CDC 1W071

Weather Craftsman

Volume 3. Severe Weather Techniques

Air Force Career Development Academy

Air University

Air Education and Training Command

1W071 03 1209, Edit Code 02

AFSC 1W071

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Material in this volume is reviewed annually for technical accuracy, adequacy, and currency. For SKT purposes the examinee should check the *Weighted Airman Promotion System Catalog* to determine the correct references to study.

Congratulations on completing volume 2 and welcome to the third portion of CDC 1W071 Weather Craftsman course. Volume 3 has two units. The first unit covers the verification, initialiation, and verification process, along with severe weather analysis both convective and non-convective. The second unit goes over radar product interpretation. After reading this volume you will have a more thorough understanding of guiding your team through the severe weather analysis process, as well as interpreting radar products to aid you and your flight in the forecast process.

A glossary of abbreviations and acronyms is included for your use.

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This volume is valued at 15 hours and 5 points.

Preparation of this volume would not have been possible without the contributions and subject matter expertise from TSgt's John Berry, and Travis Boyer, and SSgt's Russell Wilson and Scott Servian of the 335th Training Squadron, Weather Training Flight,

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

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Unit 1. Severe Weather Analysis

ONE of the most difficult and demanding duties of a weather craftsman’s job is to lead a team or duty section through a severe weather event. Atmospheric instabilities are difficult to pinpoint because they usually occur within a larger area of potentially severe activity. Convective severe weather events are comparatively short-lived, given to rapid development and dissipation, and they occur because of a combination of many atmospheric influences that are often difficult to assess. In this unit, we examine the analysis parameters for predicting the occurrence and severity of such phenomena as tornadoes, thunderstorms, hail, and damaging winds.

1–1. Convective Severe Weather

Convective severe weather happens in thunderstorms, and includes tornados, hail, and severe convective winds (≥50 knots). Your job as a forecaster is to warn personnel about these events with enough lead time for them to prepare. Before you start the severe weather analysis, you must check the weather models for accuracy. To do this we’ll go back to basics and review the verification, initialization, and verification (VIV) process. VIV is always the first step in your overall analysis.

401. Model verification, initialization, and verification

The number of meteorological models available to forecasters has increased dramatically over the last 10 years. When a new model is introduced it takes meteorologists and scientists years to determine the model’s strengths and weaknesses. They have to take into account a near infinite number of variables, such as terrain, latitude, diabatics, adiabatics, evaporation, condensation, and so forth. From their research they’re able to continually make improvements to the model’s algorithms; however, to date, no model has been improved to the point where it can be used blindly. Forecasters *must* analyze the accuracy of the models they’re using and document their findings on a forecast worksheet. The most widely used method to analyze models is the verification, initialization, and verification (VIV) process.

Discussions

The National Weather Service (NWS) as well as Air Force Operational Weather Squadrons (OWS) produce discussions on model output. These discussions will give you insight on what to watch for in a particular model as well as how certain features may be off in your weather forecasting area. Reviewing these before you start will speed up the VIV process.

In addition to the model output, the NWS maintains a color coded map of the US with all current advisories and warnings. The OWSs do this as well, but in a text and color format. Another tool to use is the Storm Prediction Center (SPC) advisory charts. SPC produces a chart that outlines areas of expected severe weather. All of these tools are a good first look, before you begin your model analysis.

Model bias

Model bias is a consistent error that a model has in certain areas and conditions. NWS maintains a model bias page on the Hydrometeorological Prediction Center (HPC) web site. A model bias may be listed as a forecasting “rule of thumb” for your area or base location. Part of your on the job training for a new position or location should be to review the “rules of thumb” and model biases. Every location has rules of thumb that apply to specific environmental conditions.

Verification

The first step in the VIV process is to verify the previous 12-hr forecast positions against the current 00-hr forecast positions for the same time. This verification helps evaluate consistency of the model solutions from one run to the next. If the model is handling systems well, then there should be little difference between positions. However, if the model is not performing well, then adjustments must be applied to the 00-hr and future forecast positions. Document how the models verified on the forecast worksheet.

Initialization

The next step in the process, initialization, deals only with the 00-hr forecast. Physically compare the 00-hr forecast positions with your analysis (satellite pictures, other real-time data) from the same time to see how the 00-hr forecast is doing. If the model’s initial placement agrees with the real-time data, then no adjustments are needed. Otherwise if the initial place disagrees, then make adjustments to the 00-hr and subsequent forecasts. Document your findings on the forecast worksheet to use later in your forecast reasoning.

Verification

The final step in the VIV process is to verify the current 12-hr model forecast with real-time data for the same time (satellite imagery, surface analysis) to determine how well the model is if the model is performing well, then no adjustments are needed. If the model is performing poorly, then you must make adjustments to the 12-hr chart and future forecast charts. Document the results of your second verification on your forecast worksheet.

Figure 1–1 is an example worksheet entry for the VIV process. The first two entries provide information on the models used and the database time. The models used by the forecaster were the Weather Research and Forecast Model (WRF), the North American Mesoscale Model (NAM), and he Global Forecast System (GFS). The database time was 1200 Coordinated Universal Time (UTC).

Model Verification/Initialization/Verification

1. Name which models were used: 1st model: ___WRF___ 2nd model: ___NAM___ 3rd model: ___GFS___
2. Database time: ___1200Z___
3. Model discussion bulletins: FXUS10 INDICATES GFS A BIT SLOWER, WRF MODEL MOVING TOO FAST, NAM HAD BEST HANDLE OVERALL
4. Verification: [WRF] OVER FORECASTING UPPER LEVEL MOISTURE, SEA LEVEL PRESSURE FORECASTED TOO LOW [NAM] MOVING FORWARD EDGE OF MOISTURE TOO FAST INTO LA, BETTER HANDLE THAN GFS ON MOVMENT OF MINOR SHORT WAVES [GFS] PREVIOUS RUN MOVED VORT MIN TOO SLOW OVER AL, LOW IN TX DEEPENING MORE AND MOVING SLOWER THAN PROGGED ON THICKNESS
5. Initialization: [WRF] LI –1 COMPARED TO –2 ON SKEW-T, MID LEVEL WINDS TOO STRONG [NAM] LOW IN TX TOO FAR NORTH COMPARED TO WATER VAPOR SHOT [GFS] VORT MAX IN NORTHERN TX ADJUSTED 1 DEG NORTH
6. Verification: [WRF] COMPARED 12Z SKEWT TO 12 HR FCST SFC–050 WINDS DID NOT VEER AS FORECASTED [NAM] LOW IN TX IS DEEPENING FASTER ADJUSTED 2MB LWR, MOISTURE STILL PROGGED TO FAR EAST ADJUSTED EDGE OF 70% RH BACK TO WESTERN LA [GFS] ADJUSTED MOVEMENT OF VORT MAX IN LA BACK TO EAST TX

Figure 1–1. Model initialization and verification.

The third entry, model discussion bulletins, the forecaster summarized the FXUS10 bulletin. It indicated the GFS was moving features too slow, the WRF was moving them too fast, and the NAM model had the best handle on the situation overall.

The fourth entry, verification, the forecaster compared all three models with the previous 12-hr forecast. The 12-hr forecast of the WRF was over forecasting the amount moisture in the upper levels and sea level pressure was too low. The NAM model was moving the forward edge of moisture into Louisiana too fast on the 12-hr.

However, the NAM model had a better handle on the movement of minor short wave troughs as compared to the GFS. On the previous run, the GFS moved the vorticity minima too slow over. Also, the GFS was not deepening the low enough in Texas and had it moving too fast.

The fifth entry is initialization; the forecaster compared real-time weather data with the 00-hr model forecast. As stated previously, initialization is the act of comparing the placement of meteorological features on model products to their actual position on real-time data, then documenting this comparison on the forecast worksheet. Referring to the example in figure 1–1, the WRF was off by one on the lifted index and the mid-level winds were too strong compared to the Skew-T. The NAM model had the low in Texas too far north compared to the water vapor shot. On the GFS vorticity chart, the vorticity maxima in northern Texas had to be adjusted one degree of latitude north.

The sixth and final entry, verification, the forecaster compared the 12-hour forecast on the current model with real-time weather data that was valid for the same time. When the WRF was compared to the Skew-T, it was observed that the WRF was forecasting winds to veer more than they actually were. The NAM model was not deepening the low enough and had to be adjusted two millibars (mb) lower. On the GFS, the vorticity maxima in Louisiana had to be adjusted west, back into eastern Texas.

Model output

Following the VIV block on the worksheet there is generally a block for you to enter model output data. Your unit may use one particular model or a combination of several. Figure 1–2 is an example block to enter data from the WRF. The entries made by the forecaster are bold and underlined. The entries are fairly simple; just read the product and enter the data on the worksheet in numeric form. After entering the model output data, the forecaster can quickly assess the model's atmospheric projection. In figure 1–2 it's rather easy to determine the model is forecasting warm air advection, falling surface pressure, decreasing stability, incoming clouds, and backing surface winds.

WRF Model Output								
Valid time:	6-Hour		12-Hour		18-Hour		24-Hour	
Thickness	**5720**		**5730**		**5740**		**5740**	
Sea Level Pressure	**1012**		**1011**		**1009**		**1008**	
	3-Hour	6-Hour	3-Hour	6-Hour	3-Hour	6-Hour	3-Hour	6-Hour
Lifted Index	**0**	**+1**	**+1**	**0**	**–1**	**–1**	**–2**	**–2**
Precip	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Clouds	-	-	-	-	-	**030–120**	**025–140**	**025–160**
SFC Winds	**3510**		**0210**		**0315**		**0315**	
Temperature	**77**		**78**		**81**		**83**	
Dew Point	**70**		**71**		**73**		**74**	

Figure 1–2. Model output.

Verification, initialization, and verification and ensembles

All weather models are sensitive to dependence on initial conditions. The initial conditions that models use are based on past and current weather observations or other weather measurements. Ensembles will show the different initial conditions used on models. With ensembles we can combine the different models to have an idea where a particular weather feature will move or track to. An example of this in action is the hurricane tracks issued by the National Hurricane Center (NHC).

Challenges of verification, initialization, and verification

Conducting VIV is necessary when utilizing model data, but it can also be an inexact and time consuming process. The time requirements and task complexity are compounded when VIV is performed for multiple models; often in an effort to determine a “model of choice” or the “best” model for a given time or situation. Fortunately, recent advancements in computing power and computer affordability have begun to provide an alternative to VIV overload—ensemble prediction systems.

Benefits of ensembles

For an ensemble prediction system, most steps of the VIV process are inherent to the ensemble and automated, while others are rendered superfluous or unnecessary. These efficiencies are made possible by the stochastic information (distributed possibilities) produced by the ensemble. Whereas a single deterministic model will have one 00-hr analysis and one solution for a given time, an ensemble composed of multiple model runs will have a set of 00-hr conditions (slightly different but plausible) and a range of possible solutions for a given time. Assuming each run (or “member”) of the ensemble is equally likely to be correct and that reality should be contained within an adequately large number of members, the forecaster’s focus can shift from determining which model is right to which ensemble solutions are possible and which are probable.

Accounting for uncertainty

Given the range of previous solutions from an ensemble, consistency of a single member (first “V” in VIV) is less important than checking an ensemble’s 00-hr mean or median solution is encompassed by its previous forecast bounds (min/max). Either can be subjectively assessed or precisely calculated from ensemble output. Additionally, a well-constructed ensemble’s set of initial conditions at 00-hr should include at least one solution close to reality, thereby providing initialization (“I” in VIV). Likewise, verification of an ensemble forecast (last “V” in VIV) is inherent in the range of possible outcomes. Recognizing the difficulty in determining the true state of the atmosphere (given observing and analysis errors), the stochastic information provided by an ensemble accounts for uncertainty and provides objective, quantified probabilities helpful to operational risk management (ORM) or to measure forecast confidence.

402. Severe thunderstorm types

Out of the thousands of thunderstorms that form every day, only a few become severe. Severe thunderstorms require a greater deal of instability than non-severe thunderstorms. The updrafts must remain unobstructed by falling precipitation, thereby maintaining the updraft core. The presence of strong mid-level winds (varying from 700mb to 300mb, depending on storm height) is essential. These winds carry the precipitation downstream where it falls ahead of the updraft, rather than back into it. These dry mid-level winds also help to dynamically intensify the updraft by increasing the density gradient between the updraft and the mid-level air.

Severe thunderstorms

Severe thunderstorms have two main characteristics that separate them from weak ones. First, they have stronger instability, which increases their updraft speeds. Second, the wind shear environment above the storm separates the updrafts and downdrafts, keeping them from interfering with each other.

The goal of severe weather analysis is to identify the preconditions that allow storms to become severe. With that goal in mind, let’s take a look at the different types of severe thunderstorms.

Single-cell

Single-cell storms are short-lived (30 to 60 minutes) cells with one updraft that rises rapidly through the troposphere. Precipitation begins at the mature stage in a single downdraft. When the downdraft reaches the surface, it cuts off the updraft and the storm dissipates. You must watch developing cells using weather radar. When severe weather does occur in single-cell storms, it's usually in the stronger and longer duration cells. Individual cells develop stronger core reflectivity at higher elevations than surrounding cells and must be closely monitored. Some single cell severe thunderstorm characteristics are:

- Weak vertical and horizontal wind shear.
- The shear profile on the hodograph has a random pattern.
- Storm motion is with the mean wind in the lowest 5 to 7kilometers (km).
- High winds and hail are possible but short-lived.
- Tornadoes are rare.

Multi-cellular

Multi-cellular storms are clusters of short-lived single-cell storms. Each cell generates a cold outflow that can form a gust front. Convergence along this boundary causes new cells to develop every five to 15 minutes in the convergent zone. These storms are longer in duration than single-cell storms because they typically regenerate along the gust front. Multi-cellular severe thunderstorm characteristics are:

- A straight-line or unidirectional shear profile.
- Strong directional shear in the lower levels, and strong speed shear aloft.
- Individual cell motion coincides with mean wind.
- Storm clusters propagate in the direction of the gust front and to the right of the mean wind.
- Possible flash flooding from slow-moving cells.
- Large hail near downdraft centers.
- Short-duration tornadoes possible along gust fronts near updraft centers.

Supercell

The internal dynamics of supercell thunderstorms consist of one rotating updraft, a forward-flanking downdraft that forms the gust front, and a rear-flanking downdraft. These storms may exist for several hours and are a frequent producer of severe weather. Three types of supercells are classic, high precipitation, and low precipitation. Cyclonically rotating cells move to the right of the mean (surface to 6km) low-level wind. Anti-cyclonically rotating cells indicate storms moving to the left of the mean wind; these storms are notorious hail producers.

Classic supercells

Classic supercells are usually isolated from the main thunderstorm outbreak and are identified by the classic hook echo in the low-level reflectivity pattern and bounded weak echo region (BWER) aloft. Classic supercell characteristics are golf ball size hail; wind gusts in excess of 50 knots (along the gust front and from microbursts in the rear-flanking downdraft); and possible tornadoes.

High-precipitation supercells

These develop in deep, moist layers with high moisture values. They are more common the further east you go from the plains. They produce heavier rain than classic supercells and are not as isolated as these storms. Radar patterns associated with high-precipitation storms are more varied than the classical hook‖. High-Precipitation storms have the potential to evolve into bow echo configurations. High precipitation supercell characteristics are very heavy rain and tornadoes and hail possible.

Low-precipitation supercells

These storms are most commonly found along the dry line of west Texas . They produce some precipitation, but have a rather benign appearance on radar. Although smaller in diameter then classic supercell storms, they are still capable of producing severe weather. High precipitation supercell characteristics are large hail and tornadoes.

403 Severe convective airmasses

Now that you have reviewed the different types of thunderstorms and the weather associated with them, let's take a look at airmasses. As you will see, some airmasses produce more severe convective storms than others.

Severe weather seems to occur most often in the Great Plains during the summer time, but it also occurs throughout the continental United States (CONUS) as well. As weather craftsmen, we must be able to forecast the onset of severe weather no matter where we happen to be stationed. Throughout years of studies, certain convective patterns and systems were noted to support severe weather outbreaks.

It's understood that tornadoes form in the conditions more favorable to severe thunderstorm development and the occurrence of hail and destructive winds is implied in any reference to a tornado-producing storm. Because of the study of these air structures, it has become generally accepted that four air structure types are responsible for most of the tornadic activity in the US. Although no geographical limitations are intended, most of these air structures are named after the regions in which each predominates.

Airmass

An airmass is a widespread body of air forming in an area of uniform terrain and temperature and having uniform properties and horizontal composition. Primary source regions are arctic, polar, tropical, and equatorial (A, P, T, and E, respectively). Airmasses forming over an ocean are characterized as maritime (m) or if the source region is predominantly over land, airmasses are characterized as continental (c). Air masses moving out of their source region will gradually modify to take on the characteristics of the surface over which they are moving. If the air mass is cooler than the new surface, a "k" is appended to the airmass label. If the airmass is warmer, a "w" is used. An example with the common airmass movement is depicted in figure 1–3

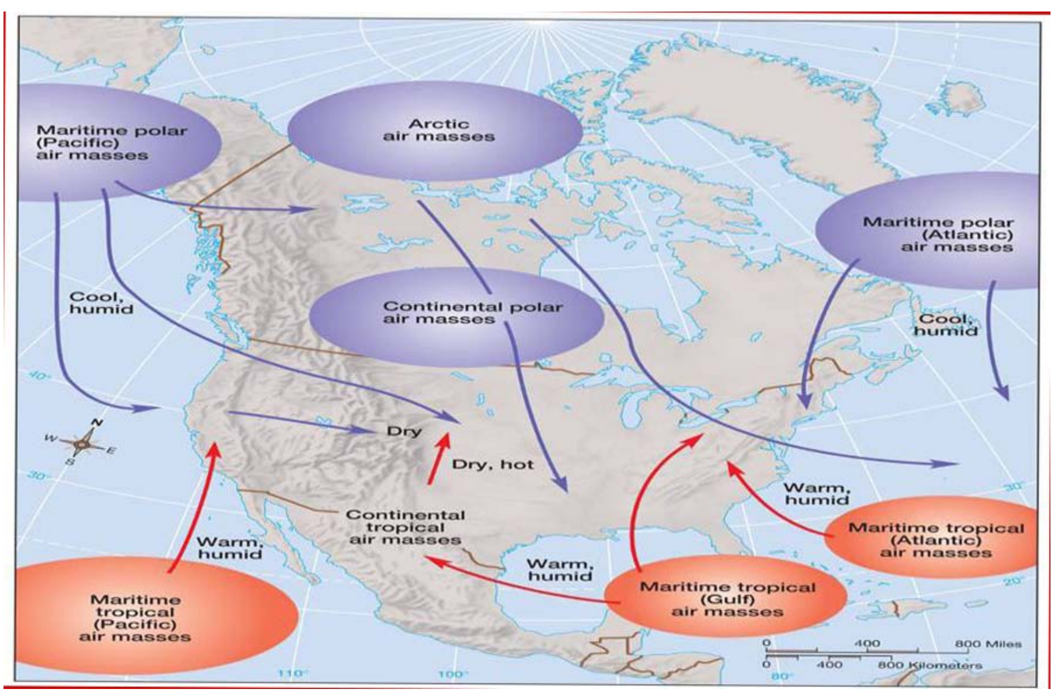


Figure 1–3. Airmass source regions.

Type I Great Plains airmass

The Great Plains lies between the Mississippi River and the Rocky Mountains. They gradually increases in elevation from the river valley to the mountains (typically east to west). The description of the Great Plains type of tornado-producing air structure is based on an accumulation of representative soundings. The atmospheric moisture is stratified with the lower layer being moist (i.e., relative humidity (RH) normally over 65 percent and surface dew point normally over 55°F) and very rapid drying is evident through the characteristic inversion. Above this inversion, the RH tends to increase slightly at first, then more rapidly above 550mb. Winds increase with altitude in the dry air above the inversion, having a component of at least 30 knots perpendicular to the flow in the warm, moist air. The median wind shown by the representative soundings at 850mb is 30 knots from 219°; at 500mb, it is 50 knots from 256°. The air from the surface to 400mb is conditionally unstable and has a negative Showalter stability index (SSI). The lifted stability index is about –6 on the mean sounding. The vertical totals index is 28, the cross totals 26, and the total totals 54.
Tornadoes in this type of airmass most frequently occur in families; their paths are commonly long and wide compared to tornadoes occurring in the other types of airmasses. The tornadoes are more numerous in late afternoon, but occur any time of the day and night. They are usually accompanied by widespread, destructive wind storms and large hail.

Morning stratus, temporary clearing, and middle clouds frequently precede tornadoes in the type I airmass. Mammatus is common with thunderstorms and is nearly always reported near those with tornadic activity. The temperature is high for the season and the time of day or night. The dew point sometimes rises very rapidly one to four hours before the storm, making the air oppressive. As the storm passes, the temperature drops very rapidly, then returns to normal unless the activity is along a cold front. Preceding winds are usually light to moderate. The pressure drops slowly for some hours and is followed by a brief small rise. Then, with the onset of the storm, the pressure plunges into a deep fall followed by a sharp rise and, in a few minutes, returns to normal following the passage of the thunderstorm cell. Generally, the weather sequence changes rapidly.

Type II Gulf Coast airmass

The Gulf Coast airmass is tropical in origin and generally warm and moist. It can be found in the Mississippi, Alabama, Georgia, eastern Texas, and Louisiana region of the US. This is the same airmass you experienced at Keesler AFB, Mississippi.

In contrast to the Great Plains airmass, tornadoes also form in a tropical type airmass that is moist up to great heights. Such storms are most common on the coast of the Gulf of Mexico and produce the waterspouts so often reported over the Gulf Coastal waters.

This airmass has very strong instability below 700mb. The temperature lapse rate is conditionally unstable with no significant inversion or stable layer; surface temperatures are usually over 80°F. The moisture content is very high, the RH being over 65 percent in practically all cases from the surface to above 20,000 feet.The winds normally decrease with altitude. There is no requirement for strong winds at any level in this air structure, though sharp wind shears do appear conducive to tornado formation. The wind at 850mb varies between extremes of 5 to 85 knots and at 500mb from 5 to 55 knots with the average direction veering about 30° between these levels.

The median values of both the lifted stability index and the total totals are the same as in tornado air mass type I (–6 and 54 respectively), although the absence of an inversion has permitted the extreme cases to reach greater instability values.

Normally, in this type of airmass only one of the many thunderstorms in a given situation produces a tornado or waterspout. When more than one develops tornadic strength to the surface, 30 to 50 miles usually separate them. Their lives are short, their paths brief and narrow, and they move more slowly than those in airmass type I. Although hail aloft does occur, surface hail and strong convective gusts are rare, since the wet bulb zero (WBZ) is normally above 11,000 feet.The weather, both before and after the tornado occurrence, is normally cloudy with showers and scattered thunderstorm activity. There is neither a temperature nor a dewpoint discontinuity and only the pressure falls rapidly before the tornado. Otherwise, the weather changes slowly with time.

Type III Pacific Coast airmass

The Pacific Coast air mass has cold air at all levels, which is the key feature of this airmass. It's responsible for waterspouts along the west coast of the US. The airmass does not extend far inland due to the Cascade, Sierra Nevada, and Coastal Mountain Ranges, which act as a wall keeping the cool, moist air on the immediate coast.

Tornadoes also form in comparatively cold, moist air. This airmass may be called the *Pacific Coast type*. It is responsible for the cold airmass waterspouts of the west coast. It has relative coldness of the air at all levels.

The temperature lapse rate is conditionally unstable, without significant inversions or stable layers. Compared to type II (the Gulf Coast type), the type III airmass is cold and the surface temperatures range from 50°F to 68°F. Moisture extends to great heights, with the RH commonly exceeding 70 percent at all levels up to at least 500mb. The winds increase and generally veer with altitude, their average speeds being 15 knots at 850mb and 50 knots at 500mb. Instability in this airmass is not as great as in the first two types discussed—the median values being a lifted index of –3. However, the total totals index is 54.

Generally, tornadoes in air of this type structure occur singly rather than in families or groups, although Mammatus, virga, and funnels often form in the vicinity. Often virga will look like a funnel cloud and generate public reports of tornadic activity.

The WBZ is usually so low that only small hail is reported and the thunderstorm gusts are often masked by strong gradient winds. Compared to those in tornado airmass type I, or even type II, tornadoes in this situation have only a brief life, with a short and narrow path.

Tornadoes in this type airmass are normally found in a rather extensive cloudy area with scattered rain showers and isolated thunderstorms. The clouds are mostly stratocumulus with buildups embedded in the lowest deck. Also, Mammatus is usually reported. The main cloud base from which the tornado appears usually remains well above the surface. Often, in this type airmass, the only evidence that a tornado existed is found in the apparent rotational pattern observed in surface debris after the storm passes. There are no abrupt or unusual changes in the weather elements except, of course, the pressure within the tornado itself. The Los Angeles basin is the primary hotspot for tornadoes west of the great Continental Divide.

Type IV Inverted V airmass

The Inverted V airmass, features maritime polar air overrunning continental tropical air between 5,000 and 8,000 feet above the surface. This creates the look of the inverted V, or dry air near the surface and moist air above. This situation is seen in the high plains region, or the lee side of the Rocky Mountains. Lee side consists of the area bordered on the east by western Nebraska, south into Texas, and west into the southwest desert regions.This air structure, when triggered, is favorable for violent straight-line windstorms. The type IV tornado-producing air structure is confined to the high plains region to the lee of the Rockies from western Nebraska, southward into Texas, and westward into the southwestern desert areas. Tornadic activity is usually confined to funnel clouds which seldom reach the ground with this type of airmass. When they do, the narrow rope-like funnel causes destruction over a comparatively small area. The presence of dry air in this structure, coupled with a favorable WBZ height, makes it a dangerous hail producer.

The lifted index for this sounding is not representative, since the lower layers are quite dry. The representative total totals index for this type sounding is 53.

A dry lower layer typifies the sounding and a cool, moist, layers aloft and is conditionally unstable. The WBZ height is near the optimum of 8,000 ft above the ground. The vertical wind profile increases in speed and veers with height. This type tornado is associated with a mid-level trough, which acts as the triggering mechanism. Rapid weather changes and Mammatus associated clouds are characteristic. This radiosonde observation (RAOB) type produces many more occurrences of microburst wind damage than actual tornado damage, especially over and west of the Rockies. When tornadoes occur with this type, they are isolated in nature, usually rapid-moving, short-lived, and their path is short and narrow.

Severe weather potential

Each of these tornado-producing air structures possesses the capability of spawning severe weather by virtue of thermal structure, humidity distribution, and, therefore, stability considerations. Monitor evaporational cooling and upper-level (800/900–300mb) lapse rate changes closely. Remember that a sounding representative of an air structure is largely time dependent; that is to say that the structure represented by the sounding may be significantly altered through the influence of the various processes and mechanisms operative in the atmosphere. The sounding reveals the *capability* of an air mass for severe weather production, but this capability is realized only if the structure is made highly unstable. You *cannot* base the forecasting of severe weather on the sounding alone, but must also depend on an analysis of the conditions and mechanisms that can alter the air structure in question.

404. Severe weather producing synoptic patterns

Identifying severe synoptic patterns is essential to identifying areas of potentially severe thunderstorms. Air Weather Service Tech Report 200 (Rev) states, "successful tornado and severe-thunderstorm forecasting is largely dependent upon the forecaster's ability to carefully analyze, coordinate, and assess the relative values of a multitude of meteorological variables and mentally integrate and project these variables three-dimensionally in space and time."

The ability to correctly identify severe synoptic patterns saves time and energy to be focused on the threat area. In this lesson, you'll review the five different synoptic patterns that are favorable for convective severe weather.

Type A – dry line

The dry line itself is a narrow, almost-vertical zone, across which a sharp moisture gradient exists–this is the defining feature. Even though the dry line is often not collocated with the zone of maximum surface convergence, it serves as a focus for convective activity. Type A pattern, thunderstorms initially form on the edges of dry air, storms tend to form rapidly in widespread, isolated clusters. This type pattern is noted for severe thunderstorms from eastern Texas to southern Iowa.

The characteristics of the dry line synoptic pattern include a:

- Well-defined southeasterly flow of moist air from the Gulf of Mexico at the low levels (surface to 850mb).
- Well-defined west to southwest maximum wind band aloft (500 to 300mb).
- Distinct surface to 700mb warm dry-air intrusion from the southwest.

There is considerable convergence along the boundary between the moist southeast flow and dry southwest flow of air. Speed convergence is also commonly found upstream from the dry line in the dry air.

The dry line is often associated with a pressure trough and/or wind shift line although neither is necessary for the existence of the dry line. Vertically, the dry air exhibits a nearly dry adiabatic lapse rate, while an inversion "caps" the moist air. The dry line synoptic pattern is normally associated with a Type I airmass.Severe weather may extend up to 200 miles to the right of the 500mb maximum wind band and usually form where the jet meets the moist/dry air convergence area. Sometimes you will see a secondary outbreak area 150 miles to the right of the 500mb horizontal speed shear zone as well.

Location techniques

It is necessary to use a moisture variable to locate the dry line. You can use mixing ratio, dew point temperature, or equivalent potential temperature to identify the transition zone between the moist and dry air.

For analysis of the dry line, the 55°F isodrosotherm is recommended as the first estimation. This is the lowest value that seems to support tornadic thunderstorms. A dew point temperature difference > 10^{o}F degrees should be present across the dry line.

Satellite imagery can also be used to help locate the dry line. Visible images often depict a thin line of convective clouds above the dry line. Infrared imagery often shows a boundary of “black stratus” at the dry line. This nocturnal observation east of the dry line is due to the fact that the moisture content has kept temperatures warmer than those in the dry air to the west.

Movement

The movement of the dry line is generally much faster than advection would support. One mechanism that accounts for the rapid movement is vertical turbulent mixing of the moist surface with the dry air aloft.

After sunrise, boundary layer mixing starts as surface temperatures rise in response to solar insolation. West of the dry line, a surface layer with an adiabatic lapse rate rapidly replaces a nocturnal radiational inversion. Any moisture trapped beneath the inversion would be freely mixed into the dry air aloft.

The greater the depth of the moist layer, the greater is the degree of heating required to break the capping inversion. Since the general terrain of the southern plains slopes downward from west to east, the depth of the moist layer also increases eastward from the dry line location.

When the needed amount of heat is absorbed, the low-level moist air mixes with the dry air aloft. The surface dew point temperature drops rapidly and the dry line “leaps” eastward to a position where no appreciable mixing between the airmasses has occurred. Dry line bulges often form due to enhanced dry air and the vertical mixing of high-momentum mid-level air to the surface. Enhanced convergence occurs at the bulge. Use the strongest 700mb winds to forecast the probable location of the dry line bulge.

In the late afternoon and evening, the dry air cools rapidly. A nocturnal inversion forms west of the dry line. The inhibition of vertical mixing (due to the inversion) leads to a decrease of the low-level winds in the dry air. East of the dry line, strong easterly flow continues resulting in a net easterly wind across the dry line. The dry line is advected westward by these winds. The entire diurnal process can reoccur the next day.

Activity

Very severe thunderstorm cells or lines form along the dry line. The most violent thunderstorms occur at the intersection points between the dry line and another boundary. Large hail, damaging winds, and tornadoes are common, as is rapid growth of storms. Activity is mainly limited to the late afternoon and early evening. Once convective activity has started, you should watch for it to continue for six to eight hours or longer. You should keep in mind that severe thunderstorms can develop along the dry line during its nocturnal retreat as well. Figure 1–4 depicts an example of the type A pattern.

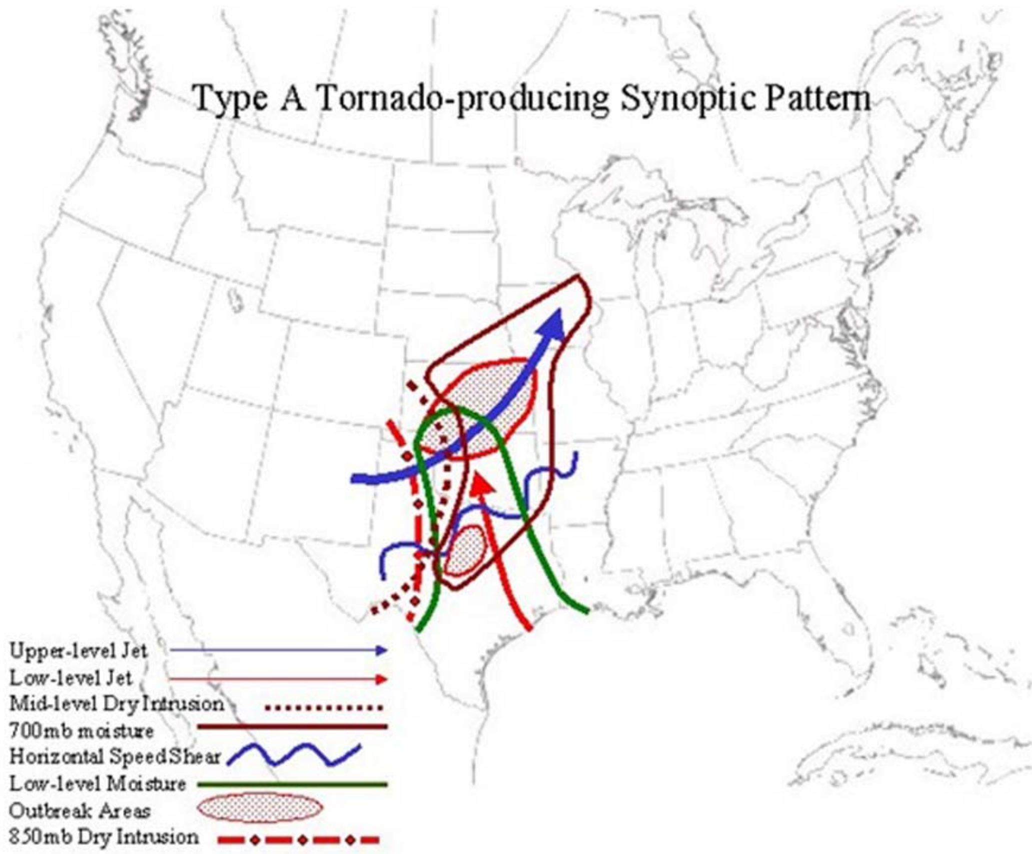


Figure 1–4. Type A synoptic pattern.

Type B – frontal

Anytime a cold front advances into a warm air regime, some instability results. Of course not all cold fronts have associated severe weather with them, but the frontal type weather pattern is the most predominant severe weather producer in the CONUS.

Characteristics

Type B is known for frontal and pre-frontal squall lines as well as strong cold air advection behind the cold front. The frontal type pattern features a well-defined flow of moist air at the low levels (usually associated with a low-level jet or maximum wind band) along with a well-developed surface baroclinic low with associated cold and warm fronts. Dry air located behind the cold front is most favorable. A well-defined mid-level (700mb) dry air intrusion from the west to southwest is also favorable. A strong, southwesterly maximum wind band aloft (500–300mb) with a major short-wave trough to the west also exists. A Type I air mass with a capping inversion usually exists.

Activity

The most violent activity occurs where a squall line intersects a warm front or outflow boundary (meso-low and line echo wave pattern {LEWP} formation). Activity mainly occurs during the late afternoon and early evening (maximum heating), but can occur at any hour due to the mechanical lifting associated with the fronts. This is because frontal thunderstorms do not require diurnal heating, and as long as the airmass stays absolutely unstable, thunderstorms in a squall line can persist

Severe weather is associated with strong cold fronts and can occur at anytime but usually occurs in the spring. Expect severe weather cells along or just ahead of a surface cold front frontal boundary

A key place to look is up to approximately 200 miles to the right of the upper-level jet to the dry intrusion area. Another key area is from 150–200 miles north of the jet, extending south to the leading edge of the dry air intrusion

Large hail, damaging winds, and violent, long-lasting tornadoes are common. The Type B synoptic pattern is responsible for the major tornado outbreaks that occur in the US. Figure 1–5 depicts an example of the type B pattern.

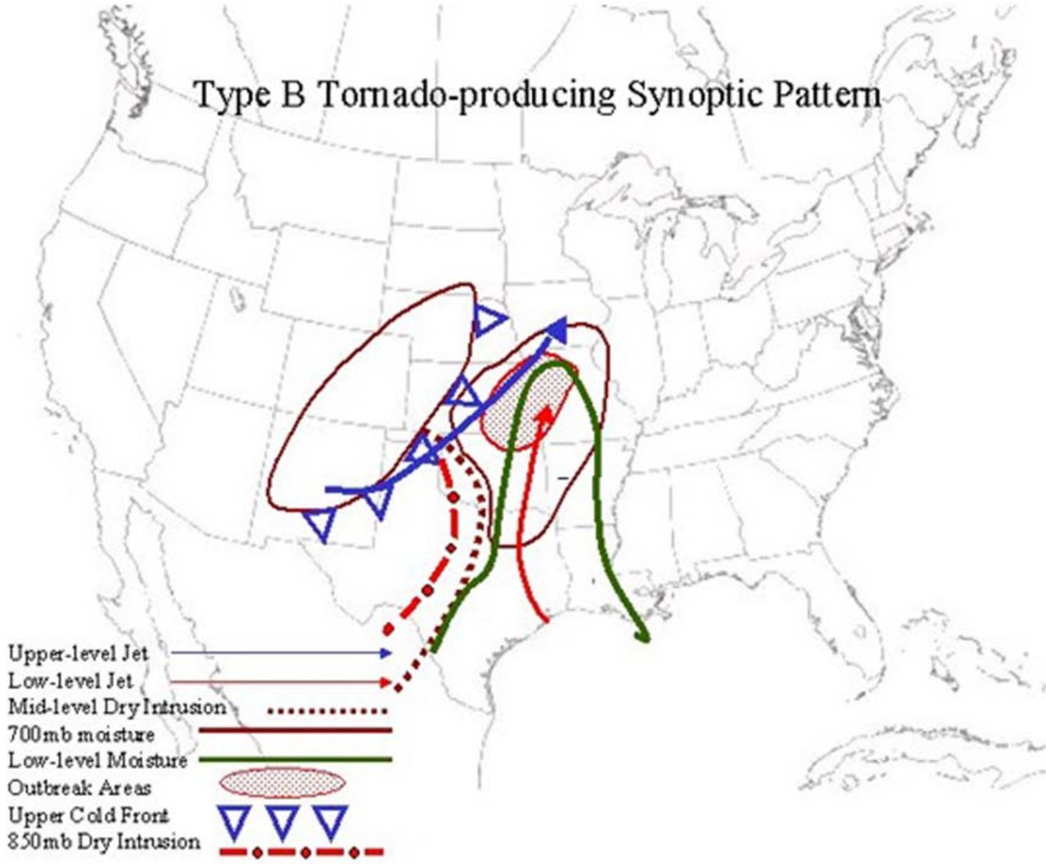


Figure 1–5. Type B synoptic pattern.

Type C – overrunning

Another synoptic scale severe weather pattern associated with fronts is the warm frontal overrunning pattern. This pattern features warm, moist, unstable air overrunning a stationary or warm frontal boundary.

Characteristics

The strongest overrunning occurs where the 850mb maximum wind band intersects the frontal boundary. The pattern also features a well-defined westerly maximum wind band aloft (500mb to 300mb), north of, and parallel to, the frontal boundary. A major short-wave trough is often embedded in the westerly wind flow and leads to further destabilization and or enhancement of frontal activity. A well-defined mid-level (700mb) dry-air intrusion is located upstream from the area of strongest overrunning. Tornadoes may occur when surface dew points are 50ºF (10ºC). Fuel comes from the release of latent heat.

Activity

Thunderstorms remain below severe limits until the mid-level dry air intrudes into the threat area. A squall line frequently forms along the leading edge of the dry air. The squall line is usually associated with a strong gust front (outflow boundary) that leaves a well-defined meso-high in its wake.

