



SkewT Diagrams: New Tools For Vertical Analysis

By Craig Sanders, Senior Forecaster at WFO Duluth

Flying the weather map to avoid or reduce exposure to hazardous weather conditions is an art based on experience, careful planning and attention to detail.

Over the decades, pilots have used a standard suite of weather products to develop a three dimensional view of the atmosphere. These products include the surface analysis chart with its highs, lows, fronts, isobars and plotted METARs.

Add to this suite upper air charts like the 850 Mb or 500 Mb charts, Winds Aloft (FD) forecasts, Pilot Reports (PIREPs), and now graphics from the Aviation Weather Center (AWC). Pilots rely on these tools to prepare for hazards that could impact their flight, especially the descent.

Pilots can now add another tool to their arsenal, the SkewT diagram shown in **Figure 1**. The SkewT is not new, but has only recently become available to pilots online. Meteorologists have used SkewTs for years to forecast everything from thunderstorms to freezing precipitation. Now pilots can use SkewTs to glean valuable information that will make flights safer.

The SkewT, or sounding chart, is a vertical snapshot of temperature, dew point and winds above a point on the earth.

At first glance, a SkewT appears to be complex, but pilots only need to know about a few lines and their relative positions,

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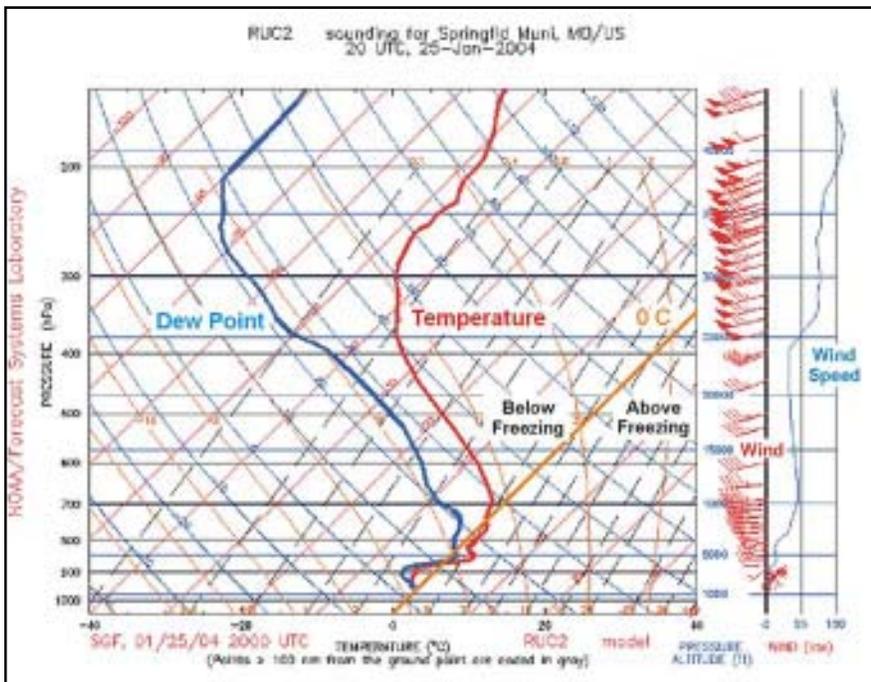


Figure 1. A forecast sounding valid at 20z January 25th for Springfield, MO

The Front

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Mission Statement

To enhance aviation safety by increasing the pilot's knowledge of weather systems and processes and National Weather Service products and services.

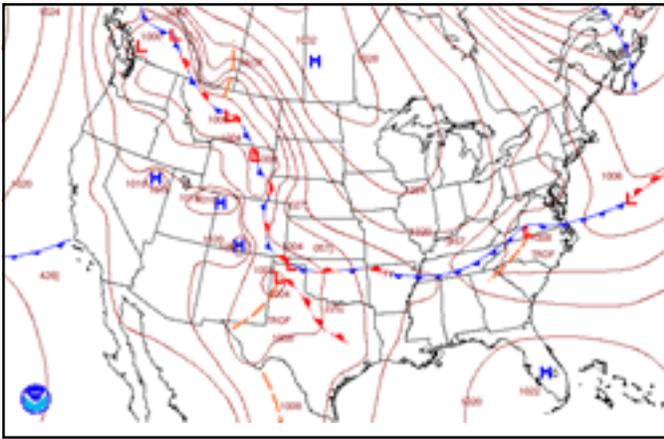


Figure 2. Surface map of a developing freezing precipitation and icing situation. A SkewT diagram is a valuable tool to diagnose the condition and aid the pilot to make good, well informed decisions.

Continued from Page 1

or orientations, to obtain valuable information about cloud bases and tops, freezing temperatures, icing zones, fog, inversions, and winds.

Let's take a recent weather situation and see how the SkewT might help. On January 24, 2004 an arctic air mass had descended into the nation's midsection as depicted in **Figure 2**. A stationary front lay pressed against the Rockies. The southern edge of the cold dome of air had stalled and the frontal zone stretched from the central plains east to the mid Atlantic coast. Temperatures were in the low 40s to low 50s south of the front in Oklahoma and Arkansas and in the 20s to low 30s north of the front in Kansas and Missouri.

Over the next 24 hours, a low pressure area formed and a warm front was depicted in the central plains. Warm air moved north from Oklahoma, and overrunning along the warm front began producing freezing precipitation in Kansas and Missouri.

By the morning of January 25, the AWC had AIRMETs for icing in place, and

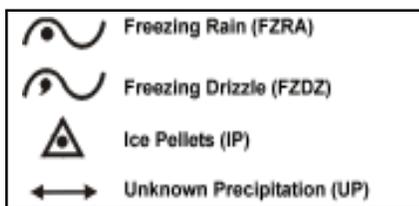


Figure 3. Map Symbols that indicate freezing precipitation and possible dangerous aircraft icing.

the ADDS surface chart verified that threat with freezing or mixed precipitation. The symbols shown in **Figure 3** appeared on hourly surface charts.

If the cold air at the surface is deep enough, about 2,000 feet or more, rain re-freezes into sleet or ice pellets. If the cold air is shallower than this,

the rain stands a good chance of remaining liquid until it hits an object whose temperature is below freezing, yielding freezing rain or clear icing on aircraft.

If the particles reach the AWOS and ASOS sensors as some other combination of partially melted and partially frozen precipitation, they are labeled as Unknown Precipitation (UP) by the weather sensor.

To get out of an icing situation like that of January 25, you have three options.

