"*Big whirls have little whirls which feed on their velocity.
Little whirls have lesser whirls. And so on to viscosity.*" —L.F. Richardson

Mariner's Guide to the 500–Millibar Chart

Joe Sienkiewicz and Lee Chesneau
National Weather Service

Detailed stock and bond information is available daily. For those willing to expend the time and effort to analyze these data the rewards can be gratifying. The same can be said in maritime circles of the surface and 500–millibar charts, provided on marine radiofacsimile by the U.S. Coast Guard from NMF (Marshfield, MA) and NMC (Pt. Reyes, CA). Both transmit five 500–millibar (mb) charts each day (two analyses, two 48–hour forecasts and one 96–hour forecast).

For your investment decisions you can depend on your broker, just as you can turn to your weather forecaster for route decisions. In both cases it is the prudent individual who uses all available resources and makes his own final decision.

The professional mariner and ocean sailor can use the 500–mb analyses and forecasts in combination with surface pressure charts to better understand and anticipate the workings of the atmosphere. With a little bit of knowledge and pattern recognition experience, you will be able to make more educated decisions concerning upcoming weather and the movement of low pressure systems.

Surface Weather Chart Basics

Surface weather charts that depict isobars, high and low centers and a variety of weather fronts are familiar to mariners. The general perception is that lows are associated with bad weather and highs mean light winds near the center with generally fair weather, but there is more to it than that. Isobars are lines of equal pressure on the surface of the earth— at the bottom of the atmosphere. Therefore, this surface pressure is a direct measure of all of the processes that are happening from upper and mid-levels in the atmosphere down to the surface! These processes include cold air sinking, warm, moist air rising, precipitation, and air streams or jet streams coming together (converging) or spreading apart (diverging). The surface pressure pattern is actually a two dimensional representation of the three dimensional atmosphere!

If you look at a surface map and think that the low over Chicago today will be over New England tomorrow and affecting my vessel the day after, you are forecasting by continuity. This is moving the existing state of the atmosphere (lows, highs and fronts) around the earth without taking account of all the processes involved. In the early part of this century that is the way meteorologists first forecast storm systems.

If you learn anything from this article remember that the atmosphere is dynamic! The surface pressure field responds to changes in the atmosphere aloft and vice versa. Storms have life cycles; they are born, some grow and strengthen, and eventually they spin down and die. The intensity and length of life of a low is a direct result of interaction between the lowest level in the atmosphere and mid and upper levels. An excellent measure of this interaction is the 500–mb height field. (Note: Z time is the same as UTC.)

Joe Sienkiewicz and Lee Chesneau are High Seas Forecasters in the Marine Forecast Branch of the National Meteorological Center located in Washington, D.C. Both have written excellent articles for the Mariners Weather Log *in the past, in addition to their strenuous marine forecast duties.*

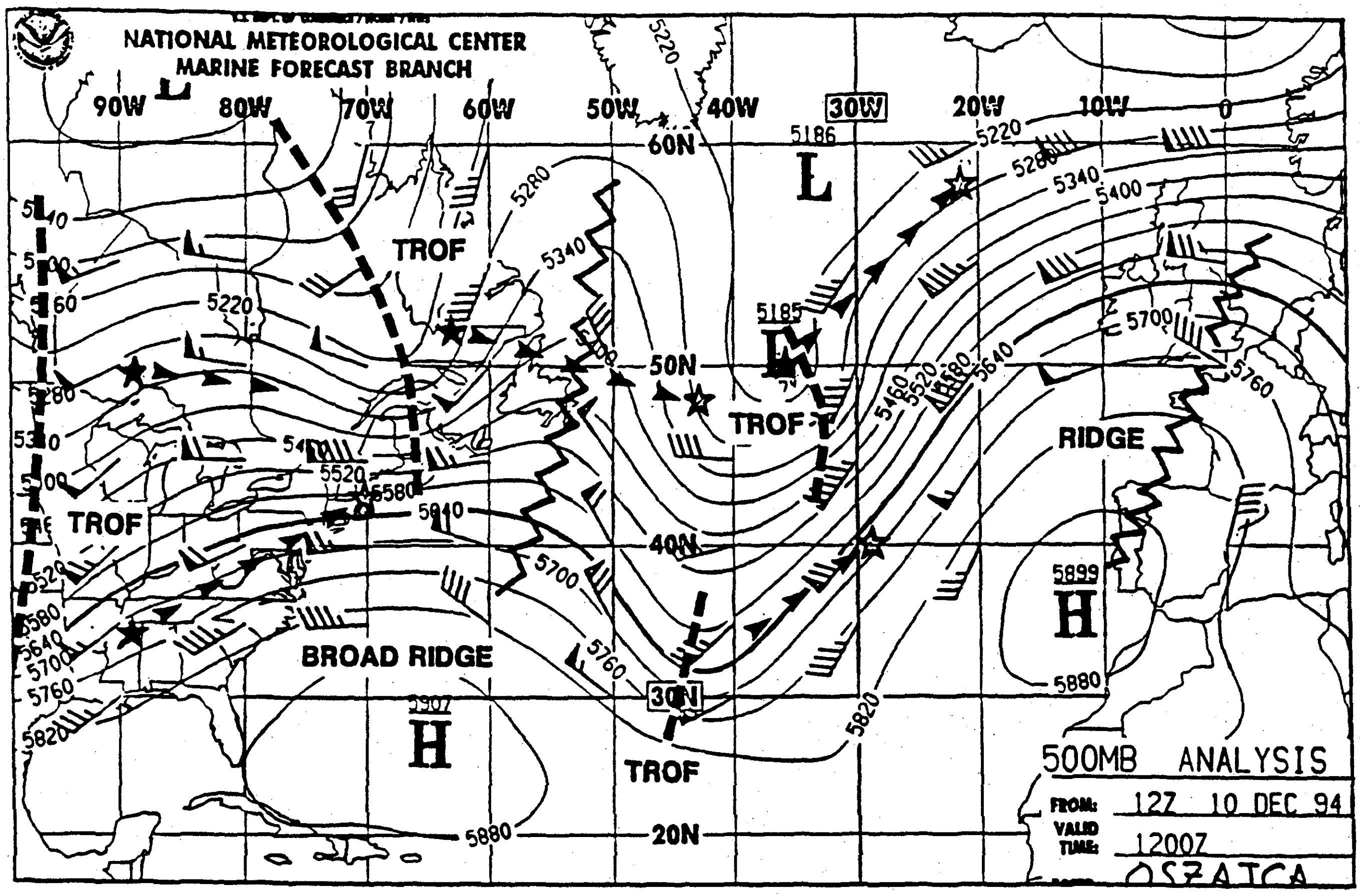

Figure 1. The 500-millibar analysis for 12Z December 10, 1994. Short wave troughs are shown by a dashed line. Zigzag lines indicate ridge axes. The location of surface low pressure centers at 12Z December 10 are indicated by a star. Observed 24 hour tracks of lows are shown by arrow heads, and the observed position of low centers at 12Z December 11 are shown with an open-faced star.