As the strength of overrunning increases so does the chance of severe weather. Severe weather continues until the dry air intrusion decreases or moves out. Expect storms to last up to six hours after max heating.

Hail is common due to the low freezing level. Strong, gusty winds occur with the passage of the gust front. Tornadoes are not common due to the cool air at the surface, although they can occur. The severe weather activity is strongest during maximum heating, but can occur at any hour. Figure 1–6 depicts an example of the type C pattern.

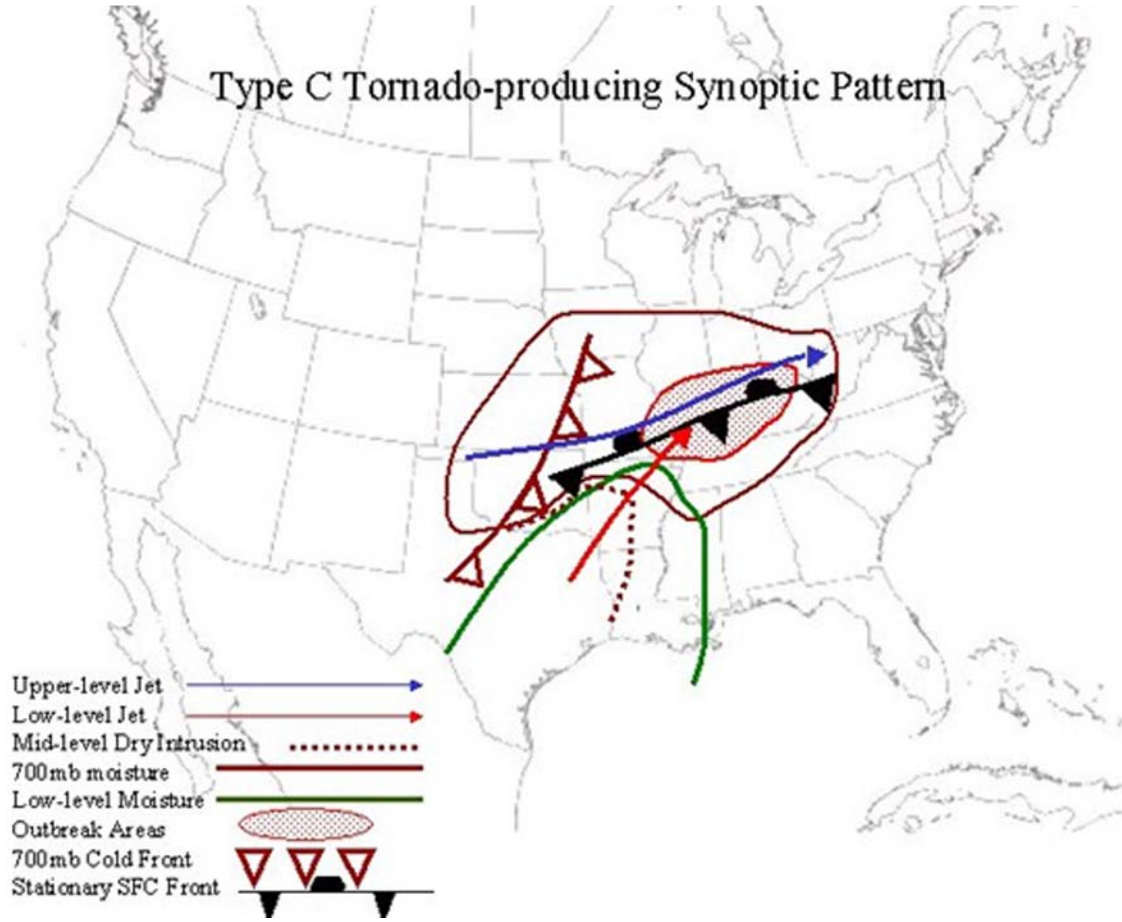


Figure 1–6. Type C synoptic pattern.

Type D – cold core

This pattern features a nearly vertically stacked, occluded system. The threat area is not associated with any fronts, but rather, behind the cold front in the clear air.

Characteristics

Cool maritime polar (mP) air is located behind the cold front and under a 500mb cold pocket aloft. Surface heating is abundant with relatively clear skies associated with the dry slot located behind the cold front that aid in the additional destabilization of the atmosphere. The reason for instability is warm air with a low-level jet advecting warm, moist air from the south-southeast under cold air aloft, which is associated with a cold core low at 500mb. The low-levels are dominated by boundary level confluence and divergence aloft. In the strongest cases, a low- and mid-level dry-air intrusion exists upstream. The airmass is typically Type III and shows maximum potential if we use the total totals index (the total totals reacts to the 500mb cold pocket).

Activity

Intense thunderstorms form shortly after noon and normally dissipate at sunset. Expect to see them in the area between the upper-level jet and the closed isotherm center at 500mb. Funnel clouds (cold-air funnels) are common with brief, but occasional, tornado touchdowns. Hail is very common due to the low freezing level. Hail normally increases in quantity and size near the cold pocket.

Look for severe weather to occur in the area 150 miles right of the upper-level jet, back to the cold core low, and to the front edge of the dry air intrusion, and to the east and northeast limit of the under running warm air. Figure 1–7 depicts an example of the type D pattern.

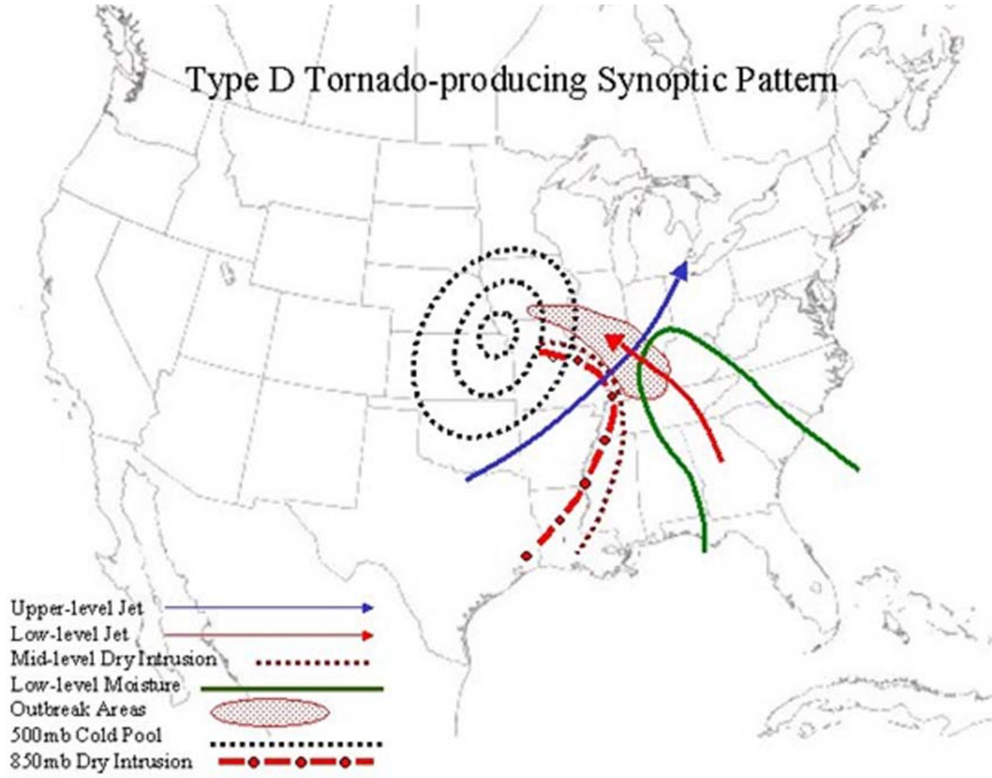


Figure 1–7. Type D synoptic pattern.

Type E – major cyclone

This system is also associated with an occluded system. However, the threat area is ahead of the warm front, much like Type C.

Characteristics

Strong, low-level overrunning of warm, moist, unstable air at 850mb over a surface warm front is a characteristic. Dry air intrusion exists at the mid levels, along with strong cold air advection located upstream of the strong overrunning. Expect to see low-level convergence as well as a defined upper-level westerly jet. Stability indices do not show the full potential of the air mass to support convection due to the cool low-level air north of the warm front.

Activity

The activity becomes severe when the dry air intrusion and cold air advection enter the threat area. Hail is the most common severe weather phenomenon, although tornadoes do occur with moderate frequency. While activity is the strongest during maximum heating time, it can occur at any hour. This type of severe weather pattern often forms in conjunction with a Type B or Type C outbreak.

In addition to developing ahead of cold fronts, squall lines associated with the Type E pattern also develop ahead of warm and occluded fronts. Severe weather may develop along and south of the upper-level jet but north of the 850mb warm front. The west-east boundary is from the 700mb cold front to the area of increasing stability. Thunderstorms form in the overrunning warm air between the 850mb warm front and the upper-level jet axis; where the 700mb dry air intrusion meets the frontal lifting of the warm, moist air in the low-levels, and the strong 500mb cold air advection. A secondary threat area exists where the 700mb dry air intrusion extends south of the 850mb warm front.

Thunderstorms can develop along the 500mb horizontal speed shear zone and along transitory, active squall lines.

You can expect to see thunderstorms develop with the onset of 500mb cold air advection into the severe outbreak area. Maximum severe activity occurs from the time of maximum heating to a few hours after sunset. At times, severe storms may continue until midnight, or until the airmass becomes more stable. Figure 1–8 depicts an example of the type E pattern.

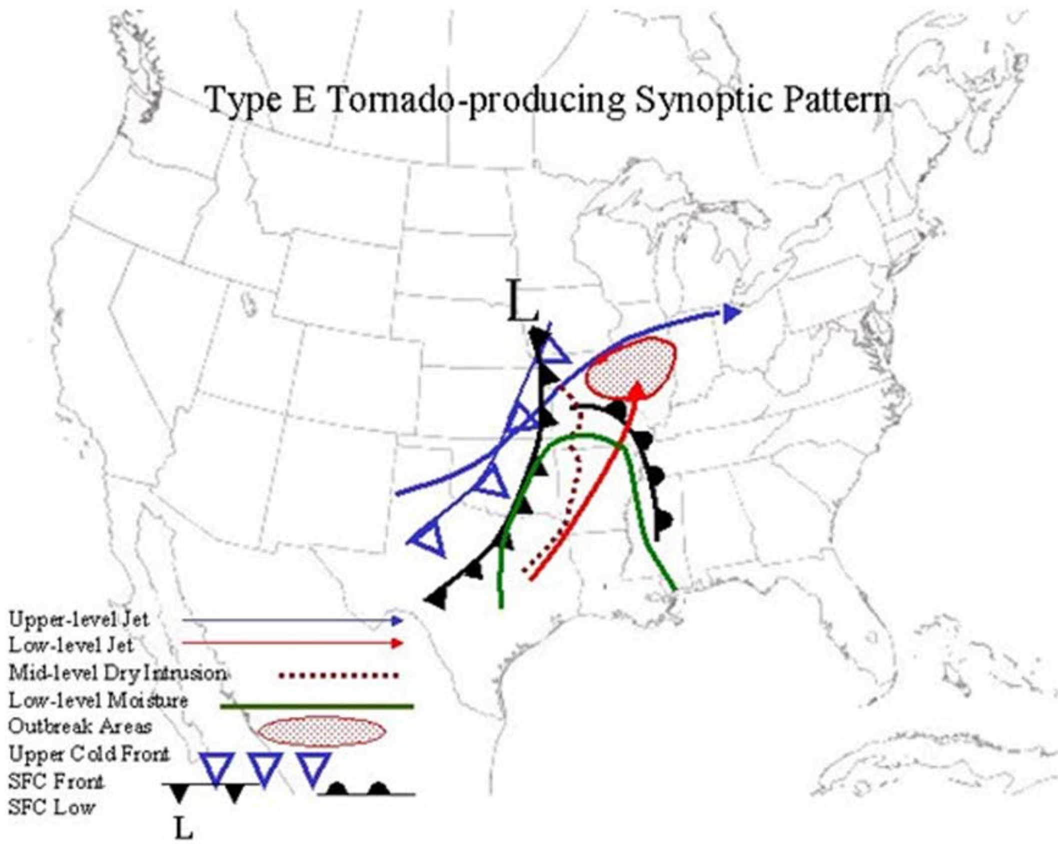


Figure 1–8. Type E synoptic pattern.

405. Convective severe weather parameters

In deciding whether any or all of the key parameters are met in any given situation, you must consider numerous parameters available from surface and upper air data. You must consider these parameters both individually, collectively, and projected in space and time.

You may have noticed that we started this unit by following the way analysis is performed, for example, VIV, thunderstorm types, airmass, and then pattern. We will continue this focusing on big picture down to small scale in this lesson. With this in mind we will cover the parameters from 300mb down to surface and instability.

200mb and 300mb analysis

At this level, the jet stream aids in increasing divergence aloft. The higher the wind speed the more the divergence potential. Let's discuss what to look for at this level.

Winds

Starting at the 200mb and 300mb level, you will look for the upper level jet. Focus on wind speeds of 86 knots or higher. The strongest storms will occur in the vicinity of this feature. Diffluence in the jet flow will enhance the lift from the lower levels.

The main diffluent areas are the left front and right rear quadrants of jet maxes in straight line flow, left front region of cyclonically curved jet max, and right rear region in an anticyclonic jet max. You'll need to streamline your diffluent zones and indicate horizontal speed shear zones when there is a significant decrease in speed per distance from the axis or the edge of the maximum wind band. Draw isotachs to locate the axis of max wind and to locate jet maxes.

Vorticity

Look for positive vorticity advection (PVA) in the right rear quadrant of the jet max; this is important because it is a prime area for development of severe weather. In addition, severe weather outbreaks often occur in the diffluent zone between the polar and subtropical jets. Another way to look at it is that most severe weather occurs south of the polar jet and north of the subtropical jet. Reference figure 1–9 for features to analyze.

Level	**Feature to Analyze**	**Why** (favorable/unfavorable; weak, moderate, strong chance for severe weather conditions.)
200mb/300mb	Identify jet maximums.	≤ 55 knots **Weak**
		56 to 85 knots **Moderate**
		≥ 86 knots **Strong**
	Streamline and identify diffluent areas.	Favorable for development.
	Shade areas of horizontal wind speed shear.	Favorable for development.

Figure 1–9. 200mb/300mb analysis parameters.

500mb analysis

This level is vital to your analysis for severe weather, timing a short wave correctly can make or break your forecast. Vorticity charts will aid you in locating the leading edge of the trough.

Mid level winds

Strong mid level wind is needed for thunderstorms to become severe. If you look at a widespread severe weather situation such as a mesoscale convective complex strong mid level winds are always present. This strong wind is an important ingredient for the transport of moisture and temperature through the atmosphere. An example would be a northwest flow (NWF) outbreaks, over 2/3 of all NWF outbreaks are associated with 500mb wind maxima exceeding 50 knots.

With this in mind, you will want to analyze on the 500mb level for any wind maxima of 50 knots or greater. This parameter is a 500mb severe weather indicator. Also, keep in mind that there is a vorticity and wind maxima relationship; vorticity maxima lie just north of the wind maxima.

Vorticity

As you will remember, vorticity is the spin of a parcel of air and is important to the lift of a column of air. Positive vorticity spins counterclockwise and negative vorticity spins clockwise. Positive vorticity advection (PVA) indicates divergence or upward vertical motion and negative vorticity advection (NVA) indicates convergence or downward vertical motion.

Strong PVA indicates strong upward vertical motion and the stronger the PVA the more lift. Greater lift is a necessary parameter for severe thunderstorms and strong PVA is always present when severe storms develop; the more perpendicular the vorticity is to the wind flow, the stronger the vorticity advection. The left front and right rear quadrants are the PVA areas or divergence aloft area.

Vorticity lines (isopleths) should be located in an area where the gradient of height contours is located. The height contour gradient is tight where the contours are spaced closer together.

You analyze the 500mb vorticity lobes to locate short wave troughs and ridges.

Height falls

500mb height falls are also associated with the vorticity pattern. As PVA is advected over your area, you will see a decrease in surface pressure. For severe weather, look for greater than 60 meters or stronger (faster) height falls from October to April using the 12 hour threshold and during the remainder of the year use the 24 hour threshold. Figure 1–10 has a complete list of all the parameters to analyze for at the 500mb level.

Level	**Feature to Analyze**	**Why** (favorable/unfavorable; weak, moderate, strong chance for severe weather conditions.)
500 mb	Identify maximum winds.	≤35 knots .... **Weak**
		36 to 49 knots .... **Moderate**
		≥50 knots .... **Strong**
	Streamline and identify diffluent areas.	Favorable for development.
	Isopleth 12-hour height falls (Oct to Apr) or 24-hour.	≤30 meters .... **Weak**
		31 to 60 meters .... **Moderate**
		≥61 meters .... **Strong**
	Perform 2°C isotherm analysis, color cold pools, identify thermal ridges and troughs.	Severe activity suppressed near and east of thermal ridge particularly when in phase with streamline ridge.
	Identify areas of cold air advection	The following temperatures are favorable:
		Dec to Feb: .... -16°C or less
		Mar, Apr, Oct, Nov .... -14°C or less
		May, June .... -12°C or less
		Jul to Sep :............ -10°C or less
	Identify dew-point depressions of 6°C or less, moisture analysis	Cut-off moisture sources indicate a short wave is present.
	Identify areas of vorticity advection	NVA: Weak or Not Favorable
		Positive Vorticity isopleths crossing 500mb height contours:
		≤30° .... **Moderate**
		>30° .... **Strong**
		Storms develop on periphery of the vorticity maximum and not directly below.

Figure 1–10. 500mb analysis parameters.

700mb analysis

At the 700mb level we focus on a smaller number of parameters in contrast to the 500mb level. The two most important are the no change line and the dry air intrusion. Let's take a look at these.

No change line

The 700mb no change line connects points of negligible temperature advection. It represents the separation of cold air advection from warm air advection. It will usually line up with the location of the 850mb warm ridge.

When you analyze for the no change line, look to see if it is ahead of a mid-level trough. If it is ahead of the trough, then a deepening of the surface low may take place. The chance of severe weather increases with a deepening low pressure system.

Dry air intrusion

The dry air intrusion is your guide to determining where the dry air is located. It is a dry line associated with severe weather when winds veer and increase with height. The steeper the gradient from dry to moist air, the more violent the activity.

Analyze for less than 50% relative humidity, dew points of 0°C or less, dew point depressions of greater than 7°C, wind velocity/perpendicular component and winds intruding at an angle of at least 41° West/26 knots. Figure 1–11 shows a complete list of 700mb parameters.

Level	**Feature to Analyze**	**Why** (favorable/unfavorable; weak, moderate, strong chance for severe weather conditions.)
700 mb	Perform 2° isotherm analysis, identify thermal troughs and ridges.	Good stacking of cold air here and at 500mb is favorable for severe.
	Indicate (12 hour) temperature no change line.	Advancement of the temperature no-change line ahead of the 700 mb trough indicates the surface low will intensify.
	Draw dew-point depression lines.	Moisture fields detached from the main moisture field indicate rising motions and a possible short wave in the area.
	Mark dry line, the dry line can be placed where dew point is ≤ 0°C, the dewpoint depression is ≥ 7° C, or the Relative Humidity is ≤ 50 %	Weak winds across the dryline: **Weak**
		Winds 15 to 25 knots crossing between 10° and 40°: ………… **Moderate**
		Winds ≥ 26 knots crossing between 41° and 90°: ………… **Strong**
	Streamline and identify confluent areas	Confluent areas are favorable for severe.

Figure 1–11. 700mb analysis parameters.

850mb analysis

As we move lower in the atmosphere to the 850mb level we will be looking at upper level fronts and convergence among other things. Two of the severe weather indicators are the placement of the temperature ridge and the presence and strength of a low level jet, we'll focus on these two now.

Temperature

A strong correlation exists between the 850mb temperature ridge, the location of the low-level moisture ridge, and the development of severe thunderstorms. If the temperature ridge is east (or downstream) of the moisture ridge, there is a weak chance of tornadic activity, however if the temperature ridge is west (or upstream) of the moisture ridge, there is a weak, but better chance of tornadic activity. Lastly, if the temperature and moisture ridges are coincident, there is a strong chance of tornadoes.

Low level jet

A low level jet is an organized band of strong winds (usually greater than 30 knots) that is representative warm moist air being pushed in front of a discontinuity line such as a frontal boundary. Low level jet features are usually at their maximum in the early AM hours (local time) about 1km above the ground (analysts should employ WSR–88D Vertical Azimuth Display (VAD) wind profile in addition to synoptic data plots to locate and refine the position of the low level jet). This feature is commonly associated with severe weather outbreaks. Figure 1–12 shows a complete list of 850mb parameters.

Level	Feature to Analyze	Why (favorable/unfavorable; weak, moderate, strong chance for severe weather conditions.)
850 mb	Streamline and identify confluent zones.	The greater the angle of winds from dry to moist air, the more unstable.
	Identify wind speed maximums.	≤20 knots ... **Weak**
		21 to 34 knots ... **Moderate**
		≥35 knots ... **Strong**
	Draw every 2°C isotherm that bisects the entire U.S. and mark thermal ridges.	Thermal ridge is often ahead of convergence zone. Cold air advection often found behind the main convergence zone, unless a dry line forms and moves out ahead of the cold advection.
	Draw isodrosotherms every 2° starting at 6°C.	Dew point:
		<8°C ... **Weak**
		9° C to 12°C ... **Moderate**
		≥13°C ... **Strong**
	Color in areas of significant moisture.	A diffuse moisture field is unfavorable for development of severe weather.
		Thermal ridge east of moisture axis: ... **Weak**
		Thermal ridge coincident with the moisture axis: ... **Moderate**
		Thermal ridge west of moisture axis: ... **Strong**
	Identify dry line.	Note the angle of winds crossing from dry to moist air, the greater the angle, the greater the instability. Where the dry line is intruding into moist areas is unstable.

Figure 1–12. 850mb analysis parameters.

Surface analysis

At the surface level dew points and convergent zones or lines of discontinuity are your focus. High dew points over 18°C in front of a boundary represent a strong potential for severe weather.

Convergent zones

Convergent zones can be frontal boundaries, sea breeze fronts, outflow boundaries or dry lines. These zones provide lift, which is an essential ingredient for convective weather to form. Then primary lifting mechanism is the cold front, but any of the other boundaries mentioned can produce severe weather.

One thing to watch for is intersecting boundaries, together with other needed parameters any two boundaries make for a prime development area for severe thunderstorms. This can be as small in scale as two outflow boundaries.

Pre-frontal squall lines that develop ahead of an approaching cold front are an ideal area for severe storm development. These lines form 50 to 150 nautical miles ahead of cold fronts and move faster than the boundary itself.

Severe thunderstorms are less common with warm fronts. Severe thunderstorms associated with warm fronts have a high potential to collapse suddenly and generate high winds.

Dry lines

Dry lines represent a significant contrast in humidity between a southerly, moist flow and western, dry continental flow. They can remain relatively static and serve as an effective outline for a continental tropical airmass situated over the American southwest. Advancing dry lines are often associated with widespread severe convective weather. They are most common on the high plains and can sometimes coincide with a leeside trough.

Temperature contrasts on either side of a dry line can vary; either side can be warmer than the other, with the dry side typically being warmest during the day and cooler at night. While there is no minimum dew point difference stated in mainstream meteorological literature, the best tools to identify dry lines are surface observations (particularly a pressure trough) and data from a meteorological satellite (look for linear cumulus development that builds with daytime heating).

Dew point

Higher dew points represent warm moist air and are vital to severe thunderstorm formation. An increase in warm, moist air increases instability and the potential for severe weather increases as well. Another thing to analyze for is height falls. It can indicate the forming of a surface feature which has the ability to change the wind direction and bring in warm moist air. The surface to 500mb thickness is a good product for indicating that the atmosphere is compressing or expanding.

Surface dew points below 13°C limit the development of severe thunderstorms. Keep in mind that weak tornadoes may occur with Type II and III airmasses when dew points are below 13°C. Figure 1–13 identifies all the surface weather analysis parameters.

Level	**Feature to Analyze**	**Why** (favorable/unfavorable; weak, moderate, strong chance for severe weather conditions.)
Surface	2 mb isobar analysis	Surface pressure patterns indicate likely areas of severe weather:
		> 1009 mb .... **Weak**
		1009 mb to 1005 mb .... **Moderate**
		< 1005 mb .... **Strong**
	Isallobaric analysis (12-hour) identify areas of falling pressure.	Squall lines often develop in narrow troughs of falling pressure. A strong pressure rise/fall couplet is favorable for severe weather. The following values indicate probability of severe weather.
		≤ 1 mb .... **Weak**
		2 to 5 mb .... **Moderate**
		> 6 mb .... **Strong**
	Identify areas of rapid temperature and dew point change.	Favorable for development of severe weather.
	2°C isodrosotherms analysis starting at 10°C.	Areas of horizontal moisture convergence are favorable. The following dew-point temperatures indicate probability of severe weather:
		≤ 10°C .... **Severe Unlikely**
		11°C to 12°C .... **Weak**
		13°C to 17°C .... **Moderate**
		> 18°C .... **Strong**
	Identify confluent streamline areas.	Areas of strong winds converging with weak winds are favorable.
	Identify highs, lows, fronts, squall lines, and dry lines and mark their previous locations.	Any discontinuity line is a likely place for thunderstorm development. Intersecting discontinuity lines are highly probable for development. Use distance between past and current locations to extrapolate onset of thunderstorms.
Surface to 500 mb thickness	Mark thickness ridge.	Probable area for squall line.
	Mark thickness no-change line (12 hour).	Indicates area of cold air advection.

Figure 1–13. Surface analysis parameters.

Atmospheric stability

Many indices have been created over the years to aid in the ability to analyze and forecast for convective severe potential. Stability applications can be useful when applied correctly, but they can't be applied to every weather situation. You must be able to use them in conjunction with other parameters. So keep in mind:

- Only indicate a potential for severe weather.
- There must be sufficient lift/instability.
- Must be something to break an atmospheric inversion if any.
- Some indices work better in specific geographical areas, i.e., mountainous versus plains.
- Track stability index changes over time.
- Take into consideration past and, if available, future stability trends.

Knowing the area that you forecast for will aid in using these indices. Figure 1–14 includes the indices to use in indicating severe thunderstorms and see figure 1–15 for indicators of tornadic activity.

Severe Thunderstorm Indicators				
Index	**Region**	**Weak (Low)**	**Moderate**	**Strong (High)**
Bulk Richardson Number (BRN)		> 50		10 to 50
		Multi-cellular storms		Supercells
Cross Totals (CT)	East of Rockies	22 to 23	24 to 25	> 25
	Gulf Coast	16 to 21	22 to 25	> 25
	West of Rockies	< 22	22 to 25	> 25
Modified Lifted Index (MLI)	Europe	0 to -2	-3 to -5	-5 and lower
Surface Cross Totals (SCTI)	East of 100°W			=> 27
	High Plains			=> 25
	Foothills of Rockies			=> 22
SWEAT Index	Midwest and Plains	< 275	275 - 300	=> 300
	(unreliable at higher elevations)			
Thompson Index (TI)	Over the Rockies	20 to 29	30 to 34	=> 35
	East of Rockies	25 to 34	35 to 39	=> 40
Total-Totals (TT)	West of Rockies	55 to 57	58 to 60	=> 61
	East of Rockies	48 to 49	50 to 55	=> 56
Wet-Bulb Zero (WBZ) Height	Not for use with deep mT air masses	< 5,000 ft	5,000 to 12,000 ft	7,000 to 9,000 ft
			Large Hail	Tornado

Figure 1–14. Severe thunderstorm indicators.

Tornado Indicators		
Index	**Value**	**Interpretation**
Energy/Helicity Index (EHI)	0.8 to 1	Weak tornadoes.
	1 to 4	Strong tornadoes.
	> 4	Violent tornadoes.
Lifted Index (LI)	< -6	Tornadoes possible.
Mean Storm Inflow (MSI)	> 20	Mesocyclone development possible.
Showalter Index (SSI)	< -6	Tornadoes possible.
Storm Relative Directional Shear (SRDS)	> 70	Mesocyclone development possible
Storm Relative Helicity (SRH)	> 400	Tornadoes possible.
SWEAT Index	≥ 400	Tornadoes possible.
Wet-Bulb Zero (WBZ) Height	7,000 to 9,000 ft (mP)	Families of tornadoes.
	≥ 11,000 ft (mT)	Single tornadoes.

Figure 1–15. Tornado indicators.

Some of the names in the index section of figures 1–14 and 1–15 are more common than others. Let's review some short descriptions of the more commonly used indices.

Showalter stability index

The Showalter stability index (SSI) is derived on a Skew-T and compares low-level moisture and upper level temperatures. SSI uses the lifted condensation level (LCL) and considers that a parcel will rise moist adiabatically to 500mb (LCL is at 850mb). The difference between 500mb parcel temperature and actual 500mb temperature is the SSI number. The table will give you an idea of the number range and correlating stability of the atmosphere.

Number range	Atmosphere stability
>+3	Strong Stability
>+1 to ≤+3	Moderate
>–3 to ≤+1	Weak
≥–6 to ≤–3	Moderate
<–6	Strong Instability (tornadic potential)

Lifted index

Lifted index (LI) is a modification of the SSI and uses the average moisture and average potential temperature in the lower 3,000 feet. If the LI is greater than zero then the airmass is stable. The following table will give you an idea of the number range and correlating stability of the atmosphere.

Number Range	Atmosphere Stability
0 to -2	Thunderstorms possible, weak severe thunderstorm potential
-3 to -5	Unstable, Thunderstorms probable; moderate probability of severe thunderstorms
-6	Very unstable, Heavy to strong severe thunderstorm probability
<-6	Strong probability of severe thunderstorm and possible tornado activity

Total totals

Total totals (TT) are used to measure the potential for thunderstorm development and severity. The sum of vertical totals (850mb temp – 500mb temp) and cross-totals (850mb dew point – 500mb temp) = TT. The following will give you an idea of the number range and correlating stability of the atmosphere.

Number range	Atmosphere stability
<50	Weak potential
≥50 to ≤55	Moderate potential
>55	Strong potential

Severe Weather Threat Index

The Severe Weather Threat Index (SWEAT) estimates the potential for severe convective weather in an air mass. It takes into account, low level moisture, instability, low level jet, upper level jet, and warm air advection. SWEAT is best computed automatically. The following values are used to discriminate between ordinary and severe thunderstorms.

Value	Weather threat
300 to 400	Chance of severe thunderstorms
400 to 500	Severe thunderstorms likely, chance of tornadoes
500 to 600	Severe thunderstorms and tornadoes likely
600 to 800	Tornadoes nearly always occur
>800	No severe weather – winds too strong

Convective available potential energy

The convective available potential energy (CAPE) is the **a**mount of energy available to a surface parcel that has reached its level of free convection (LFC). A positive CAPE value indicates upward vertical motion while a negative CAPE value indicates downward vertical motion. Increased warm moist air advection in the low levels will lower the LFC and increase CAPE. You should monitor CAPE values daily when there is a potential for severe weather. The following are indicator numbers associated with the CAPE.

- Values >1000 but less than 2500 are associated with severe thunderstorms.
- Values >2500 are associated with tornadic activity.

Bulk-Richardson number

The Bulk-Richardson number (BRN) is the ratio of the buoyancy (CAPE) of a lifted air parcel to the vertical wind shear environment in which the parcel is lifted. This is a complex equation and is best derived using automated methods. The following values are associated with BRN interpretation:

- <10: Indicates excessive shear and severe thunderstorms are unlikely.
- 10 to 50: Indicates supercell development.
- ≥ 50: Indicates weaker, multi-cellular storms.

Wet-Bulb Zero

Wet Bulb Zero (WBZ) is important in the determination of the potential for hail and hail size. The WBZ is described in feet above the ground. The following numbers indicate WBZ categories.

- WBZ height between 5,000 feet and 12,000 feet: Greatest potential for hail.
- WBZ height between 7,000 feet and 11,000 feet: Large hail.
- WBZ height > 12,000 feet and < 5,000 feet: Small hail ≥ ¼ inch.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Model verification, initialization, and verification

1. Name three of the variables to take into account in developing strengths and weaknesses for a model.

2. Describe how the National Weather Service or Operational Weather Squadron model discussions help you.

3. List two training items you should review as part of your on the job training.

4. Describe the final step in the Verification, Initialization, and Verification process.

5. List the initial conditions that models are based upon.

6. What is inherent to the ensemble prediction system?

402. Severe thunderstorm types

1. Name the characteristics that separate severe thunderstorms from weaker ones?

2. What is the goal of severe weather analysis?

3. Describe multi-cellular storm regeneration.

4. Describe the internal dynamics of a supercell.

5. Name the synoptic feature and storm type associated with west Texas.

403. Severe convective airmasses

1. Match the airmass descriptions in column A to the types in column B. Items in column B are used only once.

Column A

___ (1) The lapse rate is conditionally unstable with no significant inversion or stable layer. The surface temperatures are usually over 80°F. The moisture content is very high with the RH being over 65 percent from the surface to above 20,000 ft in practically all cases. The WBZ is normally above 11,000 ft. Tornadoes are short-lived, with narrow paths, and they move slowly.

___ (2) The lapse rate is conditionally unstable. The sounding has a dry lower layer and a cool, moist layer aloft. The WBZ is near the optimum of 8,000 ft. The winds aloft increase in speed and veer with height. Tornadoes are isolated, rapid moving, short-lived, and their path is short and narrow.

___(3) The lapse rate is conditionally unstable; The air mass is colder than the other types and the surface temperatures range from 50°F to 68°F. Moisture extends to great heights with RH often exceeding 70 percent at all levels up to at least 500mb. Tornadoes in this type air mass have only a brief life, with a short narrow path.

___ (4) This air mass has an inversion or stable layer with a conditionally unstable lapse rate above and below the stable layer. The layer below the stable layer is moist, with a comparatively dry layer above. The moisture increases slowly above the stable layer. The winds increase with altitude in the dry air above the inversion, having a component of at least 30 knots perpendicular to the flow in the warm moist air. The weather changes rapidly, and tornadoes in this type of air mass have the longest life.

Column B

a. Type I, Great Plains type.
b. Type II, Gulf Coast type.
c. Type III, Pacific Coast type.
d. Type IV, Inverted “V” type.

2. What associated weather is implied in reference to a tornado producing storm?

3. Name the four primary airmass source regions.

4. Describe how tornadoes frequently occur in the type I airmass.

5. Describe the moisture content of the type II airmass.

6. Why are hail and strong convective gusts rare with a type II airmass?

7. Name the key feature of the type III airmass.

8. Where is a type III airmass usually located?

404. Severe weather producing synoptic patterns

1. What feature defines the dry line?

2. What is the recommended tool for locating the dry line?

3. What kind of air mass is normally associated with the dry line synoptic pattern?

4. Describe the three characteristics of the dry line synoptic pattern.

5. What dew point temperature difference should be present across a dry line?

6. Look for enhanced convergence at what dry line feature?

7. What type of weather pattern is the most predominant severe weather producer?

8. Where does the most violent activity occur in the type B pattern?

9. What can lead to enhancement of frontal activity with a type C pattern?

10. Why is hail very common with an overrunning pattern?

11. Describe the features and threat area of the cold core pattern.

12. When does most severe weather occur in a type E pattern?

405. Convective severe weather parameters

1. What is the minimum significant 200mb/300mb wind speed in severe weather analysis?

2. Why is the right rear quadrant of the jet max important?

3. Describe what strong positive vorticity indicates.

4. What is the 700mb no change line represents?

5. Name five criteria in 700mb dry air intrusion analysis.

6. Explain the correlation between the 850mb temperature and moisture ridges.

7. Name the best tools for dry line identification.

8. Explain how dew points influence thunderstorm formation.

9. What Showalter stability index value indicates tornadic potential?

10. What Severe Weather Threat index value indicates likely tornadoes?

11. Define the Convective Available Potential Energy indice.

12. What is the wet-bulb zero used to determine?

1–2. Non-convective severe weather

It was a clear, breezy afternoon in South bend, Indiana on October 27, 2010. The University of Notre Dame football team was hard at work practicing and preparing for their upcoming game against the University of Tulsa. Like most other practices, this session was being recorded by student videographers, some of which were in hydraulic lifts 40 feet above ground. At 1654 Eastern Daylight Time (EDT), a sudden gust of wind from the southwest, estimated at 53 miles per hour, swept across the Fighting Irish campus; strewing garbage, bags of footballs, and other debris across the practice field. One student's hydraulic lift and platform, facing south, caught the brunt of the wind's force. The lift tipped backward and collapsed across the nearby road, dropping him 40 feet vertically to his death.

Non-convective severe weather is a very real threat to property and lives around the world. The hydraulic lifts used in this event are not any different from lifts with maintainers on-board you see on a flightline, or on the side of a building being used by civil engineers. As a weather forecaster, you'll be providing your base's decision makers with information regarding the potential arrival of these events. Severe winds can damage buildings and aircraft. Freezing rain can cause traffic accidents and damage communication and power cables and heavy snow can stop mission operations. Considering the critical impacts that non-convective severe weather can have on the mission, personnel and assets, it is imperative that you take an active role in mastering the principles for forecasting this related phenomena.

In this section, we will cover the elements of non-convective severe weather. The elements are strong non-convective winds and precipitation.

406. Strong non-convective winds

Unlike winds from tornadoes, thunderstorms or hurricanes, the risk from non-convective high winds is not immediately apparent from a glance at the sky. The phrase "high wind" doesn't always convey the same sense of terror that the word "tornado" does in our culture and, as a result, can catch a lot of people off guard. As a Weather Craftsman, it's your responsibility to recognize the impact that these wind events can have on the installations and units you support and convey this information to the appropriate decision makers. In order to perform this role with excellence, it is imperative that you develop an intimate understanding of the meteorological tactics, techniques, and procedures (TTP) used at your location to analyze and forecast strong non-convective winds. This lesson will build upon the lessons conveyed in your journeyman level career development courses. It will cover:

- Dry slot.
- Pressure tendencies.
- Isallobaric winds.
- WSR–88D Vertical Azimuth Display (VAD) Wind Profile.
- Skew-T.
- Rules of thumb.

From the days of ancient mariners to the modern era of remote sensing, it has been well known that it doesn't take a hurricane, tornado or thunderstorm to create damaging and even deadly winds. It's important that, as a Weather Craftsman, you understand the basic dynamics that can cause these events.

Dry slot

Surface wind strength is generally proportional to the near-surface pressure gradient, and very tight pressure gradients can be found in the vicinity of strong extratropical cyclones. Historically speaking, most non-convective severe wind events occur in areas of strong subsidence associated with the "dry slot" of a mature cyclone. This feature is commonly found south of the center of the low pressure system and is identified by a relatively cloud free region. Figure 1–16 shows the intense mid-latitude cyclone which caused the event described above at The University of Notre Dame. The cloud-free region separating the low (dark) clouds over Wisconsin from the bright white clouds over Ohio and Lake Huron is the signature of a dry slot.