- ◆ First, you could remove yourself from that environment by climbing above the clouds or into air colder than -20°C. Would you know where those levels are by using the conventional briefing charts, or if Flight Service had no PIREPs in the area yet? Probably not.
- ◆ A second option is to descend into air near the ground that is above freezing. That's normally how the atmosphere is structured. But if the ASOSs and AWOSs below you are reporting -FZRA, -FZDZ or UP, this option may be worse than the conditions you're already in.
- ◆ A third option is to find a layer of warmer air above freezing. This is where the SkewT excels. Conventional forecast maps and products won't tell you how to do this; they merely suggest the lowest freezing level. The SkewT on the other hand completes the three dimensional picture by portraying atmospheric temperature from the surface to about 40000 feet or so.

When two air masses of vastly different temperatures collide, the colder, more dense air slides beneath the warmer, less dense air. This is exactly what happens near warm fronts and stationary fronts from late fall through early spring. The result is a cold layer of air near the surface and a warmer layer above resulting in the atmosphere dropping below freezing from the top of the warm layer on up. The SkewT is the only tool that will show you where a warm layer might be and one in which you could find relief from the icing.

The SkewT diagram is a rather unconventional looking graph on which temperature, dew point and wind data are plotted. The vertical axis is pressure in Millibars. For technical reasons, meteorologists use this vertical coordinate rather than altitude because weather computer models deal best with pressure as the vertical component.

Notice the pressure lines are close together near the bottom of the chart, the earth's surface. The lines get progressively farther apart as you go up. This Logarithmic Pressure, (LogP) scale represents the actual pressure structure in the atmosphere. Below is an approximate relationship of pressure versus altitude under ideal or standard atmospheric conditions.

Pressure (Mbs)	Altitude (Ft)	Flight Level
100	53,083	FL530
150	44,647	FL450
200	38,662	FL390
250	33,999	FL340
300	30,065	FL300
400	23,574	FL240
500	18,289	FL180
600	13,801	
700	9,882	
800	6,394	
850	4,781	
900	3,243	
925	2,512	
950	1,773	
1000	364	
1013.2	0	

The SkewT's temperature scale is not at right angles to the pressure scale as are most conventional graphs, but skewed to the right at 45 degrees. Again, technical reasons dictate this layout. Thus, the name

Latest MAPS analysis is valid at **14:00 UTC**.
 Latest RUC analysis is valid at **14:00 UTC**.
 Select a time range and location:

Initial data source:	<input checked="" type="radio"/> MAPS (FSL 20km RUC) or <input type="radio"/> RUC (NCEP 20km) or <input type="radio"/> RAOBs or <input type="radio"/> Profilers or <input type="radio"/> ACARS (restricted)						
Start Time:	<input type="checkbox"/> Latest, or	<input type="text" value="2004"/>	<input type="text" value="Jan"/>	<input type="text" value="25"/>	-	<input type="text" value="15"/>	UTC
Number of hours:	<input type="text" value="3.0"/>						
Name, "lat,lon", or RAOB-WMO-ID:	Site:	Site info: METARs , ACARS , Profilers , RAOB locations , latest RAOB times .					
	<input type="text" value="den"/>						
Java-based plots		Ascii text (FSL format)					

Figure 4. FSL opening page for selecting soundings.

SkewT-LogP diagram or simply SkewT diagram.

The relative distance between temperature and dew point lines represent humidity. In Figure 1, temperature is red and dew point is blue.

The closer these two lines are at any point, the higher the relative humidity. When these lines are three degrees C or less apart, expect clouds and IMC. Dry air is present when the temperature and dew point lines are farther apart. The greater the distance, the drier the air.

Hazy conditions are likely when the difference is between 3 and 5 degrees C. So the SkewT can help you choose the altitude at which to file or the altitude at which you can expect to fly in VMC between layers.

If icing is a concern, the SkewT will show where the clouds are likely to be and where the temperature is conducive to icing. A major benefit of the SkewT is that it can show this even if the ASOS is reporting a low overcast obscuring higher cloud layers and no PIREPs are available to help add detail.

The wind pole in Figure 5 is a useful, visual tool for finding an altitude to take advantage of a tailwind or minimize the effect of a headwind. The long staff of each symbol indicates the direction from which the wind is blowing. Barbs on these staffs indicate speed in knots. Each long barb is 10 knots, a half barb is 5 knots; a pennant is 50 knots.

Figure 5 has three examples of how to interpret these wind flags. The wavy blue line to the right of the wind flags represents the speed in knots. This line makes it easy to find the max wind speed and the level it is at. You can plan your proposed altitude with this wind tool in more detail than with the FD Winds Aloft table, and you can locate areas of possible low level turbulence due to directional wind shear.

Now that you have a basic understanding of the SkewT's layout, let's go back to the Midwest storm. By January 25, storms at 2000 UTC freezing or mixed precipitation were underway in Kansas and Missouri. If your destination was Springfield, MO, you would want to create a forecast sounding specifically for that airport and have it valid for the time of your descent and arrival time.

The premier Website for generating

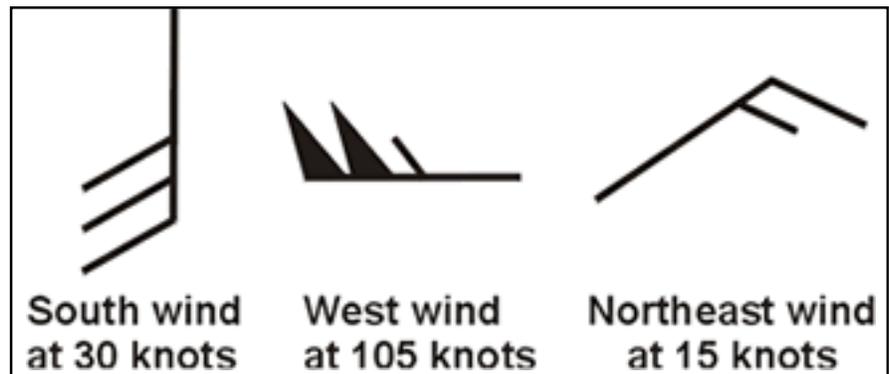


Figure 5. Wind flags represent speed and direction similar to those found on surface analysis charts.

forecast soundings is NOAA's Forecast Systems Laboratory, or FSL at: <http://www-frd.fsl.noaa.gov/mab/soundings/java/>. The site will open up to a selection box shown in Figure 4.

Select either the MAPS or the RUC model option. If either model output is not available, you'll be greeted by a solid red screen. Go back and select the alternate model.

