



The Hidden Dangers of Mountain Wave Turbulence

By [James Reynolds](#), Meteorologist in Charge, Center Weather Service Unit Albuquerque, NM



Figure 1: USAF B-52H Stratofortress flight that encountered mountain wave turbulence and lost its vertical tail, Jan. 10, 1964. Photo courtesy of White Eagle Aerospace History Blog.

With the onset of fall, strong “westerlies,” the prevailing winds blowing from the west on the poleward sides of the horse latitudes, are beginning to develop across much of the country in response to the seasonal southerly shift of the jet stream.

As winds become stronger aloft, mountain wave turbulence will develop more often and may cause significant damage to the structure of aircraft (**Figures 1-3**) and result in loss of control. General aviation pilots may also experience greatly reduced climb

rates due to severe downdrafts generated by mountain waves. Because of their life-threatening effects, it is important to understand the often unseen hazards attributed to mountain wave turbulence.

Though primarily a western U.S. problem, due to the numerous tall mountain ranges in this region, mountain wave turbulence can occur in association with just about any sizeable mountain or



Figures 2-3: American International Airways' DC-8 aircraft after losing its No. 1 engine due to mountain wave turbulence, Dec. 9, 1992. Photos courtesy of Northwest Airlines.

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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 4: Hypothetical air flow pattern associated with a mountain wave.

line of mountains. Mountain waves develop on the lee, or downwind, side of mountains. These waves are generated when strong winds flowing toward mountains in a generally perpendicular fashion are raised up over the mountains. As the winds rise, they may encounter a strong inversion or stable air barrier over the mountains that causes the winds to be redirected toward the surface. Instead of reaching back down to earth, the winds continue in an up-and-down wave-like pattern downwind of the mountains (**Figure 4**) that may extend for hundreds of miles.

Mountain waves generally exist in smooth undulating airflow, and can be a benefit to glider craft operations. Conversely, however, mountain waves may contain strong clear air turbulence in the form of breaking waves and rotors, which can be damaging to all sizes of aircraft.

If the amplitude of a wave is large enough, the waves

may become unstable and break away from the main flow leading to turbulent breaking waves (**Figure 4**). Rotors, air spinning rapidly like a wheel, can occur where wind speeds change in a wave or where friction slows the wind near the ground.

Though invisible at times, the existence of mountain waves, breaking waves and rotors can be given away by visual clues in the sky. Altocumulus standing lenticular clouds (ACSL) can develop at the top of individual waves above and downwind of mountains producing a mountain wave if sufficient moisture is in place (**Figures 5 and 6**).

If ACSL clouds are present, they can sometimes extend laterally along the entire length of the waves. The clouds would be parallel to the mountains from which they are developing.

As was previously mentioned, mountain waves can extend for hundreds of miles from the orographic feature from which they are



Figures 5 and 6: Clouds associated with mountain waves. Photos courtesy of the Comet Program.

derived. This extreme downwind extension can sometimes be seen in cloud patterns through the use of satellite imagery (**Figure 7**). Although scanning the skies for visual clues can help determine the presence of mountain wave turbulence within 50 miles or so, you should use satellite imagery as a pre-flight tool to identify mountain wave turbulence over an extended route of flight.

Lines of ASCL associated with mountain wave turbulence look like ripples in a puddle of water in satellite imagery. (**Figures 7 and 8**). Unfortunately, while it can be fairly easy to see mountain wave cloud patterns in satellite imagery under the right conditions, this same imagery cannot help a pilot determine the altitudes where the turbulence exists. It is probably best for the general aviation pilot to avoid flying in any area that is under the influence of mountain wave turbulence altogether.

Another tool pilots can use to determine the existence of mountain wave turbulence, especially when few if any clouds are present over a flight route, are pilot reports. The chances are probably high that someone has recently ventured into an area in or along a pilot's intended route of flight. Someone else's experience in the air may cause a pilot to decide the flight they want to take may not be in their best interest.