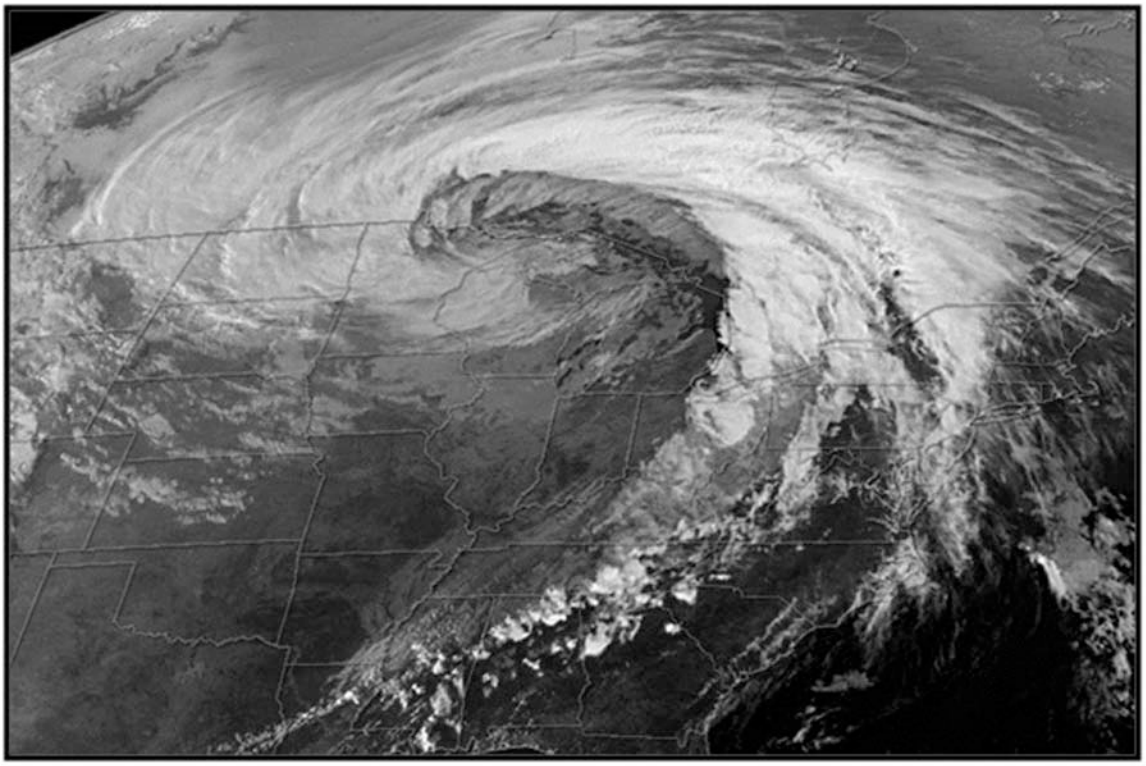


Figure 1–16. Dry slot.

High winds are often associated with dry slots due to the large amount of subsidence occurring in this region as higher momentum air aloft is pulled down from the upper atmosphere into the lower atmosphere. In this region, high wind speeds in the lower atmosphere can be easily mixed down creating gusty winds at the surface. This is particularly true when a strong gradient of post-frontal isobars on an isentropic surface is analyzed or forecasted.

Pressure tendencies

Three-hour pressure tendencies are another great way to analyze the potential for non-convective severe winds associated with extratropical mid-latitude cyclones. The surface pressure tendency equation says that pressure tendency is a function of vertically integrated temperature advection. As such, strong cold air advection in the lower troposphere will be indicated at the surface by strong pressure rises which can be an indicator of potentially high winds. The specific pressure rise value varies greatly by location due to the enhancing or negating effects of local terrain. This information should be available from your station's Forecast Reference Notebook (FRN) or via Support Assistance Request (SAR) from the 14^{th} Weather Squadron.

Isallobaric winds

Another excellent, all-purpose tool for determining strong non-convective winds associated with extratropical mid-latitude cyclones is isallobaric wind analyses and forecasts. Often viewed as pressure rise and fall couplets, these charts help identify cold frontal positions, pressure gradient tendencies and speed of surface features and winds. Figure 1–17 depicts a set of analyzed pressure rise and fall couplets with the area in between highlighted with the potential for very windy conditions.

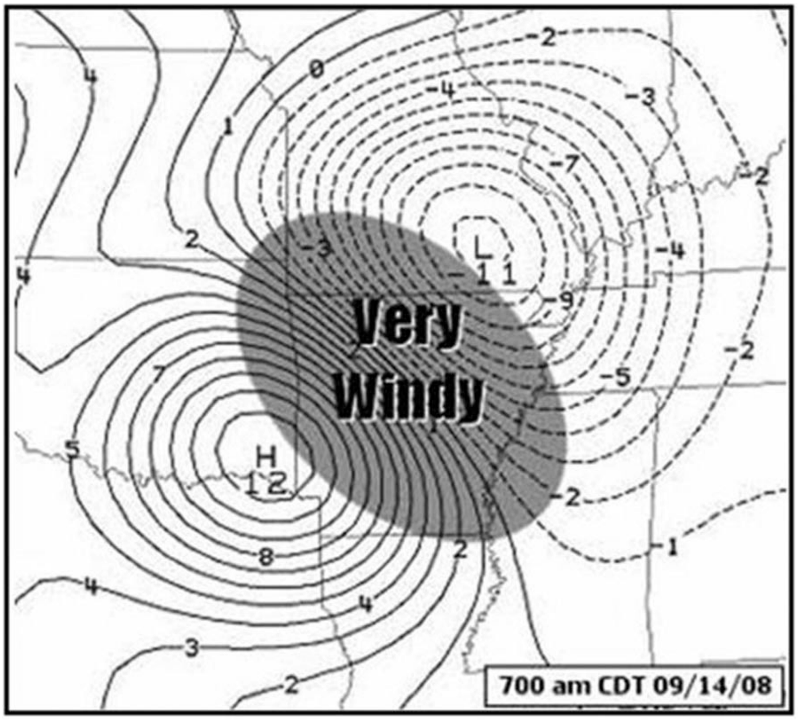


Figure 1–17. Isallobaric winds.

Velocity Azimuth Display Wind Profile

The VAD Wind profile (VWP) is excellent tool to help identify strong, gusty non-convective winds. It can help determine the horizontal wind field above a given location. You can use this data to determine the intensity and trend of low-level winds and identify the potential development of a low-level jet. Figure 1–18 shows a generic VWP with the potential from strong, gusty surface winds.

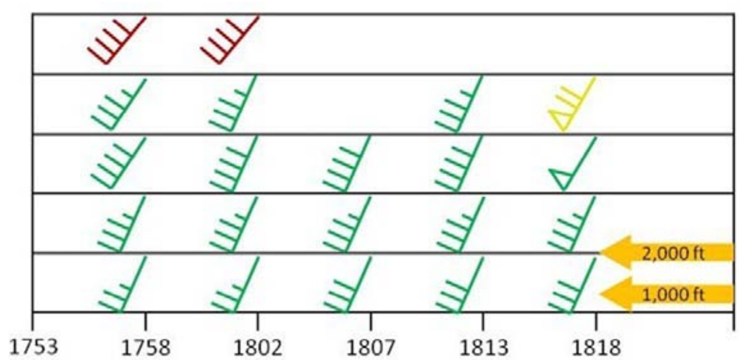


Figure 1–18. VAD wind profile.

Skew-T

Observed and forecasted Skew-T diagrams can be excellent tools for identifying the potential for high non-convective winds. They help determine the presence of low-level jets, inversions, and inversion break temperatures. If winds above the inversion are extremely high, they could potentially mix down to the surface once the calculated inversion break temperature is achieved. Likewise, upstream Skew-T soundings can be used to identify approaching strong wind fields, but these should be used with caution as localized terrain effects can significantly modify these effects. Figure 1–19 shows a Skew-T Diagram with a clearly defined low-level jet.

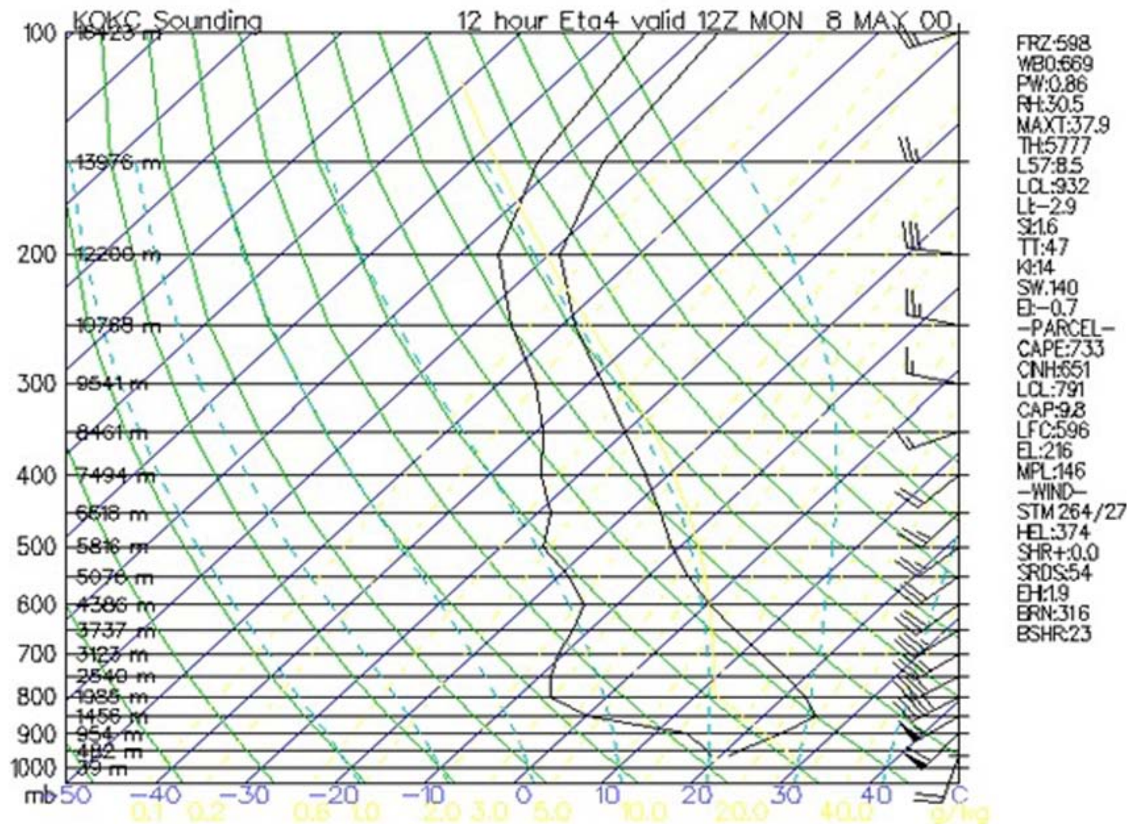


Figure 1–19. Skew-T.

Rules of Thumb

Perhaps the best, and easiest, way to forecast severe non-convective winds is to use local rules of thumb. Every base-servicing weather unit in the Air Force is tasked with researching and developing local rules of thumb for forecasting weather conditions. These rules of thumb will be clearly identified in your local FRN, and will take you far towards putting a good wind forecast together. If your station doesn’t currently have any high-wind rules of thumb, you should consult with your leadership about working on some. The 14th Weather Squadron has an enormous database of weather information spanning back decades and can help develop some very reliable, easy-to-use rules of thumb.

407. Precipitation

Rainfall amounts that exceed the drainage capabilities of a given area can lead to dam failures, mudslides, flooding and flash flooding. Likewise, heavy snow or freezing rain can quickly wreak havoc in an unprepared area, completely shut down airfield operations and cause absolute chaos on the roads. Therefore, the counsel you’ll provide to your supported decision makers will help them decide whether or not to halt airfield operations, prepare sandbags, lay road salt, release personnel and school children early, and so forth. It will affect nearly every person on your installation.

There are numerous methods and techniques available for analyzing and forecasting precipitation. Many of them were covered in your journeyman CDCs and many more are covered in Air Force Weather Agency (AFWA)/Tech Note (TN) 98–002. This lesson covers a few TTPs for analyzing precipitation. They are:

1. General non-convective precipitation
    a. Extrapolation.
    b. Cloud-top temperatures.

c. Height of freezing level.
d. Checklist for snow versus freezing drizzle.

2. Radar signatures associated with flash floods.
3. Non-convective snowfall rules of thumb.
4. Locating areas of maximum 12-hour snowfall.
5. Favorable synoptic patterns for heavy snowfall.

General non-convective precipitation

For precipitation to occur, there are two basic ingredients necessary: moisture and a lifting mechanism. Lifting mechanisms include convection, orographic lifting, and frontal lifting. In this lesson we'll identify a few basic analyses to determine the potential for precipitation type and amount.

Extrapolation

For these purposes, precipitation should be occurring upstream of your station. Begin by outlining areas of precipitation on an hourly or 3-hourly product. If available, you can then use radar or satellite imagery to refine your depiction. Next, compare the present area to several hourly, or 3-hourly, past positions. If the past motion is reasonably continuous, you can then make extrapolations for the next several hours. You can then use this information to help determine the amount of precipitation to expect. It's important that you understand and account for local effects with this type of analysis.

Cloud-top temperatures

The thickness of the cloud layer aloft and the temperatures in the upper-levels of clouds are usually closely related to the type and intensity of precipitation observed at the surface, particularly in the mid-latitudes. Climatology shows us that 87% of the time, when drizzle was reported at the surface, the cloud-top temperatures were colder then –5°C. Also, 95% of the time, during continuous rain or snow, the cloud-top temperatures were colder than –12°C. Lastly, 81% of the time intermittent rain or snow fell from clouds with cloud-top temperatures colder than –12°C and 63% of those cases had cloud-top temperatures less than –20°C. Meteorological Satellite (MetSat) imagery can be used to determine cloud-top temperatures and these statistics can help lead you in the right direction towards determining whether or not to forecast precipitation in a non-convective situation.

Height of freezing level

Forecasters often use the freezing level to determine the type of precipitation. This is based on the assumption that the freezing level must be lower than 1,200 feet above the surface for most of the precipitation reaching the ground to be snow. Figure 1–20 shows the probability of snowfall as a function of the height of the freezing level. However, forecasters must understand the complex thermodynamic changes occurring in the low-levels to correctly forecast tricky winter precipitation situations. For example, the freezing level often lowers 500 to 1,000 feet during the first one and one-half (1½) hours after precipitation begins, due to evaporation or sublimation. When saturation occurs, these processes cease and freezing levels rise to their original heights within three hours. With strong warm air advection, the freezing level rises as much as a few thousand feet in a six to eight hour period.

Height of freezing level above ground	Probability precipitation will fall as snow
12 mb	90%
25 mb	70%
35 mb	50%
45 mb	30%
61 mb	10%

Figure 1–20. Freezing level height.

If there is only one freezing level and it equals or exceeds 1,200 feet above ground level (AGL), expect liquid precipitation. If it is less than 600 feet AGL, expect solid precipitation and if the freezing level is between 600 and 1,200 feet AGL, expect mixed precipitation.

When there are multiple freezing levels, warm layers exist where the temperature is above freezing. The thickness of the warm and cold layers affects the precipitation type at the surface. If the warm layer is greater than 1,200 feet thick and the cold layer closest to the surface is less than or equal to 1,500 feet thick, expect freezing rain. Conversely, if the warm layer is greater than 1,200 feet thick and the cold layer closest to the surface is greater than 1,500 feet thick, expect ice pellets. Finally, if the warm layer is between 600 and 1,200 feet thick, forecast ice pellets regardless of the height of the lower freezing level.

Checklist for snow versus freezing drizzle

There are two types of atmospheric situations where freezing precipitation occurs. The most common case occurs when ice crystals melt as they fall through a sufficiently deep warm layer (temperature greater than 0°C). The water droplets hit a cold surface that has a temperature at or below freezing, and freeze on contact. The other situation occurs when the atmosphere is below freezing through its entire depth, and the water droplets remain supercooled until surface contact. Figure 1–21 assumes a below freezing atmosphere and supercooled water droplets and applies to the continental United States, Europe, and the Pacific regions. However, freezing precipitation is relatively rare in Korea.

1.	Does a low-level moist layer (below 700mb) extend upward to where temperatures are -15°C?	If not, then freezing drizzle is possible
2.	Is the mid-level dry layer (dew-point depression greater than or equal to 10°C) deeperthan 5,000 feet?	If yes, the precipitation may change to freezing drizzle, or a prolonged period
3.	Is mid-level moisture increasing?	If freezing drizzle is occurring and mid-level moisture is increasing, precipitation may change to all snow.
4.	Is elevated convection occurring or forecast to occur?	If yes, the mid-level dry layer may be eroded, causing snow instead of freezing drizzle.

Figure 1–21. Freezing drizzle versus snow.

Radar signatures associated with flash floods

Monitoring weather radar is, quite possibly, the best way to detect the potential for heavy rains and localized flooding. Pay attention to these signatures associated with flash floods:

- Rapidly growing echoes.
- Slow moving echoes.
- Persistency (long lasting).
- Train echoes (echoes that move repeatedly over the same area).
- Hurricanes and tropical storms.
- Lines.
- Line echo wave patterns (LEWP).
- Converging echoes and lines.

Non-convective snowfall rules of thumb

As we’ve discussed before, every base-servicing weather station in the Air Force should have some well-developed and tested rules of thumb. In the absence of any local rules of thumb regarding non-convective snowfall, you can utilize figure 1–22.

Deep occluding low	The track of the low is to the north-northeast and its speed slows from an initial 25 knots to only 5 to 10 knots during the occluding process. In practically all cases a closed low exists at 500-mb and captures the surface low. The area of maximum snowfall lies from the north to west of the center with rates of ½ to 1 inch per hour. The western edge of the maximum area is at the 700-mb trough or low center and all snow ends with the passage of the 500-mb trough or low center.
Non-occluding low	The track of the low is to the northeast or east-northeast at 25 knots or more. It is associated with a fast moving open trough (occasionally with a minor closed center) at 500 mb. The maximum area is located parallel to the warm front from north to northeast of the storm center. Duration is short (4 to 8 hours).
Post-cold frontal type	A sharp cold front oriented nearly north-south in a deep trough. A minor wave may form on the front and travel rapidly north along it. The troughs at 700 and 500 mb are sharp and displaced to the west of the front by 200 to 300 NM. Ample moisture is available at 850 and 700 mb. the area of maximum snowfall is located between the 850- and 700-mb troughs. The snowfall duration is 2 to 4 hours.
Warm advection type	Occurs infrequently. The lack of an active low near the maximum snowfall area makes it different from the others. A high-pressure ridge or wedge is situated north of a nearly stationary warm front. The area of maximum snowfall is in a band parallel to the front.
Inverted trough snowstorm	This consists of an inverted trough extending northward from a closed low-pressure system to the south. It may be just an inverted trough at the surface. The available moisture determines the extent of the snowfall area. Snowfall ends with the passage of the 700-mb trough. Heavy snow may occur when the flow at 500 mb is nearly parallel to the surface trough. The surface and 700-mb troughs move very slowly when this occurs.

Figure 1–22. Snowfall rules of thumb.

Locating areas of maximum 12-hour snowfall

You must conduct an analysis to pinpoint the areas of heavy snowfall. Follow these steps to pin point or locate maximum snowfall that occurs where these areas intersect the most.

1. Outline the surface 0°C (32°F) isotherm and 0°C (32°F) dew points.
2. At 850mb, outline areas having dew points < 4°C and moisture.
3. At 700mb, outline areas having dew points < 10°C and moisture. Also, locate areas showing the greatest 12-hour cold advection.

Favorable synoptic patterns for heavy snowfall

Analyzing the synoptic situation can help identify areas most likely to receive heavy snow. Figure 1–23 lists five different synoptic snowstorm types with various bits of information about each.

Deep occluding low	The track of the low is to the north-northeast and its speed slows from an initial 25 knots to only 5 to 10 knots during the occluding process. In practically all cases a closed low exists at 500-mb and captures the surface low. The area of maximum snowfall lies from the north to west of the center with rates of ½ to 1 inch per hour. The western edge of the maximum area is at the 700-mb trough or low center and all snow ends with the passage of the 500-mb trough or low center.
Non-occluding low	The track of the low is to the northeast or east-northeast at 25 knots or more. It is associated with a fast moving open trough (occasionally with a minor closed center) at 500 mb. The maximum area is located parallel to the warm front from north to northeast of the storm center. Duration is short (4 to 8 hours).
Post-cold frontal type	A sharp cold front oriented nearly north-south in a deep trough. A minor wave may form on the front and travel rapidly north along it. The troughs at 700 and 500 mb are sharp and displaced to the west of the front by 200 to 300 NM. Ample moisture is available at 850 and 700 mb. the area of maximum snowfall is located between the 850- and 700-mb troughs. The snowfall duration is 2 to 4 hours.
Warm advection type	Occurs infrequently. The lack of an active low near the maximum snowfall area makes it different from the others. A high-pressure ridge or wedge is situated north of a nearly stationary warm front. The area of maximum snowfall is in a band parallel to the front.
Inverted trough snowstorm	This consists of an inverted trough extending northward from a closed low-pressure system to the south. It may be just an inverted trough at the surface. The available moisture determines the extent of the snowfall area. Snowfall ends with the passage of the 700-mb trough. Heavy snow may occur when the flow at 500 mb is nearly parallel to the surface trough. The surface and 700-mb troughs move very slowly when this occurs.

Figure 1–23 Heavy snowfall patterns.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

406. Strong non-convective winds

1. Historically speaking most non-convective severe wind events associated with extratropical cyclones occur where? Why?

2. When analyzing isallobaric winds, where is the area with the highest potential for windy conditions located?

3. What can the velocity azimuth display wind profile help determine? How is this useful?

4. Why is using skew-T data to determine the presence of an inversion, along with the winds above the inversion important?

407. Precipitation

1. When using the extrapolation technique, what data can be used to refine your initial depiction?

2. With multiple freezing levels, what must occur to cause freezing rain?

3. Briefly explain the most common cause of freezing precipitation.

4. What three steps help locate an area of maximum 12-hour snowfall?

Answers to Self-Test Questions

401

1. Terrain, latitude, diabatics, adiabatics, evaporation, condensation.
2. These discussions will give you insight on what to watch for in a particular model as well as how certain features may be off in your weather forecasting area.
3. Part of your on the job training for a new position or location should be to review the "rules of thumb" and model biases.
4. The final step in the VIV process is to verify the current 12-hr model forecast with real-time data for the same time (satellite imagery, surface analysis) to determine how well the model is
5. The initial conditions that models use are based on past and current weather observations or other weather measurements.
6. For an ensemble prediction system, most steps of the VIV process are inherent to the ensemble and automated, while others are rendered superfluous or unnecessary.

402

1. First, they have stronger instability, which increases their updraft speeds. Second, the wind shear environment above the storm separates the updrafts and downdrafts, keeping them from interfering with each other.
2. The goal of severe weather analysis is to identify the preconditions that allow storms to become severe.
3. Each cell generates a cold outflow that can form a gust front. Convergence along this boundary causes new cells to develop every 5–15 minutes in the convergent zone.
4. The internal dynamics of supercell thunderstorms consist of one rotating updraft, a forward-flanking downdraft that forms the gust front, and a rear-flanking downdraft.
5. Dry line and low-precipitation supercells.

403

1. (1) b
   (2) d.
   (3) c.
   (4) a.
2. The occurrence of hail and destructive winds is implied in any reference to a tornado-producing storm.
3. Primary source regions are arctic, polar, tropical, and equatorial (A, P, T, and E, respectively).
4. Tornadoes in this type of air mass most frequently occur in families; their paths are commonly long and wide compared to tornadoes occurring in the other types of air masses.
5. The moisture content is very high, the RH being over 65 percent in practically all cases from the surface to above 20,000 ft.
6. Although hail aloft does occur, surface hail and strong convective gusts are rare, since the wet bulb zero (WBZ) is normally above 11,000 ft.
7. The Pacific Coast air mass has cold air at all levels, which is the key feature of this air mass.
8. This situation is seen in the High Plains, or the lee side of the Rocky mountains. Lee side consists of the area bordered on the east by western Nebraska, south into Texas, and west into the southwest desert regions.

404

1. The dry line itself is a narrow, almost-vertical zone, across which a sharp moisture gradient exists, this is the defining feature.
2. For analysis of the dry line, the 55°F isodrosotherm is recommended as the first estimation.
3. The dry line synoptic pattern is normally associated with a Type I air mass.
4. (1) A well-defined southeasterly flow of moist air from the Gulf of Mexico at the low levels (surface to 850mb).
   (2) A well-defined west to southwest maximum wind band aloft (500 to 300mb).
   (3) A distinct surface to 700 mb warm dry-air intrusion from the southwest.
5. A dew point temperature difference > 10^{o}F degrees should be present across the dry line.
6. Enhanced convergence occurs at the bulge.
7. The frontal type weather pattern is the most predominant severe weather producer in the CONUS.
8. The most violent activity occurs where a squall line intersects a warm front or outflow boundary (meso-low and Line Echo Wave Pattern {LEWP} formation).
9. A major short-wave trough is often embedded in the westerly wind flow and leads to further destabilization and or enhancement of frontal activity.
10. Hail is common due to the low freezing level.
11. This pattern features a nearly vertically stacked, occluded system. The threat area is not associated with any fronts, but rather, behind the cold front in the clear air.
12. Maximum severe activity occurs from the time of maximum heating to a few hours after sunset.

405

1. 86 knots or higher.
2. Look for PVA in the right rear quadrant of the jet max; this is important because it is a prime area for development of severe weather.
3. Strong PVA indicates strong upward vertical motion and the stronger the PVA the more lift.
4. It represents the separation of cold air advection from warm air advection.
5. Analyze for less than 50% relative humidity, dew points of 0°C or less, dew point depressions of greater than 7°C, wind velocity/perpendicular component and winds intruding at an angle of at least 41° w/26kts.
6. If the temperature and moisture ridges are coincident, there is a strong chance of tornadoes.
7. The best tools to identify dry lines are surface observations (particularly a pressure trough) and data from a meteorological satellite (look for linear cumulus development that builds with daytime heating).

8. Higher dew points represent warm moist air and are vital to severe thunderstorm formation.
9. <–6 Strong Instability (tornadic potential).
10. to 600 Severe thunderstorms and tornadoes likely.
11. The CAPE is the **a**mount of energy available to a surface parcel that has reached its Level of Free Convection (LFC). A positive CAPE value indicates upward vertical motion while a negative CAPE value indicates downward vertical motion.
12. WBZ is important in the determination of the potential for hail and hail size.

406

1. Historically speaking, most non-convective severe wind events occur in areas of strong subsidence associated with the “dry slot” of a mature cyclone. High winds are often associated with dry slots due to the large amount of subsidence occurring in this region as higher momentum air aloft is pulled down from the upper atmosphere into the lower atmosphere.
2. The area of tightest pressure gradient in between pressure rise-and-fall couplets.
3. The VAD Wind profile, or VWP, is excellent tool to help identify strong, gusty non-convective winds. It can help determine the horizontal wind field above a given location. You can use this data to determine the intensity and trend of low-level winds and identify the potential development of a low-level jet
4. If winds above the inversion are extremely high, they could potentially mix down to the surface once the calculated inversion break temperature is achieved.

407

1. If available, you can then use radar or satellite imagery to refine your depiction.
2. If the warm layer is greater than 1,200 feet thick and the cold layer closest to the surface is less than or equal to 1,500 feet thick, expect freezing.
3. The most common case occurs when ice crystals melt as they fall through a sufficiently deep warm layer (temperature greater than 0°C).
4. (1) Outline the surface 0°C (32°F) isotherm and 0°C (32°F) dew points.
   (2) At 850mb, outline areas having dew points < 4°C and moisture.
   (3) At 700mb, outline areas having dew points < 10°C and moisture. Also, locate areas showing the greatest 12-hour cold advection.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) Aside from the Air Force Operational Weather Squadrons (OWS), what agency produces discussions on model output?
   a. Joint Army Air Force Weather Information Network.
   b. Air Force Weather Agency.
   c. National Weather Service.
   d. Air Weather Service.

2. (401) What areas do Storm Prediction Center advisory charts outline?
   a. Areas of expected crosswinds.
   b. Areas of expected severe weather.
   c. Areas of frequent crosswind occurrence.
   d. Areas of frequent severe weather occurrence.

3. (401) What do you physically compare the 00-hour forecast with during the initialization step of the verification, initialization and verification (VIV) process?
   a. Analysis.
   b. 12-hour forecast.
   c. 24-hour forecast.
   d. Previous 12-hour forecast.

4. (401) What action is the *final* step of the verification, initialization and verification process?
   a. Verify the 00-hour forecast with your current analysis.
   b. Verify the 12-hour forecast with real-time data for the same time.
   c. Verify the previous 12-hour forecast with the current 12-hour forecast.
   d. Verify the previous 12-hour forecast against the current 00-hour forecast.

5. (401) What *initial* conditions are models used based upon?
   a. Standard atmospheric conditions.
   b. Previously forecasted conditions.
   c. Current weather observations.
   d. Model of choice conditions.

6. (402) What action is the goal of severe weather analysis?
   a. Identify the preconditions that allow storms to become severe.
   b. Identify the different types of severe thunderstorms.
   c. Determine the rear-flank downdraft wind direction.
   d. Determine the mid-level wind speed and direction.

7. (402) How many minutes do single-cell storms typically last?
   a. 20 to 30.
   b. 20 to 40.
   c. 30 to 45.
   d. 30 to 60.

8. (402) Which characteristic is *not* one of the single-cell thunderstorm?
   a. Storm motion equal to the mean wind in the lowest 5km to 7km.
   b. Weak vertical and horizontal wind shear.
   c. High winds and hail.
   d. Frequent tornadoes.

9. (402) Where do multi-cell storms typically regenerate?
   a. Along the gust front.
   b. The rear-flank downdraft.
   c. East of the westernmost cell.
   d. North of the 700mb wind maximum.

10. (402) Which characteristic is *not* one of multi-cell thunderstorms?
    a. Weak directional shear in the lower levels.
    b. Straight-line or unidirectional profile.
    c. large hail near downdraft centers.
    d. short-duration tornadoes.

11. (402) Which thunderstorm is *not* a type of supercell thunderstorm?
    a. Classic.
    b. High precipitation.
    c. Low precipitation.
    d. Moderate precipitation.

12. (402) What size hail do classic supercell thunderstorms typically produce?
    a. Marble.
    b. Softball.
    c. Golf ball.
    d. Baseball.

13. (402) Which type of supercell thunderstorm is most commonly found along the dry line of west Texas?
    a. Moderate-precipitation.
    b. High-precipitation.
    c. Low-precipitation.
    d. Classic.

14. (403) Which region is *not* a primary source for airmasses?
    a. Arctic.
    b. Tropical.
    c. Equatorial.
    d. Temperate.

15. (403) What letter or symbol is appended to the label of a modifying airmass that is cooler than the ground below?
    a. Plus symbol.
    b. Lower case c.
    c. Lower case k.
    d. Minus symbol.

16. (403) Where is the geographic area known as the "Great Plains" located?
    a. West of the Rocky Mountains.
    b. East of the Appalachian Mountains.
    c. Between the Mississippi River and the Rocky Mountains.
    d. Between the Appalachian Mountains and the Missouri River.

17. (403) In what tornado-producing airmass do tornadoes most frequently occur in families, with paths that are commonly long and wide?
    a. Type II, Gulf Coast type.
    b. Type I, Great Plains type.
    c. Type III, Pacific Coast type.
    d. Type IV, Inverted “V” type.

18. (403) What factor is evident above the inversion with a Type I airmass?
    a. Moisture increase.
    b. Rapid drying.
    c. Condensation.
    d. Turbulence.

19. (403) Which type of airmass is tropical in origin and generally warm and moist?
    a. Type I Great Plains.
    b. Type II Gulf Coast.
    c. Type III Pacific Coast.
    d. Type IV Inverted V.

20. (403) Which type of airmass has cold air at all levels?
    a. Type I Great Plains.
    b. Type II Gulf Coast.
    c. Type III Pacific Coast.
    d. Type IV Inverted V.

21. (403) Which air mass is cold with surface temperatures ranging from 50°F to 68°F, the relative humidity commonly exceeding 70 percent at all levels up to at *least* 500mb, and average windspeeds of 15 knots at 850mb and 50 knots at 500mb?
    a. Type II Gulf Coast.
    b. Type I Great Plains.
    c. Type III Pacific Coast.
    d. Type IV Inverted V.

22. (403) Which type of airmass features maritime polar air overrunning continental tropical air between 5,000 and 8,000 feet above the surface?
    a. Type II Gulf Coast.
    b. Type I Great Plains.
    c. Type IV Inverted V.
    d. Type III Pacific Coast.

23. (404) What kind of dew-point temperature difference should exist across a dry line?
    a. $< 10^{o}$ F degrees.
    b. $> 10^{o}$F degrees.
    c. $< 10^{o}$C degrees.
    d. $> 10^{o}$C degrees.

24. (404) What severe weather synoptic pattern’s airmass is typically Type III?
    a. Type C, overrunning.
    b. Type D, cold core.
    c. Type A, dry line.
    d. Type B, frontal.

25. (404) When does the maximum severe activity occur with a major cyclone?
    a. A few hours after sunrise to maximum heating.
    b. From time of maximum heating to a few hours after sunset.
    c. Just before and after maximum heating.
    d. Only during maximum heating.

26. (405) What wind speeds do you focus on at the 200 and 30 millibar level for severe weather analysis?
    a. 76 knots.
    b. 80 knots.
    c. 86 knots.
    d. 90 knots.

27. (405) In straight line flow, what quadrants are the main diffluent areas of a jet maximum?
    a. Left & right rear.
    b. Left & right front.
    c. Left front & right rear.
    d. Left rear & right front.

28. (405) Which quadrant in the jet max should you look for positive vorticity advection?
    a. Left rear.
    b. Right rear.
    c. Left front.
    d. Right front.

29. (405) At which pressure level is strong wind needed for thunderstorms to become severe?
    a. 300 millibars.
    b. 500 millibars.
    c. 700 millibars.
    d. 850 millibars.

30. (405) What does positive vorticity advection indicate?
    a. Divergence or upward vertical motion.
    b. Convergence or upward vertical motion.
    c. Divergence or downward vertical motion.
    d. Convergence or downward vertical motion.

31. (405) What parameters are the two *most* important to analyze at 700 millibars?
    a. No-change line and dry-air intrusion.
    b. No-change line and wind maximums.
    c. Dew point temperatures and dry-air intrusion.
    d. Wind maximums and dew point temperatures.

32. (405) What weather characteristic does the 700 millibars no change line usually line up with?
    a. Trough axis.
    b. Surface front.
    c. Low-level jet.
    d. 850 millibar warm ridge.

33. (405) Which zone is *not* a type of surface convergent zone?
    a. Dry line.
    b. Frontal boundary.
    c. Land breeze front.
    d. Outflow boundary.

34. (405) How far ahead of a cold front do pre-frontal squall lines form?
    a. 25 to 125 statute miles.
    b. 50 to 150 statute miles.
    c. 25 to 125 nautical miles.
    d. 50 to 150 nautical miles.

35. (405) What does a >+1 on the Showalter stability index suggest?
    a. Strong stability.
    b. Strong instability.
    c. Moderate stability.
    d. Moderate instability.

36. (405) What does a lifted index (LI) greater than zero indicate?
    a. Stability.
    b. Instability.
    c. No severe weather - winds too strong.
    d. Severe weather likely, chance of tornadoes.

37. (405) What weather occurrence does a severe weather threat index of 650 indicate?
    a. Severe thunderstorms likely, chance of tornadoes.
    b. Severe thunderstorms and tornadoes likely.
    c. No severe weather – winds too strong.
    d. Tornadoes nearly always occur.

38. (405) What atmospheric event does a negative convective available potential energy indicate?
    a. Increased warm moist air advection.
    b. Decreased cold dry air advection.
    c. Downward vertical motions.
    d. Upward vertical motions.

39. (406) What weather feature is commonly found south of the center of a low pressure system and is indicated by a relatively cloud-free region?
    a. Warm front.
    b. Cold front.
    c. Dry line.
    d. Dry slot.

40. (407) Which atmospheric occurrence is *not* a type of lifting mechanism for convection?
    a. Convection.
    b. Frontal lifting.
    c. Decompression.
    d. Orographic lifting.

41. (407) What number of feet *must* the freezing level be for most precipitation to reach the surface as snow?
    a. 1,000.
    b. 1,100.
    c. 1,200.
    d. 1,300.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Weather Radar Utilization

Can you name all the different radar products? There are over 60 of them. In this unit we will review the most common radar products, the operational uses and interpretation of them. Radar is an important tool for your meteorological situational awareness. Weather observations show you the ceiling and visibility, but what about that embedded thunderstorm that the weather observer cannot see. In addition, with the advent of automated weather sensors, a thunderstorm could be close to an airfield and the sensor may not detect it. With a thorough knowledge of how to interpret radar images you will be better prepared for severe weather and be able to warn the base populace before it occurs.

2–1. Interpretation of Radar Base Products

As you remember, the three base products of the Weather Surveillance Radar–88D or WSR–88D are reflectivity, velocity, and spectrum width. In this section, we look at all three products, including a description of the products and some operational uses of those products.

408. Base reflectivity

The WSR–88D produces over 60 different products and base reflectivity is one of most widely used. It’s the oldest of all the products available on the radar, dating back to the 1940s, when the only radar data was an image of backscattered energy (reflectivity). It was a breakthrough product back then, and today it’s still an integral part of the radar’s output. In this lesson, we look at the base reflectivity product and discover the vast amount of meteorological information it can provide.

Interpretation of base reflectivity

Use and interpretation of WSR–88D base reflectivity products is really no different from previous radars. For the WSR–88D to generate a base reflectivity product, the antenna must complete one elevation slice. Since the WSR–88D uses high-resolution color displays, it is easier to analyze for features that previously hid themselves on old monochrome radars. Features such as high reflectivity storm cores, strong reflectivity gradients, and embedded thunderstorm activity show up quite nicely on the color displays. With the WSR–88D’s extreme sensitivity, you may even see reflectivity returns from optically clear air. In clear-air mode, the radar looks as low as –28 decibels (dBZ) for reflectors such as insects, pollen, dust, salt, density discontinuities, and anything else that may backscatter even the smallest amount of energy. This information can allow you to see things like dry frontal boundaries, outflow boundaries from distant storms, sea breezes, and more.

Reflectivity signatures

For practical applications, most returns of less than +18dBZ are considered non-precipitable and are probably just cloud droplets or other minute scatterers. However, besides the uses mentioned above, you can use these returns to estimate cloud heights. During operational testing of the WSR–88D, pilot reports were used to verify these height measurements. It was found that the radar could provide accurate heights of most cloud decks, even that of cirrus. As you can see, reflectivity data collected by the WSR–88D allows you to analyze for a vast number of meteorological elements (fig. 2–1). Now let’s take a closer look at some of these useful reflectivity features.

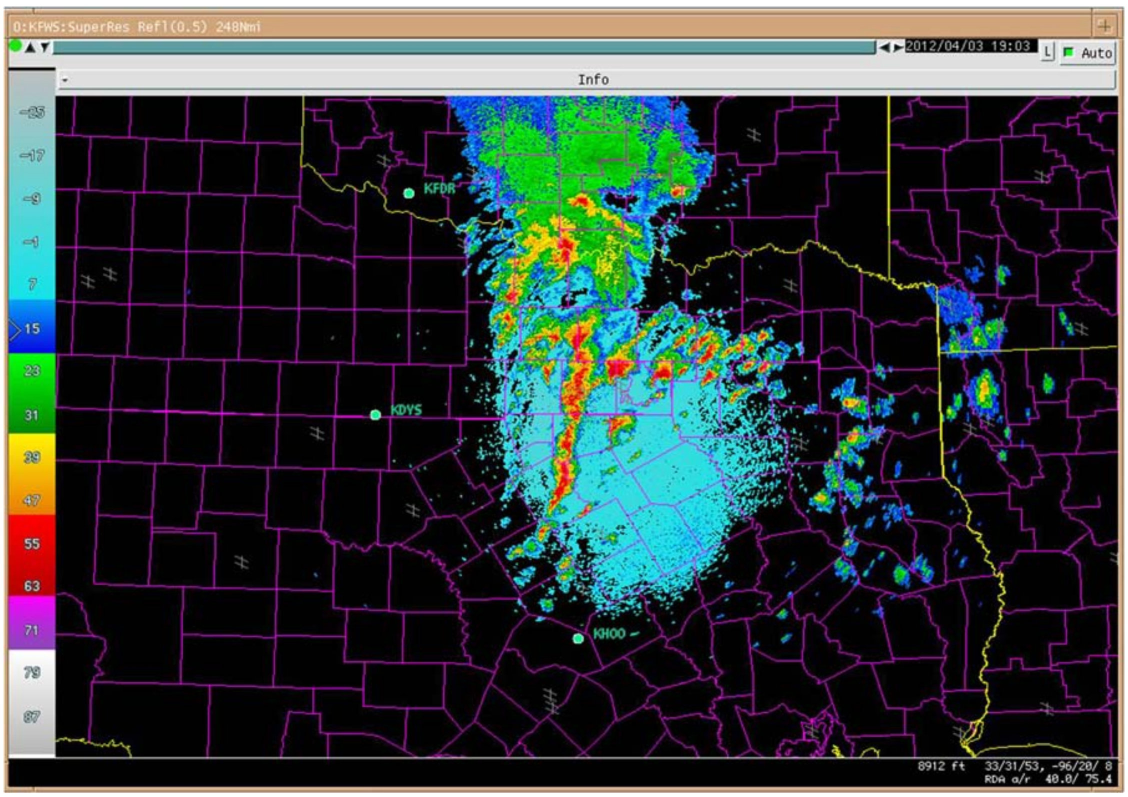


Figure 2–1. Base reflectivity.

