LATIN AMERICAN FORECAST CENTER FORECASTERS' HANDBOOK

BY

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I. GEOGRAPHY AND TOPOGRAPHY OF SOUTH AMERICA (1)

A. Geography

South America is the world's fourth largest continent. It has the general shape of a triangle; extends about 4,700 miles north to south between 12°N latitude and 56°S latitude from the Colombia-Panama border to Cape Horn; extends about 4,000 miles east to west between 34°W longitude and 81°W longitude. The Atlantic Ocean borders the continent on the east, northeast, and southeast. The Caribbean Sea borders the continent on the north, and to the west is the Pacific Ocean.

B. Topography (See Figures 1 and 2)

South America can be divided into four major regions: the Brazilian and Guiana Highlands in the north and east; the Andes Mountains in the west; the vast interior lowlands of the Orinoco, Amazon, and Parana-Paraguay basins in the center; and the Patagonia Plateau in the south.

1. The Brazilian Highlands, a vast mountain and plateau system extending from the Amazon Valley and the northeast "bulge" of South America to the Plata Estuary, average about 3,000 feet above sea level. The highest point is Pico da Banderia (9,462 ft; 20.5°S, 42.5°W). The Guiana Highlands, between the Orinoco and Amazon basins, are structurally related to the Brazilian Highlands, and comprise a low coastal plain and an inner plateau that ranges between 2,000 and 5,000 feet above sea level. There are isolated mountain peaks and ranges, with Mount Roraima (9,219 ft; 5.2°N, 60.7°W) the highest point. A series of steep escarpments overlook the Amazon basin to the south, and the plateau slopes gradually seaward to the north.

2. The Andes Mountains extend the entire length of the continent, from Lake Maracaibo in Venezuela to Tierra del Fuego, and range from 100 to 400 miles in width. Many peaks are more than 20,000 feet above sea level, with Mount Aconcagua (22,834 ft; 32.6°S, 69.8°W) the highest point in the Western Hemisphere. The Andes form a single chain in the south, but north of about 30°S latitude they broaden to enclose the Puna intermontane basin and then continue north as a series of parallel ranges. The Andes generally rise steeply from the narrow coastal lowlands, but slope more gently to the interior plains.

3. The interior lowlands, constituting about one-half of the continent, consist of gently rolling lands drained by the great rivers of the continent. The Orinoco Plain, between the north-

FIGURE 1. Physical features of South America. Inset shows the area south of 40°S (6). Mountain altitudes in feet.

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FIGURE 2. Map showing major physical features of South America (6).

ern Andes Mountains and the Guiana Highlands, is an area of alluvial deposits, interstream ridges, and low hills. It merges with the Andes on the west over a series of terraces, but is generally less than 1,000 feet above sea level. The broad plain along the Orinoco River is called the Llanos. The Amazon Plain, composed of unconsolidated sediments, slopes very gently upward from the Atlantic Ocean to the foothills of the Andes, and 1,500 miles upstream the Amazon River is still less than 500 feet above sea level. The Amazon flood plain, 50 to 60 miles wide, is characterized by wide stretches of marshes and swamps, and the lowlands are separated from the Parana-Paraguay Plain by a low divide in the plateau of Mato Grasso. The Parana-Paraguay Plain includes large fertile areas in the Argentine pampa and in the savannas of the Gran Chaco, a lowland plain in the south-central South America. There are broad swamps and lagoons along the tributaries of the Parana and Paraguay rivers, and most of the area is characterized by flat plains, isolated depressions, and sluggish drainage.

4. The Patagonian Plateau lies between the Colorado River in Argentina, and Tierra del Fuego. It is essentially a series of plateau-terraces rising to about 5,000 feet near the base of the Andes Mountains. There is extensive evidence of glaciation in the west, and the eastern margin forms the cliffed shoreline of Argentina's southeastern coast. It is bleak, rugged region characterized by crystalline and sandstone rocks, deep canyons, and recent lava flows.

C. Coasts

The coast line has relatively few indentations. Only along the southern coast of Chile with its many rias, or drowned river valleys, is the coast extensively irregular. Other major indentations are the estuaries of the Amazon and Plata rivers, Lake Maracaibo, and the Gulf of Guayaquil.

D. Rivers and Lakes

The major river systems of South America are the Amazon, the Orinoco, and the Parana-Paraguay, which together drain an area of about four million square miles, or about 60 percent of the continent. These rivers, emptying into the Caribbean Sea or the Atlantic Ocean, are generally sluggish and have broad flood plains. Other important east coast rivers are the Magdalena in Colombia, and the Sao Francisco in Brazil. West coast streams are short and swift. The largest lakes in South America are Lake Titicaca and Lake Poopo, both on the Puna, high in the Andes. Lake Titicaca, at 12,507 feet above sea level is one of the highest lakes in the world. Lake Poopo is somewhat salty.

There are numerous small glacial lakes along the eastern slopes of the Andes in Argentina, and brackish lakes are found along the Patagonia coast. Lake Maracaibo, on the north coast, occupying a depression largely enclosed by the northernmost ranges of the Andes, is a shallow body of salt water connected with the Caribbean Sea by a constricted channel.

II. SOUTHERN HEMISPHERE AND SOUTH AMERICA CLIMATE

A. South America Climate (1)

South America is essentially a warm continent, with three-fourths of its land area lying within the tropics. Its great north-south length and extensive mountain regions give it a wide variety of climates. Köppen classifications are shown in figure 3 and vegetation areas described in the following paragraphs are shown in figure 4.

1. Tropical rain forest covers most of the Amazon Basin, the Guianas, the Pacific coast of Colombia, and part of the southeastern coast of Brazil. The climate is hot and humid. Temperatures average about 80°F throughout the year with a range of less than 10°F between the coldest and warmest months. Precipitation is heavy, amounting to 70 to 80 inches per year in the lower Amazon Basin, 100 inches in the Guiana Highlands and the western part of the Amazon Basin, and as much as 300 inches along the Colombian coast, one of the world's wettest areas.

2. Tropical savanna occupies much of central Brazil and eastern Bolivia, Venezuela, and a small section of coastal Ecuador. Temperatures are similar to those of the tropical rain forests, but, except in Venezuela, there are greater seasonal contrasts. The dry season (winter), from three to seven months long, usually brings slightly cooler temperatures. Precipitation ranges between 45 and 70 inches per year in Brazil, but Venezuela savannas are drier, with 25 to 50 inches of rainfall per year.

3. The humid subtropical lands extend from the savannas southward to 40°S latitude, and stretch from 65°W longitude to the east coast. They comprise a portion of southern Brazil, most of Uruguay and Paraguay, and northeastern and eastern Argentina. The climate is characterized by warm summers, mild winters, and moderate, evenly distributed precipitation. Summer temperatures average 72°F to 80°F, and occasionally exceed 100°F, especially in Uruguay and Paraguay. Average winter temperatures range between 50°F and 65°F, and there are occasional frosts, especially in the south. In southern Brazil and Paraguay, precipitation ranges between 50 and 70 inches per year, but in Uruguay and Argentina, only 37 to 50 inches per year. Both temperatures and precipitation decrease south of the Rio Plata. Summer temperatures are 65°F to 75°F, and winters average 46°F. Annual precipitation is 25 to 35 inches.

4. Tropical and subtropical desert and steppe climates are found on both sides of the Andes. On the west, the coasts of Peru and Chile southward to latitude 30°S are one of the world's

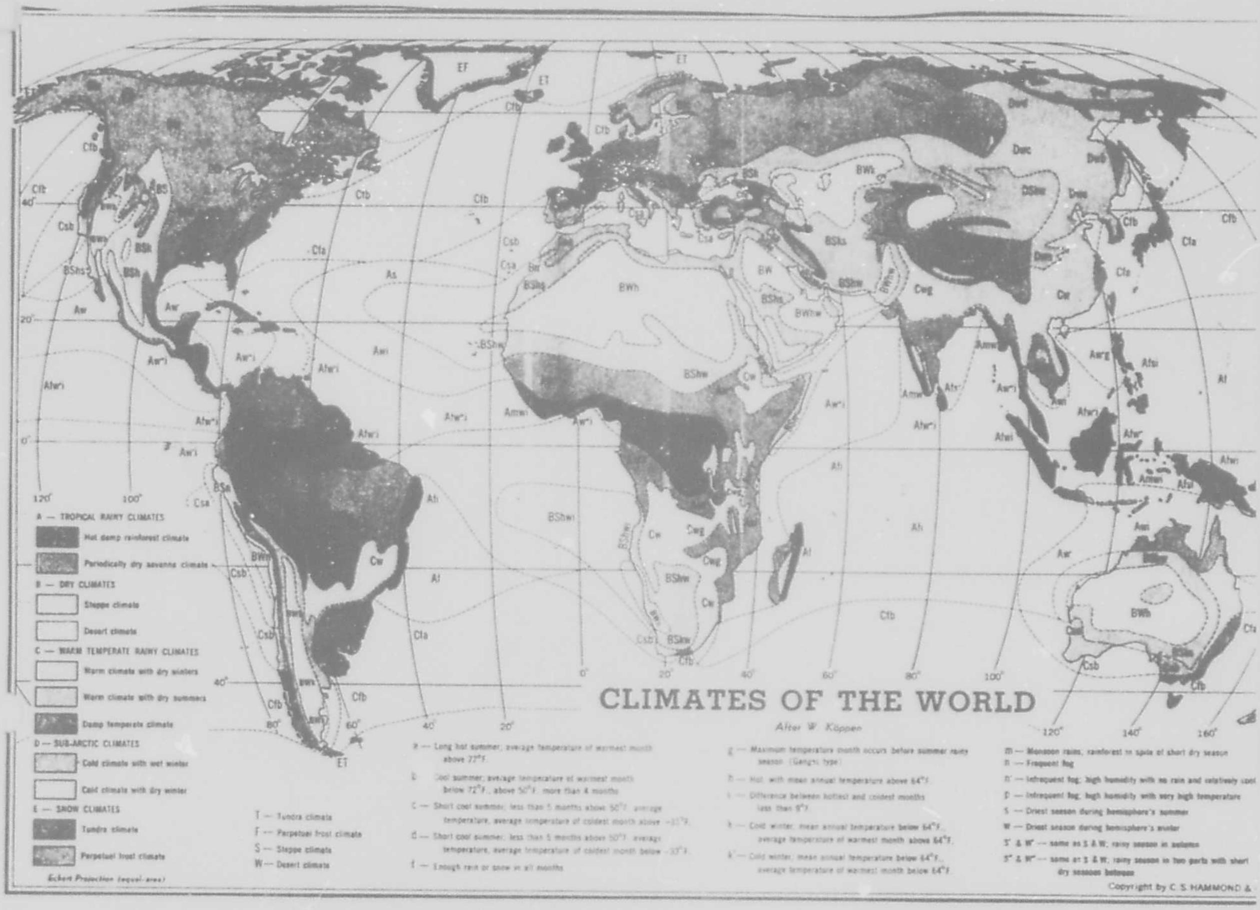


FIGURE 3. Köppen classifications for South America and other areas of the world. (6)

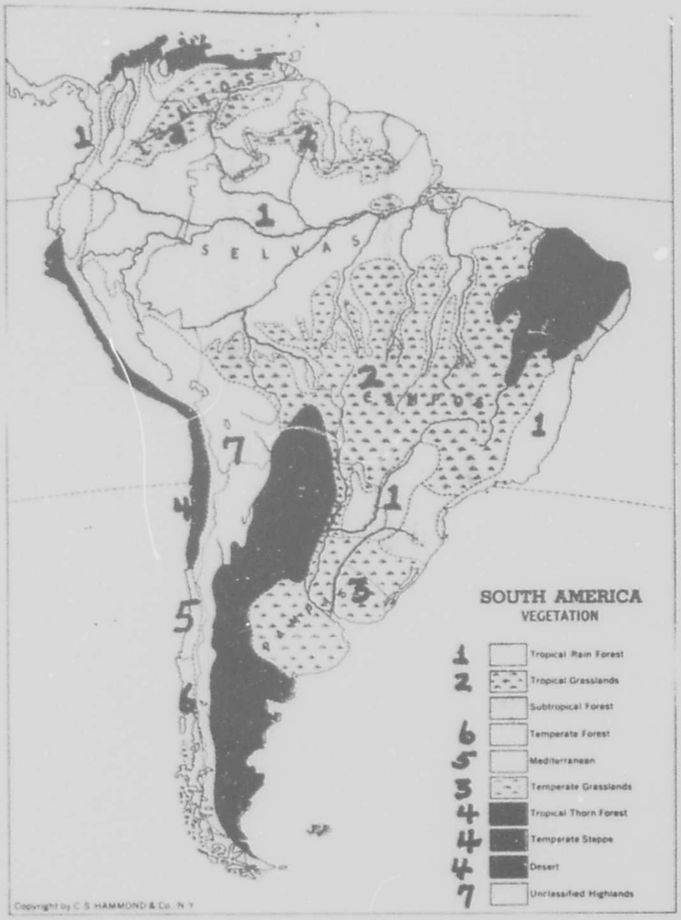


FIGURE 4. Vegetation areas in South America (6). The numbers to the left of the vegetation descriptions correspond to paragraph numbers in Section II-A.

driest regions. Average rainfall is less than two inches, and most of this comes from frequent foggy drizzles. In some years there is no rain. Temperatures range from an annual average of 73°F or more in northern Peru to 58°F in central Chile. East of the Andes, desert and steppelands cover Patagonia, which lies for the most part in the "rain shadow" of the Andes. The steppes form a broad north-south band west of the humid subtropics, and a narrower strip west of the desert at the foot of the Andes. Average summer temperatures range from 73°F in the north to 50°F in the south, and winter temperatures average 46°F in the north and 34°F in the south. Average annual precipitation ranges from 10 to 20 inches. The desert strip between the steppelands is neither as hot nor as dry as the west coast desert; its annual precipitation ranges from 3 to 10 inches. There is also a small area of steppeland in northeastern Brazil, and another near the mouth of Lake Maracaibo.

5. The dry subtropical, or Mediterranean, climate on the coast of central Chile is transitional between the steppes to the north and the more humid lands to the south. Precipitation, which is heaviest in winter, ranges from about 50 inches per year in the south to about 5 inches per year in the north, and averages about 15 inches annually for the region. Summer temperatures average 63°F to 71°F and winter temperatures average 46°F to 53°F; coastal areas have a smaller seasonal temperature range.

6. A humid marine climate characterizes southern Chile. It is one of the rainiest regions in the world, with no notable dry season. Precipitation ranges up to 200 inches per year, and the weather is moist throughout the year, with a constant succession of fog, snow, rain, and gales. Monthly temperatures average 45°F to 65°F in winter.

7. The Andes Mountains, a giant climatic barrier, have a great diversity of climatic regions, ranging from tropical highland to polar. Temperatures are largely determined by elevation. Much of the Andes, especially the Antiplano (Puna) in Bolivia and Peru, is composed of high plateaus which are generally more than 12,000 feet above sea level. They are characterized by cool summers, cold winters and an annual average precipitation of less than 25 inches. In the lower valleys temperatures range between 57°F and 68°F and annual precipitation averages 40 to 70 inches. Along the equator the snow line is at 19,000 - 20,000 feet, but at 54°S latitude, in Tierra del Fuego, the snow line is at 2,500 feet.

B. Southern Hemisphere Climate

1. Circulation features of the Southern Hemisphere/South America (8):

(A) The topography of the Southern Hemisphere favors vigorous zonal circulation. Antarctica has a convex surface profile resulting in rapid downslope seaward movement of cold air as soon as it forms.

(1) The cold anticyclonic surges of CP air are not comparable in magnitude and intensity to those of the Northern Hemisphere.

(2) Weak anticyclones that do develop are carried rapidly downstream in the strong westerly flow.

(B) South America presents the only real barrier to zonal Southern Hemisphere flow and produces dynamic and thermal effects of a magnitude large enough to disturb the zonal flow.

(C) Subtropical high pressure belts are less fragmented than in the Northern Hemisphere.

(D) The principal area of cyclogenesis in the Southern Hemisphere is located between 40°W and 60°W over the ocean east of Patagonia.

(E) During low sun (winter) the South Atlantic subtropical High pushes over interior Brazil. During high sun (summer) the South Atlantic subtropical High retreats seaward. The extension of the subtropical High over Brazil and the relatively greater subsidence of the South Atlantic High account for the lower inversion base over tropical South America compared to the inversion base in tropical North America.

(F) The powerful Antarctic cold source and reduced continental friction produces a vigorous westerly circulation in the Southern Hemisphere. This strong circulation forces the longitudinal axes of the subtropical Highs in the eastern South Pacific and western South Atlantic to lie closer to the equator than their counterparts in the Northern Hemisphere (see figures 5 & 6). Accordingly, the equatorial pressure trough and its wind convergence (ITCZ) over the oceans are asymmetrically located to the north of the geographic equator at all times of the year. This hemispheric asymmetry in atmospheric circulations (also oceanic) is reflected in contrasting rainfall patterns to the north and south of the equator, and in general northward displacement of climatic zones.

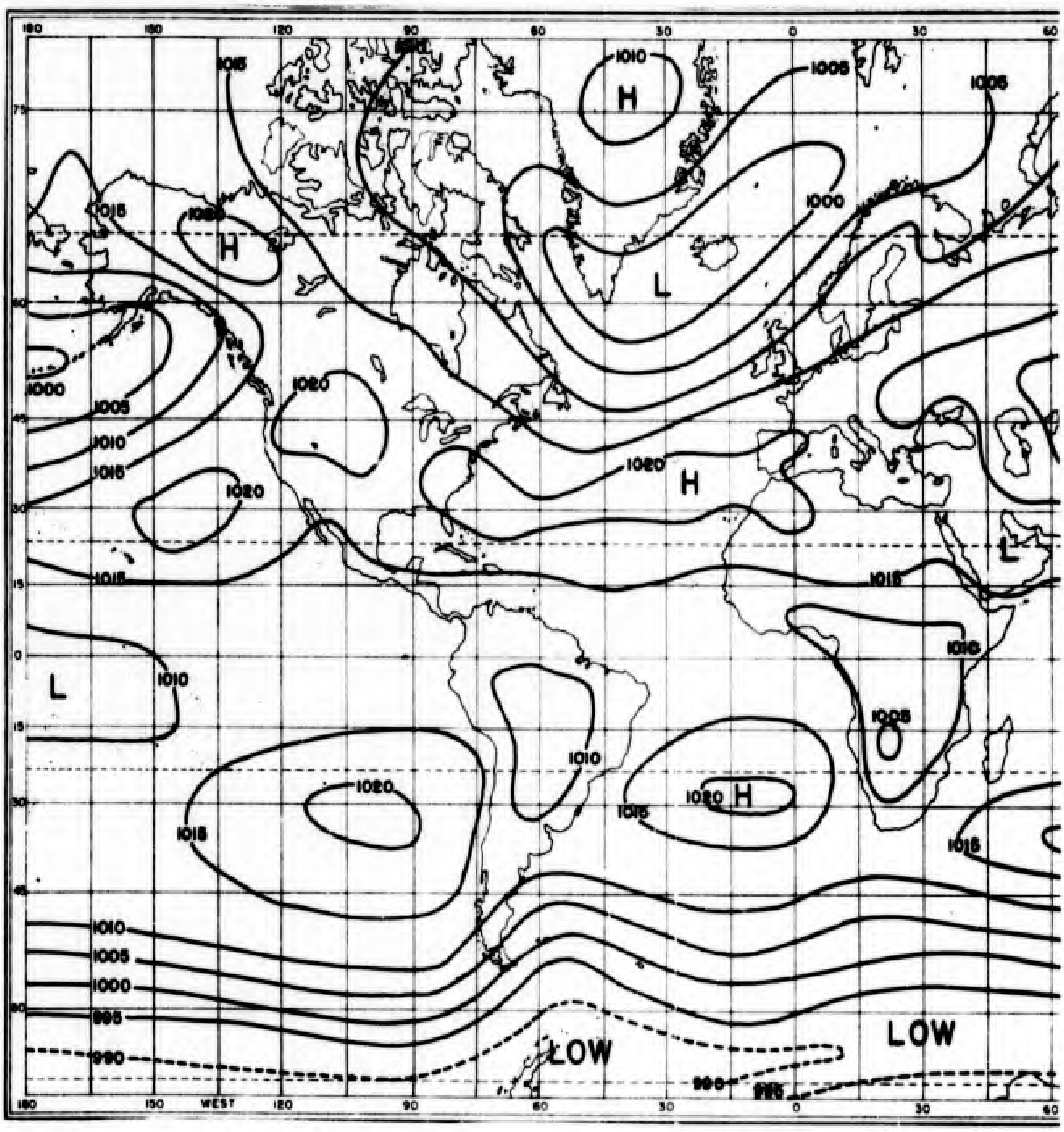


FIGURE 5. Mean Sea Level Pressure (millibars) during January (7).