In conclusion, there are few other meteorological phenomena that can be as much of a hindrance or help to flight

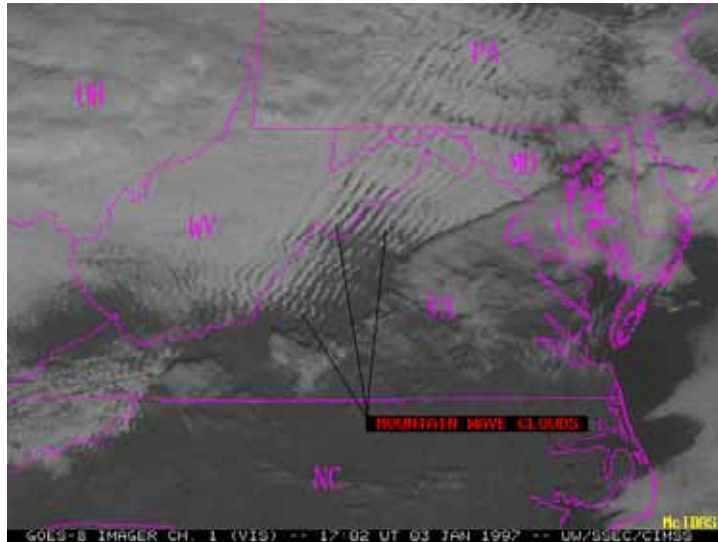


Figure 7. ACSL clouds extend downwind of the Appalachian Mountains. (Photo courtesy of the Cooperative Institute for Meteorological Satellite Studies)

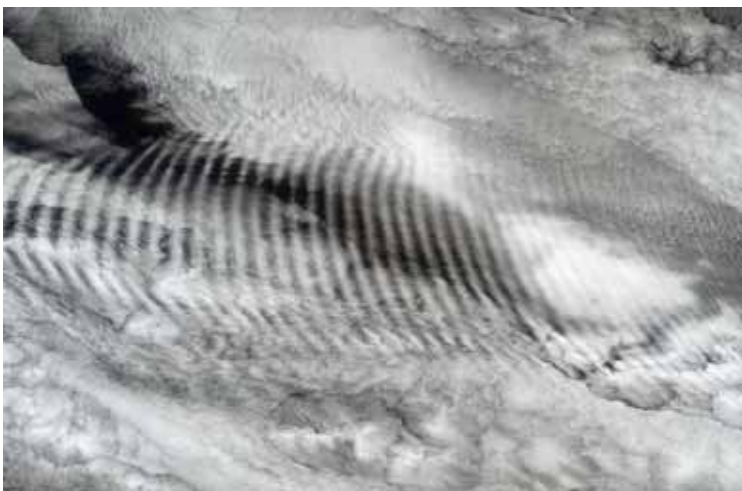


Figure 8. ACSL clouds extend far downwind of a mountain range. (Photo courtesy of NOAA)

operations as mountain wave turbulence.

While optimal mountain wave turbulence has helped glider pilots attain record high and long-lasting flights, when it is unexpected, it can be deadly.

As with any flight, situational awareness of the enroute environment is key. Mountain wave turbulence adds one more level of complexity to those flying along or downwind of tall peaks and mountains from the fall through the spring seasons. ➔

Here Comes the Sun! There Goes Your Communications!

By [Joseph Kunches](#), *Space Scientist, NOAA Space Weather Prediction Center*

Safe flights require a number of things to go right. Among these are the ability to communicate, especially at critical times. But communications, especially High Frequency (HF), can be hampered when, of all things, the sun interferes. Well, here comes the Sun!

