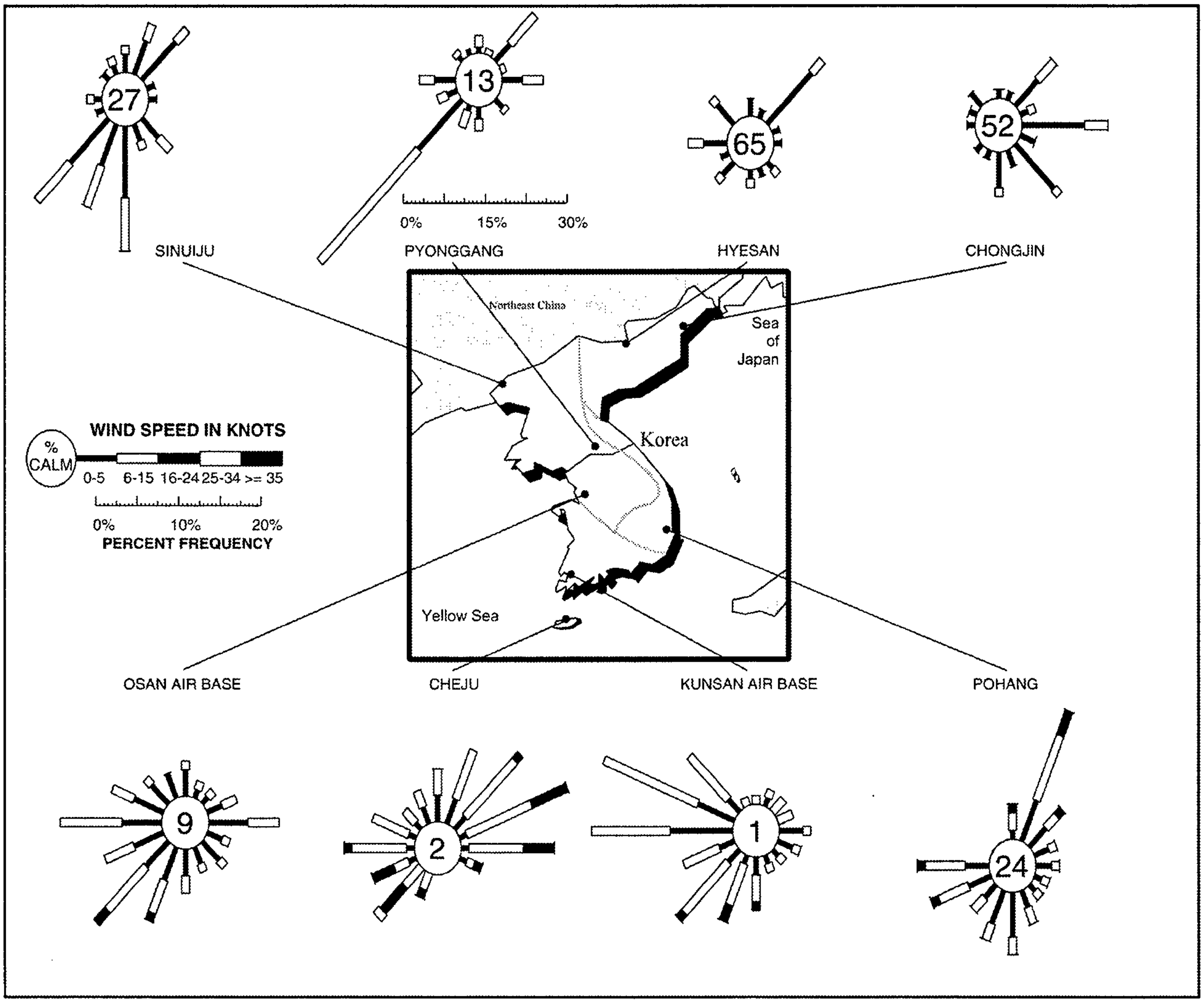


Figure 6-22. July Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds. Upper-air winds are primarily westerly with a slight northwest component (see Figure 6-23). By July, the subtropical jet lies over South Korea at approximately 40,000 feet. It weakens considerably, and core speeds average around 45-55 knots. Speeds average 20-30 knots at 20,00 feet and 40-50 knots at 30,000 feet. The jet remains over South Korea through September.

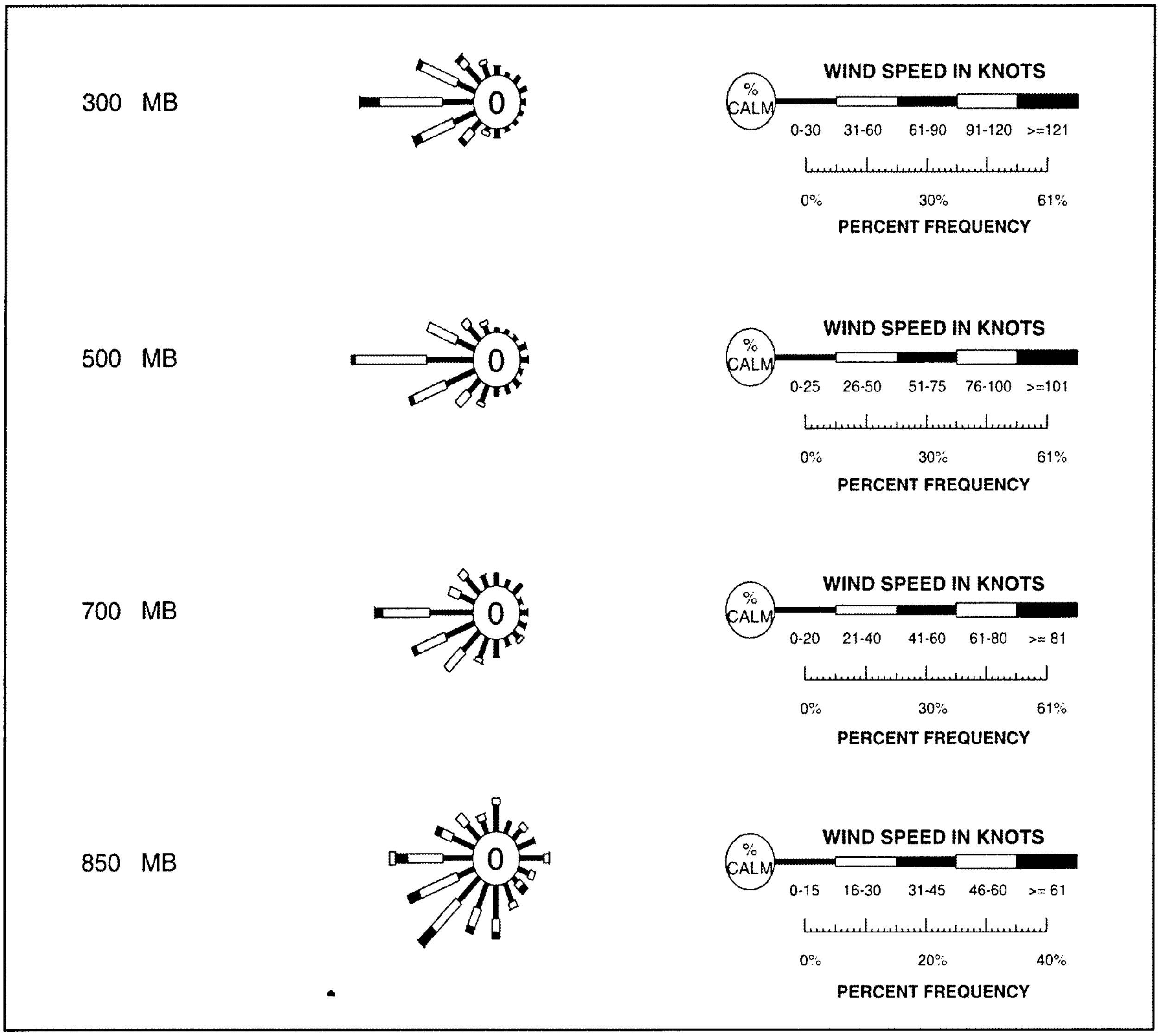


Figure 6-23. July Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Kwangju. Note: Each wind rose has a tailored legend.