Hook echoes

The hook echo is a classical radar signature often associated with tornadic activity (fig. 2–2). The hook is formed by a cyclonic swirl of precipitation around the intense, rotating updraft of the tornado vortex. The hook is not the actual tornado, but rather the return from this precipitation wrapped around the vortex. Often the actual hook echo is obscured by surrounding precipitation, thus making detection difficult at best. Let’s look at some more facts concerning the hook echo.

Location and size

The hook is located in the trailing half of the parent echo with respect to its motion and occurs most often in the right rear quadrant. It’s a small-scale feature having a dimension of about 10nm or less from the main body of the storm to the farthest extremity of the hook (fig. 2–2). This distance should never exceed 15nm. Vertical extent can be through the mid-level of the storm sometimes exceeding 35,000 feet. Normally we look for it at the lowest elevations possible.

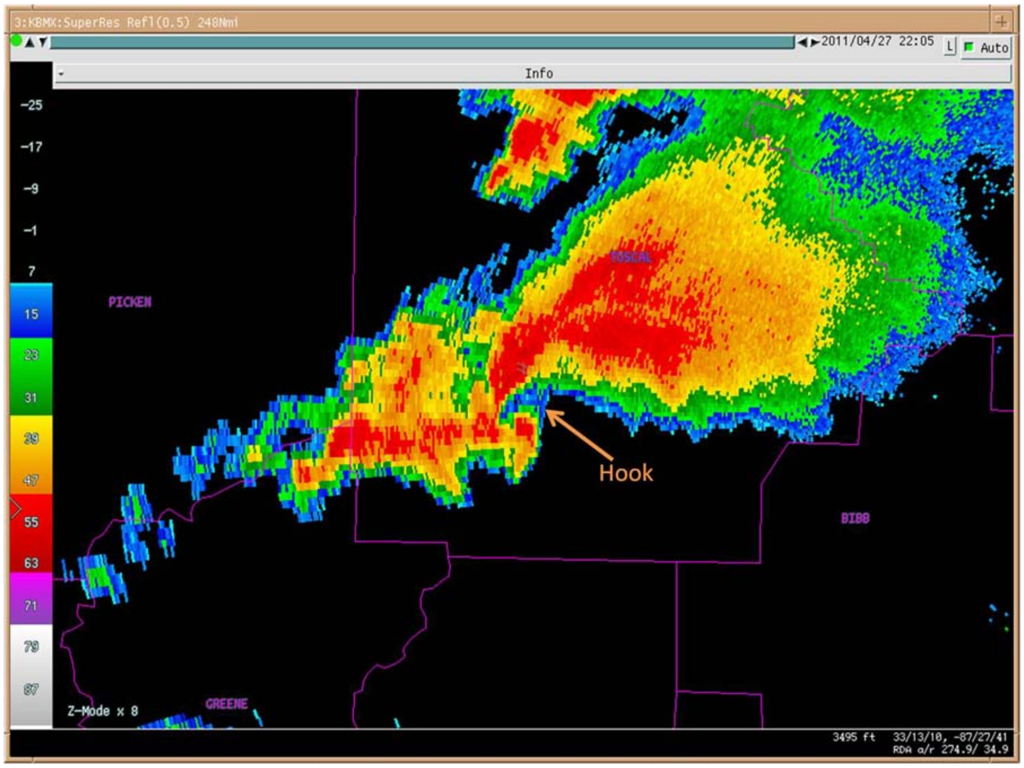


Figure 2–2. Base reflectivity (hook echo).

Hook versus tornado occurrence

Several studies have been done to correlate hook recognition and actual tornado occurrences. One study reported that of 46 hooks identified, 40 had confirmed tornadoes; the other six produced either a funnel cloud or large hail. Keep in mind there are several factors that make the hook echo a difficult signature to identify; these include its relatively small size and short duration, the possibility of being hidden in surrounding precipitation, likelihood of being missed completely at longer ranges due to beam broadening, or simply that the tornado decides not to provide us with this nifty classical signature. As you'll see later, the WSR–88D's velocity products provide a more reliable tornadic signature. However, if you can find evidence on more than one product–all the better.

Strong reflectivity gradients

In-depth studies by Mr. Leslie R. Lemon have pointed out the importance of strong reflectivity gradients in the low levels of a thunderstorm (fig. 2–2). These gradients are especially important when related to upper-storm features such as overshooting tops or mid-level overhang. In the past, locating strong gradients with non-color radars was very difficult. Refer again to figure 2–2. You can see the strong gradient of reflectivity values on the southwest side of the storm. Notice the values decrease from the core of 55dBZ (lighter red), through the yellows, greens, and blues. Values continue to decrease until around the threshold of 8dBZ. The key here is that values decrease from 55dBZ to near 8dBZ in a very short distance, thus creating a very strong reflectivity gradient.

According to research by Lemon and others, if the mid-level overhang of the storm extends at least 3.2nm (6km) beyond this low-level gradient and the highest echo top is on the storm flank that possesses the overhang, an extremely high potential exists for severe weather occurrence. You can compare the location of this gradient with higher-level features simply by displaying two different elevation cuts and using the "link cursor" feature to see their relative positions. As you monitor the development of individual thunderstorms, keep an eye on this important gradient. Usually, as the storm becomes stronger and potentially more deadly, this gradient becomes more evident and may eventually exhibit the classic hook shape (fig. 2–2).

Line echo wave patterns

A line echo wave pattern (LEWP) (fig. 2–3) is simply a line of radar echoes subjected to acceleration along one portion of the line. LEWPs show up quite nicely on WSR–88D displays because the actual line of convection is displayed even if it's surrounded by stratiform precipitation. Radar operators using non-color displays tended to merge all the activity into one large area and overlook the pattern of the echoes within.

An LEWP indicates a favorable environment for severe weather development. Although an LEWP hardly guarantees severe weather will occur, if other factors are favorable, it can be interpreted to indicate tornadoes, hail, and high winds. The most severe weather is normally expected at, and slightly south of, the crest. Severe weather occurs along this portion of the line because it's being pushed further and faster than adjacent portions. This acceleration is often caused by a meso-high located behind the LEWP. The speed of the LEWP can be an indicator of its severity since the fastest moving convective echoes tend to be the most severe.

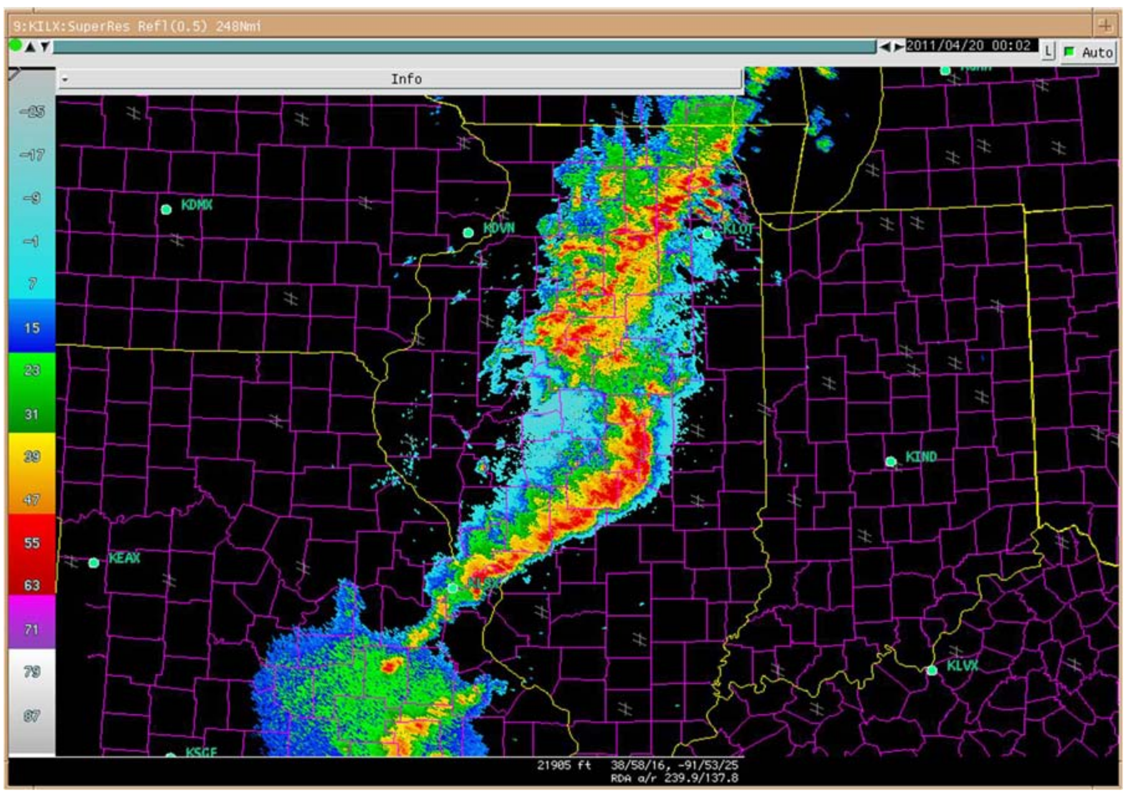


Figure 2–3. Base reflectivity (LEWP).

Embedded thunderstorms

Embedded convection is easily identifiable with color products (fig. 2–4). Since the WSR–88D uses a 10 centimeter (cm) wavelength, less attenuation occurs in precipitation. In other words, the 10cm wavelength allows the radar to see through the stratiform precipitation. As a result, embedded storms are quickly located and their intensities accurately measured.

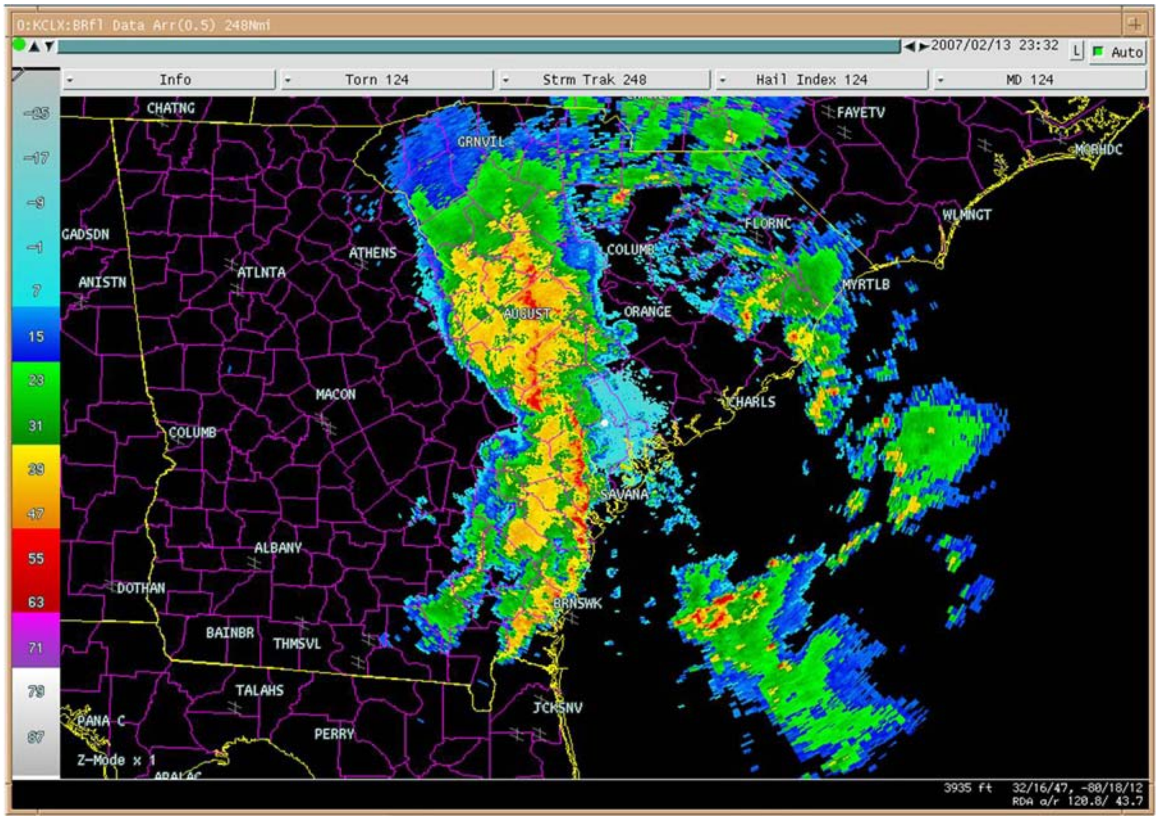


Figure 2–4. Composite reflectivity (embedded).

Outflow boundaries

An outflow boundary (fig. 2–5), also referred to as a gust front is usually the leading edge of horizontal airflow resulting from cooler, denser air sinking and spreading out at the ground. Sometimes with very slow moving or stationary storms you will see circular outflow boundaries on radar images (fig. 2–6).

Large outflow boundaries act as a trigger for new thunderstorm development, almost like a small-scale cold front. Although many thunderstorms generate outflow boundaries, few are as well-defined on weather radar as the one in figure 2–6.

Currently, we rely on satellite data to detect these outflow boundaries. However, often we cannot see them, due to high cloud cover or poor resolution. Also, to see outflows on meteorological satellite imagery, clouds must be present. With the WSR–88D, we can see the outflow even if no clouds are present because of the gradient in the refractive index due to density differences that exist with the boundary. The WSR–88D detects signal returns down to –28dBZ. Remember that precipitable moisture usually provides a minimum return of +18dBZ. These outflow boundaries were usually invisible on previous radars unless the density contrast was very abrupt, or some clouds or precipitation accompanied them. Now, using the WSR–88D, we can locate and track the movement of these outflows to predict phenomena better, such as enhanced thunderstorm development, low-level wind shear, and strong straight-line winds.

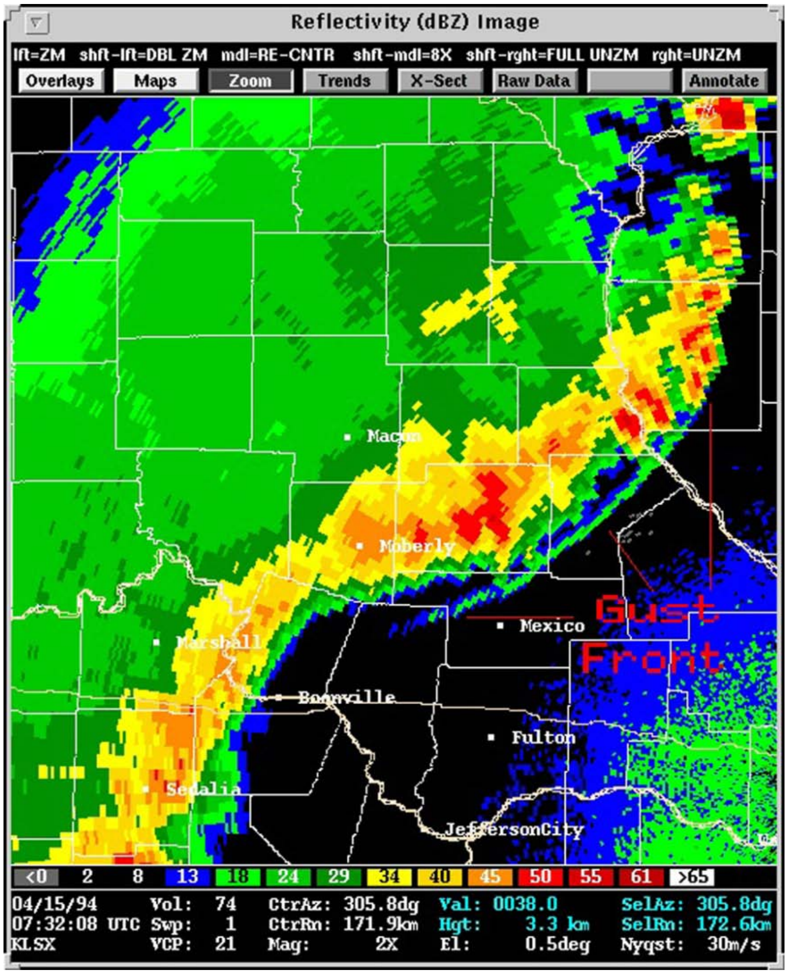


Figure 2–5. Base reflectivity (outflow boundary).

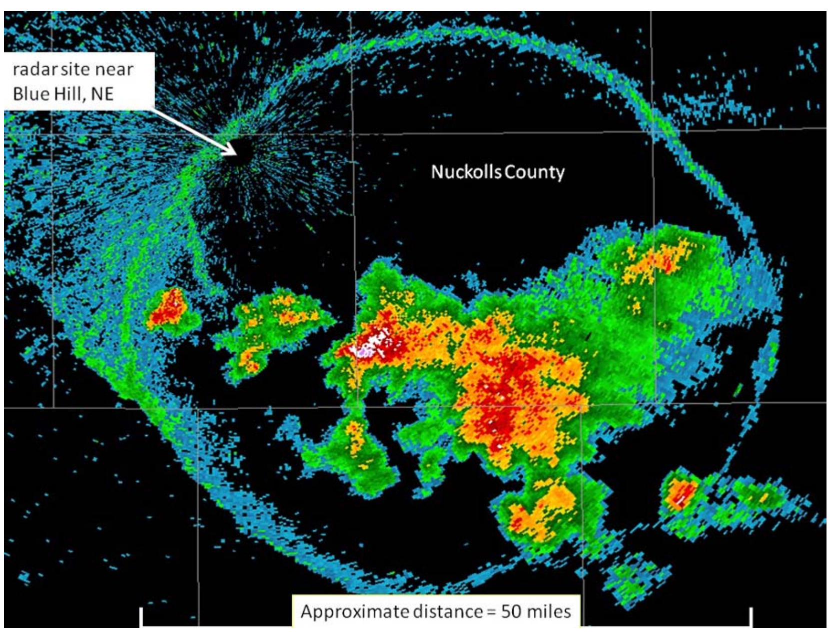


Figure 2–6. Base reflectivity (circular outflow boundary).

Melting level

The WSR–88D can detect the melting level (fig. 2–7) during the presence of a widespread stratiform cloud deck. The melting level is that level where frozen precipitation particles melt during their descent to the surface. When the frozen particles begin to melt, they become coated with water and provide a much stronger return than either the frozen particles above or the liquid droplets below. This level may be seen on WSR–88D reflectivity displays. It appears as a ring, or partial ring, of enhanced reflectivity around the radar data acquisition (RDA) site. Factors that may preclude seeing the melting level include too few clouds present at the melting level, disruption of the melting level by some form of turbulence or convection, and heavy precipitation that may saturate the display.

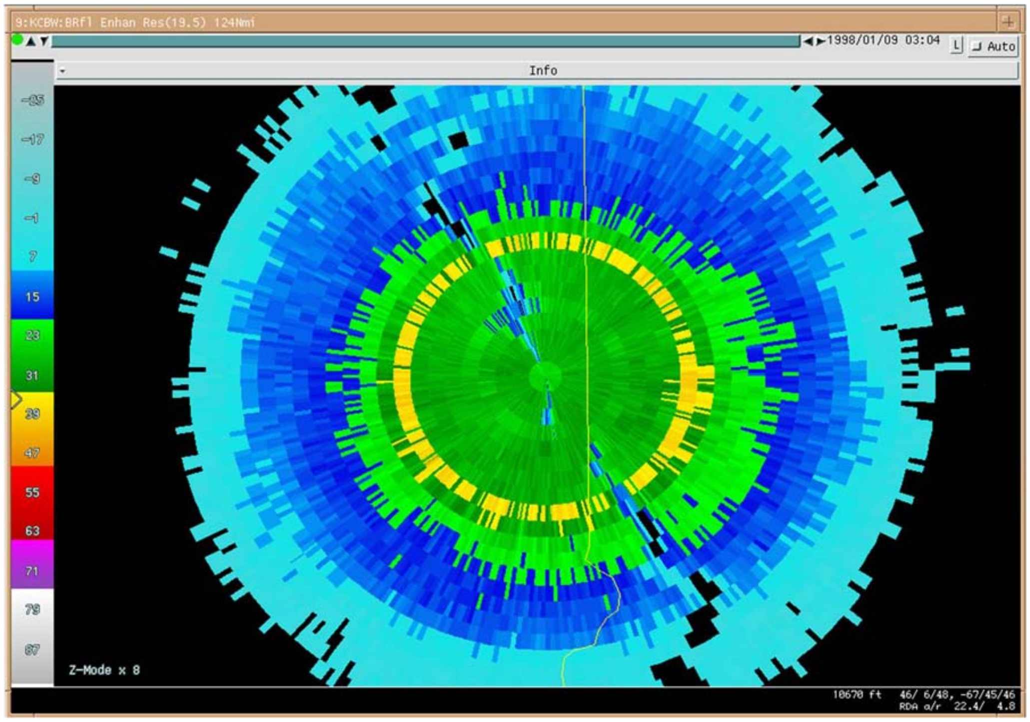
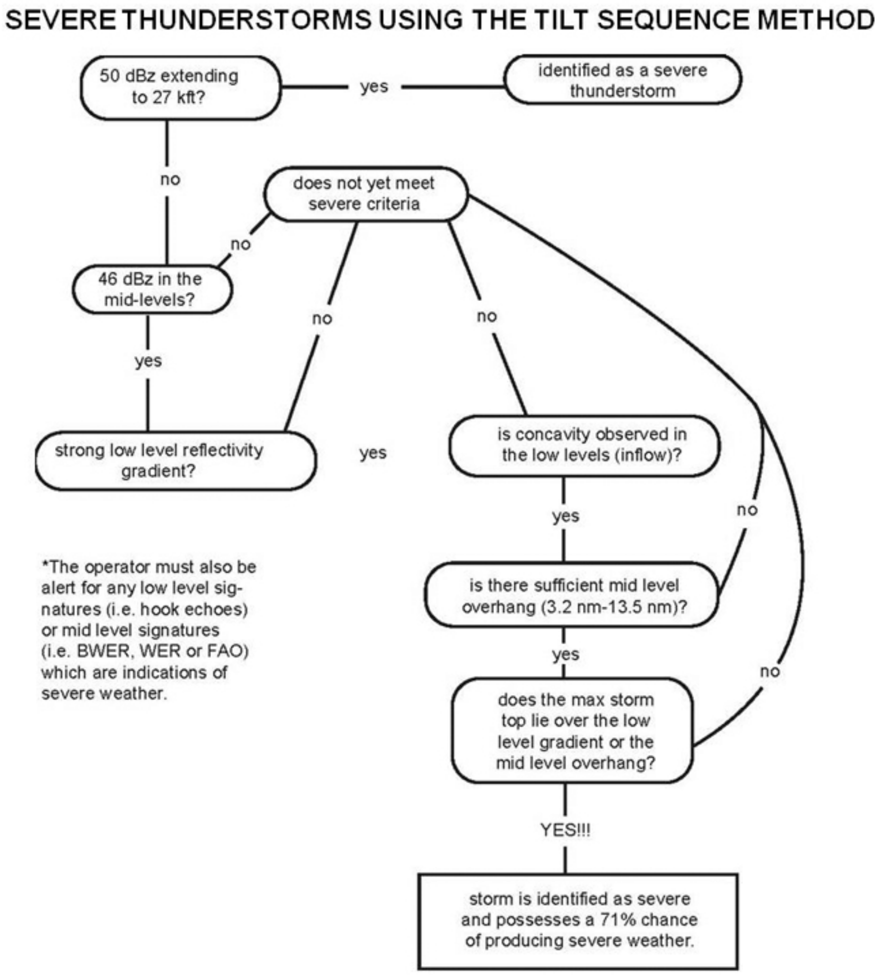


Figure 2–7. Base reflectivity (melting level).

Tilt sequence method

You as a forecaster will not confine your data to one rawinsonde sounding, but look at the horizontal distribution of meteorological variables at several levels. Similarly, the radar operator needs to know the horizontal echo distributions at low, mid, and high levels for severe weather detection. The tilt sequence method of severe storm interrogation was developed by Leslie R. Lemon, using WSR–57 data, as an objective method to identify storms containing the horizontal and vertical characteristics indicative of severe weather production (fig. 2–8).

To conveniently compare reflectivity echo distributions at various heights, employ a quarter screen format. In window 1, which will be the upper left window, the 0.5° elevation is examined to determine storm inflow (characterized by low-level concavity bounded by a strong reflectivity gradient with echo core displaced toward that flank). In window 2 and 3, the upper right and lower left respectively, identify the maximum mid-level overhang (occurs from 16,000 to 29,000 feet, may be necessary to examine two or three intermediate elevation angles to identify). In window 4, the lower right window, identify the storm's maximum top (Echo Tops Product, or if finer resolution is needed, the highest elevation angle of detection).



MANUAL VERIFICATION OF MESOCYCLONE AND TVS

MESO:

$$\frac{(\text{max inbound}) + (\text{max outbound})}{2} =$$

$\geq$ 30 knots within 80 nm of the RDA

OR

$\geq$ 22 knots > 80 nm from the RDA

-values must be within 5 nm of each other
-should have vertical continuity (10 kft)
-must have time continuity (two volume scans)

TVS: (gate to gate)

(max inbound) + (max outbound) =

$\geq$ 90 knots within 30 nm of the RDA

OR

$\geq$ 70 knots $\geq$ 30 nm from the RDA

-values should be gate to gate
-must have vertical continuity (two elevation angles)
-should have time continuity (two volume scans

Figure 2–8. Tilt sequence and manual verification of meso/TVS.

Method of examination

Echoes having or developing an intense updraft (strong severe weather potential) normally display the following characteristics on the updraft flank (generally the right rear, but occasionally the rear or left rear) (fig. 2–9).

1. Strong or intense low-level reflectivity gradient with echo core displaced toward the updraft flank.
2. Low level concavity bounded by strong reflectivity gradients.
3. 6 to 25km (3.2 to 13.5nm) of mid-level overhang beyond the low-level echo edge, capped above by a major reflectivity core ($\geq$ 46 dBZ), further capped by the maximum echo top (found over the strong gradient). Beneath the overhang is the weak echo region (WER).
4. Once a storm reaches the mature stage the bounded weak echo region (BWER) may develop. The following features will distinguish this region:
    a) It will appear as a circular region of low reflectivity extending upward within the mid-level overhang; typically $\leq$ 8km (4.3nm) in diameter.
    b) It will be located either near the center, or toward the south flank of the overhang.
    c) The location will be bounded by an intense gradient, capped by an echo core ($\geq$ 46 dBZ), then capped by the echo top.

If a storm exhibits these characteristics severe weather production potential is high. Verification of severe weather occurrence is 71 percent.

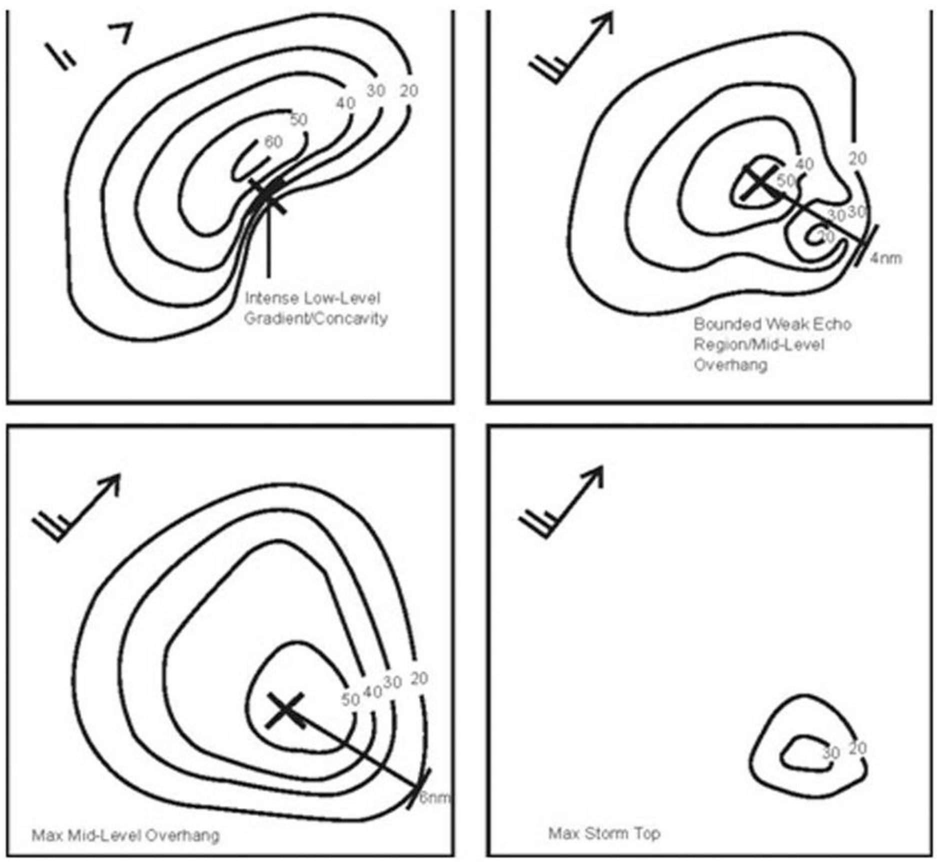


Figure 2–9. Horizontal echo characteristics.

Other echo characteristics

In some short-lived severe storms (10–25 minutes) the only indication of severity may be a core $\geq$ 50 dBZ extending at least 27,000 feet vertically.

On the downstream flank (relative to mid- and high-level winds) the low level echo may exhibit two lobes caused by deflection of flow on either side of an intense blocking updraft.

A well-defined pendant accompanied by extensive mid-level overhang is a good indication of impending tornado development. Further indication of tornado development occurs if the pendant wraps up into a hook echo. If the wrap up is accompanied by a collapse of the WER and echo top, potential for tornado production is extreme.

Criteria for severe thunderstorm using the tilt sequence method

Reflectivity values ≥ 50 dBZ extend to 27,000 feet above ground level (AGL) or higher (fig. 2–10). In absence of this, these conditions must be satisfied:

1. Peak mid-level (16,000 to 39,000 feet AGL) reflectivities must be ≥ 46 dBZ.
2. Mid-level overhang must extend at least 6km (3.2nm) beyond the strongest reflectivity gradient of the low-level echo.
3. Max echo top must be located on the storm flank possessing the overhang and above the low-level gradient between the echo core and echo edge, or lie above the overhang itself.

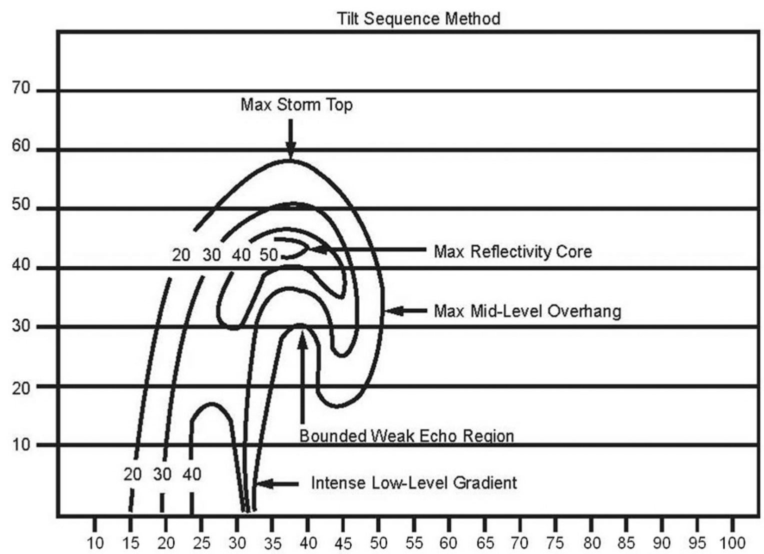


Figure 2–10. Vertical storm characteristics.

Criteria for tornado identification using the tilt sequence method

This method requires the last three criteria above be met as well as either or both of the following:

1. A low-level pendant exists beneath or bounds the mid-level overhang on the west.
2. A BWER is detected.

409. Base mean radial velocity

Decision time is rapidly approaching—what kind of warning will you issue? Can this thunderstorm produce a tornado? What is happening inside this storm? The WSR–88D brings a new dimension in severe weather forecasting. Using base velocity products, the radar operator can now interrogate motions in and around potentially severe weather-producing storms.

The WSR–88D not only aids in severe weather forecasting, it also aids in everyday forecasting decisions. For example, you are able to interrogate the vertical wind profile every couple of minutes. With the mere click of a button, an up-to-date velocity display is available for your inspection.

Although a single Doppler radar measures only the component of the wind that is parallel to the beam, multiple horizontal and vertical weather features are identifiable. In this lesson we describe the uses of the velocity product.

Interpretation of base radial velocity product

The use and interpretation of base radial velocity products ranges from everyday routine weather station operations to severe weather forecasting. It is useful in detecting and locating rotating thunderstorms and in determining wind field characteristics. Determining vertical wind profiles is accomplished using the entire product display, while individual storm features are determined by focusing in on a small area of the display. This lesson provides an introductory look at velocity interpretation, then specific uses of the velocity product.

Identify vertical variations

While examining the WSR–88D velocity display for vertical variations in the wind field, several significant features can be identified. Although the atmosphere produces millions of differing vertical profiles, time restraints allow us to only look at a few. They are veering and backing winds, low-level and mid-level jets, turbulence, frontal boundaries, and overrunning. Recall that cool colors indicate inbound velocities while warm colors indicate outbound velocities. Also, recall that to determine wind direction, the radar operator must reference the Doppler zero line.

Veering winds with height

Veering winds with height (representative of warm-air advection) produce a very distinct pattern. Whenever veering winds are encountered, the Doppler zero line takes on a noticeable S-shaped pattern (fig. 2–11).

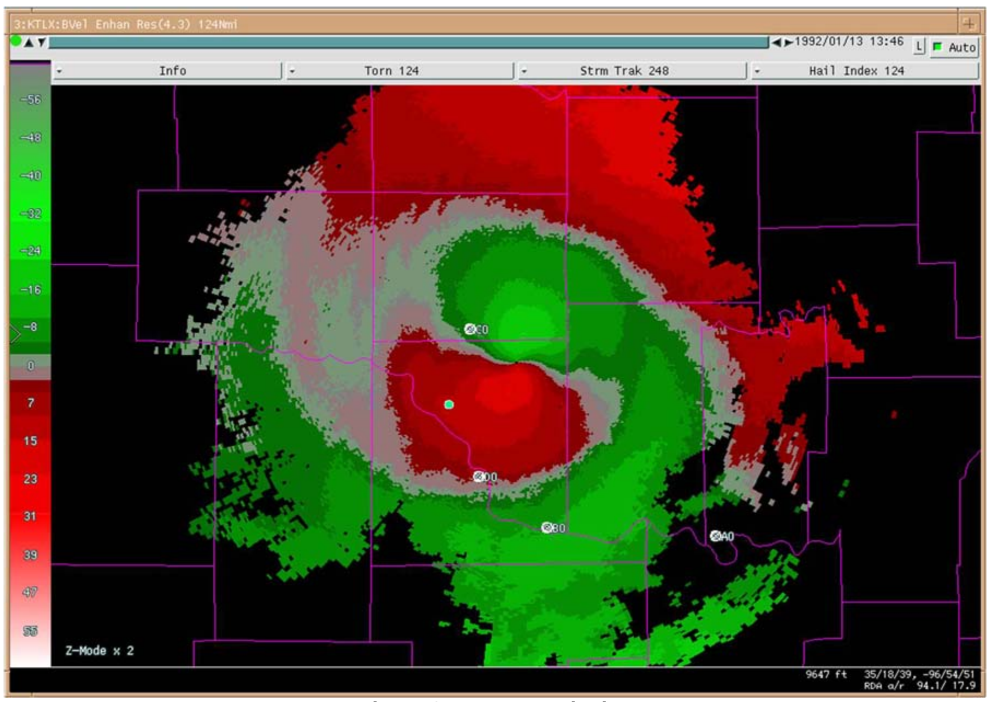


Figure 2–11. Base velocity.

Turbulence

Abrupt changes in wind speed and/or direction are associated with turbulent air (fig. 2–11). The depth and height of the turbulent layer are obtained using antenna elevation and slant range to that point.

Backing winds with height

Backing winds with height (representative of cold-air advection) also produce a distinct pattern. Whenever backing winds are encountered, the Doppler zero line takes on a noticeable backward S-shaped pattern (fig. 2–12).

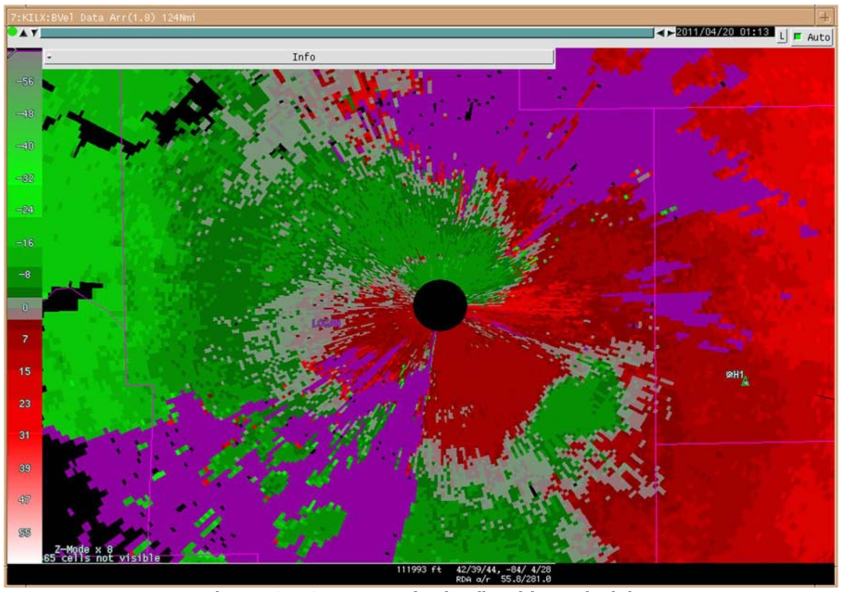


Figure 2–12. Base velocity (backing winds).

Low-level and mid-level jets

Whenever the speed profile has a speed maximum or jet within the display, there is a pair of closed contours 180° (directly opposite) from each other (fig. 2–13 contains both a low-level and mid-level jet). The height of the maximum value is computed using the antenna elevation and the slant range to that point. The WSR–88D, on request, calculates this for you and displays it in the legend area.

Frontal boundaries

With adequate radar returns, it is possible to determine the wind field both ahead of and behind a front. Figure 2–14 clearly shows a frontal zone transitioning from northwest-to-southeast of the radar location. The frontal zone is marked by a rapid change in wind direction over a very short transition region. In all three examples, wind direction is northwesterly behind the front and southwesterly ahead.