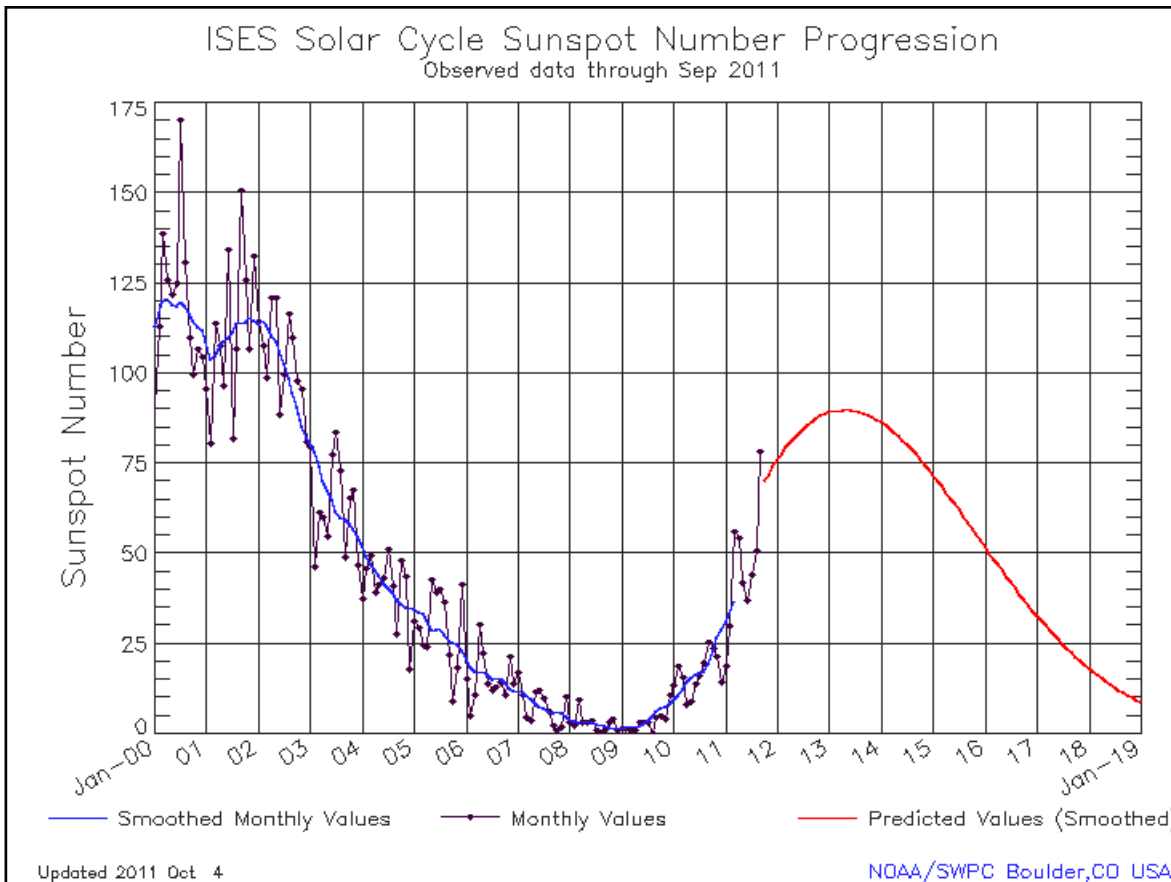


Figure 1: Solar sun spot number progression

The new solar cycle is underway. Numbered Solar Cycle 24, the current rendition of the roughly 11-year-long sunspot cycle record, illustrates how the solar magnetic field intensifies and wanes over time.

As the new cycle ramps up, eruptive activity increases. Predicting those eruptions is the job of the [Space Weather Prediction Center](#) (SWPC). The SWPC monitors the Sun and solar wind 24/7. SWPC issues alerts, warnings and watches to the public and affected customers online and via email through [SWPC's Product Subscription Service](#).

At the Sun, strong magnetic fields actually cause the region to be cooler than the background, appearing as dark blemishes. Sunspots are not hard to observe from Earth. The Chinese recorded observations as far back as a few thousand years ago. The modern record extends back to about 1700. **Figure 2** shows the variability of sunspots over time.