Enter the UTC time for your arrival time or the time you will be flying over if this will be one of your en route way points. Next type in the three-letter ID of the airport.

You can also enter a latitude and longitude if your airport doesn't have an ID; however, with the dense network of ASOSs and AWOSs, it's usually easy to pick the nearest airport ID.

The FSL site does not recognize five letter FAA intersections. It's helpful to get two more versions of the SkewT, so leave the "Number of Hours" at 3.0. It may take a few seconds longer to process but you can use these versions to see how the conditions depicted in the sounding might change over a three hour period.

The sounding that was generated for this storm is shown in Figure 1 and is also inserted into the 3D view of the January 25 weather map in Figure 6. The classic warm frontal structure is shown: cold air near the surface with a warm layer above and then cold air above that.

The temperature line crosses the zero degree C reference line twice and demonstrates a multiple freezing level. When the

red temperature line is right of the zero degree reference line, the air is above freezing. Otherwise, the air is below freezing.

Note that in the cold (blue) arctic air mass, the temperature line is below freezing, i.e., to the left of the zero degree reference line. Above this blue area, the temperature line is to the right and is above freezing. If you were approaching Springfield at 2000 UTC, you would encounter a warm layer as shown. Your OAT would verify this. This warm layer would be a good choice if you were icing up. You could choose to stay at that altitude and fly south toward the warm front in an increasingly deep warm layer until you were away from the front and in surface-based layer of warmer air.

Cloud tops are also indicated on this forecast sounding. The temperature and dew point lines are closer together in the cold air, indicating relative humidity near 100%. Ceiling reports on that day confirmed that there were low ceilings and marginal visibilities.

Just above the cold air, the temperature and dew point lines become farther apart indicating lower humidity and possible cloud tops. The advantage of a sounding in this situation is that you get a good idea whether to climb to VMC or to a warm layer. If there are no PIREPs, you really wouldn't have definitive information about cloud tops or your options.

If you plan to take this chart with you, you may prefer a text printout of the sounding. Select "text frame" and a text box will pop up. You can't directly print this box but you can cut and paste the data into a word processor page and then print it. Compare the data in this table or on the SkewT with your OAT and GPS to see if the forecast is on target.

The SkewT may seem a bit cluttered and may prevent you from getting good detail. No problem. The zoom feature will expand any section of the SkewT you want.

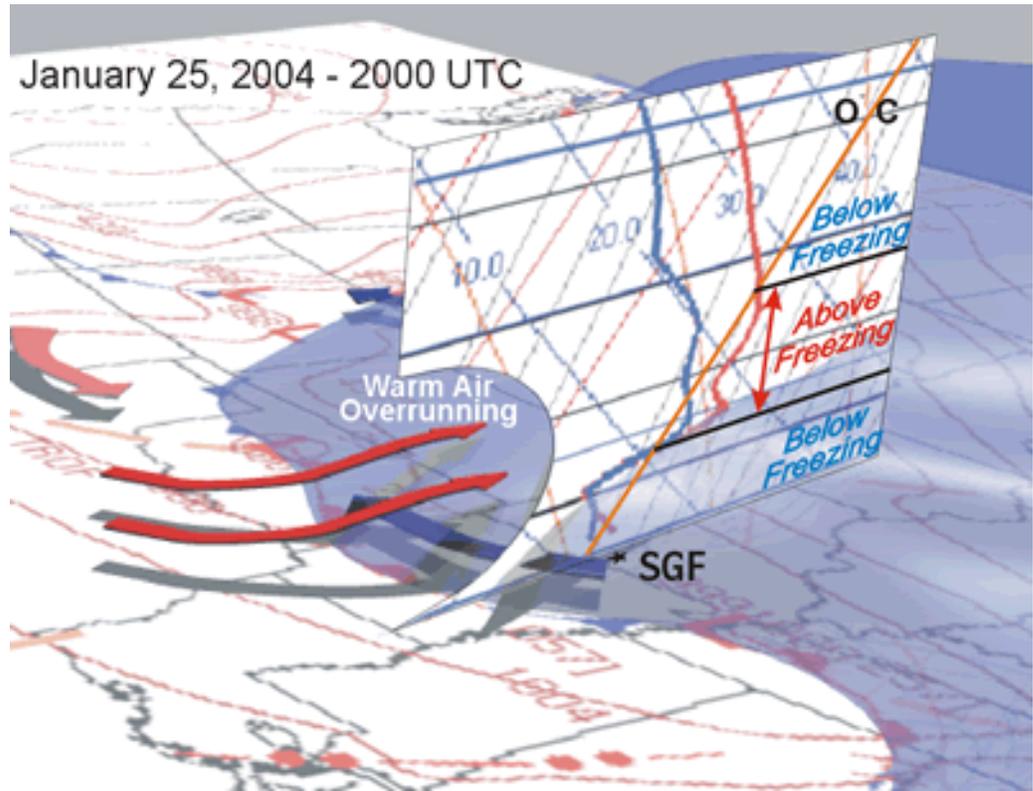


Figure 6. A SkewT sounding for Springfield, MO (SGF) superimposed onto the surface map for January 25th at 2000 UTC. Warm air is overrunning the dome of cold, dense air and is producing a layer of above-freezing air between the cold surface air below and colder air higher in the atmosphere. This is typical of freezing rain situations.

To zoom, use your mouse to draw a box from the upper left corner of the desired region down to the lower right of the desired area. A red box will outline the area you've chosen. Release the mouse and a new zoomed in subsection of the chart is displayed. To return to the full diagram, select "Reset Scale" button.

The upper region of the warm frontal zone is shown by a change in the winds aloft. Note the winds are from the east on the north side of the warm front. Higher up, the winds become more southerly. This is over running. In freezing precipitation, an east, southeast or northeast wind GPS readout shows you are likely located in the cold air ahead of the warm front. Your OAT would help to confirm this.

As you fly toward the warm front, you'll see the winds turn more southerly or southwesterly on your GPS, and the OAT will begin to rise. These are the clues you'll want. Practice this near warm fronts when no freezing rain is expected. Knowing how winds change in frontal zones can be a helpful skill. A SkewT, GPS wind data and your OAT gauge make an effective suite of tools when flying in frontal zones.

Finally, a powerful tool of the FSL sounding Website is the interactive feature and the realtime detail it offers pilots and dispatchers. Running the cursor over the sounding immediately displays the data you need so you don't have to decipher the chart's lines. The readings update instantly as you move your mouse. Temperature, dew point, pressure altitude, and winds at each significant point on the sounding are printed on the screen and marked by a short black line segment.