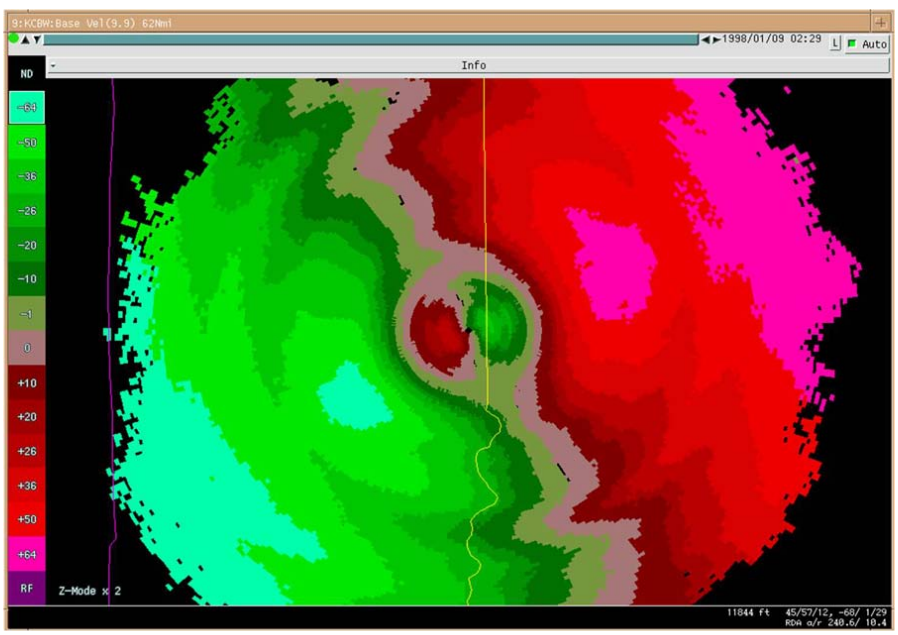


Figure 2–13. Base velocity (low-level and mid-level jets).

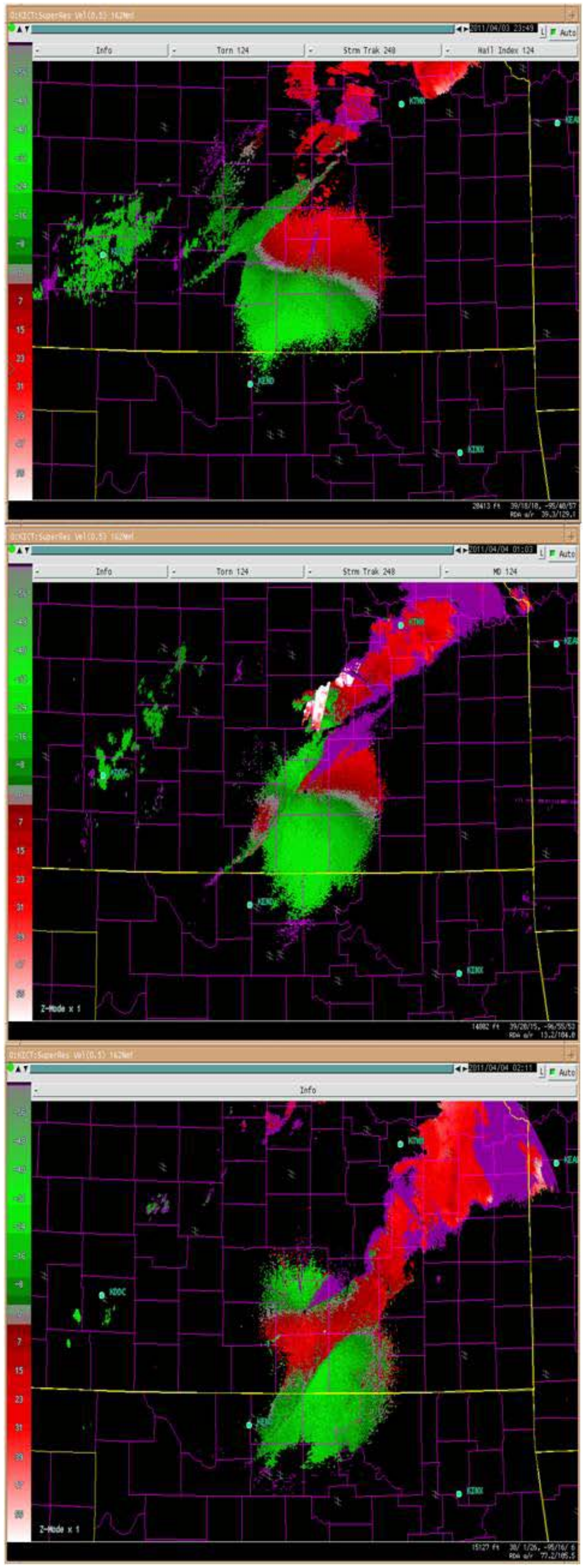


Figure 2–14. Base velocity (frontal passage)

When the radar detects pure cyclonic rotation, the Doppler zero line is oriented parallel to the viewing direction. Notice the Doppler zero line in the diagram, it is oriented parallel to the viewing direction.

To the right of the zero Doppler line, flow is away from the radar and the flow on the left is toward the radar. Since a Doppler radar measures only the radial component of the wind, it does not sense all the rotation; it senses only that flow either side of the zero Doppler line, as mentioned above. Due to the rotation, the velocity at the center is zero and increases linearly to a maximum value at the core (point x) and then decreases linearly to the edge, on both sides of the signature.

Therefore, the single Doppler velocity signature of a mesocyclone (or any vortex) has a pattern that is symmetric about the radar viewing direction and has peak values of opposite sign at the core either side of the circulation center.

Many times the area of perpendicular motion in the signature is smaller in size than the resolution of the radar. When this happens, the Doppler zero line is not depicted on the image. This is the case with the rotational couplet in figure 2−15. When the Doppler zero line is not depicted within a rotational couplet, you call it an “inferred zero line.” If the Doppler zero line were there, it would be located between the inbound and outbound velocity areas.

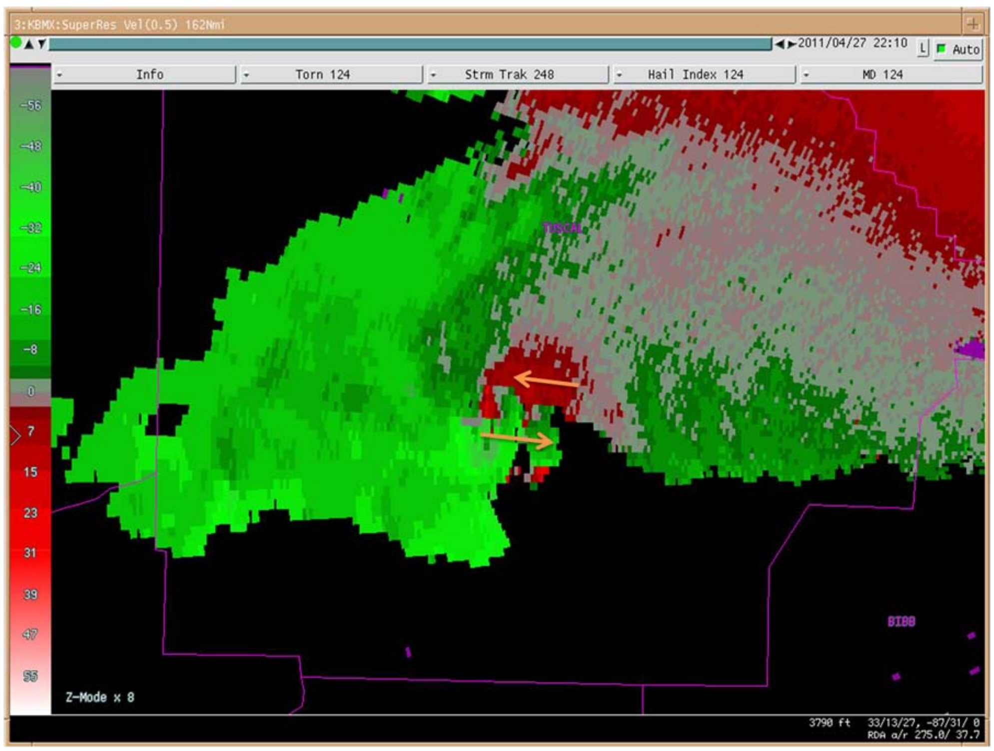


Figure 2–15. Rotation.

Divergence

Depicted similarly to rotation, figure 2−16 illustrates a zoomed-in area of a divergent couplet on a base velocity product. The divergent field occurred at the top of a thunderstorm and is accompanied with a black and white diagram detailing the wind flow. In the picture, the radar is located to the southeast of the divergent couplet. In a divergent signature, the zero line is perpendicular to the radar viewing direction because the radar does not sense motion toward the left or right of the divergence center.

As you find with rotation, the zero line may not be depicted and is termed an inferred zero line. Maximum flow toward and away is measured along the viewing direction. Divergent signatures are found near the storm top, above the updraft and near the ground in the precipitation downdraft.

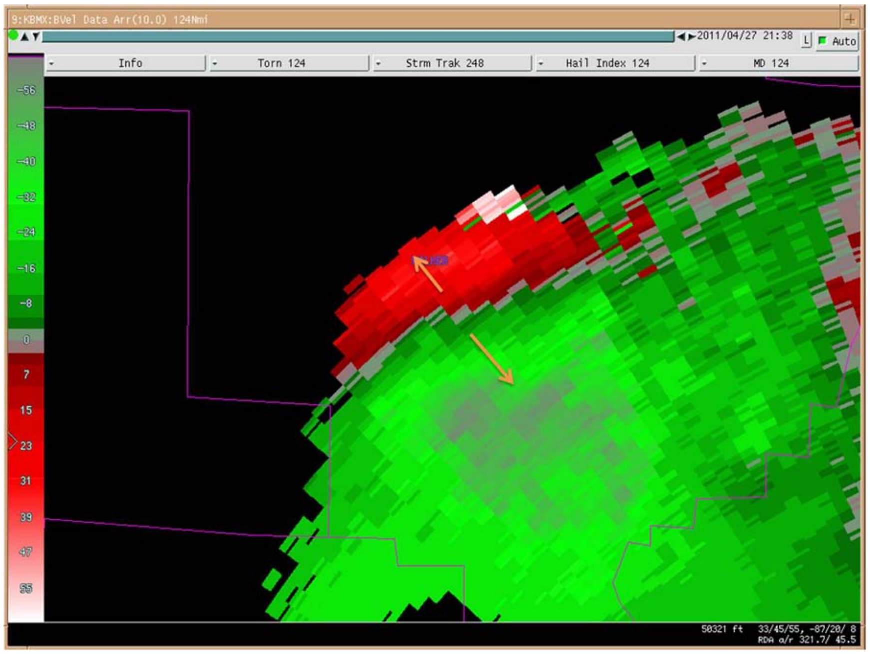


Figure 2–16. Divergence.

Convergence

The convergence signature in figure 2–17 is a good example of the convergent portion of a thunderstorm. The radar is located to the northwest of the convergent couplet. As with the divergent signature, the convergent signature's zero line is perpendicular to the radar viewing direction and may not be depicted. Convergence signatures are normally found near the surface below the storm's updraft.

As you can see from the three previous examples, the signatures for rotation, divergence, and convergence are all basically the same. The only difference between the signatures is the direction at which you view them. Knowing the location of the radar is crucial to identifying whether a storm signature is convergence, divergence, or rotation.

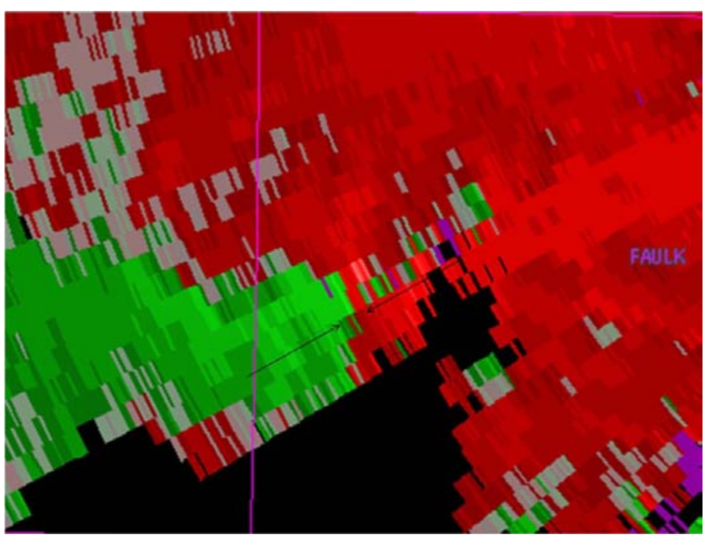


Figure 2–17. Convergence.

Uses of the horizontal variations

While examining the WSR–88D for horizontal variations in the wind (individual storms), several significant features can be identified. They include mesocyclones, tornadic vortex signatures, hail size, microburst/downburst, and much more. Let's look at each of these and see how we go about identifying them.

Mesocyclones

A mesocyclone is a 3D region in a storm that rotates and is closely correlated with severe weather (fig. 2–18). Notice in the figure, the mesocyclone changes from convergence (upper-left quadrant) to rotation (upper-right quadrant) and finally to divergence (lower-left quadrant) at the top of the storm.

By interrogating several slices of a storm and correlating them three-dimensionally, we can verify the existence of a mesocyclone.

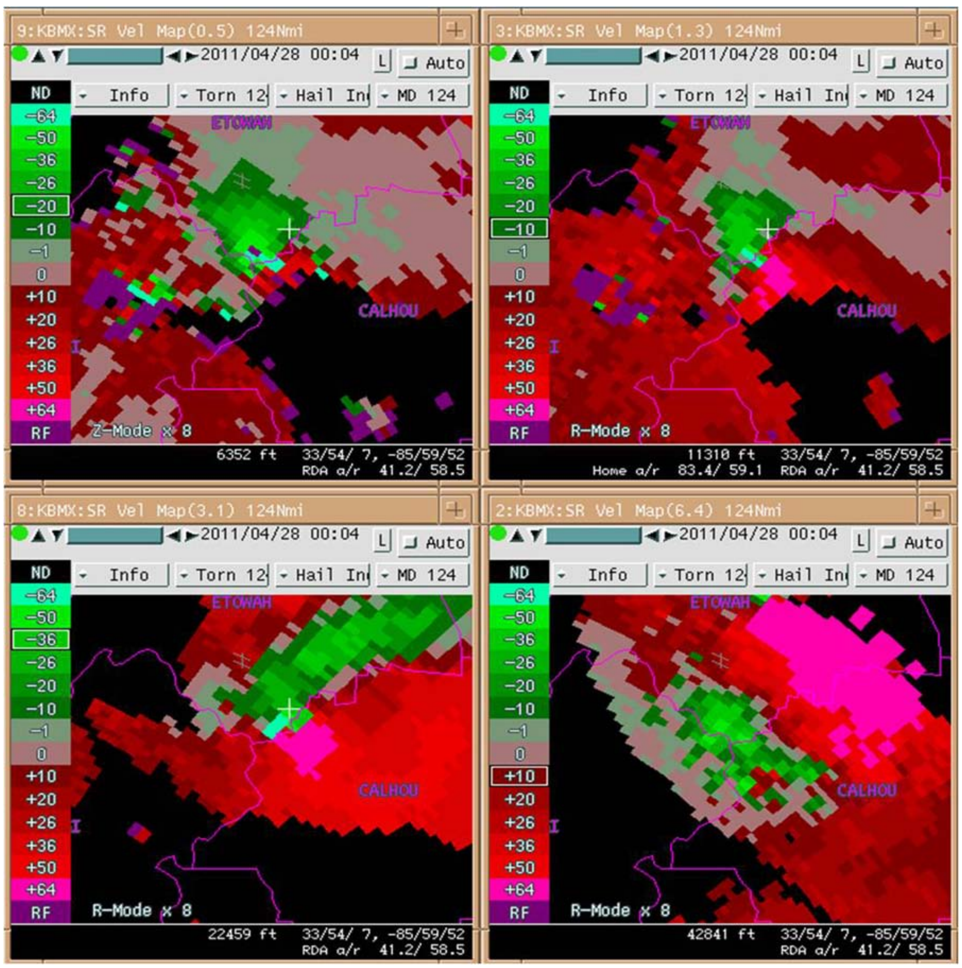


Figure 2–18. Base velocity (quad display of mesocyclone).

Tornadoes

Using the velocity product and locating a rotational field does not alone signify the existence of a tornado. Most tornadoes exist within a preexisting mesocyclone and are usually found in or near the mesocyclone's core (fig. 2–19). Note the tight rotation (point A) within the center of the larger area of rotation. This area of tight rotation is known as a tornadic vortex.

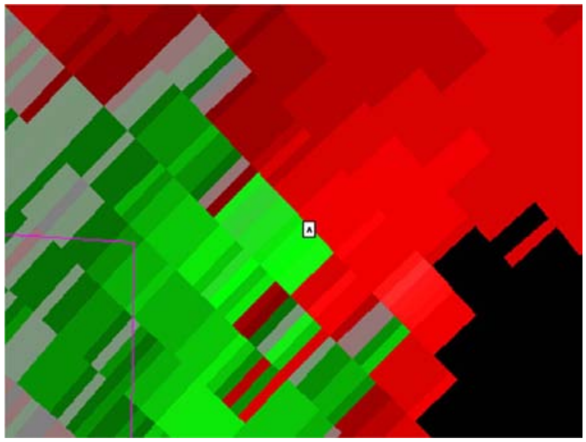


Figure 2–19. Base velocity (tornado).

Hail size

You may be asking yourself, how do we determine hail size through the velocity field? Since hail size is directly related to the strength of the updraft within the storm, we can determine size by measuring the updraft. We can measure the updraft by correlating it to the amount of divergence aloft.

The National Severe Storms Laboratory (NSSL) has developed a hail size nomogram (fig. 2–20) with step-by-step procedures for determining hail size. (This nomogram was developed for the Oklahoma area and needs adjusting for your location.)

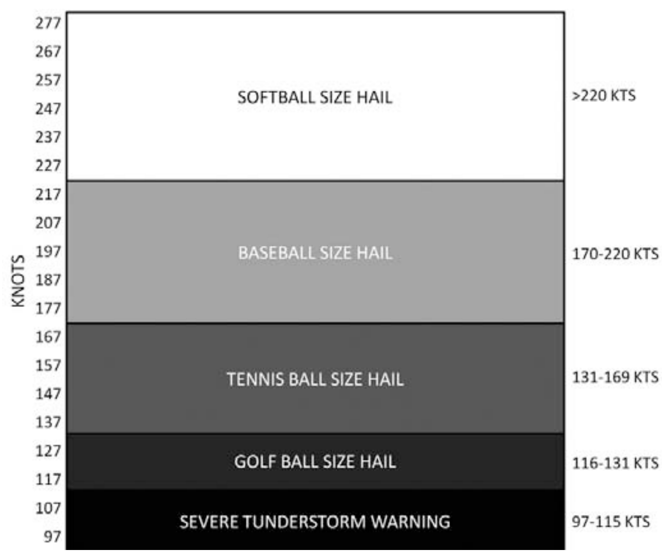


Figure 2–20 Hail nomogram

Velocity interpretation

The use of base velocity products range from routine daily weather station operations to severe weather forecasting. Determining vertical wind profiles is accomplished using the entire product display while individual storm features are determined by focusing in on a small area of the display (horizontal wind profiles). Let's take an introductory look at velocity interpretation, then specific uses of the velocity product.

Range versus height

The WSR–88D samples through 360° at a series of fixed elevation angles. At each elevation angle, distance outward along the radar beam represents an increase in height above the ground. In other words, the further you move away from the antenna, the higher the beam is off the ground. This is an extremely important point to keep in mind when you look at a velocity product. You must remember that the very center of the display represents the height of the radar tower, while the outer edges of the display are thousands of feet above the ground (fig. 2–21).

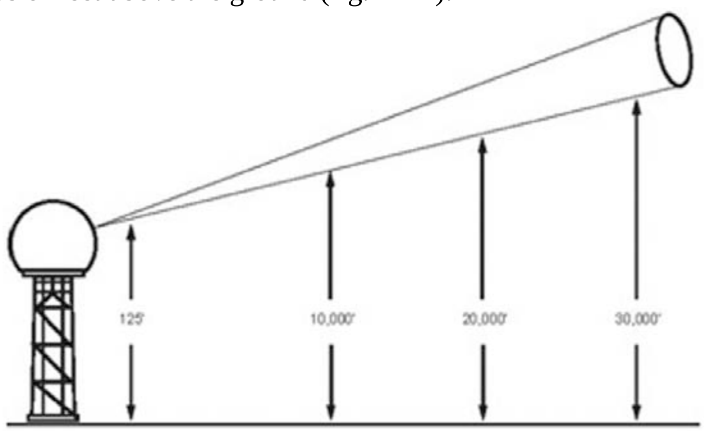


Figure 2–21. Range versus height.

Determining wind direction

The orientation of the zero Doppler line is extremely important to velocity interpretation. Figure 2–22 indicates how to interpret wind direction using the gray zero Doppler velocity line. The presence of the zero line indicates the wind direction is perpendicular to the radar beam at that azimuth. For example, along the outer edge of the display; the velocity is zero when the radar points to the north and south. This means that the wind is either blowing from west to east or east to west at the height corresponding to the edge of the display (keep in mind the pseudo 3D display). Since Doppler velocities are negative along the western edge of the display and positive along the eastern edge, the wind is obviously blowing from west to east at the height of the display.

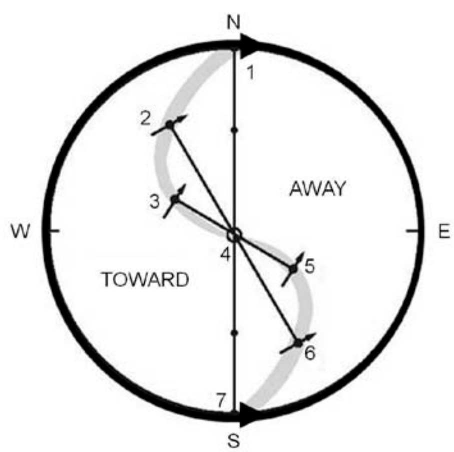


Figure 2–22. Determining wind direction.

When the radar beam points toward point 2 on the zero line, it is pointing toward 330°. The wind direction at that point is 330°+ 90° If all we had was a zero line and no other data, we would not know if the wind was from 240° or 60°. However, since the wind is blowing generally from west to east, the wind at point 2 must be 330 - 90 = 240°. Similar arguments at points 3, 5, and 6 result in wind directions of 300° - 90° = 210°, 120° + 90° = 210°, and 150° + 90° = 240°, respectively. At point 4, the zero line is oriented east to west. Since inbound velocities are to our south, the wind direction must be 180°. Simple, isn't it? But what about wind speed?

Determining wind speed

Once you have mastered wind direction, determining wind speed should be a breeze. Recall from our discussion above that the WSR–88D only measures the full component of the wind, when the wind is moving parallel to the beam. Therefore, to determine wind speed for any given height, you must read the speed from the point at which the full component is being registered. How do we do this?

First, remember that as you move from the center of the screen out to the edges of the display, height above the ground increases. Therefore, if you have moved two inches out from the center of the display, in any direction, that point would always represent the same height. For example, if you moved two inches from the center of the display out to the north, and that point represented 10,000 feet, then moving two inches from the center to the south, east, west, or any other direction would also represent 10,000 feet. With that in mind, let's look at the procedures for determining wind speed.

First, determine the wind direction for any point along the Doppler zero line. Once you know the wind direction, determining wind speed is simple. The wind speed is found on the radial and range that corresponds to the wind direction in degrees and range. Another way to determine wind speed is to move 90° from the point (wind direction) on the zero line, toward the direction the wind is from. You must remain at the same distance from the radar when you move 90°. At the 90° point the radar is sensing the full component of the wind so your true wind speed is derived here.

Although the wind speed profile controls the overall pattern including spacing between contours, the vertical profile of wind direction controls the contour curvature. The most informative contour for wind direction is the zero velocity contour. Notice that the zero contour is the same in each row of figure 2–23, however, the overall pattern of each profile is quite different. With this in mind, you can see that both speed and direction combine to form our unique velocity displays.

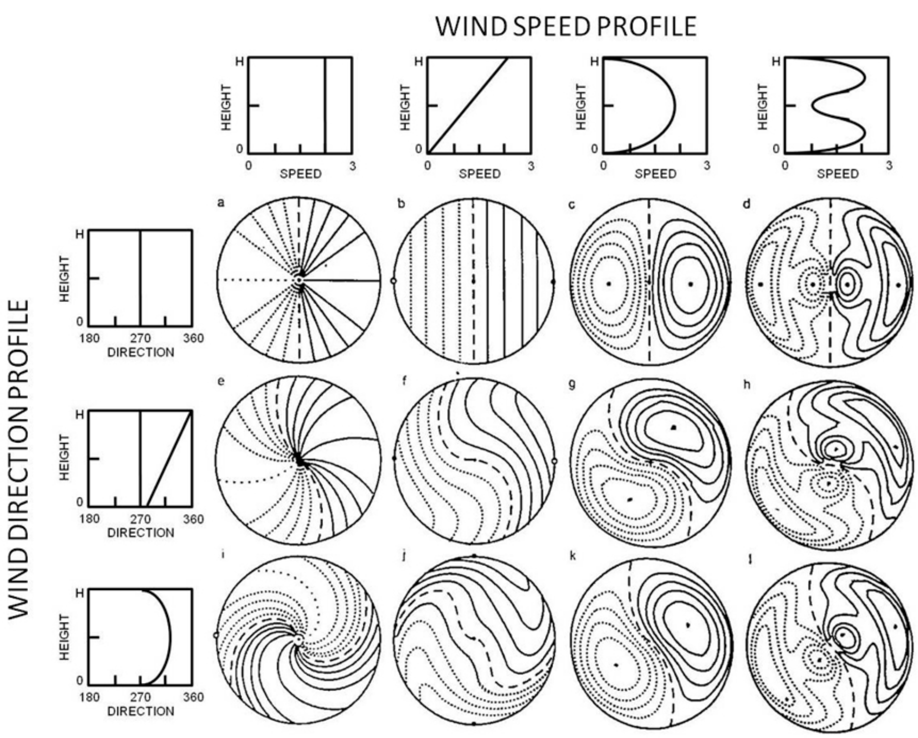


Figure 2–23. Wind speed profile.

410. Spectrum width

The spectrum width (SW) product is probably the most under-utilized of the three base products. This is not because it doesn't provide valuable information. It's generally because the product is not as straightforward to interpret as the other two base products. Interpretation of the spectrum width is difficult and, as with many things, requires operator skill and experience to exploit its potential fully. In this lesson, we'll look at some operational uses of SW.

Interpretation of spectrum width

Despite the fact that the SW product is not straightforward, there are many meteorological applications for the product. We will look at four specific uses for this product. The uses are verifying areas of suspected turbulence, discovering or monitoring icing conditions, identifying areas of possible convective development, and checking data reliability. It provides assistance in your analysis of atmospheric motions. The SW product is most effective when used with other products such as in conjunction with velocity and reflectivity products.

Turbulence

Since SW measures the combination of motions within a sample volume, we can assume turbulence or shear within areas of high spectrum width. This relationship helps verify the existence or nonexistence of turbulence.

Figure 2–24 is a velocity display containing abruptly veering winds and a low-level jet. Using velocity alone, a forecast of light to moderate turbulence from the surface to a point above the abrupt change in wind direction is logical. However, by using the SW product we can refine our turbulence forecast.

Figure 2–24 shows a SW product at the same elevation angle and approximately the same time as our velocity product. Note the high SW values to the northeast and south of the radar data acquisition (RDA). These high values correspond with the abrupt change in wind direction seen on the velocity product. Note however, that areas associated with the low-level jet maxima contain very low SW values. Therefore, we can assume that there is little or no turbulence associated with the low-level jet itself and our turbulence forecast can be adjusted accordingly.

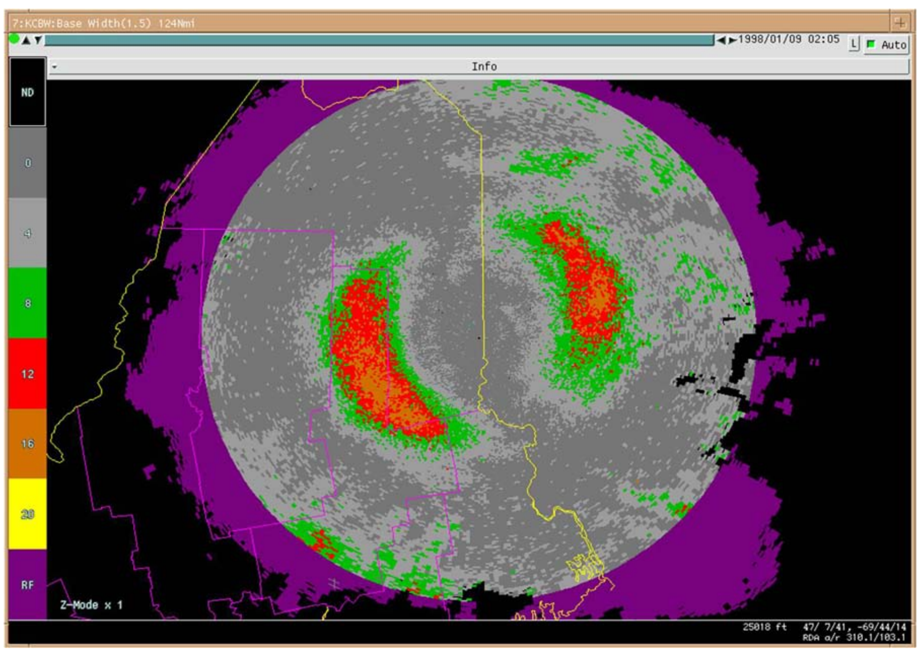


Figure 2–24. Spectrum width.

Icing

Although there is currently no WSR–88D product specifically designed to help in forecasting icing, SW can help. Due to the increased variance in the velocities of the particles within the melting level, the result is high spectrum widths. This area of high spectrum width appears as a ring or partial ring centered on the radar (much like the rings you saw on the reflectivity products). Armed with this information, the forecaster can monitor the height of the melting level (bright band) to help in forecasting icing, and precipitation type.

Convective development

Convective development is often seen on the spectrum width product before any significant returns show up on a reflectivity product. Consider a reflectivity product having a return of 15dBZ. Using reflectivity alone, this echo is considered insignificant. However, if this 15dBZ echo is displayed when spectrum width is displaying high values, closer interrogation is warranted. Since spectrum width measures the variance of motions within a sample volume, these high spectrum width values may be indicating the motions associated with convective currents. High spectrum width with low reflectivities may be your first indication of storm development.

Data reliability check

Spectrum width data is useful for evaluating the validity of mean radial velocity estimates. Due to the motion variability of individual contributing particles, velocity estimates in areas of high spectrum width may be less accurate than those obtained in low width areas. Also, data reliability tends to drop near the edges of echoes where the signal-to-noise ratio can become less than desirable. This effect is often seen by high SW values along the outer edges of these returns.

Limitations

The SW product is not always reliable. Other products, such as the Skew-T diagram and centrally prepared products should be analyzed along with the various WSR–88D products available. Phenomena, such as turbulence, are often localized, transient features that require more than a quick glance at SW to find. Additionally, SW information collected from weak signal returns near the noise threshold leads to erratic spectrum estimates and noisy SW data.

The base reflectivity product depicts the familiar echo patterns everyone is used to seeing. The velocity and SW products will take practice to be able to evaluate rapidly. When making a forecast, these products should never be used alone. If you see a significant signature on base reflectivity, look at base velocity or any of the derived products, discussed next, to help support or dispute the existence of what you first detected.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Base reflectivity

1. Below what measurement of dBZs are most returns considered non-precipitable?

2. A hook echo radar signature is actually what?

3. Where is a hook echo usually located in relation to the parent storm?

4. In what level of the storm should the radar operator look for a hook?

5. The most severe weather with a line echo wave pattern is normally located where?

6. WSR–88D’s 10cm wavelength makes finding embedded thunderstorms in stratiform precipitation easier by reducing what atmospheric problem?

7. How does the melting level appear on WSR–88D single-slice reflectivity products?

8. What factors may prevent detection of the melting level on WSR–88D reflectivity products?

9. What is a good indication of a well defined pendant accompanied by extensive mid-level overhang?

10. With an absence of reflectivity values ≥ 50 dBZ extending to 27,000 feet AGL or higher, what criteria must be satisfied for severe thunderstorm identification on base reflectivity?

409. Base mean radial velocity

1. A backward S-shaped velocity pattern suggests what type of advection is occurring?

2. What is most likely occurring when a base velocity product displays a rapid change in velocity values over a very short distance with a directional change?

3. The radar is to the south of a velocity pattern with inbound velocities on the left side and outbound velocities on the right side as you look at the pattern. There is a Doppler zero velocity line, oriented north-to-south, separating the inbound and outbound velocities. What does this pattern suggest?

4. The radar is to the north of a velocity pattern with a Doppler zero line oriented west-to-east. On the north side of the zero line, closest to the radar, there are inbound velocities. On the south side of the zero line, farthest from the radar, there are outbound velocities. What does this pattern suggest?

5. How can one measure the strength of the updraft to determine hail size on a base velocity product?

6. What does the presence of the zero line on the base velocity product indicate?

7. Once the wind direction has been determined, how can one determine wind speed?

8. What is the most informative contour for wind direction?

410. Spectrum width

1. What can the spectrum width product be used for?

2. What can the spectrum width product identify to aid in forecasting icing?

3. For which product can the spectrum width product be used as a data reliability check?

4. What type of atmospheric development shows up on the spectrum width product before any significant returns show up on a reflectivity product?

5. Spectrum width information collected from weak signal returns near the noise threshold can lead to what?

2–2. Interpretation of Radar Derived Products

All products are generated in the radar product generator (RPG) from processed base data (reflectivity, velocity, and spectrum width). These products are then distributed to open principle user processors (OPUP) where they are stored, displayed, and archived. The RPG produces and transmits the various meteorological products. These products are derived from several fundamental relationships between reflectivity, spectrum width, and radial velocity patterns through use of algorithms. They provide operators with conclusions concerning the locations, movement, and severity of meteorological phenomena. These conclusions are only as reliable as the data from which they derive. Therefore, it is imperative that the operator understands the application and limitation of each derived product.

411. Composite reflectivity

During our lesson on reflectivity, we made the point that the base reflectivity products give us a “birds-eye” view of the radar coverage area. However, never forget that each reflectivity display is only giving us a small sample of the radar coverage area. Each product only gives us a single slice of the atmosphere. If you want to sample the entire volume of your radar coverage, you need to sample each elevation scan. A product that could display all the echoes present, despite where they are in our radar coverage area, would definitely be useful. Composite reflectivity (CR) is one product that can do this for us. Data collected for generation of the composite reflectivity product is derived from all elevation slices.

Interpretation of composite reflectivity

The CR product permits a view of reflectivity levels for the total range of the radar. Because of this, it provides an instant snapshot of the most important reflectivity features. However, typical signatures, such as hooks and curvature, are not easily identified since reflectivities from many different elevations may be presented side-by-side.

Correlation of the composite reflectivity with other products

Composite reflectivity can be your first step in identifying significant weather features. Further information, such as height above ground or the 3D structure of the reflectivity pattern, must be determined by using other products. Looking only at a CR product, how can you determine the significance of these returns? It should now be obvious that you need the help of other products, such as base reflectivity, to interrogate this situation properly.

Quick check

The CR product is also best used as a quick check on the overall reflectivity pattern. You may routinely view only a few of the total available slices of base reflectivity data. Thus, you are not sampling the entire vertical range of the radar. Here, you can display the CR as a check of whether any new echoes have developed in an area not covered by the particular elevation slices you are currently using.

Melting level

Under favorable conditions, features that have strong reflectivities, at approximately the same height over the radar coverage area, are detected. In the past, the melting level in the atmosphere was often identified on a range/height indicator (RHI) scope by a feature called the bright band. On the CR product, you are also able to identify the melting level from the distinctive circles of higher reflectivities (fig. 2–25).

Unfortunately, with the CR product, this is more of a hindrance than a benefit—the multiple rings tend to clutter the display. You cannot determine the height of the melting level using CR since it is a volumetric product. However, the CR quickly shows the melting level is detectable in a given situation. You can then use an appropriate slice of base reflectivity to investigate further. As you can see in figure 2–25, each elevation slice that detects the melting level is depicted at the range or distance from the RDA where the melting level is encountered. This results in multiple rings of enhanced reflectivity around the RDA. Recall that with the base reflectivity products, you can easily determine the height of this enhanced ring. At any given elevation angle, the WSR–88D computes range and cursor height almost instantaneously.

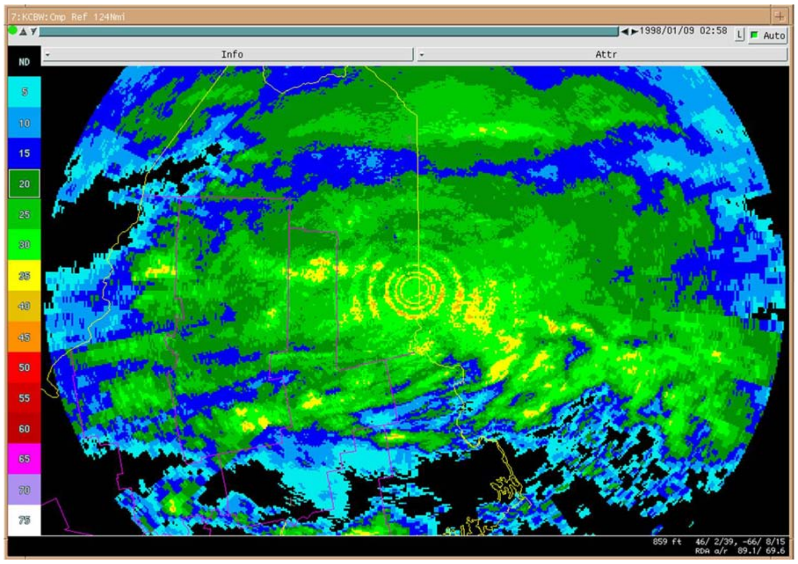


Figure 2–25. Composite reflectivity (melting level).

Limitations

The CR gathers its values by picking the strongest reflectivity from any height—meaning many of our typical signatures are not visible on the CR product. Do not use the CR product for identification of horizontal plane signatures that don't typically exhibit high reflectivities such as hook echoes. Other features, such as outflow boundaries and bounded weak echo regions (BWER), may also be disguised on the CR product. If you detect a classical feature on the CR, investigate it further by using appropriate slices of base reflectivity. Besides the loss of traditional patterns in the CR product, other points should be kept in mind. For instance, altitude information regarding the 3D structure of reflectivity is lost. Use other products, like base reflectivity and storm structure, to obtain the height of the maximum reflectivity.

Further, note that since the CR is made up of information that comes from the base reflectivity products, many of the same situations that affect the quality of reflectivity data also cause problems with CR. For instance, ground clutter and anomalous propagation (AP) can cause problems in the reflectivity displays and, therefore, may also give non-weather-related values to the CR product.

412. Vertically integrated liquid

The WSR–88D receives a reflectivity signal from a distant target, and then produces color displays of that signal. You can interpret these displays and make determinations on the severity of the storm, direction and speed of motion, amounts of rainfall, and so on. Base reflectivity and composite reflectivity display the reflectivity in a straightforward manner through dBZs. However, other methods of displaying information are possible and can be designed to help you identify potentially severe convective activity. Vertically integrated liquid (VIL) is one such product (fig. 2–26).