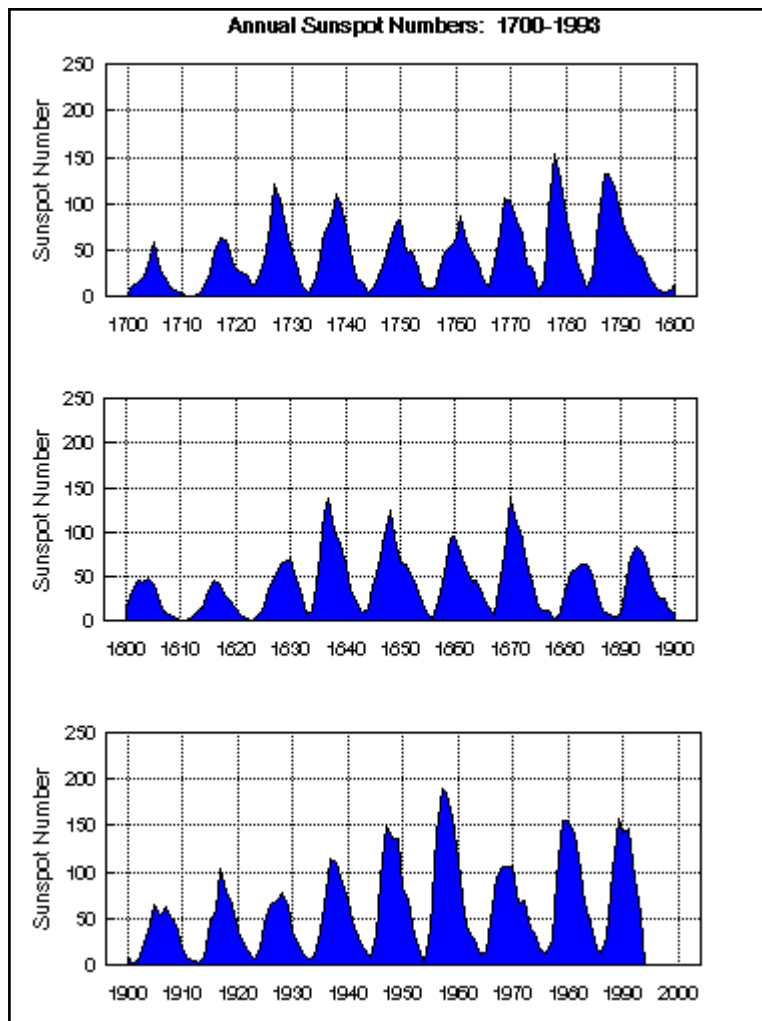


Figure 2: Variability of sunspots over time

In **Figure 3**, the bright areas are sites of very strong magnetic fields. At a lower level of the solar atmosphere, which can be seen from the ground, those regions are dark and have sunspots. The dark regions in this picture relate to weak magnetic fields associated with another feature referred to as coronal holes.

When the magnetic field intensifies, local areas produce eruptions, solar flares and coronal mass ejections. Flares are literally flashes of energy, from the radio to x-ray wavelengths. Coronal mass ejections are clouds of the Sun itself, the outer corona of which is shot into space. Plasma consists of charged particles and a magnetic field. When one of these clouds goes by Earth, magnetic storms often ensue.

But back to flares: an unwanted consequence of these lovely bursts of light and energy is they shower the day-side ionosphere—the upper atmosphere of the Earth consists of a cold plasma that turns radio waves around the curvature of the horizon—with extreme ultraviolet light (EUV). This EUV liberates even more electrons, but the electrons are lower down in the ionosphere than usual. The so-called D Region is put in a state that, rather than mirror HF back to earth, attenuates or even absorbs the HF transmission. This effect causes HF blackouts for up to a few hours for the major events.

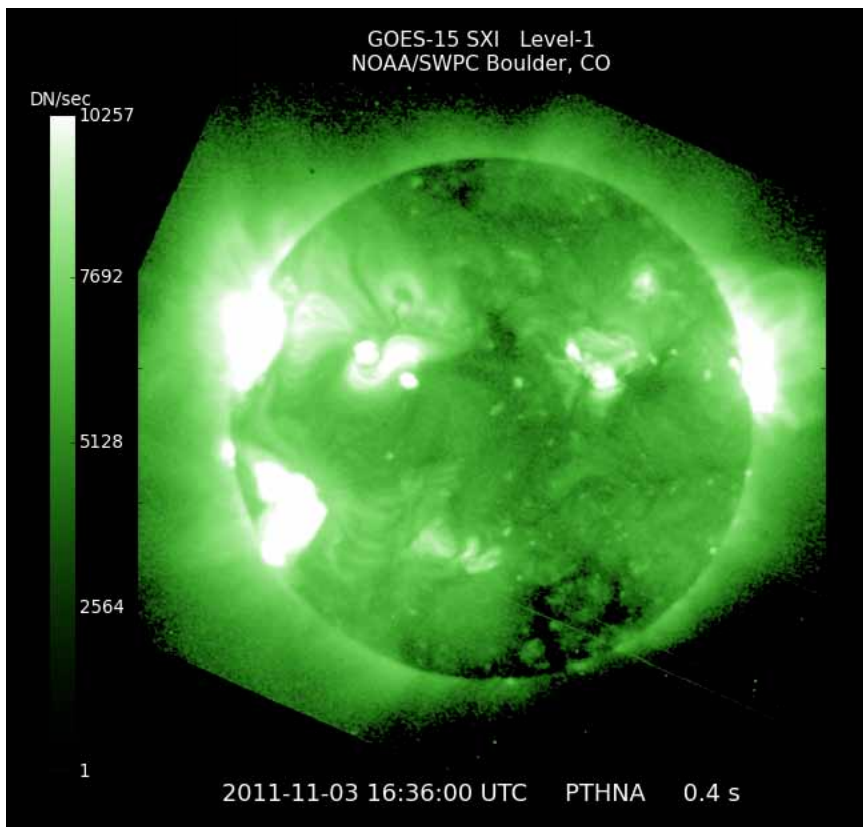


Figure 3: The bright areas are sites of very strong magnetic fields

The SWPC operates a real-time model showing HF impacts from solar flares. **Figure 4** shows the affected region over which HF is absorbed to various degrees. The bottom right of this figure offers a prediction of the disruption duration. This model runs in real-time. The input data is primarily solar x-ray flux displayed here.