The 500–millibar Basics

The 500-mb surface is a constant pressure surface approximately midway up in the troposphere (the lowest layer of the earth's atmosphere). The pressure exerted by the air column above this level is exactly 500 mb, but the height of this surface varies. The 500-mb constant pressure surface generally averages approximately 5600 meters (18,000 feet) in height but can vary from roughly 4700 meters in an extremely cold (more dense) atmosphere to nearly 6000 meters in a very warm (less dense) atmosphere.

The solid contours shown on the 500-mb chart (Figure 1) represent geopotential height (basically, height in whole meters with a slight difference). The number 5640 means 5640 meters. In a sense you are looking at a topographic map of the 500-mb pressure surface. **The 500-mb heights are higher in warmer air masses (less dense) and lower in colder air masses (more dense).** Therefore, the heights generally are lower to the north and higher to the south. In Figure 1, look at the height differences from the contour at 30°N, 30°W (5820) and south of Iceland near 60°N, 20°W (5220) meters (approximately 600 meters difference).

The closer the 500-mb height contours are together, the stronger the horizontal and vertical temperature contrasts and the faster the wind speed at 500 mb (the wind at this level is for the most part parallel to the height contours). A simple rule of thumb– **the tighter the height contours, the higher the wind speed, the stronger the temperature difference below 500 mb.** In Figure 1, a strong band of southwesterly winds extends from near 30°N, 40°W to northern Scotland– good indication that a moderate to strong surface front exists in this area.

Winds at 500 mb are generally not the actual jet stream, which is usually between 200 and 300 mb. Jet streams exist due to horizontal temperature contrasts. In an extremely cold atmosphere, the arctic jet stream can extend down to 500 mb. However, meteorologists do call wind speed maxima at 500 mb jets or jet streaks. On the 500-mb charts distributed over radiofacsimile, only 500-mb heights and winds are depicted. The distribution of height contours and therefore the strength of 500-mb winds implies the

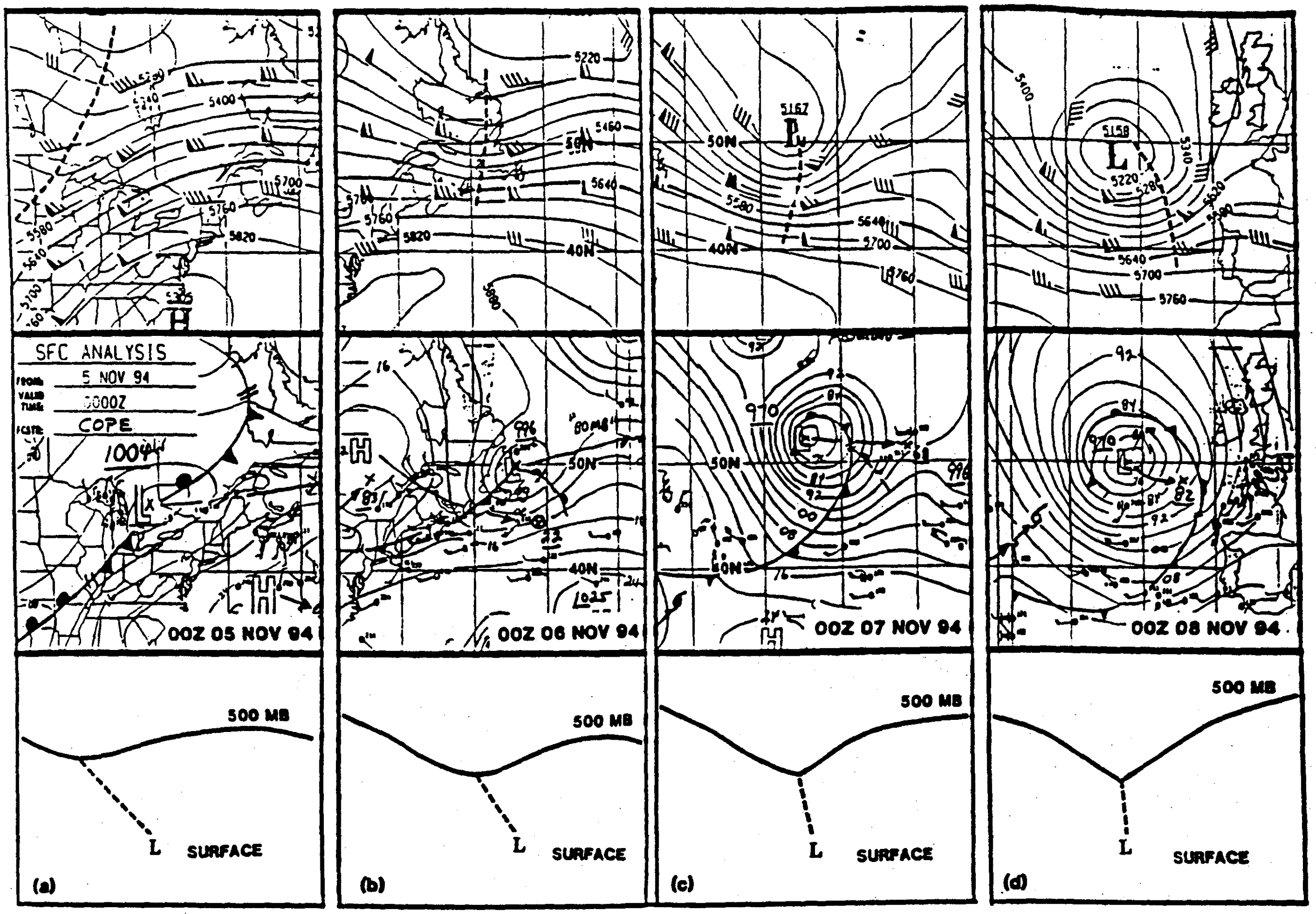

Figure 2. The four panel diagram shows the 500-mb analyses and short wave trough axes (dashed line), surface pressure analyses, and vertical cross-sections of 500-mb pressure surface, surface low position and vertical trough axis (dashed line) for (a) 0000Z November 5, (b) 0000Z November 6, (c) 0000Z November 7, and (d) 0000Z November 8, 1994.

strength of horizontal temperature contrasts.

L's and H's represent areas of relatively higher and lower heights. An L or H with a closed contour around it implies that the high or low has a closed circulation with the wind circulating around it. In Figure 1, a 5899 closed high can be seen just west of the Straits of Gibraltar. An open 5185 low can be seen at 50°N, 37°W (there is no closed height contour and no closed circulation).

Troughs are areas of relatively lower heights and are U or V-shaped in the contours. Several troughs axes are indicated in the chart by dashed lines. For example, a trough extends from just east of Hudson Bay to the Canadian Maritimes. A more complex area of troughing can be seen in the mid-Atlantic with one trough along 35°W and a second between 40° and 50°W south of 40°N.