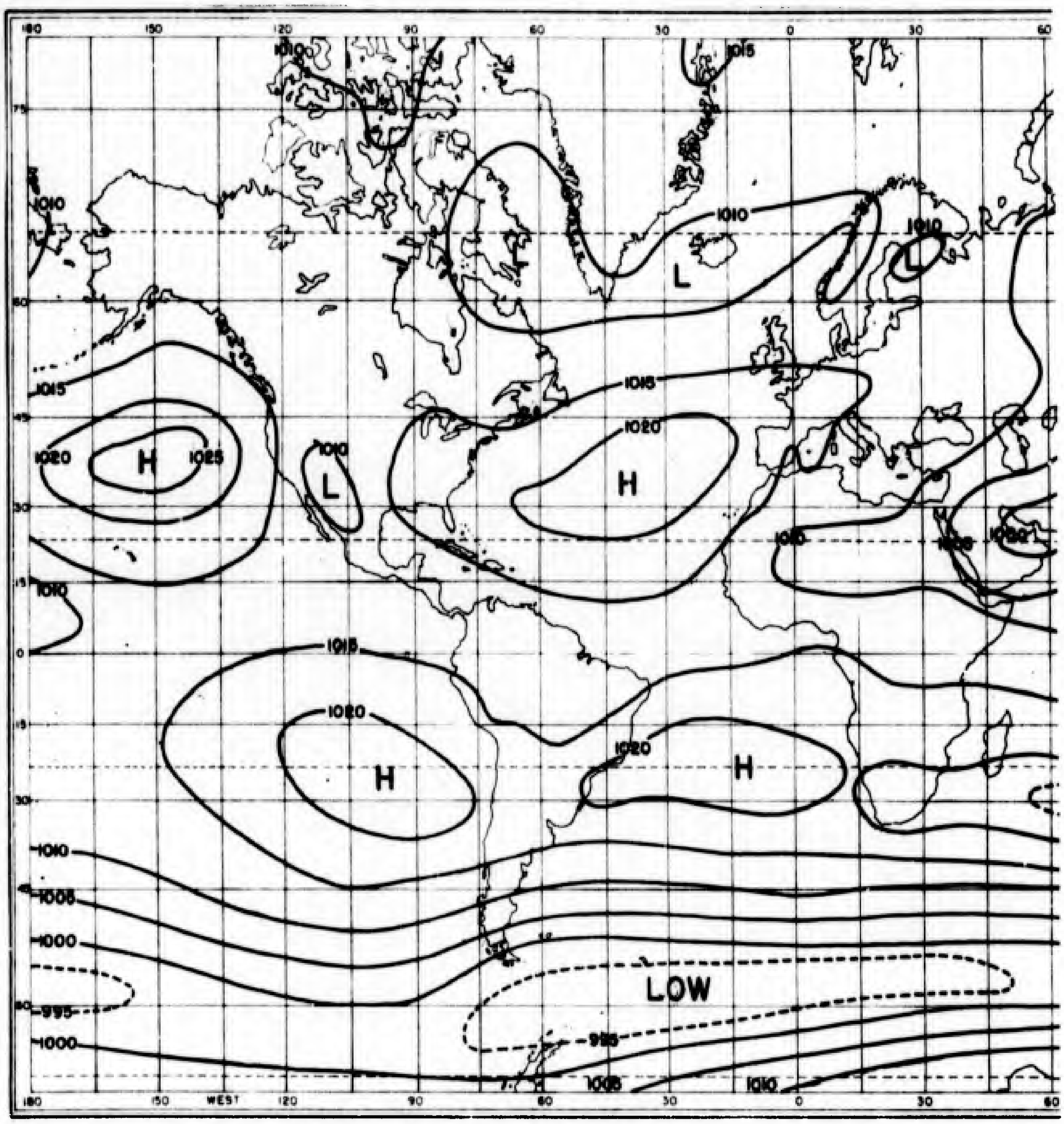


FIGURE 6. Mean Sea Level Pressure (millibars) during July (7).

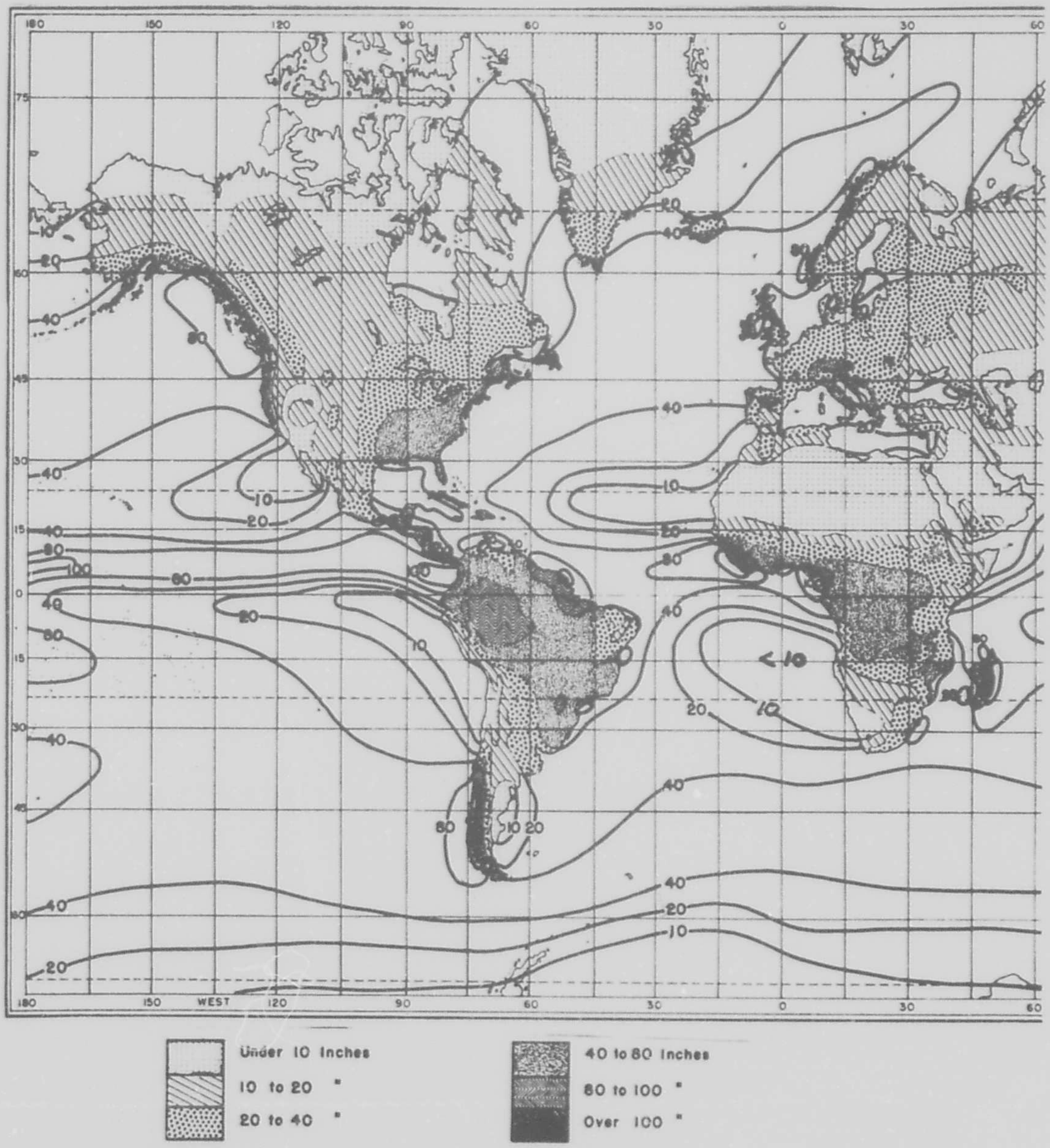


FIGURE 7. Annual Precipitation (7). Note the wet areas on the Pacific coast of Colombia and southern Peru, and the dry areas in northern Chile, Peru, northeastern Brazil, and southern Argentina.

2. Examples of climatic rainfall anomalies in South America include the excessive wetness of the Pacific side of Colombia; the unusual equatorward displacement and intense aridity of the Chilean - Peruvian dry climates; the low sun rainfall maximum along the Brazilian coast south of Cape Sao Roque; the drought area in northeastern Brazil inland from Cape Sao Roque; the dry littoral in northern Venezuela-Colombia; and the Patagonian desert (see figure 7).

3. Figures 8 and 9 show the average cloudiness during January and July, respectively. Note that the relative maximum of seven tenths cloud cover over most of central Brazil during January changes to a relative minimum of less than four tenths cloud cover during July (Brazil's dry season).

4. Figures 10 and 11 show the average frequency of fog for December-February and June-August, respectively. Note the relative maximum of fog occurrence along the coast of Peru during December-February and along the coast of Chile during June-August.

5. Figure 12 shows the average ocean surface currents during February-March. Figures 13 and 14 show the isotherms of mean sea-surface temperature and main ocean currents during January and July, respectively. Note that abnormally cold water is found off the west coast of South America north of 40°S latitude. This is the combined effect of the weak north-flowing Peru Current and the upwelling of cold water along the coast. South of 45°S latitude the sea-surface temperatures tend to be rather high (for that latitude) resulting from the South Pacific Ocean westerly current (West Wind Drift) deflecting southward around Cape Horn.

6. Figures 15 and 16 show the average location of fronts and air masses during January and July, respectively.

7. Figure 17 shows the mean pressure, tracks of depressions, and regions of frontogenesis during July.

8. Figures 18 and 19 show the streamlines of mean winds at 3,000 feet above sea level during January and July, respectively.

9. For a rather extensive discussion of the General Circulation of the Atmosphere over South America, Tropical Climatology, and Temperate Region Climatology, the reader is referred to "South American Climatology" by Air France, April 1965 (4).

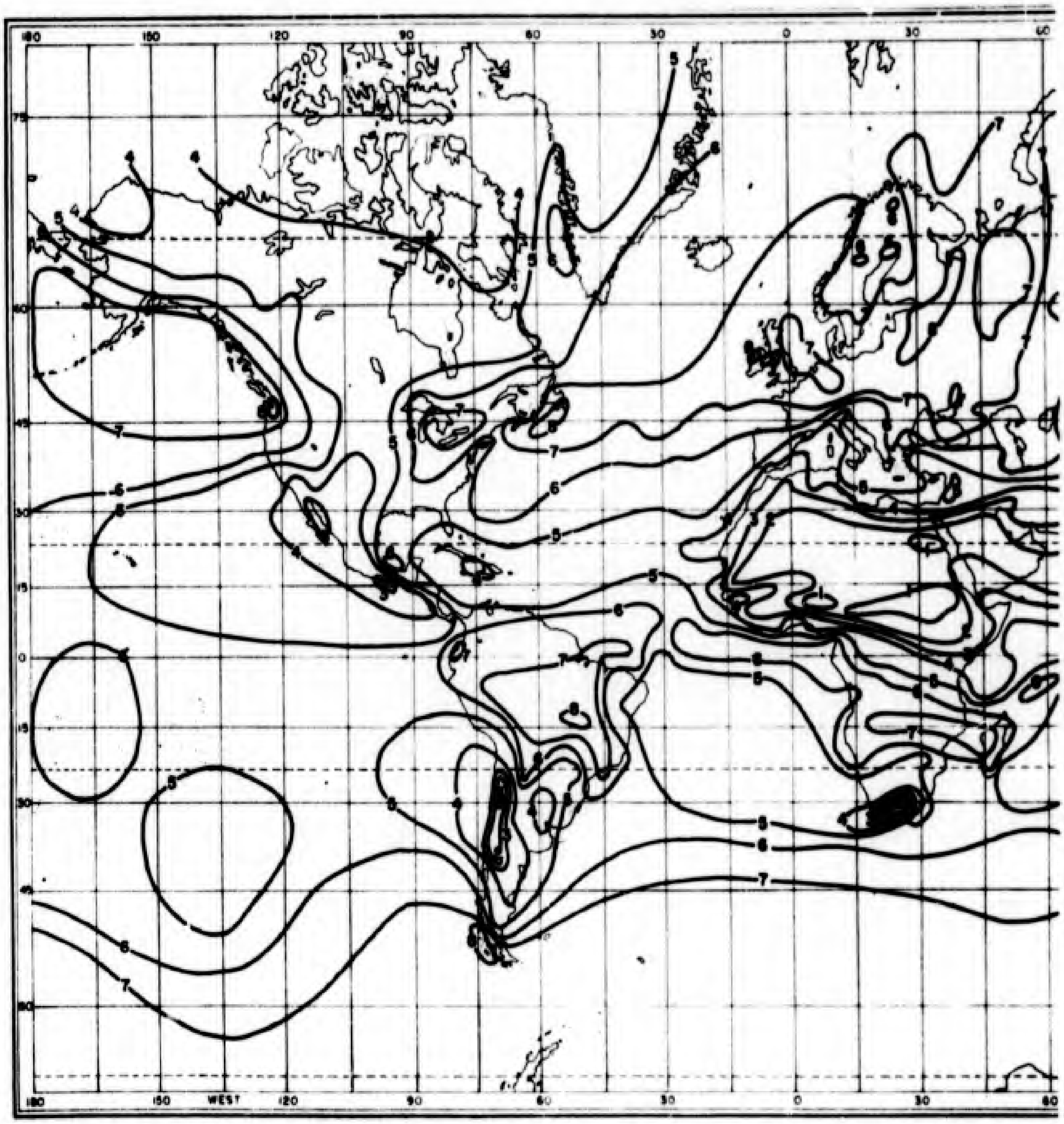


FIGURE 8. Average cloudiness (in tenths of sky cover) during January (7). Note the relative maximum of cloudiness over northern Brazil.

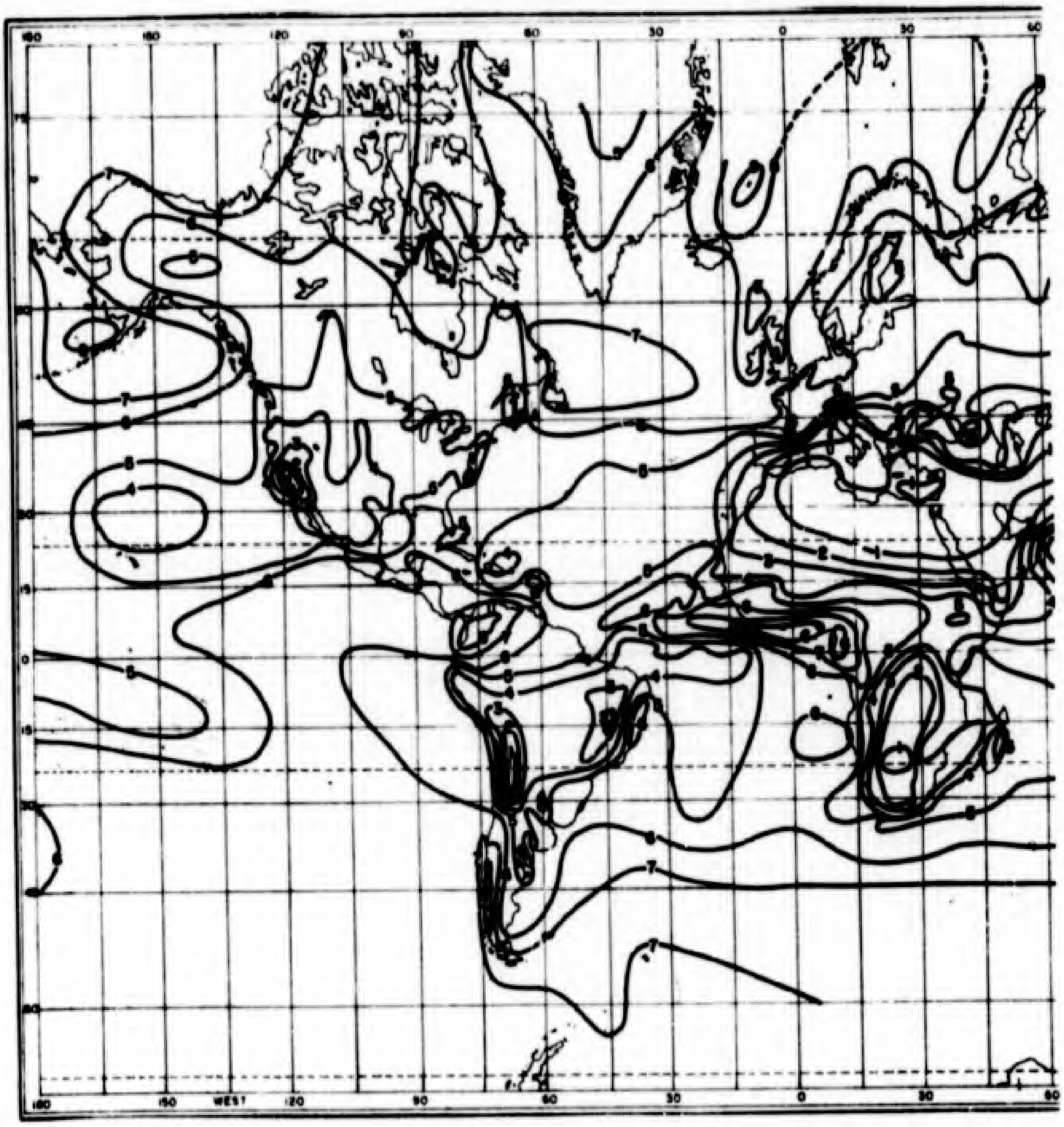


FIGURE 9. Average cloudiness (in tenths of sky cover) during July (7). Note the relative minimum of cloudiness over northern Brazil.

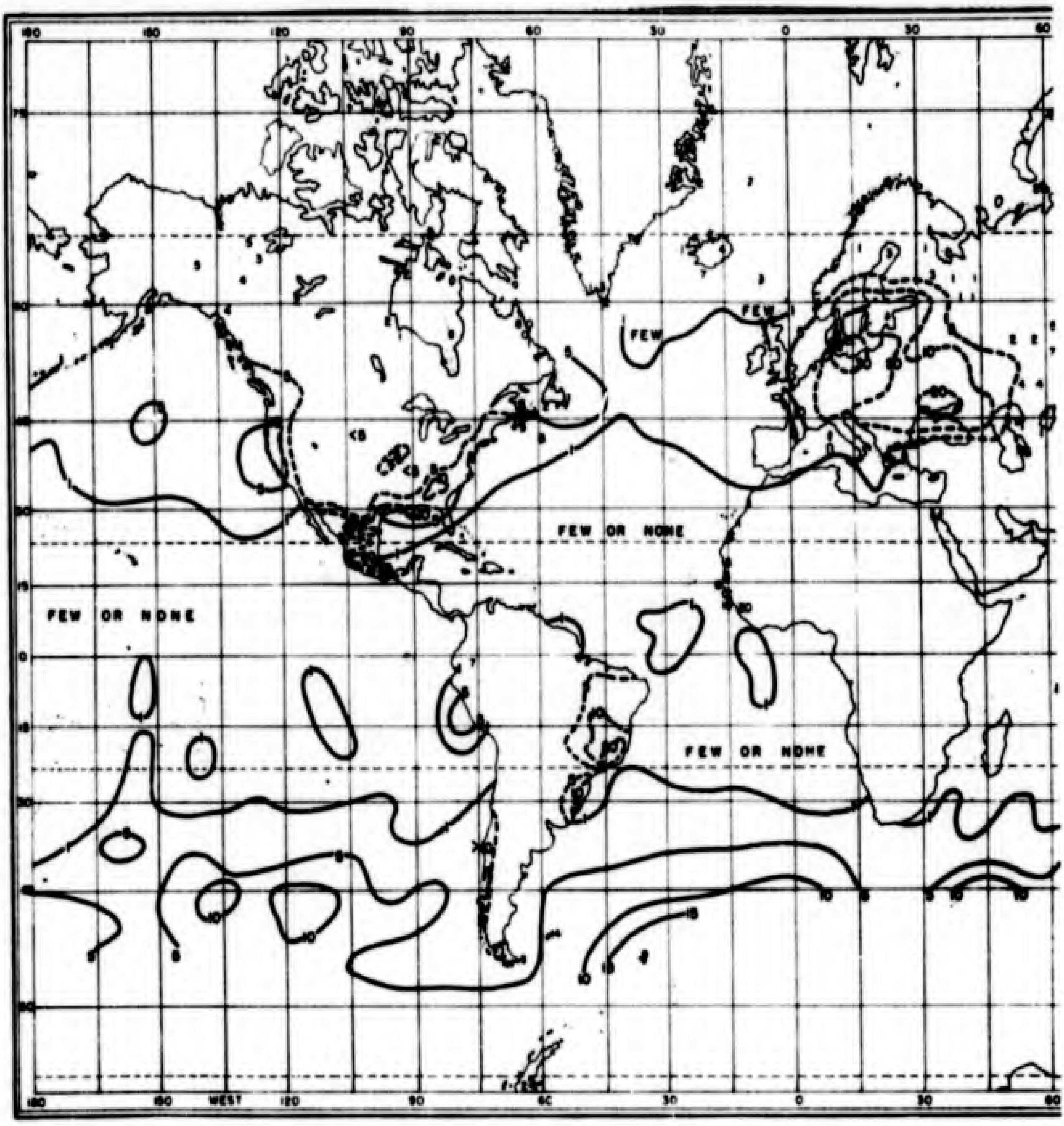


FIGURE 10. Average frequency of fog for December-February (7). Note the relative maximum of fog along the coast of Peru. Solid lines are percentage of all ship observations. Broken lines and isolated numbers indicate number of days with fog.

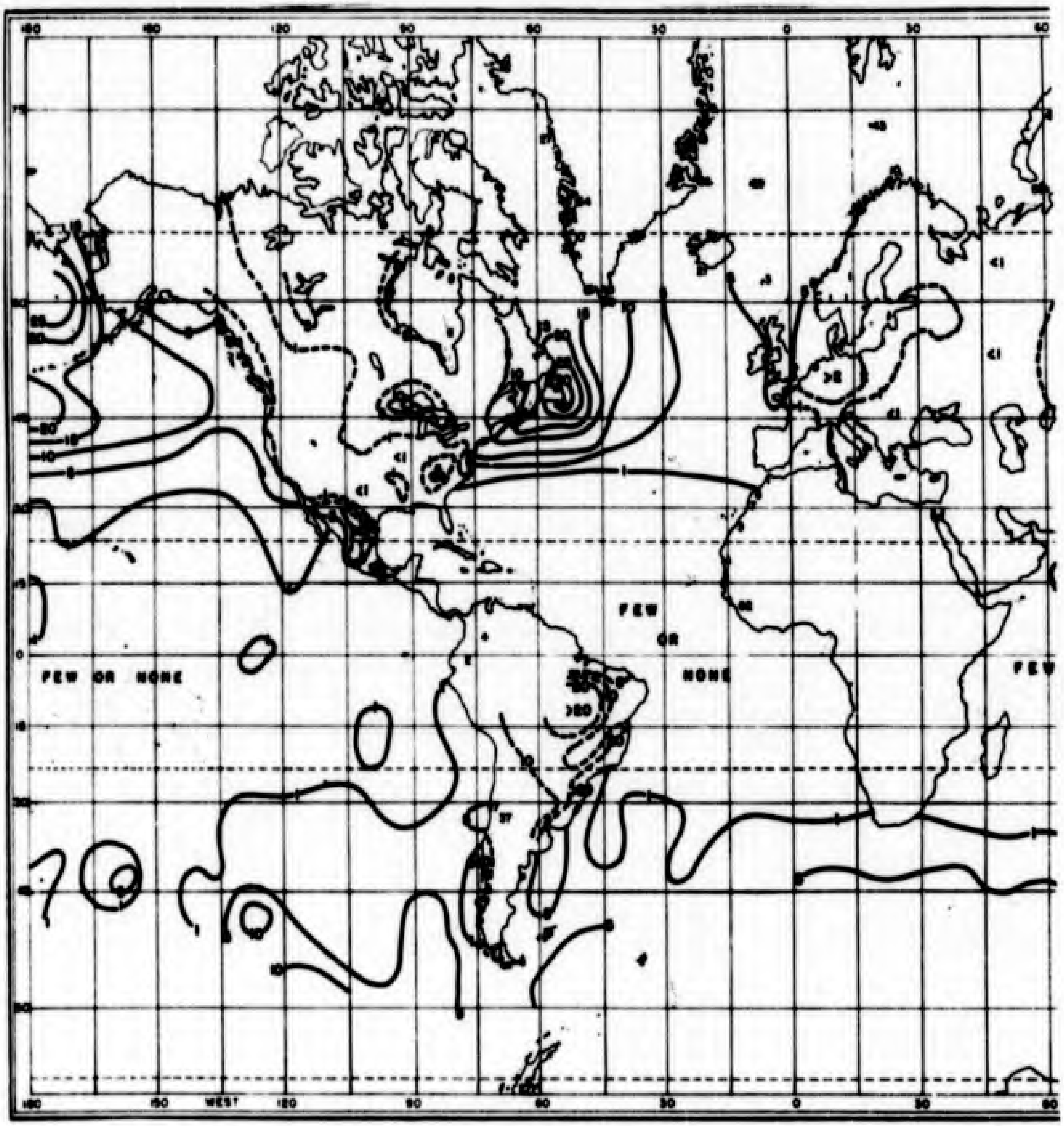


FIGURE 11. Average frequency of fog for June-August (7). Note the relative maximum of fog along the coast of Chile. Solid lines are percentage of all ship observations. Broken lines and isolated numbers indicate number of days with fog.

