Unified Surface Analysis Manual

Weather Prediction Center
Ocean Prediction Center
National Hurricane Center
Honolulu Forecast Office

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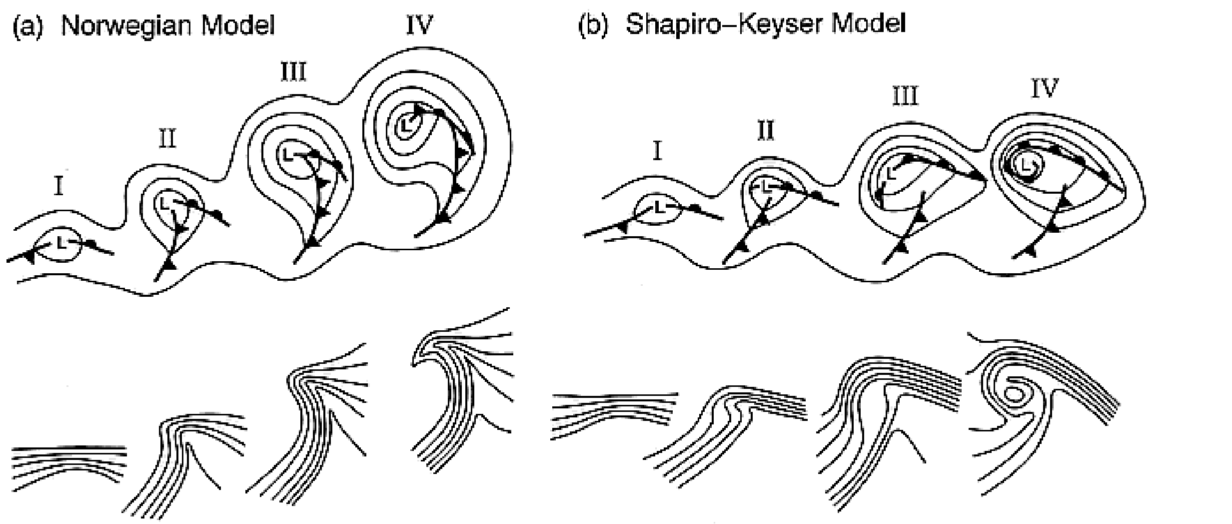
Chapter 1:
Surface Analysis – Its History at the Analysis Centers

1. INTRODUCTION

Since 1942, surface analyses produced by several different offices within the U.S. Weather Bureau (USWB) and the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) were generally based on the Norwegian Cyclone Model (Bjerknes 1919) over land, and in recent decades, the Shapiro-Keyser Model over the mid-latitudes of the ocean. The graphic below shows a typical evolution according to both models of cyclone development.



Conceptual models of cyclone evolution showing lower-tropospheric (e.g., 850-hPa) geopotential height and fronts (top), and lower-tropospheric potential temperature (bottom). (a) Norwegian cyclone model: (I) incipient frontal cyclone, (II) and (III) narrowing warm sector, (IV) occlusion; (b) Shapiro–Keyser cyclone model: (I) incipient frontal cyclone, (II) frontal fracture, (III) frontal T-bone and bent-back front, (IV) frontal T-bone and warm seclusion. Panel (b) is adapted from Shapiro and Keyser (1990) , their FIG. 10.27) to enhance the zonal elongation of the cyclone and fronts and to reflect the continued existence of the frontal T-bone in stage IV. The stages in the respective cyclone evolutions are separated by approximately 6–24 h and the frontal symbols are conventional. The characteristic scale of the cyclones based on the distance from the geopotential height minimum, denoted by L, to the outermost geopotential height contour in stage IV is 1000 km.

The National Meteorological Center (NMC) created Northern Hemisphere Surface Analyses from 1954 to 1996 from the equator to the North Pole, including adjacent ocean areas. The Weather Prediction Center (WPC) and its predecessors have created North American Surface Analyses since 1942. The Ocean Prediction Center (OPC) and its predecessors have created surface analyses since the 1970s for the open waters of the Atlantic and Pacific Oceans, north of 18 degrees north. The Miami Weather Forecast Office and National Hurricane Center (NHC) composed surface analyses starting in 1942 for the waters of the Atlantic and much of the Pacific east of Hawaii between the equator and the latitude of 50^0 N. The Weather Forecast Office Honolulu (HFO) performed surface analyses for the waters of the Pacific Ocean across the tropical, subtropical, and mid-latitudes sections of the northern Pacific south of 50^0 N and the tropical and subtropical sections of the southern Pacific north of 30^0 S. The Anchorage Forecast Office (ANC) drew surface analyses for the northeast Pacific, eastern Asia, and the state of Alaska for many years. This led to a significant duplication of effort over portions of the Northern Hemisphere. Due to this redundancy, it was decided in 2001 that the various analysis centers would limit their analyses to their areas of responsibilities (AOR) and would combine the analyses from the other centers to create one seamless surface map for much of the Northern Hemisphere. This collaboration was intended to save each center time and concentrate more fully on their regions of expertise. By 2002, this plan went into place between NHC, OPC, and WPC, with HFO joining the collaboration effort in 2003.

The WPC contributes a surface analysis covering the area from roughly 30°N to 85°N latitude, including much of mainland North America, the Canadian Archipelago, and the Arctic Ocean. The Tropical Analysis and Forecast Branch (TAFB), part of the NHC, produces the surface analysis portion covering the tropical and subtropical regions from the equator northward to 31°N (except 30°N in the Pacific Ocean) from 20°E westward to 140°W, including overland areas of Florida, Mexico, South America, Central America, Africa, and the Caribbean. The HFO generates analyses between 140°W westward to 130°E in the northern Pacific south of 30°N. OPC produces a pair of analyses for the Atlantic and Pacific oceans that span from NHC's and HFO's boundaries northward to Eastern Asia, the Aleutians, Greenland, Western Europe, and the Mediterranean Sea. The two OPC analyses are split at the 105^0W longitude between their Atlantic and Pacific portions. All surface analyses are produced using the nAWIPS/Nmap2 system. The analyses include all synoptic-scale systems and isobars every 4 millibars (mb)/hectopascals (hPa), while mesoscale features are depicted in the data-rich contiguous United States (CONUS) and in other locations where data permits. Intermediate isobars (every 1-2 millibars/hectopascals) may be included in areas of weak pressure gradient in WPC, HFO, and NHC analyses. The usage of intermediate isobars is left to the analyst's discretion based on the pattern and value added to the analysis; aesthetics also may play a role. All surface analyses are saved, exchanged, and disseminated using a vector graphic format (VGF). The NWS unified surface analysis involves extensive collaboration between OPC, NHC, WPC, and HFO (collectively referred to as the analysis centers.)

A good surface analysis incorporates a variety of data sources to accurately depict the physical processes occurring in the atmosphere at analysis time. Examples of the data sources include surface observations (including ship, fixed buoy and C-MAN, as well as those over land), satellite data, ocean surface winds as measured by scatterometer (ASCAT/OSCAT), and model analysis fields. Surface analyses are subjective in nature, and even skilled analysts can show marked differences in their analyses (Uccellini et. al 1992). Through collaboration amongst the analysis centers, consistency with past analyses; and a review of the atmospheric models initializations, the Unified surface analyses provide NOAA's National Weather Service (NWS) customers and users with the best consensus and consistent "one NWS" surface analyses.

Chapter 2: Datasets available for creation of the Unified Analysis

1. COMMON DATASETS AVAILABLE TO SURFACE ANALYSTS

A. SURFACE OBSERVATION REPORTS

Surface observations are key to generating good surface analyses, although good surface analyses incorporate a variety of data sources to accurately depict the physical processes occurring in the atmosphere at that given time. The different analysis centers have varying levels of observations available with varying levels of timeliness after the synoptic hour. For example, the WPC has the densest dataset, with over 2000 METARs for the United States alone and an additional 50,000 sites available through the U.S. mesonet at the Global Systems Division (GSD), formerly known as the Forecast Systems Lab (FSL). Many of the METARs are in by H+0:05, with the military sites and Canadian sites becoming available by H+0:10. Synoptic observations and buoy reports from the Great Lakes, Atlantic, and Pacific coastlines can lag, but they are normally in by H+0:20. The other centers are not as fortunate. Ship observations and data buoys are a primary data source for OPC, NHC, and HFO, with a relatively complete suite of ship observations not available until between H+1:00 and H+1:30. Figure 1 is an example of a station plot with legends to decode present weather, wind direction and speed, pressure tendency and sky cover. Note: Sea-level pressure is plotted in tenths of mb/hPa, with the leading 10 or 9 omitted. For reference, 1013 mb is equivalent to 29.92 inches of mercury. Below are some sample conversions between plotted and complete sea-level pressure values:

410: 1041.0 mb
103: 1010.3 mb
987: 998.7 mb
872: 987.2 mb

Figure 1. Sample Station Plot and legends to decode present weather, pressure tendency, wind direction and speed and skycover.

There are three basic surface observation sets used at the Analysis Centers: METAR (from United States and Mexico land stations) observations, SHIP (which includes ships and buoys) observations, and SYNOP (international observations coded every 3-6 hours). For placing a surface front, cyclonic wind shear and the presence of a surface trough is essential. Placement of a front along a ridge line is considered impossible per the Margules equation (Byers 1959). According to Byers, steep frontal slopes are normally favored by a large wind difference and high latitude, which would imply weaker/broader discontinuities as one works towards the equator. This can be seen in real-time, particularly over the relatively warm tropical oceans areas such as the subtropical Atlantic from the Gulf Stream southward, Gulf of Mexico, and in the subtropical Pacific.

Fronts are defined to be at the leading edge of temperature/dew point gradients, so using tools based on the current observations such as 24-hour temperature change or 24-hour dew point change, with isotherms (lines of equal temperature) and isodrosotherms (lines of equal dewpoint) included, can be of great assistance. Over the lower 48 (contiguous United States, or CONUS), GEMPAK scripts can be run by the analyst using the RUC initialization, and comparing it to the initialization from 24 hours prior, to get 24 hour changes in temperature, dew point, and pressure in real-time.

Pressure change, during a 3 hour period as coded in the 5 group in METAR observations, is a useful tool in defining cold/occluded front passage, as they tend to lie at the leading edge of relative rise/ fall couplets. This can be seen in three patterns:

(1) Falling, then rising
(2) Falling, then falling less rapidly
(3) Rising, then rising more rapidly

Arctic/secondary fronts over the continent tend to display pattern (3), while most other cold fronts show pattern (1). If during times of diurnal pressure minimum, such as 4 am/pm local time, pattern (2) will reveal itself. Over the continent, where observation coverage is greater, locally strong pressure rises will be seen behind squall lines and outflow boundaries. It is easy to mistake an outflow boundary for a frontal zone. However, a large area of relatively similar rises and falls usually leads the analyst in the right direction for frontal placement. Over the oceans, ships are usually moving, and three-hour pressure changes can be a less reliable indicator of frontal passage.

Warm fronts are broader/less vertical boundaries and tend to show weaker signatures in the wind, temperature, and dew point pattern. However, a trough will usually help reveal a warm front's position, and an area of strong pressure falls will usually be seen near its location. Also, stratiform rain, depicted by light rain and drizzle, tends to lie on the pole ward side of warm/ stationary fronts, as well as long-lived outflow boundaries.