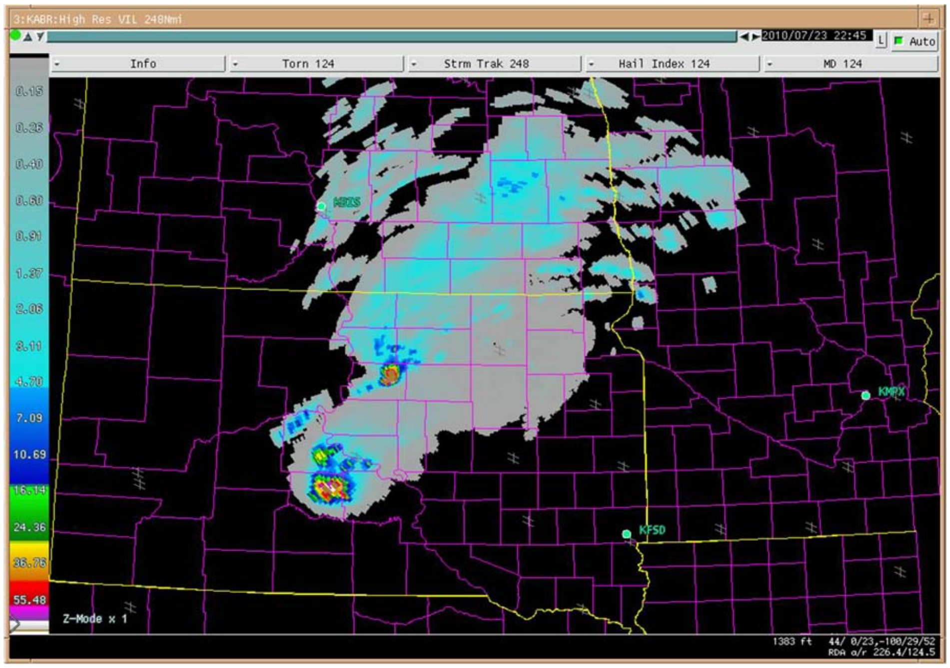


Figure 2–26. Vertically integrated liquid.

Interpretation of vertically integrated liquid

As mentioned earlier, the VIL product's primary function is identifying strong storms that may become severe. Because VIL values are tied directly to the strength of the updraft in a storm, VIL values will increase with the strengthening of the updraft. VIL is very useful in monitoring the general radar echo pattern for the beginning stages of significant convective development and for helping to distinguish thunderstorms from rain showers. As convective development progresses, relative values of VIL are useful in distinguishing strong, possibly severe, thunderstorms from those not likely to be severe.

Significant vertically integrated liquid values

What we call "significant" or high VIL values vary from location to location, season to season, and from one weather system to another. In Oklahoma, operators have found critical VIL values (when a storm becomes potentially severe) vary from values of 35 in late fall or winter to values of 60 or more in summer. This might sound pretty confusing, but you quickly get a feel for VIL values by using other products along with VIL. For instance, comparing values of reflectivity in dBZs to VIL values for the same storm helps determine the range of values you need to be aware of. Other products available on the WSR–88D are also useful. (*NOTE*: These products are discussed later, specifically the severe weather probability, hail detection, storm structure, mesocyclone and tornadic vortex signature products).

Vertically integrated liquid gradients

The gradient of the VIL values is also important. Strong but continuous VIL gradients are significant just as is true with reflectivity values. On the other hand, very abrupt, erratic changes are seldom observed in nature and therefore should be viewed with skepticism when seen on WSR–88D products such as VIL.

Vertically integrated liquid trend

A final point when observing VIL is that the upward trend over several volume scans should be consistent. Storms generally require a certain amount of time to develop; thus, the VIL values should never abruptly jump from low to high values (fig. 2–27 shows a time lapse of VIL).

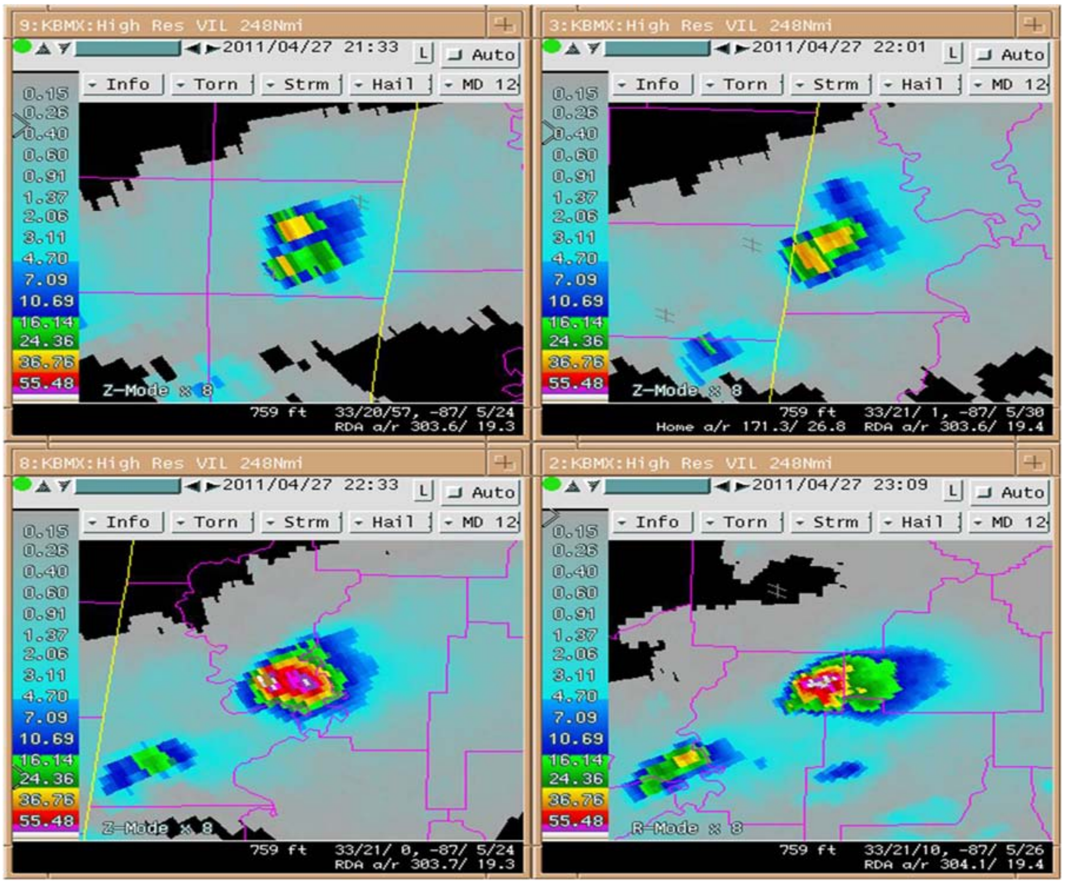


Figure 2–27. Vertically integrated liquid trend.

Limitations

The VIL product is a valuable tool that provides you with a method to differentiate between potentially severe storms and those that never rise above garden variety. VIL algorithms display VIL values for storms based on reflectivity data converted to liquid water content. However, no product is without its limitations. Here are a few to be aware of concerning VIL.

Seasonal and diurnal variations

Already, you know that VIL values change with the seasons and from location to location. More specifically, VIL values change from diurnal and air-mass variations as well. This is not a straightforward process—under different weather conditions the minimum VIL value associated with severe weather varies by different amounts—but general trends can be expected. For instance, warm, moist air masses tend to exhibit higher VIL values during severe weather occurrences, while cool, dry air masses produce much lower values. What are good VIL values? A value of 40 or 80 doesn't tell you much alone. You need to know the typical values for your specific location and synoptic situation.

Tilted and fast-moving storms

Another problem may also cause unrepresentative values of VIL (fig. 2–28). The VIL algorithm calculates values for grid boxes (stacked in the vertical) that are 2.2 × 2.2 nautical miles. A storm that is strongly tilted may not have all of its vertical extent within the same stack of grid boxes. So what happens? The VIL algorithm does not know that the storm is tilted. It just follows the same rules it always uses. But near the top of the stack of boxes, the storm is not in the same vertical stack that it is in at the bottom. In a bad case, the algorithm could be adding up "empty" boxes, and thus a low value of VIL would be reported for a large storm.

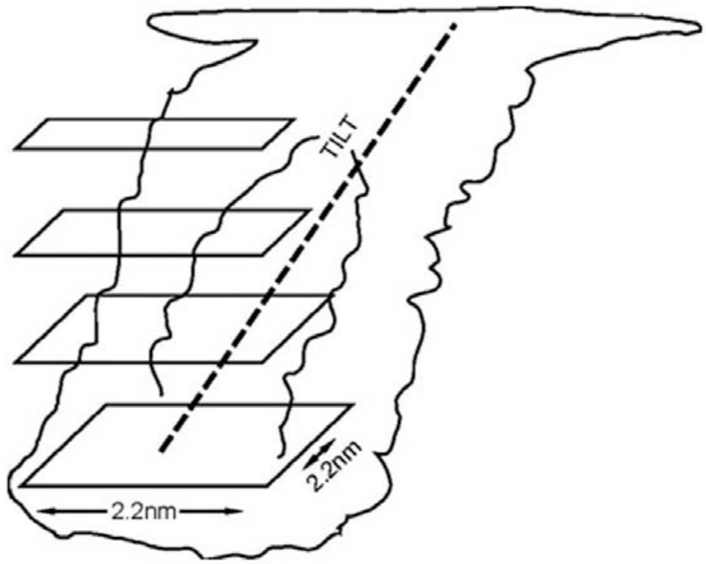


Figure 2–28. Vertical stacking.

The same problem of low VILs occurs with storms that move much faster than the average of the other storms present in the radar coverage area. Here, the VIL algorithm is again calculating values using a vertical stack of boxes. But realize that at least five minutes is used to scan from the lowest elevation to the highest. As you can imagine, a fast-moving storm has traveled enough to move through and even exit the stack of boxes, thus fooling the VIL algorithm. The result is an underestimation of the true severity of the storm. As you can see, the VIL algorithm, or any other for that matter, works best when storms closely approximate the norms on which the algorithm was based.

413. Echo tops

Most of the WSR–88D products depict data with an emphasis on horizontal detail. The vertical structure often must be inferred from other sources. However, several derived products are designed to present data in a specific manner. The echo tops (ET) product is one example. The display is simple and easy to interpret. However, the price you pay for this convenience is a specialization that limits the number of ET product applications.

Interpretation of echo tops

The ET product is based on data from base reflectivity and it allows the radar operator to monitor the echo tops throughout the radar viewing area. The height of the ETs is a concern for forecasters and aviators and is used as an indicator of various atmospheric dynamics. The ET product computes echo top height by using 2.2 x 2.2 nautical mile (nm) grid boxes. For instance, an echo top of a thunderstorm increasing in height is probably increasing in intensity while a decreasing thunderstorm echo top could suggest a weakening storm. If the echo top collapses very quickly, it may be an indication of a downburst occurring on the surface. Other volumetric products such as VIL, used in correlation with ET, can be of additional help in understanding what is happening in the atmosphere. Since ET is a volumetric product, volumetric overlays such as hail, and mesocyclone may be placed on it if desired. Figure 2–29 is an example of an echo top product.

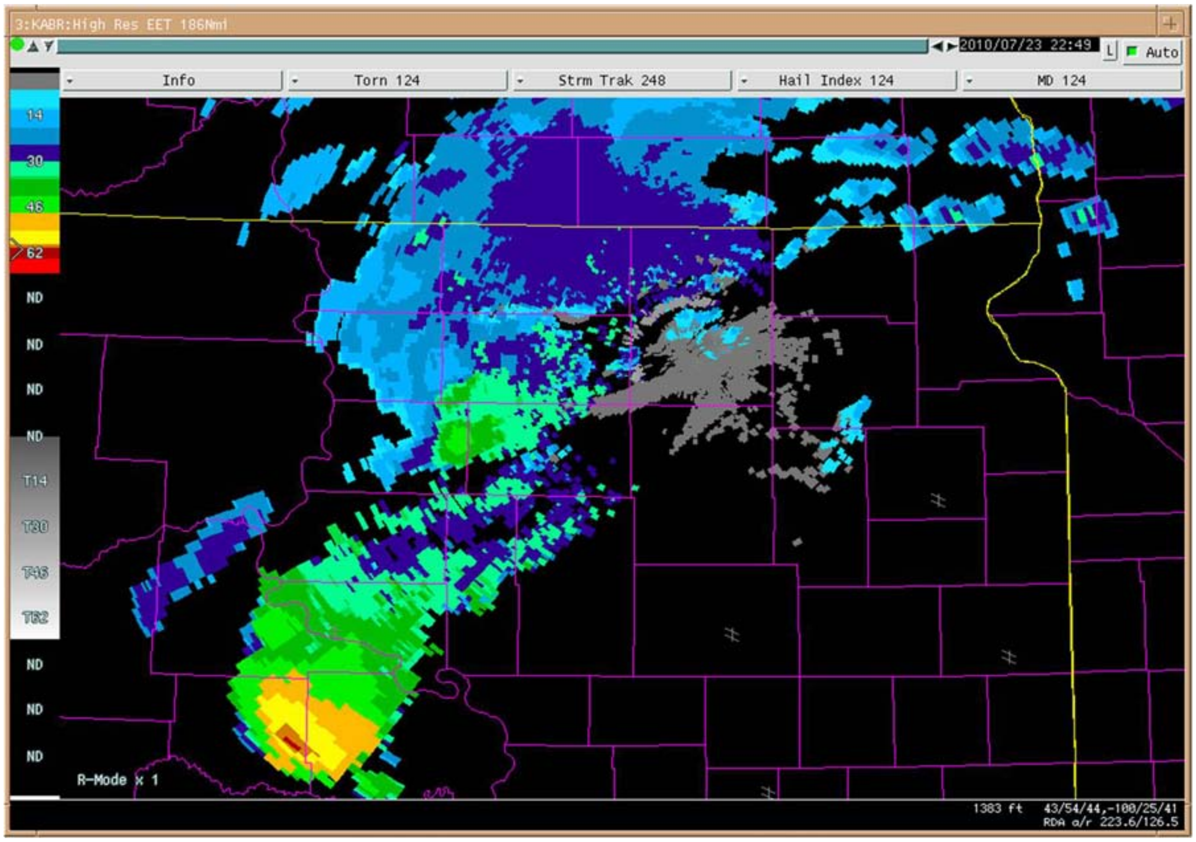


Figure 2–29. Echo tops.

Identification of updrafts and downdrafts

Since the ET is directly related to the updraft, you can monitor the ET product to gain some insight into the actions of the updraft. A lowering or collapsing of the ET may indicate a sudden weakening of the updraft—and thus you can time the onset of severe weather events at the surface (much like you can with the VIL product). Look at figures 2–30 and 2–31. Note that you can use both the VIL and ET products together to provide some assurance and/or verification that your interpretations are supported by actual cell dynamics and not by some aberration of the algorithms.

For example, as seen in figure 2–30, a drop of VIL values alerts you to the possibility that the updraft has suddenly weakened and allowed large amounts of precipitation to drop out of the updraft. You then expect a similar drop in the height of the echo tops to occur since they also relate to a strong updraft (fig. 2–31). In figure 2–31, you can see the aerial coverage and heights of the highest echo tops decrease correspondingly to the decreases in VIL. Slight differences in time between these events are expected, but this type of correlation is your assurance that your assumptions are correct.

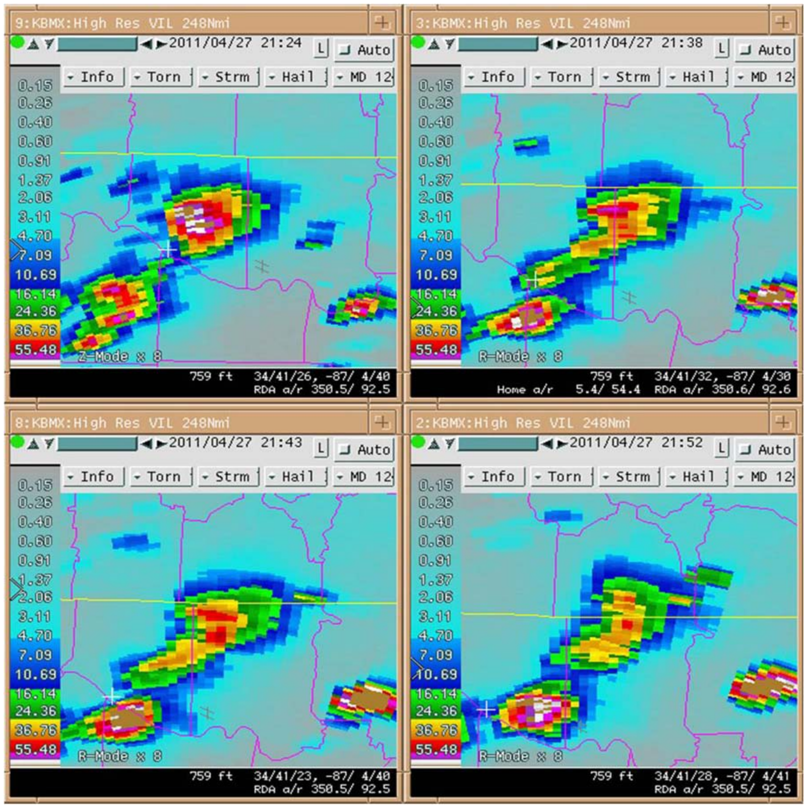


Figure 2–30. Vertically integrated liquid (comparison).

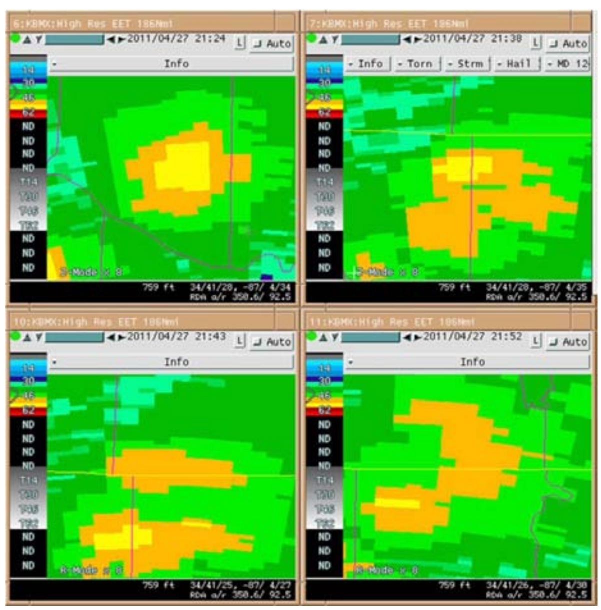


Figure 2–31. Echo tops (comparison).

Beginning of convective development

If a stratiform situation exists and convective clouds start to develop within the stratiform clouds, the echo tops are usually detected before any indications on base reflectivity. As the updrafts develop and push the tops of the cloud higher, these higher tops are seen as mid-level echo tops on the ET product.

Correlation with base reflectivity and VIL is recommended, as reliance solely on one product is discouraged. Keep in mind that the ET product is very useful in identifying the presence of vertical tilt within a storm.

Limitations

The ET product does have some limitations you must consider when using the product. The following are some of the limitations to consider.

Inaccurate echo top height calculations

The ET product provides a simple, easy-to-view display of the height of the ETs. But as the saying goes, "if it looks too good to be true…" And of course, correct interpretation of even a simple product like ET requires that you be aware of possible drawbacks.

Since an ET may be the result of an updraft, you may think of several ways in which ET can be used to support other radar operations besides just aviation interests. For example, since the maximum ETs are assumed to be above the updraft of a thunderstorm, ET might be used to help identify strong updraft areas. Or, on the other hand, you might also use this technique to identify the amount of storm tilt or stacking by comparing the ET to displays of lower elevations.

Do not confuse the ET product with the capabilities of an RHI scope of conventional weather radars. The information displayed may be adequate support for briefing requirements, but making direct meteorological conclusions from the ET product alone is not a sound practice. Another basic point to keep in mind is that the "echo tops" displayed by the WSR–88D are probably *NOT* the actual cloud tops. Recall that the ET algorithm discards reflectivities below a preset threshold (the default is 18.5dBZ). Quite possibly, the cloud tops do extend beyond the heights the ET product displays. A minimum significant reflectivity threshold needs to be established before you can use ET to safely estimate actual cloud tops.

Stair-step pattern

Another commonly seen problem is the apparent "stair-step" appearance of the ET product—the echo tops abruptly increase in height with range. This problem has two causes. First, remember the antenna's maximum elevation angle is 19.5°, and thus a limited height capability close to the radar. At these close ranges, the product reports a limited ET no matter how tall the storm is. The result is a series of heights encircling the RDA site, with increasingly higher echo tops farther from the antenna.

A second cause also adds to this stair-step pattern and is most easily observed in weather systems with uniform tops. Since the beam is spreading vertically and horizontally with distance, the resolution of the beam is decreasing with range. The result is possible errors in the ET heights.

Looking at figure 2–32, note how the ET product plots echo tops at the height of the center of the beam. This happens despite whether the echo is detected throughout the beam, at the very center of the beam, or from just the lower edge of the beam. The result—identical heights are displayed although some variation is occurring. Now, when the next higher elevation is used, another set of identical heights is displayed. This effect, a sudden jump from one height to the next higher height, occurs at the same range from the RDA. This uncertainty in the accuracy of height measurements can be quite significant (at 124nm, errors of 6,500 feet are possible).

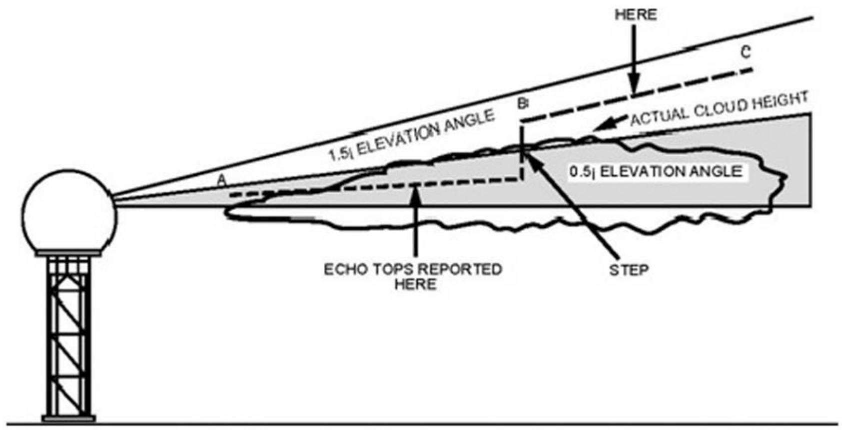


Figure 2–32. Echo top beam limitations.

Data contamination

The ET product also does not correct for data contamination from side lobes. This contamination causes overestimation of tops in areas of strong reflectivity. Further, incorrect estimations occur when the actual storm top occurs between gaps in the volume coverage pattern, or especially if the true tops are above the highest elevation slice.

414. Precipitation products

The storm total precipitation (STP) product is one of four precipitation products that the WSR–88D generates. The others are the one-hour precipitation (OHP) product and the three-hour precipitation (THP) product and user selectable precipitation (USP) product. We'll concentrate on the STP and USP products.

Storm total precipitation

The STP product gives us information on the total amount of precipitation over a certain amount of time (fig. 2–33). It provides continuously updated information on precipitation accumulations within 124 nautical miles of the radar. At first glance, you may wonder why we need a product like this. This product will mainly be used by US government hydrologists. However, you can use it to verify weather warnings when you have a malfunctioning rain gauge or to verify warnings in remote areas like missile fields or ranges. Let's take a look at the uses for it. There are five uses for this product:

1. Aids in the monitoring of total precipitation accumulations, whatever duration.
2. Estimate of total basin runoff due to a single storm.
3. Estimate of basin saturation due to previous rainfall events.
4. Evaluation of flood reports.
5. Post storm analysis.

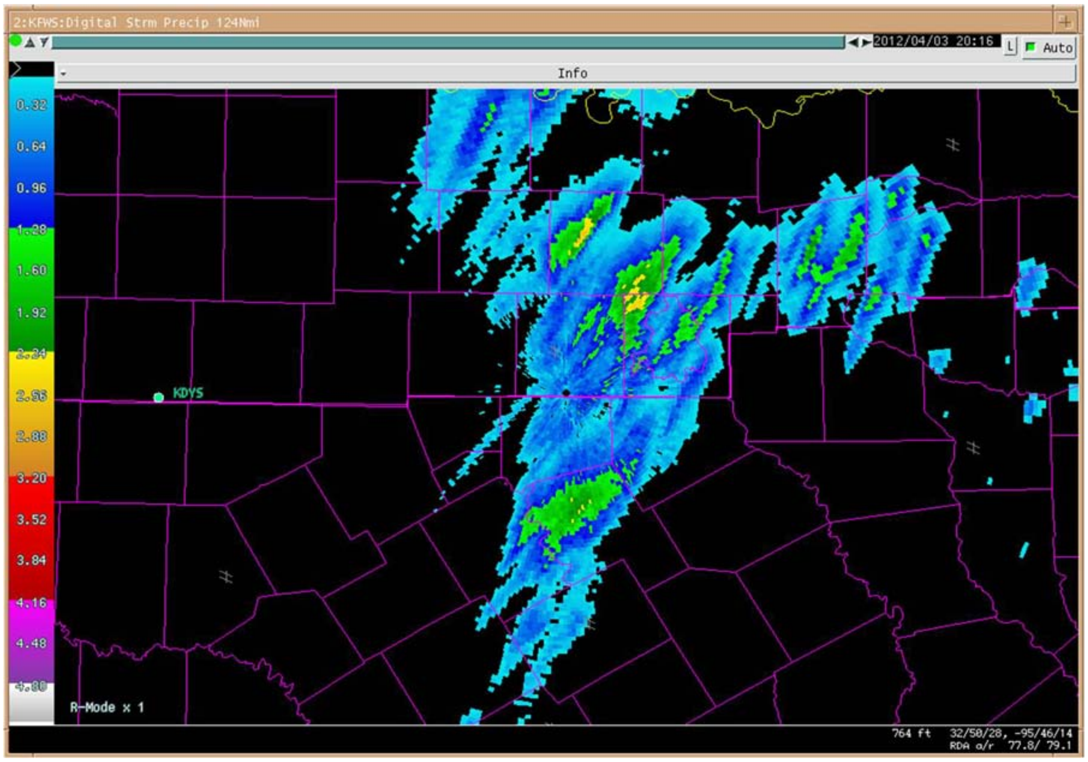


Figure 2–33. Storm total precipitation.

Limitations

The STP product has limitations though. Extended WSR–88D system outages during precipitation events compromise the data. Breaks in precipitation of more than one hour reset the system. It has trouble with small-scale features such as non-precipitation reflectivity, like clutter or anomalous propagation, which may contaminate data. The algorithm, therefore the product, does not account for snow or frozen precipitation, bright bands, and so forth.

User selectable precipitation

Now we’re going to look at another precipitation product called the user selectable precipitation (USP) product. One advantage that the USP product provides over the STP product is that gaps of precipitation will not affect amounts. The main difference between the precipitation products is the period of time the products use to accumulate precipitation amounts. As the name of the USP implies, the operator can select the duration for which USP collects rainfall estimates. The total number of hours used to build the product is included in the table that accompanies the USP product. Let’s take a look at the uses for it. There are five uses for this product:

1. Monitoring precipitation for a specified time period.
2. Post storm analysis.
3. Estimation of basin run-off for a specified time.
4. Estimation of basin saturation.
5. Evaluation of flood reports.

Limitations

The same limitations that affect the storm total precipitation product affect the user selectable precipitation product. The database for the USP product is limited to 30 hours. Keep in mind that the USP product is a customized product (requires operator input); therefore, the RPG only satisfies 10 unique USP requests per volume scan. The maximum number of hours that the USP can be generated set for is 24.

415. Mesocyclone Detection

The Mesocyclone Detection (MD) product uses a combination of the WSR–88D's extensive computer processing capabilities along with the base velocity information to build an extremely valuable product (fig. 2–34). This product is designed to take the burden of constant interrogation off the shoulders of the operator by continually searching for the rotating fields associated with mesocyclones. In this lesson, we take a brief look at the MD product.

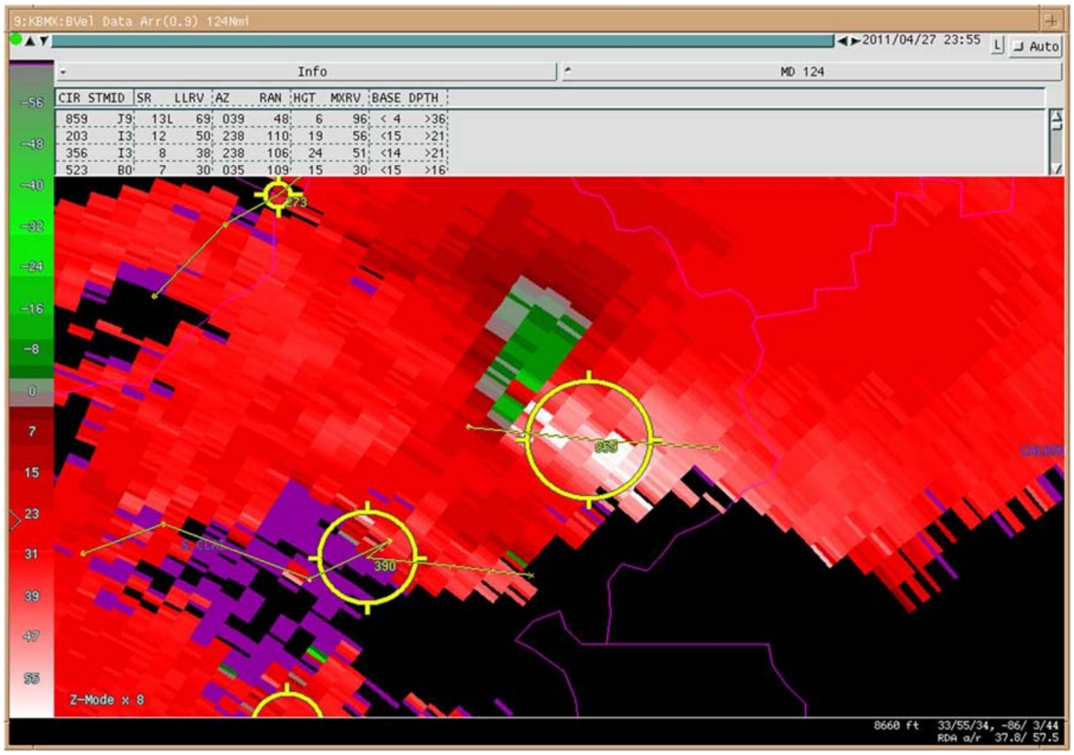


Figure 2–34. Base velocity (mesocyclone overlay).

Interpretation

The MD product is tailored to identify the vortical flow field associated with the updraft of a severe convective storm. It uses 3-D correlated shear, uncorrelated shear, and mesocyclone output criteria for the mesocyclone product. At times, it identifies microbursts associated with vortical flow (based on the associated shear). Remember, less than half of all verified mesocyclones produce tornadoes. However, greater than 90 percent of all mesocyclones produce some form of severe weather. This product does not manually verify mesocyclones. It is only used to alert the OPUP operator to the possible existence of a mesocyclone within a storm. Further interrogation is required!

Identifying mesocyclones using velocity products

The 2D processor searches for cyclonic shear by identifying pattern vectors. Once the mesocyclone algorithm identifies all pattern vectors, it attempts to consolidate them to form 2D features. Once the mesocyclone product identifies a feature, it is your turn to start the interrogation process. You can use a three-step process for mesocyclone detection using the velocity products. Keep in mind the optimum effective range of the mesocyclone detection algorithm is 65 nautical miles.

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Step	Action/Characteristic
1	• Determine if sufficient rotational velocity exists between closed isodops of opposite sign ▪ Compute the rotational velocity ▪ Add the absolute values of the wind speeds ▪ Divide the number by two • Significant shear is defined as rotational velocity of: ▪ 30kts within 80nm of the RDA ▪ 22kts between 80 and 125nm
2	• Determine vertical continuity ▪ Vertical extent can be as small as 50% of horizontal diameter but never less than 10, 000 feet ▪ Even with volume coverage pattern (VCP) 11, the 1.5 degree elevation slice may be too high to detect distant mesocyclones. Therefore, recognition may occur without satisfying a vertical continuity check at long ranges
3	• Determine time continuity ▪ Shear pattern should exist for at least two volume scans ▪ The mesocyclone product itself does not establish time continuity

416. Tornadic vortex signature product

Like the mesocyclone product, a tornado detection algorithm (TDA) that analyzes the base velocity data to detect regions of strong, localized, cyclonic shear produces the tornadic vortex signature (TVS) product. The TDA is designed to identify and classify areas of cyclonic shear that exhibit the strength, depth, and size characteristics associated with tornadic circulations.

In this lesson, we look at the TVS product description, the theory of TDA and its limitations, and finish with visual TVS identification guidelines using the base velocity product (fig. 2–35).

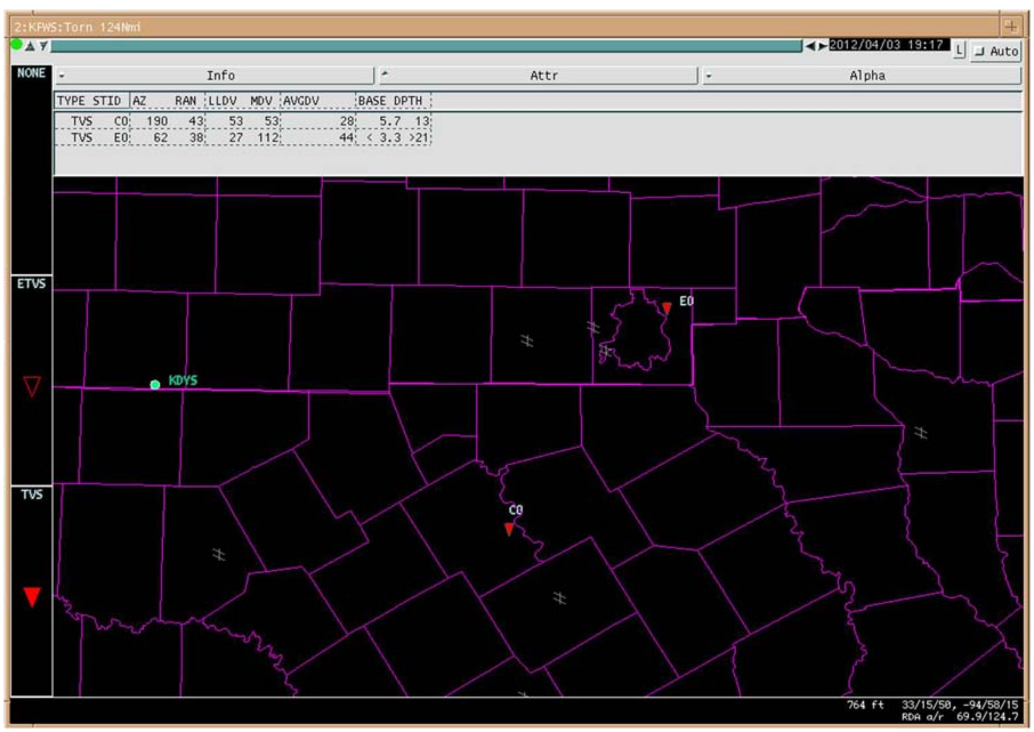

Figure 2–35. TVS graphic product.

Interpretation of the tornadic vortex signature product

Like the mesocyclone product, the primary use of TVS is to identify areas of significant cyclonic shear. The TVS product should not be used as a stand-alone product; instead, it should be used to alert the user when to intensify his or her metwatch. Once the TVS product has identified a potential area, then turn your attention over to other products, such as base velocity or storm relative mean radial velocity for further investigation. A TVS is depicted by a red filled, inverted, isosceles triangle.

Procedure for visual tornadic vortex signature identification using velocity products

The NSSL in Norman, Oklahoma has developed a three-step procedure for visual TVS identification using velocity (storm relative mean radial velocity) products. A TVS signature on the WSR–88D appears as a small-scale, abnormal region of high shear. Joint Doppler Operational Project (JDOP) investigators noted that the signature is detectable, up to 20 minutes before tornado touchdown (based on strong tornadoes located near the radar). However, not all tornadoes produce a detectable signature. The table illustrates a condensed version of the three-step procedure.

Step	Action/Characteristic
1	• Significant localized shear must exist between azimuthally adjacent sample volumes ▪ Localized shear is defined as: ▪ At least 90kts within 30nm of the RDA. ▪ At least 70kts beyond 30nm of the RDA. ▪ TVS detection beyond 55nm is difficult due to beam broadening and the relatively small size of the TVS.
2	• Determine vertical continuity ▪ Localized shear should extend several thousand; it should consist of at least two elevation angles, not necessarily contiguous.
3	• Determine time continuity ▪ Shear pattern should exist for at least two volume scans.

417. Velocity azimuth display winds

One of the most useful and unique products generated by the WSR–88D are the velocity azimuth display (VAD) winds profile (VWP). The VAD algorithm utilizes in-outs from the mean radial velocity and base reflectivity products. The VAD winds profile, or simply VWP, is similar to having real-time rawinsonde data at your disposal every five or six minutes (fig. 2–36). The VWP provides a time-height profile of wind velocity at a pre-determined range. Data thresholds for the VWP can be changed by the user control panel.

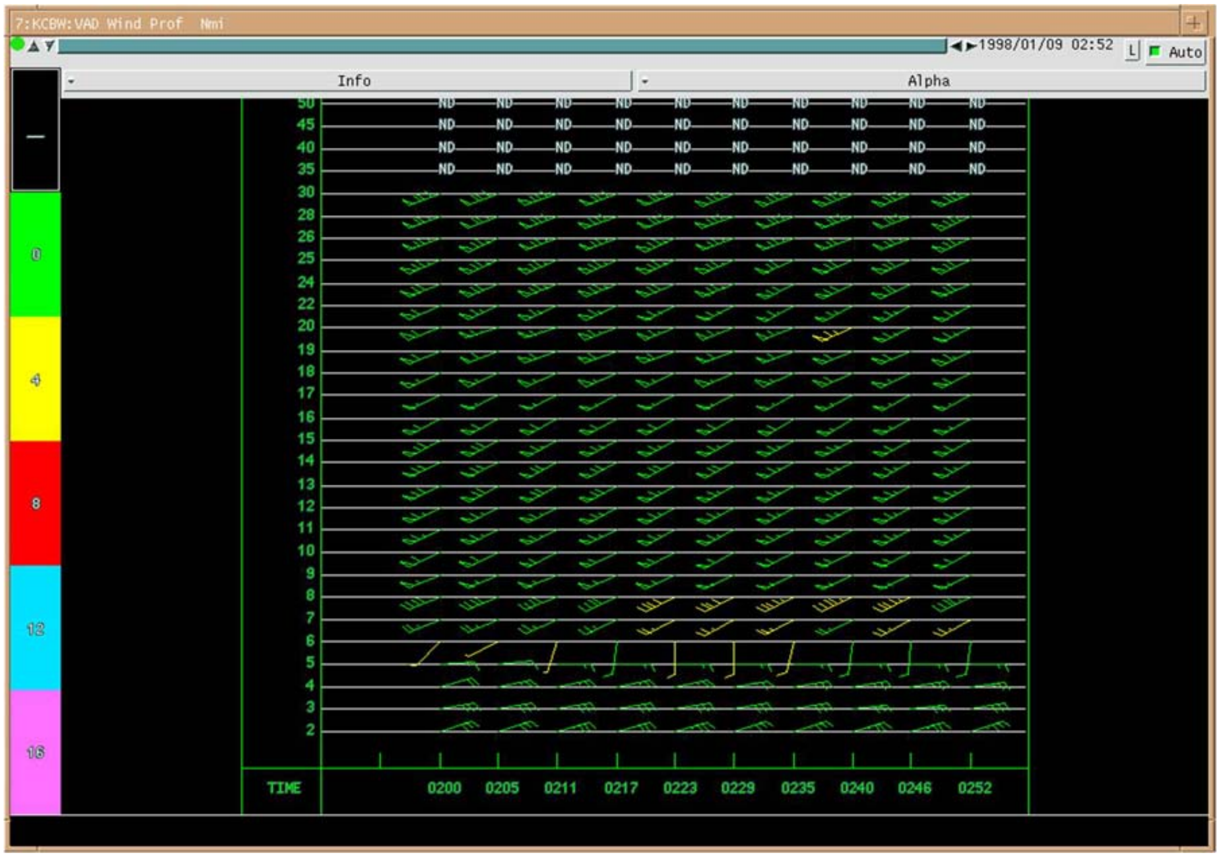

Figure 2–36. Velocity azimuth display wind profile.