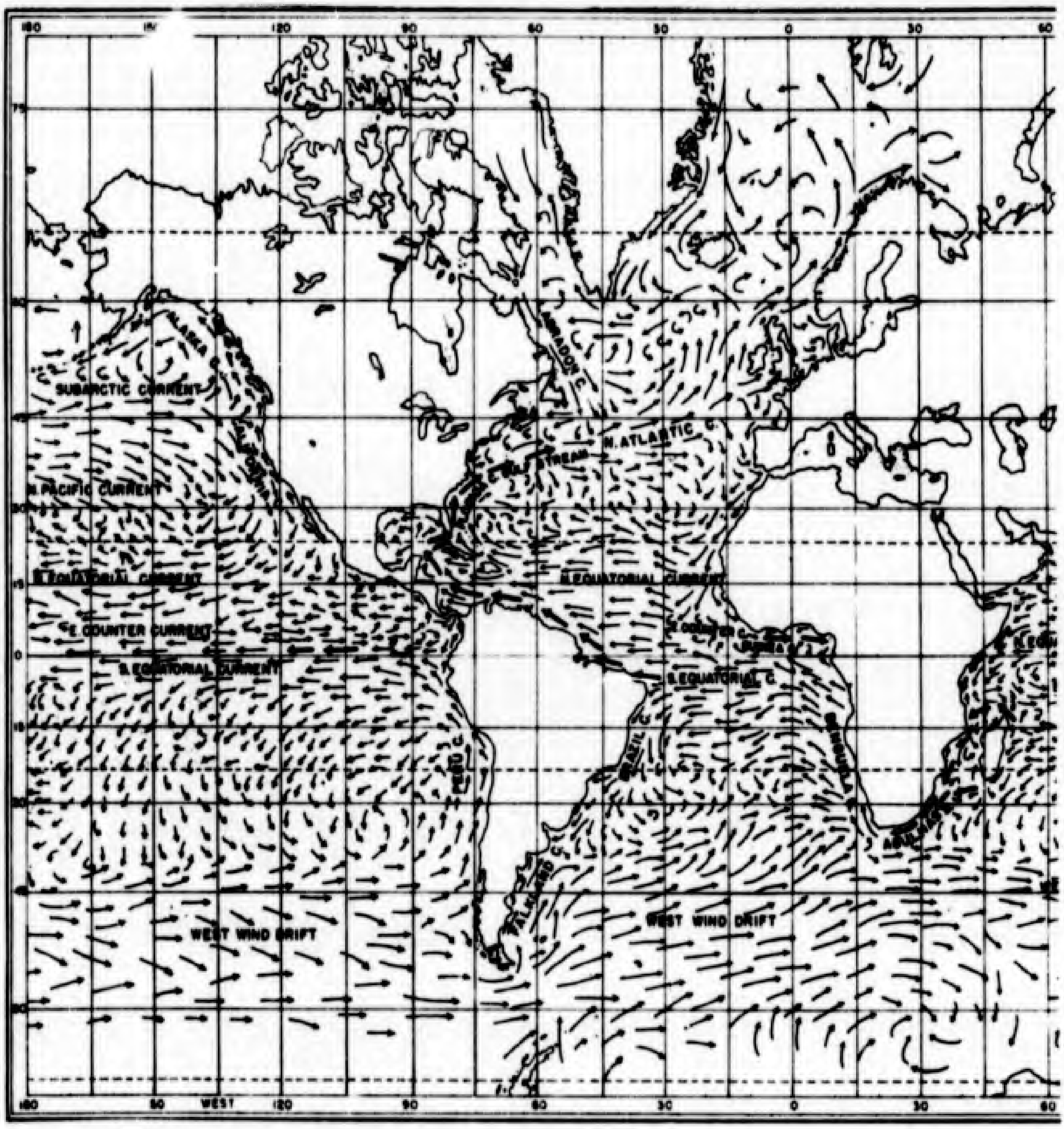


FIGURE 12. Average ocean surface currents during February-March (7).

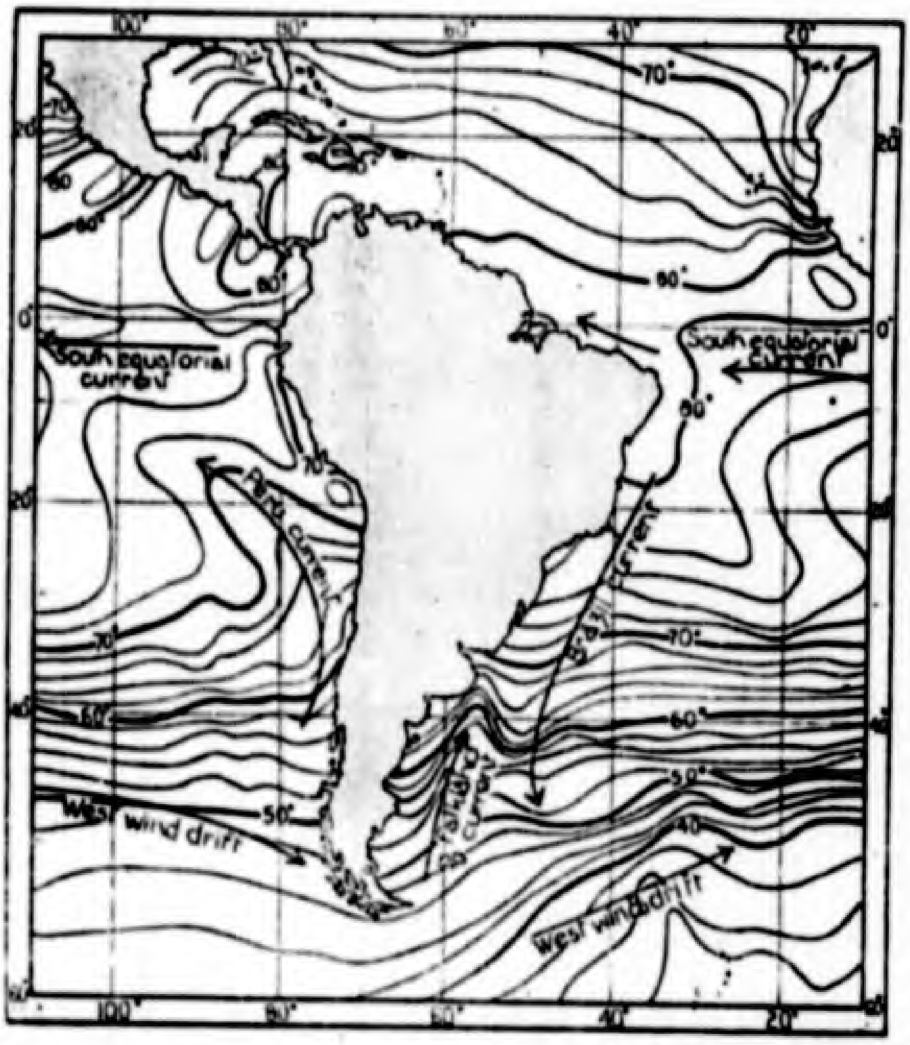


FIGURE 13. Isotherms of mean sea-surface temperature and main ocean currents during January (3). The isotherms are drawn for every 2°F.

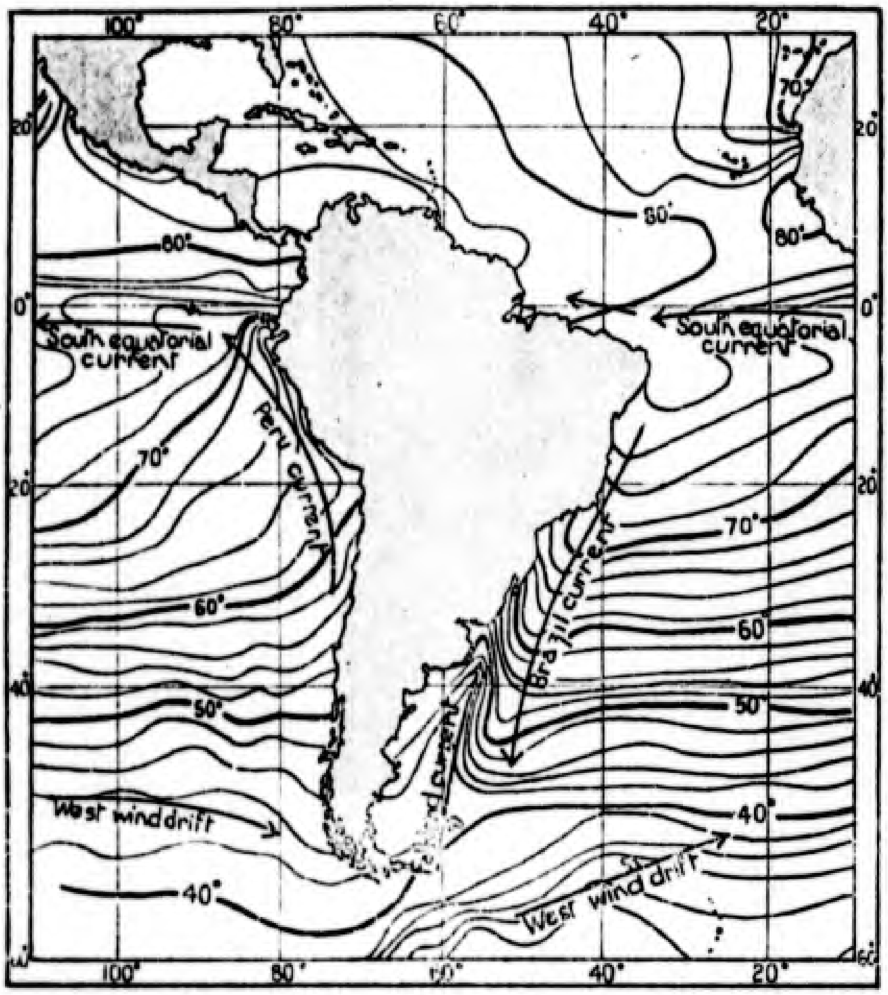
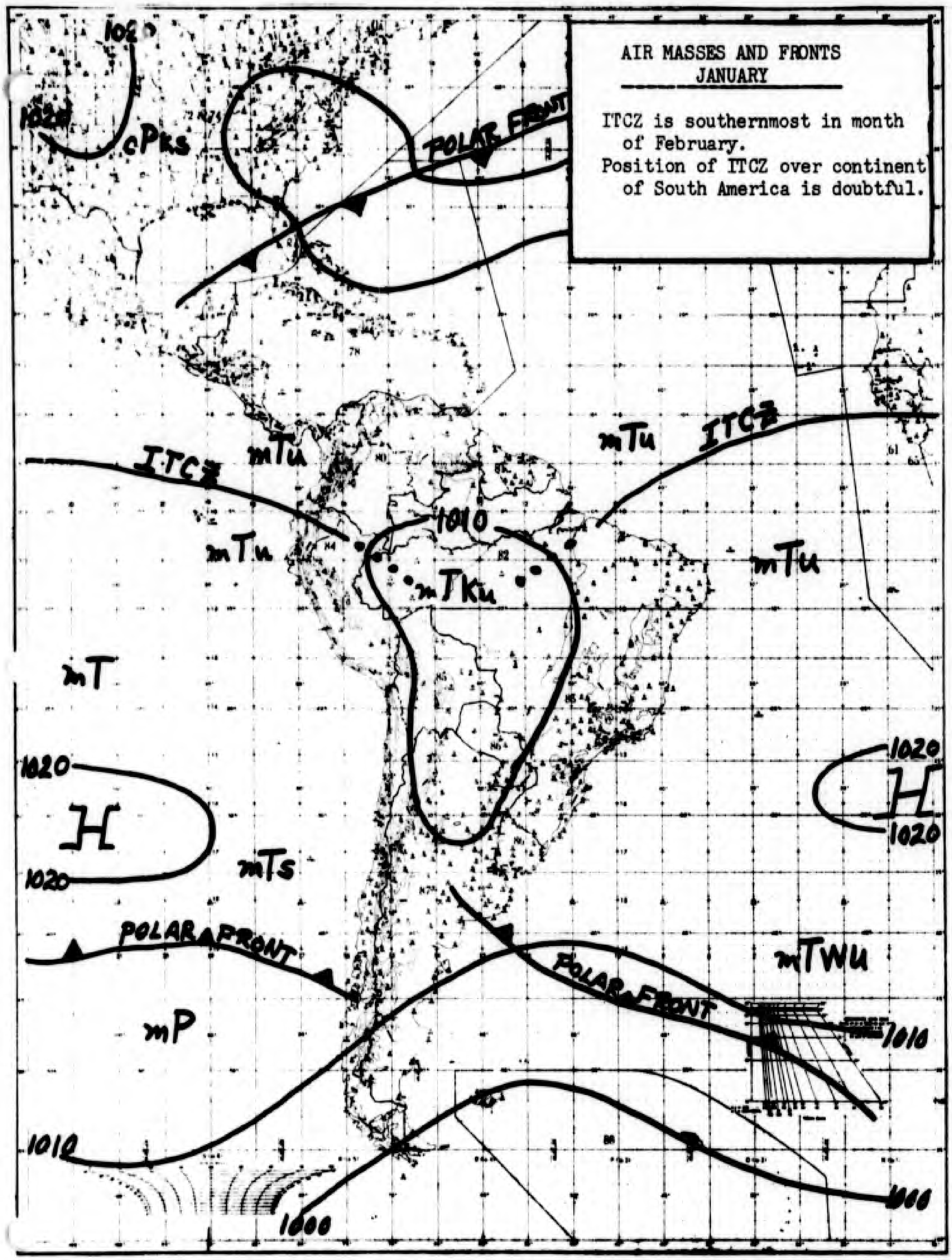


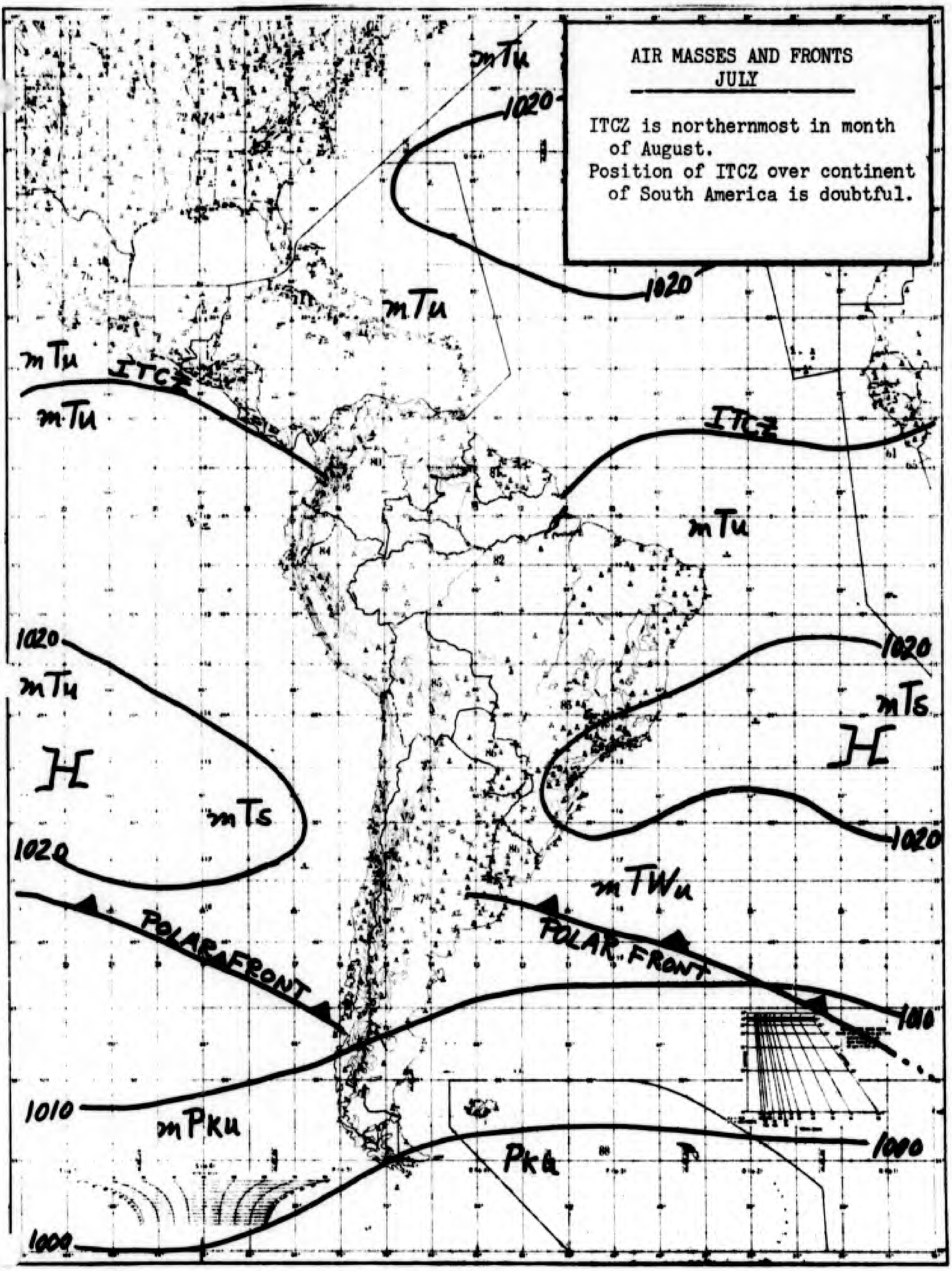
FIGURE 14. Isotherms of mean sea-surface temperature and main ocean currents during July (3). The isotherms are drawn for every 2°F.



AIR MASSES AND FRONTS
JANUARY

ITCZ is southernmost in month of February.
Position of ITCZ over continent of South America is doubtful.

FIGURE 15. See inset (7).


AIR MASSES AND FRONTS
JULY

ITCZ is northernmost in month of August.
Position of ITCZ over continent of South America is doubtful.

FIGURE 16. See inset (7).

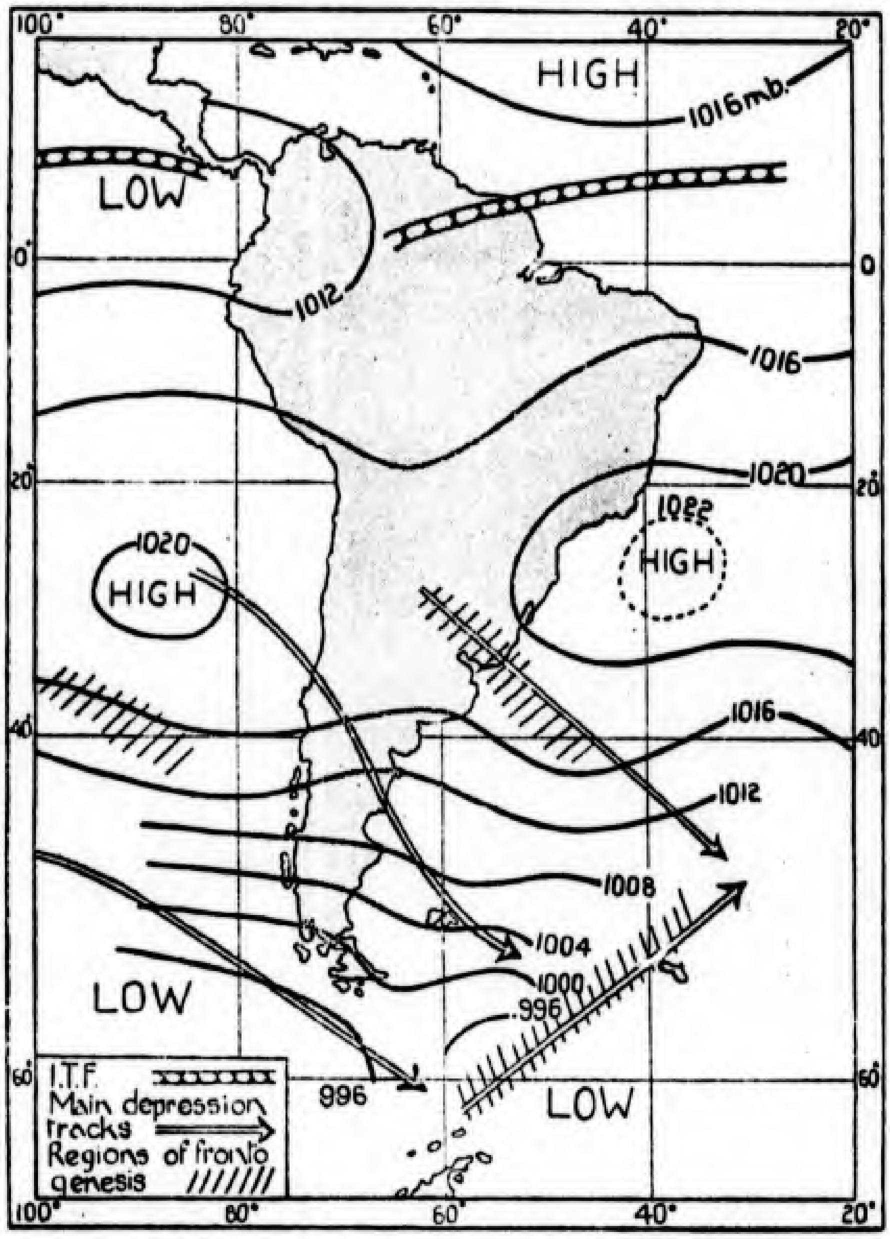


FIGURE 17. Average pressure, tracks of depressions, and regions of frontogenesis during July (3).