Precipitation.

Northeast Highlands. This is the rainy season. During July, rain occurs nearly 2 out of every 3 days. Occurrences begin to decrease in August. The combination of warm, moist, unstable air, onshore flow, and frequent frontal low passages results in remarkable rainfall. Rainfall in the south central portions of the peninsula averages 200 to 300 mm per month; extremes have reached 625 mm. Peak recorded 24-hour rainfall exceeds 350 mm. Only along the eastern Manchurian/North Korean border do amounts drop to 125 mm. Even the lowest monthly totals exceed 75 mm (see Figure 6-24). Onset of the heavy summer rains occurs between 25 June and 5 July.

Recorded thunderstorms are rather rare, as reflected in Figure 6-25. Most sites average less than 3 thunderstorm days per month. Higher ridges and the Hamgyong Mountains have twice that number. Average tops are 35,000 to 40,000 feet. Severe thunderstorms are extremely rare; most tops are less than 45,000 feet. The favored time of day for thunderstorms is 1200-1900L.

Northwest Hills and Plains. Precipitation is quite heavy during summer. Korea receives better than 60 percent of its total annual amount in these 3 months. Average amounts range from 102 mm in June to 305 mm at the height of the rainy season in July. August totals drop to 254 mm, and they decrease in September to 102-127 mm. Maximum 24-hour rainfall has reached 584 mm. The heaviest rains are received in a 3-week period from late July to mid-August. The exact timing of this rainfall depends on the strength of a low in the Sea of Okhotsk and the polar front. The Okhotsk low pulls the polar front northward. As a result, cold, moist air pours down the Siberian coast into Korea. Until the polar front moves completely over the area, rainfall will be intermittent (occur roughly every two days) and persist for a day or more. With the polar front, a light rain or drizzle will continue almost unabated for a week or more, but heavier rain will fall when a disturbance moves along the front.

Thunderstorms occur an average of 3-5 days a month. They form as the result of intense surface heating rather than with the polar front. Thunderstorms tend to build in the hills and mountains. A large amount of rain may also result from a dying tropical storm as it passes through the area. Less than 5 percent of tropical storms track through this area.

East Coast Plain. During the summer months, the east coast plains get most of their precipitation. In the south, maximum rain falls (152-254 mm) occur in June through late July. In the north, the maximum rain falls (203-304 mm) occur from very late in July to early September, when the polar front is farthest north.

Thunderstorms occur more frequently in summer than in other seasons due to the location of the polar front and the instability it creates. Despite this, most stations see only one or two thunderstorms a month throughout summer.

Southwest Hills and Coastal Plain (includes Cheju Island). The summer months get the most precipitation; July is the maximum month. In June, rainfall amounts range from 114-178 mm. July amounts range between 178-279 mm. The exceptions to this are stations in the rain shadow of a mountain. These places only get 101-127 mm. Amounts begin to drop off once again in August and range from 140-228 mm. In general, stations in the southwestern corner of the peninsula get more rain than others.

Thunderstorms occur more frequently in summer than in other seasons due to the location of the polar front and the instability it creates. Despite this, most stations see only one or two thunderstorms a month throughout summer.

Figure 6-24. July Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

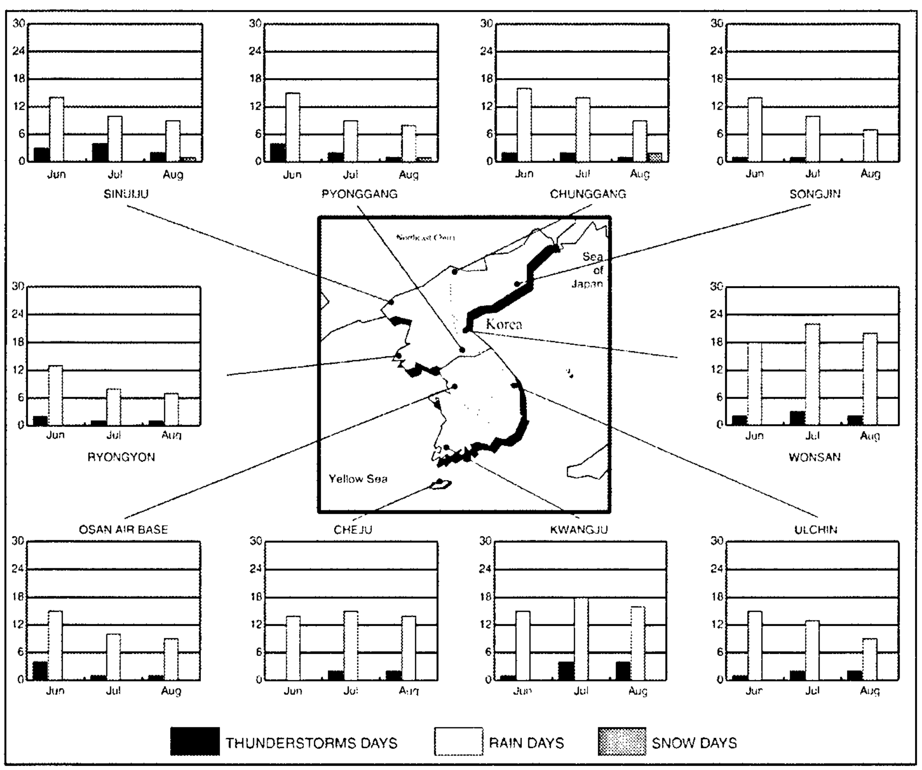


Figure 6-25. Summer Mean Monthly Precipitation and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at Korean locations.

Temperatures.

Northeast Highlands. Warm and muggy characterizes the summer season, much like the Midwestern United States. Coastal sites have mean highs from 75° to 78°F (24° to 26°C) in the northern half of the area and 80° to 84°F (27° to 29°C) in the southern half (see Figure 6-26). Inland areas reach 86° to 89°F (30° to 32°C). Mean lows range from 60° to 64°F (16° to 18°C) on the coasts and 70° to 73°F (21° to 23°C) inland (see Figure 6-27). Extreme highs of 100°F (38°C) and lows of 32°F (0°C) occur along the eastern Manchurian border because it is drier here than anywhere else in the area.

Northwest Hills and Plains. As the polar front pushes north, warm, humid, subtropical air invades. Because of the clouds and rain, temperatures are mild with very little diurnal change. June temperatures remain relatively cool. The mean highs are 68° to 72°F (20° to 23°C), and the mean lows are near 60°F (16°C). Average highs for July climb to 81°F (27°C) with lows near 68°F (20°C). By August, the mean high temperature rises to 85°F and the mean low temperature is again near 68°F (20°C). On at least one day in each month, the temperature climbs above 90°F (32°C). Interior locations have record high temperatures over 100°F (38°C). Extreme lows fall to 35°F (2°C) in June and September.