Ridges are areas of higher heights and are shaped like an upside down U or V and are indicated by a zigzag line. A strong ridge extends north northeastward from off the African Coast to the British Isles. A broader, flatter ridge can be seen off the southeast U.S. coast extending to between 50°W and 60°W.

On the charts distributed over radiofacsimile by NMC and NMF, the 5640-meter height contour is enhanced in bold. Some basic rules of thumb used by marine meteorologists concerning the 5640 contour and 500 mb wind maxima are as follows:

– In wintertime the 5640 contour is an excellent indication of the southern extent of surface winds of force 7 westerlies or greater. In summer the 5640 height contour is more representative of force 6 surface westerlies.

– The surface storm track is usually 300 to 600 nautical miles north and parallel to the 5640 height contour.

– Fronts (cold fronts, in particular) and surface storm centers move at approximately ⅓ to ½ the 500-mb wind speed.

– The surface wind speed, especially in the west to

southwest quadrant (in the cold air) of a surface low is approximately 50 percent of the 500-mb wind speed.

Long Waves—Short Waves

If you could look at a time lapse movie loop of the 500-mb height contours over the Northern Hemisphere for a year, you would see a westerly circulation undulating northward and southward as what appear to be waves of troughs and ridges pass around the globe. The bigger waves appear to stand still or move slowly for a period of time and then either break down or move westward. When a larger wave moves westward, it is said to retrograde. The smaller waves move quite rapidly from west to east and tend to enhance or flatten as they pass through the larger waves.

The bigger waves are called long waves or long wave troughs and have a wavelength between 50 to 120 degrees of longitude and number from approximately three to seven around the Northern Hemisphere. These waves are responsible for the overall weather pattern or storm track. For example, prolonged drought or excessive storminess over an area is a result of the long wave pattern.

The long wave pattern tends not to fluctuate significantly for a period of 10 days or more. It can be difficult to pick out the long waves on the mercator projection charts distributed on radiofacsimile over NMF and NMC. This is due in part to the type of projection and extent of the area covered by these charts. A hemispheric chart projection of the mean 500-mb pattern for a period of several days is more useful for this purpose.

The smaller wave troughs that travel rapidly in the westerly flow are called short wave troughs or simply short waves. Short waves are associated directly with specific low pressure systems. They tend to have a life cycle of less than a week and rotate through the longer wave troughs. Their size tends to be on the order of 1000 to 2500 kilometers in scale.

The long waves and short waves interact like wind waves and swell. When in phase, a wind wave tends to enhance the swell making a significantly higher amplitude wave. When out of phase, the wind wave will tend to dampen or flatten the swell. Similar interactions occur in the atmosphere. When in phase, short waves help to enhance the longer wave pattern and are themselves enhanced or gain amplitude (this results in stronger surface lows). When out of phase, the short waves can dampen the long wave pattern and in turn their amplitude can be reduced (flattened).

Short Waves and Surface Lows

Let's take a look at the 500-mb and surface pressure patterns associated with a developing Atlantic low pressure system in the fall of 1994. The four panels 24 hours apart (Figure 2) show the development of a short wave trough (dashed line) and surface cyclone as they move off North America in strong west to east or zonal flow. The low then strengthens to a storm over the central North Atlantic.

In the first frame the 500-mb short wave trough is still west of the Great Lakes with the 1004-mb surface low over southeastern Ontario. For the development of a mid-latitude low pressure system, it is necessary for the short wave trough axis in the vertical to tilt back toward cold air (lower heights) with height. A typical distance is a quarter wavelength separation between the surface low and 500-mb trough at the early stages of development. You can see that the surface low is approximately half way between the 500-mb trough axis and the 500-mb ridge over eastern Canada— a quarter wavelength.

Twenty-four hours later, the short wave trough is over the Canadian Maritimes with a 996-mb surface low just crossing the coast of Newfoundland. The 500-mb short wave has flattened as it crosses over the top of the ridge to the south. The surface low has deepened 8 mb over the past 24 hours and the distance between the 500-mb trough axis and surface low has closed by about half the original distance. To indicate that this low is expected to deepen explosively over the next 24 hours, the forecaster has written the word "bomb" along the expected track of the low. In the future the Marine Forecast Branch will refer to lows deepening 24 mb in 24 hours as "rapidly intensifying" as opposed to "bombs."

In the third panel explosive deepening has indeed taken place. The surface low has deepened 26 mb over the past 24 hours. The 500-mb short wave trough has amplified (become more U or V shaped or extended north to south). We no longer have just a 500-mb trough but now have a 5167-meter low center just to the west of the surface low. The upper-level low is beginning to "close off" meaning height contours are beginning to encircle the low at 500 mb. The closing off of the 500-mb low indicates the closed circulation has grown with height from the surface to 500 mb. Closing off is a good indication that the surface low is beginning to slow. There is still some tilt of the trough to the west suggesting that the surface low will still deepen a little more.

In the last frame the surface low and 500-mb low are vertically stacked with little or no tilt of the upper-level trough. This indicates that the atmospheric column has become more homogeneous in temperature and moisture content. The surface low has matured (968 mb at 1200Z) and is beginning to fill or weaken. A well defined closed circulation now extends to greater than 500 mb.

In this sequence we have seen three stages in the life cycle of a short wave trough. First is the developing phase where the 500-mb short wave trough lags behind the surface low and amplifies with time. The tilt of the trough axis in the vertical decreases with time and the surface low deepens. The second or closing off phase is shown in panel C as height contours begin to encircle the newly formed 500-mb low and close off the vortex. The circulation has become closed from the surface to 500 mb and the surface low slows its forward motion. In the mature phase, the 500-mb low is vertically stacked above the surface low. There is no more deepening and the cyclone begins to fill.

To summarize, this low pressure system in 72 hours moved from the Great Lakes to 20°W and deepened 36 mb. The rapid speed of motion was a direct result of the 500-mb flow being west to east or zonal.

Behavior of Short Wave Troughs

Let's follow the 500-mb wind maxima through the life of two short wave troughs as they interact. The 500-mb and surface analyses for every 12 hours from 1200Z October 12 to 0000Z October 15, 1994 are shown for this mid Pacific development in Figure 3.

At 12Z October 12, a benign looking 1010-mb low can be seen at 33°N, 176°E with a weak short wave 500-mb trough at approximately 172°E (there is some tilt with height, so further deepening is expected). Upstream, south of Kamchatka, is a moderate northwest flow to 65 knots and a fairly flat short wave trough (second dashed line) along 163°E. However, energy at 500 mb is poised to dig southeastward from the second short wave toward the 1010-mb low. Without the 500-mb chart one would not expect much in the way of deepening of this surface low.

By 00Z October 13, the two short waves have begun to phase as indicated by the two dashed lines beginning to line up and have amplified over past 12 hours (become more V or U shaped). There is also some short wave ridging (upside down U curvature of the height contours) to the east as indicated by the zigzag line. The surface low has deepened 10 mb— nearly 1 mb per hour during the past 12 hours.