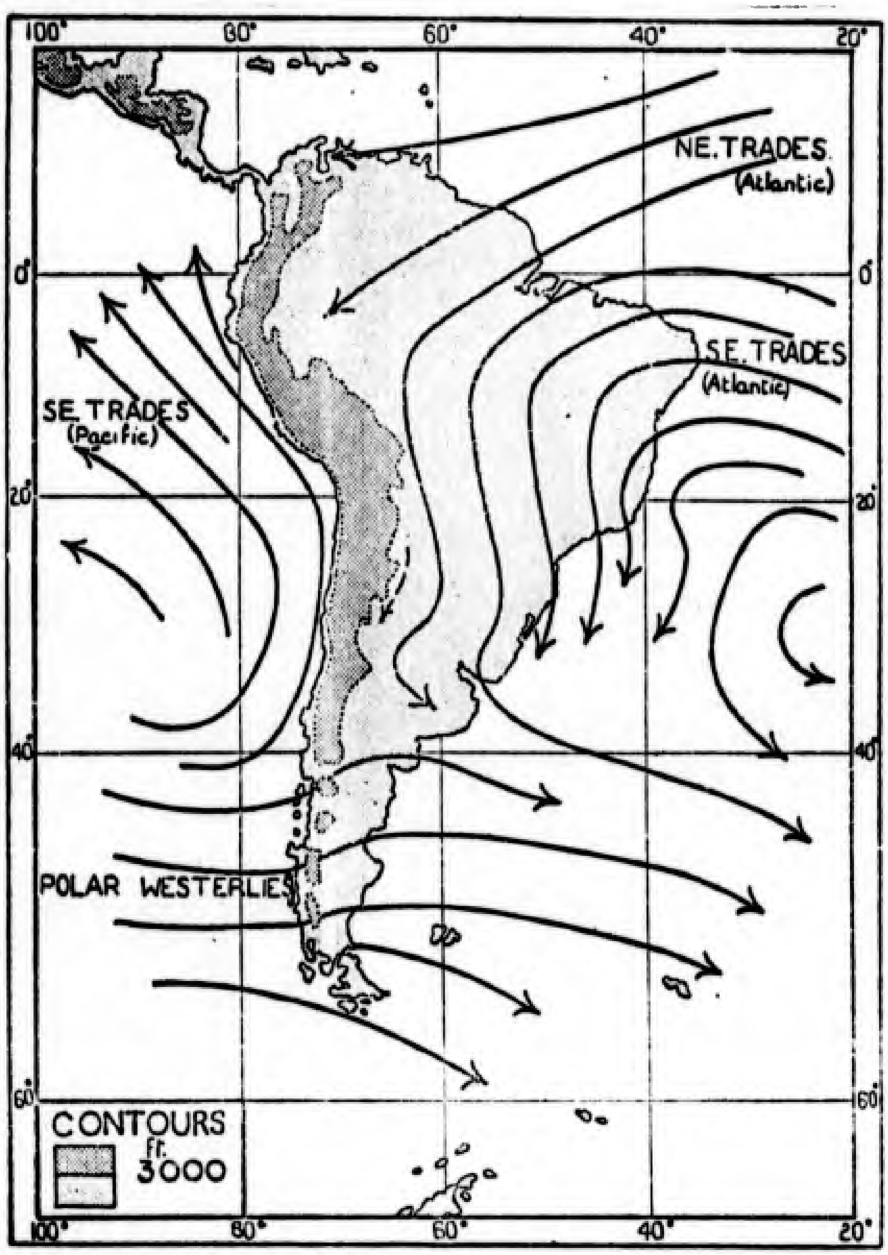


FIGURE 18. Streamlines of mean winds at 3,000 feet above sea level during January (3).

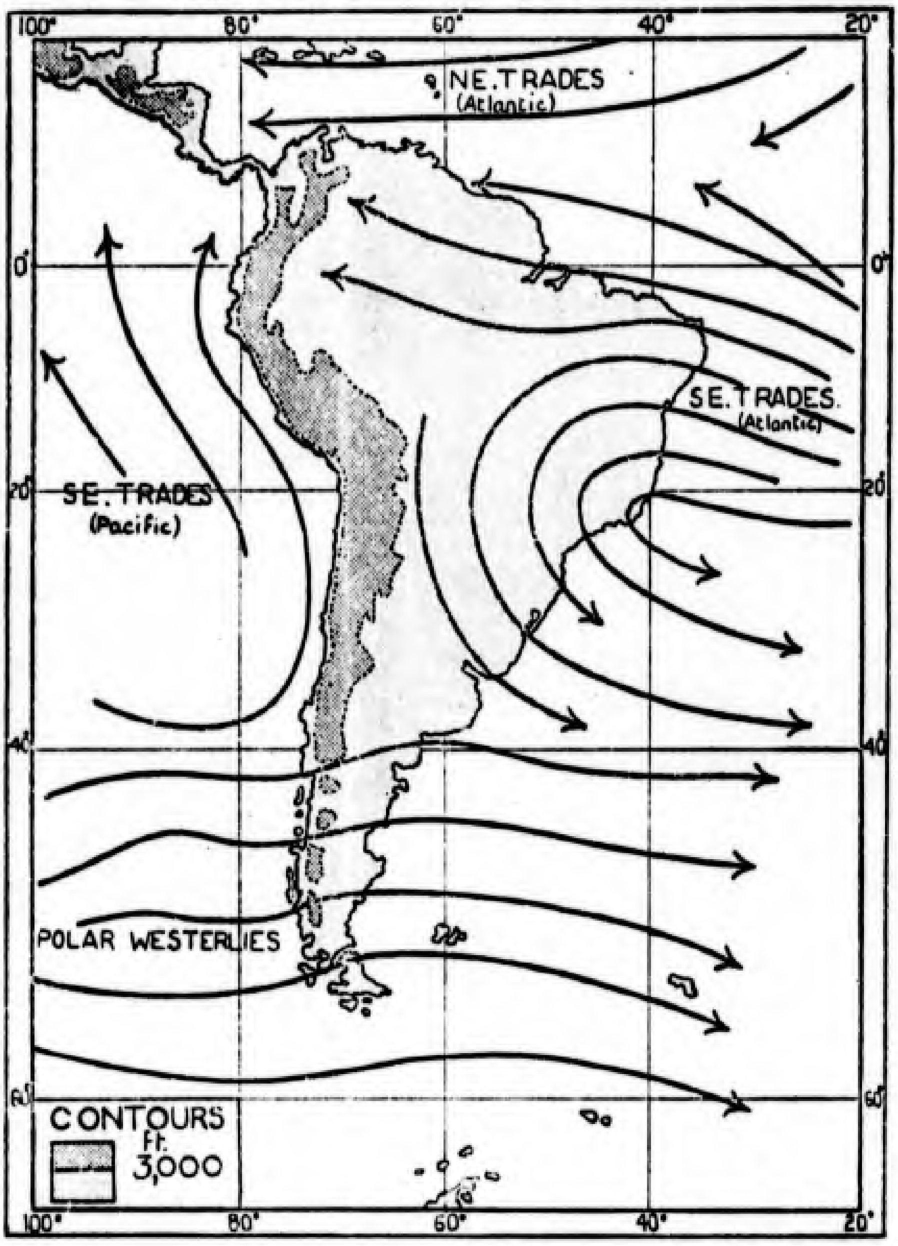


FIGURE 19. Streamlines of mean winds at 3,000 feet above sea level during July (3).

III. ANALYSIS PROCEDURES AND EXAMPLES

A. Data Reliability

1. Surface Data

(A) Many South American stations report data that deviate from the current synoptic pattern. This is particularly true of sea level pressure. Each analyst must decide which data is useable based on the synoptic situation, continuity, and common sense. Following is a list of stations which often report erroneous sea level pressure values:

68906
80210
80222
84686
85242
85907
85915
85935
85967
87047
87217
87322
87418
87509
87803
87925
87934

(B) Pan American World Airways (Rio forecast office) has furnished a page of suggested corrections to sea level pressure (see Appendix I) for use with Brazilian weather reports from Pan American circuits.

2. Upper Air Data

(A) Radiosonde wind/temperature/pressure surface height data should be used with first priority in upper air analyses, aircraft reports with second priority, and satellite wind estimates with third priority. The satellite wind estimates are from cumulonimbus blowoffs (or anvils) and vary in altitude from 300 mbs to 100 mbs.

(B) Whenever radiosonde data seem questionable, the data should be first checked for transmission and plotting errors. If the data are still questionable use a Skew T-Log P diagram (or other thermodynamic diagram) to authenticate the data, using thickness computations as required.

(C) Heights of standard surfaces can be vertically extrapolated from ship reports using the Skew T-Log P diagram as follows:

(1) Plot the surface temperature and dew point at the given sea level pressure.

(2) Estimate the 700mb and 500mb temperatures, using continuity of temperature patterns from previous upper air analyses.

(3) Draw a straight line between the 700 and 500mb temperatures and extend this line to 800 mbs. This lapse rate is valid except when a front exists between the 700 and 500mb levels.

(4) Draw an adiabatic lapse rate from the surface temperature to the base of the clouds. Cloud heights are determined from the ship report or from the lifted condensation level. When the sea surface temperature is warmer than the surface air temperature, or when strong winds occur, a dry adiabatic lapse rate usually prevails. Warm air moving poleward over colder water usually has an isothermal lapse rate in the lowest 40 mbs before assuming a dry adiabatic configuration.

(5) If a low overcast cloud deck prevails, a moist adiabatic lapse rate prevails through the cloud layer. If the clouds are scattered or cumuloform, a lapse rate between moist and dry adiabatic should be drawn throughthe cloud layer.

(6) An isothermal lapse rate is drawn from the cloud tops to the intersection with the line from the 700mb level. This lapse rate represents a typical inversion for stratiform clouds.

(7) Minor adjustments may be required at times in one or more of the above steps before the final lapse rate is drawn.

(8) Compute the 1000mb height using the nomogram in the upper left corner of the Skew T diagram.

(9) Compute the 1000 to 700mb and the 700 to 500mb thickness using the equal area method. Add the computed thicknesses to the 1000mb height to determine heights for the 700 and 500mb pressure surfaces.

(10) If a 300mb height is desired, a standard lapse rate may be used between 500 and 300 mbs.

B. Extratropical Systems

1. Fronts and Troughs

(A) Stacking Procedures. Forecasters in the Latin American Forecast Center use stacking procedures as an analysis aid. For frontal situations a slope of four degrees (measured along a meridian) per analysis level is used to position troughs through the 300mb level. Two degrees slope is used from the 300mb to the 250mb trough lines. This procedure is used as a first approximation for positioning trough lines. The trough lines are adjusted only if data show that the positions are definitely erroneous. Figure 20 shows the stacking intervals used from the surface through the 250mb trough.

(B) Satellite Data. Satellite mosaics/nephanalyses are used to position weather systems over the South Pacific and South Atlantic. Conventional data (when available) are used in conjunction with satellite data in surface and upper air analyses.

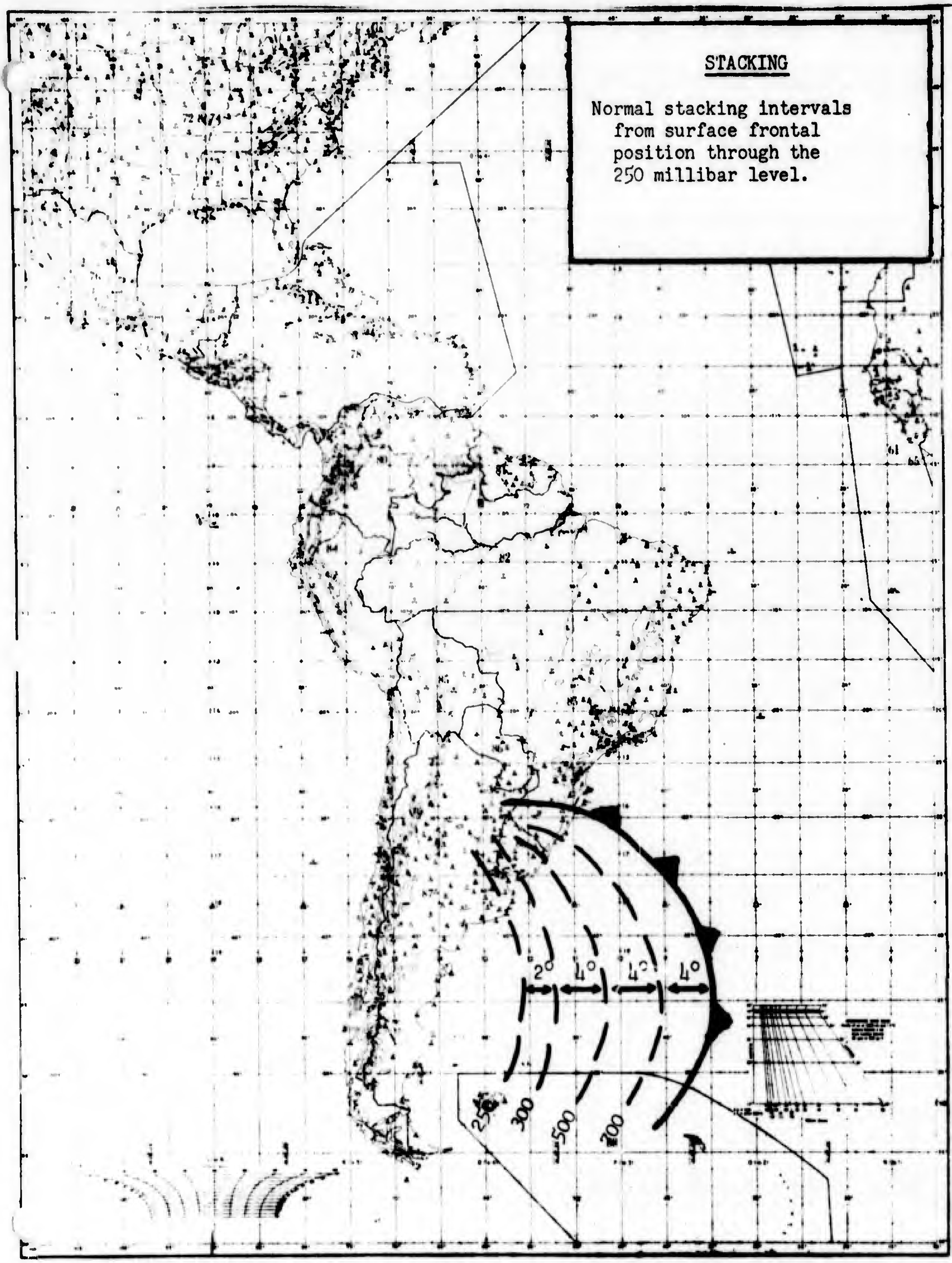
(C) West of the Andes.

(1) Most frontal systems approaching Chile have occluded during their trajectory across the Pacific. Satellite mosiacs/nephanalyses aid locating the "triple point" on the occluded front when jet stream cirrus streaks are visible. Radiosonde data from stations 801, 860, and 926 also aid positioning the upper air jet stream and subsequently the "triple point" on the occluded front.

(2) The semi-permanent ridge of high pressure over the eastern South Pacific usually maintains pressure greater than 1020 mbs from 25°S to 45°S latitude. Moderate pressure falls (2mb or more/3 hours) along the west coast, particularly south of 40°S, indicate that a frontal system is approaching.

(3) When the front is in the pressure trough, large pressure rises (4 mbs or more/3 hours) occur with frontal passage. The wind direction shifts to the southwest; rainshowers accompany the front and continue intermittantly following frontal passage.

(4) When the front is ahead of the pressure trough, small to moderate pressure rises may follow the frontal passage but, generally, pressure falls continue because of the approaching pressure trough. Clouds and precipitation will not extend significantly ahead of the front because ridging



STACKING

Normal stacking intervals from surface frontal position through the 250 millibar level.

FIGURE 20. See inset.

at upper levels will be over the surface front. In this orientation the ridging (or divergence) supports lower level convergence associated with the trough but weakens activity associated with the front.

(5) Fronts seldom move north of 35°S, even during the winter. No significant temperature change occurs with frontal passage north of 50°S unless an Arctic surge occurs (infrequent along the west coast).

(D) East of the Andes.

(1) When weather systems move across the Andes the pressure gradient increases ahead of the front. Large pressure falls occur in the lee of the Andes enhancing the normal "lee side trough". Downslope motion ahead of the front causes rising temperatures and decreasing dew points. When the front moves into the lee side trough, moderate pressure rises occur with frontal passage. Correspondingly, the wind direction shifts to the southwest and dew point temperatures decrease. Normally, dew point discontinuity is more evident than temperature discontinuity across the front. Little cloudiness remains with fronts east of the Andes because of the subsiding air in the lower levels. The bases of remaining clouds are usually fairly high, 6,000 to 10,000 feet, and the air in the lower levels is dry enough to evaporate most precipitation before it reaches the ground. Fronts usually separate in the mountains with one part of the front remaining west of the Andes. After separating, the front east of the Andes starts moving independently of the western front.

(2) Warm fronts are modified and lose their identity when moving into and over the Andes.

(3) Cold fronts that cross the Andes cause no more than scattered middle cloudiness over land and adjacent water areas. The cold front usually separates from the front west of the Andes, south of 35°S latitude. As the cold front continues equatorward over Argentina, cloudiness increases, especially if poleward moving tropical air is not blocked by a polar high over Southern Brazil.

(4) Most occlusions crossing the Andes will be cold front occlusions. Scattered low and middle cloudiness occurs with little if any precipitation resulting. Warm front occlusions occur less frequently than cold front types, usually on the order of one out of ten occlusions. Warm front occlusions usually occur when the remnants of an old

polar or arctic front is oriented east to west near 50°S latitude. As another polar front moves across the Andes the downslope motion causes the air to warm so that the air mass is relatively warmer than that poleward of the old front. The low originally associated with system crossing the mountains will remain off the west coast of Chile 18 to 24 hours and fills as a low forms and deepens east of the mountains. Concurrently, the warm front occlusion occurs. Broken low clouds and overcast middle clouds occur poleward of the warm and occluded portions of the system. Extensive cloudiness and variable intensity precipitation persist as long as the low remains west of Chile.

(E) Figures 21, 22, and 23 are examples of system analysis for the 700, 500, and 300mb levels. Note that the 300mb example shows an isotherm analysis for a situation when the tropopause is below 300 mbs.

(F) Figure 24 shows a 700mb analysis for a polar-arctic surge.

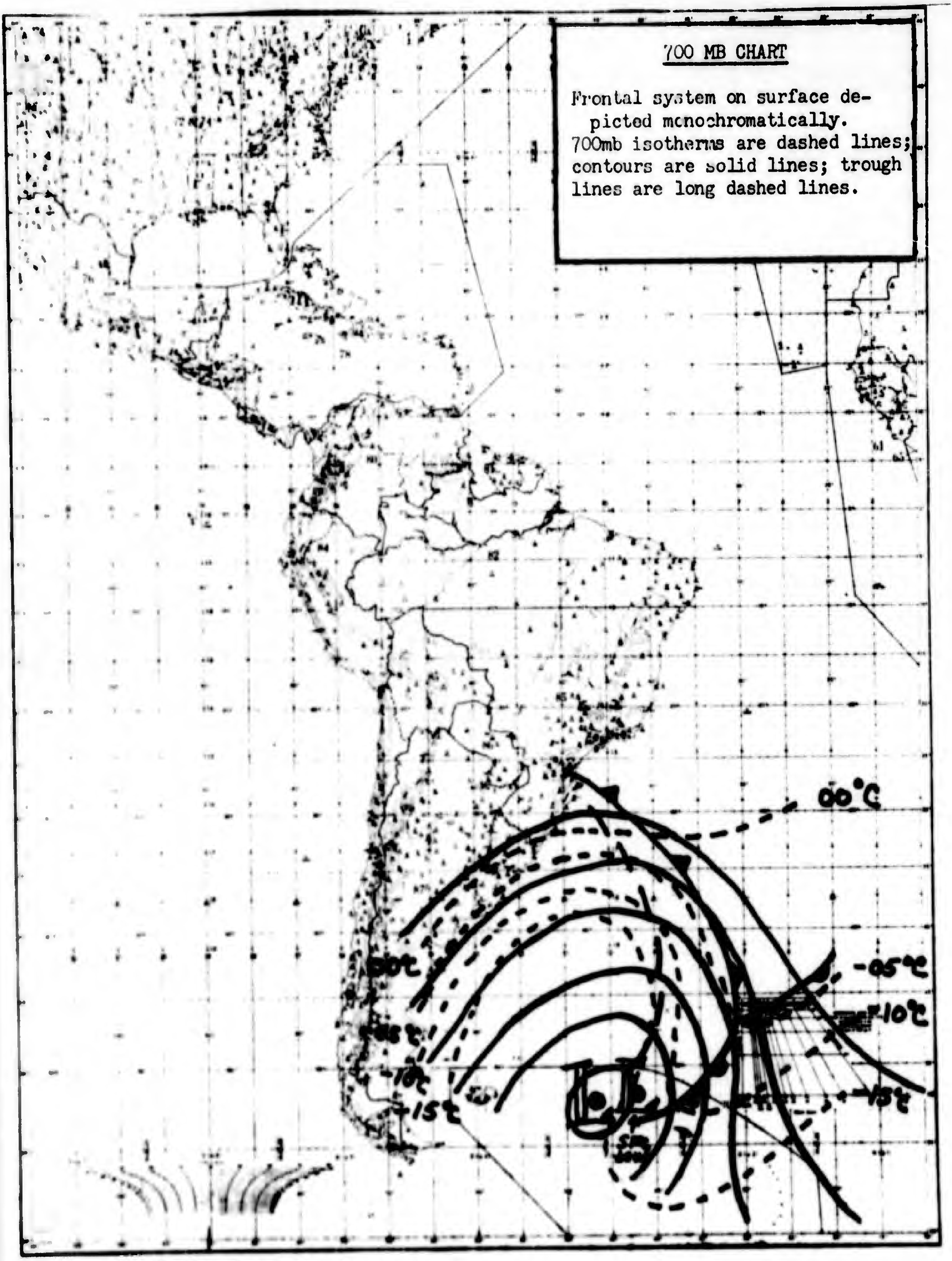
(G) Figure 25 shows a 700mb analysis for an unstable wave.

(H) Figure 26 shows a 500mb analysis for situations where,

(1) the frontal system and 500mb trough are moving at the same speed;

(2) where the frontal system is moving faster than the 500mb trough.