Tropical waves usually slope eastward with height and are associated with a maximum of low-level wind turning and convergence. Figure 2 shows their characteristic pattern in the low-level pressure and wind field (Riehl 1945.)

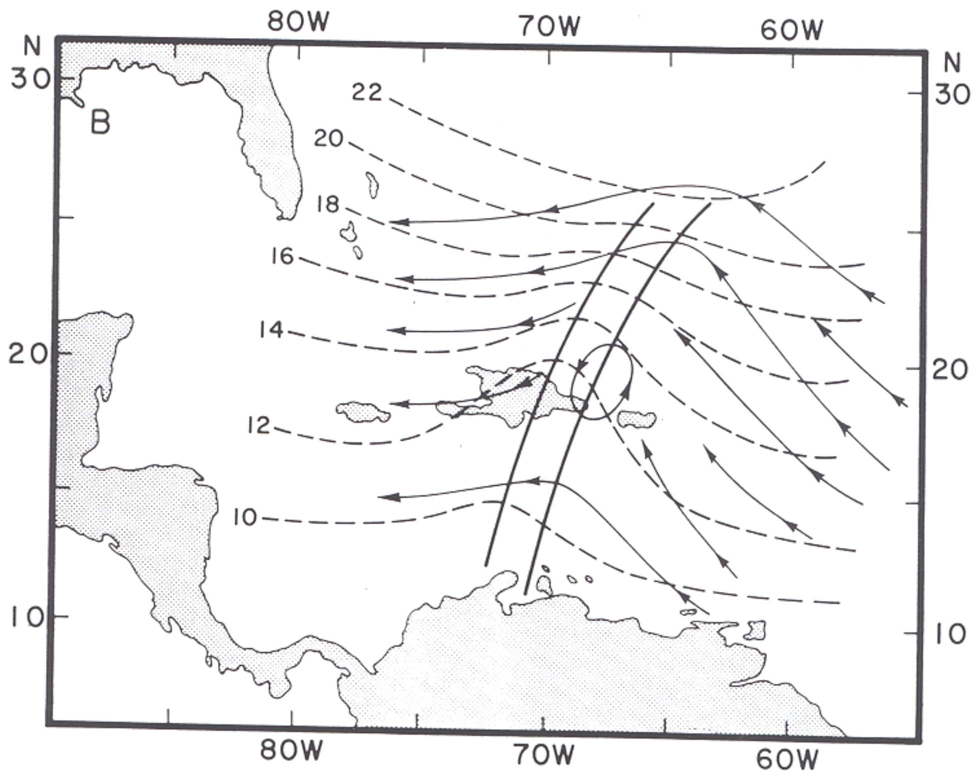


Figure 2. Characteristic pattern in the low-level pressure and wind field for tropical waves.

2. UPPER-AIR SOUNDINGS/CROSS SECTIONS

Looking for wind veering/backing with height can indicate warm/cold advection and indicate frontal passage. Soundings plotted in AWIPS can show temperature advection at each level over the past 24 hours, confirming cold frontal passage. Significant warm advection can indicate warm frontal passage. Parallel winds with height indicate proximity to a boundary, usually on the equatorward/warm side. In an upper air cross-section, fronts slope back into the cold air mass and lie at the leading edge of packing in the potential temperature surfaces. Tropical waves tend to slope back to the east with height, due to southwest winds aloft existing east of the tropical upper tropospheric trough (TUTT), a climatological feature of the central

Atlantic and Caribbean Sea, as well as the central Pacific. Anomalies in the wind from east-to-west (u-component of the wind vector) or from north-to-south (v-component of the wind vector) can be used to help find tropical waves in sounding time series from tropical locales. Figure 3 is an example from the middle of July 1995, showing a trio of waves emerging off the coast of west Africa.

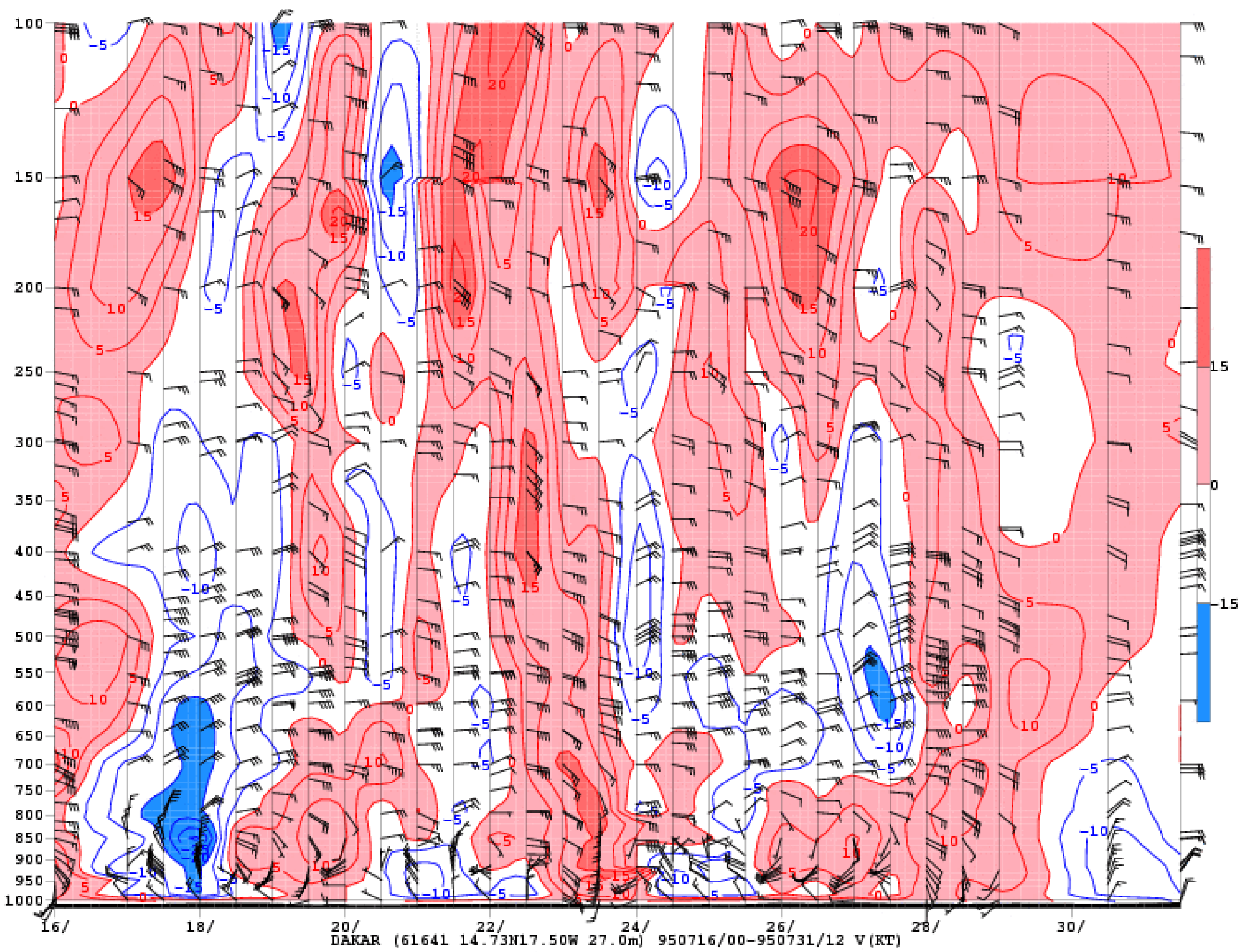


Figure 3. An example from mid-July 1995, showing a trio of waves emerging off the coast of west Africa.

Whether it is from a model-derived field or from a skew-T log-P diagram from an individual upper air site, a more in-depth understanding of the frontal situation can be gleaned from looking at information aloft. AWIPS software allows for cross-sections that can show frontal slope and where it intersects the surface in the theta (potential temperature) or theta-E fields. One must be careful in using individual upper air sites well back into the cold sector because topography can interfere with frontal progression downstream. Figure 4 is an example of a cross section that can be generated on the AWIPS software at the various analysis centers for use in a real-time surface analysis.

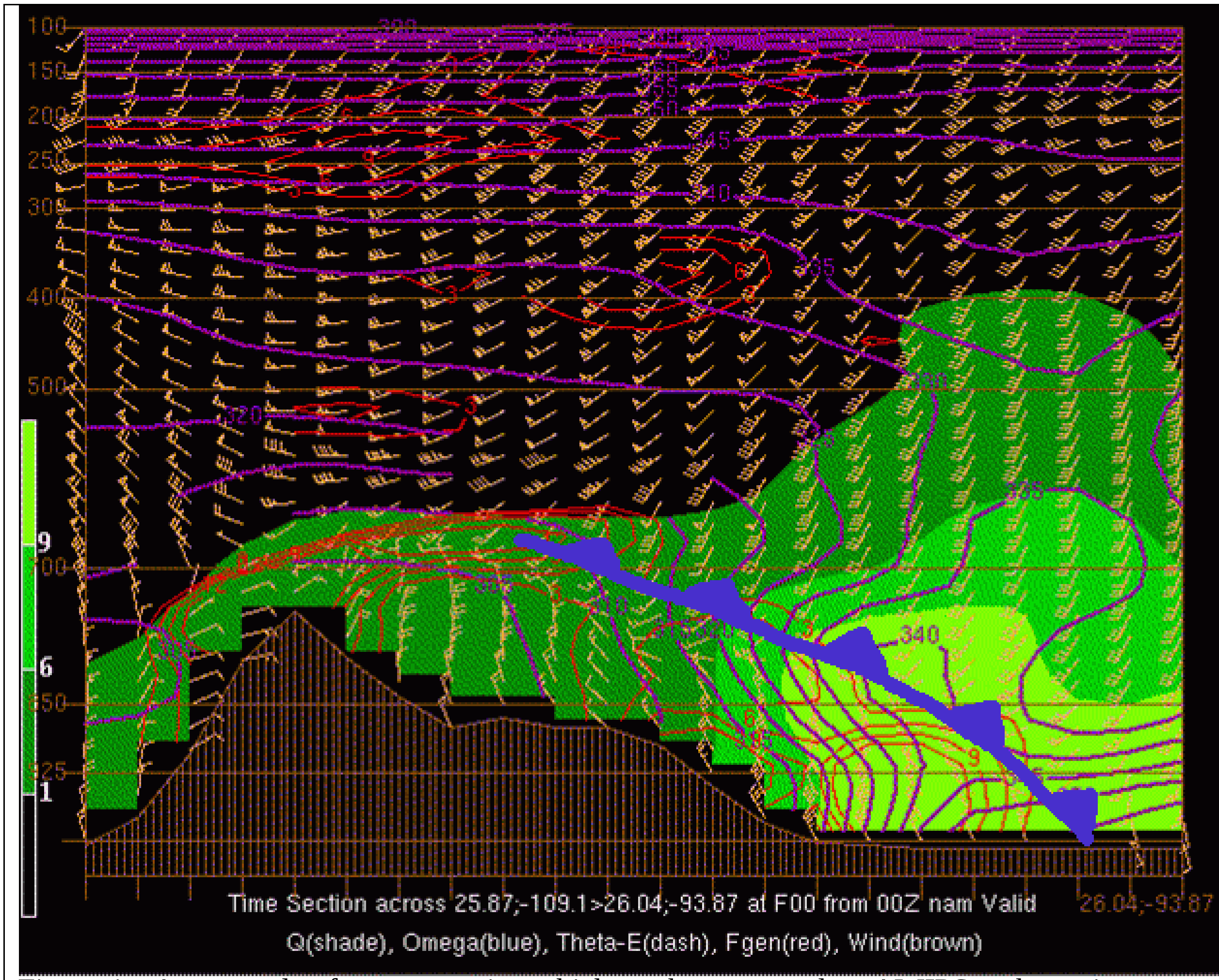


Figure 4. An example of a cross section which can be generated on AWIPS at the various analysts centers for use in real-time surface analyses. The position of the front is shown.