Interpretation of the visual azimuth display winds product

Interpreting the VAD winds profile is just like interpreting the winds on any Skew-T diagram. The VWP displays the true wind speed and direction. Wind shafts point in the direction from which the wind is coming. The wind barbs show wind speed with the longer barbs showing speed closest to every 10 knots and the shorter barbs showing speeds nearest to every five knots. For instance, if a wind shaft at 5,000 feet extends to the west and contains two long barbs and one short barb, the wind direction is westerly with a speed of 25 knots.

The VWP can display vertical wind profiles from up to 11 different times. This helps you in identifying several meteorological conditions that evolve over time, such as inversions, wind shifts, and the development of jet streams.

Inversions

An example of detecting the presence of an inversion using the VWP is something like this. You are the WSR–88D operator at the beginning of a day shift with high pressure dominating, clear skies, and ground fog present. Surface winds are calm. You request and display the latest VWP.

On examination of the product, you notice wind speeds below 2,000 feet decreased from 25 knots just after midnight to less than six knots currently. During the same period, wind speeds above 2,000 feet remained unchanged. This scenario describes a radiational inversion setting up in the area of the RDA. As the inversion breaks during the day, frequent monitoring of the VWP shows increasing wind speeds below 2,000 feet as upper winds subside or transfer toward the surface. With this information, forecasts that are more accurate can be made concerning gusty winds following the dissipation of an inversion.

Wind shifts

A cold front is moving southeastward toward your weather station. The RDA site is 25 miles west of the weather station and the VAD analysis range is set at 30 miles. As the low-level winds begin to veer (shift from southwest-to-northwest) with frontal passage, you can see this on the VWP. As the cold layer deepens, you'll see the winds become northwesterly at higher and higher altitudes. The VWP allows you to monitor this progression at five-minute or six-minute intervals depending on the particular VCP in use. This is only one example of the many wind shift scenarios you can analyze using the VWP.

Jet streams

As a jet stream develops, the wind velocities at a given altitude are seen increasing on successive wind profiles of the VWP. Similarly, as a jet stream dissipates, the VWP allows you to monitor the decreasing wind speeds at the affected altitudes. With this information, the accuracy of climb winds, turbulence, and other related data is enhanced.

Limitations

The VWP algorithm does have certain weaknesses. Let's take a look limitations.

Non-uniform winds

The VWP collects its velocity data from a series of levels or planes. An example of one of these planes is shown in figure 2–37. Each elevation slice samples a plane that looks similar to the one shown. The VAD analysis range (slant range) changes depending on the wind altitude levels selected for display on the VWP. If the true wind is not uniform throughout this plane, the VWP winds may be incorrect. If the VAD algorithm finds no difference between the zero velocity line and zeroth harmonic, then the offset is zero, and the wind field is uniform. Consider the following example.

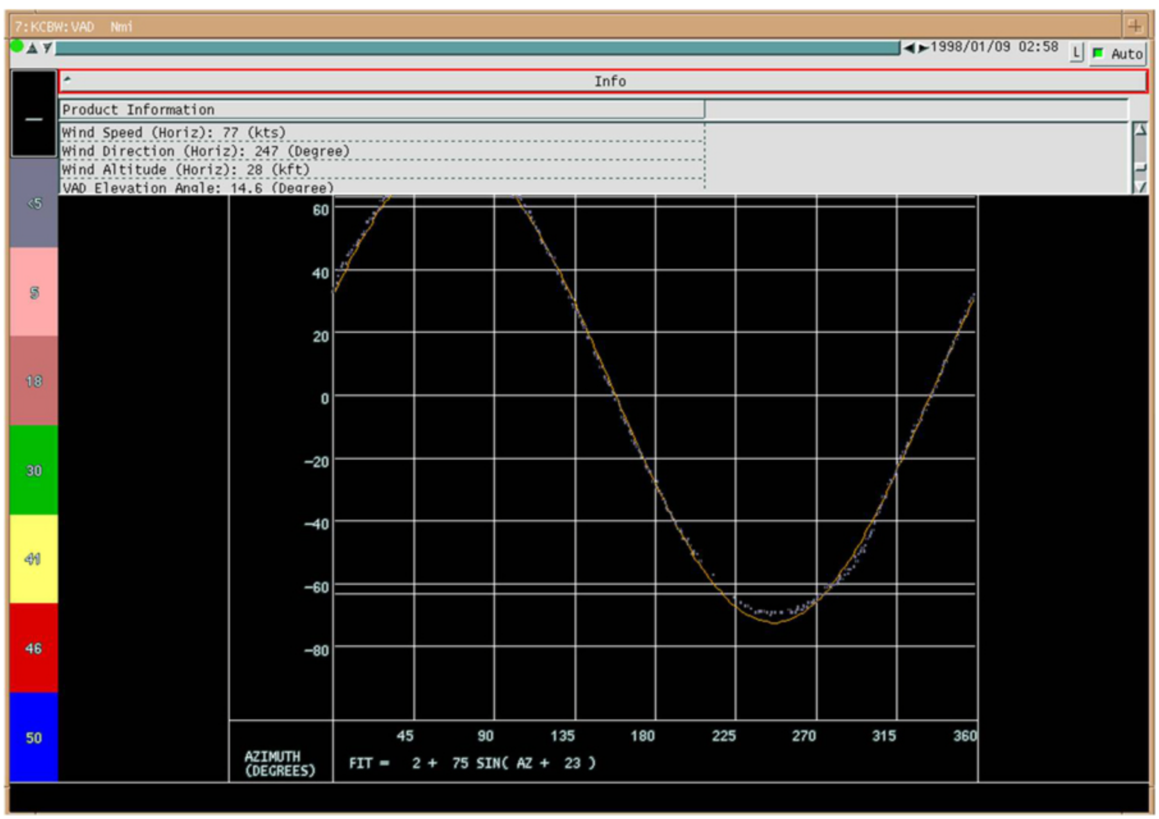

Figure 2–37. VAD analysis range.

Let’s say the VAD analysis range is 20 miles. If the wind flow at 20 miles west of the antenna is 270° at 40 knots, but the wind flow at 20 miles east of the antenna is 270° at only 20 knots, a bias occurs. As you already know, this represents speed convergence. This situation would be discernible on the VAD plot product but not on the VWP itself. If this difference is not too great, an average wind speed is reported. However, if this difference exceeded the predetermined symmetry threshold for the algorithm, winds for this layer would not be reported.

Data thresholds

Like other algorithms, the VAD algorithm contains several adaptable parameters from which the unit control position (UCP) operator can establish threshold values. Some parameters establish thresholds not to be exceeded, while others establish minimum values that must be met or surpassed. If these thresholds are not satisfied during algorithm processing, the result may be that no wind data are reported for that particular altitude. When this happens, an ND or no data is displayed for that altitude on the VWP.

Recall that in order for weather radar to receive information about atmospheric phenomena, there must be a sufficient amount of scatterers available in the region being sampled. In very dry air above the boundary layer, there may be an insufficient amount of scatterers available to produce VAD data. This is another instance where ND is displayed. The VWP winds are color coded according to the reliability of the displayed winds.

418. Storm relative mean radial velocity map and region

Velocity signatures are often associated with severe thunderstorms; however, what will happen if these storms are moving rapidly? Won’t this have an impact on our velocity measurements? Yes it will, but help is here! Two important products that can greatly help us with this problem are the storm relative mean radial velocity map (SRM) and storm relative region (SRR) (figs. 2–38 and 2–39).

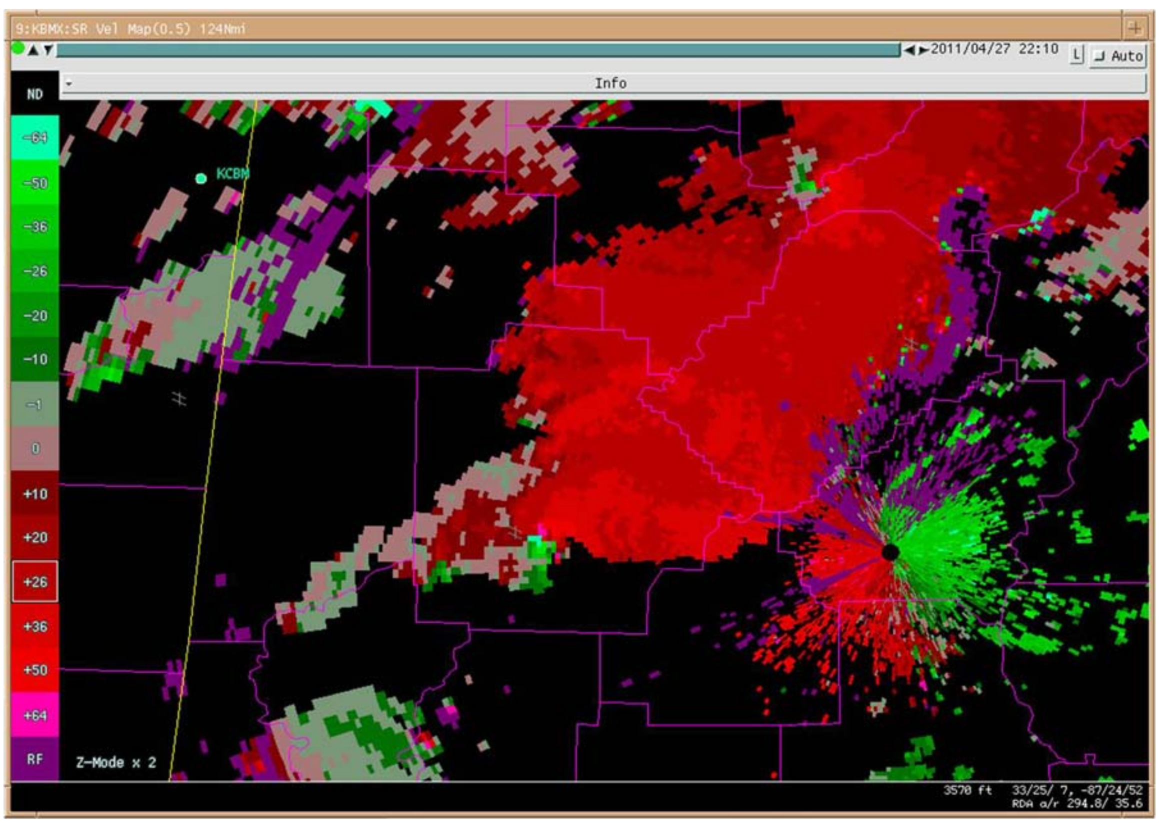

Figure 2–38. Storm relative velocity map product.

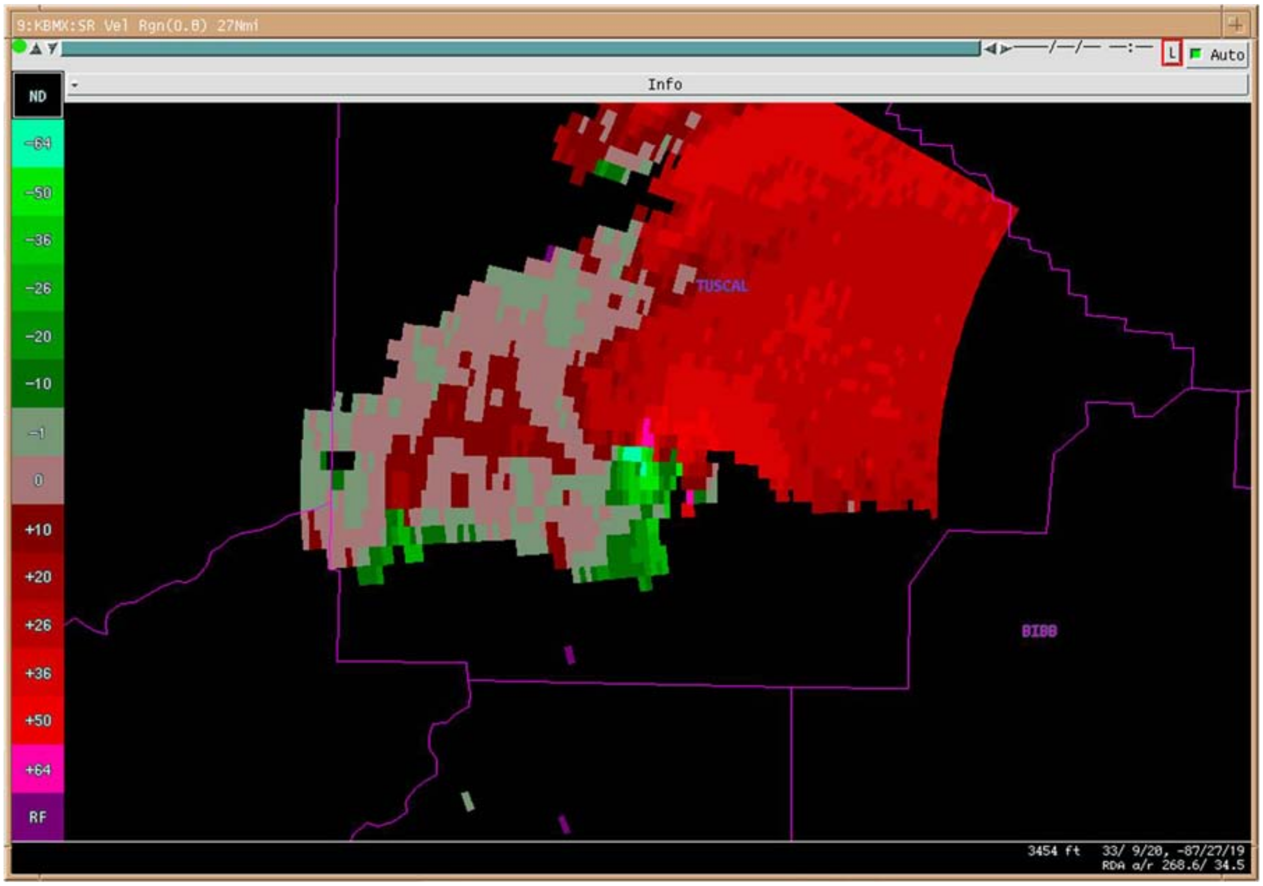

Figure 2–39. Storm relative velocity region product.

The SRM and SRR products are derived from the base velocity product. They greatly aid in determining the convective currents and intensities within storms. Problems arise when storm motion obscures actual values on velocity products. The SRM/SRR products simply make the storms look like they're standing still. This product provides you a detailed look at potential severe weather by balancing out the velocity couplets and making the signatures more readily identifiable.

Interpretation

One of the most difficult tasks a new Doppler radar operator has is to locate an area of rotation when a classic rotational couplet does not exist. Let's look at how to use the SRR and SRM products to aid in the identification of severe storm characteristics.

Storm relative mean radial velocity

Imagine a day with isolated thunderstorms dotting the radar coverage area. A particular storm displays a very strong reflectivity return with what might be a pendant. At this point, it is difficult to discern if a severe storm exists. On interrogation of the base velocity product, you note an isolated area of strong outbound velocities (>50kt) right next to an area of zero or near zero velocities. To the untrained operator, no signature exists. However, what is causing the high area of shear?

This is the perfect time to use the SRR product. By requesting an SRR product over the storm of interest, a wind vector equal to the storm motion is subtracted resulting in a balanced rotational couplet. Now, computing rotational shear is easy and you can make sound warning decisions.

Storm relative region

While you use the same scenario as above, picture a large line of thunderstorms. As it approaches, you notice it is taking on the appearance of a bow. Higher reflectivities appear at the crest and at the southern end of the line. While studying the base velocity product you notice two areas of strong outbound velocities (>50kt) right next to corresponding areas of near zero velocities.

To the operator with little experience, there is no signature. But there is! The SRM looks out 124nm and calculates the average of all storm motions. A wind vector equal to that average is subtracted from the entire display. Now we have a true picture of the storm's rotations, allowing us to make a more informed warning decision.

Storm relative mean radial velocity map and region computation

Data values displayed are the maximums for a given resolution. For example, for the SRR, data resolution is 0.27nm × 1°, but the value displayed is the maximum value contained in a pair of 0.13nm gates.

The SRM/SRR products depend on the storm-tracking algorithm. If it is off, then the SRM/SRR products are off unless the user inputs correct direction and speed values. The inputs to the SRM/SRR are as follows:

1. For SRR, storm motion defaults to the motion determined by the storm track algorithm for the centroid *nearest* the product center if a storm is identified within the 27 × 27nm window. Otherwise, it defaults to the SRM value when no storms are identified within the window.
2. For SRM, storm motion defaults to the *AVERAGE* track found by averaging *ALL* tracks calculated by the storm track algorithm.

419. Cross-section products

Cross-section products allow us to view the atmosphere in the vertical to get a different perspective on storm structure or other properties of the environment. The WSR–88D provides the capability to view base moments: reflectivity (fig. 2–40), and velocity (fig. 2–41), that can be cut at any angle within 124nm of the RDA. This unique capability allows us to examine the atmosphere in a way that far surpasses conventional radar sets.

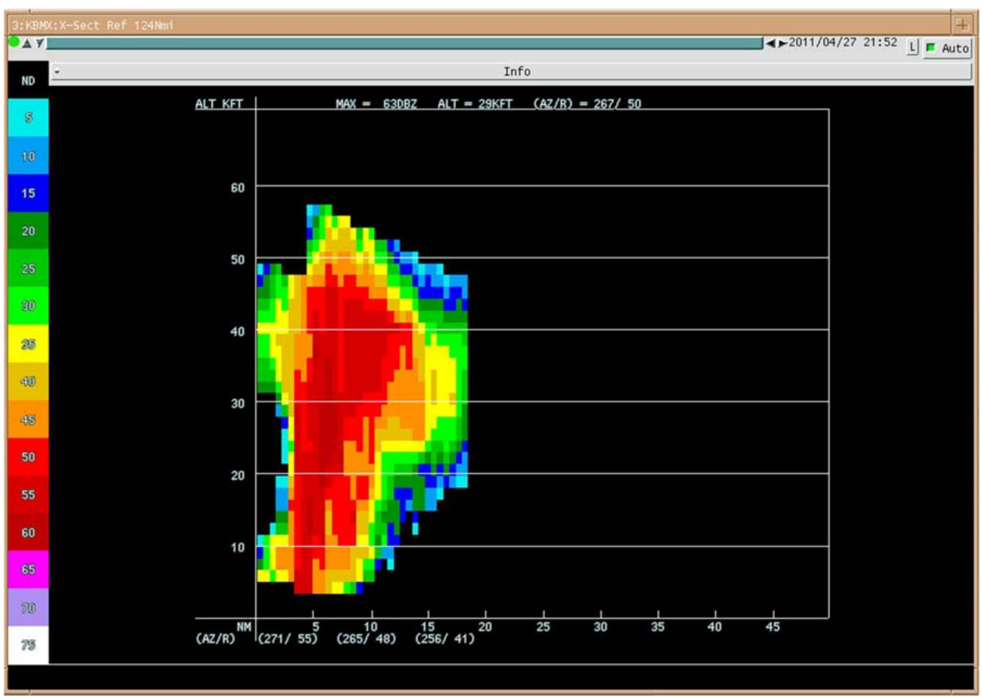

Figure 2–40. Reflectivity cross-section product.

Figure 2–41. Velocity cross-section product.

Application and interpretation

Primarily, the cross-section products are used to examine the vertical structure of potentially severe storms in all three moments.However, they are also useful in determining important meteorological information during non-convective, even clear-air events. Resolution of the cross-section products remain constant.

Reflectivity cross-section

Let's examine each of the three moments and see how they work together. The first moment we'll look at is the reflectivity cross-section product.

Clear-air mode

In clear-air mode, some important features can be analyzed. There are four of these, let's have a look.

Depth of the moist layer

Using a reflectivity cross-section, the operator can determine the depth of the moist layer by analyzing the vertical extent of scatterers.

Frontal slope

A reflectivity cross-section cut perpendicularly across a dry frontal boundary allows the operator to view the frontal slope. Even if no scatterers exist, the change in refractive index reflects enough energy to be seen.

Changes in refractive index

The height of many refractive-index changes (inversions, freezing levels, etc.) may be determined. They appear as areas of enhanced reflectivities on the cross-section.

Cloud bases and tops

For observing purposes, the reflectivity cross-section provides an objective means to measure cloud bases and tops. They appear as layers of well-defined returns.

Precipitation mode

In precipitation mode, all clear-air applications are relevant. The following features can also be identified.

Weak echo regions and bounded weak echo regions

When interrogating the vertical structure of convective storms, the operator can determine the existence and/or vertical extent of WER or BWER. They are caused by intense updrafts creating an area of little or no precipitable echoes within a thunderstorm. WER appears on cross-sections as an area of significantly weaker reflectivities extending vertically through a storm.

Location of the maximum reflectivity core

The height and intensity of the maximum reflectivity core help to evaluate the severe weather potential. A well-defined core of extremely high reflectivities suspended in the mid- and upper-levels of a storm results from an intense updraft. The stronger the updraft, the more likely the storm is to produce severe weather.

Hail spikes

A hail spike due to side lobe contamination is another significant feature to look for. For a side lobe to return enough energy to be detected, it must have encountered an extremely intense scatterer resulting in a narrow spike of elongated reflectivities above the storm's top. This is a good indicator of a hail-producing storm.

Reflectivity gradients, mid-level overhangs, max top position

In the lesson on base reflectivity, we discussed strong horizontal reflectivity gradients and their relationship to mid-level overhang. Reflectivity cross-sections are useful in determining the extent of mid-level overhang. Hand-in-hand with strong reflectivity gradients and mid-level overhang is the location of the maximum echo top in respect to the location of the storm's low-level maximum reflectivity gradient (inflow). All these features are examined in the reflectivity cross-section product and add immeasurably in the evaluation of a storm's potential to produce severe weather. But, the WSR–88D not only provides reflectivity cross-sections, it also builds velocity cross-sections.

Velocity cross-section

To analyze significant storms, we should always include an analysis of the velocity cross-section. There is one important point to keep in mind when requesting velocity cross-sections. The plane along which the cross-section is built *MUST* be either parallel or perpendicular to the radar viewing direction. If the cross-section is cut at any other angle, you are viewing the radial component of radial velocities. This makes the data extremely hard to interpret.

Clear-air mode

In the clear-air mode, you can interpret for turbulence, the height of the boundary layer and frontal slope.

Turbulence

In clear-air mode, velocity cross-sections are used to determine the existence and depth of turbulent layers. Turbulent layers contain strong velocity gradients in the vertical. The shear is computed by calculating the difference in velocities per thousand feet.

Boundary layer

Boundary layers are also easily seen. They appear as the point where significant change in velocity occurs, or often they are determined as the top of the scattering region. The vertical extent of the boundary layer can be of great significance to forecasters in timing the onset of convection.

Frontal slope

Frontal slope may be easier to determine on the velocity cross-section.

Precipitation mode

In precipitation mode, all the uses found in clear-air mode apply. In addition, the following phenomena are often evident.

Vortical flow fields (spiraling wind fields)

The existence, strength, and vertical depth of vortices are analyzed. This allows classification of these vortices as mesocyclones, TVSs, or other less significant features. When correlated with features found on reflectivity cross-sections, a strong case for severe weather exists. It is imperative the operator knows where the cross-section was cut to correctly identify these features.

Divergence

In the lesson on base velocity, we learned to determine hail size based on storm summit divergence. Velocity cross-sections provide a quick place to determine the strength of that divergence and therefore can aid in determining hail size.

The vertical velocity structure of many other features, such as outflow boundaries, can be examined in velocity cross-sections.

Limitations

Now that we have examined each available cross-section application and interpretation, let's look at some important limitations of cross-section products.

Echo characteristics

Values mapped on the cross-section products may be from birds, insects, clouds, precipitation, or any number of scatterers. These targets affect velocity values the most.

Range

Both end points must be within 124nm. Beyond 124nm, the lowest elevation angle is so high that the lower components of the storms aren't sampled anyway.

Beam broadening

Beam broadening affects all cross-section products differently. Reflectivities at long ranges are reduced and gradients may not be visible. Velocity maxima and minima are also reduced.
Small features such as TVSs may not be visible.

Cross-section orientation

Velocity cross-sections *MUST* be either parallel to or perpendicular to a radial to be useful.

Interpolation

Cross-section products do not interpolate from the lowest elevation angle to the surface or above the highest elevation angle. This results in a stair-stepped display.

420. Storm series algorithms

The WSR88D has several useful algorithms. You can use the algorithms to track storms with a storm identification (ID), track and forecast location, identify the possibility of hail, even look at the characteristics of a storm. Let's start with storm ID.

Storm cell identification tracking

The storm cell identification tracking (SCIT) algorithm is a combination of several algorithms. The algorithms work together to provide information such as individual storm cell ID numbers, storm cell location center point of an identified storm component, tracking, forecast , output used by the hail detection algorithm and storm structure product.

Interpretation of cell-based vertically integrated liquid

A calculation of VIL is made for each cell identified by the storm cell centroids algorithm. The cell-based VIL algorithm vertically integrates the maximum reflectivity values of a cell's correlated components. This is a different calculation than produced by the gridded VIL algorithm, a fast-moving or highly tilted storm usually has a higher cell-based VIL than grid-based VIL. Up to 100 cells can be identified by the storm cell centroids algorithm. The cells are ranked by their cell-based VIL.

Limitations

This algorithm performs best with isolated, well-defined storms. Height components may be incorrect in large areas of uniform reflectivity values. Range is another factor to consider when speaking of limitations. Due to VCP limitations, the cone of silence affects cell attributes close to the radar. At greater distances from the radar, bases may be overestimated due to the beam height above ground.

Storm track information

The storm track information (STI) product algorithm provides data on past, present, and future positions of thunderstorms. Storm cell tracking tracks up to 100 storms by matching cells found in the current volume scan. It uses the cell based VIL to match cells between each volume scan. If the storm cell tracking algorithm is unable to correlate a centroid with a centroid from the previous volume scan, then it labels the storm as "NEW" and does not forecast a track.

Applications

The SCIT algorithm shows a high level of skill in identifying distinct individual cells occurring in lines or clusters. This ability to identify individual cells leads to better tracking and forecast results. The accuracy of a previous volume scans forecast determines the length of the next forecast. Better storm identification leads to better cell attribute calculations and an improved hail index product.

Limitations

Recall from previous discussions that storm cells are defined by areas of highest reflectivity. Storm cell segments are best defined as contiguous sample volumes along a radial that are greater than or equal to specific reflectivity thresholds. If stronger reflectivity values exist in a storm above the lowest component, the algorithm may misconstrue that component as the lowest component. This would cause a misinterpretation of the storm's overall mass and would affect other algorithm calculations. Also, when in VCP 21, large errors may occur in the cell attributes of storms. Storm calculation can be adversely affected by what the radar is **not** sampling in the data gaps associated with this VCP.

Linear motion

Linear motion is an overlay used to manually identify storms that have escaped detection by the storm cell-tracking algorithm and for non-convective echoes. Linear motion was created to manually compute 60 minutes of forecasted motion on base and composite reflectivity products.

Procedure

To use linear motion, first toggle on the echo of interest, then, using the product back (or product forward) function box, select the same echo on an earlier (or later) product. This action results in the automatic display of the linear motion in the lower right hand portion of the screen.

Hail detection algorithm

The hail detection algorithm (HDA) is used to identify which storms have the potential to produce hail. It provides estimates on probability of hail, probability of severe hail, and maximum expected hail size. The algorithm can detect hail independent of the storm type, tilt, or overhang.

Applications

The HDA has shown a very high probability of detection of cells that contain severe hail, especially greater than 1 inch in diameter. The probability of severe hail (POSH) algorithm will look for hail greater than three quarters of an inch. While false alarms may be a limitation, the display parameters are adaptable at the OPUP, and local adjustments to thresholds may reduce false alarms.

Limitations

The HDA needs accurate and timely measurements of the MSL altitudes for the 0° C and –20° C levels. *Failure to update this information degrades the algorithm's performance***.** In limited operational use, the POSH and MEHS have tended to overestimate the chances and size of hail in weak wind and tropical environments. The accuracy of the hail estimates partially depends upon the accuracy of the cell component information provided to the algorithm.

Storm structure product

Imagine someone giving you a piece of paper with important information about a specific storm's characteristics. The storm structure product does exactly that! This product provides information on cell based vertically integrated liquid, height of maximum reflectivity, and maximum reflectivity in the cell. This product is displayed in an alphanumeric format at the applications terminal, and supplies pertinent information on a storm's structure using output from the SCIT and hail detection algorithms. Storm structure also provides input for cell trends. For this reason, the storm structure product should be placed on your routine product set list.

Cell trends

As stated earlier, output of the storm structure product can be viewed as a graphic display called *cell trends*. Cell trends is a graphic display that gives up to a 10-volume scan history of cell parameters for algorithm-identified storm cells. Cell trends is ***not*** an actual product. It has no product ID# or mnemonic. Cell trends cannot be archived; however, it can be generated from an archived storm structure product. Cell trends can only be generated from the graphics tablet.

Uses of cell trends

Cell trends provides continuity on individual storm cells over a period of time. By tracking the increase or decrease of storm tops, maximum reflectivity values, and cell-based VIL, you'll have a better idea of what to expect from storms in the area. The cell trends display provides an effective way of determining the life cycle of convective development. You can also determine the status of supercells and the potential for microbursts. After a weather event occurs, the cell trends display may be used for post-storm analysis.

Limitations

The volume coverage pattern employed has a direct impact on the cell trends display. VCP 21 has fewer slices, resulting in more variability of displayed data. Range to the cell is another concern when using the cell trends display. At far ranges, data may be unreliable due to the cell being sampled by only the lowest elevation slices and storm cell bases will be overestimated. Inversely, cells in close proximity to the RDA, may be affected by the cone of silence, resulting in the mid- and upper-levels of the storm not being sampled.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

411. Composite reflectivity

1. What is the best use for the CR product?

2. How can you identify the melting level on the CR product?

3. List three limitations of the CR product.

412. Vertically integrated liquid water

1. What is the primary function of the VIL product?

2. What three factors cause considerable variations to significant VIL values?

3. Why would the VIL product be potentially unreliable with strongly tilted storms?

4. Under what conditions does the VIL product work the best?

413. Echo tops

1. What might a rapidly collapsing echo top indicate?

2. Why is the ET product useful for identifying convective development in a stratiform environment?

3. Why can't the forecaster use the ET product as an indicator of the actual cloud top?

4. Data contamination from side lobes can cause what kind of impact on the ET product?

414. Precipitation products

1. List uses for STP product.

2. When does the STP reset?

3. List the limitations of the STP product.

4. What is the difference between the STP and USP products?

415. Mesocyclone

1. What should the operator do when the mesocyclone product indicates an area of rotation?

2. What are the three steps to the manual verification process with a mesocyclone on velocity products?

416. Tornadic vortex signature product

1. What is the primary use of the TVS product?

2. Should the TVS be used as a standalone product?

3. What are the three steps to the manual verification process with a TVS on velocity products?

417. Velocity azimuth display winds

1. Provide examples of meteorological conditions that can be identified on the VWP.

2. What does the VWP display when the morning inversion begins to break?

3. For the SRM, how is storm motion determined?

418. Storm relative mean radial velocity map (SRM) and region (SRR)

1. What is the primary use of the SRM/SRR products?

2. On which algorithm is the accuracy of the SRM/SRR dependent upon?

3. For the SRM, how is storm motion determined?

419. Cross-section products

1. What is the primary use of the cross-section products?

2. How can the operator view frontal slope using a reflectivity cross section?

3. What meteorological feature causes a WER or BWER to appear on a reflectivity cross section?

4. What do the height and intensity of the maximum reflectivity core on a reflectivity cross section help the operator to evaluate?

5. What important point must the operator keep in mind when requesting velocity cross sections?

6. What are the limitations of the cross section products?

420. Storm series algorithms

1. What is the series of algorithms that provide information such as individual storm cell ID numbers, storm cell tracking and forecasting known as?

2. How does the cell-based VIL value of a fast moving or strongly tilted storm compare to that of the same storm on the grid-based VIL product?

3. Why might the storm series algorithms be unrepresentative when the radar is in volume coverage pattern 21?

4. What is the purpose of the linear motion feature of the OPUP?

5. What is the purpose of the HDA?

6. What is the output of the storm structure product?

7. What are the limitations of the cell trends display?

2–3. Situational interpretation

This section is designed to assist the WSR–88D operator when using the large number of Doppler products for specific weather scenarios. Where to start, where to end, what to look for, and how to interpret, are very important considerations for different types of weather phenomena. The WSR–88D product/phenomena matrix saves you a considerable amount of time by identifying which products are most useful in certain situations. It provides a systematic approach to using the various products to identify certain meteorological phenomena. It will aid you in determining which products are best in identifying weather features. Furthermore, this unit provides explanations of why certain products are more useful than others and why they should be viewed in a certain order for a particular situation.

As you examine the various scenarios within this unit, you'll find that the product matrix will become an invaluable asset in the interrogation process. The weather scenario types include:

- Widespread precipitation.
- Winter.
- Clear air.
- Tropical storm.
- Severe weather.

There are many things to consider as you examine each scenario. Use those suggested products listed on the product matrix once you have determined the phenomena on display within each scenario.

421. WSR–88D product/phenomena matrix

The WSR–88D product/phenomena matrix (fig. 2–42) is a table designed to assist you, the radar operator, in the systematic interrogation of meteorological phenomena. It was developed, and verified, by Air Weather Service forecasters at the WSR–88D Operational Support Facility at Norman, Oklahoma during the Operational Test and Evaluation of the radar. As such, it may need geographical and climatological refinement before it can be 100 percent useful at your location. However, it is still a very useful tool to get you started.

	Vertically Integrated Liquid	Storm Track	Storm Structure/Cell Trends	Hail Index	Mesocyclone Detection	Tornado Vortex Signature	Velocity Azimuth Display Wind Profile	Base Reflectivity	Composite Reflectivity	Echo Tops	Base Velocity	Strom Relative Map/Region	Base Spectrum Width	Cross Sections
Ground Clutter/Anomalous Propogation	4*	4						1		5	2		3	
Fronts/Inversions/Clear Air							4	1			2		3	
Downburts/Microburst	3*	3	6	3	3			2		4	5	1		
Wind Shear							2				1		3	4
Turbulence							2				1		3	4
Icing								1			3		2	4
Stratiform Precipitation	3							1	2	4	5		6	7
Melting Level								1			3		2	
Rain/Snow Line								1			3		2	
Snow Showers (Heavy)	5	2			2			1	2*	6	3		4	
Hail	3*	3	5	3	3	3		1				2		4
Severe Thunderstorms	3*	3	8	3	3	3	6	1		5		2	7	4
Mesocyclone	4*	4		4	4	4		2				1		3
Tornadoes	4*	4		4	4	4		2				1		3
Flash Floods	3*	3						1	2	4		6		5
Tropical Storms	5*	5	9	5	5	5	3	1	4	6	2		7	8

Figure 2–42. Product/phenomena matrix.

To get a feel for how the matrix works, let's proceed through a scenario using the matrix and accompanying product reasoning.

Scenario

It is two hours after a strong cold front has passed through your station. Cloudiness is decreasing and the barometric pressure is rising rapidly. A cold continental polar (cP) air mass is rapidly moving into your flying area. The centralized forecast guidance bulletins are advising that strong gusty surface winds will start to affect your area four to six hours after frontal passage. Obviously you want to provide timely warnings of these strong winds if they should materialize. You want to use the WSR–88D to met watch this situation but are uncertain as to which products are best to use. The product/phenomena matrix is your salvation.

Procedures

The table illustrates the proper procedures for using the matrix. Refer to the matrix as we proceed through the step-by-step procedures (fig. 2–42).

Step	Action
1	Decide what phenomena you want to look for. In this case, “wind shear” and “turbulence” are logically associated with strong surface winds.
2	Use the row headings on the left side of the matrix and find the appropriate phenomena mentioned in step 1 above. In this case, the first of the two phenomena we come to is “wind shear.”
3	Proceed to the right on the line that identifies “wind shear” until you locate numeral “1.” Go up the column to find the name of the WSR–88D product to use. This is the first and best product to view for identifying wind shear.
4	Repeat step 3 to find the second (#2), third (#3), etc. product that will help you identify if wind shear is occurring.
5	Use the “product reasoning” to help understand why the suggested products are the best possible choices. Once you have looked at the recommended products for one phenomenon, repeat steps 1–5 for the other phenomena.

In our example, Base Velocity, Spectrum Width, VAD, and Cross Section Products would be used to help us identify the occurrence of strong low-level winds and the “product reasoning” discussion tells us why.

422. WSR–88D product usage reasoning

The products used are based on experiences with the WSR–88D. Changes to algorithms or data processing may require a change in types of products used. In most cases, the order of products used is based on the order the products are generated by the radar. However, in the case of severe thunderstorms/hail, “VIL” is the number one product because of its proven capability to isolate the severe versus non-severe cells.

Ground clutter/anomalous propagation

Echoes will first be identified on the base reflectivity product. VIL should be used to distinguish ground clutter/AP from possible precipitation echoes. The VILs should be very low or nonexistent. Severe weather probability (SWP) used in conjunction (overlay) with VIL should also show low or nonexistent values. Storm track (overlay) should also show little or no movement. Likewise, echo tops will show little, if any, data. Mean radial velocity will be noisy, erratic, and will not reflect the environmental flow.

Downburst/microburst

Mean radial velocity is the best product for the identification of an occurring downburst/microburst. Base velocity and reflectivity products can be used to forecast the likelihood of this phenomena by tracking the life cycle of a thunderstorm. With the occlusion of the meso-low and the weakening or disappearance of the updraft, the thunderstorm will collapse, therefore increasing the possibility of a downburst/microburst. The severe weather analysis displays can help determine the current stage of the thunderstorm’s life cycle. Although VIL and SWP are used primarily for hail identification and forecasting, they also show promise for downburst or microburst forecasting. A large area of VIL values will sustain for extended periods of time and then rapidly collapse indicating the transfer of energy downward. Storm track, hail index, and mesocyclone can also help pinpoint the most likely location for these phenomena. Echo Tops collapse as the thunderstorm energy is transferred downward toward the surface. The layered reflectivity maximum and cell trends can aid in determining the collapse of thunderstorms by looking for a decrease in the mid and upper level reflectivity values.

Wind shear

Mean radial velocity is the best product for identifying areas or layers of wind shear. These areas/layers show up as abrupt changes in the velocity pattern. Associated with these abrupt changes are the areas of high spectrum width values. Also, higher spectrum width values may be indicative of sharply changing wind speeds. The VAD product can also be valuable for identifying layers of wind shear. However, low-level wind shear may not show up in the VAD product. Many cases have been observed in which the shear is only a few hundred feet in depth and can only be found in the base velocity.

Turbulence

Turbulence, although not directly measured by the WSR–88D, can be inferred within areas of abrupt velocity changes. Also, higher spectrum width values may be indicative of turbulent airflow and eddies. Velocity cross-section products can be useful in evaluating the likelihood of turbulence. The VAD products may help identify layers of potential turbulence, but the vertical resolution of these velocity estimates may be too coarse for specific turbulence measurements.

Icing/melting layer

Although there are no products designed to assist in forecasting icing, base reflectivity and spectrum width can be used to monitor the melting level. With the increased sensitivity, it is easy to determine the depth of the moisture, not just precipitation. The melting level will show up as a ring, or a partial ring, of slightly higher reflectivities and spectrum width values. Base velocity and spectrum width can be used to monitor the possible lowering/raising of the melting level due to an approaching boundary.