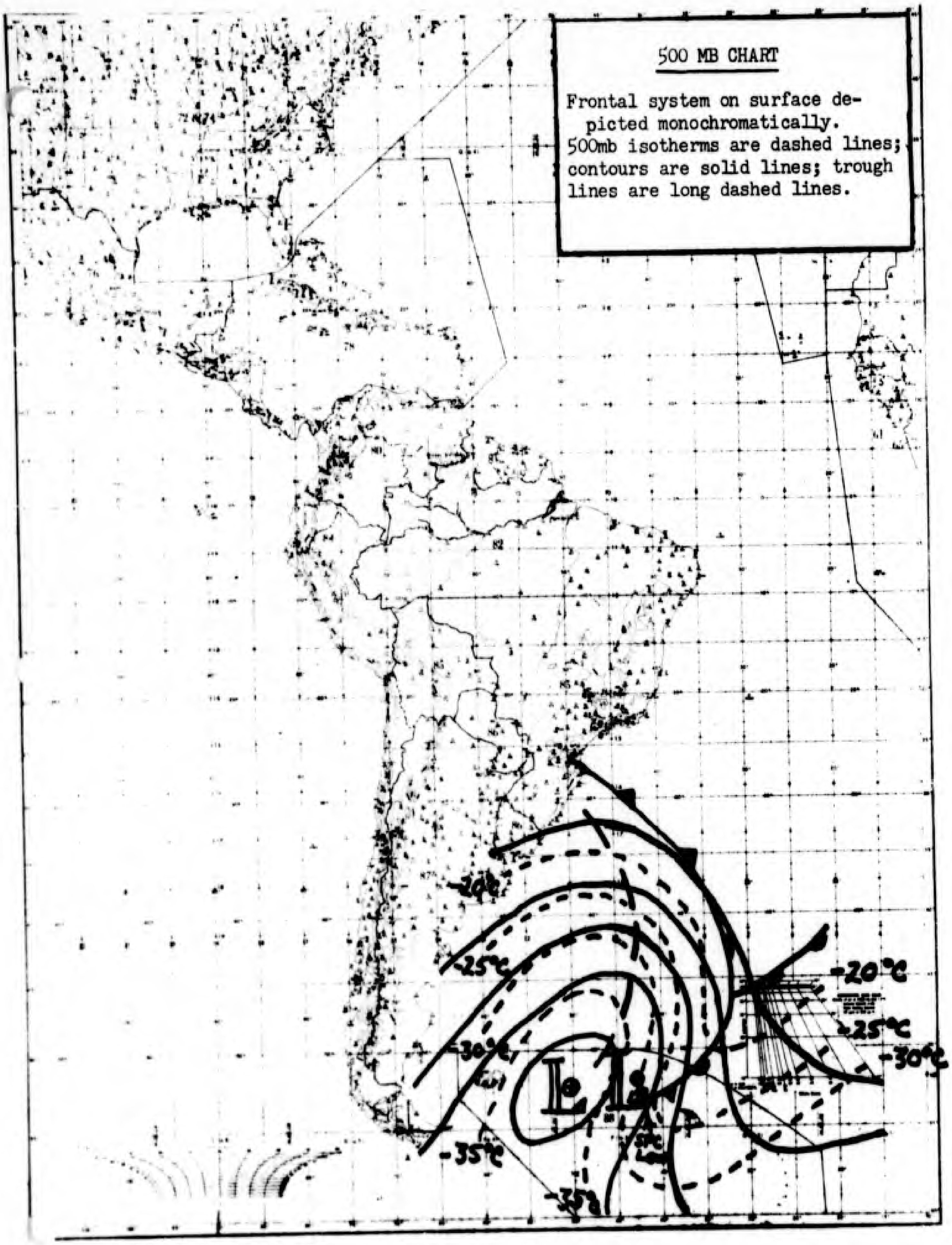
2. Cyclone Development and Stacking. The Classical Norwegian Cyclone Models are used in analysis in conjunction with satellite data. In all situations, low's (cyclones) are sloped aloft toward cold air. When a wave forms and begins to occlude, the cold air aloft is poleward and westward of the surface low. When the occlusion is fully matured the cold air aloft is located over and often equatorward of the surface low. The procedure used in the Latin American Forecast Center is to stack the upper air lows westward and equatorward of the surface low during the occluding stages. When the cyclone occlusion has fully matured, the upper air lows are nearly vertical and slightly equatorward of the surface low. Concurrently, a new surface low usually forms on the "triple point" of the front; the old occlusion washes out and the new wave and cyclone start occluding.



700 MB CHART

Frontal system on surface depicted monochromatically. 700mb isotherms are dashed lines; contours are solid lines; trough lines are long dashed lines.

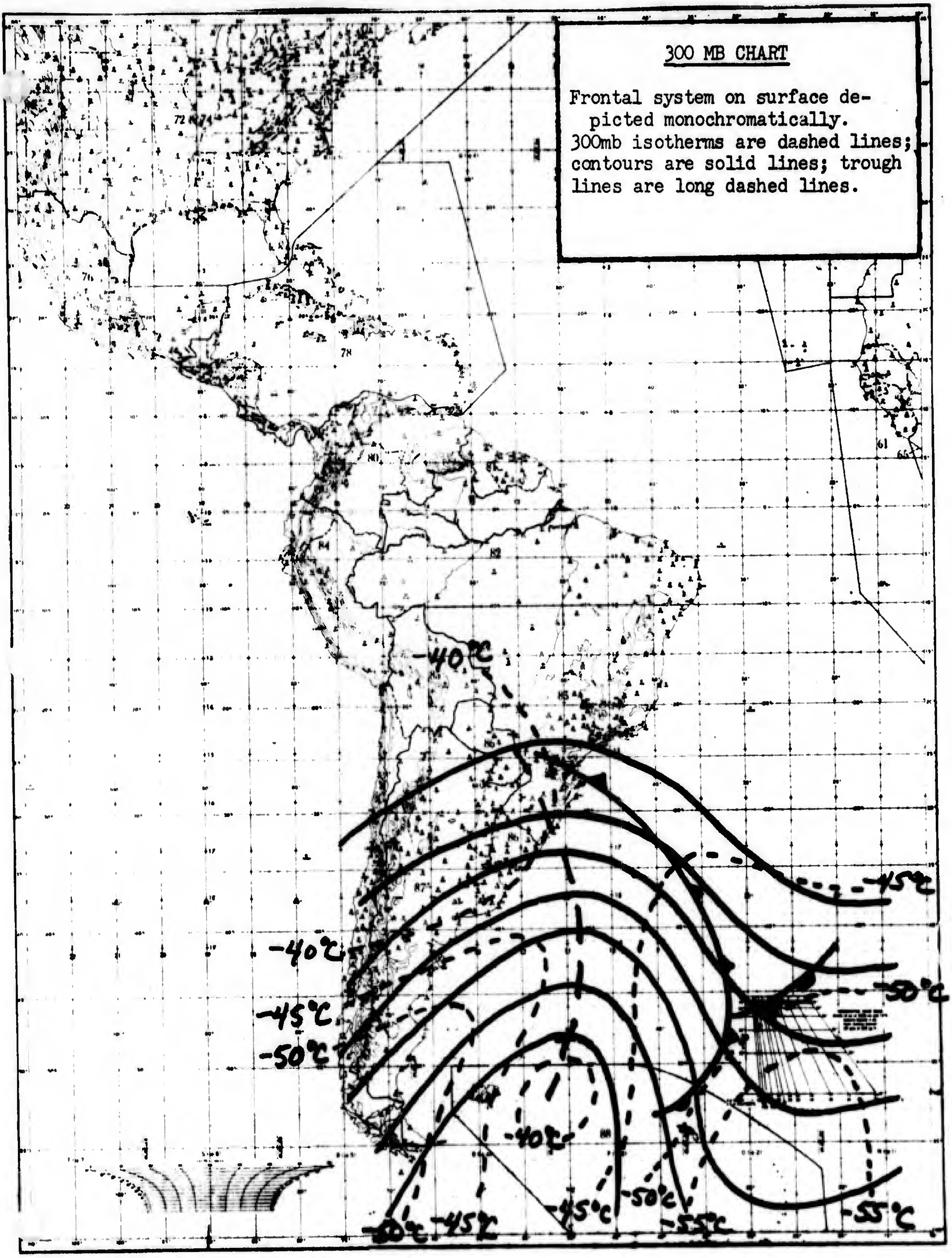
FIGURE 21. See inset.



500 MB CHART

Frontal system on surface depicted monochromatically. 500mb isotherms are dashed lines; contours are solid lines; trough lines are long dashed lines.

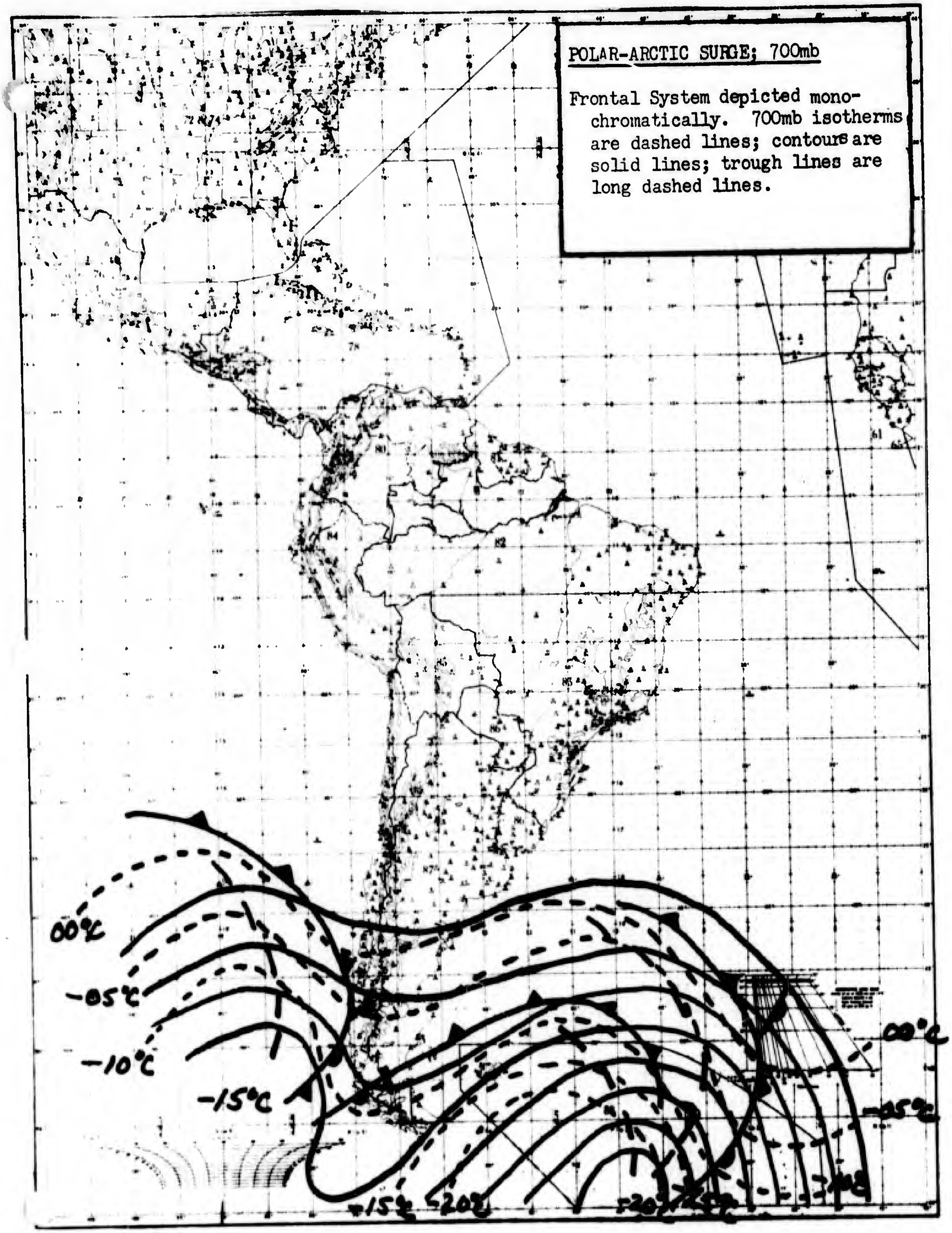
FIGURE 22. See inset.



300 MB CHART

Frontal system on surface depicted monochromatically. 300mb isotherms are dashed lines; contours are solid lines; trough lines are long dashed lines.

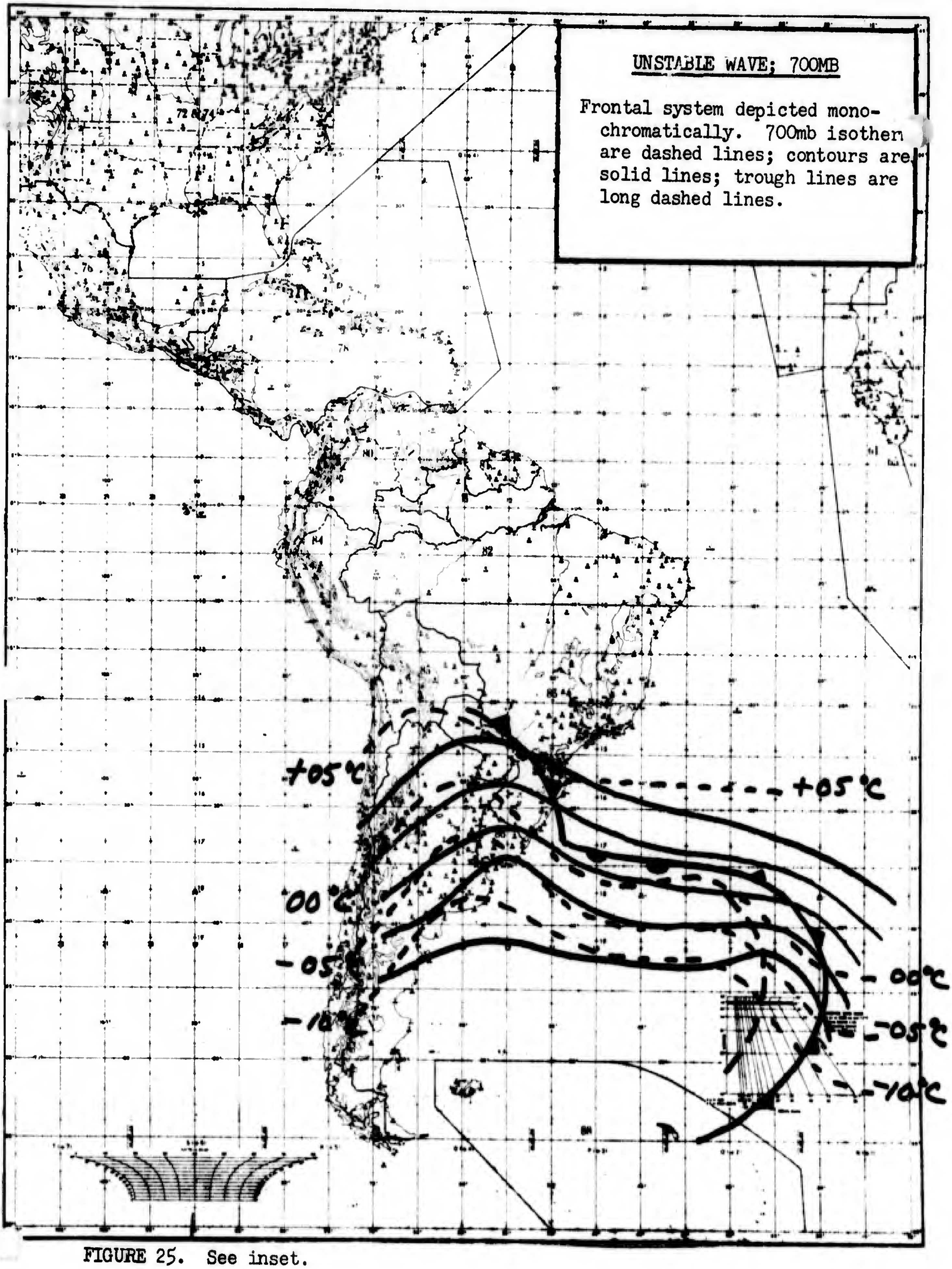
FIGURE 23. See inset.



POLAR-ARCTIC SURGE; 700mb

Frontal System depicted monochromatically. 700mb isotherms are dashed lines; contours are solid lines; trough lines are long dashed lines.

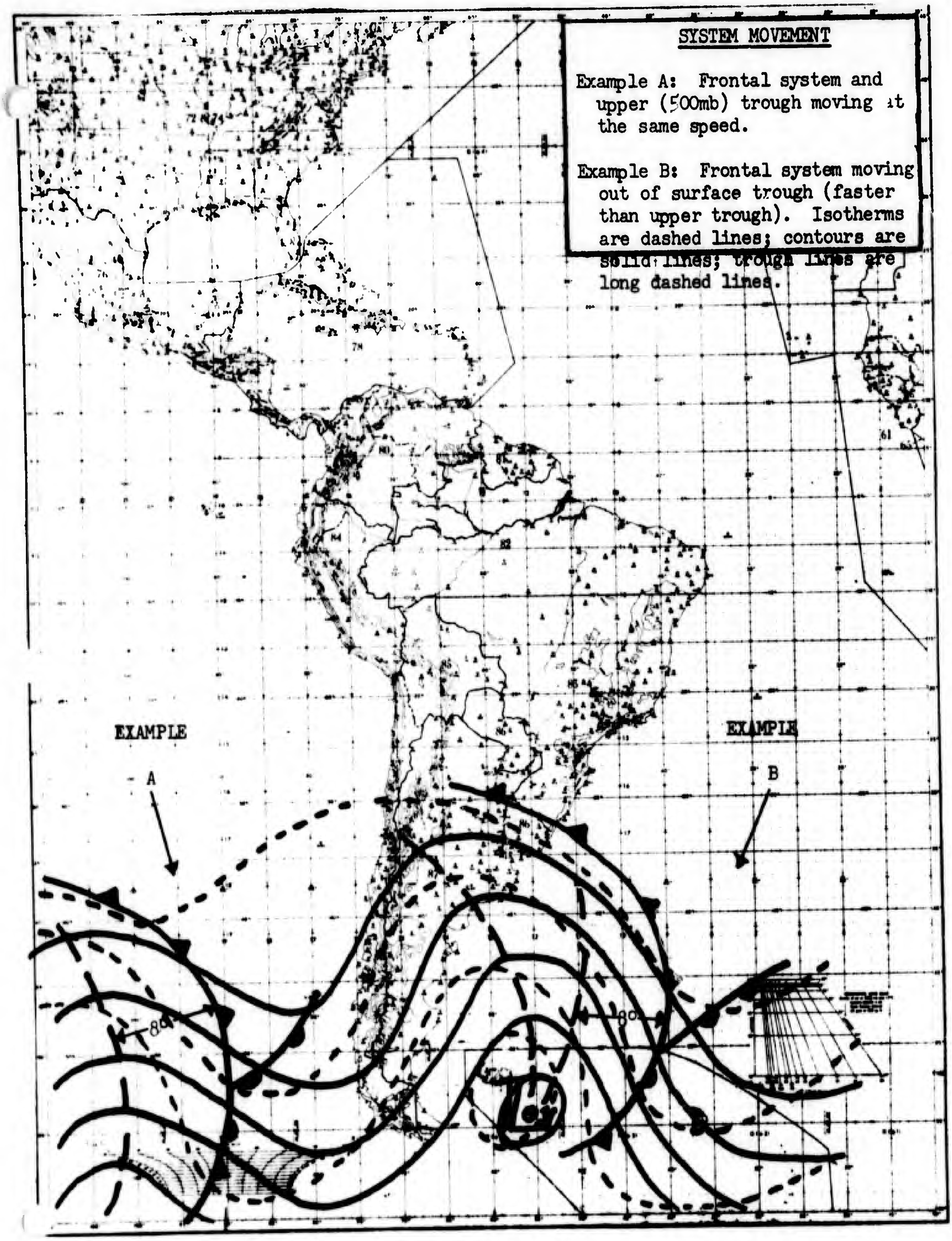
FIGURE 24. See inset.



UNSTABLE WAVE; 700MB

Frontal system depicted monochromatically. 700mb isotherm are dashed lines; contours are solid lines; trough lines are long dashed lines.

FIGURE 25. See inset.



SYSTEM MOVEMENT

Example A: Frontal system and upper (500mb) trough moving at the same speed.

Example B: Frontal system moving out of surface trough (faster than upper trough). Isotherms are dashed lines; contours are solid lines; trough lines are long dashed lines.

FIGURE 26. See inset.

3. Anticyclones and Ridges.

(A) Ridges of high pressure are sloped aloft toward warm temperatures. The usual pattern, when normal atmospheric conditions exist, is to position ridges two to four degrees (measured along a meridian) per analysis level (700, 500, 300, and 250mb) westward of the surface ridge. The ridges are spaced so that the 250mb ridge is just ahead of the surface front located westward of the surface ridge.

(B) Occasionally, a blocking anticyclone will form off the southwest coast of South America with the surface center located near 80°W and 40°S. The upper air flow associated with approaching fronts tends to become parallel to the front between 85°W and 100°W, effectively stalling this portion of the front. The blocking effect weakens poleward of 50°S allowing the poleward portion of the front to move south of the high. Eventually this portion of the front becomes stationary in an east-west configuration near 50°S. Upper air flow on the east side of the ridge allows arctic fronts to move equatorward to the position of the stationary front. East of the Andes this situation results in a single front separating tropic and arctic air masses. The upper air flow over this system has a relatively strong equatorward component causing the front east of the Andes to separate from the front west of the Andes, and move rapidly equatorward. The large thermal and moisture contrast across this front produces considerable cloudiness, precipitation, and conditions favorable for severe weather.