There is also a companion model for polar and high latitudes fueled with energetic proton flux. The ionospheric physics at high latitude is different from that at middle and low latitudes. It is the precipitation of protons that causes the ionosphere to absorb the HF transmissions. [Both of these models are online.](#)

As the new cycle develops, these events will become more common and potentially dangerous. Check for HF information at the SWPC site. →

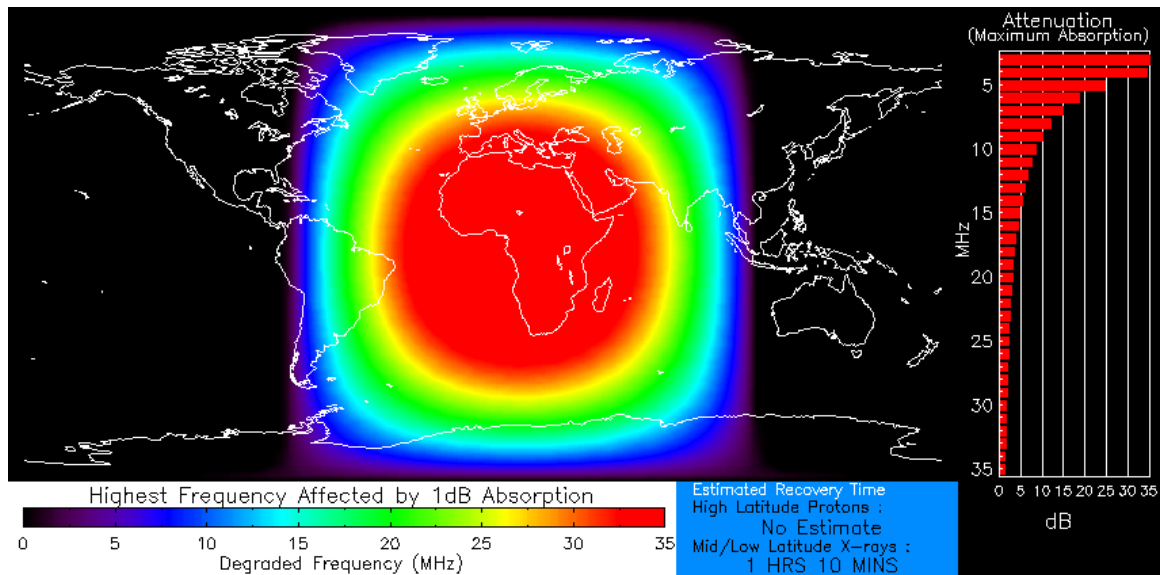


Figure 4: Affected region over which HF is absorbed to various degrees

Flying in the Void, PIREPS Vital to Flight Safety

Gregory S. Harris, Aviation Meteorologist, Aviation Weather Center

During thunderstorm season, it is important to know where NWS Weather Radar has significant gaps in coverage, i.e., where there are no weather radar echoes. West of the 102nd meridian, high terrain blocks the radar beam, leaving voids in weather radar coverage. The beam blockage affects the accurate depiction of thunderstorms across the airspace. In some regions, the lack of a weather radar is to blame. The areas with no coverage are shown in **Figure 1** as unshaded, white, areas. Knowing these vulnerabilities is important.

The gaps or voids in weather radar coverage affect more than the NWS. Since the NWS is the provider for weather radar information, any system receiving this data also will be affected.

The weather radar gaps will be evident on Air Traffic Control (ATC) displays and in-cockpit datalink weather services providing NEXRAD radar imaging. These gaps in radar coverage necessitate greater reliance on pilot reports of convective activity, making the Pilot Report (PIREP) a vital tool in these areas.

When flying in or through these radar data voids, communicating en-route weather conditions via the PIREP is critical to air safety. A PIREP provides vital information that improves aviation forecasts and warnings, especially when the convective activity is not viewable on ATC displays. The controllers rely heavily on the pilot to provide reliable information they can use to reroute air traffic when necessary. Although pilots and controllers may be discussing convection while trying to deviate around the weather, the weather may not be transmitted as a PIREP if you do not report it.