East Coast Plain. July and August are the warmest months of the year. Most stations have extreme high temperatures that range from 93° to 98°F (34° to 37°C) to over 100°F (38°C). Mean highs are considerably more pleasant, in the 71° to 86°F (22° to 30°C) range. June mean low temperatures are in the 60° to 66°F (16° to 19°C) range. Mean lows for July and August range between 73° and 78°F (23° to 26°C). By the end of June, record lows rarely dip below 60°F (17°C) even at high elevations. The coastal waters moderate temperatures near the coast and temper the range between highs and lows as far inland as the sea breeze reaches. Inland areas have the widest diurnal spread and are most likely to have higher maximum temperatures.

Southwest Hills and Coastal Plain (includes Cheju Island). July and August are the hottest months of the year. Most stations have extreme high temperatures over 100°F (38°C) and mean highs are between 84° and 87°F (29° and 31°C). These statistics indicate daytime temperatures often top 90°F (32°C) in the summer. Mean low temperatures in June are 62° to 66°F (17° to 19°C). Mean lows for July and August are 73° to 77°F (23° to 25°C). Extreme low temperatures range between 42° and 46°F (6° and 8°C) for mountain stations in June and 53° to 57°F (12° to 14°C) for the whole summer everywhere else.

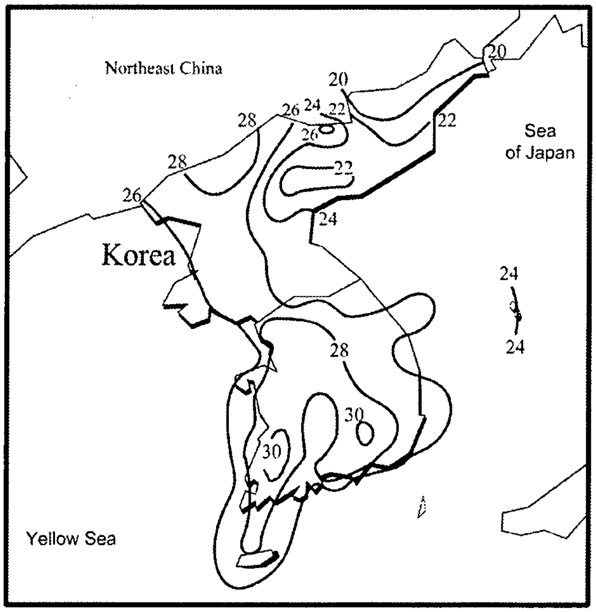


Figure 6-26. July Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for summer.

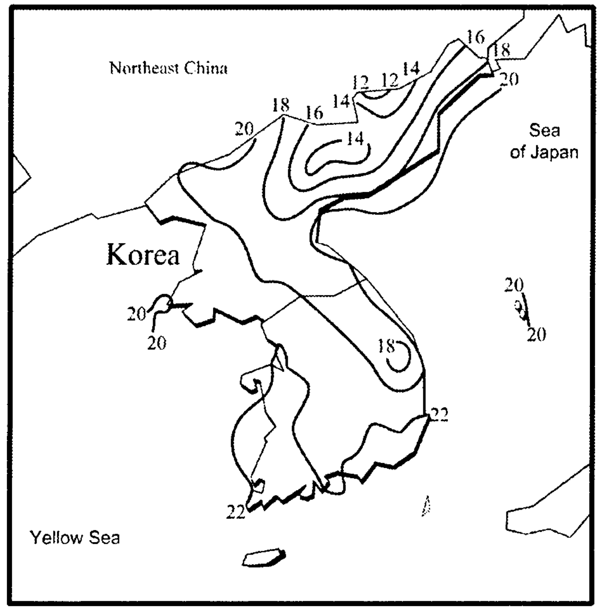


Figure 6-27. July Mean Minimum Temperatures (°C). These temperatures represent the average low temperatures for summer.

Hazards. Sea survival times are at their longest of the year in this season. Those off the northeast coast approach 8 hours.

The southern half of the peninsula is affected by typhoon-associated winds and rain about once a year as the storms cross South Korea into the Sea of Japan. A tropical storm may affect the area any time from mid-July to mid-September. The preferred track is through the Yellow Sea followed by a northeastward recurve across Korea. By the time these storms reach Korea, they have lost much of their strength; the major hazard is flooding from heavy rainfall.

Flooding, mud slides, and almost impassable unpaved roads are common problems. The relatively flat river beds and winding river courses are susceptible to severe floods during July and August; areas with extensive flood control works are less susceptible. Bridges and paved roads may wash out. Unpaved areas become (and remain) mud. Flash floods are common; rivers rise rapidly. The Yalu has reached 26 feet, and the Imjin near 44 feet above flood stage. Roads and bridges wash out; land slides are common.

Air operations below 3,000 feet are difficult, except during late morning and early evening because of the extensive cloud decks and mountain obscurations.

Trafficability. About 75 percent of the Korean peninsula consists of steep, rugged mountains and hills. The rest consists of plains and lowlands, mostly along the west coast and in scattered inland areas. Soils of the peninsula are mainly mixed coarse- and fine-grained. Shallow coarse-grained soils cover most mountains and hills. The fine-grained soils occur mainly in coastal areas, on the flat plains, and in some hill areas. Most of these fine-grained soils are deep to very deep; some are highly plastic (high clay content) and some are highly organic. The more plastic a soil is, the stickier and slipperier it is when wet. The more organic it is, the less weight it can bear, although it is less sticky or slippery than clay soil.

In the mountains and hills, movement conditions are unsuitable at all times because of forests and steep, rugged terrain. Movement is possible along established routes and corridors in valleys, but these are very limited. In the plains and lowlands where rice is grown, movement is unsuitable because of flooded fields and soft soils. Direction of travel is limited by stream banks, canals, forests, and rough, dissected terrain. In the wet season, conditions of movement are unsuitable in all but very localized areas.

General Weather. *Chobun* (Korean for autumn equinox) defines the time when the weather changes from humid/tropical conditions to a cooler, drier regime. The polar front hurries southward in the fall transition period. By October, the front is already south of Okinawa and drier weather arrives. This is the most pleasant time of year in Korea. The Asiatic high has not yet set up strongly enough to advect in cold air, and circulation is at its most ambiguous. Still warm, but far less humid than summer, fall weather is a welcome relief from the high humidity of summer. There is still some precipitation in this season, but it tapers off dramatically by the end of the season. September is a peak month for typhoon activity, but only 14 percent of storms in the western Pacific recurve over Korea. October has less than 1 percent, but the season is not officially over until the end of November

Sky Cover.

Northeast Highlands. The incidence of ceilings below 3,000 feet decreases as shown in Figure 6-28. Extensive, layered clouds are found only with frontal systems and rare typhoons. Such systems can bring layered clouds from 1,500 feet to 30,000 feet to the southern two-thirds of the peninsula. Otherwise, only one day out of four has 2,500- to 3,000-foot ceilings. Clouds tend to build by late morning and clear somewhat after dark. Mountains are almost always obscured by cloud cover associated with frontal systems. Otherwise, clouds are often above 2,500 feet from late morning to late afternoon.