SkewT diagrams represent an old meteorological diagnostic tool that has earned new life and respect as a short term forecast tool for pilots and dispatchers thanks to the meteorologists, programmers and other technical professionals at NOAA's Forecast Systems Lab.

SkewTs provide details not easily gleaned from traditional maps and text products. With repeated practice you'll learn to rely on this tool as much as you have the AWC products or TAFs. It will give you the extra edge of awareness and confidence you need if you find yourself flying in frontal zones and the hazardous weather they can produce. →

Utility of a Near-Realtime Aircraft Tracking Program in a CWSU

By S. Douglas Boyette CWSU Memphis, TN

Flight Explorer Professional¹ (FE) is PC software used at Center Weather Service Units (CWSUs) in the NWS Southern Region. FE generates near realtime aircraft position information similar to the Aircraft Situation Display data (ASD) used by FAA Traffic Management staff.

The program also offers NEXRAD radar data. The system displays only those IFR aircraft using transponders and being tracked by air traffic controllers. It can overlay NEXRAD radar data. The program also displays map backgrounds, such as NAVAIDS, Victor Airways, Jet Routes, Airports, ARTCC and sector boundaries, TRACON areas, and Special Use airspace such as Military Operation Areas.

The benefit of using FE in a CWSU operational environment is twofold: it enhances situational awareness and it improves coordination between the CWSU meteorologist and FAA decision makers.

CWSUs are located in the FAA's 21 Air Route Traffic Control Centers (ARTCCs) nationwide. These units are staffed with four NWS meteorologists serving the

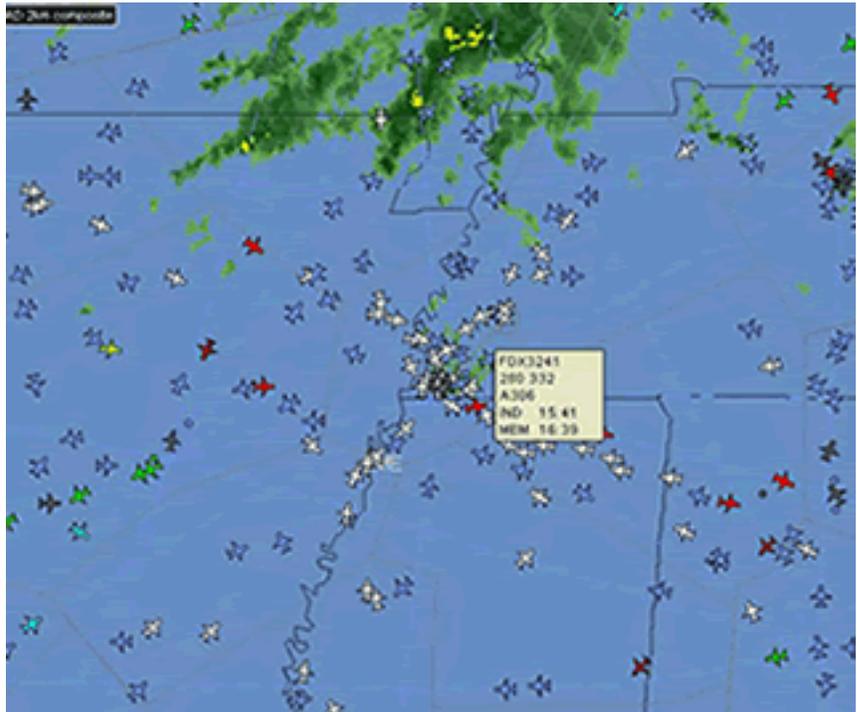


Figure 2. Aircraft with a destination of Memphis International Airport (MEM) are color-coded white. In this diagram, aircraft heading for Atlanta (ATL) are color-coded red, while those destined for Dallas-Fort Worth (DFW) are color-coded green. Dark red would indicate aircraft bound for the Houston area.

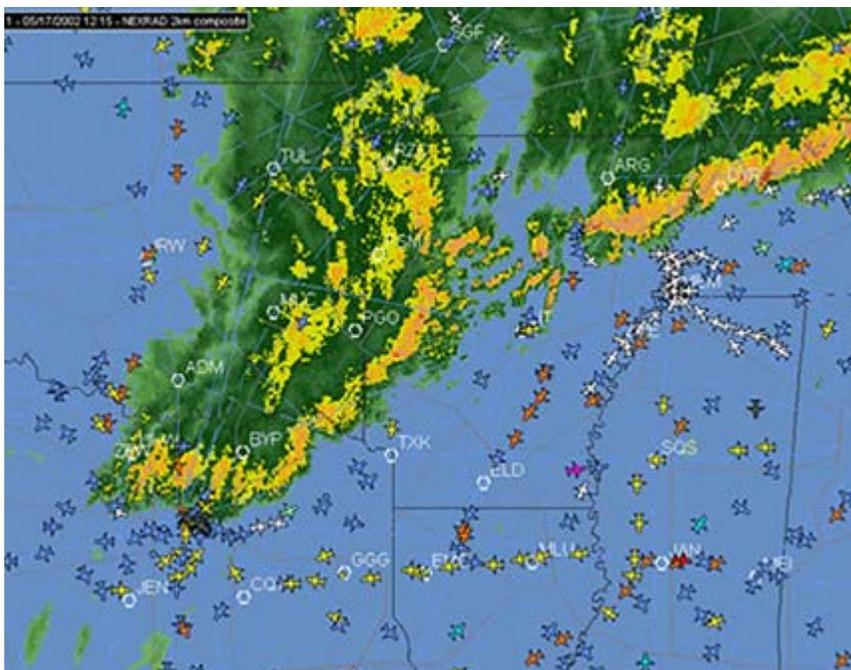


Figure 1. An example of the Flight Explorer (FE) program as used by the Memphis (ZME) Center Weather Service Unit.

needs of the National Airspace System 16 hours a day, 365 days per year. CWSU forecasters play an integral role in the safe and efficient flow of aircraft across the United States by providing up-to-the-minute weather information and forecasts to FAA decision makers throughout the system.

Using the FE program has greatly enhanced the situational awareness of forecasters at the Memphis CWSU. Use of the program also has improved the understanding of basic air traffic patterns within the Memphis ARTCC airspace and surrounding Centers.

Forecasters can now dynamically track aircraft moving into and out of the airspace in juxtaposition to live weather. Although the NEXRAD background overlay feature updates slowly, it does help focus on areas of weather impact.

The advantage of the meteorologist having near-realtime aircraft information cannot be understated.