3. SATELLITE IMAGERY

Cold fronts usually are located at the back edge of low cloud lines at higher latitudes for two reasons. The first is due to strong westerly winds aloft near the frontal wave/point of occlusion, which shift the front aloft ahead of the main surface boundary (Bader et. al. 1995). The second is due to moisture overriding the surface boundary near its tail end which forces most of the cloudiness to its poleward side. Frontal ropes are especially useful when seen on visible imagery, but one must be careful not to confuse a frontal rope for an arc cloud, otherwise known as an outflow boundary. On infrared imagery, in the absence of clouds, the raw density discontinuity can be seen easily as a gradient in the shading (or color scale if enhanced.) Normally, drawing a frontal zone poleward of the jet (inferred as the northern edge of a streak of cirrus clouds) is to be avoided, to maintain proper three-dimensional structure with height. Exceptions are seen for features undergoing frontolysis (weakening), regions where strong winds aloft near a jet streak force the upper portion of the frontal zone past the surface front in question, and areas of significant terrain can hold up the frontal progression, such as western North America in the vicinity of the Continental Divide. Used in concert with other tools, satellite imagery can be quite helpful.

Tropical waves tend to slope to the east with height. When the wind speeds and directions are relatively constant with height then the convection is mostly center on the position of the wave. When easterly winds increase with height, most of the convection is to the west of the wave. When there are west to southwesterly winds aloft, most of the convection shifts to the east of the wave (Figure 5).

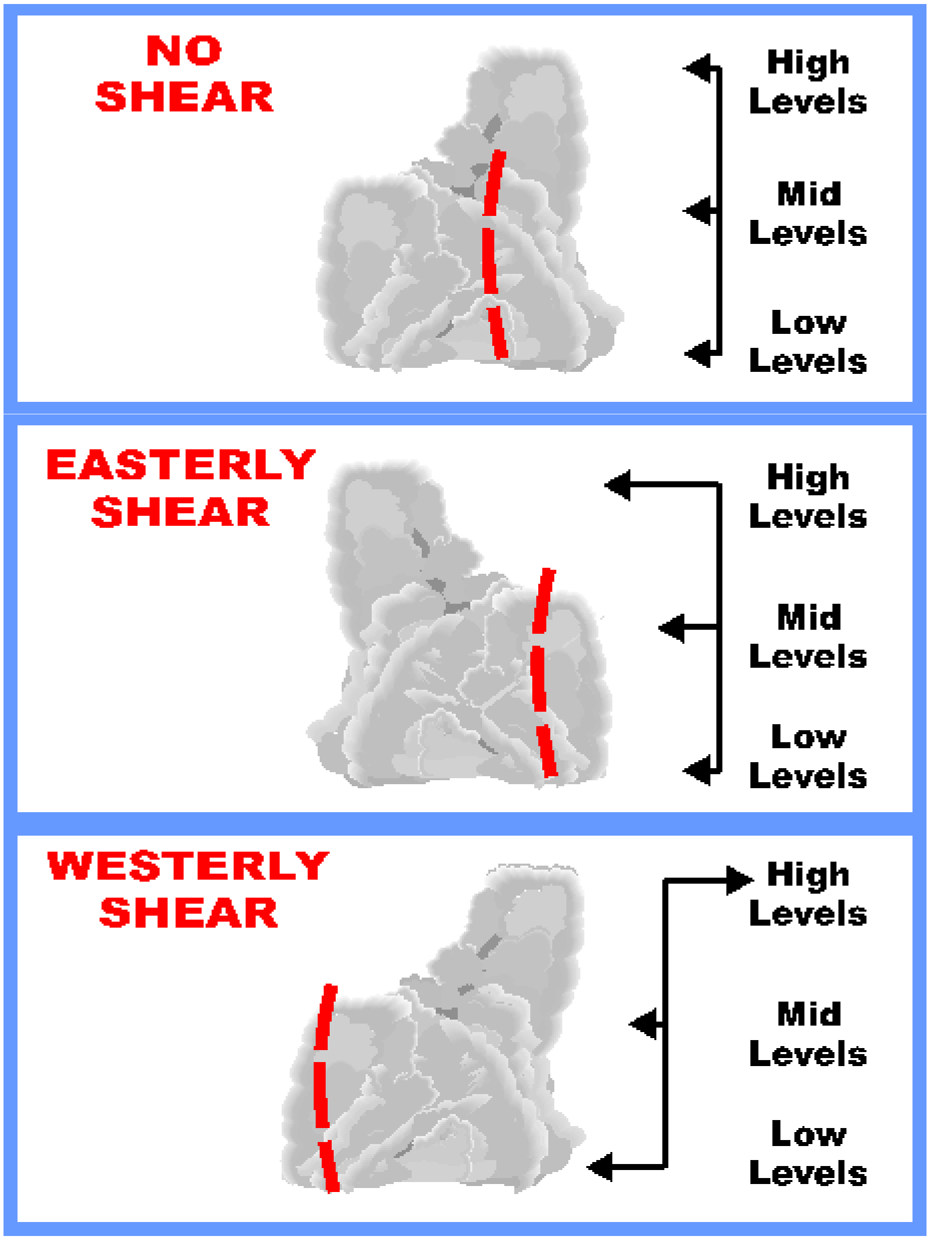


Figure 5. An idealized portrait of a tropical wave in relation to its thunderstorm activity under different shear conditions.

A. INFRARED SATELLITE IMAGERY

Infrared satellite imagery shows areas of temperature contrast quite well day or night, particularly over land masses, which cannot be caught by visible imagery. Figure 6 below is an example of a complex analysis across the southern Plains, where a cold front and a dryline were clearly shown in infrared imagery. In this daytime case, the warmer temperatures are shown by an increasingly purple hue. Surface observations are also shown for comparison.

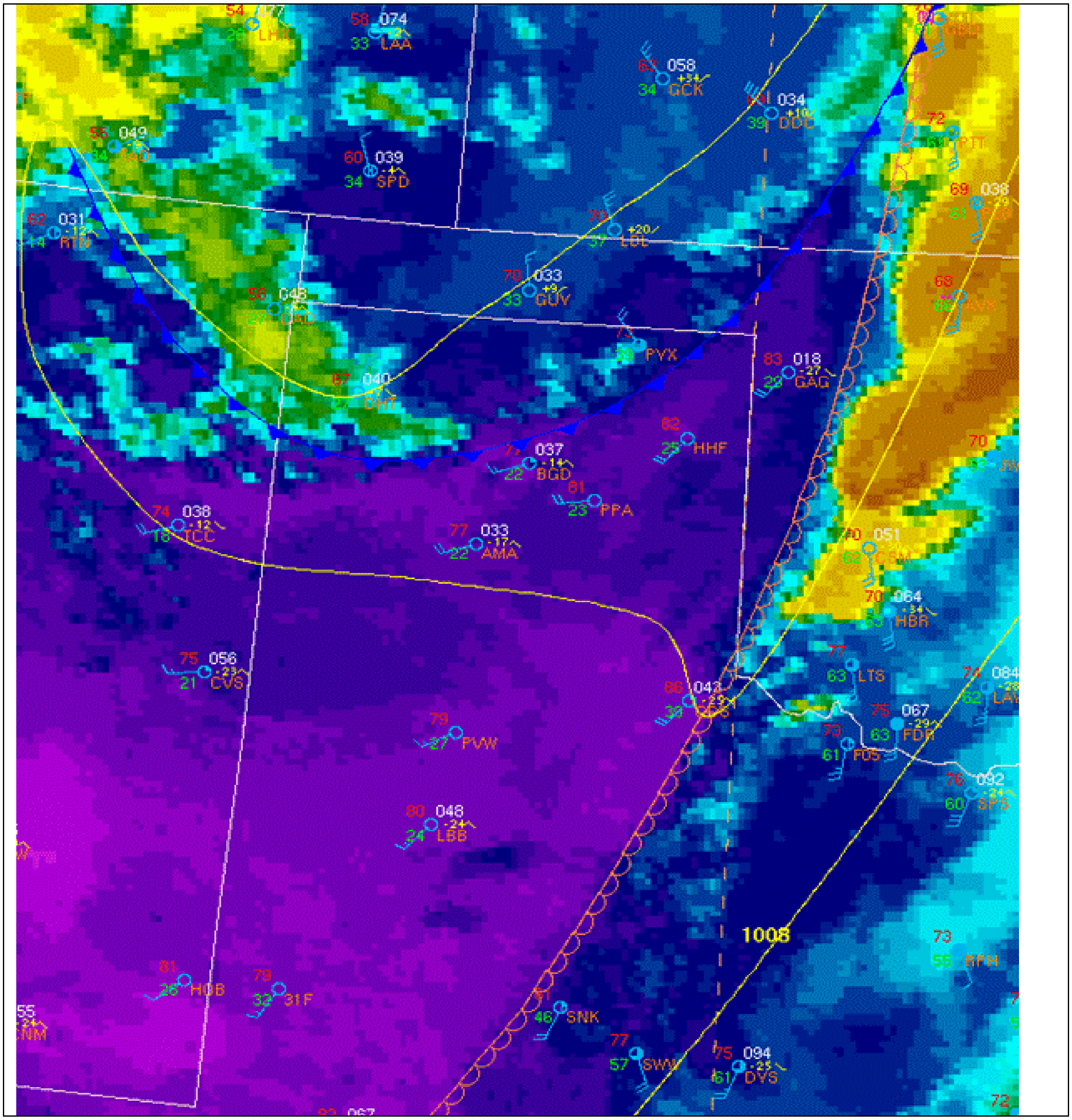


Figure 6. Surface analysis over the Southern Plains.

Figure 7 is an example from the Pacific Ocean, using a GOES-10 infrared image of a Pacific instant occlusion. GFS surface pressure field is in yellow while 1000mb-850mb thickness is in dashed green contours. Approximate locations of occluded, cold, warm, and developing cold (blue dashed) fronts are shown.