Twelve hours later the surface low has deepened another 15 mb to 985 mb and the pressure gradient has dramatically tightened in the northwest quadrant of the low. Storm force winds should be expected in this region. At 500 mb the wind maxima has now spread to the east of the trough. An 80-knot maxima exists in the northwest flow along 40°N. The trough axes are lined up as the two short waves are now phased.

At 00Z October 14, the open trough at 500 mb has closed off a 5436-meter low— a circulation now extends up to 500 mb. The 500-mb wind maxima continues to grow to the east of the storm as the low moves slowly northeastward. The low is now vertically stacked and has nearly completed its deepening. One ship observed a 50-knot northeast wind north of the storm system.

By 12Z October 14, although the 500-mb low is at 5416 meters, the closed contours have opened up. The 500-mb low is lifting northeastward while the surface low is elongated toward the northeast as indicated by a second low shown near the intersection of the warm and cold fronts. The wind maxima at 500 mb is evenly distributed east and west of the 500-mb trough but is growing on the east side, so the 500-mb low is beginning to open up and lift out. Twelve hours later the 500-mb low has opened up and dissipated. The 500-mb wind maxima to the west of the system is gone and the bulk of the wind energy is now east of the northeastward-pointing short wave trough axis. The surface low is elongating northeastward— the direction the toward which the strongest 500-mb winds are blowing.

In review, the greatest deepening in the surface low took place during the first three time periods as the two 500-mb short wave troughs phase, and the strong wind maxima begins to extend around the base of the 500-mb short wave trough. The cyclone is vertically stacked at 00Z October 14 with the closed 500-mb low right over the surface low and wind maxima continuing to strengthen east of the 500-mb trough axis. Little or no deepening should be expected after this point. In the final two frames, we see the wind maxima weaken west of the system and strengthen to the east of the 500-mb trough axis, the closed 500-mb low opens up to a trough and the surface low begins to weaken and elongate northeastward. This sequence is fairly typical for the formation of a low and evolution of the 500-mb trough and associated wind maxima.

500 Millibar Patterns

Now that we have gone over the behavior of 500-mb short wave troughs and surface cyclones, let's take a look at some typical 500-mb flow patterns.

Zonal Pattern

Rapid west to east flow where the 500-mb

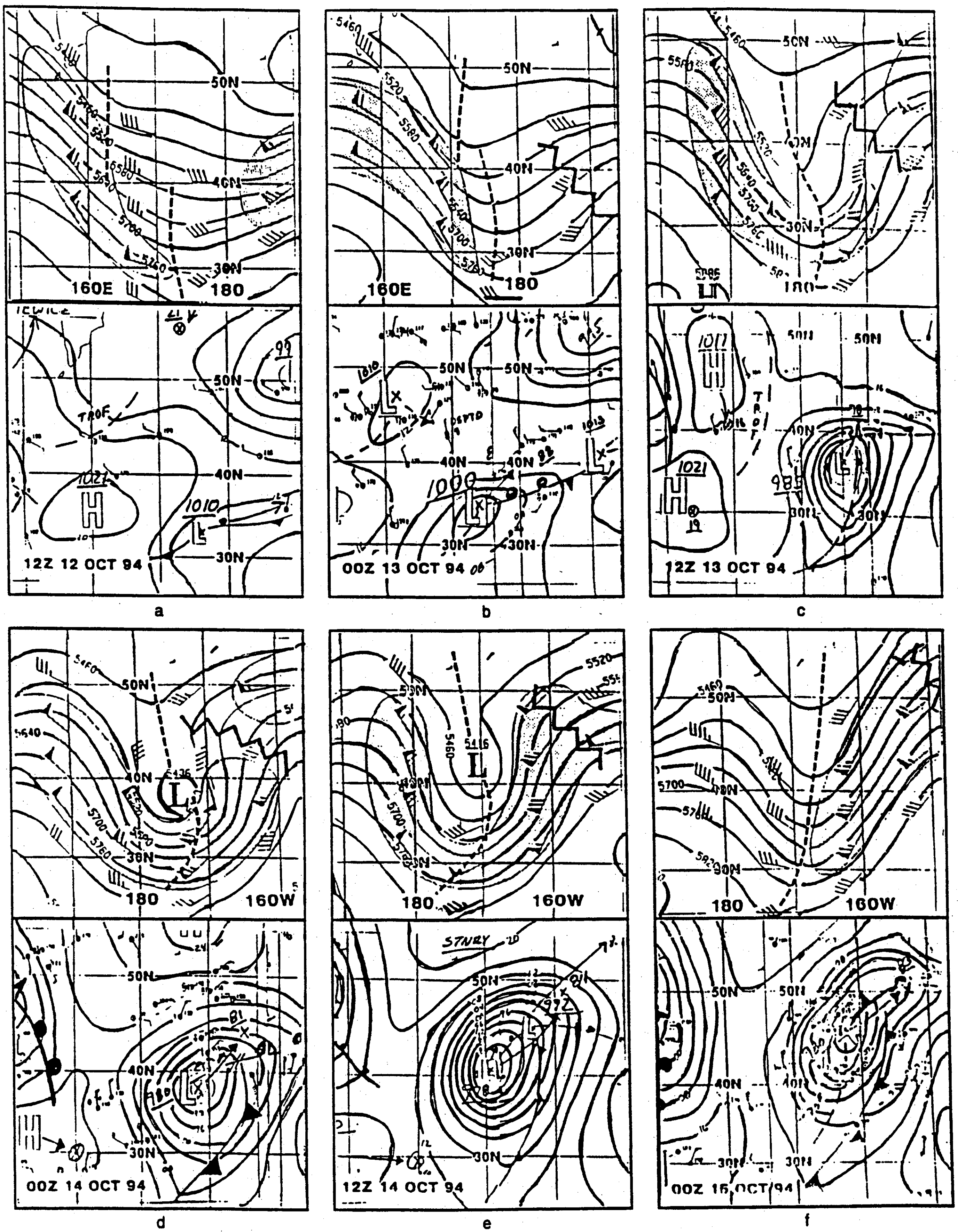

Figure 3. Six panel diagram showing 500–mb and surface pressure analyses for: (a) 1200Z October 12, (b) 0000Z October 13, (c) 1200Z October 13, (d) 0000Z October 14, (e) 1200Z October 14, and (f) 0000Z October 15, 1994.

