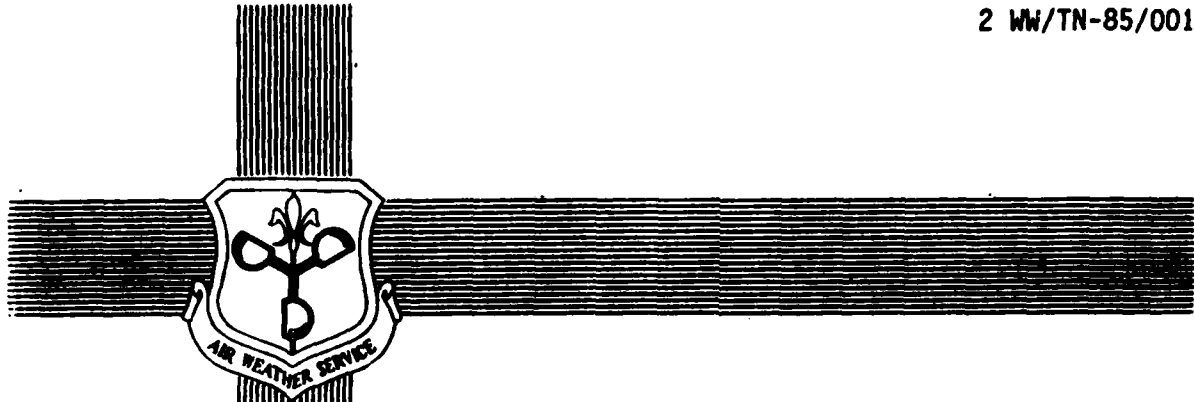


MICROCOPY RESOLUTION TEST CHART
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THE EUROPEAN
LFM-STYLE
FORECAST AIDS

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FOREWARD

Several people deserve our thanks for making this publication possible. First, in addition to being a major contributor to the text, Major Dan White, Det 15, 28 WS/CC, regenerated the idea of a 2 WW facsimile package and nursed it to fruition. Second, thanks to those, in addition to the principal authors, who donated their time and experience toward completing this project. And finally, to SSgt Danny Giles and Annette Rozinski for typing the manuscript.

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- V. 500MB HEIGHTS AND VORTICITY
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- VIII. SUMMARY

INTRODUCTION

**BY: Capt Francis G. Tower
Chief, Scientific Services Branch**

The purpose of this publication is to provide you, the forecaster, with guidance on how to use the 2nd Weather Wing's "LFM Style" facsimile products. The authors have gone an extra step to briefly review the basic meteorology, apply it to the models, and then provide guidelines. For this reason, this Technical Note (TN) has much wider application than just for the facsimile products. It touches on an aspect ~~we~~ forecasters are most likely to forget; fax charts are just tools, and as such are only as good as we make them.

As is true in most professions, ~~we~~ have come to rely heavily on computer products - almost to the point of blind acceptance. Yet, ~~our~~ attitude should be to consider computer-generated products as a friendly colleague who, although keenly analytical, is prone to making real blunders when presented with bad data. For this reason, the concepts of initialization and continuity are reviewed first.

The remaining sections cover how to use the specific fields on ~~our~~ "LFM" package in detail great enough to be used as a reference to charts in general. This TN can assist you in setting up your LAFP in that reasons for specific entries on your TAF Worksheet can be drawn from these charts.

We have already provided specific information on chart content, valid/receipt times, MANOP headings, etc. Since this TN deals with application of these products, you should file other pertinent information on chart content, etc., with this publication.

We hope that this TN proves to be useful to you. As always, we in the Aerospace Sciences Division solicit your constructive criticism.

THE CHARTS

1. The LFM style forecast aids are the FXEU series facsimile charts. These charts are derived from the AWSPE model and from the on-time (00Z/12Z) data bases. The characteristics and behavior of the AWSPE are:

- a. Characteristics (from AFGWCP 105-1, Vol I)
 - Models only the Northern Hemisphere octagon.
 - Uses seven levels from the surface to 50mb (the top level is semiactive).
 - Is a whole mesh grid spacing 381km or 200km at 60 DEG North.
 - Has no moisture variable.
 - Is initiated by HIRAS.
 - Uses smoothed topography.
- b. Behavior
 - Forecasts temperature, heights, horizontal winds, stream function, vertical velocity, and absolute vorticity.
 - Is better than SIXLVL in handling short-wave systems, minor impulses, and cutoff lows. However, it usually moves short-waves too slowly and is slow in moving cutoff lows to the northeast.
 - Forecasts jets broad and weakened. The position of the subtropical jet is poorly forecast and has a weak intensity. Wind forecasts near and above the tropopause are much better than SIXLVL.
 - Can under-forecast development due to lack of moisture.
 - Forecasts the 1000-500MB thickness (vertical depth) too deep over land and too shallow over water.
 - Over accentuates the vorticity pattern and, in zonal flow, moves it southeast too fast. Spurious activity centers develop at southern boundary.

2. Use these characteristics and behavior patterns to make these charts work better for you. Don't be put off by the list of things it can't do or doesn't do well. If we didn't mention them you would learn to use the charts and, if given time, find out most of them. We are giving you a headstart by asking you to use this information from the beginning.

3. The MANOP header for these charts breaks down as follows:

- a. FXEU + Nos 1,2,3, and 4 + Ltrs A,B,C, and D
- b. FXEU = basic header
- c. No 0 = analysis
No 1 = 12 hour prog
No 2 = 24 hour prog
No 3 = 36 hour prog
No 4 = 48 hour prog
- d. Ltr A = 500MB HGTS/VORTICITY
Ltr B = 850MB HGTS/1000-850MB THICKNESS
Ltr C = 700MB OMEGA/850-500MB THICKNESS
Ltr D = 700MB HGTS/700MB 2 DEG and 5 DEG T-TD SPREADS

e. For example: FXEU2B is the 850MB HGTS/1000-850MB thickness, 24 hour prog.

4. Briefly, here is the philosophy behind selecting these particular facsimile charts:

a. 500MB HGTS/VORTICITY. This is a standard and we feel all forecasters should use it. We have attempted to present vorticity and its uses in a simple, readable manner in Section V.

b. 850MB HGTS/1000-850MB THICKNESS. These fields can be used to define frontal boundaries and air masses in the lowest layer. In particular, finding arctic/polar air masses associated with the Greenland and Siberian highs.

c. 700MB OMEGA/850-500MB THICKNESS. Mid-tropospheric omega fields are very useful in determining relative changes in strength, determining character of precipitation, and evaluating convective potential. 850-500MB thickness provides a very conservative tool for tracking frontal systems. In areas of high terrain it is very successful in tracking fronts and in eliminating low-level contamination.

d. 750MB HGTS/700MB SPREADS. We originally asked for 1000MB DVALS/1000-850MB THERMAL ADVECTION. Thermal advection fields were not available to us so we opted for the best alternate that was offered. The chart is useful since it gives you a moisture representation in the 2 and 5 degree temp/dew point spreads. Adding the 700MB heights was complimentary to the 850MB and 500MB heights we have on the other charts. We may switch the omega with the 700MB heights to better utilize parameters we have on those two charts. Omega will compliment the moisture representation, while the 700 heights can be used to advect the 850-500MB thickness.

5. Now that you are familiar with the charts and why we selected them, let's move on to how to use them. We have organized this tech note as more of a tool to aid you in forecasting in general rather than specifically for these charts. For this reason we have included a review section, and a section on the jet stream, along with discussing omega, thickness, and 500MB heights/vorticity. We felt that it would be more useful to the forecaster if we didn't try to deal with each chart separately.

REVIEW

1. Initialization. When bad data is entered into the computer resulting in a bad analysis, we must be aware. More important, though, is our ability to recognize the bad analysis. When receiving any analysis, the forecasters first instinct should be to verify its accuracy. However, we often tend to ignore the analysis and go straight to the prognosis while not realizing that the prog was derived from a bad analysis. Assuring a good analysis should be the first thing you do and thus, always be an integral part of the forecast routine. A simple comparison of the upper air pattern with an IR satellite photograph taken near the time of the analysis is generally all that is needed.

Understanding the relationship between your analysis and the cloud signature on the satellite picture is a basic skill that all forecasters must learn. Most forecasters will find that their experience with satellite imagery has provided them with more expertise than they realize. The important thing to remember is to concentrate on associating cloud features with synoptic patterns (troughs, ridges, centers, PVA, etc) as opposed to cloudy areas versus cloud free areas. Bear in mind that the satellite imagery reflects all levels of the atmosphere and you should use an acetate overlay to analyze the specific level(s) you are interested in. For example: Where cirrus is present you might adjust the 300MB analysis; Mid level clouds, the 700/500MB levels; low clouds, surface/850MB analysis; comma cloud patterns to validate PVA or vorticity centers; (over Europe, abundant moisture often creates elongated cloud bands with wave shape formation, indicating maximum PVA, not in association with a front) and shadow lines or transverse banding to locate jet streams. This analysis of the satellite picture should not be time consuming - key on certain prominent features such as long/short wave troughs, well developed lows or well defined fronts.