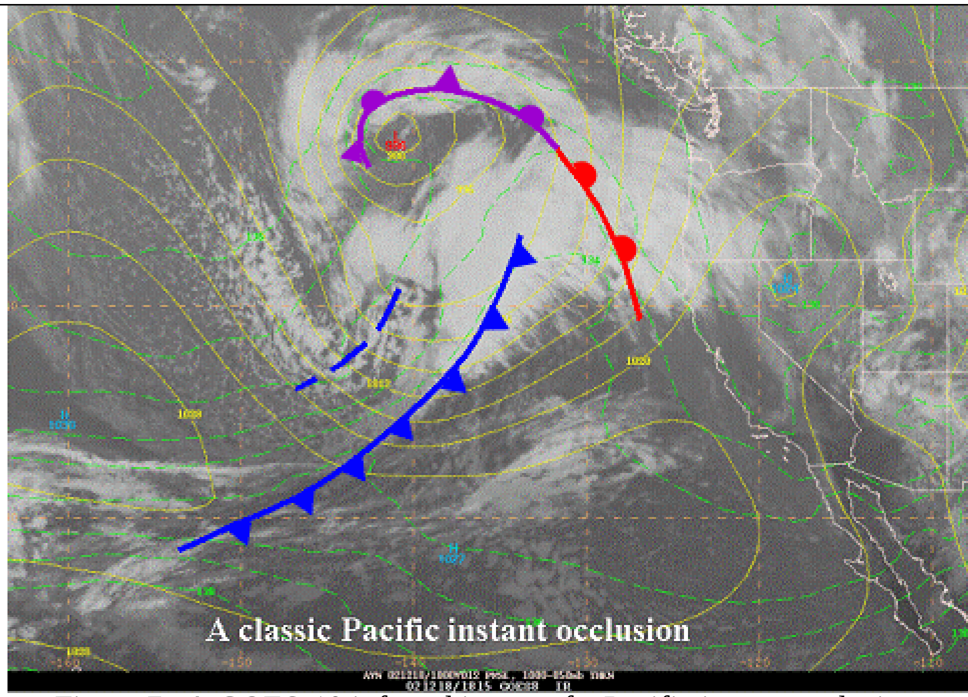


Figure 7. A GOES-10 infrared image of a Pacific instant occlusion.

B. VISIBLE SATELLITE IMAGERY

Figure 8 is an example of a case where visible imagery was quite helpful over the subtropical Pacific Ocean, with the surface observations included for comparison. Frontal ropes, such as the one seen below northwest of Hawaii, are extremely helpful in determining frontal placement, both over land and over sea.

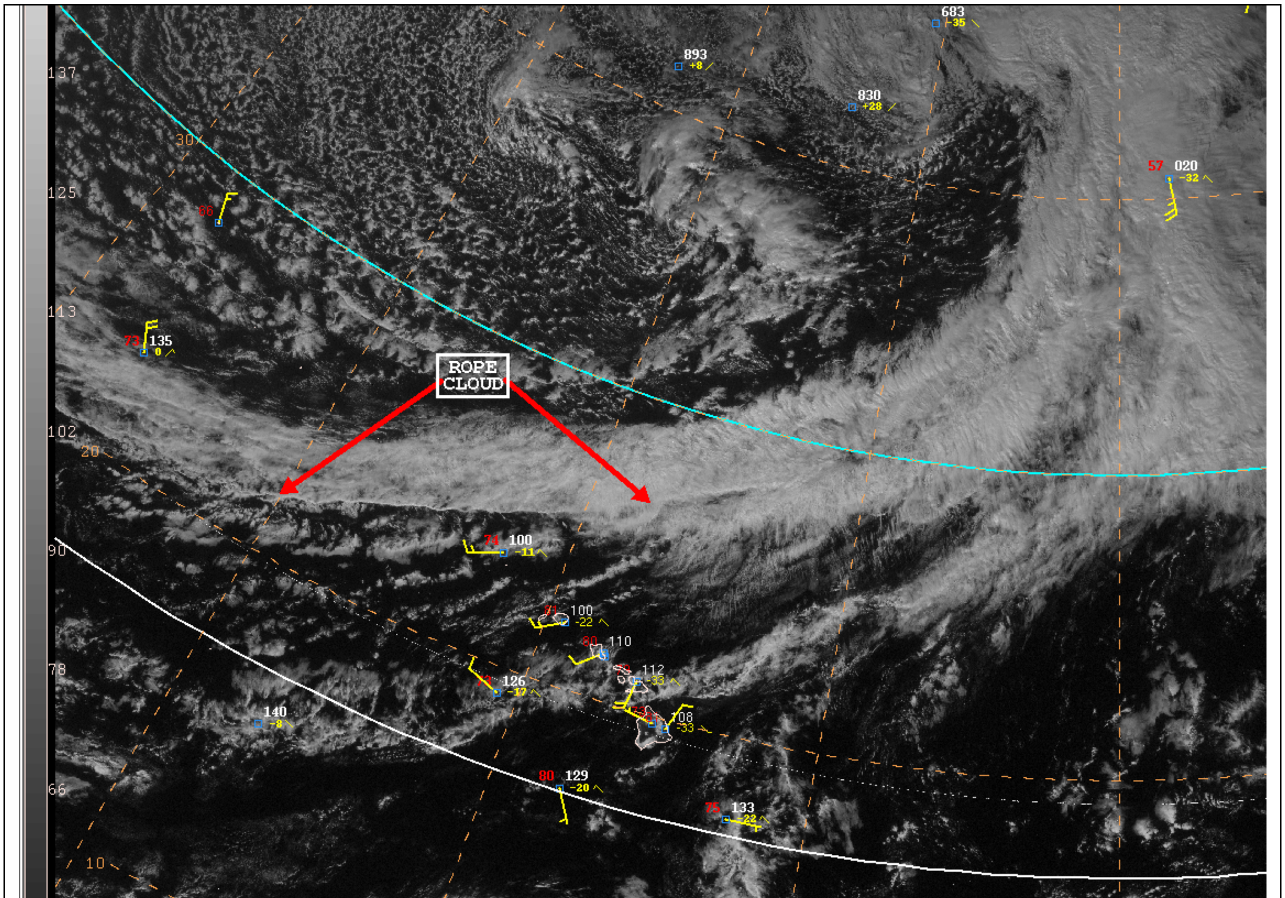


Figure 8. GOES visible imagery depicting a frontal rope over the Central Pacific Ocean.

Satellite imagery-based Hovmoeller diagrams are quite useful at showing day-to-day shifts in the position of tropical waves in the deep tropics. Figure 9 is an example from August 1999, showing the tropical waves associated with the formation of Cindy, Dennis, and Emily.

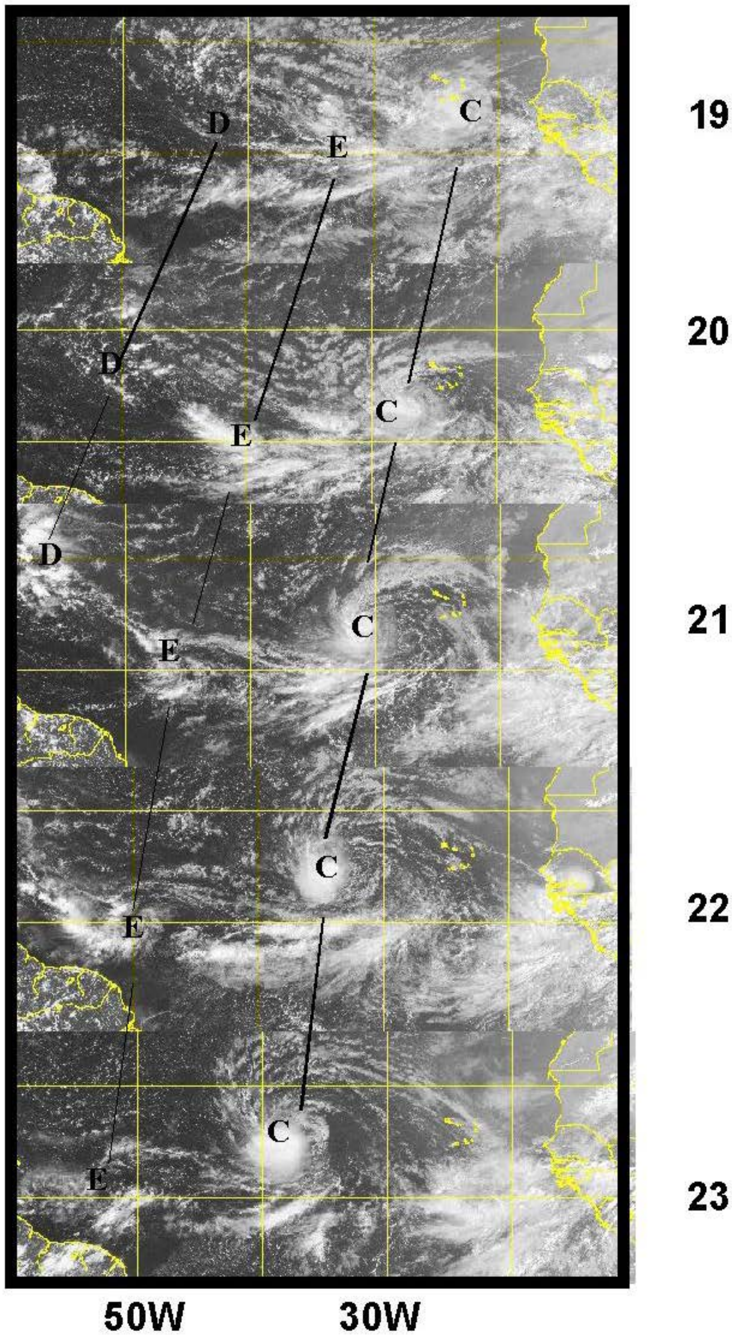


Figure 9. Satellite imagery-based Hovmoeller diagrams showing day-to-day shifts in the position of tropical waves in the deep tropics from August 1999, showing the tropical waves associated with the formation of Cindy, Dennis, and Emily.

C. ASCAT/OSCAT

When regular surface observations are not available from land or sea, remote sensing can yield additional information. ASCAT/OSCAT wind vectors are derived via satellite, covering 54 percent and 90 percent of the world's oceans per day, respectively. Despite this high resolution data, there are drawbacks. The satellite that derives this information is a polar orbiting platform, meaning it only produces two useable wind swaths per day, which can be fairly dated by the time of the surface analysis. Also, there are gaps between each pass. Sometimes these gaps are directly over the area of interest, whether it is an occluded cyclone, a frontal boundary, or a tropical cyclone. Figure 10 is an example of an OSCAT pass over the Mid-Latitudes offshore Atlantic Canada, showing a couple of these gaps.