Stratiform precipitation

The high sensitivity of base reflectivity allows us to determine the depth of the clouds associated with stratiform precipitation. Composite reflectivity can help isolate areas of embedded shower activity or heavier rainfall. VIL should be used to isolate convective activity. Mean radial velocity can be used to identify the moisture conveyor belt and upper-level influences that will affect the aerial coverage and intensity of precipitation. Velocity has also been used to identify stationary bubble highs that cause heavy precipitation to persist over small areas. Echo tops will identify the top of the 18 dBZ return, highlighting areas of convection. The VAD product can also help identify and track changes in the atmospheric flow aloft. The layered reflectivity maximum (LRM) product can also be used in stratiform regimes by looking for uniform reflectivity values, and by identifying embedded convection as isolated areas of higher values.

Rain/snow line

The rain/snow line can be located by identifying the melting level, using base products, and it’s height above the surface. The WSR–88D user should monitor the depth of the cold air to determine the delineation between rain and snow. The VAD product can also be used to identify the warm conveyor belt above the cold air (veering winds aloft). This is accomplished by identifying a sharp wind direction shift aloft.

Snow showers (heavy)

As with most precipitation phenomena, it is best to start with base reflectivity. Base velocity can be used to locate the dynamics which are or will cause heavier convective snow showers such as low-level convergence, rotation, or upper-level divergence. Spectrum width should be used to determine the “confidence” of the velocity estimate and possible turbulent flow. VIL is the best product to use to isolate the heavy storms. SWP and mesocyclone overlays will also aid in isolating the very heavy cells. However, in this case, the 3D correlated shear may be the only indication of an extreme snow shower. Mesocyclones, although possible, most likely will be a very rare occurrence. Storm structure will aid in the analysis and can also be used to build a climatological data base. The other products can be used for additional information as needed.

Hail

VIL has proven to be the best tool available for quick identification of potential hail producing storms. The NWS WSFO at Norman, OK uses VIL two ways for hail determination with extremely good success. First is a climo database of seasonal VIL values for hail greater than 3/4 inch. Second, they set the daily threshold for VIL values versus hail size based on first reports. Another method for determining hail size is based on the upper-level storm divergence. Other products such as weak echo regions (WER) and cross-sections can be used to verify information found on other products.

Severe thunderstorm

VIL is listed as number one here because of its proven capability. Normally, if the VIL values are high and sustained over a period of time, most other severe parameters are present. Velocity is the next key to severe storm analysis. Reflectivity is useful for the determination of the core location along with the reflectivity gradient and dynamics or helps verify if the required phenomena exists. Additional velocity and reflectivity data may be obtained from the other products listed in the matrix. FMH–11, part D, section 4.7.3, contains more detailed information. Much of this information was obtained from studies by the National Severe Storms Laboratory (NSSL), the NWS Techniques Development Lab (NWSTL), and experiences during testing.

Mesocyclone

Base velocity and Storm Relative Mean Radial Velocity (map or region) are the best products to identify and/or confirm the existence of a mesocyclone. These products should be used in conjunction with the mesocyclone, tornadic detection algorithm (TVS), outputs and storm track to isolate and forecast the movement of mesocyclone storms. The severe weather analysis package is also very helpful in determining the relative strength of an identified mesocyclone. VIL and SWP are good tools for isolating storms that have mesocyclonic potential. High spectrum Width values are also associated with mesocyclonic rotation. The weak echo region product may be helpful in detailing the reflectivity structure associated with the mesocyclone.

Tornadoes

Base velocity and storm relative mean radial velocity (map or region) are the best products to identify and/or confirm the existence of a TVS. They should be used in conjunction with the mesocyclone and tornadic detection algorithm (TVS) outputs and Storm Track to isolate and forecast the movement of possible tornadic storms. The severe weather analysis package is also very helpful in isolating and determining the strength of possible tornadic rotation within a storm. Base Reflectivity can be used to identify the classic “hook” signature or inflow boundary often associated with fully developed tornadoes. VIL and SWP are good tools for isolating storms that have tornadic potential (see severe thunderstorms). A high spectrum width couplet is usually associated with the TVS couplet. The weak echo region product may be helpful in detailing the reflectivity structure associated with a tornadic storm.

Flash floods

VIL used in conjunction with storm track will identify areas of potential heavy precipitation and the relative speed of movement of these areas. Base reflectivity may also be helpful in isolating high precipitation areas. Base velocity can be used to locate the moisture conveyor belt, identify an upper-level impulse that enhances the rate and/or aerial coverage of precipitation. Base velocity can also be used to identify bubble highs that tend to cause heavy precipitation to persist over small areas. Echo tops can be used to highlight shower activity embedded within large areas of precipitation.

Tropical storms

The tropical storms algorithm’s performance on a model has not yet been seen. Composite reflectivity can be used to view the aerial extent of the storm within the radar range. Base reflectivity should be used to identify the bands and possible heavier precipitation areas with VIL used to isolate the heaviest rainfall areas. Base velocity used with reflectivity will help pinpoint the eye location when within the radar range. Base velocity will also be best for determining velocity characteristics within the tropical storms for mesocyclonic circulation and/or the existence of a TVS. Echo tops will show the height of the 18 dBZ return but will not provide much other information. Cross-sections and other window products can provide additional information on structure.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

421. WSR–88D product/phenomena matrix

1. What is the matrix designed to assist the radar operator with?

2. What is required to make the matrix most useful at your particular location?

422. WSR–88D product usage reasoning

1. On which product will ground clutter/AP echoes first be identified on?

2. What display can aid in determining the collapse of thunderstorms by looking for a decrease in the mid and upper level reflectivity values?

3. What products can be used to monitor the melting level?

4. What product is the best for identifying areas or layers of wind shear?

5. How can the rain/snow line be identified?

6. What is the best product for quick identification of potential hail producing storms?

7. What are the best products to identify and/or confirm the existence of a mesocyclone?

8. What product can be used to view the aerial extent of a tropical storm within the radar range?

Answers to Self-Test Questions

408

1. +18dBZ.
2. Precipitation wrapped around the vortex.
3. In the trailing half of the parent echo with respect to its motion and most often in the right rear quadrant.
4. At the lowest elevation possible.
5. At and slightly south of the crest.
6. Attenuation.
7. As a ring, or partial ring, of enhanced reflectivity around the RDA site.
8. Too few clouds present at the melting level, disruption of the melting level by some form of turbulence or convection, and heavy precipitation.
9. Impending tornado development.
10. Peak mid-level reflectivities > 46 dBZ, mid-level overhang extends at least 3.2nm beyond low-level tight gradient, and max echo top located on the storm flank and above the low-level tight gradient.

409

1. Cold-air advection.
2. Frontal passage or zone.
3. Rotation.
4. Divergence.
5. By correlating the strength of the updraft to the amount of storm-top divergence aloft.
6. Wind direction is perpendicular to the radar beam at that azimuth.
7. By locating the radial and range that corresponds to the wind direction.
8. The zero velocity contour.

410

1. Verifying areas of suspected turbulence, monitoring icing conditions, identifying areas of possible convective development, and checking data reliability.
2. The height of the melting level.
3. Velocity.
4. Convective development.
5. Erratic spectrum width estimates and noisy spectrum width data.

411

1. As a quick check of the overall reflectivity pattern.
2. It appears as distinctive circles of higher reflectivity.
3. Many of the typical horizontal plane signatures that do not exhibit high reflectivities are not visible on the CR product (e.g., hook echo). Other features may also be disguised on the CR product. If you detect a classical feature on CR, investigate it further by using base reflectivity. Altitude information about the 3D structure of reflectivity is lost. Since CR is made up of information that comes from the base reflectivity products, many of the same situations that affect the quality of reflectivity data also cause problems with CR. (Any three limitations will suffice).

412

1. To identify strong storms that may become severe.
2. Location, season, and air mass (weather system).
3. Because it is based on vertically correlated grid boxes; if the storm has enough tilt, the algorithm could add up “empty” boxes above the low-level returns and subsequently underestimate VIL.
4. When storms closely approximate the norms on which the algorithm is based.

413

1. A downburst may be occurring at the surface.
2. As the updrafts develop and push the tops of the clouds higher, the higher cloud tops are displayed as mid-level echo tops.
3. Because the algorithm discards reflectivities below 18.5 dBZ.
4. Overestimation of echo tops in areas of strong reflectivity.

414

1. Monitoring total precipitation accumulation regardless of duration, estimating basin runoff, estimating basin saturation, evaluating flood reports, and post storm analysis.
2. When there are breaks in precipitation of more than one hour.
3. Extended outages compromise data, breaks in precipitation of more than one hour reset the system, non-precipitation reflectivity may contaminate data, the algorithm does not account for snow or frozen precipitation, bright bands, etc.
4. The period of time that the products use to accumulate precipitation amounts.

415

1. Begin a more thorough interrogation of the storm.
2. (1) Determine sufficient rotational velocity (30kts within 80nm of the RDA, 22kts beyond 80nm).

   (2) Determine vertical continuity (never less than 10kft).

   (3) Determine time continuity.

416

1. To identify areas of significant cyclonic shear.
2. No, it should be used to alert the user that it is time to intensify metwatch.
3. (1) Identify significant localized shear (90kts within 30nm of the RDA, 70kts beyond 30nm).

   (2) Determine vertical continuity (at least two elevation angles).
   (3) Determine time continuity.

417

1. The VWP can aid in identifying meteorological conditions like inversions, wind-shifts, and the development of jet streams.
2. Increasing wind speeds below 2kft as upper winds subside or transfer toward the surface.
3. The VAD algorithm always assumes that environmental wind flow is uniform.

418

1. To determine the convective currents and intensities within storms.
2. The storm tracking algorithm.
3. For SRM, storm motion defaults to the average track found by all storms identified on the storm track algorithm.

419

1. To examine the vertical structure of potentially severe storms.
2. By cutting the cross section perpendicular to the frontal boundary.
3. Intense updrafts.
4. Severe weather potential.
5. The plane along which the cross section is built must be parallel or perpendicular to the radar viewing direction.
6. Echo characteristics may be from an abundance of scaterrers, end points must be within 124nm; beam broadening with range decreases the accuracy of cross sections; velocity cross sections are only useful when they are cut parallel or perpendicular to the radar viewing angle; cross section products do not interpolate from the lowest elevation angle to the surface or above the highest elevation angle.

420

1. The SCIT.
2. The cell-based VIL of a fast moving or strongly tilted storm is usually higher than grid-based VIL.

3. Because of the data gaps of the VCP.
4. To manually identify the forecast track of storms that have escaped detection by the storm cell tracking algorithm and for non-convective echoes.
5. To identify which cells have potential to produce hail.
6. Cell trends.
7. The volume coverage pattern employed has a direct impact on the cell trends display. VCP 21 has fewer slices, resulting in more variability of displayed data. Range to the cell is another concern when using the cell trends display. At far ranges, data may be unreliable due to the cell being sampled by only the lowest elevation slices and storm cell bases will be overestimated. Inversely, cells in close proximity to the RDA, may be affected by the cone of silence, resulting in the mid- and upper-levels of the storm not being sampled.

421

1. The systematic interrogation of meteorological phenomena.
2. Geographic and climatologic refinement.

422

1. Base reflectivity.
2. The cell trends display.
3. Base reflectivity and spectrum width.
4. Base velocity.
5. By identifying the melting level on base products.
6. VIL.
7. Base velocity and SRM/SRR.
8. Composite Reflectivity.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

42. (408) For the Weather Service Radar (WSR)–88D to generate a base reflectivity product, the antenna *must* complete
    a. one elevation slice.
    b. one complete 360° circle.
    c. an entire volume coverage pattern.
    d. at least two complete volume coverage patterns.

43. (408) Which decibel (dBZ) value is considered the *approximate* precipitable/non-precipitable threshold?
    a. –30 dBZ.
    b. –18 dBZ.
    c. +18 dBZ.
    d. +30 dBZ.

44. (408) What does the line echo wave pattern (LEWP) signature mean to a forecaster?
    a. A favorable environment exists for severe weather development.
    b. High pressure is forming and the threat of severe weather has ended.
    c. Continued thunderstorm development is certain but severe weather is unlikely.
    d. The current state of the atmosphere is much too stable for severe weather development.

45. (408) Embedded thunderstorms are detected by the Weather Service Radar (WSR)–88D quite well because
    a. it uses airborne radar technology to seek out these storms.
    b. the storms move much faster than the surrounding precipitation.
    c. its 10cm wavelength can see through the stratiform precipitation.
    d. the storms move much slower than the surrounding precipitation.

46. (408) Outflow boundaries may be seen on the Weather Service Radar (WSR)–88D even when no clouds are present because
    a. the WSR–88D can detect returns of greater than +18dBZ.
    b. precipitable water is present although it is not visible to the human eye.
    c. low-level wind shear is usually present with the boundary, making it more visible.
    d. a gradient in the refractive index due to density differences that exist with the boundary.

47. (409) Which product is used in the detection and location of rotating thunderstorms and in determining wind field characteristics?
    a. Base reflectivity.
    b. Base radial velocity.
    c. Severe weather analysis.
    d. Severe weather probability.

48. (409) When the Doppler zero line has a noticeable S-shaped pattern, winds are considered to be
    a. from 270°.
    b. veering with height.
    c. backing with height.
    d. increasing with height.

49. (409) Which concept should be considered when trying to determine hail size?
    a. Strength of the updraft.
    b. Rotation at the base of the storm.
    c. Strength of the convergence aloft.
    d. Rotation in the mid-levels of the storm.

50. (410) The spectrum width product is *most* effective when
    a. used alone.
    b. used with other products.
    c. displayed in 16 data levels.
    d. overlaid on composite reflectivity.

51. (411) Which statement is *not* a use of the composite reflectivity product?
    a. It is the first step in identifying significant weather features.
    b. It can be used as a quick check on the overall reflectivity pattern.
    c. It can be used to show the 3-D structure of the reflectivity pattern.
    d. It provides an instant snapshot of the most important reflectivity features.

52. (411) The melting level is displayed on the composite reflectivity product as a
    a. straight line of higher reflectivities.
    b. circular pattern of higher reflectivities.
    c. series of ellipses centered over each snow shower.
    d. series of spots that show ice forming on the radome.

53. (412) Vertically integrated liquid (VIL) algorithms display VIL values for storms based on
    a. water droplet size converted to liquid water content.
    b. water droplet size converted to water vapor values.
    c. reflectivity data converted to liquid water content.
    d. reflectivity data converted to water vapor values.

54. (412) A strongly tilted storm may cause what kind of vertically integrated liquid values to be displayed?
    a. Taller.
    b. Lower.
    c. Higher.
    d. Shorter.

55. (413) The echo tops product is based on data from what other product?
    a. Base velocity.
    b. Spectrum width.
    c. Base reflectivity.
    d. Vertically integrated liquid.

56. (413) The echo tops product is very useful in
    a. identifying bounded weak echo regions.
    b. assessing the possibility of hail damage.
    c. showing the presence of vertical tilt within a storm.
    d. depicting the true cloud tops within 124 nautical miles.

57. (414) The storm total precipitation product provides continuously updated information on precipitation accumulations within how many nautical miles of the radar?
    a. 120.
    b. 124.
    c. 200.
    d. 240.

58. (414) A limitation of the storm total precipitation product is that it
    a. has trouble with large-scale features.
    b. has trouble with small-scale features.
    c. gives us a limited post storm analysis.
    d. displays total precipitation accumulations.

59. (414) What is an advantage that the user selectable precipitation product provides over the storm total and three-hour precipitation products?
    a. Data is presented in 16 levels.
    b. A product is available every volume scan.
    c. Gaps of precipitation will not affect amounts.
    d. Accumulation amounts are available for a 124 nautical miles area.

60. (414) How many hours is the database for the user selectable precipitation product limited to?
    a. 24.
    b. 30.
    c. 36.
    d. 48.

61. (414) The *maximum* number of hours that the user selectable precipitation product can be generated for is
    a. 12.
    b. 24.
    c. 30.
    d. 36.

62. (415) What number of nautical miles is the *optimum effective* range of the mesocyclone detection algorithm?
    a. 32.
    b. 65.
    c. 124.
    d. 240.

63. (416) Why is tornadic vortex signature detection beyond 55 nautical miles difficult?
    a. Beam broadening.
    b. Beam wander.
    c. Scintillation.
    d. Ducting.

64. (417) The inputs to the velocity azimuth display algorithm are
    a. base reflectivity and spectrum width.
    b. mean radial velocity and spectrum width.
    c. mean radial velocity and base reflectivity.
    d. mean radial velocity and velocity cross section.

65. (417) The velocity azimuth display winds profile provides
    a. an alphanumeric list of wind velocities by height.
    b. a graphic display of wind velocity at one azimuth.
    c. a graphic display of wind velocities at various ranges.
    d. a time-height profile of wind velocity at a pre-determined range.

66. (417) Data thresholds for the vertical winds profile can be changed
    a. by unit control panel.
    b. by radar data acquisition.
    c. on the principal user processor.
    d. on the radar product generator.

67. (417) The velocity azimuth display wind profile displays
    a. the radial component of the wind.
    b. the true wind speed and direction.
    c. only the component of the wind perpendicular to the beam.
    d. radial winds, provided the root mean square is less than four meters per second.

68. (417) The *maximum* number of vertical wind profiles that can be displayed on a single velocity azimuth display winds profile is
    a. 9.
    b. 10.
    c. 11.
    d. 12.

69. (417) The velocity azimuth display wind profile (VWP) can detect features such as
    a. wind shifts and jet streams.
    b. inversions and microbursts.
    c. convergence and divergence.
    d. thermal winds and forecasted time of a wind shift.

70. (417) If the velocity azimuth display (VAD) algorithm finds no difference between the zero velocity line and the zeroth harmonic, then the offset is zero, and the wind field is
    a. uniform.
    b. divergent.
    c. convergent.
    d. not determinable.

71. (417) The color-coded root mean square of the displayed velocity azimuth display winds is related to what characteristic of the winds?
    a. Strength.
    b. Altitude.
    c. Direction.
    d. Reliability.

72. (418) The storm relative mean radial velocity map and storm relative mean radial velocity region product depends on what algorithm?
    a. Reflectivity.
    b. Storm series.
    c. Mesocyclone.
    d. Storm-tracking.

73. (419) Resolution of cross-section products
    a. vary depending on the product requested.
    b. vary with the height of the phenomena.
    c. vary with range from the radar data acquisition site.
    d. remain constant.

74. (419) In clear-air mode, the reflectivity cross-section is used to determine
    a. hail spikes.
    b. the freezing level.
    c. bounded weak echo regions.
    d. the extent of mid-level overhang.

75. (419) The range of a velocity cross-section is limited to
    a. 32 nautical miles (nm).
    b. 64 nm.
    c. 124 nm.
    d. 240 nm.

76. (419) Which data collection limitation of the reflectivity cross-section product causes reduced values at long ranges?
    a. Range folding.
    b. Velocity aliasing.
    c. Beam broadening.
    d. Decreased pulse length.

77. (419) A velocity cross-section limitation causing small features at long distances to go undetected is
    a. beam broadening.
    b. product resolution.
    c. aliased velocity data.
    d. lack of height continuity.

78. (419) What is an important thing to keep in mind when requesting a velocity cross-section?
    a. Storm motion.
    b. The orientation of the storm.
    c. Where the reflectivity cross-section was cut.
    d. It must be either parallel, or perpendicular to, a radial.

79. (420) The storm cell centroid algorithm performs *best* when
    a. solid lines of thunderstorms are present.
    b. a mesoscale convective complex is present.
    c. embedded multicell thunderstorms are present.
    d. isolated, well-defined thunderstorms are present.

80. (420) The storm track information product algorithm provides data on
    a. past positions of thunderstorms.
    b. forecasted positions of severe thunderstorms.
    c. past and present positions of severe thunderstorms.
    d. past, present, and future positions of thunderstorms.

81. (420) What determines the length of a forecast made by the storm position forecast algorithm?
    a. Storm's cell based vertically integrated liquid.
    b. Accuracy of previous volume scan's forecast.
    c. Storm's current speed of movement.
    d. Size of storm cell centroid.

82. (420) The *most* important product used in defining storm segments is
    a. hail.
    b. storm tracking.
    c. spectrum width.
    d. base reflectivity.

83. (420) Which statement *best* defines a storm cell segment?
    a. That portion of a severe thunderstorm that is directly below the anvil top.
    b. That portion of a storm that exceeds the maximum reflectivity thresholds.
    c. The smallest portion of a vertically stacked thunderstorm that exceeds maximum reflectivity thresholds.
    d. Contiguous sample volumes along a radial that are greater than or equal to specific reflectivity thresholds.

84. (420) The three estimates the hail detection algorithm provides are probability of
    a. hail, possibility of severe hail, and forecast hail size.
    b. severe hail, maximum hail size expected, and possibility of hail.
    c. hail, probability of severe hail, and maximum expected hail size.
    d. large hail (>3/4 inch), probability of severe hail, and forecast hail size.

85. (420) The probability of severe hail algorithm will look for hail greater than
    a. 1/4 inch.
    b. 1/2 inch.
    c. 3/4 inch.
    d. 1 inch.

86. (420) What information needs to be routinely updated to increase the hail detection algorithm's performance?
    a. Height of the wet bulb zero value.
    b. Mean sea level altitudes for 0°C and –20°C.
    c. Mean sea level altitudes for 0°C and –10°C.
    d. Wind speeds for 10,000 feet above ground level.

87. (420) Which product provides information on cell-based vertically integrated liquid, height of *maximum* reflectivity, and *maximum* reflectivity in the cell?
    a. Cell trends.
    b. Storm structure product.
    c. Storm tracking information product.
    d. Storm cell identification and tracking algorithm attribute table.

88. (420) What information does the cell trends product provide the forecaster?
    a. Forecast of life cycle for convective development.
    b. Status of supercells and the potential for microbursts.
    c. Status of microbursts and potential for overshooting tops.
    d. Forecast for maximum reflectivity values and cell-based vertically integrated liquid.

89. (421) What agency developed the Weather Service Radar (WSR) 88–D product/phenomena matrix?
    a. National Oceanic and Atmospheric Administration.
    b. National Weather Service.
    c. Air Weather Service.
    d. United States Navy.

90. (422) What product is *best* used to isolate storms associated with heavy snow showers?
    a. Velocity.
    b. Reflectivity.
    c. Vertically integrated liquid.
    d. Severe weather probability.

Glossary of Terms, Abbreviations, and Acronyms

Terms

adiabatic process—A thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system.

airmass—A widespread body of air forming in an area of uniform terrain and temperature and having uniform properties and horizontal composition.

alerts–Plain**—**Language messages accompanied by an audio alarm that alerts radar operators to significant weather. Specific alert criteria are identified by the operator.

Algorithm—A step-by-step procedure for solving a mathematical problem. Several algorithms may be combined as part of a larger computer program. The Weather Service Radar (WSR)–88D relies on algorithms while producing derived products.

anomalous propagation—The abnormal bending of the radar beam as it passes through the atmosphere.

antenna—A conductor or system of conductors for radiating and/or receiving radio energy. The Weather Service Radar (WSR)–88D antenna is directional and includes both the radiating element (feed horn) and the reflector for focusing the energy.

attenuation—The reduction in power of a signal due to refraction, scattering, or absorption of energy.

azimuth—The horizontal direction expressed in degrees, usually from true north. Any point on or above the horizon can be located by its angles of azimuth and elevation, and the range.

base data—Digital data sent from the radar data acquisition (RDA) computer to the radar product generator (RPG) computer. The data consists of the first three Doppler spectral moments—Z, v, and W. Those digital fields of reflectivity, mean radial velocity, and spectrum width data in spherical coordinates provided at the finest resolution available from the radar.

base reflectivity—A reflectivity product at a specific elevation that has been obtained directly from the base reflectivity data.

black stratus—The net effect of a warm earth in areas covered by air with high moisture content appears darker on infrared (IR) imagery. These boundaries can be monitored and used as an estimate of the extent of nocturnal fog and stratus development and advection.

cutter filtering—Removing non-meteorological echoes that interfere with the observation of desired meteorological signals.

collapsing echo tops—A decreasing of the height of storm tops within a small number of volume scans.

component—(1) The portion of a storm at any one elevation angle. A stack of components forms the radar's depiction of a storm. (2) One part of a system; a vector pointing northwest is made up of a north component and a west component.

composite reflectivity—A Weather Service Radar (WSR)–88D volumetric product that displays the highest reflectivities detected above a given area on the earth's surface.

conditional instability—The state of a layer of unsaturated air when its lapse rate of temperature is less than the dry-adiabatic lapse rate but greater than the moist-adiabatic lapse rate.

convective cells—Cumuliform clouds, usually with vertical updrafts in the center and sinking downdrafts in the outer regions.

convergence-–Atmospheric flow approaching the same point from different directions.

data contamination—Bad or erroneous radar data mixed in with good data. For example, side lobe contamination.

DBZ—A decibel of the equivalent radar reflectivity factor.

Decibe—A logarithmic expression for the ratio of two quantities, such as the ratio of power transmitted to the power received at the antenna.

derecho—A rapidly moving extratropical convective system known to produce widespread significant straight-line wind damage.

derived product—A product created from the computer processing of base data.

divergence—Atmospheric flow leaving the same point in different directions.

Doppler Velocity—Velocity detected by using the Doppler process. Often used in the same sense as radial velocity.

downburst—A strong downdraft associated with thunderstorms that induces an outflow of damaging winds on or near the surface.

downdraft—current of air with marked vertical downward motion.

drizzle—Drops of precipitation less than 0.5mm in diameter. Unlike fog, drizzle droplets fall to the ground.

dry line–A severe weather producing system that is typically located over western Texas, Oklahoma, and southern Kansas.

dry slot—A zone of dry (and relatively cloud-free) air which wraps east- or northeastward into the southern and eastern parts of a synoptic scale or mesoscale low pressure system.

dynamics—Atmospheric motions.

echo—(1) In radar, a general term for the appearance, on a radar indicator, of the radio energy returned from a target. (2) Electromagnetic energy backscattered from a target and received by and displayed on a radar scope or color graphic display.

echo tops product—A product that displays the height of storm tops by using a color code that corresponds to various heights.

elevation angle—The angle between the horizon and a point above the horizon.

elevation slices—Rotations of the antenna at preprogrammed elevation angles.

embedded thunderstorms—Convective storms located in a stratiform cloud layer that show no visual signs of being present.

ensembles—Multiple forecasts created by a single computer model used to eliminate uncertainty in longer-range forecasting.

first moment—Also known as the mean Doppler velocity. The first moment of the power normalized spectra is equal to the mean motion of scatterers. For near-horizontal antenna orientations, this is essentially air motions toward or away from the antenna.

frequency—The number of recurrences of a periodic event per unit time. Radar waves have a frequency specified per second.

grid box (alert)—A computer-referenced box, at surface level, to which radar data is interrogated.

ground clutter—Echoes resulting from physical obstructions such as buildings, trees and mountains.

gust front—An outflow boundary that consists of winds meeting gust criteria. On the surface, its passage resembles that of a cold front.

height of maximum reflectivity—The altitude (mean sea level {MSL}) of the most intense reflectivity inside the storm.

hook echo—A classical radar echo often shaped like a figure six. The hook echo is associated with tornadic activity.

isallobaric wind—The wind velocity whose coriolis force exactly balances a locally accelerating geostrophic wind.

Joint Doppler Operations Project (JDOP)—A project conducted by the United States Air Force, Federal Aviation Administration, and National Weather Service from 1977–1979 that proved the meteorological applicability for operational Doppler radar.

level of free convection (LFC)—The level at which a parcel of air lifted dry-adiabatically until saturated and saturation-adiabatically thereafter would first become warmer than its surroundings in a conditionally unstable atmosphere.

lifted condensation level (LCL)—The level at which a parcel of moist air lifted dry-adiabatically would become saturated.

line echo wave pattern (LEWP)—A line of radar echoes that has been subjected to an acceleration along one portion of the line. This results in a mesoscale wave pattern in the line.

low-level jet—An organized band of strong winds in the lower levels with a southerly component.

low-level wind shear—The low-level local variation in the wind vector or any of its components in a given direction. Usually occurs within 2,000 feet above ground level (AGL).

mammatus—Hanging protuberances, like pouches, on the undersurface of a cloud.

mean radial velocity—The average velocity of air flow parallel to the radar beam within a sample volume.

melting level—The level where frozen precipitation particles melt into water during their descent to the surface. The melting level usually appears on radar displays as a broad area of high reflectivity.

mesocyclone—A three-dimensional (3-D) region in a storm that rotates cyclonically, meets a series of criteria, and is closely correlated with severe weather

mesocyclone algorithm—An algorithm that uses shear pattern recognition to detect mesocyclones. Detection can be displayed by the MESO product.

microburst—A small-scale downburst of about 0.5 nautical miles (nm) to 2.5nm in outflow size with peak winds lasting 2-to-15 minutes.

mid-level overhang—In the middle levels, the edge of a storm component that extends outward beyond the edge of the storm component at the lowest level.

minimum significant reflectivity— A parameter that sets the minimum reflectivity value that will be used as a threshold value.

model bias—A consistent error that a model has in certain areas and conditions.

moment—Any of the three types of base data: reflectivity, mean radial velocity or spectrum width.

no change line—A line connecting points of negligible temperature advection.

outbound velocity—Radial velocity away from the radar. By convention, outbound velocities are assigned a positive sign.

outflow—The low-level divergent air flow pattern, often resulting from a thunderstorm downdraft striking the earth's surface and spreading horizontally outward.

outflow boundaries—The leading edge of horizontal air flow resulting from cooler, denser air sinking and spreading out at the surface. Outflow boundaries often are caused by the downdraft of thunderstorms.

overrunning—A condition existing when an air mass is in motion aloft above another air mass, at the surface, of greater density. This term usually is applied in warm air ascending the surface of a warm or quasi-stationary front.

overshooting tops—Storm tops that exceed the main body of the storm in the vertical.

pattern vectors—A series of azimuthally adjacent sample volumes at the same range from the radar antenna that has a continual increase in Doppler velocities. Pattern vectors are used by the Weather Service Radar (WSR)–88D to identify closed rotation.

precipitation mode—A volume coverage pattern (currently Volume Coverage Pattern {VCP} 11 or VCP 21) that is designed for detecting precipitation.

radar—An acronym for radio detection and ranging. An electronic instrument used to detect atmospheric scatterers such as precipitation.

radar beam—A focused conical-shaped beam of electromagnetic energy emitted from an antenna and used to detect meteorological and other targets.

radar data acquisition (RDA)—The first major component of the Weather Service Radar (WSR)–88D after the antenna. The RDA functions as a transmitter/receiver subsystem, receiving analog data from the receiver and processing it into base data.

radar product generator (RPG) —The Weather Service Radar (WSR)–88D component that uses raw Doppler data to produce meteorological products. The RPG is the "brains" of the WSR–88D.

radial component—The part, or component, of the wind velocity that is parallel to the radar beam.

radial velocity—The component of velocity parallel to the radar beam.

range—The distance from the radar antenna to a target.

refractive index—The ratio of the wavelength or phase velocity of the radar waves in the atmosphere compared to the velocity in a vacuum. Changes in the refractive indexwill cause a change in the propagation velocity of the wave.

resolution—The minimum angular separation at the antenna at which two targets can be distinguished (a function of beam width); and/or the minimum range at which two targets at the same azimuth can be separated (one-half the pulse length).

rotation—Circular motion around an axis. In Doppler radar interpretation, a velocity signature that usually indicates a severe storm and the existence of a mesocyclone or tornado.

sample—To examine a specified volume of the atmosphere.

sampling volume—The volume of the atmosphere that is being instantaneously sampled by the radar; the power returned at any one instant that is the total backscatter from a volume of atmosphere equal to ½ the pulse length by the beam diameter.

scalable—The ease with which a system or component can be modified to fit the problem area.

scan—One complete rotation of the antenna at a single elevation angle.

scattering—The change in direction, frequency, or polarization of electromagnetic energy caused by small particles suspended in a medium.

scope—A display device, consisting of a cathode ray tube (CRT), used on older, conventional weather radars, to view radar echoes.

sensitivity—The degree that the radar can detect a weak target.

severe weather— Meteorological phenomena that cause destruction of resources. Examples of severe weather events are tornadoes, hail storms that produce hail ¾-inch or larger in diameter, and thunderstorms with associated winds of 50 knots or greater.

severe weather probability (SWP) —An algorithm and product that uses information from the Vertically Integrated Liquid (VIL) algorithm to assess the probability for severe weather.

shear—The speed or directional variation in a wind field.

shear pattern—The characteristics of a region of shear that can be recognized and correlated to a meteorological feature.

side lobes—Concentrated elements of focused power outside the main radar beam. Backscatter from side lobes can be displayed as if it were in the main beam. Ground clutter is a common result from side lobes.

side lobe contamination—The display of reflectivity that is the result of side lobe radiation. This reflectivity is indistinguishable to the radar from normal reflectivity and may present interpretation problems to the operator.

signal-to-noise ratio—A ratio of the intensity of the minimum signal capable of being detected (sensitivity) to the amount of interference generated by the radar.

slant range—The line of sight distance between two objects.

spectrum—The series of radar energy that has been arranged according to wavelength (or frequency). A spectrum is created when energy is subjected to dispersion.

Spectrum Width—A measure of dispersion of velocities within the radar sample volume. Standard deviation of the velocity spectrum.

squall line—A line of active thunderstorms, either continuous or with breaks, including contiguous precipitation areas resulting from the existence of the thunderstorms.

stair-step pattern—Increasing plateaus or tops, such as would occur if a flight of steps was represented. Often a result of the limited vertical resolution caused by the gaps between elevation scans.

storm analysis—A computer program containing six algorithms that provides information about the dynamics, structure, and related atmospheric phenomena.

storm cell centroid—The center point of mass volume within a storm component. The vertical stacking of individual storm centroids is the computer model of a storm.

storm cell segment—A run of adjacent sample volumes that have met or exceeded the minimum reflectivity and length thresholds that allow its inclusion into the storm structure algorithm. Consecutive segments are used to build centroids.

storm cell tracking—A product/algorithm that provides the past, current and forecast positions of isolated thunderstorms.

storm component—The circular, two-dimensional (2-D) representation of a series of adjacent storm segments. The center of mass of the storm component is the storm centroid.

storm cores—The inner portions of a convective storm.

storm structure (SS) —A product that produces a 3-D perspective of identified storms through nine separate parameters.

stratified cloud layers—Clouds in sheet-like layers with very little vertical extent.

strong mesocyclone—A mesocyclone that has a rotational velocity of 50kts or greater (within a range of 80nm) or 40kts or greater (within a range of 80nm to less than 125nm).

supercell thunderstorm—Large, long-lived (up to several hours) thunderstorm cells, consisting of quasi-steady updrafts and downdrafts, that exhibit rotation and are producers of severe weather.

synoptic scale—The scale of the migratory high and low-pressure systems of the lower troposphere, with wave lengths of 1,000 to 2,500km.

target—Precipitation or other phenomena that produce radar echoes.

threshold value—An adaptable parameter that serves as a maximum value which must meet or exceed a threshold value to be accepted by an algorithm or displayed on a product (e.g., velocity equals or exceeds 50 knots).

tornadic vortex signature (TVS) —The radar "signature" of a vortex indicative of a tornado or tornadic circulation.

turbulence—Irregular, random fluctuations in the wind velocity field in the horizontal and vertical planes.

variance—In spectrum width, the variability of the frequencies in a sampling volume; an indication of spectral shape—turbulent targets generally have more variance and less turbulent targets have less variance.

vector—Any quantity, such as force, velocity, or acceleration, which has both magnitude and direction at each point in space, as opposed to scalar, which has magnitude only.

velocity azimuth display (VAD) —An algorithm and product that computes a vertical profile.of horizontal wind velocity for a specified range around the radar data acquisition (RDA) site.

vertical tilt—A storm is said to have tilt if a line connecting the centroid of a mid-level storm component to the centroid of the lowest storm component is to the right or rear of the direction of movement of the storm.

vertically integrated liquid (VIL) —The VIL algorithm estimates the total amount of liquid suspended in a vertical column of the atmosphere.

vertically integrated liquid (VIL) values—Units of kilograms per square meter (km/m2) of liquid water content in a vertical column.

virga—Precipitation that falls from a cloud but evaporates before reaching the earth's surface.

VIV process— The process used by forecasters to analyze the accuracy of the computer models used.

volume coverage pattern (VCP) – A combination of elevation slices designed to provide

radar coverage over a specific volume of the atmosphere.

volume scan—The process of completing a series of specified elevation angles in a specific sequence.

volumetric product—Any product the Weather Service Radar (WSR)–88D produces that requires data from the entire Volume Coverage Pattern (VCP) before processing can be completed.

vortex— In its most general use, any flow possessing vorticity. More often the term refers to a flow with closed streamlines. A tornado is a vortex.

vortices—Any atmospheric flows which possess vorticity.

vorticity—A vector measure of local rotation in fluid flow.

wavelength = (speed of light)/(frequency) —The measure between successive troughs and successive crests in energy sine waves commonly expressed in centimeters (cm).

wet bulb zero—The height where the wet bulb temperature goes below 0 ºC.

wind shear—The localized variation of the wind vector (or any of its components) in a given direction, height and time.

weather surveillance radar (WSR)–88D – WSR 1988—Doppler; the official designation of the radar commonly called Next generation Radar (NEXRAD).

Glossary of Abbreviations and Acronyms

AFWA	Air Force Weather Agency
AFB	Air Force base
AGL	above ground level
AP	anomalous propagation
BRN	Bulk-Richardson number
BWER	bounded weak echo region
CAPE	convective available potential energy
CDC	career development course
cm	centimeter
CONUS	continental United States
cP	continental polar
CR	composite reflectivity
dBZ	decibel
EDT	Eastern Daylight Time
ET	echo tops
ETVS	Elevated Tornadic Vortex Signature
FRN	Forecast Reference Notebook
FROPA	Frontal Passage
GFS	Global Forecast System
HAD	hail detection algorithm
HPC	Hydrometeorological Prediction Center
ID	identification
JDOP	Joint Doppler Operational Project
LCL	lifted condensation level
LEWP	line echo wave pattern
LFC	level of free convection
LI	lifted index
LRM	layered reflectivity maximum
MD	Mesocyclone Detection
MEHS	Mean Expected Hail Size
MetSat	Meteorological Satellite

Millibar	mb
mP	maritime polar
MSL	Mean Sea Level
NAM	North American Mesoscale Model
ND	no data
NHC	National Hurricane Center
NSSL	National Severe Storms Laboratory
NVA	negative vorticity advection
NWF	northwest flow
NWS	National Weather Service
NWSTL	NWS Techniques development Lab
OHP	one-hour precipitation
OPUP	open principle user processor
ORM	operational risk management
OWS	Operational Weather Squadron
POSH	Probability of Severe Hail
PVA	positive vorticity advection
RAOB	radiosonde observation
RDA	radar data acquisition
RH	relative humidity
RHI	range/height indicator
RMS	root mean-square
RPG	radar product generator
SAR	support assistance request
SCIT	storm cell identification tracking
SPC	Storm Prediction Center
SRM	Storm Relative Mean Radial Velocity
SRR	Storm Relative Region
SSI	showalter stability index
STI	storm track information
STP	storm total precipitation
SW	spectrum width
SWEAT	severe weather threat
SWP	severe weather probability

TDA	tornado detection algorithm
THP	three-hour precipitation
TN	Tech Note
TT	total totals
TTP	tactics, techniques, and procedures
TVS	tornadic vortex signature
UCP	unit control position
US	United States
USP	user selectable precipitation
UTC	Coordinated Universal Time
VAD	velocity azimuth display
VCP	volume coverage pattern
VIL	vertically integrated liquid
VIV	verification, initialization, and verification
VWP	VAD winds profile
WBZ	wet bulb zero
WER	weak echo region
WRF	Weather Research and Forecast Model
WSFO	Weather Service Forecast Office
WSR–88D	Weather Surveillance Radar

Student Notes

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AFSC 1W071
1W071 03 1209
Edit Code 02