Many units will not have satellite data for quite some time. Obviously you must find alternate methods of initializing your analysis. You can use your own local analysis, radar observations, upper air soundings, or ask a nearby station that has satellite data to discuss the analysis with you after they have initialized it. Once you have initialized your analysis you can use it with confidence. At the same time you have gained a feel for the dynamics affecting the atmosphere.

The next step is to compare your initialized analysis to your progs and validate them. This can be done as you use them in the forecast generation process. Simply find the prog with the DTG that matches the analysis and compare them. The prog should be quite similar to the analysis. If it is not, then you must make some adjustments to it and future progs which used that analysis for its data base. You now have a feel for how well the model is handling the current weather patterns. One note of caution when fine tuning your prog charts - don't automatically make direct translations (i.e., the 24 hour prog was 15 knots slow so you adjust the 36 and 48 hour progs by 15 knots to compensate). You must consider geography, local influences and changing patterns/parameters before making any adjustments. The initialization just tells you how good/bad your analysis and prognosis products are.

2. Continuity. One of the most fundamental and useful analytical tools we have is continuity. Of course, it is only good if used and much better if

used properly and consistently. Three important reasons for using continuity are:

- a. It allows you to visually track the movement and changes in the intensity of significant weather features.
- b. It can be used to track changes in the position of isotherms and contours (or any number of isolines or parameters) as well as lows and fronts. Track those features that are critical to you.
- c. It provides a smooth transition at shift change times.

Two important things to remember about continuity are, (1) always try to maintain continuity. Adjustments are sometimes necessary, but they should have strong justification and be well documented, and, (2) use common sense, rather than blindly applying continuity. Be alert to changes such as trend reversal and recurvature of lows, especially those coming over the Atlantic ocean and entering the European continent.

3. Persistence. AWSP 105-56 has a short paragraph on persistence which is well worth reading. Here, let's just define the two types of persistence. "Static persistence" is the repetition of an initial condition regardless of any previous trends. This is just taking the observation at forecast time and continuing it without change through-out the forecast period. "Trend persistence" continues an established trend. If conditions have been deteriorating, then you would continue forecasting downward and vice versa for improving conditions. Both types can be used for short (1-2 hour) periods. For longer periods use only trend persistence. Use the WSCC tables for depicting the "trend margins". If extrapolation of trend persistence leads to very small numbers (i.e. rare occurrences) for a given month, stop using this method.

4. Stacking. This should be obvious, but let's cover it anyway. Lows tend to stack toward colder air aloft, while highs tend to stack towards warmer air aloft. These stacking combinations are dynamically stable, i.e. this is a normal relationship and the atmosphere will try to maintain this stacking. The reason stacking was reviewed was simply to remind you that it exists and should be on your list of things to look at.

5. Extrapolation. Again, AWSP 105-56 is a good source and is well worth reading. Extrapolation is another useful tool that must be used with caution. As we mentioned with continuity, don't proceed blindly. When using continuity to extrapolate you must remember to be alert to changes. Some influences to the environment that you should look for are:

- a. Dynamic influences. Changes taking place within a system.
- b. Climate controls. The effect of topography moisture sources, air masses, and time of year
- c. Diurnal effects
- d. Pollution sources

All of these influences must be considered in your extrapolation techniques. You must systematically identify the changes that are taking place, or likely to take place, in the atmosphere during the forecast period. Here again, be aware of rare occurrences and make adjustments accordingly. Of course, you do this as part of your normal routine.

6. Analysis and Forecast Techniques. A good review source is 2WW/FM-83/003. Read the sections on air mass analysis, atmospheric structure and analysis, climatology, clouds and continuity as a minimum.

a. Start your analysis with the upper air (jet stream) and work your way down to the surface.

b. You must make a synoptic scale forecast before you make a TAF scale forecast - it never works the other way around.

c. Ridges and troughs exist where the warm/cold air is. Pay attention to thermal patterns and advection of warm/cold air.

d. Surface moisture patterns are very sensitive to local moisture sources such as evaporation from lakes, rivers, swamps, or forests.

e. Short waves propagate within the long wave field or with the jet stream normally with the same speed as the 700MB flow.

f. At a given pressure level, a moist area that increases in size from one map time to the next is indicative of upward vertical motion. The rate of growth is directly related to the magnitude of vertical motion.

g. Systems stacked vertically move slowly and systems stacked toward cold air move more rapidly.

h. Warm advection through lower layers creates upward motion and destabilization.

i. Cold advection through lower layers creates downward motion and stabilization.

j. Warm advection through 500MB creates height rises at 500MB or building ridges.

k. Cold advection through 500MB creates height falls at 500MB or deepening troughs.

JET STREAM

The polar jet is characterized by a strong band of winds in the upper troposphere. This band of strong wind is subjected to marked variations in vertical and longitudinal extent. Around the globe the upper air pattern transfers heat from the tropics poleward and polar air equatorward, thus providing an effective means of setting the atmosphere in a state of equilibrium. As the polar jet meanders about the mid latitudes of the globe, its intensity varies. Winds in some locations can be weak and diffuse while in other areas winds can exceed 250 kts. The intensity of the polar jet is a function of temperature. As thermal differences increase so do the wind speeds. In analyzing upper air charts you can see that the stronger the baroclinic zone present, the stronger the jet. Thus, at the surface, weak non-discrete frontal boundaries can be attributed to weak, diffuse upper level jet support.

Figure 1 (next page) shows the three dimensional model of the relationship between the polar front and upper level jet. Here we can see the relationship between the baroclinic zone of the front and the isotach pattern. As the thermal contrast increases, the wind speeds will increase as well. Thus, the stronger the upper level jet, the stronger the frontal boundary. According to Margules, frontal boundaries are zones of cyclonic shear. In order to preserve the characteristics of the boundary, horizontal convergence is required. Such convergence is a result of the vertical motion induced by the jet.

In Figure 2, we see that, ahead of a trough line, we find low level convergence and upward vertical motion with compensating divergence aloft. Behind the trough, upper level convergence, subsidence and low level divergence dominate. The rate of such a circulation is dependent on the baroclinic zone or jet present. As the jet increases, surface convergence will increase, allowing frontogenesis to take place. Conversely, in regions of weak diffuse upper level jet support, low level convergence will be weak. In such regions, frontal characteristics are equally weak and difficult to locate.

You should track the continuity and intensity of the jet stream and the amplitude and wave length of troughs and ridges. Answer questions such as "Is the jet stream increasing in amplitude?" or "Is it becoming more zonal?" Then relate the position and strength of the jet stream to the troughs and ridges to obtain clues that digging, troughing or pure translation should occur in the atmosphere below. Also look for areas of high level diffluence (enhances upward vertical motion) and high level confluence (enhances subsidence). Note jet maximums - these usually relate to the position and strength of surface systems.