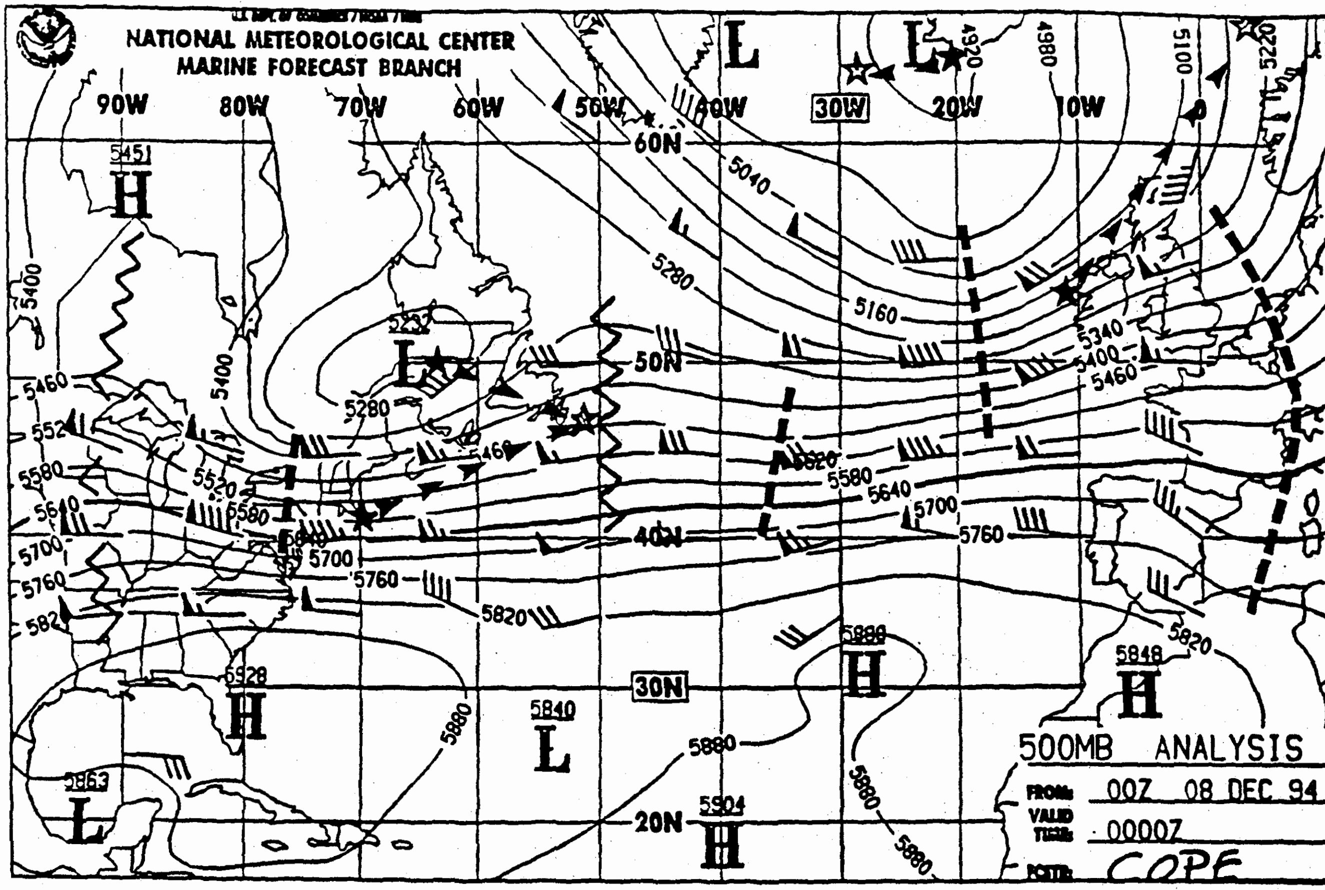

Figure 4. 500 mb analysis for the North Atlantic for 0000Z December 08, 1994 showing a zonal pattern. Short wave troughs and ridges are indicated with dashed and zigzag lines, respectively. Positions and tracks for surface lows are as indicated in figure. 1.

height contours are aligned west to east is called zonal flow (see Figure 4). Any short waves embedded in zonal flow tend to move rapidly from west to east. It is not unusual to see surface lows or fronts move 35 to 50 knots. A good rule of thumb: **a low or front embedded in zonal flow in winter will move, on average, between 30 to 50 percent of the 500-mb wind speed.**

In Figure 4 westerly flow at 500 mb extends from central North America across the Atlantic to western Europe with a 90-knot maxima over Ohio and near 50°N, 20°W. Fronts embedded in these areas may move as rapidly as 40 to 45 knots. Positions of surface lows are indicated with a filled-in star; 24-hour forecast positions valid at 0000Z December 09 are indicated by an open star with the 24-hour low track shown by arrowheads.

Zonal flow patterns tend to be unstable and short-lived. They often break down into a more amplified pattern fairly rapidly. When a transition from a zonal to a more amplified or meridional pattern is taking place, a strong surface storm will usually develop. The 500-mb chart shown in Figure 4 is 2½ days earlier than the more amplified pattern shown in Figure 1. The surface low center off the New England coast in Figure 4 moved east northeastward at nearly 30 knots to southeast of Newfoundland where it merged with an older low (nearly vertically stacked) located over the Gulf of St. Lawrence. The resultant low strengthened rapidly to 975 mb by 0000Z December 09 and the 500-mb pattern was amplified.

Another low embedded in strong 500-mb southwesterlies off Ireland, moved northeastward at 35 knots across Scotland to the Norwegian Sea. A third low nearly vertically stacked under the closed 4891-meter 500-mb low off Iceland drifted west towards 30°W.

Notice two distinct ribbons or streams of flow. The dominant flow is west to east from North America to Europe. The second stream drops southeastward from Greenland and merges just west of Europe with the more southerly stream. Merging streams create areas of constricted height contours, generating higher 500-mb wind speeds and strong temperature differences below 500 mb (strong fronts). Think of this as the northern stream supplying very cold air and southern stream supplying relatively moderate warm air and moisture. It is not unusual to see as many as three streams at 500 mb.