Please request to report a PIREP when dealing with convective weather so it can be rebroadcast to other pilots, controllers and meteorologists. Transmission of this information enhances safety of flight, weather hazard forecasts and warnings. The following examples highlight the WX and EM sections:

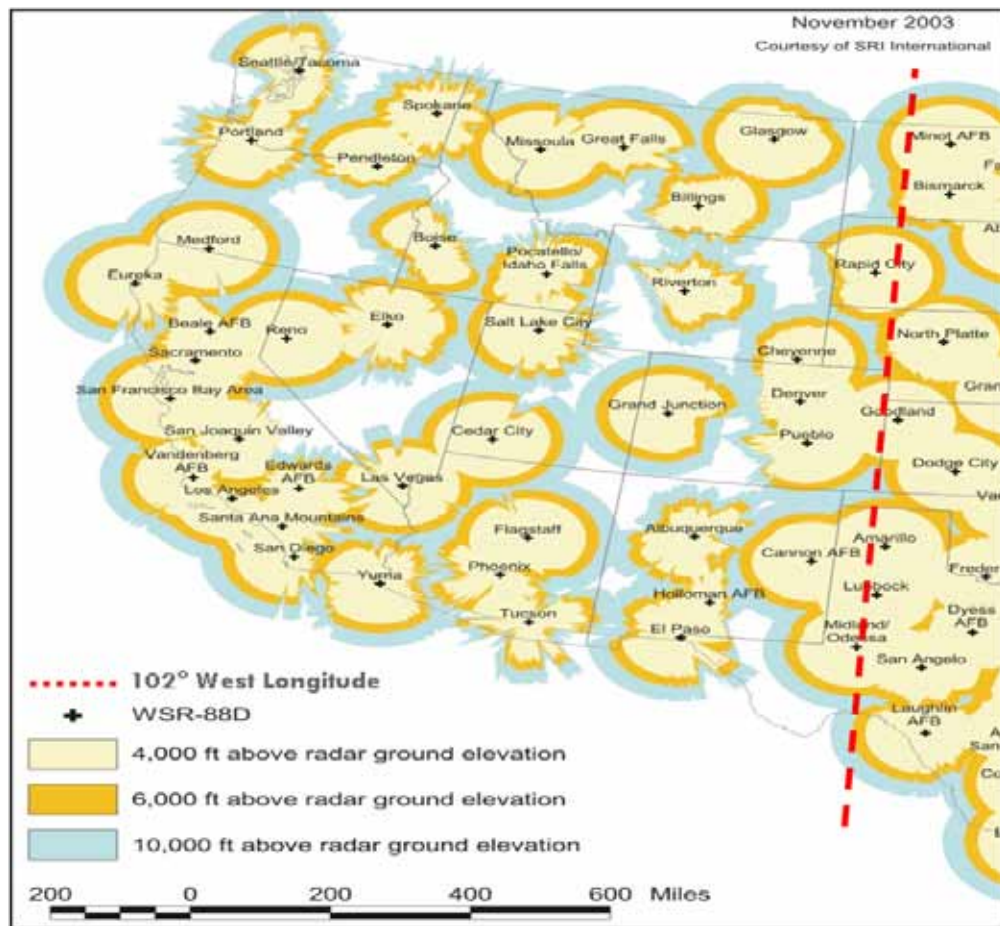


Figure 1. NWS Weather Radar Coverage Map west of 102° Longitude. Courtesy SRI International