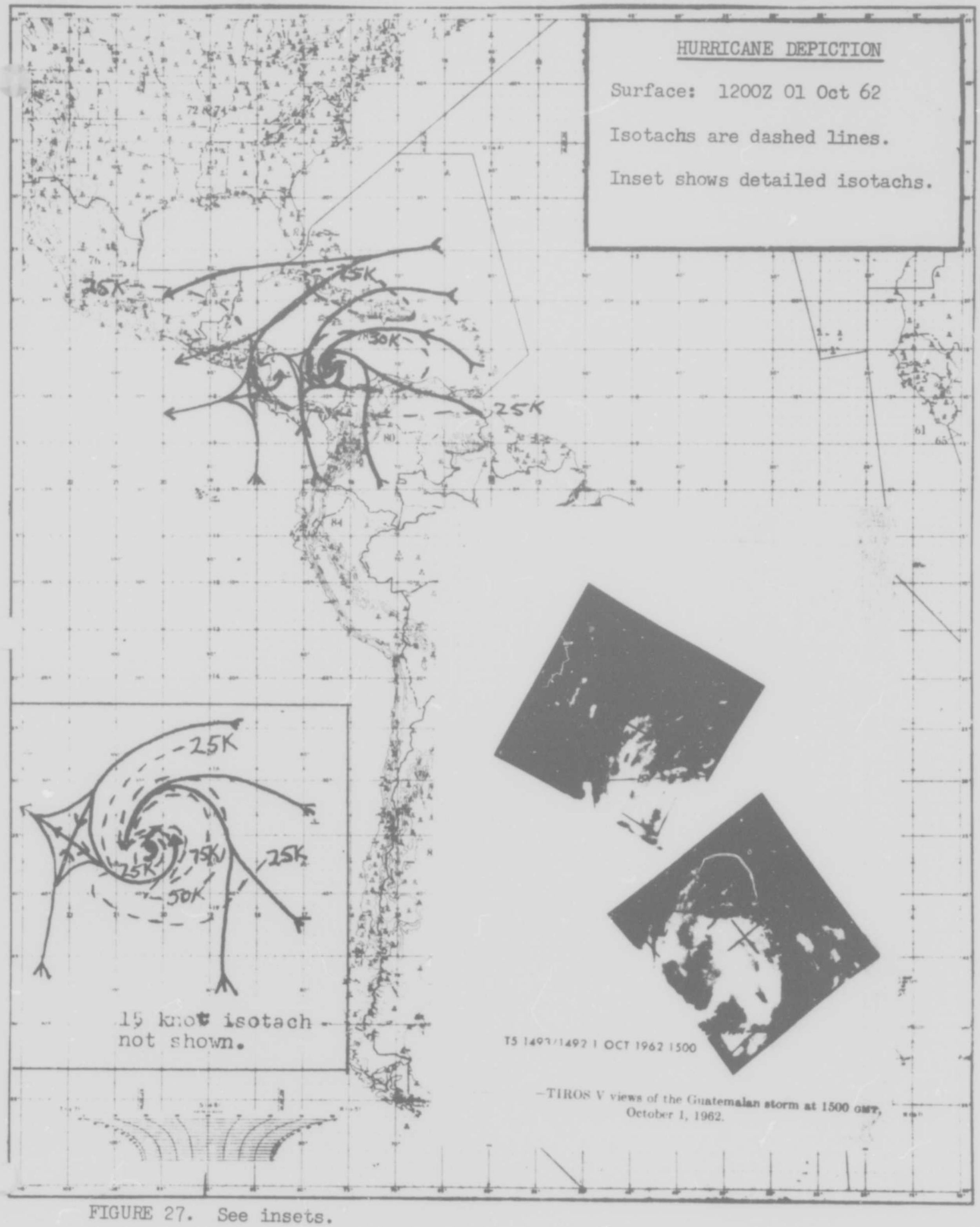
C. Tropical Analysis

1. The principle features analysed in the region from 30°N to 30°S latitude are the subtropical Highs, the intertropical convergence zone (ITCZ), and tropical cyclones.

(A) Subtropical Highs slope aloft toward warm air. In the Northern Hemisphere the subtropical Highs usually slope southwestward with height; in the Southern Hemisphere subtropical Highs usually slope northwestward with height. A good first estimate for positioning subtropical Highs aloft is to slope the High four degrees per analysis level (700, 500, and 300 mbs) equatorward and westward of the surface High. Anticyclonic centers at 250 mbs are not as common as at lower levels, however, when a center does exist it usually is several degrees equatorward of the 300mb position. Ridging usually occurs at the 250mb level in the area with warmest temperatures even though an anticyclonic center isn't analysed. Adjustments are made to the first estimate of anticyclone positions using conventional and satellite data.

(B) The intertropical convergence zone (ITCZ) is relatively easy to analyze using ESSA satellite mosaics or other satellite data. Active weather areas frequently are spaced 20 to 30° longitude apart along equatorial regions from Africa to Central America. Occasionally, the entire ITCZ is active; rarely is it completely inactive. The position of the ITCZ averages near 0° latitude during the Southern Hemisphere summer and approximately 15°N latitude during the Northern Hemisphere summer. The position of the ITCZ tends to be displaced as much as 5 degrees northward over the western half of the North Atlantic Ocean compared to its position over the eastern half of the North Atlantic during the Northern Hemisphere summer. The climatological position of the ITCZ as shown by Figures 15 and 16 no longer appears valid, especially over South America.

(C) Tropical cyclones are analysed and forecast using information provided by the Weather Bureau's Miami Tropical Analysis Center, as a guide for the Caribbean area. Satellite data and aircraft reports aid analysis of tropical cyclones in other tropical areas. Figure 27 shows an example of a surface analysis of a hurricane (a tropical storm analysis would be similar). Figures 28, 29, and 30 show the 700, 500, and 200mb streamline analysis for the same hurricane. Note that the level of nondivergence in a tropical storm or hurricane is above 500 mbs. The change to divergent flow aloft generally occurs between 400 and 250 mbs, depending on the intensity of the storm or hurricane.



HURRICANE DEPICTION

Surface: 1200Z 01 Oct 62

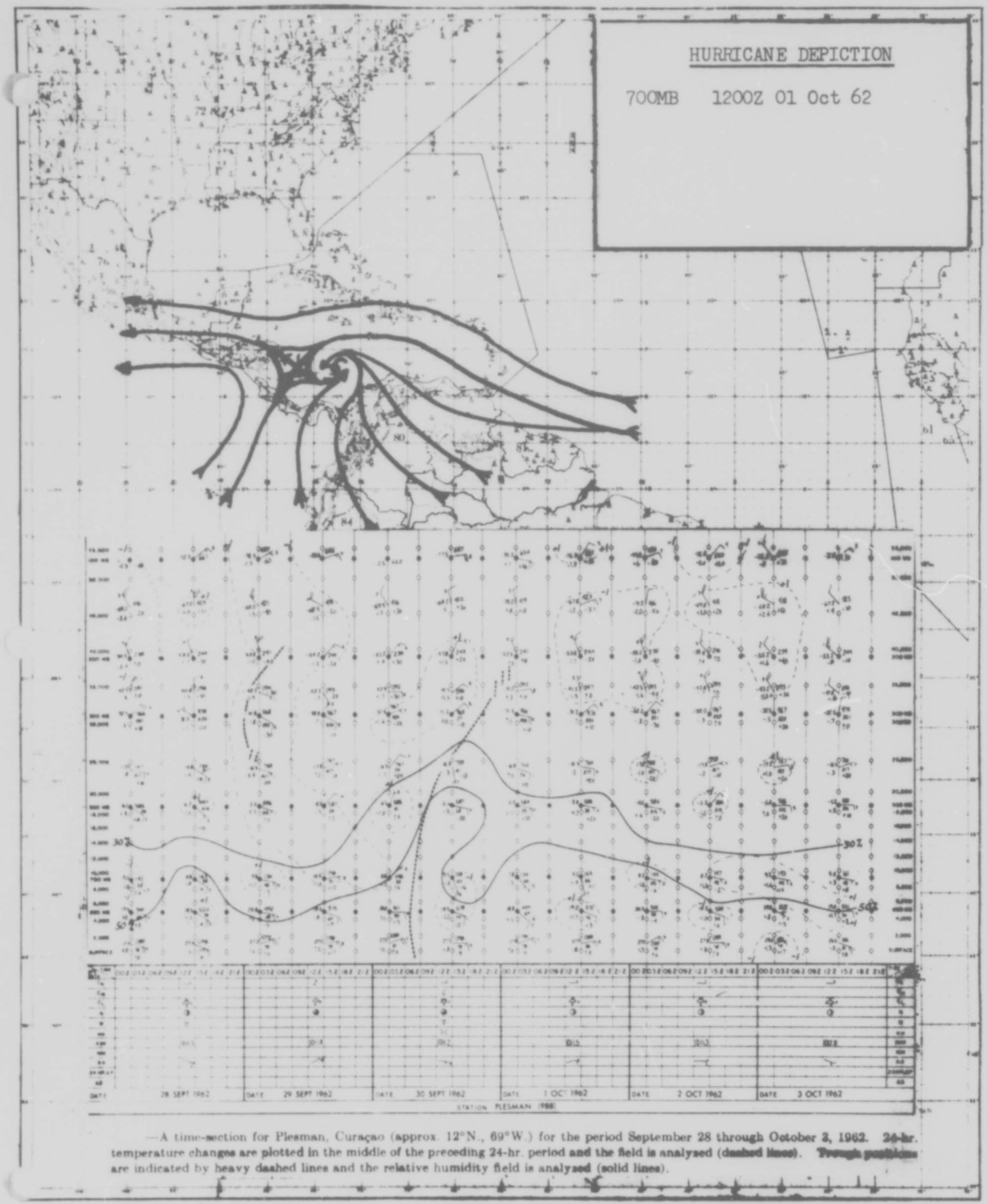
Isotachs are dashed lines.

Inset shows detailed isotachs.

15 knot isotach not shown.

—TIROS V views of the Guatemalan storm at 1500 GMT, October 1, 1962.

FIGURE 27. See insets.



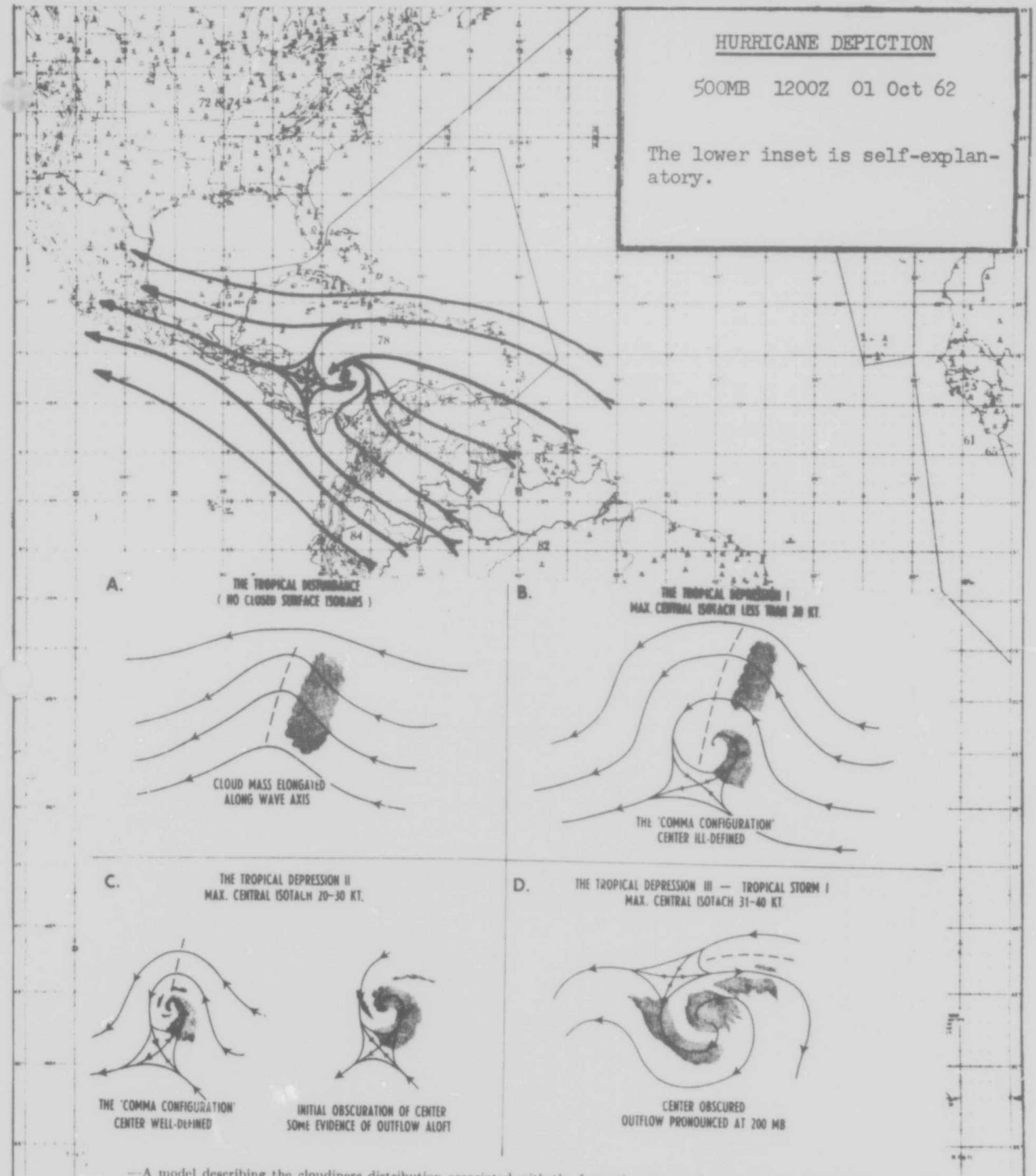
—A time-section for Plesman, Curaçao (approx. 12°N., 69°W.) for the period September 28 through October 3, 1962. 24-hr. temperature changes are plotted in the middle of the preceding 24-hr. period and the field is analysed (dashed lines). Trough positions are indicated by heavy dashed lines and the relative humidity field is analysed (solid lines).

FIGURE 28. See insets.

HURRICANE DEPICTION

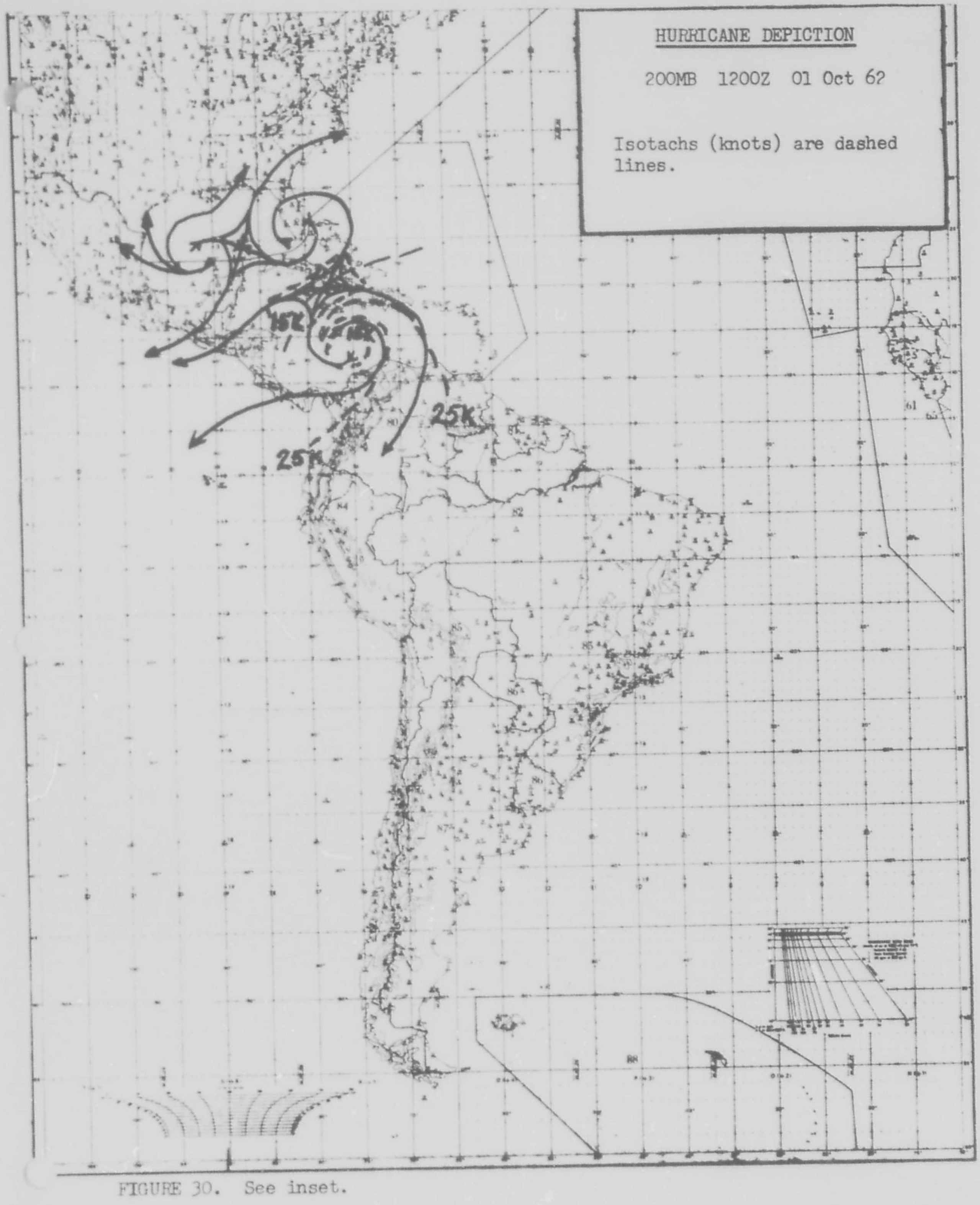
500MB 1200Z 01 Oct 62

The lower inset is self-explanatory.



—A model describing the cloudiness distribution associated with the formative stages of tropical cyclone development. The model applies to formative tropical cyclones of the Northern Hemisphere embedded in easterly flow. In stages A, B, and C, the typical gradient wind streamline pattern is superimposed over the shaded TIROS-observed cloudy areas. In stage D, the typical 200-mb. streamline pattern is shown

FIGURE 29. See insets.



HURRICANE DEPICTION

200MB 1200Z 01 Oct 62

Isotachs (knots) are dashed lines.

FIGURE 30. See inset.

D. Jet Stream Analysis

1. The jet stream results from an established unstable condition aloft which stabilizes itself in the high speeds of the jet stream.

2. The tropospheric temperature gradient must have a maximum at the jet axis. The lateral packing of isotherms is greatest under the jet axis; the isotherm concentration lessens outward from the axis both poleward and equatorward. A subtropical jet stream can be maintained by a weaker temperature field than that required in middle and high lattitudes, because of the decreasing coriolis force toward the equator.

3. Mid-latitude winds increase with height in the lower troposphere and reach a definite maximum near the tropopause. Above the tropopause wind velocities decrease with increasing height because of the reversal of horizontal temperature gradient (cold over the equator, warm over the poles).

4. The position of the polar jet is closely related to the position of the polar front. The proximity of the polar front to the jet stream is easily verified by inspection of a 500mb chart. The polar front usually intersects the 500mb surface along the M26°C isotherm. On the warm side of this isotherm a well defined maximum wind band generally coincides with the M18°C isotherm. The jet stream usually is positioned near the 5580 meter contour of the 500mb analysis.

5. During the Southern Hemisphere summer, the mid-latitude jet core occurs at approximately 11,600 meters, and in winter near the 250mb height (10,363 meters). Over deep, cold lows the jet often dips 1,000 to 1,500 meters below its normal altitude. The jet stream is not a smooth current of air; it follows the convolutions of the height contours on constant pressure surfaces and varies in height similar to tropopause leaves. The distance between two successive jet waves varies from 50 to 120 degrees of longitude. These long waves gird the hemisphere in phase with the contours of the closest constant pressure surface. When the amplitude of the contours increases beyond a critical limit, the jet disintegrates, cold air moves in a circular path, and closed cold lows form in the equatorward portions of the troughs. Zonal circulation is reestablished poleward of the low and a new jet stream forms.

6. Successive unstable long waves in the jet stream are dynamically related to one another; intensification of one wave influences the next wave downstream. In other words, the deepening of a specific upper air trough leads to the deepening of the next trough downstream.

7. Jet streams, particularly in wind maxima regions, do not cross contours at large angles. Diverging contours downstream cause jet

deflection toward greater heights; converging contours downstream tend to turn a jet toward lower heights.

8. Isotach maxima and minima that alternate along the axis of the jet stream are related to short waves in the westerlies and their associated surface systems. Isotach maxima move downstream with about the same velocity as short waves, with the distance between maxima varying from 10 to 25 degrees longitude. The maxima tend to be enclosed, symmetrical, lenticular-shaped isotachs which retain their shape over short periods of time. These maxima undergo definite life cycles with periods of formation and decay which often may be followed from one analysis chart to the next.

9. Beginning with a balanced symmetrical arrangement of isotachs along the jet stream axis, isotachs downstream from the maximum center are displaced downstream faster than those to the rear of the center. Isotachs of high velocity winds are displaced downstream faster than slow ones, resulting in an increased area enclosed by the highest valued isotach, and packing of the isotachs downstream from the maximum center. A rapid rearrangement then takes place with the maximum merging with the minimum velocity area downstream; the minimum velocity area disappears. The resulting pattern evolves to the beginning stage and the cycle is repeated.

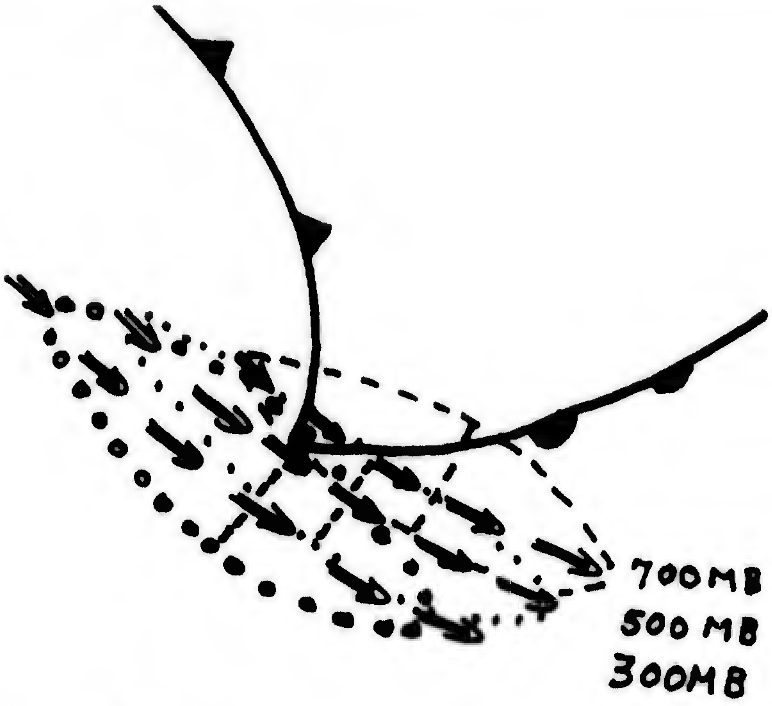
10. Isotach maxima along the jet axis play an important role during formation of unstable waves which eventually occlude. Vorticity also plays an important role in occluding systems. These roles are discussed using Figure 31 as an illustration.

(A) At 700 mbs the axis of the wind maximum is equatorward of the surface position of an unstable open wave, with the center of the isotach maximum downstream from the wave. The quadrant of the isotach maximum over the wave at this level possesses positive vorticity advection by virtue of cyclonic shear increasing downstream. The curvature term is negligible.