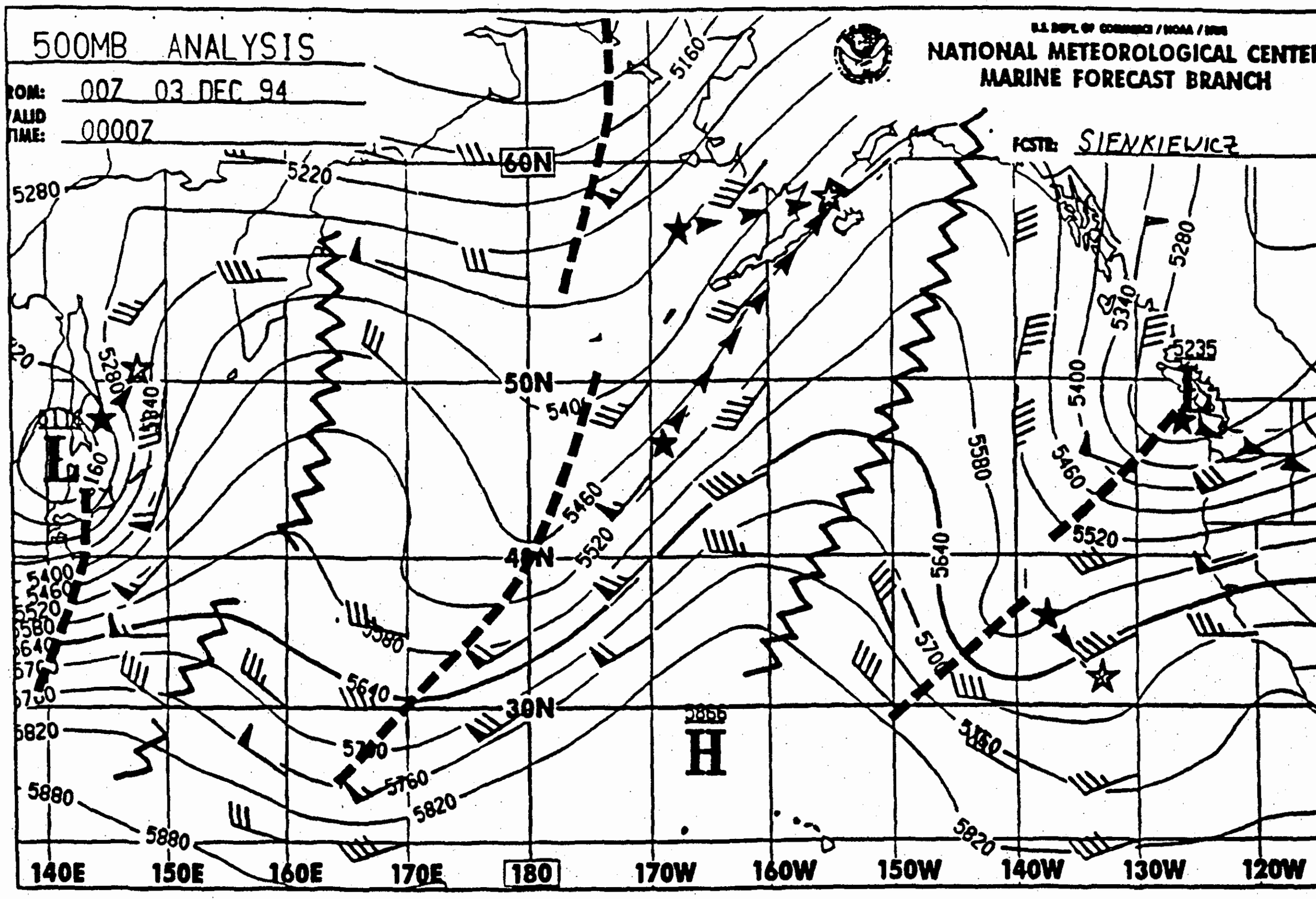

Figure 5. The observed 500-mb chart is for the North Pacific at 0000Z December 03, 1994 and shows a meridional pattern. Meridional patterns tend to move cold air south and warm air north.

Meridional Pattern

In a meridional pattern the contours have more amplitude (north–south orientation) than in a zonal flow (see the example from the North Pacific in Figure 5). Meridional patterns tend to move cold air south and warm air north. Surface lows and 500–mb short waves will move more toward the north or south than in a zonal pattern (along a meridian). Look at the 24–hour tracks in this example. The surface low at 47°N, 169°W moved northeastward at 30 knots to just off Kodiak Island. The low and short wave trough west of California moved southeastward. The surface low, associated with a closed low north of Japan, moved slowly northeastward. A large ridge extends from Alaska to west of Hawaii and northerly flow east of the ridge brings cold air southward from interior British Columbia and Northwest Territories out over the waters west of the Pacific Northwest. Southwesterly flow is moving warm moist air from south of 30°N near 170°E northeasterly toward Alaska.

The concept of different streams can easily be seen on this chart. East of Japan the northern stream weakens as it moves over a ridge along 160°E. The southern stream is stronger west of 170°W and less amplified than the northern stream. Farther east the northern stream is stronger in the northerly flow east of 140°W with a weaker southern stream trough near 35°N, 140°W.

The stream concept is important because the interaction between short waves embedded in different streams and in particular where the short waves phase together are areas for potentially significant surface low development.

Remember that the 500–mb field is in motion. Therefore, it is a good idea to look at the 500–mb forecasts to see how the pattern is expected to evolve. It is not unusual to have a progressive meridional pattern where short wave troughs and ridges, although they are amplified, continue their eastward progression. In the fall of 1994, both the Atlantic and Pacific had strong, progressive meridional patterns.

Blocking Pattern

A high amplitude ridge that blocks the west to east progression of the westerlies is aptly named a