CWSUs are unique in the weather business because they operate alongside

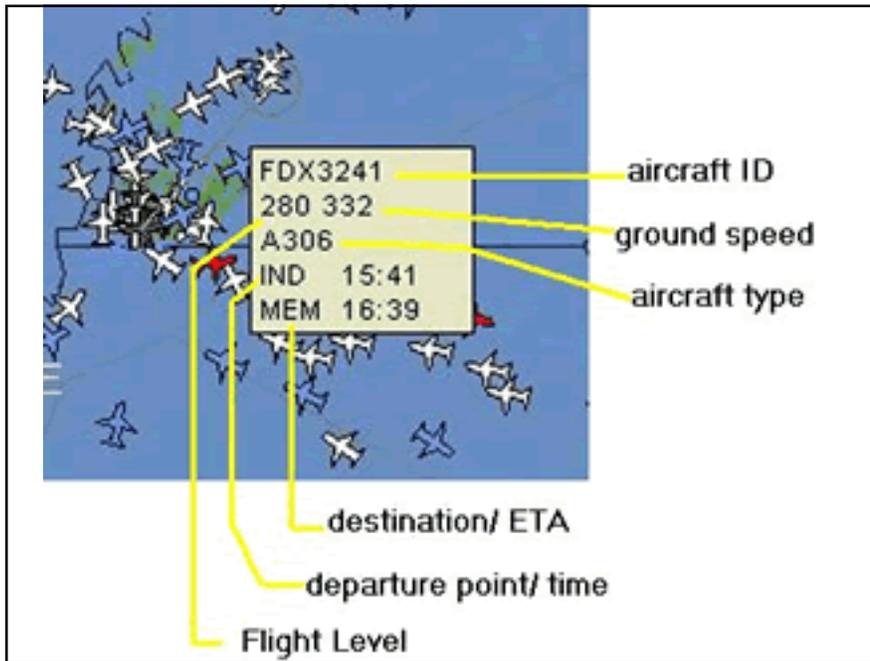


Figure 3. An example of the “data block” available in the FE program. All the elements in this box can be important situational awareness tools for the meteorologist involved in air traffic operations.

their primary customer. To make this work well, CWSUs need the tools to allow them to understand what that primary customer requires.

FE software provides an ongoing snapshot of both position and impact of the weather most affecting the customer.

For example, a forecaster does not need FE to know that a cluster of thunderstorms over a strategic NAVAID may be more significant to a customer than a cluster somewhere else; however, the forecaster can serve that customer better by knowing how many airplanes are en-route to that NAVAID when thunderstorms are forecast.

The color coded displays on the program are instrumental to its success. ZME has color-coded all airplane icons heading to the major hub airports within and outside ZME.

For example, during an unexpected drop in ceiling or visibility, the program allows forecasters to quickly understand whether large volumes of airplanes could possibly go into holding or if only one or two might be impacted, crucial information. Certainly the meteorologist would brief the decision-makers about the condition regardless but it becomes most critical when airplanes are already in-flight and a potential

problem is developing.

A CWSU’s mission is to help the FAA ensure a safe and efficient flow of air

traffic. This program facilitates that goal.

Finally, the FE program has a feature that lets the user display flight plans on the map, which quickly provides the forecaster with a heads-up on potential trouble.

For example, if by viewing the flight plans the forecaster realizes numerous aircraft are moving toward an area with a moderate chance of broken areal coverage of thunderstorm, he or she instantly knows the importance of that forecast. In a similar vein, the forecaster also obtains “ground truth” on how well a forecast verified based on the screen’s unfolding traffic picture. Instant feedback is a helpful, if humbling, learning tool.

The FE program’s second goal is satisfied by the improved understanding between CWSU meteorologists and FAA decision-makers. Companies frequently perform market research to learn how to better serve customers. FE programs allow a CWSU to perform a type of market research by identifying what is important to the customer.

Additionally, programs such as FE can improve the interaction between controllers and meteorologists, who are often

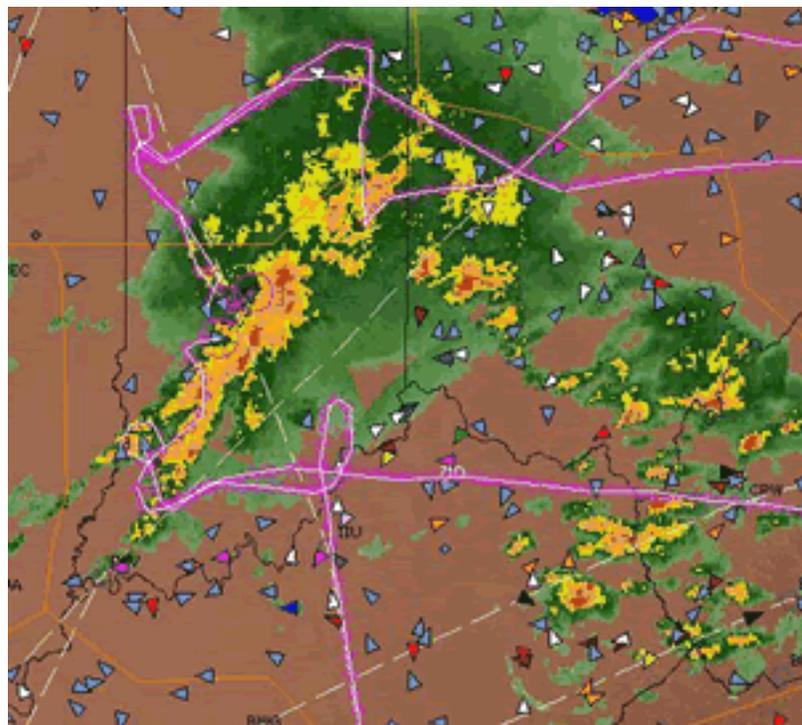


Figure 4. This is an example of a thunderstorm impact to the Indianapolis ARTCC airspace that occurred in May of 2003. Several aircraft have been tagged to indicate the navigational paths taken to reach Indianapolis International Airport (IND) during this time period.



Figure 5. This training aid was made using a screen shot from FE. The diagram gives an overview of normal air traffic flows to Atlanta and Chicago. Notice the blending point of Memphis, TN and Meridian, MS for Atlanta landing traffic.

thinking on different wavelengths! If the forecaster can relate to the problems encountered by the FAA decisionmaker and vice versa, it smooths data exchange.