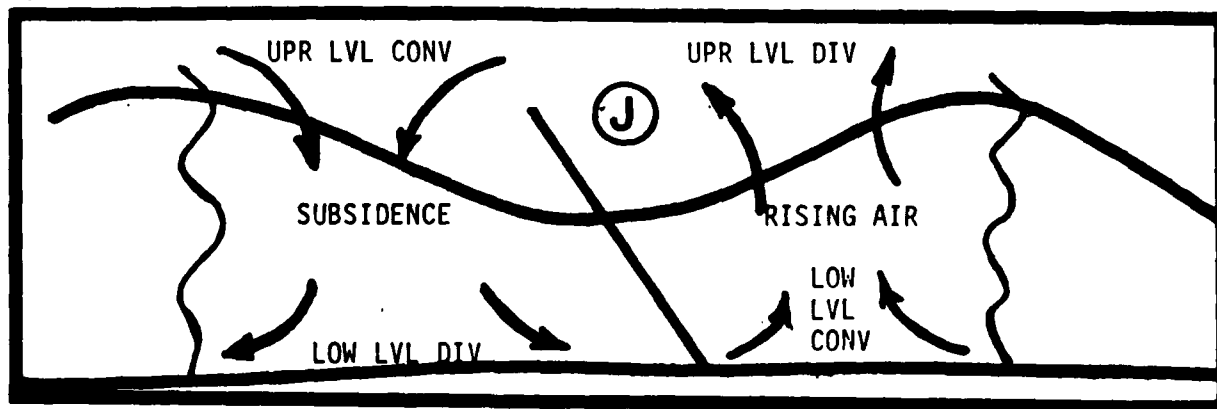


Figure 2

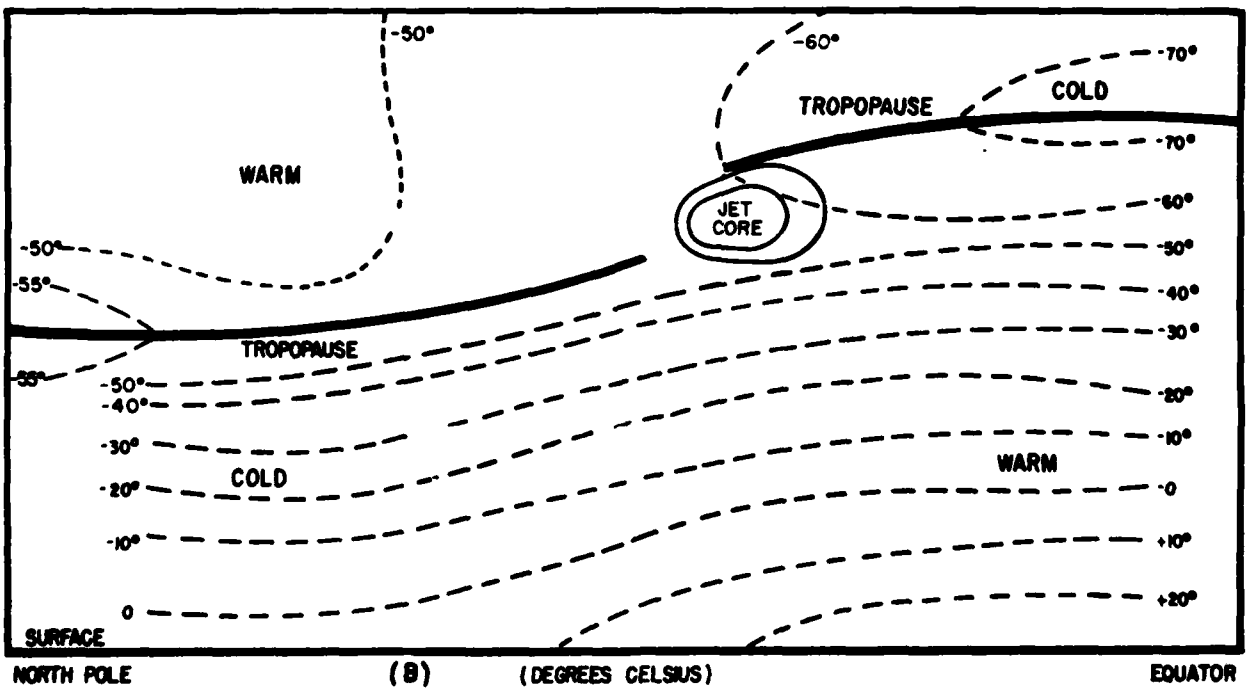
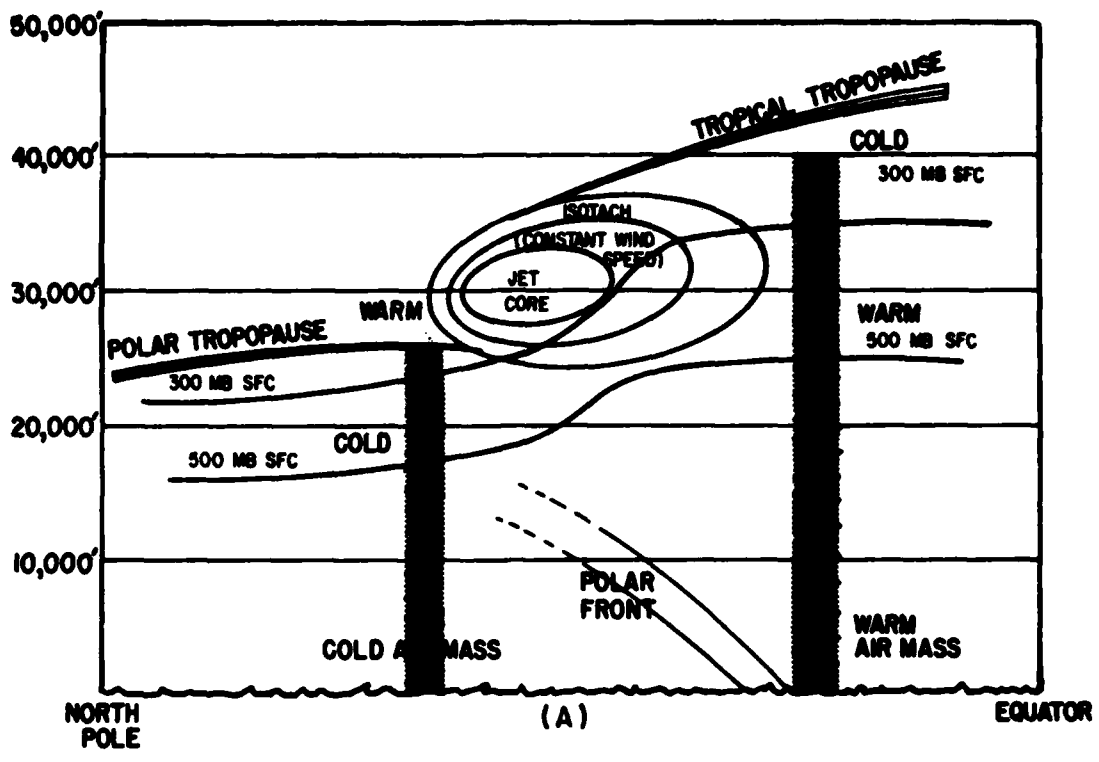


Figure 1

500MB HEIGHT/VORTICITY

During World War II and immediately following, an explosion in global coverage of upper air data was realized. Such data allowed meteorologists to analyze, in detail, various levels of the atmosphere. Such information was instrumental in showing the relationship between the mid-to-upper troposphere and the surface weather features.

Over the decades, the use of the 500mb flow pattern has been one of the most utilized charts in forecasting synoptic scale features. In recent years, the introduction of satellite derived soundings along with standard RAOB/PIBAL reports have dramatically increased data coverage around the globe. Such coverage has allowed for a far superior analysis of the upper levels resulting in more accurate computer progs. However, no amount of data will ever be sufficient in depicting the exact state of the atmosphere. Hence, no computer generated prog package can be expected to produce flawless forecasts. As forecasters, we must be aware of our products weaknesses and learn how to make compensating adjustments in order to produce the best possible product for our customers. Conversely, we must learn to exploit computer products when and where we can. This is the double-edged blade of the man - machine mix.

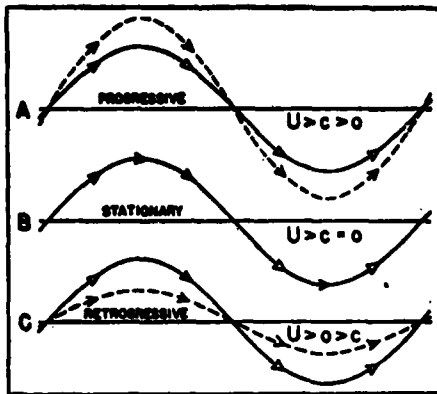
As synopticians, we are aware that weather is influenced by many factors - one of which is the polar front. It is along this boundary that we look for cyclonic developments to take place. In locating and forecasting cyclonic development the 500mb chart becomes a very useful tool. At the 500mb level we tend to locate three features:

- (1) 500mb jet stream (maximum wind bands).
- (2) Short wave troughs/ridges (SWT/SWR).
- (3) Areas of positive and negative vorticity advection (PVA/NVA).

In analyzing for max wind bands on 500mb/vort charts two parameters are used-- contour spacing and vorticity. In using contour spacing as a guide, you are locating areas with the tightest contour gradients. The smaller the contour interval, the stronger the baroclinic zone which results in a stronger wind speed. However, many times you will find several contours of equally tight spacing between them. Here the vorticity isopleths are used for fine tuning your position of the jet.

Generally, the location of the jet can be traced along a single height contour around the globe. However, given a large amplitude wave pattern with strong jet support, the jet core can deviate from one contour to another. Due to a number of forces involved, jet maxima will tend towards lower height contours in cyclonically curved trajectories while jet maxima in anticyclonic trajectories will tend towards higher heights.

As the jet stream meanders around the globe in a sinusoidal pattern, we are interested in identifying the movement and strength of SWT imbedded in the jet stream. It is these impulses we are wary of in the forecasting of sensible weather. In discussing the movement of SWT, lets review the Rossby wave equation.