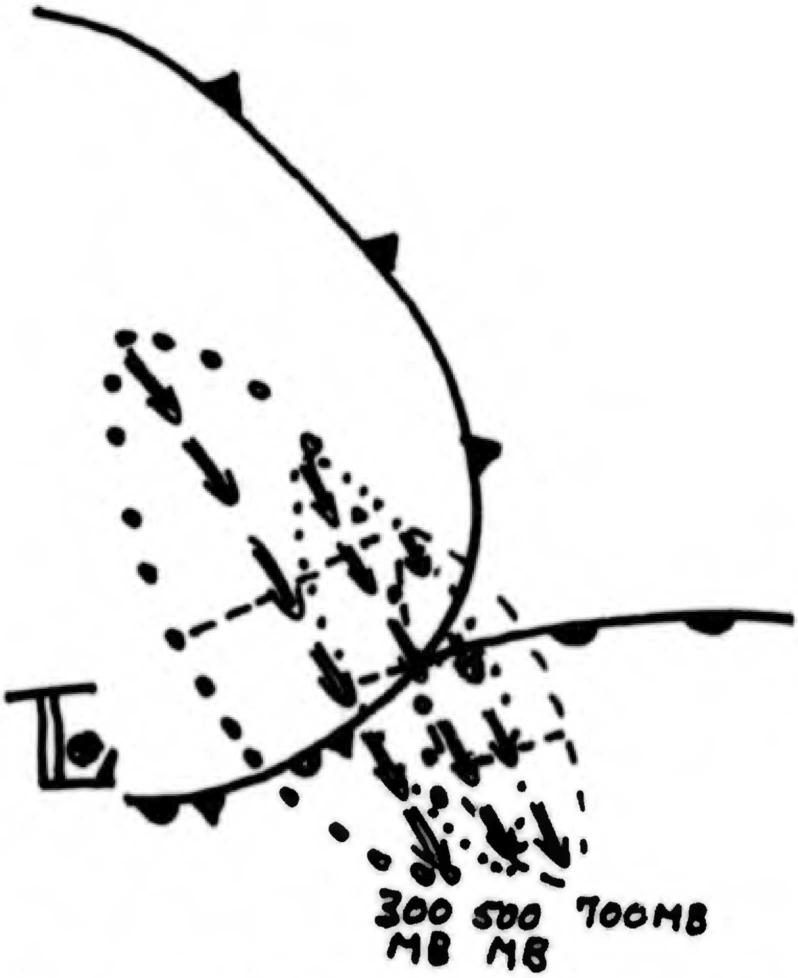
(B) Assuming the level of non-divergence to be near the 500mb level, the axis of the maximum wind will be directly over the surface wave leading to neutral vorticity advection (which is the case at the level of non-divergence).

(C) At the 300mb level, the axis of the maximum wind is poleward of the surface wave with the center of the isotach maximum upstream from the wave. The quadrant of the isotach maximum over the wave at 300 mbs has negative vorticity advection by virtue of anticyclonic shear (the curvature term again being negligible) increasing downstream.

(D) The net result is increased upward vertical motion over the wave which causes lower pressure (deepening). Since the wave is upstream from the center of the low level isotach maximum, it



A. Developing Wave.



B. Occlusion.

FIGURE 31. Positions of maximum wind axes and isotach patterns at 700, 500, and 300 mbs for (A) a developing wave, and (B) an occlusion.

tends to move faster than the maximum, and as the upper trough develops, the upper wind maximum increasingly trails the lower maximum.

(E) As the occlusion process begins, the situation at 700 and 500 mbs is essentially unchanged with respect to vorticity advection. The 700mb wind maximum axis is equatorward of the occluded point on the front, with the center of the wind maximum downstream. The 500mb jet axis continues to be over the triple point on the front. The surface position of the triple point on the occluded front and the occluded portion of the front will have moved downstream so that the low center associated with the occlusion will be poleward of the 300mb jet axis and ahead of the associated isotach maximum. The developing low moved from under the left rear quadrant to the right forward quadrant of the upper level isotach maximum. This quadrant of the isotach maximum has negative vorticity advection because of cyclonic shear decreasing downstream.

(F) As long as the surface low is influenced by divergence in the upper levels, the deepening process continues. The low eventually comes under the influence of the right rear (facing downstream) quadrant of the jet maximum. This quadrant has positive vorticity advection and the low will begin to fill. The occluded low will be nearly vertical with the upper low, and a new low usually forms at the triple point and breaks away from the old occlusion which continues to degenerate.

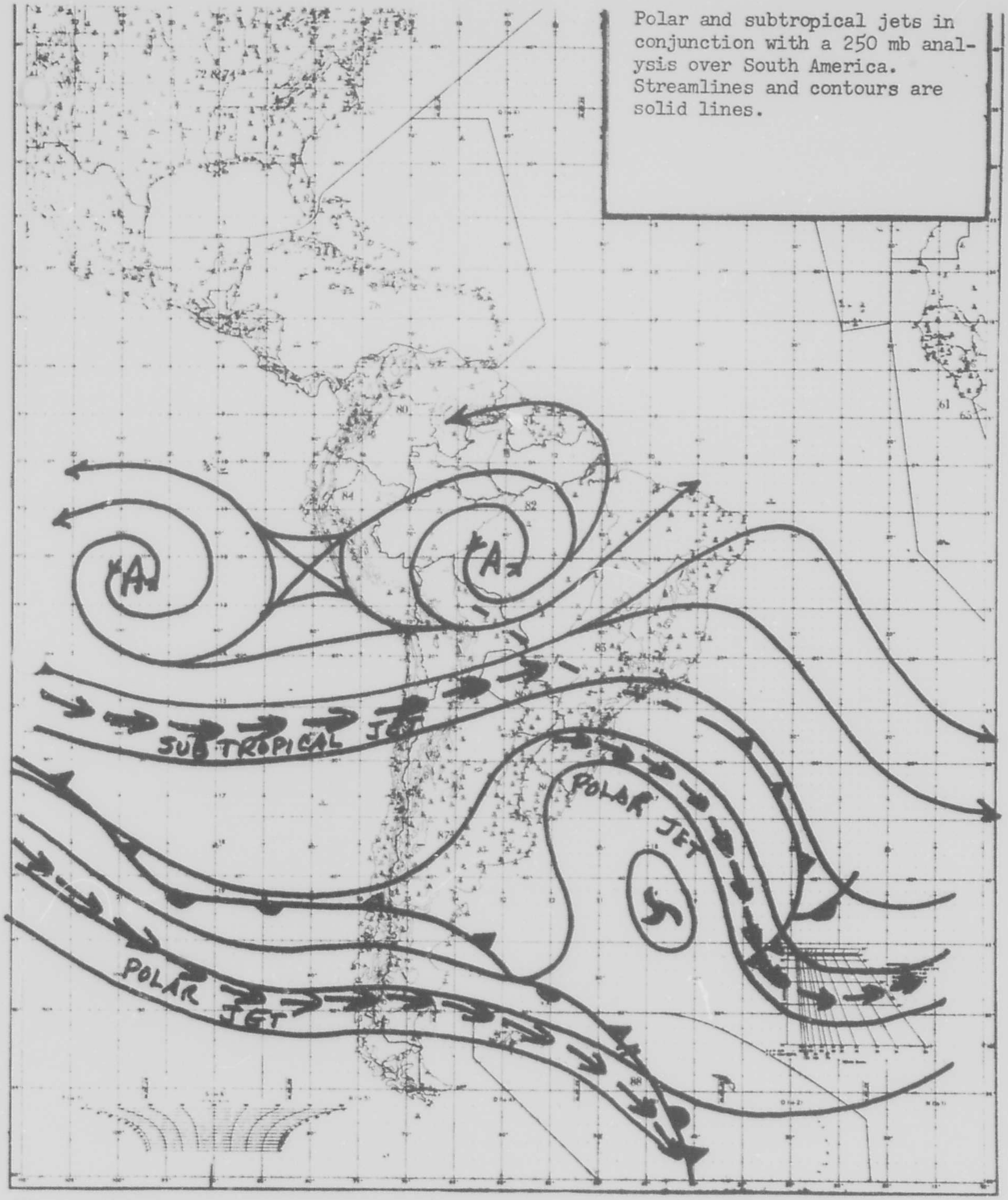
11. Summary of jet stream characteristics:

(A) The maximum wind band associated with the polar front should be oriented parallel to the isotherms.

(B) Jet streams crossing height contours should cross to greater heights in the rear of a trough and toward lower heights ahead of a trough.

(C) Polar jets should not cross cold fronts. As a surface wave goes under a jet and moves toward colder air, it will deepen and occlude. The jet then crosses occluded fronts poleward of the triple point (above 500 mbs). Whenever possible, unstable waves should be positioned equatorward of the jet stream, unless they are beginning the occluding process.

(D) When the jet core or tropopause is below the level being analysed, the jet should be positioned in the center of the cold air; reversed thermal winds will cause wind speeds to decrease more rapidly poleward of the jet.



Polar and subtropical jets in conjunction with a 250 mb analysis over South America. Streamlines and contours are solid lines.

FIGURE 32. See inset.

(E) Figure 32 shows a jet analysis for 250 mbs. This example shows polar jets associated with separate polar systems, and a subtropical jet equatorward of both polar trains.

E. Analysis Guides

1. Surface Analysis:

(A) Finalize the surface analysis after the preliminary upper air analyses indicate that all surface systems and fronts have the proper vertical support, circulation, and advection patterns.

(B) Occluded fronts should be drawn to reflect the surface weather pattern. The occluded front crosses isobars into the low and should not extend equatorward past the center of the low. When occlusions reach the mature stage, the low becomes nearly vertical with height. Following maturity the occluded front begins to wash out, usually in conjunction with a new low forming on the triple point of the front.

(C) Suspect wave formation in frontal zones where there is a broadening or poleward bulge in the cloud pattern. Jet stream cirrus located poleward of the suspect area further supports wave development. If a suspect area meets the above criteria and, in addition, a high pressure cell appears to be moving off the east coast of South America (poleward of the front), wave formation and development is almost certain.

(D) Carefully analyze satellite data and conventional data to determine whether a frontal system is occluded, and, if occluded, the same data should aid locating the warm front and occlusion point (triple point) on the front. Jet stream cirrus helps identify the point of occlusion on a front. When a wave has moved poleward of the 500mb jet stream, the frontal system should be analysed as an occlusion.

(E) Arctic fronts rarely surge north of 45°S latitude (the southern boundary of our area of forecast responsibility); however, a routine, thorough analysis of weather systems south of 45°S is necessary so that arctic surges north of 45°S can be accurately identified and forecast. Downslope warming east of the Andes often masks the effects of an arctic front in southern South America. Dewpoint temperature discontinuity becomes the only significant feature that can be used to locate the arctic front until downslope warming discontinues and temperatures again reflect arctic characteristics.

(F) Insure that the previous analyses were definitely in error before making large changes in system location. If HWD forecasts frequently break continuity, using agencies soon lose faith in the product. Whenever possible, gradual changes should be used to update the HWD forecast.

2. Upper Air Analysis:

(A) Ridges should be analysed ahead of fronts. Fronts are maintained by temperature differences in air masses. Warm air is fed into a system ahead of a front, correspondingly, upper air ridges (up to the tropopause) must be ahead of fronts. If data indicates that a ridge is behind the front, frontolysis is occurring and the front should be washed out or regressed to a position that is supported by the proper upper air thermal patterns.

(B) Thermal advection patterns should support frontal characteristics. When neutral advection is analysed through an upper air trough, the surface analysis should indicate either an induced pressure trough or a cold trough. Cold air advection should always be indicated behind surface cold fronts or occluded fronts up to and often into the upper air trough.

(C) Surface pressure troughs usually lag far behind the surface front in an old occlusion. Upper air troughs tend to stack up on the surface pressure trough in old occluded systems.

(D) Southern Hemisphere mid-latitude troughs and ridges usually end between 40° and 50°S depending on season. Ridges often occur poleward of mid-latitude troughs. Arctic troughs seldom are in phase with mid-latitude troughs and when they are in phase it is for brief periods of time.

(E) Convergent and divergent asymptotes should support nephanalyses. Wind flow is one of the few features that can be analysed in the tropics. Convergent asymptotes (up to 500 mbs) should be positioned over weather areas and divergent asymptotes (up to 500 mbs) should be positioned over relatively clear areas.

(F) Sharp troughs seldom occur at 300 mbs and higher. In most cases, troughs can be smoothed and still fit data.

(G) The 500mb jet stream should be positioned immediately over or just poleward of a developing surface wave. As the low develops and occludes, it moves poleward of the 500mb jet and the jet is then located over the occluded point on the front.

IV. APPLICATION OF DIVERGENCE AND VORTICITY PRINCIPLES IN ANALYSIS AND FORECASTING (5).

A. The proper vorticity changes and the inferred divergence/convergence patterns should be indicated in wind analysis to explain observed or forecast weather conditions.

B. The basic principle is that low level convergence should be topped by upper divergence to provide the necessary vertical motions for clouds, rain, and cyclonic system development.

1. Air parcels that move through a wind maximum pattern and show a loss of absolute vorticity must diverge.

2. Air parcels that move through a wind maximum pattern and gain vorticity must converge.

C. Low level wind patterns should indicate an increase of absolute vorticity and convergence in bad weather areas.

1. Streamline and isotach patterns should reflect increasing absolute vorticity into areas of bad weather. Increasing cyclonic shear and or curvature will usually show this.

2. Streamlines should remain straight or curve cyclonically in poleward moving currents (with small shear) to indicate convergence.

3. Equatorward moving flow with little shear should show increasing cyclonic curvature (convergence) in areas of bad weather, anticyclonic curvature (divergence) in areas of good weather.

D. Wind patterns in upper levels (500mb and above) should show a loss of vorticity and divergence over regions of bad weather.

1. Flow (without shear) moving equatorward should be straight or anticyclonically curved over bad weather areas.

2. Air moving poleward with little shear at upper levels should show either a marked increase in anticyclonic or a marked decrease in cyclonic curvature over bad weather areas.

V. SATELLITE MOSAIC INTERPRETATION

A. An example of system analysis using satellite mosaics is shown in Figure 33. Verification data from the NMC surface chart and 500mb chart for approximately corresponding times are shown in Figures 34 and 35, respectively. Table 1 contains a list of observations corresponding to the circled letters in Figure 33. Using Figures 33, 34, and 35, note the following features:

1. The 500mb low slopes to the WNW of the surface low; however, a pocket of cold air (M20°C) exists to the SW of the surface low.

2. The 500mb maximum wind band corresponds to the relatively cloudfree area SE of the 500mb trough position. Considerable streaking of clouds is apparent just NW of this area.

3. A weak secondary 500mb trough exists in the southern Appalachians and may contribute to the formation of clouds shown in that area.

B. Figure 36 shows an example of ITCZ cloudiness between 5°N and 10°N latitude along northern South America and adjacent waters. Convective clouds are observed over parts of northern Brazil. Layered and convective clouds produced by an old frontal system are observed from the Andes near 10°S, extending southeastward toward the east coast of Brazil.

C. Figure 37 shows the typical stratus pattern observed along and west of the Peru and Chile coasts between 15°S and 27°S latitude. Convective clouds are observed along and east of the Andes north of 20°S latitude.

D. Figures 38 and 39 show a frontal system as it moves across the Andes. Note that there is a relative minimum of cloudiness in the lee of the Andes in both figures. The frontal cloudiness increases as it moves off the east coast of Argentina, over water.

E. Figure 40 shows an example of a mature cyclone and associated frontal system off the east coast of Brazil and Argentina.

F. AWS Technical Report #212 (2) is an excellent guide for satellite photograph/mosaic interpretation.

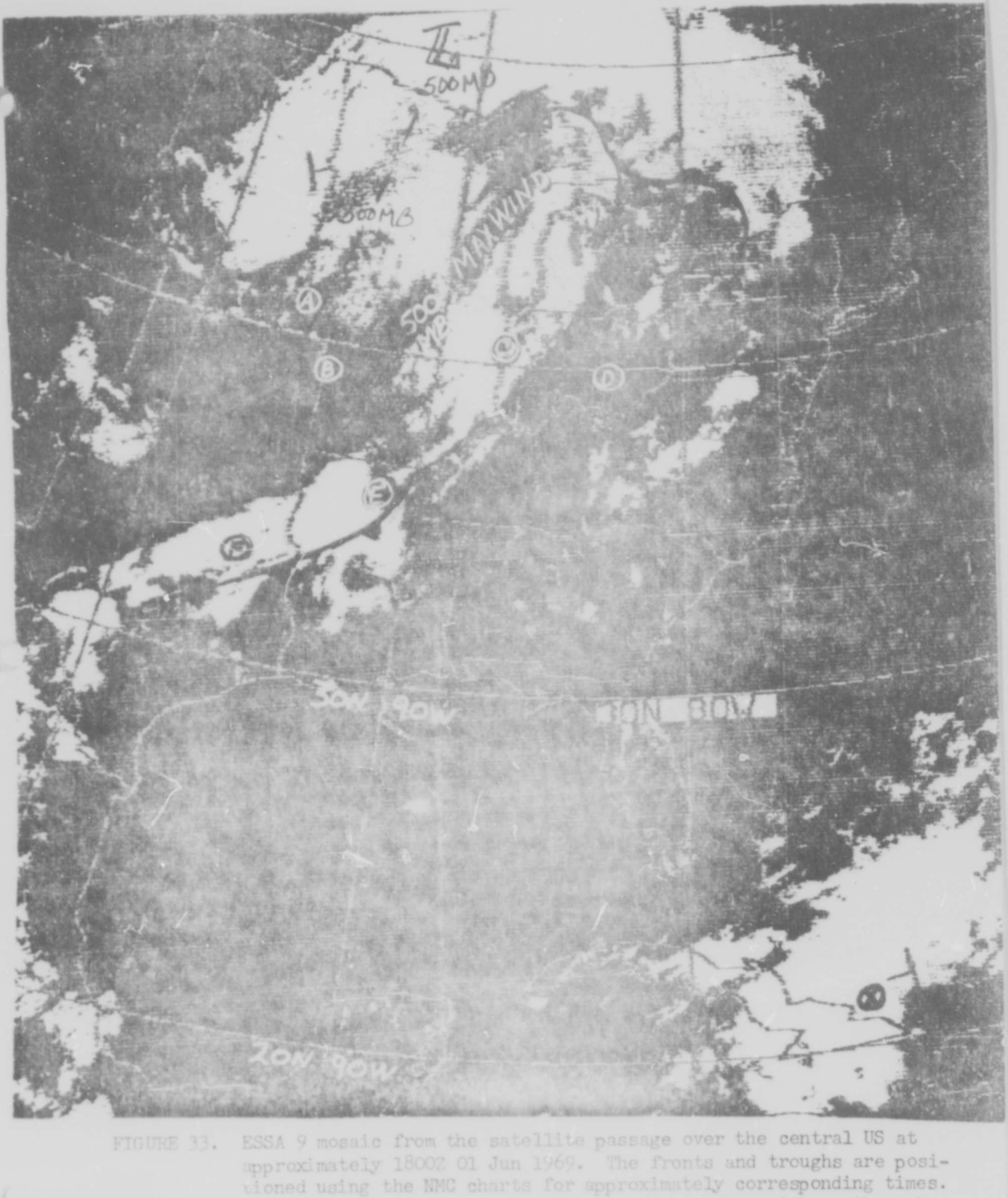


FIGURE 33. ESSA 9 mosaic from the satellite passage over the central US at approximately 1800Z 01 Jun 1969. The fronts and troughs are positioned using the NMC charts for approximately corresponding times. The circled letters are the location of stations with weather observations (see Table 1) at the time of the satellite passage.

NOT REPRODUCIBLE

FIGURE 34. SURFACE ANALYSIS 2100Z 01 Jun 1969

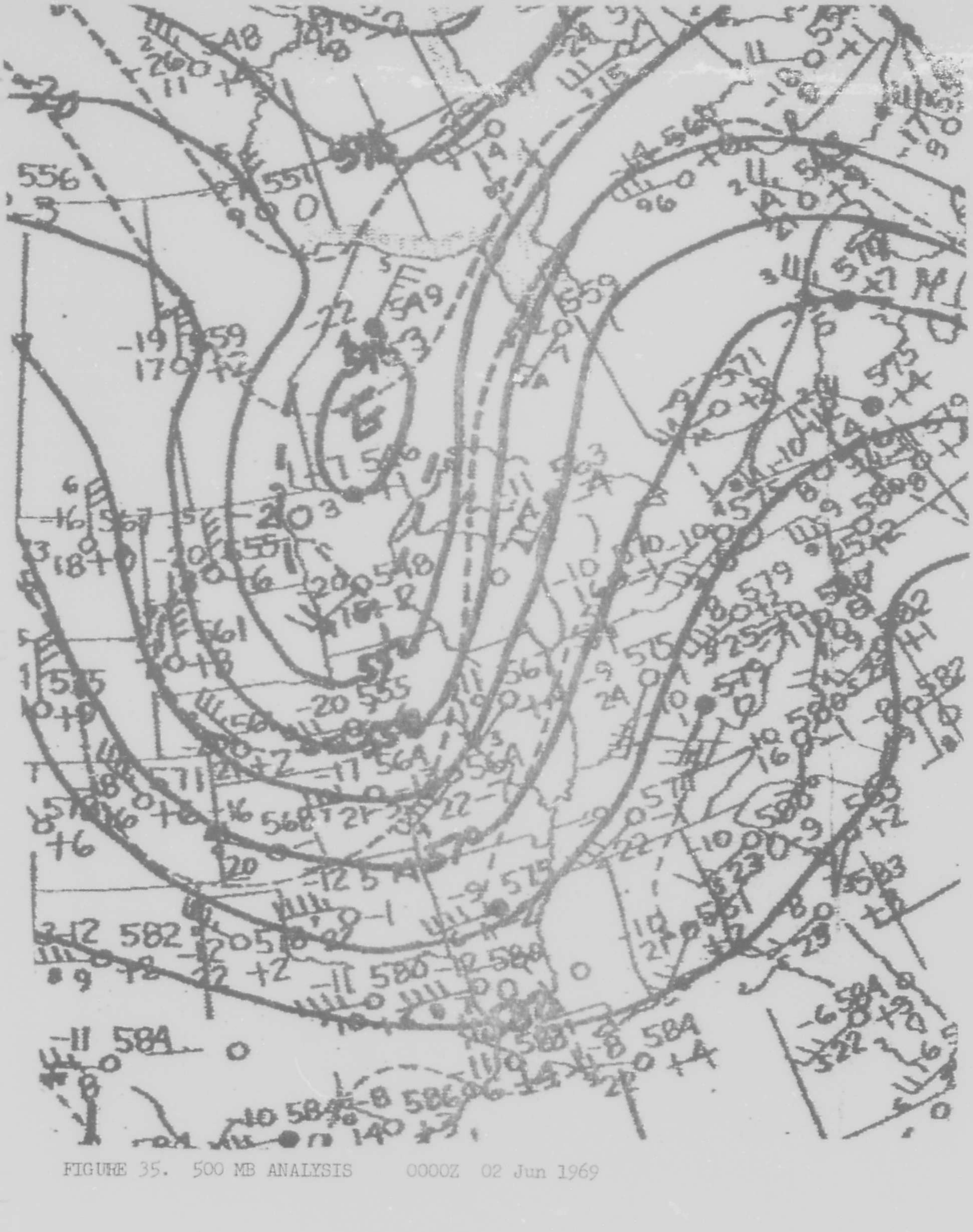


FIGURE 35. 500 MB ANALYSIS 0000Z 02 Jun 1969

TABLE 1. LIST OF SURFACE OBSERVATIONS FOR 1800Z 01 JUN 69

(Letters correspond to those indicated in Figure 33)