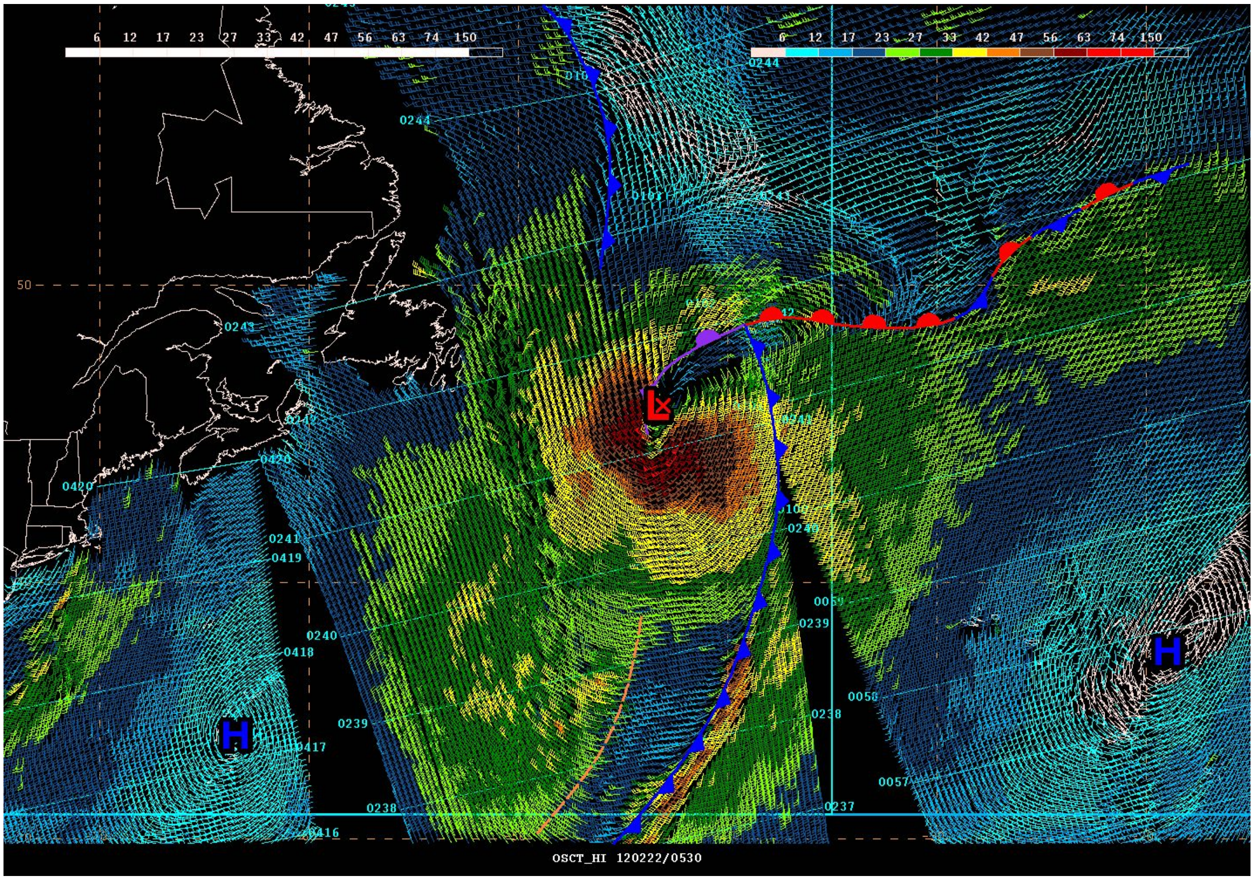


Figure 10: 25 km OSCAT pass from 0530Z, 22 February 2012, with wind speeds at gale (yellow), storm (brown), and hurricane force (red). Occluded front (purple) and cold front (blue) are shown.

Satellite-derived winds give you only part of the picture. When used in coordination with surface observations and geostationary satellite imagery they can be very helpful. Increases in the wind field are seen both poleward of occlusions and warm fronts, as well as behind cold fronts. Increases in the wind pattern show pressure gradient, and indirectly indicate the presence of surface troughs.

4. RADAR IMAGERY

Similar to satellite, the appearance of thin discontinuities, such as fine lines, can help in the placement of frontal zones and outflow boundaries, which can be seen when the WSR-88D radars are in clear air mode. Linear convection can help define cold fronts, while broad areas of light rain are usually seen poleward of a warm front. Squall lines are in exception, as they usually form along fronts and propagate eastward into the warm sector. Used in concert with other tools, radar imagery can be quite helpful when available. For large areas of the Atlantic, Pacific, and central portions of the Gulf of Mexico, radar data are not available.

5. MODEL-DERIVED FIELDS

Model derived fields, such as 1000-850 hPa thickness, 1000-500 hPa thickness, and 850-700 hPa thickness, can be quite useful in finding features, especially in areas with few observations. Using the leading edge of the thickness gradient helps determine placement of warm/stationary/cold fronts, while thickness ridges indicate occluded fronts and lee troughs Boundary layer moisture convergence is also quite helpful, but there are places where both can lead analysts astray. Thickness gradients appear at the edge of thermal circulations over the Sonoran Desert, which does not automatically indicate a frontal zone. Pre-frontal onshore winds off the cold eastern Pacific Ocean can weaken thickness gradients as cold fronts approach from the west. The presence of Hudson Bay, the Great Lakes, as well as the Gulf Stream/loop current can also contort the thickness pattern most months of the year and mask the position of frontal zones in their vicinity. Lee troughs can rob the boundary layer moisture convergence on portions of frontal zones to their north and northwest. Using derived fields without corroboration from other tools/fields can create mistakes on surface analyses, and are not used on their own.

A. LOW LEVEL THICKNESS PATTERN

Use of the 1000-850 hPa thickness pattern can be helpful in placing frontal zones over bodies of water as well as flat terrain, with fronts placed on the leading edge of the packing. The western sections of North America are an exception (generally west of the 105th meridian), where due to the height of the terrain 850-700 hPa thickness patterns are used to help place fronts. Most derived fields have a flaw and the thickness pattern is no exception. Areas of thickness gradient will be enhanced near natural temperature discontinuities, such as the loop current in the Gulf of Mexico, the Gulf Stream, and in the vicinity of the Great Lakes and Hudson Bay in Canada. Thermal circulations in the Sonoran Desert and over the Mexican Plateau, especially in summer, also tend to be surrounded by numerous thickness lines which may incorrectly imply a front in the vicinity. Thickness alone is no substitute for other sources of data, such as surface observations, radiosonde observations, and satellite imagery. Figure 11 is an example of 850-700 hPa thickness levels in the Great Basin, with surface observations included.

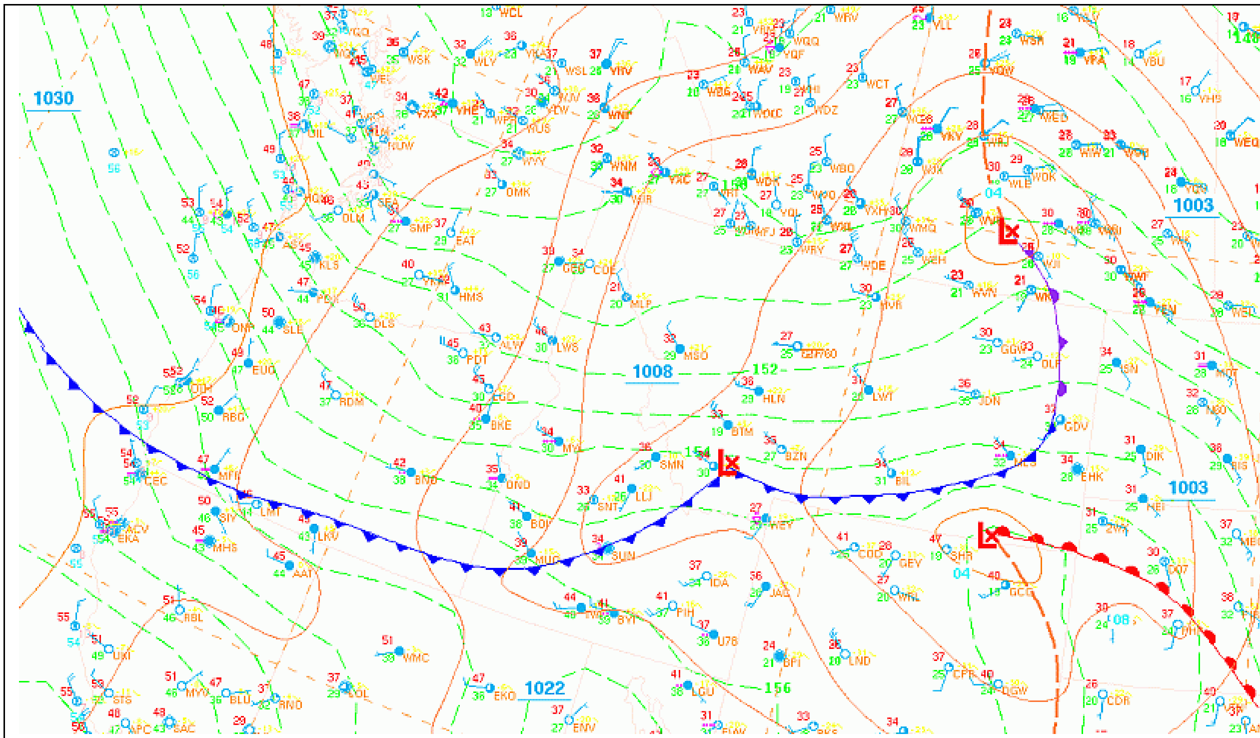


Figure 11. An example of 850-700 hPa thickness levels in the Northwest with surface observations included. Even in this textbook example, note how local winds in certain spots in the West make the placement less than obvious.

B. BOUNDARY LAYER MOISTURE CONVERGENCE

This can be an excellent tool for finding frontal zones and surface troughs. Usually, this field is used in coordination with the surface dew point or theta-E (equivalent potential temperature) to paint a fuller picture of the current synoptic situation. Moisture convergence also has limitations, such as when it appears near the coast due to frictional convergence overnight and where winds upslope into the terrain. So like thickness, it cannot be used as the only determinate. Theta-E has limitations near natural temperature discontinuities, such as near the loop current in the Gulf of Mexico, the Gulf Stream, and in the vicinity of the Great Lakes and Hudson Bay in Canada. Away from these problem spots, the theta-E gradient is quite useful over the subtropical oceans. Additional problems can occur when mesoscale features are initialized in the model, including drylines, which can obscure the placement of the front. Figure 12 is an example of the moisture convergence field, with surface observations included.