$C = + =$ Progression

$C = 0 =$ Stationary

$C = - =$ Retrogression

$C =$ Wave speed

$U =$ Speed of the mean westerly flow

$\beta =$ Parameter which is a function of latitude

$L =$ Wave length

$$C = U - \beta (L - 2\pi^2)$$

For short wave lengths the second term, $\beta (L - 2\pi^2)$ is smaller than U . Thus, the speed of the wave is greater. As the wavelength increases, the second term increases resulting in a decrease in the wave speed. If the wavelength becomes sufficiently large, $\beta (L - 2\pi^2)$ would be larger than U resulting in a negative value indicating retrogression of the trough.

In determining the movement of upper level features, we see that the mean westerly flow of the jet and the wavelength of the system itself are important factors. However, changes in the atmosphere are constantly taking place. Intensification or weakening of troughs and ridges down stream can work in varying a system's progression. Such factors to be aware of are:

1. Thermal advection patterns - 500mb, 700mb, and 850mb.
 - a. Cold advection into a trough will aid in its intensification which can increase the amplitude and change the wavelength of the pattern.
 - b. When the coldest air is at the base of the trough, the trough is at its maximum strength.
 - c. When cold advection moves downstream with warm advection moving into the trough, weakening and slow progression can be expected.
2. Wind Maximums - 500mb and 300mb.
 - a. Jet max located upstream of a trough will lead to intensification.
 - b. Trough is at max amplitude when jet max is at base of trough.
 - c. When jet max moves east of trough base, trough weakens and lifts out.

As you can see these two parameters are very similar; as they should be. A jet max is simply a "package" of cold air with a strong baroclinic zone.

On most 500mb charts, upper air patterns are displayed with their associated vorticity patterns. Vorticity is an extension of the concept of angular

velocity of solid rotation. It is essentially the angular velocity of a fluid particle about a local axis. Though a rather difficult concept to grasp, most are aware of the value in using vorticity patterns in forecasting. Though there are a variety of ways of expressing vorticity mathematically, two terms dominate in its production—shear and curvature of the wind field. In Figure 4, separate examples of how curvature and shear produce vorticity are depicted. In Figure 4A, we see that the natural curvature of the wind field works to increase the angular velocity, thus increasing the value of vorticity. In Figure 4B, we see that no curvature in the wind field is present. However, due to the strong horizontal shear, a cyclonic rotation is induced north of the jet providing an increase in positive vorticity while south of the jet anti-cyclonic shear increasing the negative vorticity.

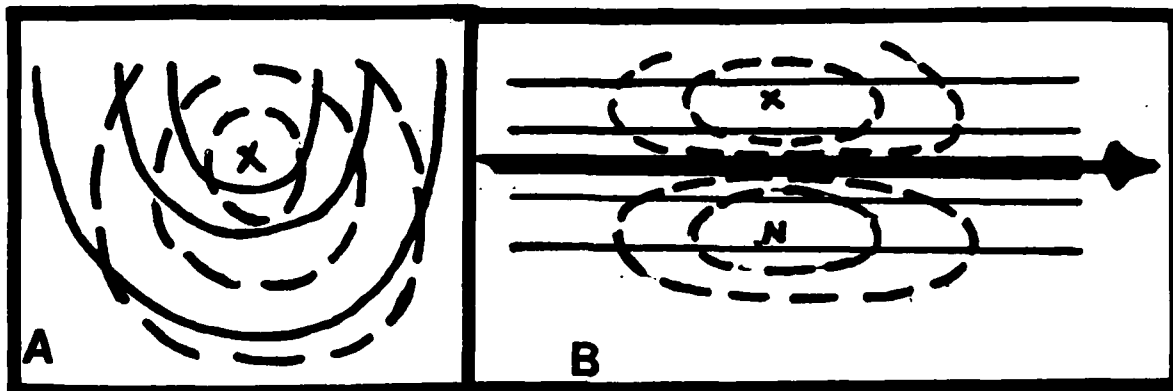


Figure 4

Given a vigorous trough with a strong jet, both curvature and shear act to increase the production of vorticity. In locating areas of weather development, we are not concerned with the location of vorticity itself, but rather the advection of vorticity. It is the advection of vorticity which is associated with the development of clouds and precipitation. The intensity of vorticity advection is a function of wind speed, vorticity gradient and the angle at which the wind is advecting the vorticity field. The stronger the vorticity gradient and winds blowing perpendicular to the vorticity gradient, the greater the vorticity advection.

In regions where the wind and vorticity gradient is weak, though the flow is perpendicular to the vorticity isopleths, the vorticity advection is weak (Figure 5A). Likewise, in regions where winds and vorticity are strong but the flow is parallel to the vorticity isopleths, the vorticity advection would be weak (Figure 5B).

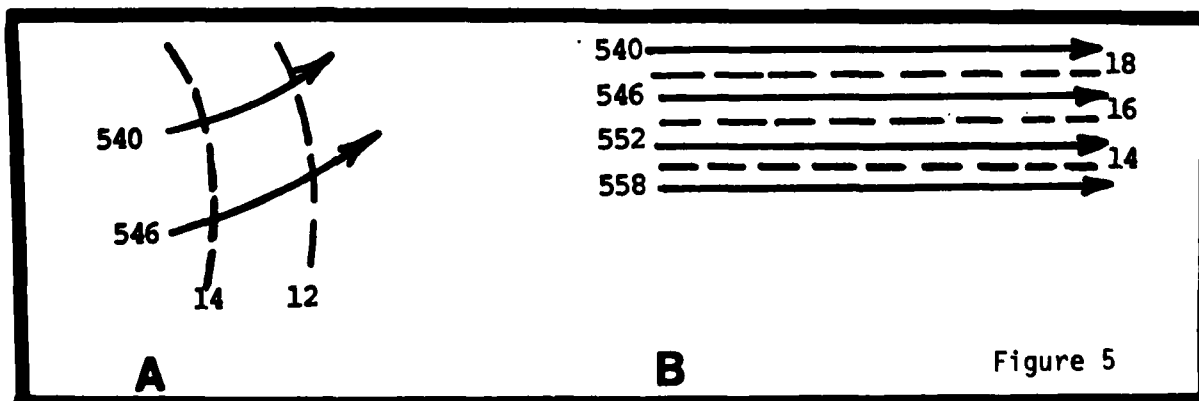


Figure 5

The advection of vorticity and its result in producing sensible weather is analogous to thermal advection. Positive Vorticity Advection (PVA) analyzed on 500mb charts are areas associated with cloud development and (given sufficient moisture) precipitation. PVA is located from the upper trough to the downstream ridge. As stated earlier, curvature and shear are the two major contributors in the production of vorticity. It is in this region of cyclonic curvature of the jet where we find the greatest low level convergence, upward vertical motion and upper level divergence. Consequently, in regions of strong PVA and sufficient moisture, sensible weather is found (Figure 6). Negative vorticity advection is located from the trough to the upstream ridge. In this region, upper level convergence provides subsidence and low level divergence. Such motion enhances clearing.