Another useful quality of FE involves training recent hires or transfers. New forecasters must quickly get a grasp on where the Airways, Jet Routes and Nav aids are in relation to traffic flows for their new airspace. FE provides one-stop shopping for this purpose. (See **Figure 5**.)

There is yet another FE advantage. PIREP retrieval and dissemination is a crucial aspect of the CWSU meteorologist's duties. When an air traffic controller calls or provides a PIREP for the meteorologist to disseminate, he or she can check FE to see where the aircraft was in relation to the displayed weather or forecast jet stream position. FE also provides a quick way to cross check and quality control the PIREP. Occasionally a controller may deliver a PIREP with an event time that is questionable. The FE program usually can pinpoint the airplane in question and shed light on where the aircraft might have been when encountering the phenomenon.

Here's a real life example: A cold front was moving across ZME, and thunderstorms were preceding the front. Most of the thunderstorm activity was east and

northeast of ZME. At approximately 8:30 AM local time, an FAA Area Supervisor approached the CWSU requesting assistance in routing an aircraft around weather.

The aircraft, shown in **Figure 6** as N222ME, was an AC69, a twin engine turbo-prop business aircraft en-route from

Oxford, MS, to Washington Dulles Airport (IAD). The aircraft had onboard radar but the unit was not operating so the pilot wanted to avoid as much bad weather as possible. Initially the aircraft had been given a route to the east of the bad weather, via Raleigh Durham (RDU). The pilot was concerned the routing of RDU-IAD would place the aircraft into the path of the weather, since the showers and thunderstorms were in progress.

FE is only one tool in this process, but in this instance it enhanced communication between the meteorologist and supervisor to the benefit of the user. The meteorologist on duty used both Harris WARP mosaic radar information and the FE to brief the SUP on possible routes for N222ME.

The SUP was impressed when the meteorologist identified an airplane icon on the FE screen as N222ME. With the aircraft precisely identified the route was discussed and, based on the indication of the FE display and other products, the SUP decided to offer N222ME a route west of the present weather.

Approximately 5 minutes later and after conferring with controllers, the supervisor returned to the CWSU and indicated that N222ME had been given a route to Cleveland (CLE) then IAD.

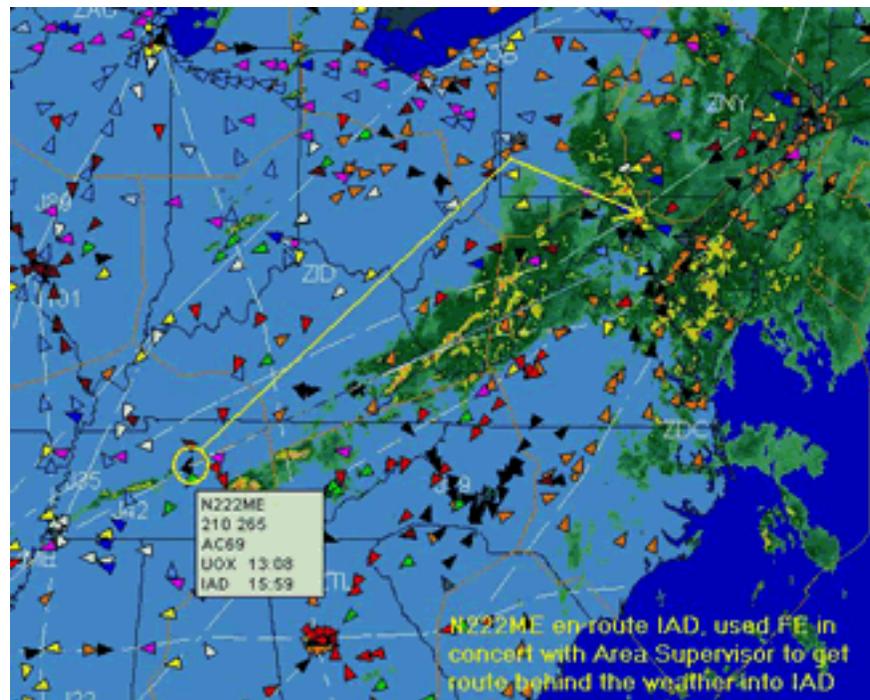


Figure 6. Example of an aircraft being routed around weather with the help of the FE program.

Again, after viewing the FE display and WARP, it was clear this route was too far west of the weather. A more easterly route was discussed, direct to Pittsburgh then IAD, saving the pilot fuel without compromising safety.

In this event the customer was well served, since representatives from both agencies were able to quickly view the airplane in direct relation to the suspect weather and make decisions accordingly.

Access to programs like FE, that depict active flights superimposed with weather radar data, appears to be an in-

valuable tool to enhance situation awareness, understanding and communication within the CWSU environment. It also provides a fantastic training tool for new hires or transfers. →

¹ Reference to any specific commercial product, process, or service by trade name, trademark manufacture, or otherwise does not constitute an endorsement, a recommendation, or a favoring by the NWS or the United States Government.

Wind Shears in the Lowest 2000 feet of the Atmosphere

By Richard E. Arkell, NWS Davenport, IA

Wind shear presents an invisible challenge to pilots, especially in the lowest 2,000 feet of the atmosphere, or boundary layer, where the wind structure can be quite complex. Two of the most important types of shear are low level wind shear (LLWS) and turbulence.

The segregation of shears into LLWS and low level turbulence categories is to some extent artificial, since they are part of a continuous spectrum of shears in the boundary layer. For example, large turbulent eddies could be described as quickly changing LLWS. It is possible, however, to make operationally useful distinctions between the two.

The primary difference between LLWS and low level turbulence is that LLWS is an organized shear. For example LLWS might be found at the top of fairly calm air when a strong temperature inversion exists. At night, this calm layer, typically up to 2,000 feet thick, is topped by strong winds in a low level jet at the top of the inversion.

Low-level turbulence is more localized. Eddies of disturbed, hence turbulent, shear might be found near the ground on a day with unstable conditions and gusty winds. In a temporal sense, LLWS is shear that changes slowly, and turbulence is shear that changes rapidly.

The NWS further separates LLWS into non-convective and convective categories. Convective LLWS is associated with showers and thunderstorms.

This aviation hazard exists at the leading edge of a thunderstorm outflow boundary and also directly under a storm where the downdraft spreads out in opposing directions once it reaches the ground. Thunderstorms can also contain dangerous turbulence.

These types of wind shear, convective LLWS, non-convective LLWS, and turbulence are shown schematically in **Figure 1**.

And Now, The Forecast . . .

The National Weather Service offers a suite of products that forecast turbulence and LLWS.