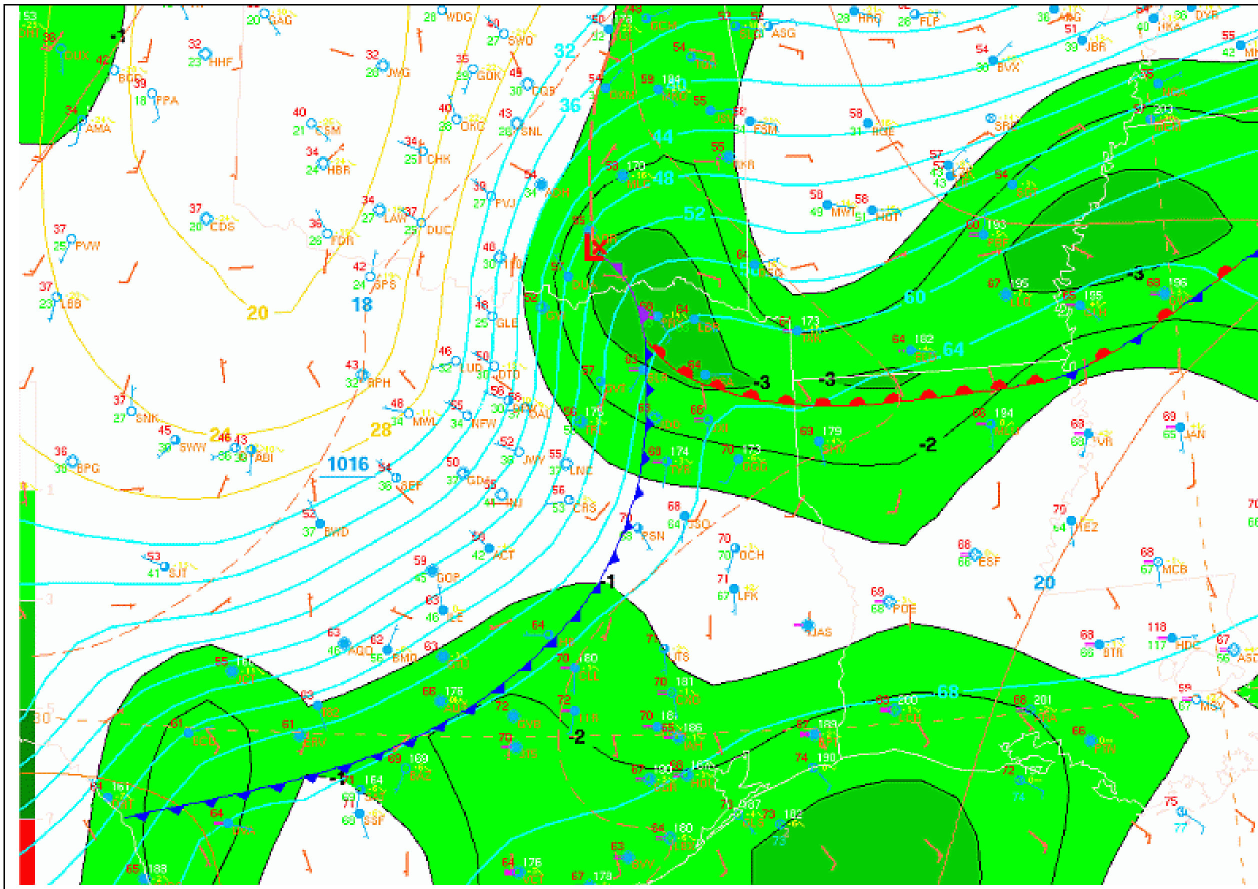


Figure 12. An example of the moisture convergence field, with surface observations included.

C. LOCATION OF THE UPPER LEVEL JET

Another simple check for vertical continuity is the location of the upper level jet, located at or below the 250 hPa level in the winter and above the 200 hPa level during the summer. Fronts are located equatorward (usually southward) of their respective branch of the jet stream which can be easily located on either water vapor imagery or model-derived plots of the wind pattern of the 250 hPa, 200 hPa, or 100 hPa pressure levels. Most branches of the jet stream have frontal zones associated with them, save the subtropical jet which normally shows up weakly in the surface dew point field and tends not to have any temperature gradient. If a frontal zone from one of the other branches of the Westerlies slips equatorward of the subtropical jet, it becomes quite diffuse.

Chapter 3:
The Unified Surface Analysis

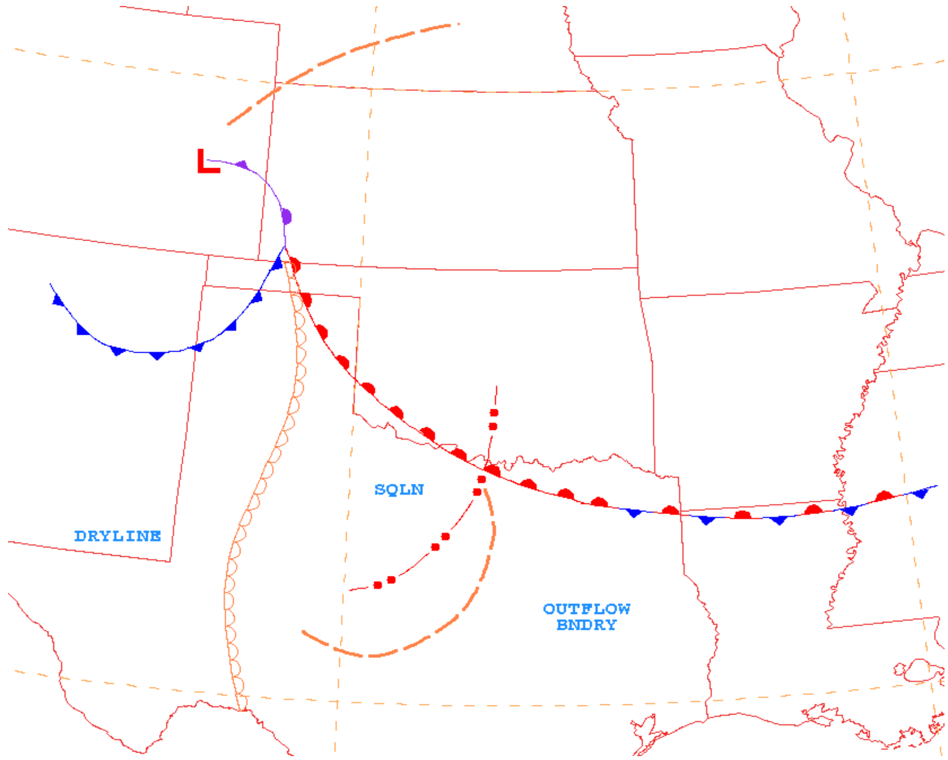
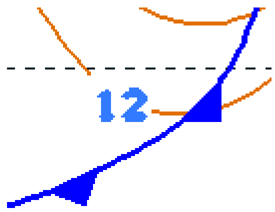


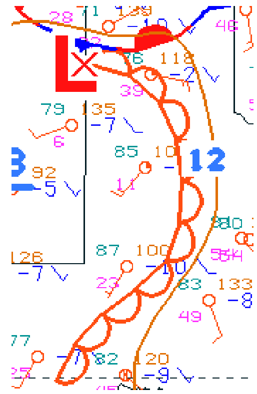
Figure 1. Idealized depiction of features that could be seen on the Unified Surface Analysis in the Mid-Latitudes

1. Features Depicted and their related definitions

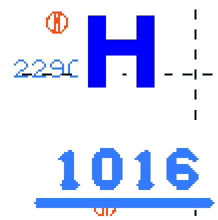
Cold Front: The leading, progressive edge of a density discontinuity ahead of a cooler/drier air mass. These boundaries tend to be narrower than warm fronts due to the higher density low-level air in their wake which helps drive their forward motion. Over the continent, a minimum of 6C (10F) over 500 km (300 nm) is usually needed for a frontal zone with smaller differences needed over the oceans. It is depicted as a blue line with periodic spikes facing into the warmer air mass.



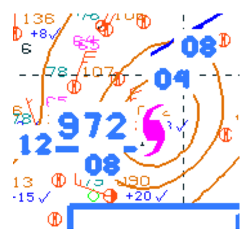
Dryline: The leading edge of a significant density/dewpoint discontinuity forced by foehn winds off the Rockies, usually ahead of a significant synoptic scale system moving through the West/Southwest. They usually progress eastward during the heating of the day, and westward at night. A tight 14C (25F), or a broader 17C (30F), dewpoint gradient is used to help determine the existence of a dryline. The dryline does not have to be the leading edge of all the change in the dewpoint, merely where the best gradient/leading edge of foehn winds exists (mainly after Bluestein). A dryline as drawn as a brown line with scallops facing into the moist air mass.



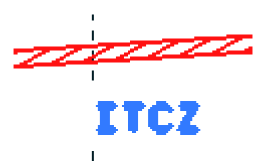
High Pressure System: A relative maximum in the pressure pattern, usually accompanied by at least one closed isobar, which normally has an outward, clockwise circulation from its center in the Northern Hemisphere and an outward, counterclockwise circulation in the Southern Hemisphere. It is depicted as a blue H with its central pressure underlined nearby its placement.



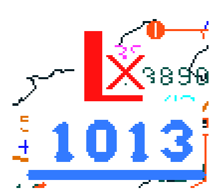
Hurricane/Typhoon. A tropical cyclone in which the maximum sustained surface wind (1-minute mean) is 64 kts (74 mph) or more. The term hurricane is used for Northern Hemisphere tropical cyclones east of 180^{0} longitude to the Greenwich Meridian. The term typhoon is used for Pacific tropical cyclones north of the Equator west of the International Dateline. Labeled as TYPH, HURCN, or HRCN on the Unified Surface Analysis.



Intertropical Convergence Zone. A zonally elongated axis of surface wind confluence in the tropics, due to confluence of northeasterly and southeasterly trade winds, and/or confluence at the poleward extent of cross-equatorial flow into a near-equatorial heat trough. It is depicted as a pair of ref lines with cross hatching. The feature is labeled as ITCZ on the Unified Surface Analysis.

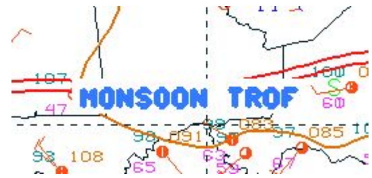


Low Pressure System: A relative minimum in the pressure pattern, usually accompanied by at least one closed isobar, which normally has an inward, counterclockwise circulation in the Northern Hemisphere and an inward, clockwise circulation in the Southern Hemisphere. It is depicted as a red L with an x at its center of circulation with its central pressure underlined nearby its placement.

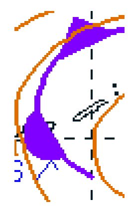


Maximum 1-Minute Sustained Surface Wind. When applied to a particular weather system, refers to the highest 1-minute average wind speed (at an elevation of 10 m with an unobstructed exposure) associated with that weather system at a particular point in time.

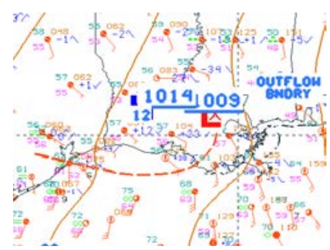
Monsoon Trough: an elongated area of low pressure along the Intertropical Convergence Zone (ITCZ) that leads to an enhancement of monsoon precipitation over land. To its south lie southwesterly low-level winds, as opposed to the ITCZ which is a confluent zone of easterly winds. The monsoon trough is the main focus for tropical cyclogenesis in the northwest Pacific ocean, and plays less of a role in tropical cyclone formation across the northeast Pacific, western Caribbean sea, and northeast Atlantic ocean. This feature is depicted in red with a set of two parallel lines, showing the location of minimum sea level pressure. This feature is labeled MONSOON TROF on the analysis.



Occluded Front: A front that forms southeast/east of a cyclone that moves deeper into colder air, in the late stages of wave-cyclone development. Cold occlusions result when the coldest air surrounding the cyclone is behind its cold front, and are normally seen on the west sides of ocean basins and with clipper systems descending from the arctic. Warm occlusions form when the coldest air surrounding the cyclone is ahead of its warm front, forcing the cold front aloft. Warm occlusions are normally seen on the east side of ocean basins and just to the lee of the United States portion of the continental divide (mainly after Glickman 2000). It is depicted as a purple line with alternating bumps and spikes.