Northwest Hills and Plains. Cloud cover slowly diminishes until the polar front moves southward out of the region. Once this occurs, clouds are confined to patchy afternoon layers at 2,500-3,000 feet along the north sides of ridges. Extensive layered clouds are found only with frontal systems and rare typhoons. Such systems can bring layered clouds from 1,500 feet to 30,000 feet to the southern two-thirds of the peninsula. Clouds tend to clear somewhat after dark, and build by late morning. Mountains are often obscured from late morning to late afternoon and very commonly with frontal systems. In September, between the hours of 0400 and 0600L, the ceilings below 3,000 feet occur an average of 38 percent of the time and decrease to 24 percent of the time in October. Due to their location in reference to the Nangrim mountain range, Pyonggang and Kanggye experience the greatest frequency of ceilings less than 3,000 feet: 45 percent of the time and 80 percent of the time, respectively.

East Coast Plain. Cloud cover begins to taper off in the fall as the moisture dropped by summer rains begins to evaporate. As fall progresses, cloudy skies give way to partly cloudy, and then to predominantly fair skies by the end of October. Ceilings at or below 3,000 feet occur most often in the morning hours (30-50 percent of the time) then drop off the rest of the day (well under 10 percent of the time). Ceilings at or below 1,500 feet are even more reduced, 30-40 percent of the time in the morning hours and less than 5 percent of the time the rest of the day. Most stations report ceilings at or below 1,000 feet less than 5 percent of the time at all hours. Mountain stations regularly report higher percentages of ceilings under 1,500 feet for the morning hours (average 55 percent of the time), but reflect the norms for other hours. By the end of October, all percentages drop very sharply as general conditions become drier.

Southwest Hills and Coastal Plain (includes Cheju Island). Cloud cover begins to taper off in the fall as the moisture dropped by summer rains begins to evaporate. As fall progresses, cloudy skies give way to partly cloudy and then to predominantly fair skies by the end of October. Ceilings at or below 3,000 feet occur most often in the morning hours (30-50 percent of the time) then drop off the rest of the day (under 10 percent of the time). Ceiling at or below 1,500 feet are even more reduced, 30-40 percent of the time in the morning hours and less than 5 percent of the time the rest of the day. Most stations report ceilings at or below 1,000 feet less than 5 percent of the time at all hours. Mountain stations regularly report higher percentages of ceilings under 1,500 feet for the morning hours (average 55 percent of the time), but they reflect the norms for other hours. By the end of October, all percentages drop sharply as general conditions become drier.

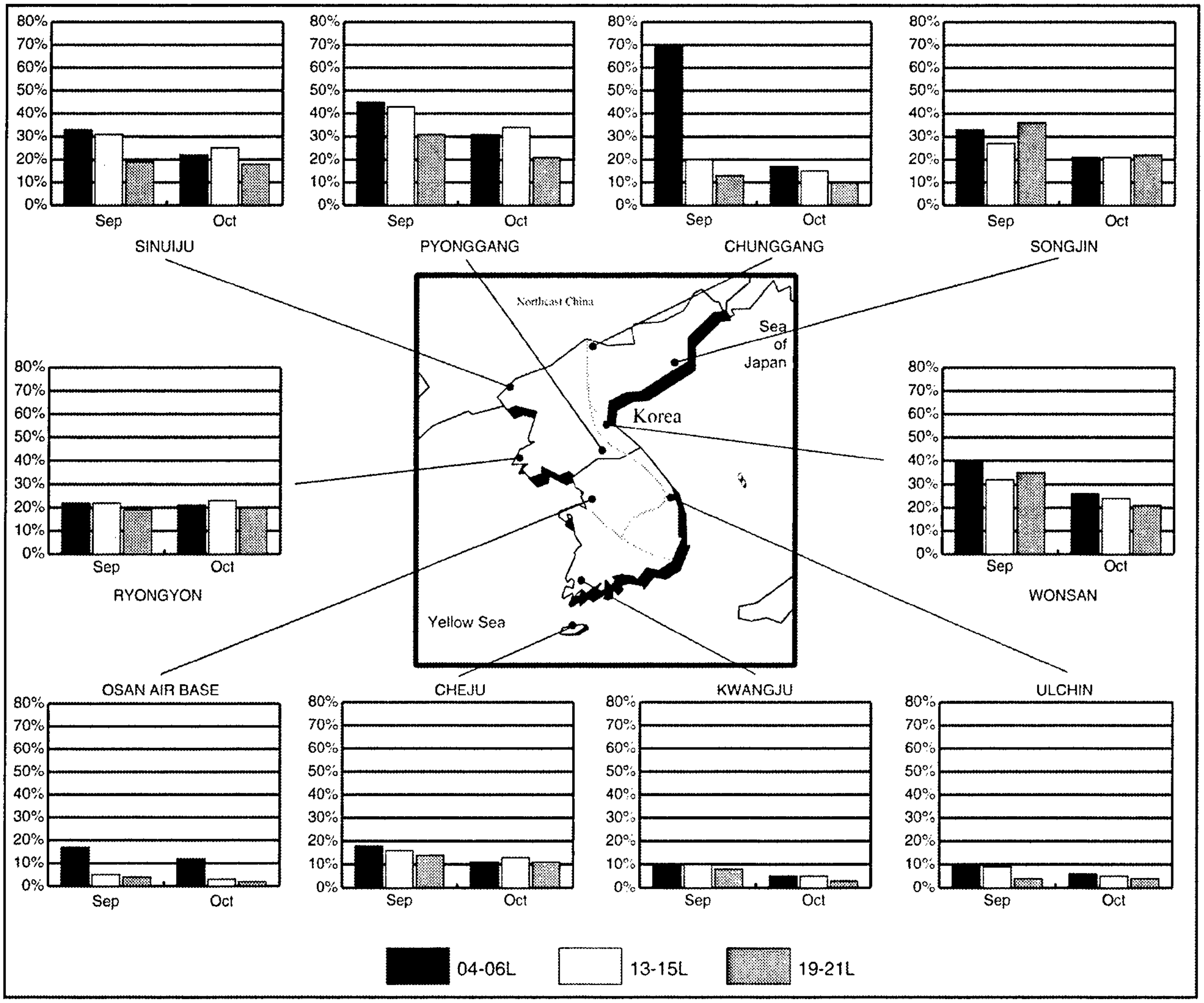


Figure 6-28. Fall Ceilings below 3,000 Feet. The graphs show a breakdown of ceilings below 3,000 feet based on location and diurnal influences.

Visibility.

Northeast Highlands. As temperatures fall, available moisture becomes less, and visibility (see Figure 6-29) increases dramatically. The frequency of visibility below 4,800 meters from 0400 to 0600L varies widely from 1 percent of the time at Sinpo to 73 percent of the time at Chunggang. The main inland visibility restriction is found around villages and cities. The primary visibility obstruction is urban smoke. Coastal fog, especially at night, is still possible. Afternoon visibility is almost uniformly good except during rain. In the afternoon, the visibility less than 4,800 meters occurs less than 5 percent of the time except at Chunggang, where visibility less than 4,800 meters occurs 11 percent of the time. Rain and rain showers associated with passing frontal systems reduce visibility to between 4,800 meters and 9,000 meters.