UA OV SJN/TM 1815/FL300/TP B737/WX TS ALQDS/RM TS TOPS FL340..DEV
20 MI N OF CRS..RAPID DVLPMT

UUA OV FTI/TM 2110/FL180/TP E145/WX 1 INCH HAIL/RM TS OVR
MOUNTAINS..TOPS UNKN..BASES 080

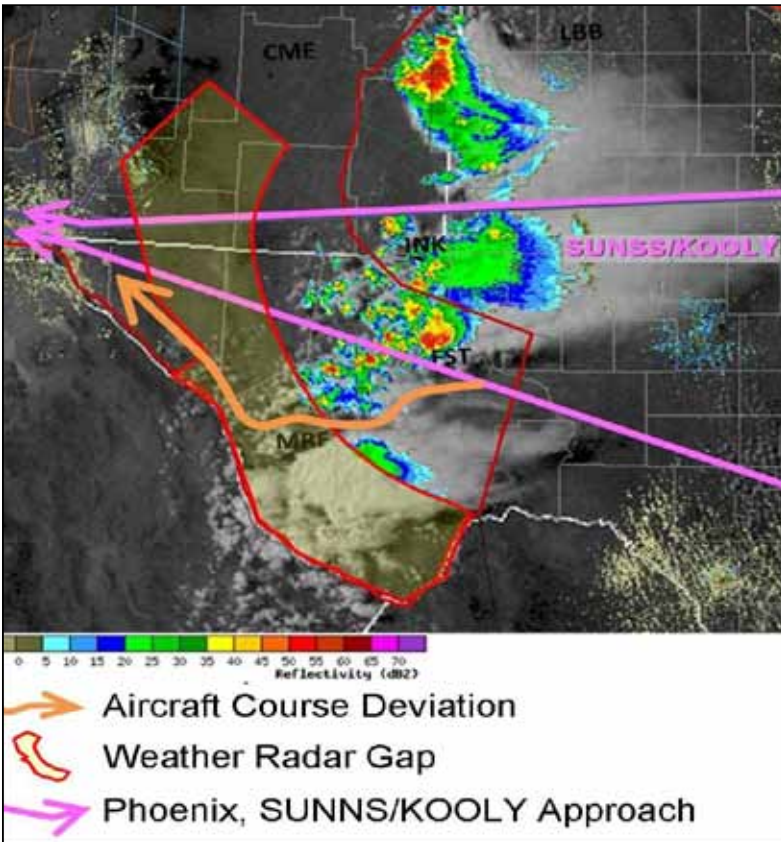


Figure 2: Example of aircraft deviation with weather radar, visual and radar gaps indicated. Satellite and radar imagery are courtesy of NWS.

Figure 2 shows scattered thunderstorms over Southwest Texas (SW TX) at 23 UTC on May 25, 2008. The red highlight indicates a weather radar void; the orange line traces the aircraft’s deviation to avoid the thunderstorms.

Notice the clouds are well developed north and south of Medium Range Forecast as the aircraft picks its way through the storms. Such cloud development suggests active thunderstorms in the weather radar void. The available weather satellite data is not as timely as lightning detection (Table 1).

As aircraft move into an area with no weather radar coverage, reporting and distribution of PIREPs greatly enhances safety. FAA Order 7110.10 states, “Urgent PIREPs are to be transmitted as soon as possible,” while routine PIREPs will be transmitted “...as soon as practical.”

Regarding the air traffic controller’s updates to the Hazardous Inflight Weather Advisory Service: “The update recording shall be completed as soon as practicable, but not more than 15 minutes from time of receipt of new hazardous weather information.” FAA Order 7110.10 Chapter 2, Section 4.

Table 1 shows the typical delay times involved in the receipt of data from radar, lightning, satellite and PIREP information. It is essential to understand the time delays when making a route or reroute decision.

Understanding the information noted in Table 1 and the data voids shown in Figure

1 better equips you to smartly use in-cockpit satellite datalink weather data. Using just one source of data is insufficient to maintain vigilance during the convective season. A good practice is to use the lightning data in conjunction with radar. Figure 3 shows lightning detection efficiency over North America.

To further clarify the application of lightning data in areas of sparse

Table 1. Radar/Lightning/Satellite/PIREP Latency Matrix	
Product	Delay in Minutes
Radar	≈ 3-11*
Lightning	≈ 5**
Satellite	≈ 15**
PIREP	≈ 5 [!] - 15 ^{!!}
<p>* Approximation due to differences in scan times with various Volume Coverage Pattern modes.</p> <p>** Approximation due to differences in vendor receipt and transmittal practices.</p> <p>! In accordance with FAA Order 7110.10, severe PIREPs are to be transmitted “as soon as possible;” routine PIREPs “...as soon as practical.”</p> <p>!! Delays due to differences in transmittal practices from sources such as FAA, Flight Service Station and airline dispatch.</p>	