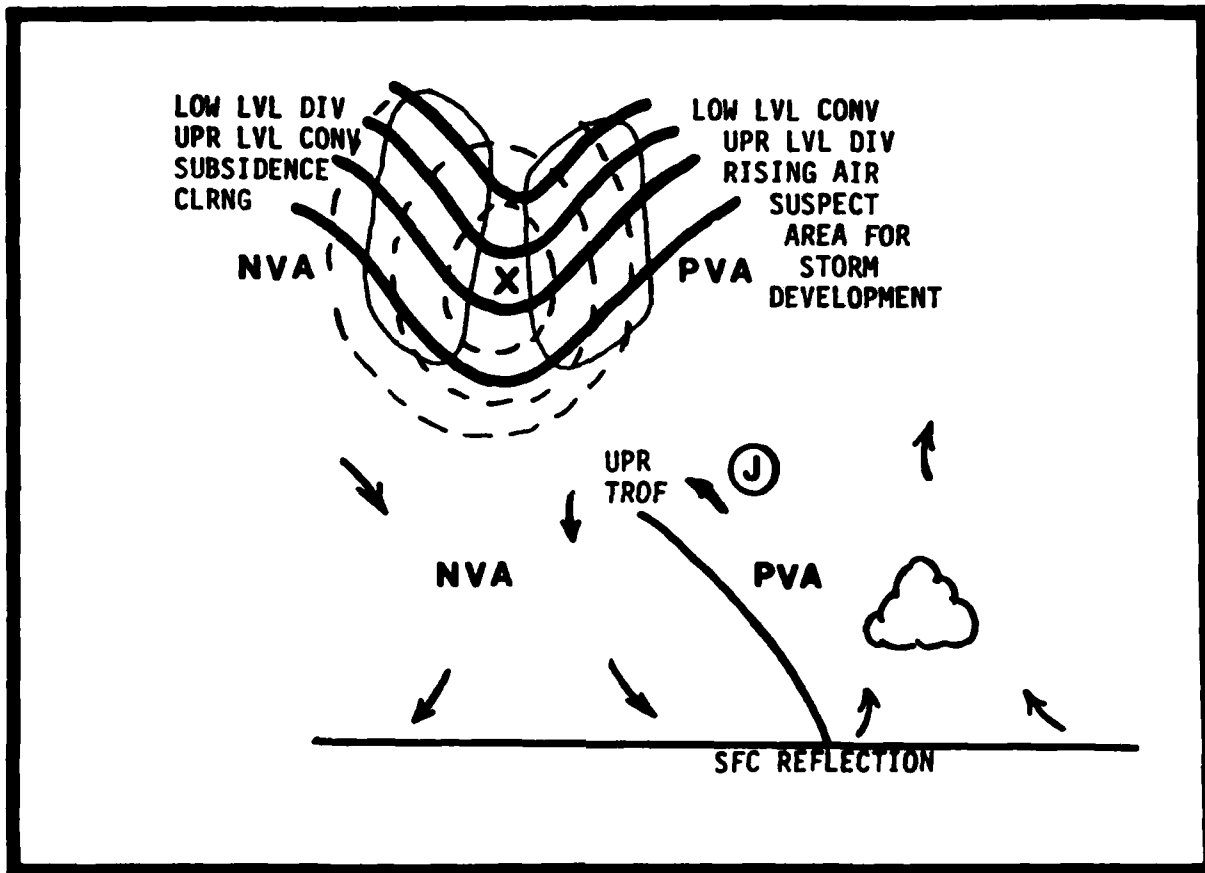


Figure 6

In the development of cyclogenesis, PVA plays an important role. As an upper trough approaches a weak surface front, frontal intensification can be expected. Regions of strong PVA will correlate well to the strongest low level convergence intensifying the surface boundary. The compensating upper level divergence will cause the surface pressure to fall. With sufficient low level convergence and the evacuation of mass by way of upper level divergence-cyclogenesis may then take place.

Cyclonic development along a frontal boundary is common in producing significant weather. However, cyclogenesis can occur within the cold air well north of the boundary and still produce significant weather. Within the cold air, thermal contributions in the development of a system are negligible. Petterssen's development equation mathematically relates the importance of 500mb vorticity advection and all the other parameters necessary for development. It states that surface development is equal to the sum of 500MB vorticity advection, thermal advection term (warm advection ahead of a storm acts positively towards development), stability term (moist, stable air favors development), and diabatic heating term. The latter term plays an important role in European winter storm development when cold air aloft from Canada or Greenland moves over the warm Atlantic water. Within the cold air disturbances can develop (originally "eddyies") formed by cold outflow down the Rhein Valley to real extratropical cyclones with the resulting cyclogenesis chiefly a function of diabatic heating. The Genoa low is an excellent example of this process.

From Petterssen's equation, we can see the PVA, stability, diabatic heating and thermal advection all contribute in the development of surface cyclones. However, we see the development of surface lows in the cold air where thermal advection is restricted. Thus, the advection of positive vorticity, stability and diabatic heating terms must be sufficient to allow cyclogenesis to take place. Cyclone development along the polar front as well as development entirely within the cold air is well documented in AWSTR 212. The report indicates that a well organized comma shaped cloud pattern within the cold air is closely related to the upward vertical motion accompanied with PVA. Here, the thermal contribution to vertical motion is negligible. Where as in a developing frontal system, both the PVA and the thermal advection patterns contribute equally.

Cyclogenesis occurring within the cold air is categorized by Weldon as either a "cold air vortex" or "the induced wave". Cold air vortex refers to a vigorous SWT that had developed well in the cold air behind a significant frontal cloud band. The surface reflection is generally a compact cyclonic circulation with an extended trough of low pressure correlating to the 500mb PVA field (Figure 7). The associated weather can be as vigorous as any dynamic wave on a boundary.

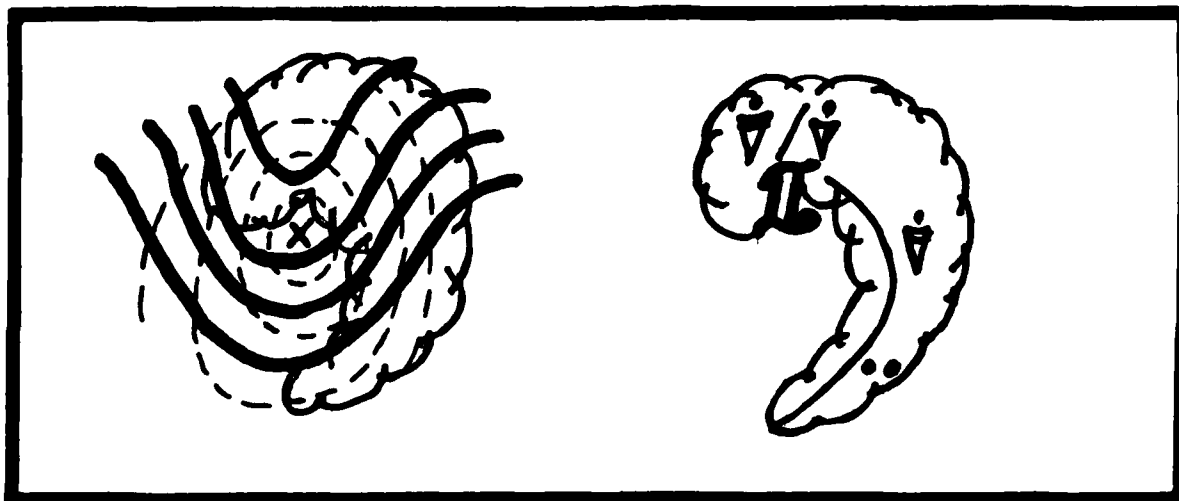


Figure 7

Most often such development is noted after cold air associated with a mature cyclone moves well equatorward. With the frontal boundary extended well to the south, an approaching SWT is unable to interact with the baroclinic zone. However, the vorticity advection associated with the upper-level trough is sufficient in initiating sufficient vertical motion (Figure 8).