Northwest Hills and Plains. As temperatures fall, available moisture lessens and visibility increases dramatically. The frequency of visibility below 4,800 meters from 0400 to 0600L decreases from 41 percent of the time in the south to 16 percent of the time in the north. The predominant inland visibility restriction is found around villages and cities. The primary visibility obstruction is urban smoke. Coastal fog, especially at night, is still possible. In the afternoon, visibility less than 4,800 meters occurs less than 3 percent of the time. Rain and rain showers associated with transitory frontal systems reduce visibility to between 4,800 and 8,000 meters. Visibility remains between 4,800 and 6,000 meters in rain and fog 1 day out of 3 during September. Only after the polar front passes does visibility improve dramatically. Even then, night and early morning visibility drops to as low as 3,200 meters in ground fog or smoke on 1 day out of 3.

East Coast Plain. This is harvest time in Korea, and it causes some visibility problems as farmers burn field debris. This agricultural practice drops visibility quite a bit, especially in valleys and basins where local air circulation does not clear the air. The smoke and ash in the air contributes to reduced fog visibility as well under radiation inversions. Despite this, overall visibility remains above 4,800 meters about 90 percent of the time throughout the region. Smoke, fog, and haze reduce valley visibility to less than 4,800 meters an average of 20-30 percent of the time during morning hours.

Southwest Hills and Coastal Plain (includes Cheju Island). This is harvest time in Korea and it causes some visibility problems as farmers burn field debris. This agricultural practice drops visibility quite a bit, especially in valleys and basins where local air circulation does not clear the air. The smoke and ash in the air contributes to reduced fog visibility as well under radiation inversions. Despite this, overall visibility remains above 4,800 meters about 90 percent of the time throughout the region. Smoke, fog, and haze reduce valley visibility to under 4,800 meters an average of 20-30 percent of the time during morning hours.

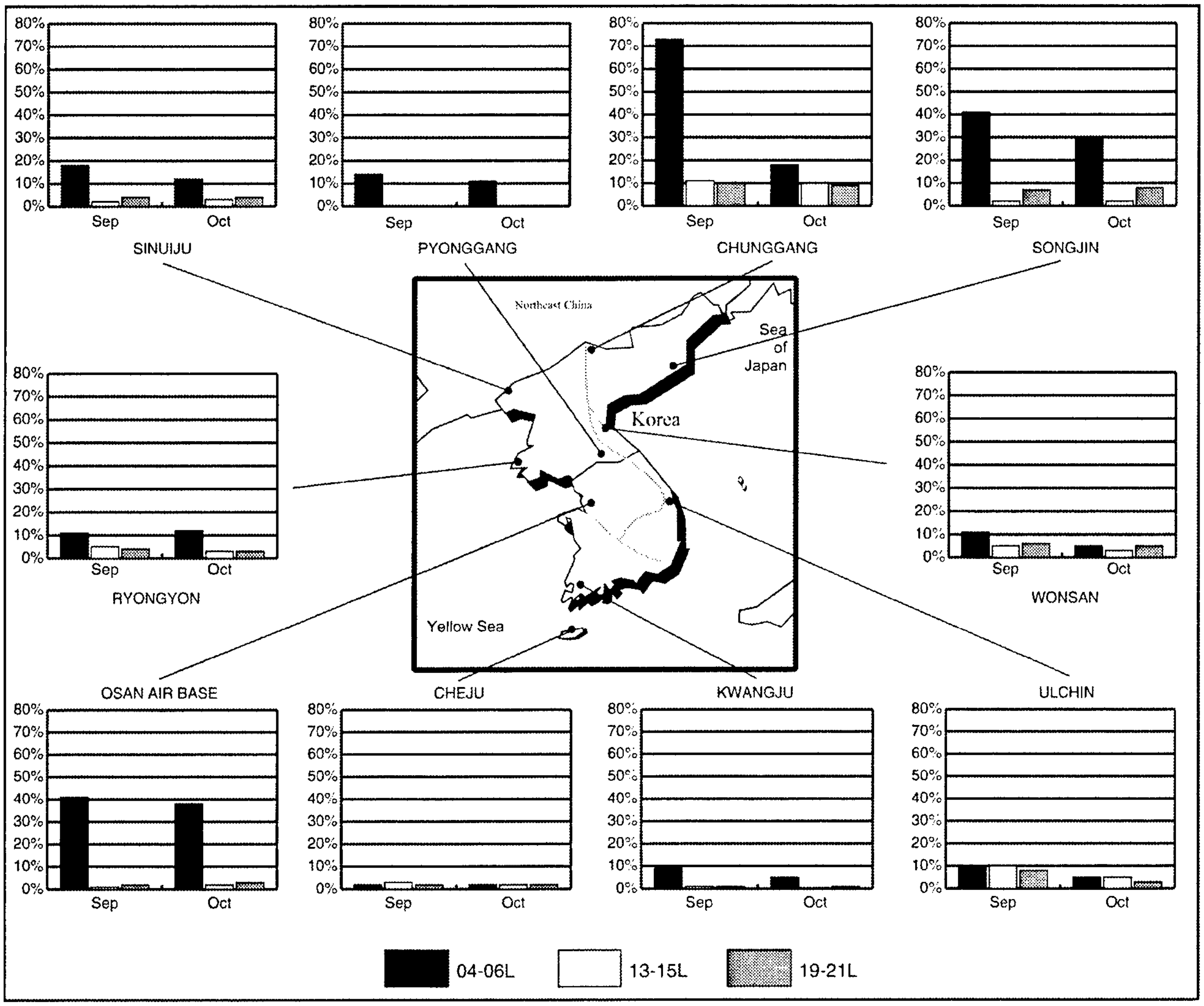


Figure 6-29. Fall Visibility below 4,800 Meters. The graphs show a breakdown of visibility below 4,800 meters based on location and diurnal influences.

Surface Winds.

Northeast Highlands. The increased northerly surface component reflects the rapidly building Asiatic high and southward movement of the polar front. Chongjin, which is located in extreme northeast North Korea, has a small, but measurable, percentage of winds in the 16- to 24-knot category (see Figure 6-30). Most nights and early mornings, however, are calm. Land/sea breezes are reinforced, especially along the northeast coast, by mountain/valley breezes. Only defined synoptic systems disturb the relatively light winds of the Manchurian frontier.

Northwest Hills and Plains. The increased northerly surface wind reflects the rapidly building Asiatic high and southward movement of the polar front. Nights and early mornings are often calm. Only defined synoptic systems disturb the relatively light winds of the Manchurian frontier. Late morning and afternoon winds remain basically southwesterly at 8-16 knots. Nighttime winds are northeasterly through southeasterly at 4-8 knots. Gusts exceed 27 knots with frontal lows or with rare thunderstorms.

East Coast Plain. Overall flow is still generally from the south, but this is a transition season as the polar front moves quickly southward. For stations on the coasts, local land/sea breezes still have an impact on surface winds, especially in September, but they are not as strong as they were in high summer. Sea breezes begin near midday and persist until the early evening hours. Land breezes pick up before midnight then die off quickly at sunrise. Mountain/valley breezes have a similar impact on local winds for inland stations.

Southwest Hills and Coastal Plain (includes Cheju Island). Overall flow is still generally from the south, but this is a transition season as the polar front moves quickly southward. Local land/sea breezes also still have an impact on surface winds, especially in September, but they are not as strong as they were in high summer. Sea breezes begin near midday and persist until the early evening hours. Land breezes pick up before midnight then die off quickly at sunrise. Mountain/valley breezes have a similar impact on local winds at inland stations.