LETTER	STATION	CLOUDS	WIND
A	OFF	45 BRKN	3115G22
B	GVW	20 SCTD UNK BRKN	3109
C	RAN	8 SCTD 100 SCTD THIN CI OVC	3011
D	FFO	40 BRKN	2215G24
E	BYH	50 SCTD 80 SCTD 100 BRKN	2115
F	GSW	40 OVC	0216
X	78365	27 SCTD 33 OVC	CALM

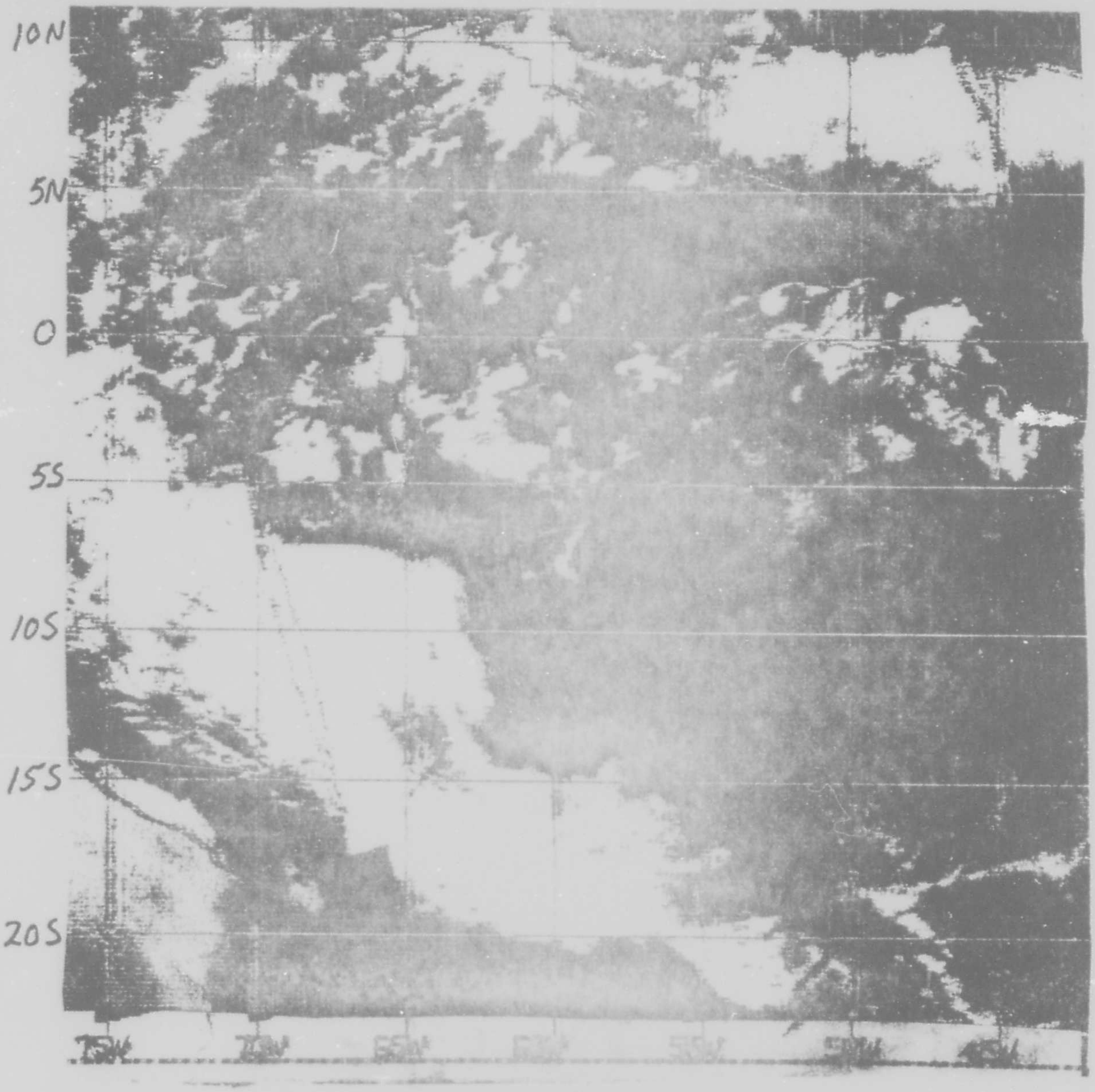


FIGURE 36. This example shows ITCZ cloudiness between 5°N and 10°N latitude, convective clouds over northern Brazil, and remnants of a frontal system and trough along the Andes near 10°S, extending southeastward toward the east coast of Brazil. ESSA 9, 8 Jul 70.

NOT REPRODUCIBLE

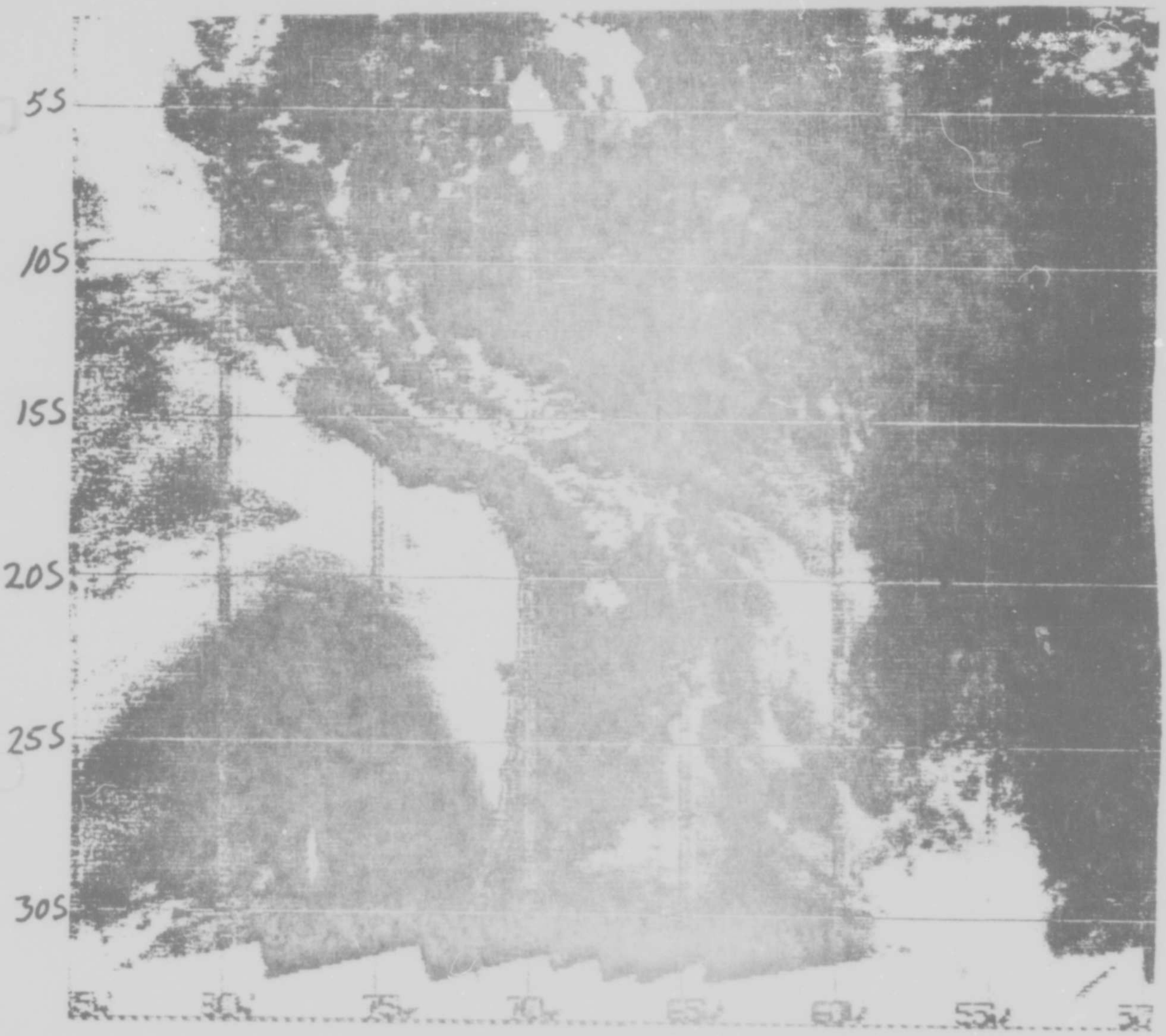


FIGURE 37. Example of the typical stratus coverage along and west of the Peru and Chile coastline. Convective clouds are observed along the eastern slope of the Andes north of 20°S latitude. ITOS, 20 Aug 70.

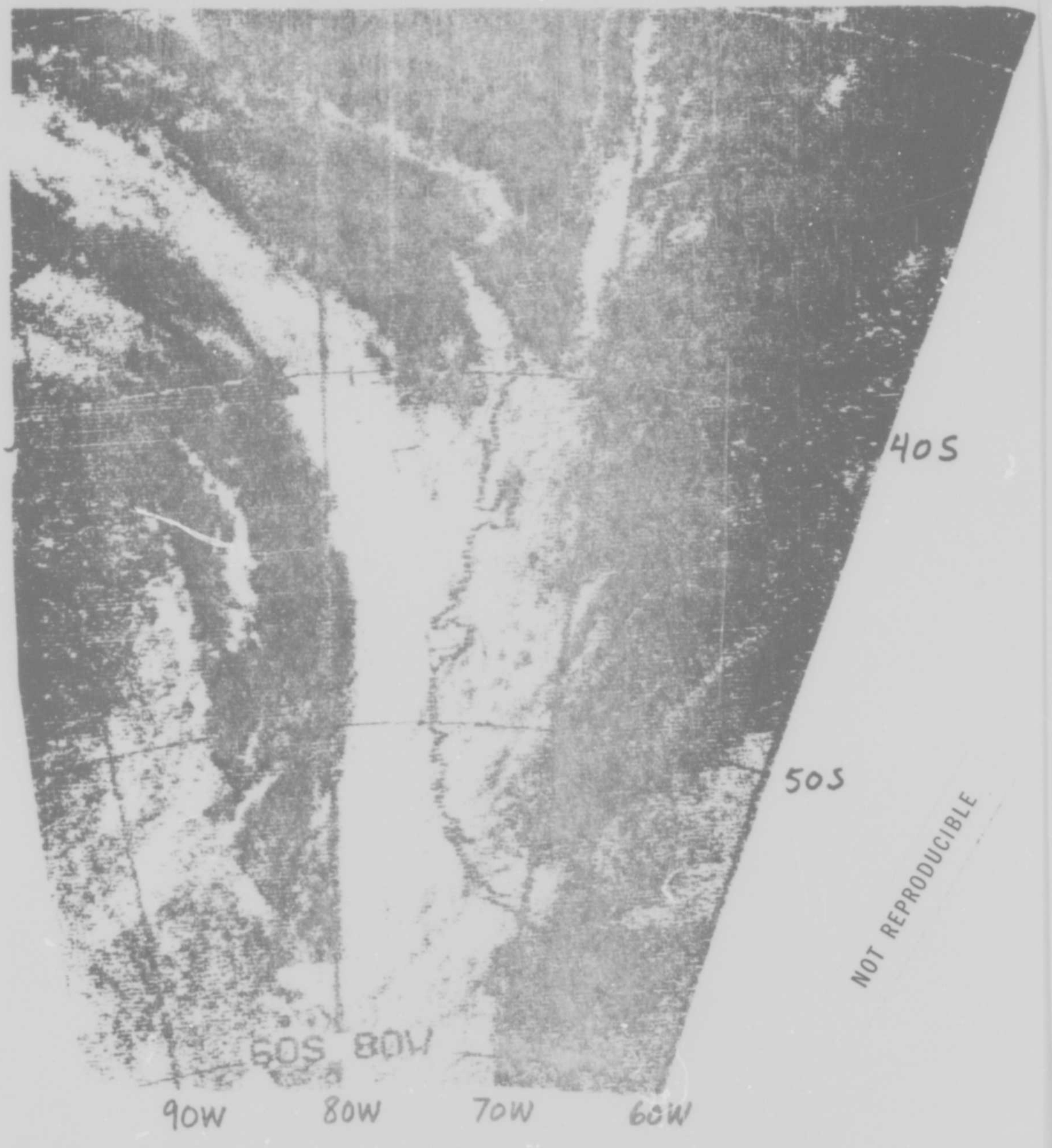


FIGURE 38. Example of a frontal system approaching the west coast of Chile. Note the decreased cloudiness east of the Andes. ESSA 9, pass 2378, 1813GMT, 4 Sep 69.

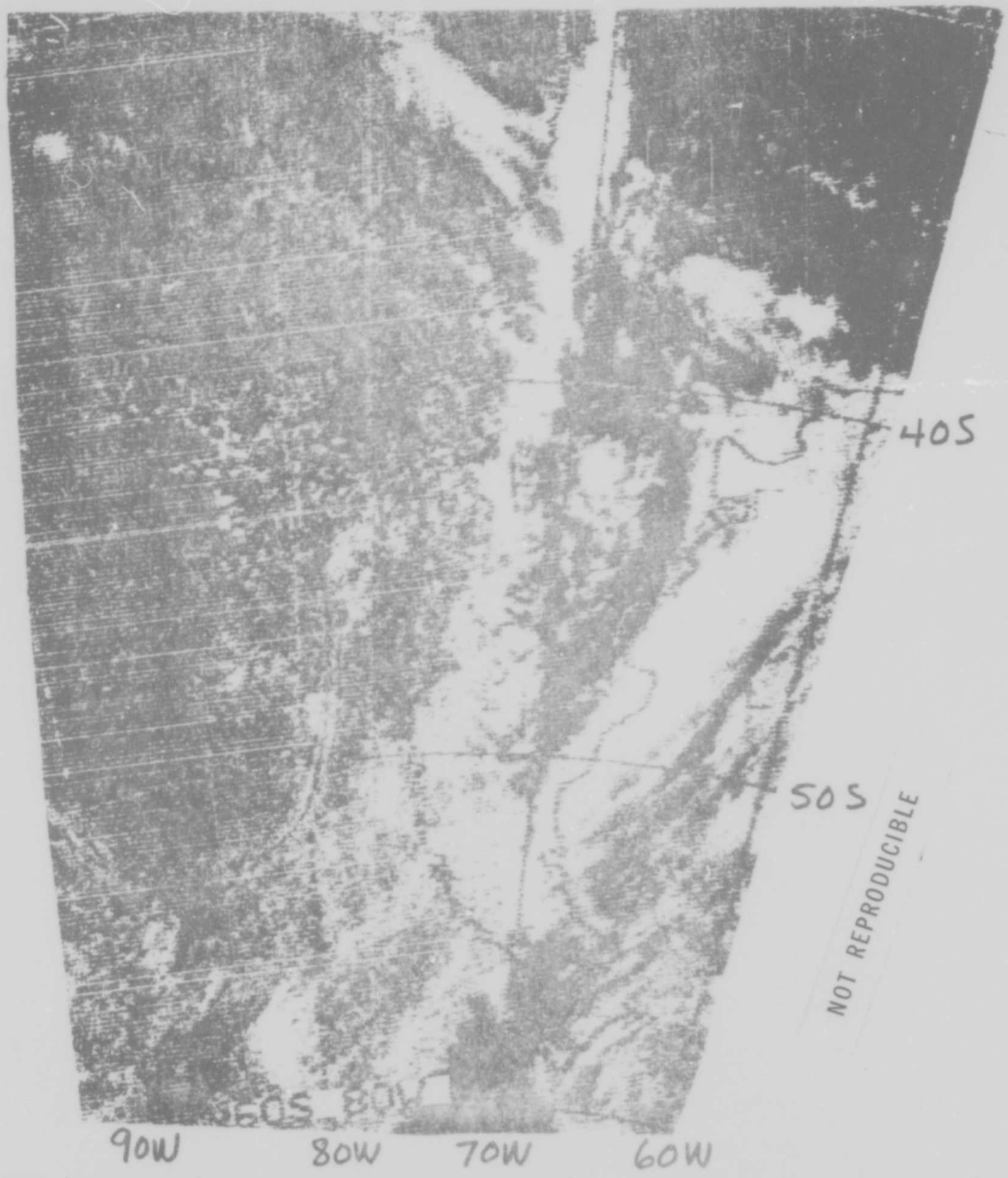


FIGURE 39. Same frontal system as in Figure 38 after passage across the Andes. Cloudiness increases as the front moves off-shore over water. Note the residual cloudiness over the western slopes of the Andes. ESSA 9, pass 2391, 1813GMT, 5 Sep 69.

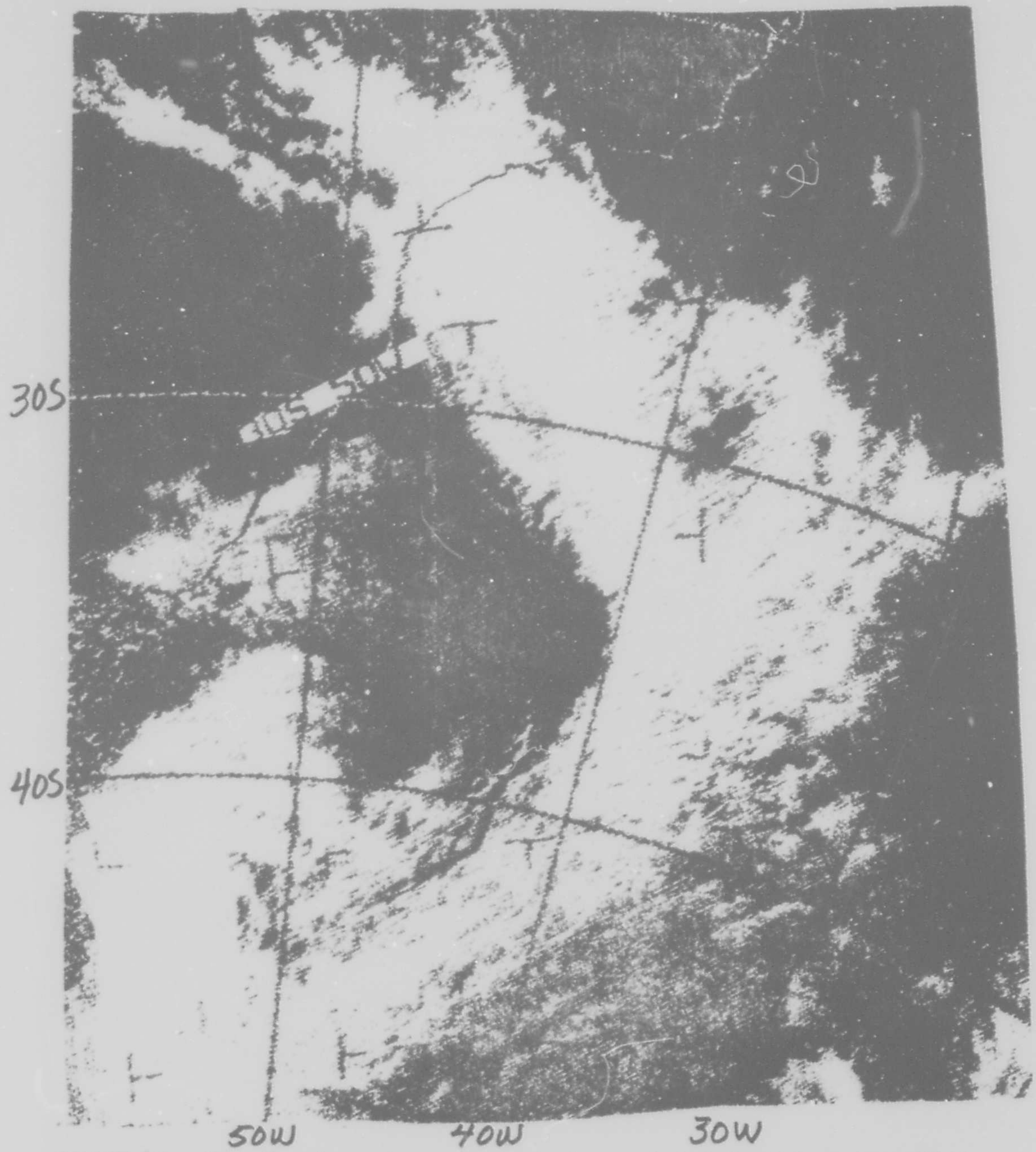


FIGURE 40. Example of a mature cyclone and associated frontal system off the East Coast of South America. ESSA 9, pass 2378, 1813GMT, 4 Sep 69.

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APPENDIX I

SUGGESTED PRESSURE CORRECTIONS FOR BRAZILIAN STATIONS

BRAZILIAN STATIONS-SUGGESTED PRESSURE CORRECTIONS (RIOWUPA)

JUNE 18, 1970

82024	-6.0	83096	-2.0	83768	-2.5
108	-3.5	156	+2.0	776	+2.5
191	+2.1	229	+0.5	780	-3.0
193	+1.4	236	-0.5	781	-1.0
243	-1.5	248	+0.5	782	+3.0
244	-1.8	319	-4.0	840	-3.0
280	+1.0	344	-2.0	842	-2.0
287	+2.0	348	-1.0	844	-1.5
288	+2.2	361	+2.0	864	+2.0
317	-2.0	362	+2.0	891	-1.0
331	-1.8	377	+2.0	895	-4.0
332	-1.8	378	-1.5	897	-1.5
336	-5.5	497	+2.0	899	-1.0
392	+1.0	525	+4.5	914	+2.0
397	+1.0	576	-1.5	924	+2.5
410	+2.0	577	-2.5	925	-1.5
418	-1.0	583	-2.0	928	-2.0
487	+2.5	589	-2.0	931	+1.5
578	+2.0	611	-2.5		
579	+2.5	612	-2.5		
583	+3.5	648	+1.8		
610	-1.8	649	-1.5		
678	-4.5	671	-1.5		
765	+2.0	679	+3.0		
768	-2.0	688	-2.0		
798	+1.0	689	-1.0		
825	-5.0	720	+1.5		
863	+3.5	721	+1.0		
915	-3.0	722	-1.0		
930	+3.0	726	+2.0		

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13. ABSTRACT

This handbook contains a summary of the geography and climatology of South America and adjacent oceans; analysis and forecasting procedures for extratropical; Southern Hemisphere, Systems, and tropical systems; jet stream analysis and its application to forecasting; application of divergence and vorticity principles in analysis and forecasting; and, satellite mosaic interpretation.

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Forecasting Principles						
Satellite Interpretation						