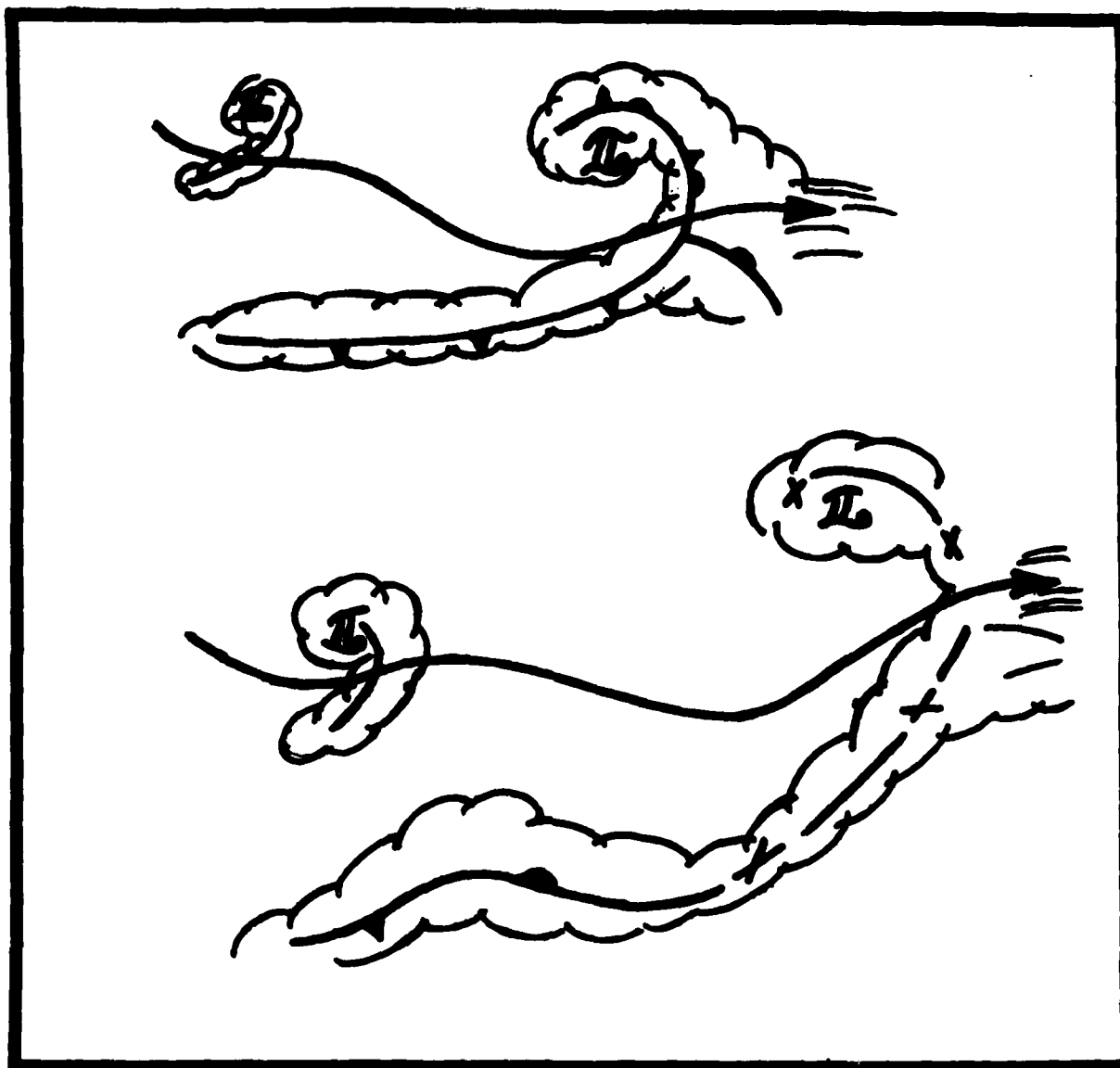


Figure 8

The latter situation, an induced wave, occurs when the upper air pattern warrants. In this situation, a cold air cyclone develops well into the cold air as in the first case. However, as the SWT progresses through the upper air pattern, the vortex is carried in close proximity of an existing frontal boundary producing an appearance of an "instant occlusion". As the comma shaped cloud pattern approach the frontal boundary a slight wave is induced in the boundary. At AFGWC such a situation is depicted as a "trough over wave" configuration. Figure 9 depicts a typical sequence in the formation of an induced wave.

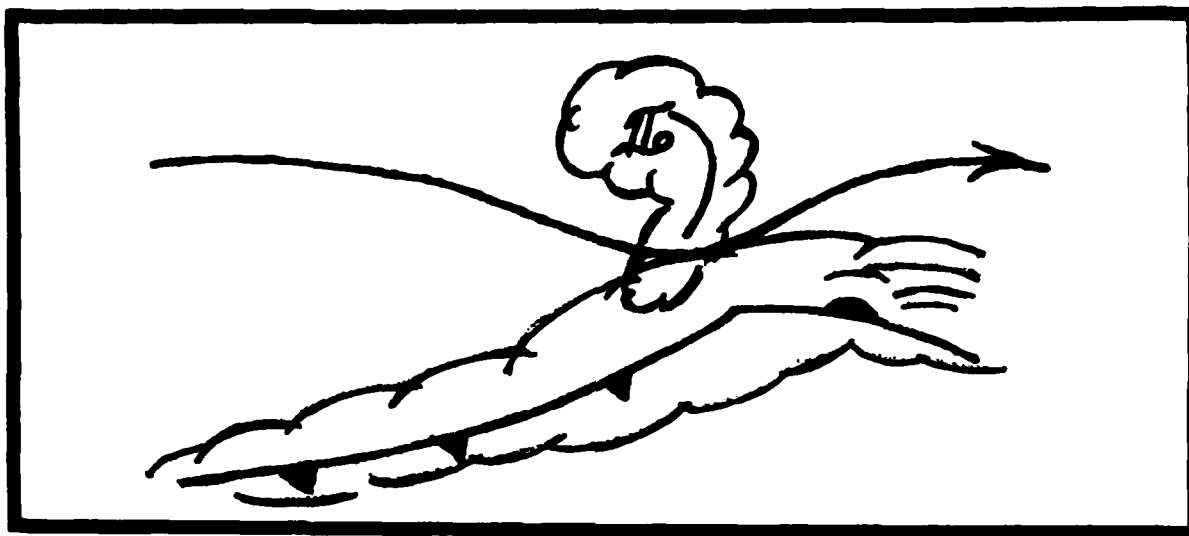


Figure 9

In this situation, the system takes on the appearance of an occlusion. Though the low is considered as the mechanism in inducing the frontal wave, there is no thermal exchange between the air masses. The low is still maintained within the cold air. In Fig 10, we see the thermal relationship between a cold air vortex and a pre-existing frontal boundary. These "PVA storms" also occur entirely in the warm air (south of the polar jet). They are reasonably well documented and sometimes, in fact drift northward and cross the jet.

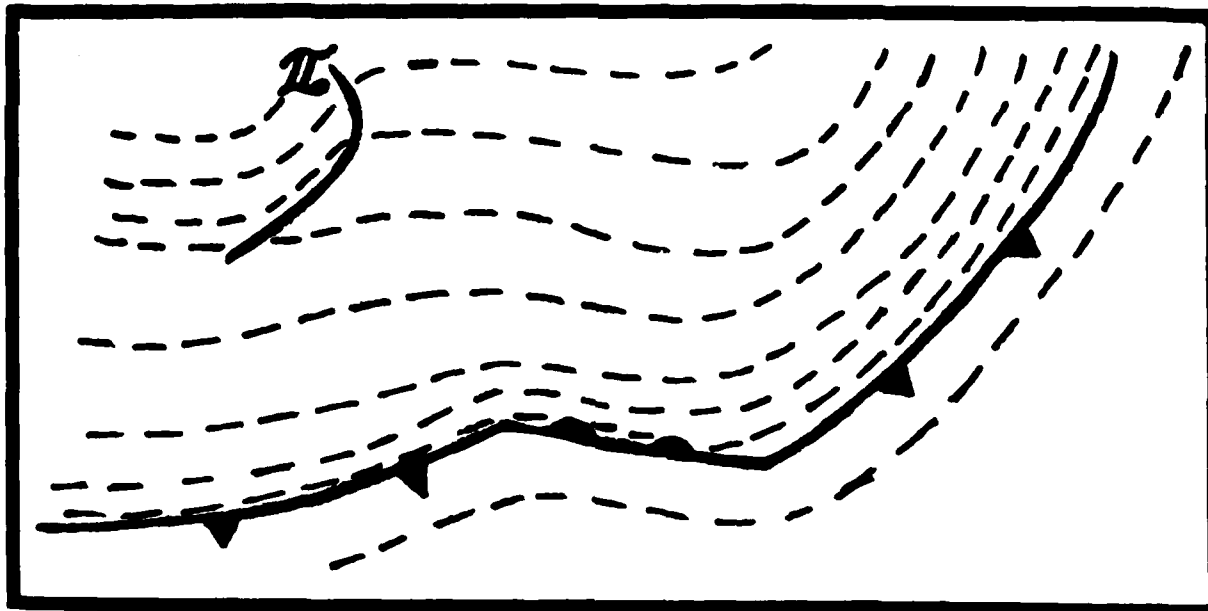


Figure 10

In Figure 10, we can see the normal thickness packing associated with a polar boundary. In addition, we see a second concentration of thickness packing, separate from that of the polar boundary, associated with the approaching upper level trough/surface cold air cyclone. The thickness ridge associated with the cold air cyclone is a result of the low level circulation and the vertical motion associated with the PVA field. As illustrated, SWT imbedded within the jet stream pattern can produce a surface reflection. However, the associated PVA is not always intense enough to produce a surface reflection though sufficient vertical motion exists for clouds and/or precipitation. Thus, 500mb charts play an important part in formulating your daily forecast.

POSITIVE VORTICITY ADVECTION IMPLIES:

1. Increasing upward vertical motion (or decreasing downward vertical motion)
2. Convergence (or decreasing divergence)
3. Increasing humidity
4. If initially saturated, then onset of precipitation
5. If precipitation is already occurring, then expect heavier rates of precip

NEGATIVE VORTICITY ADVECTION IMPLIES:

1. Increasing downward vertical motion (or decreasing upward vertical motion)
2. Divergence (or decreasing convergence)
3. Warming of the layer (subsidence)
4. Decreasing humidity
5. If initially light precipitation, then expect precip to stop
6. If heavy precipitation initially, then expect rate of precip to diminish

NO CHANGE IN VORTICITY IMPLIES:

Persistence

THICKNESS

Thickness is one of the most basic thermodynamic properties used by operational forecasters. There is no mystique associated with it--it is very simply the thickness of a slice of atmosphere between two vertical reference points, usually 1000-500mb. Cold, dense air is less thick between two reference points than is warm air (less dense air) between the same two reference points. Thickness, therefore, is directly related to the average temperature in a column of air. It follows then that a thickness gradient is a very usable representation of a density gradient. See figure 1 for a good example of the thermal representation of the thickness (density) relationship between warm and cold layers.

The operational forecaster is always seeking out density gradients--the very definition of a front. The tighter (steeper) the gradient, the more violent the sensible weather and, usually, the faster the front. Conversely, weak (shallow) gradients are usually associated with gradual, nondescript changes to sensible weather elements and are slower moving boundaries. Such frontal boundaries have become modified in the lower layers, resulting in a decrease in the low level convergence necessary for maintaining the front. The two air masses separated by the front have mixed sufficiently that traditionally front finding techniques (rapid change in temperature and/or dew point, windshifts, and marked pressure changes) fail.