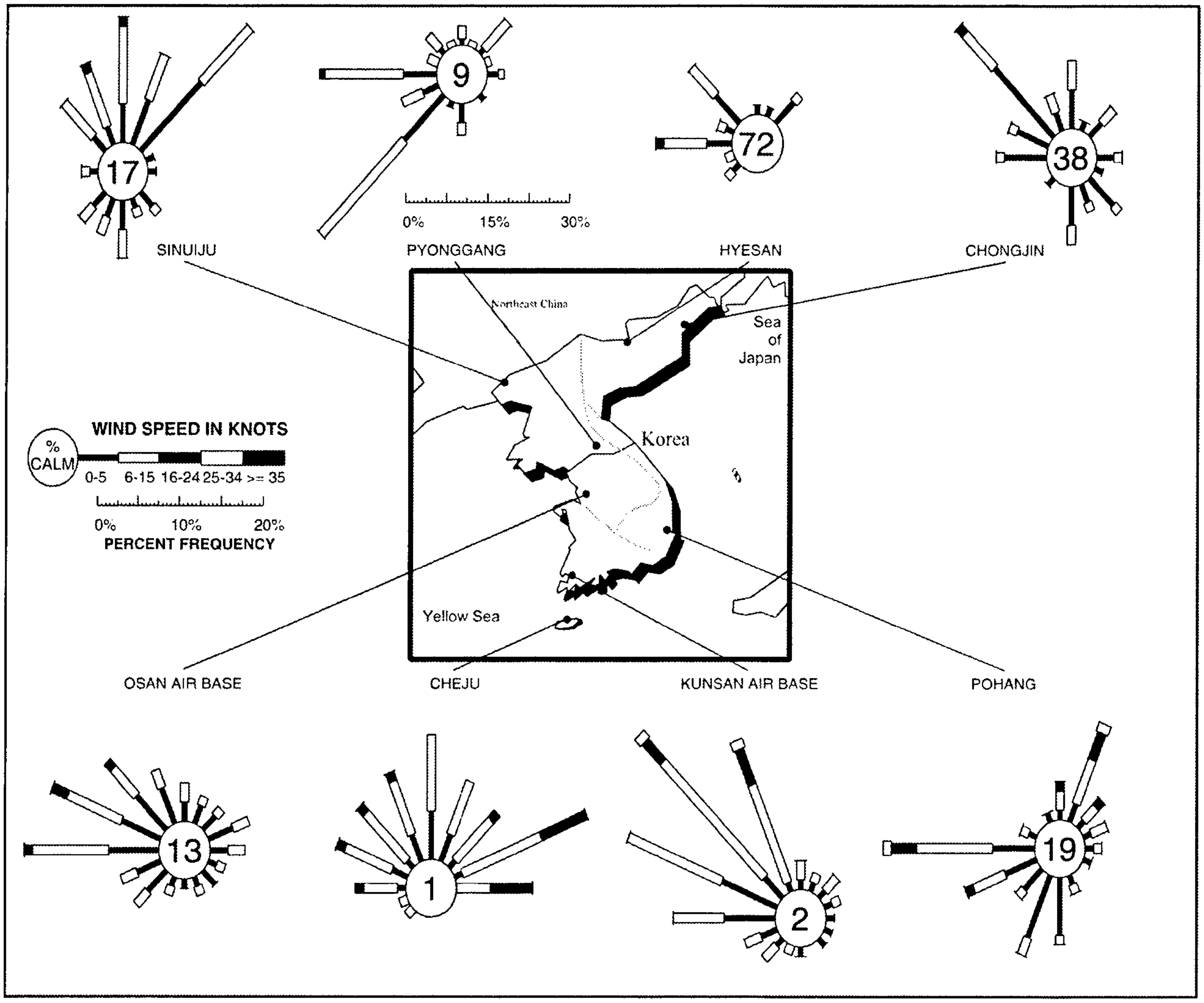


Figure 6-30. October Surface Wind Roses. The figure shows the prevailing wind direction and range of speeds based on frequency and location.

Upper-Air Winds. Upper-level winds remain westerly, and speeds slowly increase as the polar jet strengthens. The polar jet moves southward. Highest mean speeds, as reflected in figure 6-31, reach near 100 knots. The subtropical jet begins to strengthen, but it usually will not overlay and merge with the polar jet until December. Speeds increase to 85-105 knots by the first week in October and begin to top 150 knots on occasion by the end of the month.

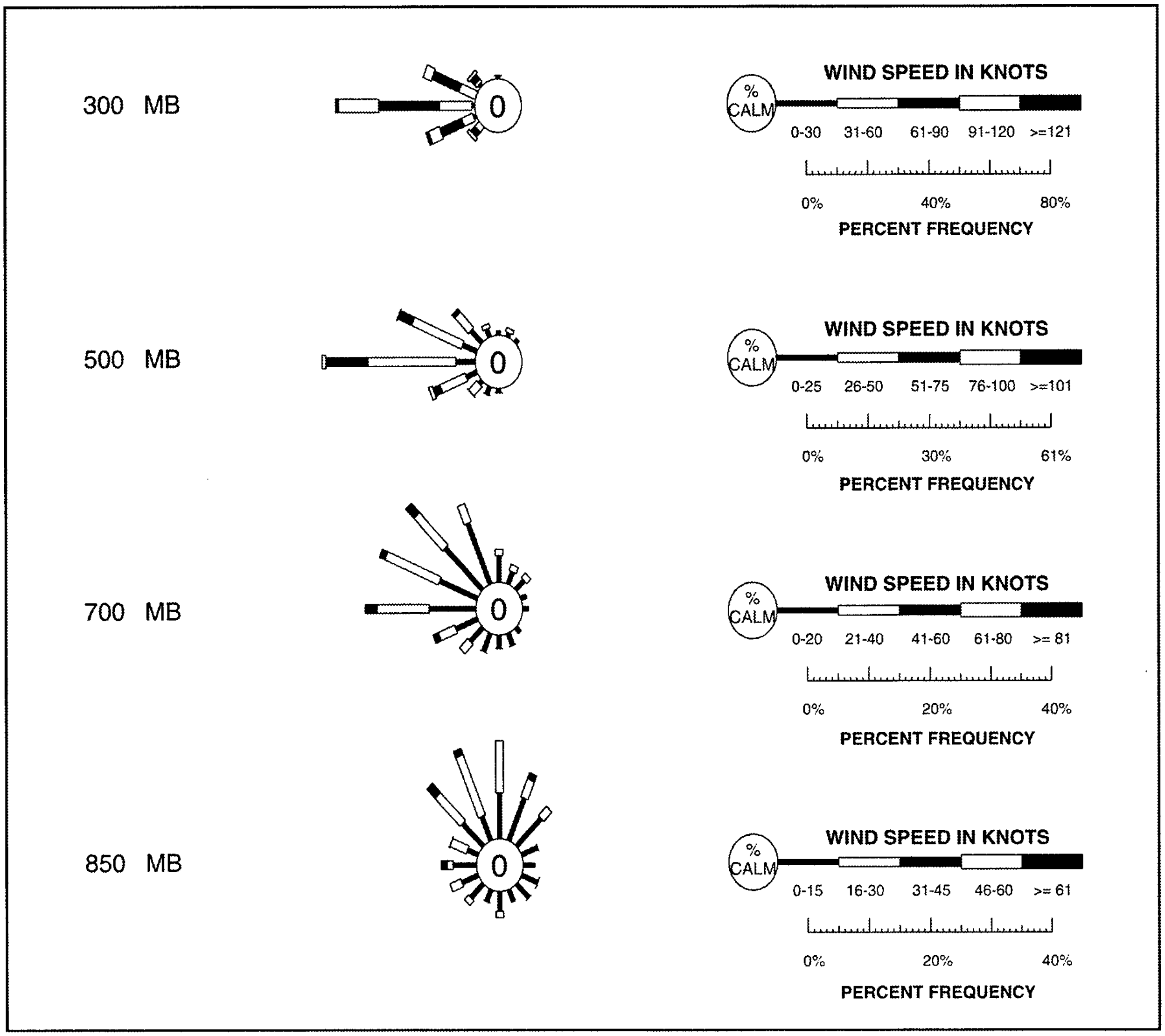


Figure 6-31. October Upper-Air Wind Roses. The wind roses depict wind speed and direction for standard pressure surfaces between 850 and 300 mb at Kwangju. Note: Each wind rose has a tailored legend.