- ◆ Terminal Forecasts (TAFs)
- ◆ Transcribed Weather Broadcasts (TWEBs)
- ◆ Airmen's Meteorological Information

AIRMETs focus on non convective LLWS. In TAFs and TWEBs, LLWS is included for shear at or below 2,000 ft. AGL if the wind's vector change is 10 kts. or more per 100 feet of vertical distance in a layer at least 200 feet thick. This results in a thresh-

old of 20 kts as the minimum forecastable LLWS. In a TAF, non convective LLWS would be indicate as:

```
TAF
KPUB 181122Z 181212 13012KT 5SM
-RA SCT010 OVC035 WS020/27055KT
```

```
FM1400 32010KT P6SM FEW 008
BKN045
```

where **WS** indicates that this is a non-convective Low Level Wind Shear remark. **020** is the height of above ground-**27055KT** is the forecast wind direction (true) and speed (knots) at the top of the light wind layer. (Compare this wind speed with the surface wind of 13012KT.)

The wind shear conditions is a prevailing condition from 1200Z until the beginning of the next FM group, in this case 1400Z. It does not indicate the severity of the shear.

Convective LLWS is implied in any TAF that contains a forecast of thunderstorms. The strength of potential LLWS can be inferred by a **VRB** remark with the range of wind speeds following. For example,

```
TAF
KGRB 241732Z 241818 11006KT 4SM
-SHRA BKN030
```

```
FM2300 22006KT 3SM -SHRA OVC030
PROB30 0406 VRB20G35KT
```

```
1SM +TSRA BKN015CB=
```

In this case the remark applies to the time range of 0400Z through 0600Z.

Low level turbulence is not explicitly forecast in TAFs or TWEBs but is implied by a forecast of high wind speeds. The speeds mentioned could imply the danger. On the other hand, AIRMETs and SIGMETs do specifically forecast turbulence and the expected altitudes. The AWCs ADDS page is an excellent source for learning about these advisories.

Wind shear is also addressed in Center Weather Advisories (CWAs). CWAs are issued by the Center Weather Service Units (CWSUs) at the Air Route Traffic Control Centers and have the significance of SIGMETs. You can find CWAs on the AWC homepage. Look for the CWSU Corner and the associated interactive map.

Here's an example of a CWA for Low Level Wind Shear in a blowing dust

(BLDU) and blowing sand (BLSN) condition near Los Angeles (LAX):

ZLA1 CWA 160400
ZLA CWA 101 VALID TIL 160600
35ENE LAX

NUMEROUS ACFT REP LOW LVL WS
BLW 005. SFC WND GUSTS 50 KT.
VIS OCNL 1SM BLDU BLSA. CONDS
EXP TO CONT AFT 06Z. NO UPDATES
AFT 160500Z.

The Collaborative Convective Forecast Product (CCFP), which is a joint effort of the AWC, the FAA, and the airlines, is useful for locations of convective LLWS, but it does not specifically mention the LLWS threat. It is implied, however, when thunderstorms are forecast.

Pilot reports of wind shear can be extremely helpful for other pilots and forecasters alike. Sometimes pilots inadvertently report LLWS as turbulence or turbulence as LLWS.

The Details . . .

Normally a gradual, vertical trend in wind speeds is present during the day. The atmospheric temperature decreases with height, characteristic of a well mixed lower layer. Non convective LLWS occurs when the layer near the ground is cooler than the air above it, creating as a temperature inversion.

This condition prevents the winds from mixing in the boundary layer. Instead the winds decouple within or at the top of this boundary layer. Winds are light at the surface, but remain stronger and possibly blow from a different direction aloft.

This shear may be associated with nocturnal inversions, marine layers, sea breeze fronts, warm and cold front passages, cold-air damming against a mountain barrier and lee side mountain affects. Sometimes, the shear may not meet the 20kt/200ft NWS criteria, as with most warm and cold fronts, or be too transient in nature for inclusion in the forecast, as with most sea breeze fronts.

In such situations, the shear is experienced by pilots mainly as turbulence, with a net vector change after passing through the turbulent zone.

The most common type of non convective LLWS is associated with nocturnal inversions, which are often created by sur-