Historically, thickness chart presentations, whether done locally by labor intensive graphical subtraction techniques or whether prepared centrally and received via weather facsimile, have been the 1000-500mb slice of the atmosphere. In the days of locally prepared thickness charts, the calculation of one layer was all there was time for. Certainly if one is all the forecasters can have, then 1000-500mb makes a lot of sense. It captures virtually all synoptic scale density gradients in the lower troposphere--"where the action is," so to speak. However, the forecaster using a single 1000-500mb thickness chart must learn to temper the gradients shown with other data and some expert synoptic reasoning. At the end of the process the forecaster can obtain a fair approximation of the thermodynamic processes in progress upon which to formulate problems. For example, intense, shallow thermal lows in regions such as the southwestern United States, Iberia, and North Africa produce sufficient distortion (contamination) of the 1000-500mb thickness pattern for all except the most astute forecaster to be duped into believing that a frontal wave is active in these areas. Similarly, the Alps, Carpathians and Balkans trap the very cold continental polar (sometimes misnomered Arctic) air mass on the north side, producing a very strong north-south oriented gradient in the lower portion of the 1000-500mb layer. This orographic induced contamination (distortion) of the thickness can easily confuse even the most expert synoptician. It becomes almost impossible to track maritime fronts that have gone aloft over the continental polar air. Over high plateaus such as Iberia and the Anatolian Plateau, that portion of the 1000-500mb layer which lies below the surface is calculated, resulting in a fictitious thickness pattern. The forecaster using 1000-500mb thickness must be forever vigilant for other sources of contamination (distortion) as well.

Determining the intensity of a front and whether or how it is modifying becomes a very complicated exercise in keeping station continuity for a large number of regular reporting stations; knowledge of vertical structure comes from plotting several RAOBs and painstakingly preparing the attendant cross section chart. It is little wonder that three dimensional thickness

representations of thermodynamic processes have fallen from favor with operational forecasters who have opted for 500mb vorticity charts which, of course, do an excellent job of capturing synoptic scale thermodynamic events at 500mb.

In the modern era of supercomputers and digital facsimile, the detachment forecaster need not be constrained to a single thickness chart--especially one which demands expert abilities and taxes precious time. The objective is to quickly and easily extract relevant information regarding three dimensional atmospheric thermodynamic processes using tried and proved methods that can readily be assimilated by the detachment forecaster. Splitting the 1000-500mb layer into two distinct layers achieves this objective

The layers we chose are 1000-850mb and 850-500mb. These layers seemed a natural for incorporating mandatory reporting levels, height of significant terrain features (Iberia, Anatolya Plain, Alps, Carpathians, Caucasus, etc), and most importantly, the meteorology of the thermodynamics we need to identify (average height of the continental polar "cold dome", shallow thermal lows, over running fronts, modifying (washing) fronts, intensity of fronts, etc.).

The 850-500mb thickness is a very conservative field. By conservative, I mean very slow to change (dissipate) existing gradients because it does not rapidly respond to external energy exchange occurring in the lower atmosphere. It is especially useful in tracking fronts across areas of high terrain where surface stations are sparse and beleaguered with local effects, such as the Rocky Mountains, Iberian Peninsula, the Alps, and the Anatolian Plateau. Remember, the leading edge of the 850-500mb thickness gradient approximates the position of the front at 700mb. Therefore, to locate the surface front in mountainous terrain is impossible using surface data alone. Judicious use of the 850-500mb thickness permits the forecaster to maintain a reasonable continuity across the most difficult terrain.

The 850-500mb thickness is also very useful in eliminating low level thickness distortions such as thermal lows and the continental polar "cold dome". That is to say, real density gradients that exist above these features are readily identifiable, easily oriented, and even more easily tracked--making the forecast problem a much more tractable one. The 850-500mb thickness is an essential tool in tracking modifying (washing) fronts. These fronts continue to be vigorous mid-tropospheric weather producers long after they can no longer be found using conventional surface data or even 1000-850mb thickness patterns. Yet most washing boundaries are very easily recognized in the 850-500MB thickness pattern. Analogously, the 850-500MB thickness is essential in tracking maritime fronts that have been pushed aloft by colder, drier continental polar air.

In fact, a comment often heard from detachment forecasters located in Germany is that cold frontal passage (referring to maritime polar air) is frequently accompanied by a 1-2°C rise in temperature. Consider this winter situation: Across the Alps and Carpathians, the distinction in air masses is an easy exercise. Similarly, across the Kjolen Mountains of Norway, it is quite easy to distinguish the maritime air on the western slopes from the continental polar air on the east. However, from the southern end of Norway to the Alps, there exists a front that embellishes a very broad transition

zone. Surface observations from Paris and Berlin clearly indicate that a continental polar front exist somewhere between the two cities. However, the forecaster is unable to confidently "draw the blue line" even using all the available data between the two cities. Why? Simply because the transition zone is very broad and diffuse. Now, a maritime polar front begins pushing across Europe. As it begins to be forced aloft by the colder air, it mixes with the very shallow (less than 2,000ft thick) continental polar air found on the far western extent of the air mass. This turbulent mixing creates air that is warmer than the unmixed air it replaces and, voila! "cold" in quotes because it is important that forecasters understand the cold front is beginning to be pushed aloft. When it reaches an altitude sufficient to preclude mixing at the surface, then temperature rises are no longer experienced as it passes overhead--in fact, rain/freezing rain/snow and pressure tendencies then become the best surface data indicators of passage. The point here is this whole process is made very understandable, very recognizable, and very forecastable when using 1000-850mb and 850-500mb thickness charts as the principal diagnostic tools.

By eliminating the 1000-850mb layer from the 1000-500mb thickness we have eliminated what might be termed the contaminant or noise layer and have produced an exceptionally conservative 850-500mb thickness field that yields a wealth of information regarding mid-tropospheric thermodynamic process. We have eliminated distortions (contaminants) produced by thermal lows; contaminants produced by fictitious thicknesses that don't exist below the surface of areas of relatively high terrain; distortion produced by intense, shallow air masses; and, distortions produced by frontal modification. We have therefore, extracted the ability to easily track fronts across areas of high terrain, to track fronts as they traverse over intense, shallow air masses (front aloft), and to track modified or washing front (a different type of front aloft).

There is one subtlety in the use of the 850-500mb thickness chart of which forecasters must remain forever cognizant. Thickness lines do not lose their utility when thought of as isotherms (thickness is determined by the mean virtual temperature of the layer). It is, therefore, the natural tendency of forecasters to place fronts immediately on the leading edge of thickness (isothermal) gradients. When using this technique on 850-500mb thickness charts it must be recognized that the forecaster is approximating the 700mb position of the front. To locate the frontal position at any other level (for example the surface), the forecaster must infer and apply a frontal slope. Typical slopes are:

a. Cold fronts vary from about 1:50 to 1:100 depending upon speed. A very useable approximation is 1:50 for fast (25 knots or greater) movers and 1:100 for slower fronts (less than 24 knots).

b. Warm fronts vary from 1:100 to 1:300. An approximation that produces good results (to be refined using 1000-850mb thickness) is 1:150.

The 1000-850mb thickness, unlike the 850-500mb thickness, is not very conservative. It is readily influenced by diurnal effects and it magnifies the contaminants we wished to nullify in the 850-500mb thickness chart. The 1000-850mb thickness is virtually meaningless over areas of high terrain. However, thermal lows and continental polar air masses (sometimes misnomered Arctic fronts) are very apparent on 1000-850mb thickness charts. Since a