Precipitation.

Northeast Highlands. Most precipitation is still rain; however, Hyesan, which is located on the North Korea-Manchurian border, has isolated snow—mostly after 15 October. The snow line over the higher Hamgyong Mountains appears by mid-October; by the end of October it is down to 2,500 feet (760 meters) north of 40° N. Precipitation amounts are low, an average of 25 to 75 mm; the area south of 40° N has recorded up to 450 mm (See Figure 6-32). Precipitation frequency, shown in Figure 6-33, decreases to between 3 and 9 days a month. Thunderstorms become extremely rare.

Northwest Hills and Plains. Most precipitation is still rain; frequencies decrease to between 3 and 9 days a month. The snow line over the higher Hamgyong Mountains forms by mid-October; by the end of the month, it is down to 2,500 feet (760 meters) north of 40° N. Monthly rainfall ranges from 140 mm in September to 56 mm in October. Isolated snow showers occur in late October with unusually early, strong, Siberian air outbreaks. Thunderstorms become extremely rare.

East Coast Plain. During fall, rainfall drops off in a clear progression from north to south. The early part of September is the last part of the heaviest precipitation period for North Korea (127-203 mm) because the polar front is farthest north. It shifts south quickly, and rainfall drops off very sharply in North Korea by mid-September. A definite trend of lower precipitation amounts can be easily tracked down the peninsula. The southern half of the eastern plain gets 127-203 mm of rain in September but only 50-101 mm of rain in October. By the end of October, even the southernmost parts of the east coast plains are noticeably drier. Thunderstorm activity, which is always limited, drops off in the fall. Most stations do not show thunderstorm activity. Those that do, mostly coastal areas, report only 1-2 per month for both September and October.

Southwest Hills and Coastal Plain (includes Cheju Island). This area has precipitation an average of 15-20 days per month in the southernmost coastal areas and 12-18 days per month inland. Cheju Island gets a large amount of rainfall especially on the windward side of the volcano. Thunderstorm activity, which is always limited, drops off in the fall. Most stations do not show thunderstorm activity. Those that do, mostly coastal areas, report only 1-2 per month for both September and October.

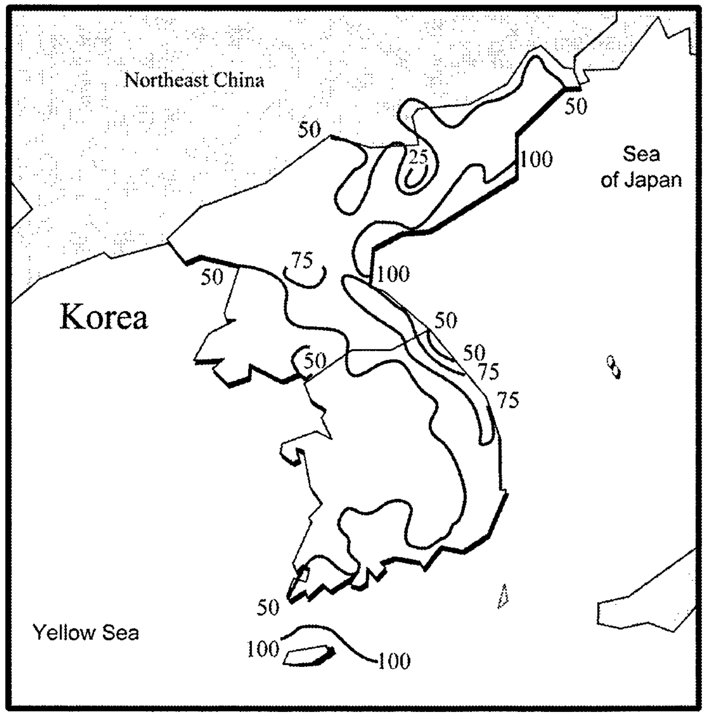


Figure 6-32. October Mean Precipitation (mm). The isopleths indicate mean precipitation totals.

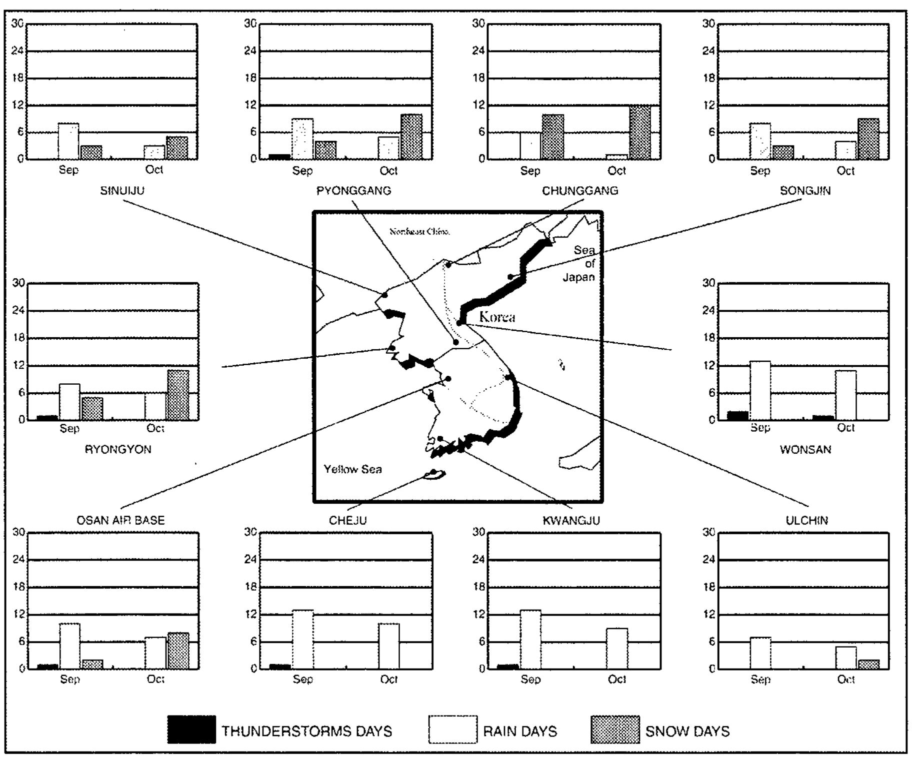


Figure 6-33. Fall Mean Monthly Precipitation and Thunderstorm Days. The graphs show the number of days with rain, snow, and thunderstorms based on average occurrences at scattered locations within Korea.

Temperatures.