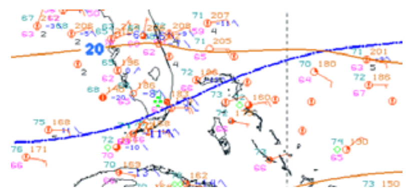
Outflow Boundary: A mesoscale surface boundary formed by the horizontal spreading of thunderstorm-cooled air. These features may last more than a day (after Glickman 2000). It is normally depicted as a trough with a label of "OUTFLOW BNDRY"



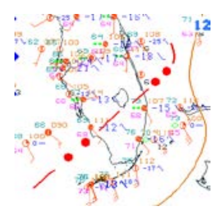
Post-tropical Cyclone: A former tropical cyclone. This generic term describes a cyclone that no longer possesses sufficient tropical characteristics to be considered a tropical cyclone. Post-tropical cyclones can continue carrying heavy rains and high winds. Note that former tropical cyclones that have become fully extratropical...as well as remnant lows...are two classes of post-tropical cyclones. It is depicted on the Unified Surface Analysis in the same manner as a low pressure area.

***Remnant Low*:** A post-tropical cyclone that no longer possesses the convective organization required of a tropical cyclone...and has maximum sustained winds of less than 34 kts (39 mph). The term is most commonly applied to the nearly deep-convection-free swirls of stratocumulus in the eastern North Pacific. It is depicted on the Unified Surface Analysis in the same manner as a low pressure area.

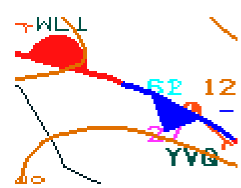
Shearline: The final stage in the life cycle of a cold front over the subtropics and tropics. Lying equatorward of the subtropical ridge, these boundaries have lost all temperature contrast over the warm ocean and have minimal dewpoint contrast across them. They delineate an area where wind speed quickly increases on the poleward side of the boundary by 10+ knots from nearly the same direction (within 45 degrees) within a 60-90 nm zone. As mid- and high-level cloudiness previously associated with the front has dissipated due to lack of upper-level support, a shearline is indicated on satellite imagery as the leading edge of a line of low-level clouds with tops near 10,000 ft (3,040 m). Shearlines lie in troughs, but as surface data over the subtropical/tropical ocean is sparse, the trough may not be recognized in the available surface observation field. Using streamline analysis, a shearline is denoted by a confluence of streamlines equatorward and west of the col area where a cold front divides the subtropical ridge. The symbol for shearline is an alternating dot-dash pattern, in the color of blue.



Squall Line: A solid line of convection, usually associated with rapid pressure fluctuations and high winds. The squall line will normally be placed at the leading edge of the wind shifts and inside the leading pressure trough. The symbol for squall line is an alternating two dot-dash pattern, in the color of red.



Stationary Front: The equatorward edge of a slow-moving density discontinuity with a motion of less than 10 knots (12 mph). Winds tend to lie parallel to these boundaries. Over the continent, a minimum of 6C (10F) over 500 km (300 nm) is usually needed for a frontal zone with smaller differences required over the oceans. It is depicted with alternating red bumps and blue spikes.

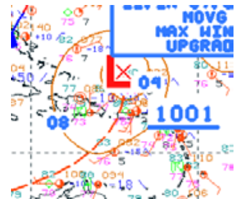


Subtropical Cyclone. A low pressure system that develops over subtropical waters that initially has a non-tropical circulation but in which some elements of tropical cloud structure, such as deep convection, are present. On the map, it is depicted with an Lx symbol, like other low pressure areas.

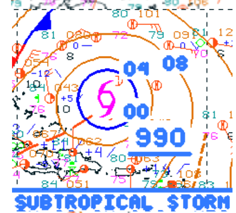
- The most common type is an upper-level cold low with a circulation extending to the surface layer and maximum sustained winds generally occurring at a radius of about 100 miles or more from the center. In comparison to tropical cyclones, such systems have a relatively broad zone of maximum winds that is located farther from the center, and typically have a less symmetric wind field and distribution of convection.
- A second type of subtropical cyclone is a mesoscale low originating in or near a frontolyzing zone of horizontal wind shear, with radius of maximum winds generally less

than 30 miles. The entire circulation may initially have a diameter of less than 100 miles. These generally short-lived systems may be either cold core or warm core.

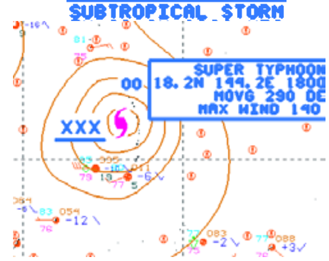
- Subtropical cyclones which attain maximum sustained winds above 64 knots (74 mph) usually attain sufficient tropical characteristics to be considered hurricanes.



Subtropical Depression. A subtropical cyclone in which the maximum sustained winds speeds (1-minute mean) is 33 kts (38 mph) or less. Labeled as SUB T.D. on the Unified Surface Analysis.



Subtropical Storm. A subtropical cyclone in which the maximum sustained winds speeds (1-minute mean) are between 34 kts (39 mph) and 63 kts (73 mph). On the Unified Surface Analysis, it is depicted with a tropical storm symbol and labeled SUB T.S.

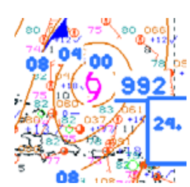


Super Typhoon. A "super" typhoon is a tropical cyclone that is classified as having winds of 130 kts (150 mph) or greater. This term is only used by the Joint Typhoon Warning Center for strong tropical cyclones in the northwest Pacific ocean. Labeled as STYPH on the Unified Surface Analysis.

Tropical Cyclone. A warm core, non-frontal, synoptic scale cyclone originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined circulation.

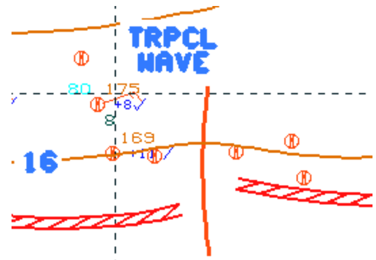
Tropical Depression. A tropical cyclone in which the maximum sustained winds speeds (1-minute mean) is below 34 knots (39 mph). Labeled as T.D. on the Unified Surface Analysis.

Tropical Disturbance. A discrete tropical weather system of apparently organized convection - generally 100 to 300 nmi (185 to 555 km) in diameter - originating in the tropics or subtropics, having a non-frontal migratory character, and maintaining its identity for 24 hours or more. It may or may not be associated with a detectable perturbation of the wind field.

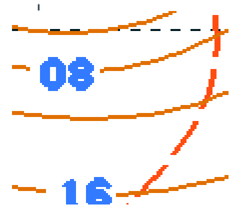


Tropical Storm. A tropical cyclone in which the maximum sustained winds speeds (1-minute mean) are between 34 knots (39 mph) and 63 knots (73 mph). Labeled as T.S. on the Unified Surface Analysis.

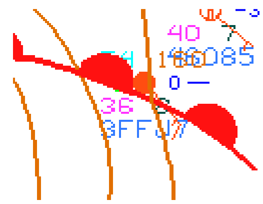
Tropical Wave. A trough or cyclonic curvature maximum in the trade-wind easterlies. The wave may reach maximum amplitude in the lower middle troposphere or may be the reflection of an upper tropospheric cold low or equatorial extension of a middle latitude trough. They are labeled with the words TRPCL WAVE or TROPICAL WAVE on the unified analysis.



Trough: An elongated area of low pressure with no distinct low level center. Winds usually flow cyclonically through it, outside of terrain influences. A trough is drawn as a wide orange, dashed line.

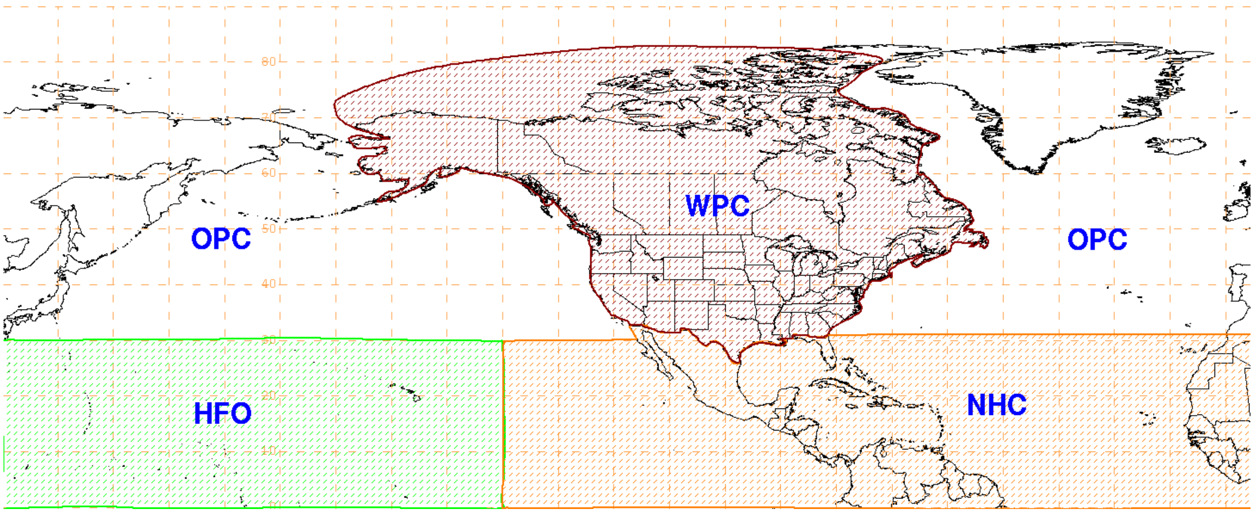


Warm Front: The equatorward edge of a density discontinuity behind a retreating and modified cool, dry air mass. This type of frontal zone is significantly broader than a cold front, due to the slower erosion of the superior density airmass ahead of the boundary. Over the continent, a minimum of 6C (10F) over 300 nm (500 km) is usually needed for a frontal zone while smaller differences are necessary over the oceans. It is depicted as a red line with periodic bumps facing into the cooler air mass.



Chapter 4: Creation/Merging of the Unified Surface Analysis

Each center/office produces unique surface analyses which lie adjacent to the areas of responsibility of other centers/offices. On the top of the next page is an image, in Mercator projection, showing the various surface centers' areas of responsibility for the Unified Surface Analysis. Note: the WPC area is orange, the OPC area is in white, the NHC area is in brown, the HFO area is in green. The southern bound of the analysis is the equator with the western bound 130E and the eastern bound 30E.



VGF SWAPPING AND CLIPPING WITH WPC, HFO, OPC, and NHC

A) UNIFIED ANALYSIS DEADLINES

Analyses must be swapped with other centers/offices for coordination and construction of one National Weather Service Unified Analysis (UA). The UA is constructed in several steps where OPC, WPC, NHC, and HFO exchange analyses, coordinate features along the boundaries, and append final analyses. Time is allowed for coordination between the analysis centers, as there can be marked differences of opinions concerning frontal placement, even between knowledgeable analysts (Uccellini et al. 1992.) The following timeline outlines deadlines and necessary steps for construction of the UA.