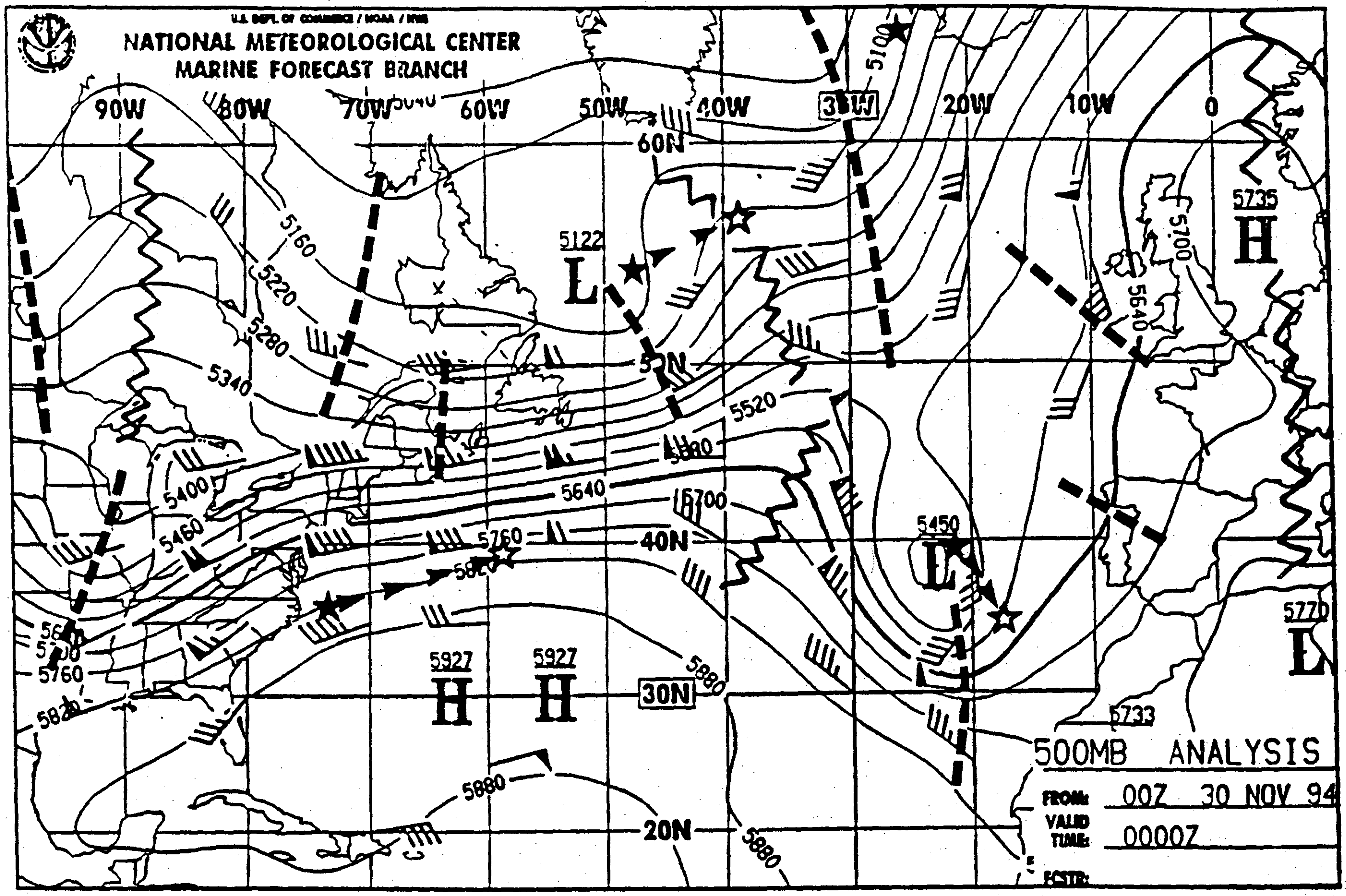

Figure 6. The 500-mb chart for the North Atlantic for 0000Z November 30, 1994. This chart shows a blocking pattern over Europe and the extreme eastern North Atlantic. The split in the westerlies can be seen at 50°N, 25°W.

blocking ridge. Figure 6 shows a blocking pattern with a large ridge blocking the westerlies over western Europe and the eastern North Atlantic.

In a blocking pattern, short waves will be steered northward or northeastward over the blocking ridge. If the amplitude of the ridge is large enough, then short wave troughs approaching from the west may try to undercut or drive under the block. This undercutting helps to set up a split in the westerly flow to the west of the blocking ridge and eventually helps to break down the block.

In Figure 6 the split in the westerlies can easily be seen near 50°N, 25°W. The 5450-meter closed low near 38°N, 24°W is a result of the westerlies trying to undercut the blocking ridge. Due to the strength of the northwest flow to the west and northwest of the 500-mb low, the low is said to be "digging" to the southeast. Thus the surface low and 500 mb both move southeastward.

Closed lows that form to the west of a blocking ridge and dig southeastward tend to be fairly strong and it is not unusual to have surface winds at 45 to 50 knots to the west and southwest of the surface low.

Two lows near Iceland and south of Greenland are moving northeastward and north northeastward due to the blocking ridge to the east. Blocks may last 10 days or more.

Cutoff Lows

If a 500-mb pattern becomes amplified enough then it is possible for a low to form on the southern boundary of the westerlies and become "cutoff" as shown in Figure 7. The closed circulations associated with the lows over eastern Kansas, the mid Atlantic (40°N, 45°W) and Spain are cutoff from the main stream of zonal westerlies north of 55°N. Weak ridging separates the higher latitude westerlies from the three cutoffs. Cutoffs tend to remain stationary and persist for several days. They may be accompanied at the surface by strong winds (in particular, in the north to northwest flow to the west of the developing low), showers, and thunderstorms. Also, it is not unusual to have strong easterlies to the north and northeast of the center due to the strong pressure gradient between the cutoff and strong surface high to the northeast or east. Cutoffs either gradually weaken or are picked up by the higher latitude westerly flow when the pattern amplifies again and the capping

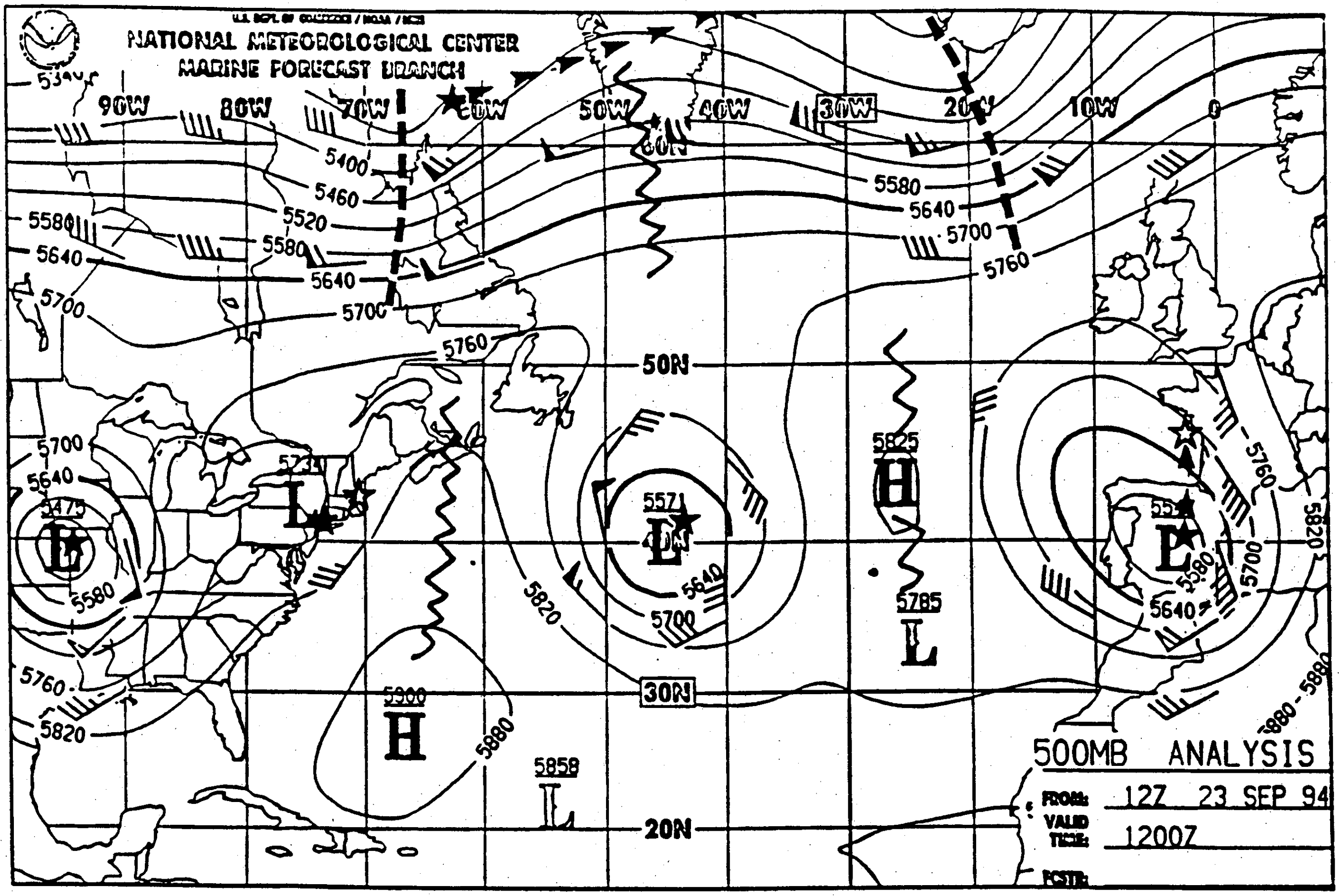

Figure 7. This 500-mb analysis for the North Atlantic at 1200Z September 23, 1994 shows three cutoff lows. These systems play a significant role in any surface features beneath them. Cutoff lows tend to persist and remain stationary for several days. They are often accompanied by strong surface winds to the west of developing surface lows.

ridge breaks down. They tend to occur most in the spring and fall when the westerlies migrate north and south, respectively.