Northeast Highlands. Temperatures, especially in the north, cool rapidly north of 40° N. Mean first frost dates over the central Hangyong are in early September. North of 41° N, all areas normally experience at least one frost by the end of that month. Mean highs average 60° to 70°F (16° to 21°C); lows average near 40°F (4° to 7°C) (see Figures 6-34 and 6-35). Extreme lows throughout the country have dipped into the 19° to 25°F (-4° to -7 °C) range while along the Manchurian border, they have reached 3°F (-16°C). Extreme high temperatures in the northeast highlands range from 80°F (27°C) in the central region and north, to 95°F (35°C) in the south.

Northwest Hills and Plains. Temperatures, although falling, remain mild. Mean highs drop from 73°F (22°C) in September to near 55°F (13°C) in early November. Mean lows drop from 56°F (13°C) to near 35°F (3°C) during the same period. Extreme highs range from 90°F (32°C) in September to 80°F (27°C) in October. Extreme lows are from 37°F (4°C) to 24°F (-4°C), respectively.

East Coast Plain. The summer heat fades quickly in the fall. Temperatures vary in accordance with elevation and proximity to water. The higher the elevation, the lower the temperature. The closer to water, the warmer the temperature. Mean high temperatures drop to the 61° to 66°F (16° to 19°C) range by October although extreme high temperatures still top 100°F (38°C) in September. Mean low temperatures are in the 50° to 62°F (11° to 17°C) range for most stations. Higher elevation stations, especially in the northern third of the eastern plain, approach freezing by October. Extreme lows are generally around the 42° to 46°F (6° to 8°C) range, but high elevation stations report extremes between 10°F and 14°F (-12° and -10°C). As usual, temperatures in the north are lower.

Southwest Hills and Coastal Plain (includes Cheju Island). The summer heat fades quickly in the fall. Temperatures vary by elevation and proximity to water. September extreme high temperatures drop into the 87° to 95°F (31° to 35°C) range and the mean highs range from 66° to 84°F (19° to 29°C). Cheju, surrounded by water, has the warmest extreme low temperatures: 55°F (13°C) in September and 40°F (5°C) in October. Coastal stations, also moderated by nearby water, have extreme lows between 30° and 42°F (-1° and 6°C) for September and between 23° and 35°F (-5° and 2°C) for October. Mean low temperatures range from 62° to 68°F (17° to 20°C) in September to between 53° to 57°F (12° to 14°C) in October.

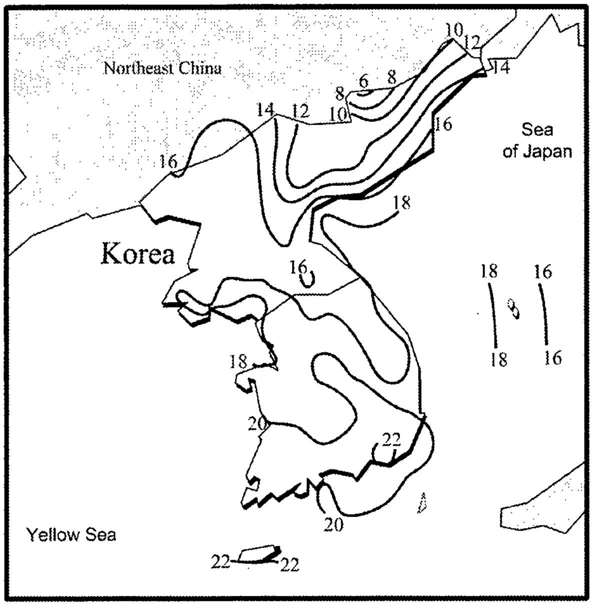


Figure 6-34. October Mean Maximum Temperatures (°C). These temperatures represent the average high temperatures for fall.

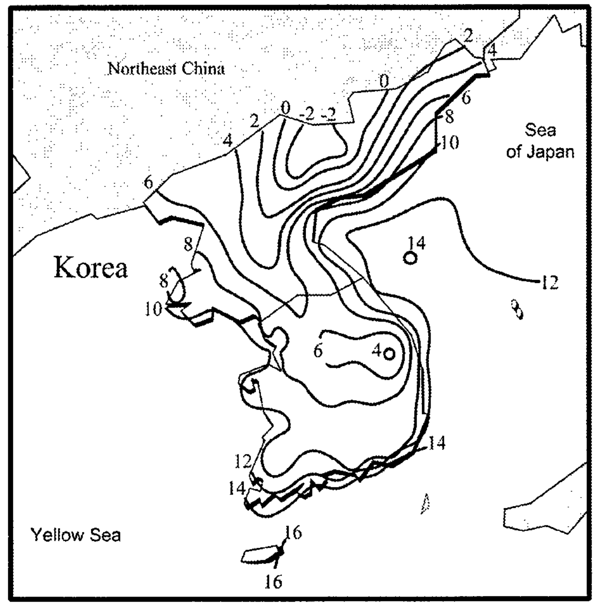


Figure 6-35. October Mean Minimum Temperatures (°C). These temperatures represent the average low temperatures for fall.

Hazards. The rapid onset of extremely cold temperatures has drastic effects on unprepared personnel. Sea survival times drop dramatically. Average times off the northeast coast fall to under 4 hours and off the northwest coast, to less than 6 hours. The ground rapidly freezes north of 41° N. While this solves mud-related trafficability problems, it opens a new set. In extremely cold temperatures, the ground freezes hard; artillery, as an example, cannot properly fire as the recoil mechanism (normally anchored in the ground) cannot hold the weapon. Equipment freezes and frostbite claims personnel.

Incloud icing poses problems for helicopters and light fixed wing aviation. Strong, low-level winds cause mountains waves and moderate-to-severe turbulence over rough terrain. There may be no clouds, such as ACSL or roll/rotor clouds, to indicate severe turbulence is present.

An abnormally early heavy snow (which can occur in October) can drop 20 to 25 cm of snow along the northeast highlands, on the east coast, and over the southeastern Hamgyong Mountains. Very heavy rains occur with lows that move northeast along the polar front or with the remains of typhoons moving northeastward across northwestern Korea. These cause significant flooding and mud slides. Aircraft operations are still greatly hampered by mountain-obscuring cloud layers through mid-October.

Trafficability. About 75 percent of the Korean peninsula consists of steep, rugged mountains and hills. The rest consists of plains and lowlands, mostly along the west coast and in scattered inland areas. Soils of the peninsula are mainly mixed coarse- and fine-grained. Shallow coarse-grained soils cover most mountains and hills. The fine-grained soils occur mainly in coastal areas, on the flat plains, and in some hill areas. Most of these fine-grained soils are deep to very deep; some are highly plastic (high clay content) and some are highly organic. The more plastic a soil is, the stickier and slipperier it is when wet. The more organic it is, the less weight it can bear although it is less sticky or slippery than clay soil.

In the mountains and hills, movement conditions are unsuitable at all times because of forests and steep, rugged terrain. Movement is possible along established routes and corridors in valleys, but these are very limited. In the plains and lowlands where rice is grown, movement is unsuitable because of flooded fields and soft soils. Some movement is possible in winter across frozen rice fields. In other areas of the plains and in some low hills, mainly where dry crops are grown along the west and south coasts, movement conditions are fair in the dry season. Direction of travel is limited by stream banks, canals, forests, and rough, dissected terrain. In the wet season, conditions of movement are unsuitable in all but very localized areas.

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