TIME	**ACTION (synoptic and intermediate analyses)**
H + 0:00	NHC, WPC, OPC, HFO begin analysis.
by H + 1:00	NHC/OPC save analysis and send preliminary vgf (surface analysis file) to WPC/OPC/NHC (automated script). A pop-up window will appear at H+0:58 as a reminder to save the map.
by H + 1:00	NHC sends message to WPC stating that the analysis is complete or delayed (including reason).
H + 1:00-1:30	NHC/WPC coordinate via chat software or phone (if necessary) with features along boundary and sends updated vgf as required.
H+ 1:30	WPC completes and transmits final North American Analysis.
H + 1:00-2:00	NHC/OPC finalize analyses.
H + 2:00-2:15	HFO completes preliminary analysis and sends vgf to NHC by H+2:00. HFO sends message via chat software informing NHC that the analysis is ready. NHC coordinates with HFO (if necessary) via chat software or phone and clips the HFO analysis from the equator to 30N west of 140^{0}W. NHC draws isobars but traces HFO features south of equator west of 120W.
H + 2:00-2:30	OPC and NHC exchange initial analysis vgfs and coordinate oceanic

	features along boundary (if necessary). For complex coordination, a phone call may be required.
H + 2:30	OPC completes analysis and sends vgf with a "FINAL" stamp, along with a message to NHC.
H + 2:30-2:45	NHC appends the OPC vgf (combined WPC/OPC analysis) north of 30N/31N.
H + 2:45	NHC transmits/launches final analysis and sends chat message to OPC that the final analysis has been launched.

Notes: 1) If the WPC/HFO/OPC analysis is not at the designated time, or soon thereafter, the corresponding centers are informed that center's analyst that the vgf is not available or incomplete. This may be due to communication problems. In the event that a complete analysis is not available by the designated time despite contacting the appropriate center, check with the lead forecaster to determine if isobars/features will be drawn outside of the other centers' area of responsibility to make up the gap on the unified analysis. 2) Analysts coordinate with their fellow forecasters/lead forecaster with approval given by the above stated deadlines.

B) UNIFIED ANALYSIS COORDINATION AND FILE SWAPPING

In addition to the coordination outlined in the above timeline, the analysts should inform the other relevant analysis centers if anything will delay the completion of the analysis or VGF swapping (i.e. data flow or computer issues). Communication with corresponding centers is accomplished via telephone or instant messaging. Instant messaging is encouraged for short and simple information exchange such as "The NHC/OPC/WPC/HNL analysis is ready to be clipped." More complex exchange such as coordinating a feature requires a telephone call. At times during coordination with the other analysis centers, an updated analysis may need to be sent once the initial swap deadline has passed. Modification of the surface analysis can be accomplished beyond the above stated deadlines by simply saving the updated map. Files are swapped with each center via a cron facility and daemon processes which run in the background and execute at specified times. In addition, a script can be run that will manually send the analysis to the other centers. The lead forecaster should be consulted if agreement cannot be reached by the analysts at the disagreeing center(s). The final Unified Analysis can be viewed at (www.opc.ncep.noaa.gov/USA.shtml).

Cron facility for VGF swapping with NHC/OPC/WPC:

WPC/NHC: H + 0:45 → First surface analyses swapped with updated files sent automatically every minute from H+0:46-H+1:00, then every 6 minutes from H+1:00-H+1:18). The NHC analysis is considered complete for WPC purposes at H + 1:00 in the absence of a chat message. A pop-up window will display 2 minutes before the initial VGF is sent reminding the analyst to save the map and create the coded messages.

OPC/NHC/HFO: H + 2:00 → NHC sends first surface merged NHC/HFO to OPC (updated files sent in five minute increments between H + 2:00 and H + 3:15) and receives a merged OPC/WPC analysis. A pop-up window will display 2 minutes before the first analysis is due (H+2:15) reminding the analyst to save the map.

C) FILE CLIPPING AND APPENDING

Clipping scripts are available that will create a VGF from the WPC, HFO, OPC, and NHC surface analyses. Once executed, the script clips the desired center's analysis which can then be appended to the analysis thus eliminating the need to trace. As a result, once the forecaster appends a VGF from either analysis center to his/her own analysis, the analyst will only need to connect isobars/features along the neighboring centers boundaries and, if necessary, smooth the isobars and features to achieve a smooth/unified analysis. The analyst will not draw isobars or features outside of their area of responsibility unless there are technical problems with the VGF exchange and clipping procedures and it is coordinated by phone. In some instances, the analyst may delete duplicate text and symbols and/or retype some of the text labels which lie right along the boundary which might be stripped away during the execution of the clipping script. This must be done manually by the analyst using tools in the product generation palette. The analyst underlays the latest OPC/WPC/HFO/NHC analysis while appending the file to ensure that all relevant text and symbols which occur along the WPC/NHC/OPC/HFO boundary are retained.

The HFO analysis will *only* include synoptic features (fronts, lows, etc) south of the equator (0N). The NHC analyst will add isobars south of 0N west of 120W. The early OPC analysis will *only* include synoptic features (fronts, lows, etc) for the western Atlantic and eastern Pacific for inclusion into the WPC analysis. The WPC analyst will need to modify isobars in the OPC area to conform to the features analyzed and the available observations at the time of their map.

The clipping script will execute with no input from the forecaster other than the execution of the commands *as long as* the VGFs are available from the corresponding center.

The following acronyms are used on the Unified Surface Analysis:

- moving - MOVG
- stationary - STNRY
- maximum – MAX
- Position – PSN
- Gusts – G
- Degrees – DEG
- Joint Typhoon Warning Center – JTWC
- Japanese Meteorological Agency - JMA

A. Tropical cyclone text boxes

(1) By synoptic time (H) plus 1 hour (H + 1:00), or soon thereafter, the TAFB analyst will depict the following information (including north of 31N) on the surface analysis and made available to analysts at WPC and OPC. [Note: This information will only be included in WPC analysis area, because of their earlier production time.]

- The tropical cyclone symbol (hurricane, tropical storm, or tropical depression) taken from the latest issued (H + 3:00) Forecast/Advisory (TCM), or if an intermediate Public Advisory (TCP) was issued, the tropical cyclone symbol from this bulletin.
- A text box that includes 1) the name and intensity category (hurricane, tropical storm, or tropical depression) taken from the latest issued (H + 3:00) TCM, or, if available from the intermediate TCP, and 2) the position to the nearest tenth of a degree (available from the intermediate TCP, or the Hurricane Specialist tropical cyclone advisory composition worksheet or the compute data worksheet, hereafter called worksheet).

[Note: the location of the symbol placed on the surface analysis will be a synoptic position].

In the text box, intensity or movement is not initially included as the final WPC analysis does not include this information. The central pressure in millibars (mb) (equivalent to hectopascals or hPa) will be placed near the tropical cyclone center. Also, the outermost closed isobar is required (additional isobars may be drawn at four or greater millibar intervals if sufficient data is available while preserving legibility). For systems north of 31N, WPC and OPC, will draw their own isobars. If an intermediate TCP, TCU (tropical cyclone update), or TCE (tropical cyclone estimate) statements are not issued, the name and intensity category of the tropical cyclone is from the latest issued TCM, e.g., use the name and intensity category given in the 0900 UTC TCM for the 1200 UTC surface analysis. No analysis center's final analysis should upgrade or downgrade a system before the respective tropical cyclone center upgrades/downgrades a system.

An example a text box supplied to WPC will look like this:

T.D. ONE 25.0N 90.3W NHC PSN

(2) All centers (NHC/TAFB, OPC, and WFO HFO) will reflect the status of the system at synoptic time. Text boxes will include the following information [Note: the original text boxes sent at H +1:00 will be deleted]:

- name and intensity category of the tropical/subtropical cyclone
- maximum sustained wind
- "SEE LATEST (issuing center) ADVISORY" disclaimer.

Tropical/subtropical cyclone text boxes west of the International Dateline in the northwest Pacific will contain the same information (except for the last bullet). The information required will usually be taken from advisories issued by the Joint Typhoon Warning Center (JTWC). When information from JTWC is not available, data from JMA will be utilized. TAFB analysts will construct the text boxes over the Atlantic south of 50N and the East Pacific south of 50N east of 140W, OPC for the Atlantic north of 50N and the Pacific north of 30N west of 140W, and HFO for the Pacific Ocean area south of 30N and west of 140W.

HURCN XXXX MAX WIND 90 KT G 105 KT SEE LATEST NHC ADVISORY

Sample text box

[Note: Substitute “CPHC” for NHC for systems between 140W and 180^0 longitude in the north central Pacific, “JTWC” for systems west of the 180^0 longitude in the northwest Pacific, “WPC” for weakening tropical depressions over the lower 48.

B. Tropical disturbance text boxes

The determination of whether a system should be called a tropical disturbance is often subjective. Therefore in NHC’s area of responsibility (AOR), coordination is essential and the analysts consult with the TAFB lead forecaster or TAFB satellite classifier and the duty hurricane specialist to determine if a tropical disturbance should be depicted on the map. In CPHC’s AOR, the analyst will consult with the hurricane specialist. Motion is determined using extrapolation from previous positions or consulting the classifier. For WPC, there will be situations where a TAFB analyst begins the surface map and then passes the map off to the next shift (i.e. day shift to evening shift) for completion. In these situations, it is important for NHC to relay all relevant information to subsequent shifts so that continuity can be maintained. If the tropical disturbance is being upgraded to a tropical depression, the H + 3:00 TCM is used for pressure and movement.

Tropical Disturbances are depicted on the surface analysis as an “Lx” and the four-digit underlined central pressure near it. The central pressure will be determined from the worksheet available in the NHC operations area or from the best track in the ATCF (Automated Tropical Cyclone Forecasting system) workstation. A text box containing the position and movement is **not** needed. Follow this example for depicting a Tropical Disturbance when using the “Lx” symbol:

Lx
<u>1010</u>
TRPCL DISTURBANCE

Or

TRPCL DISTURBANCE
14N 101W
MOVG WNW 10KT

C. Drawing Isobars Around a Tropical/Subtropical Cyclone.

For systems south of 31N, the outermost *closed* isobar (may be an intermediate isobar) will be drawn for all tropical cyclones. Even though *in-situ* data is often absent for systems over open water, analysts should make use of any other available data to draw the outermost isobar as accurately as possible. For NHC, this information is utilized by the hurricane specialist to initialize the GFDL Hurricane Prediction System. Additional isobars within the outermost closed isobars will be drawn as the tropical cyclone approaches land and nearby waters if data is available and it does not degrade the appearance or legibility of the analysis. The outermost isobar is usually relatively close to the center of the tropical cyclone and should not normally cover a large area or have an unusual shape. In cases where the outermost isobar is significantly away from the center, additional isobars will be drawn within the outermost closed isobar. For systems north of 31N, NHC supplies the TC symbol and text box as WPC and OPC will draw their own isobars. For systems west of 140^0W, HFO draws their own isobars.

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Appendix A: Unified Graphics Legend showing Ocean Center symbology