These are just samples of several basic 500-mb patterns. At any given time a variety or combination of patterns may exist over an ocean basin. It is not unusual in the Pacific to have strong zonal flow over the western Pacific with a meridional or even a blocking pattern over the eastern Pacific.

Derivation of the 500-mb Height Field

You might wonder how the 500-mb height field is determined over the oceans. Globally, each day at 0000 and 1200Z over the continents, at selected island sites, and on several specially equipped merchant ships, weather balloons are launched to sample the vertical structure of the atmosphere. One of the mandatory levels at which the height, wind, temperature, and humidity data are measured is the 500-mb level. Although balloon data is scarce over the oceans, ship surface weather observations, commercial aircraft reports at jet stream level and satellite derived moisture profiles and wind estimates are all combined and quality-controlled to help determine the initial state or three dimensional structure of the atmosphere over the oceans. In addition, 6-hour forecasts from the operational computer forecast models are used as a first estimate as to the initial state of the atmosphere. Think of all the global observations being used to tweak the previous computer model forecasts in the right direction, which makes for relatively consistent model forecasts. Note that your ship observations have an impact in determining the three dimensional structure of the atmosphere.

The highly sophisticated operational forecast computer models that simulate the atmosphere are then run using the analysis determined from a combination of the observed data and previous model forecasts. The 500-mb height fields from the analysis process and 48- and 96-hour forecasts from the NMC Global Spectral Model are transmitted via radiofacsimile. Studies have shown that 500-mb forecasts tend to be more accurate than surface pressure forecasts.

The Bottom Line

One way to use the 500-mb charts is to set up

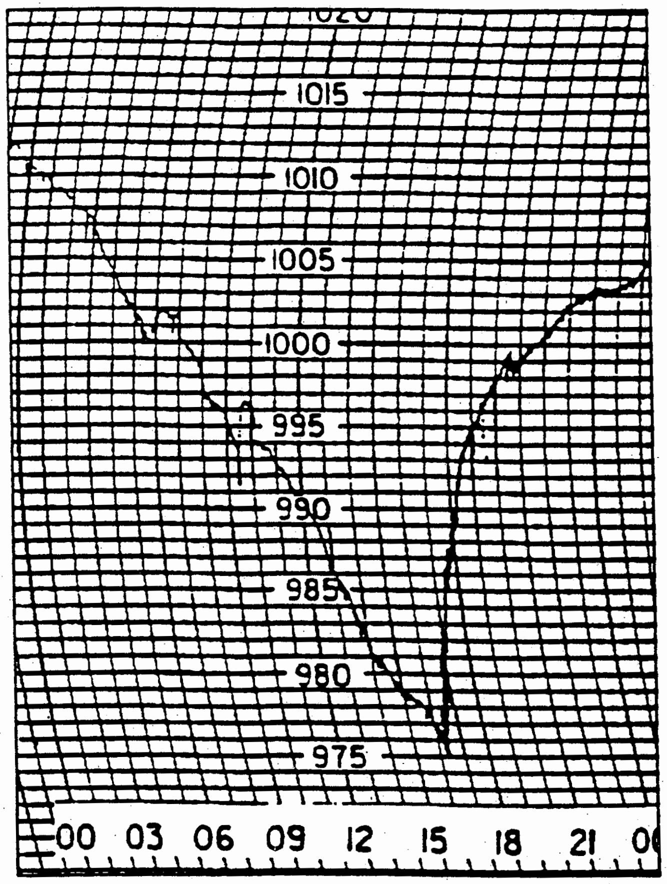

Figure 8. Barograph trace from President Washington enroute from Oakland, CA to Guam for October 13, 1994. Its pressure was 10 mb lower than was analyzed on the 12Z chart.

a display of both surface and 500-mb analyses along with the 48- and 96-hour forecasts in the chartroom or on the bridge.

You may want to outline the wind maxima associated with each trough expected to affect you and gain experience that way. Is the wind maximum to the west, evenly distributed or to the east of the short wave trough? In other words will the trough dig, lift out, or just stay steady state in the overall flow? Take a look at the previous forecasts. Are there any big changes from the earlier series of surface and 500-mb analyses and forecasts to the current series?

Remember that the 500-mb pattern and specific short waves are linked and associated with the motion and life cycle of surface storm systems. Look at the progression of the 500-mb pattern from analysis time to 48 hours to 96 hours. Is the pattern becoming more meridional, zonal, or blocked over the next 4 days? Next look at specific short waves and associated surface features that will be affecting you over the next several days. Think of the examples in the article. You may want to mark the position of surface lows on the 500-mb chart to see how the surface low relates to the 500-mb short wave trough (does the trough tilt with height or is the system vertically stacked).

The bottom line is that through some experience on your own and with knowledge gained through this article and elsewhere you can begin to see through repetition how the 500-mb pattern and surface pressure fields are linked. Also, pattern recognition will give you a better idea as to how and why storm systems develop and move the way they do. Talking to Port Meteorological Officers, Marine Forecasters and taking courses at schools like MITAGS all help you to gain experience in using the 500-mb chart.

A yacht delivery captain was visiting the Marine Forecast Branch at NMC on the afternoon of October 12th, 1994. He was shown a 3-day loop on a computer workstation of the surface pressure and wind forecasts in 6-hour increments of the development of the storm shown in Figure 3. He was amazed that in 24 hours (by 12Z on the 13th) storm conditions were forecast to develop so rapidly out of what looked like a benign low. He was then shown the 500-mb height field forecasts for the same period. As we reviewed each forecast time step, it was explained that at 500 mb you could see the ingredients for rapid development (strong northwest flow at 500 mb, phasing of two short waves, and sharp rapid amplification of the 500-mb short wave) before you could see them at the surface. The development of the storm was no surprise, however, even the computer model forecast was too slow at deepening the storm system.

American President Lines' ***President Washington*** went through the center of this low at approximately 1630Z on October 13. Its barograph trace (Figure 8) showed a central pressure of 975 mb with an extreme pressure rise to the west of the storm center. The 975-mb central pressure was 10 mb deeper than the 985 mb indicated on the 12Z October 13 analysis. The ***President Washington*** also experienced 55-knot winds to the west of the occluded front shown at 12Z October 13. While 500-mb analyses and forecasts don't always provide the answer, a much clearer picture of the surface weather conditions is presented with a knowledge of conditions at both levels.

No matter how you receive weather information a basic understanding of 500-mb patterns and relationships to the surface pressure field will help you make more educated decisions for a safe and economical transit.