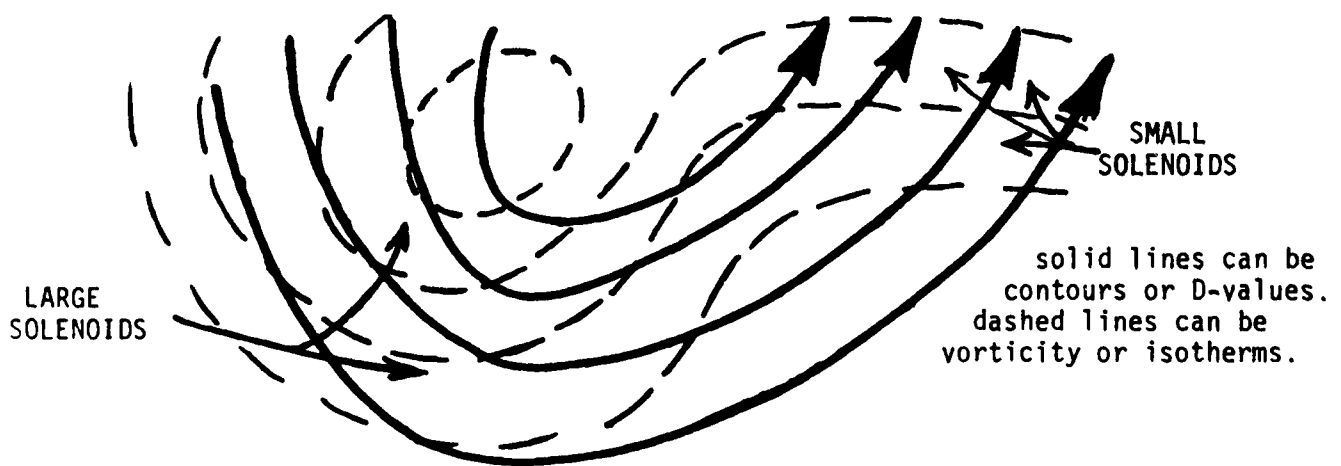
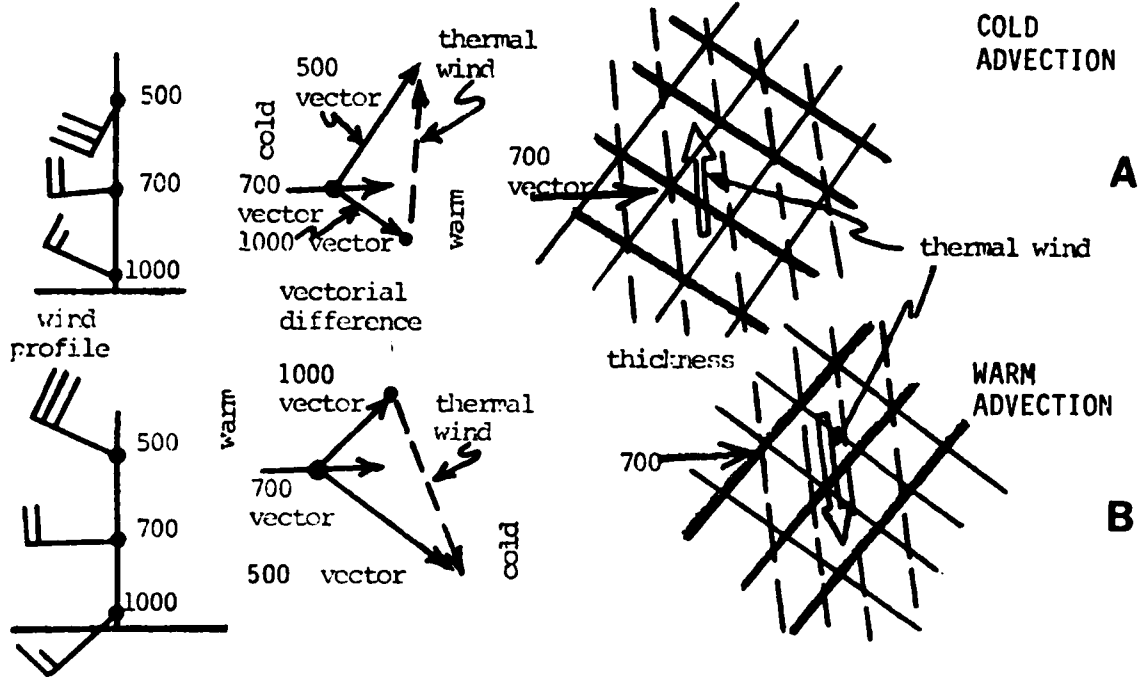
same as using 500mb height/vorticity charts, i.e., the smaller the solenoids, the greater is the vorticity advection.) This "eyeball" technique yields useful information to the more experienced forecaster. However, the rest of us should use more exact techniques.

The more precise technique requires a rudimentary knowledge of vectors. The vectors we are dealing with (wind vectors) point in the direction the wind is blowing and vary in length according to the wind speed (the faster the wind the longer the wind vector). The individual forecaster can devise whatever scale is appropriate for the case at hand, i.e., a choice of 1 inch = 20 kts may be useful in most instances but cumbersome in others. In each case the forecaster should choose a scale they are comfortable with. That is all we need to know about vectors.

Now to return to the problem of determining the relative strength of the thickness/thermal/density advection--using vectors. The direction of the (geostrophic) wind for any level is given by the height contours for that level, i.e., the wind is parallel to the height contours. The windspeed is given (printed) on most charts received from AFGWC, e.g., the FUEW series. However, the windspeed can also be determined using a geostrophic wind scale. After determining the wind direction and speed at some geographic point for the two levels of interest, we draw the vectors representing those two winds with their tails touching as in figure 11A. The thermal wind is represented by the vector that completes the triangle with the two wind vectors. The tail of the thermal wind vector touches the head of the low level wind vector and the head touches the head of the upper level vector (see figure 11B). The thermal wind vector you will recall is parallel to the thickness with lower values of thickness to the left. The area of this triangle is directly proportional to the thickness advection, i.e., the larger the triangle, the stronger the advection. The area of a triangle is $1/2$ the base times the height.

Another useful vector that can be determined is the average geostrophic wind for the layer. The tail of the average geostrophic wind vector joins the tails of the lower and upper level wind vectors and is drawn to the midpoint of the thermal wind vector.

In summary, thickness is one of the best thermodynamic tools available to forecasters. Supercomputers and digital facsimile products make it possible for forecasters to have thickness charts that describe mid-tropospheric thermodynamics separately. This separation from the lower troposphere enhances the forecaster's ability to track fronts across high terrain as they modify, and over shallow cold domes. Tracking fronts over cold domes further enhances our ability to forecast snow and/or freezing rain/drizzle.



OMEGA

Omega charts are simply representations of vertical velocity. All AWS forecasters are familiar with the 700mb vertical velocity panel of the Limited Fine Mesh (LFM) as taught at Chanute. Omegas are computed using the omega equation and thus the name.

Omega is a change in pressure with time of a parcel of air. Since upward motion results in a decrease in pressure, rising air is indicated by a negative omega. Omega charts show vertical motion directly and quantitatively. Remember, negative values mean rising air. A plus sign is used on the LFM to indicate rising motion. The LFM representation of vertical velocity is in microbars per second while AWS omega charts represent vertical velocity (omega) in millibars per 2 hours. The AWS representation is somewhat finer than is the LFM and, therefore, vertical velocities will appear to be stronger on AWS charts than they are on the LFM. Apart from these two small differences, the charts can (and should) be used exactly the same.

Knowledge of vertical motion in the atmosphere is basic to weather forecasting. Vertical motion reveals information regarding the development, intensification, and decay of systems. Moreover, the intensity (strength) of vertical motion is related to the intensity of the system. That is to say, associated with very strong upward vertical motion will be moderate to heavy precipitation and clouds of large vertical extent. Conversely, weak upward vertical motion will bring only wide spread cloudiness and the indication the dynamics are too weak to produce precipitation. However, areas with upslope flow may enhance the upward vertical motion enough to produce drizzle with poor flying weather (for instance; Benelux, Western Germany and Western U.K.).

One of the most powerful uses of omega is in conjunction with moisture-- just as depicted on the LFM. At this time, AFGWC does not have a moisture data base accessible by field forecasters. However, the Automated Weather Analysis and Prediction System (AWAPS) includes moisture. Moreover, satellite sounding techniques are getting better and better. AFGWC already computes both height and temperature from these soundings and the ability to retrieve moisture is not far off. AWAPS, coupled with improved satellite sounding retrieval techniques, will make it possible for us to realize the full potential of omega by 1987.

SUMMARY

By now, you should have a good feel for how to get the most out of these charts. We've covered our reasons for selecting these particular charts, reviewed some basics, and talked about some key parameters available on the charts. We would like to summarize by talking about the most obvious uses of each chart and how they work with each other.

500MB HGTS/VORTICITY

Locate troughs, ridges short waves
Max wind band using contour gradient
PVA/NVA for developing/clearing areas
Use with thickness for thermal advection
Use with 700MB spreads to validate available moisture
Forecast mid-level cloudiness/precipitation

850MB HGTS/1000-850MB THICKNESS

Locate and evaluate the intensity of fronts
Locate thermal lows and shallow air masses
Determine thermal wind
Forecast surface temp, precip type, and surface wind
Locate low-level max wind band using contour gradient

750MB OMEGA/850-500MB THICKNESS

Use with 700MB spreads to locate moisture sources (omega plus high humidity)
Determine thermal wind
Locate and track fronts over high terrain
Track washing fronts
Track fronts aloft
Locate warm/cold ridges/troughs or pockets using thickness

700MB HGTS/700MB T-TD SPREADS

Locate major and minor troughs and ridges
Locate mid-level moisture sources
Use with 850-500MB thickness for thermal advection
Use as an 850MB approximation over higher terrain

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