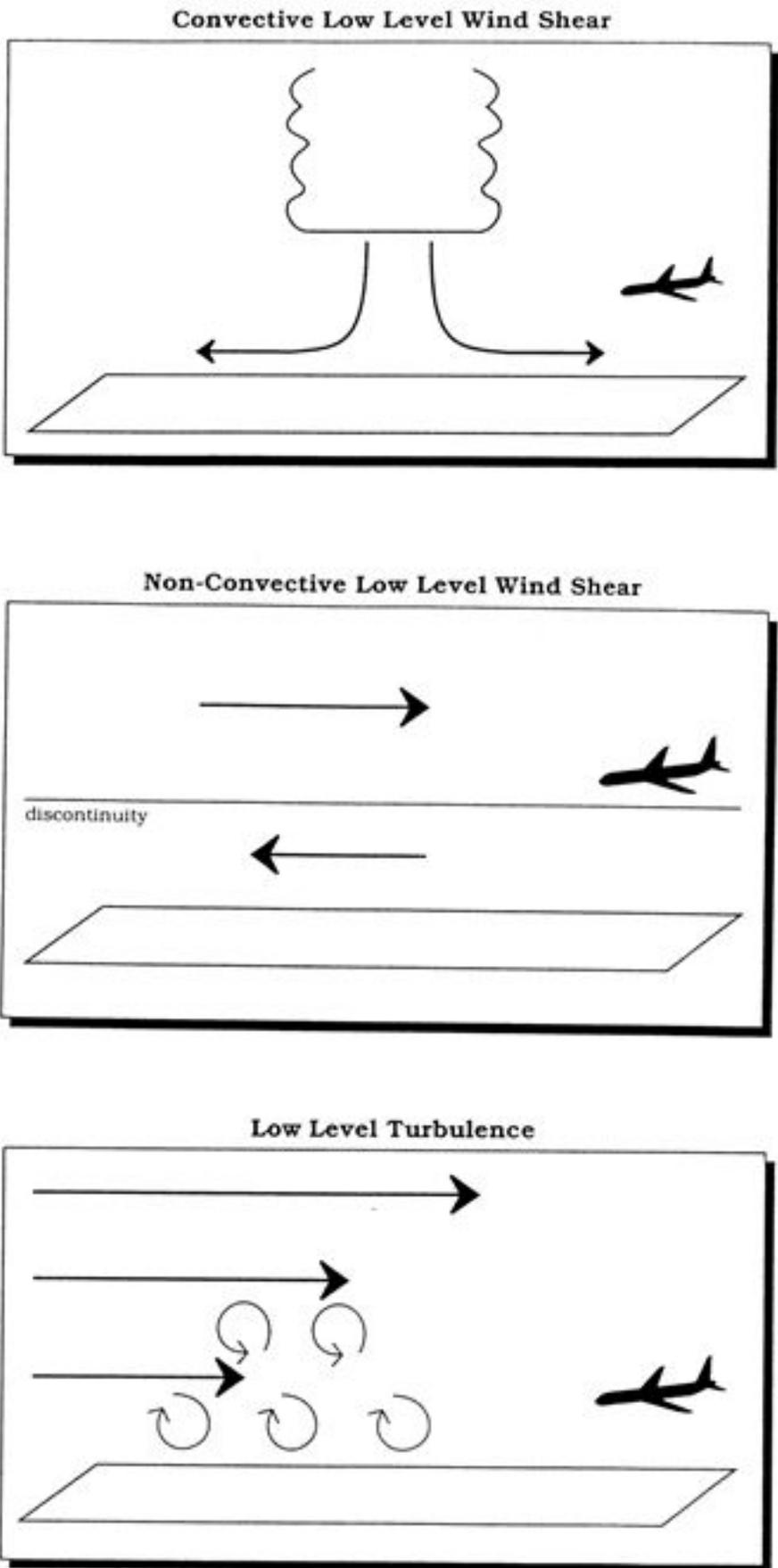


Figure 1: Convective LLWS, non-convective LLWS, and turbulence.

face cooling due to radiation under clear skies if surface winds are light.

Valleys can intensify the inversion development through cold air drainage. In a nocturnal inversion, a cool layer is trapped under warmer air. If a low level jet (wind maximum) develops in the warmer air just above the inversion, very strong wind shears will result.

The low level jet strengthens during the night, and is accompanied by LLWS. It often dissipates around sunrise when the atmosphere begins to mix.

Marine layers, such as on the West Coast during the summer, can also produce very strong cases of non-convective LLWS. Typically, a marine layer increases in depth with time, with the top of the inversion lifting from around one thousand feet to four to five thousand feet through a 4 to 5 day period. Santa Ana winds coming down from the mountains and riding up over the top of this layer can accentuate this condition.

Sea breeze fronts can create non-convective LLWS, although the depth of the sea breeze changes fairly rapidly with time, increasing a few thousand feet from mid-morning into the afternoon hours. If the sea breeze front is strong enough, and if there is a prevailing wind above the front, the vector change in winds aloft can meet the NWS non-convective LLWS criteria.

Wind shears across frontal boundaries don't usually meet the LLWS criteria. The shear across the frontal transition zone is usually more characteristic of turbulence, although the net vector change is still quite significant. If the front is extremely strong, wind shears across a frontal boundary can meet NWS non-convective LLWS criteria. Wind shears associated with a cold front are at or behind the front's surface position. Wind shears associated with a warm front are ahead of its surface position. In addition, fronts that result from cold-air damming accompanied by overrunning, as occur in the Virginia and Carolinas Piedmont during the cooler part of the year, can produce some significant shears.

Wind shears associated with mountain waves on the lee side of mountains can also reach within 2,000 feet of the ground on occasion. These shears, how-

ever, which can be extremely strong, are usually too transient for inclusion in a TAF.

Convective LLWS is associated with downdrafts and gust fronts from showers and thunderstorms or microbursts. The nature of the shear will depend upon the symmetry of the outflow, the strength of the outflow, and the stage of development. Also, outflow regions from different thunderstorms can merge, further complicating the situation. In their most intense form, downdrafts and the resulting outflows are referred to as downbursts.

The wind shears associated with low level turbulence usually occur at a smaller, more irregular scale than either convective or non-convective LLWS. They consist of eddies or waves on the order of a few meters to a few hundred meters across. Low level turbulence results primarily from:

- ◆ Mechanical mixing caused by high winds interacting with the terrain
- ◆ Convection
- ◆ Frontal surfaces and boundaries
- ◆ Gravity waves
- ◆ Aircraft wake effect.

Over rough terrain, even light to moderate winds can produce significant turbulence.

How to Deal With Wind Shear . . .

Non-convective LLWS, convective LLWS, and low level turbulence can all affect aircraft performance, sometimes drastically. Sometimes these phenomena will occur together, as is the case with thunderstorms. An aircraft's size, weight, speed, power to weight ratio, and engine type are critical factors in determining its response to a given shear environment.

The pilot's response to LLWS involves both power settings and angle of attack. Each aircraft is vastly different. The best way to prepare and practice is to thoroughly review those sections of the aircraft operating handbook or practice in certified simulators for that aircraft type.

A pilot encountering non-convective LLWS has a few options. In a tailwind condition, the wings lose the lift of the relative wind, and the pilot can increase

power to increase IAS. For increasing headwinds, the pilot may choose to back on power. If the pilot is unsure about the direction of the shear, an increase in power may be warranted to be on the safe side.

A pilot's response to convective LLWS may be different from that for non-convective LLWS. The primary difference is non-convective LLWS presents the pilot with one wind shift or vector wind change, while convective LLWS often presents the pilot with multiple wind shifts along the flight path. In an idealized scenario, an aircraft may first experience a headwind, followed by a downdraft, followed by a tailwind. Pilot training is the best way to learn the difference. No firm rules exist for handling all situations.

A pilot encountering low level turbulence on take-off or final approach on a windy day will usually increase power. This will keep the fluctuating air speed from dropping below the stall speed.

This response contrasts with what a pilot would do when an aircraft encounters turbulence at cruising altitude. With turbulence, the pilot would slow the aircraft to near the maneuvering, or turbulence penetration, speed.

Low level turbulence is often more dangerous to small aircraft than large aircraft because their smaller wings allow them to be influenced by smaller scales of turbulence.

For both LLWS and low level turbulence, the dangers for the approach phase of flight are different from those for the take-off phase. Approach can be dangerous because the aircraft has downward momentum, is in a nose-down attitude (until final flair out), and has throttled back to idle.

It could have a hard time recovering from an unexpectedly strong tailwind, especially in a downburst situation. Takeoff can be dangerous for a different set of reasons. Since the engines are at full power, additional power, if needed, is not available and aircraft weight is usually significantly higher due to fuel load.

In summary, there are distinct differences between the types of wind shear and turbulence. There are also differences in how an aircraft responds to this shear. Vigilance and training are the keys in dealing with these invisible phenomena. →