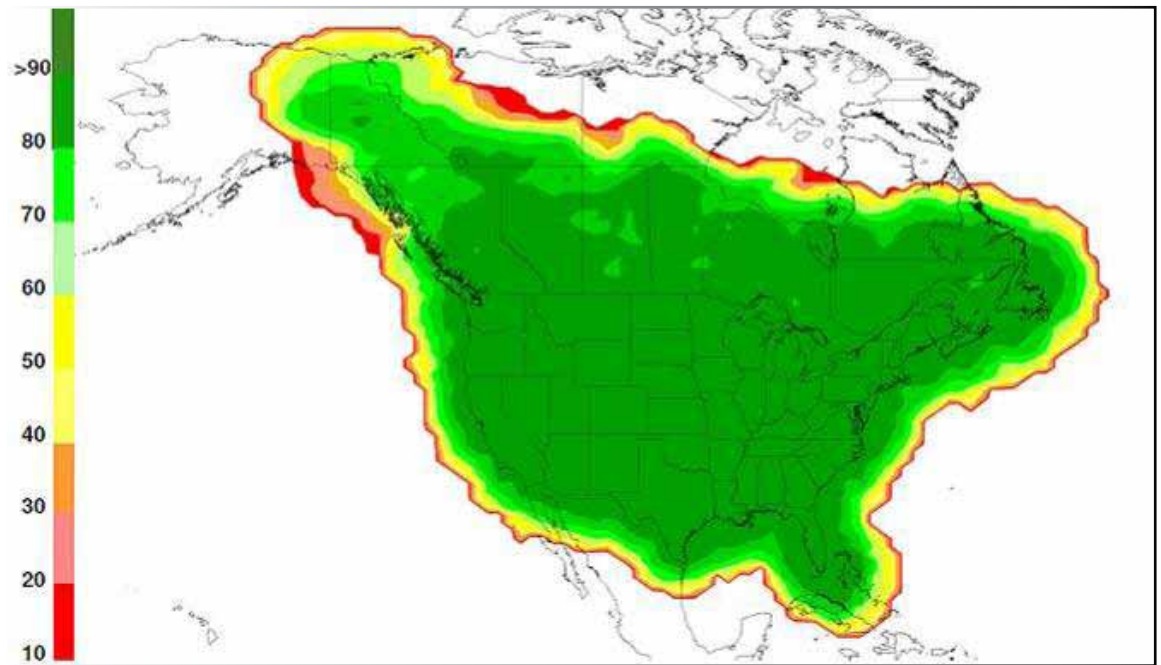


Figure 3: Map of the detection efficiency (DE) over the United States and Canada for the North American Lightning Detection Network. This map indicates over 90% detection of all cloud-to-ground lightning flashes over the contiguous 48 states in the National Lightning Detection Network. Image courtesy of Vaisala.

weather radar coverage, consider the following example from the radar data void over the southeastern plains of Montana and western North Dakota. WSR-88D radar data is shown from the Glasgow, MT, and Minot, ND, radars in **Figures 4-6**. The images show composite reflectivity with lightning

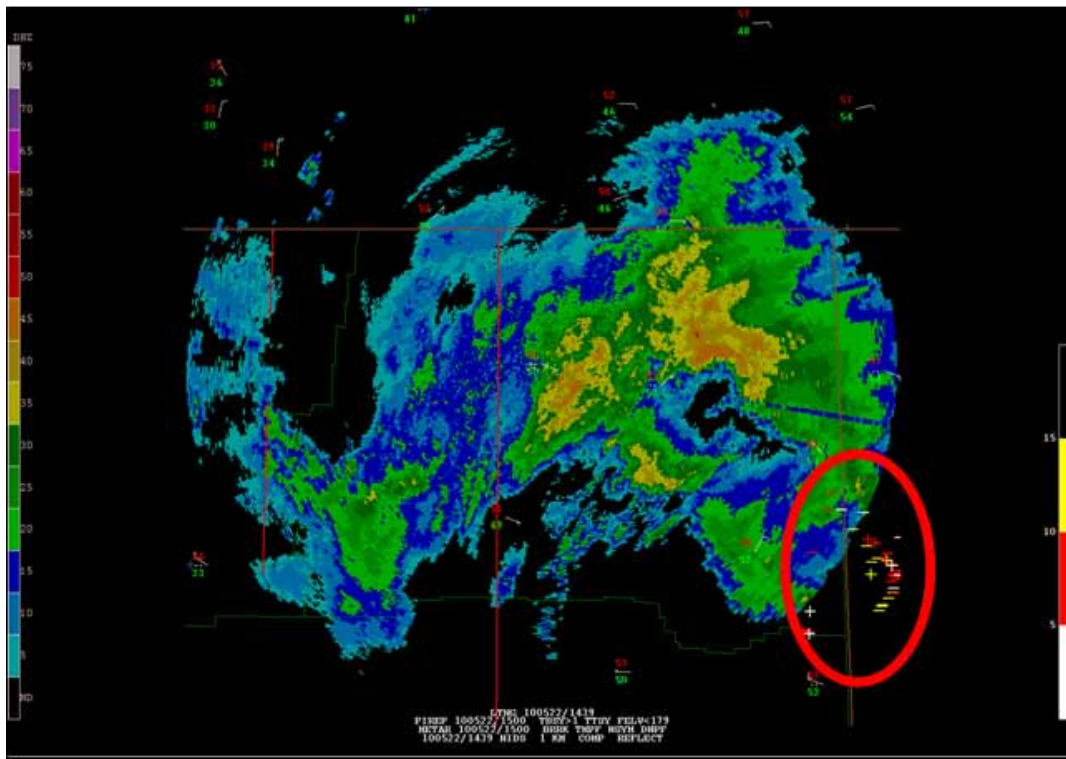


Figure 4: Glasgow, MT, composite reflectivity valid 1439Z on 5/22/2010 with 0-5 minute (white), 5-10 minute (red), and 10-15 minute (yellow) lightning data, surface observations, and PIREPs. The lightning plots on the lower right hand side of the image are outside the radar antenna's range (red circle).

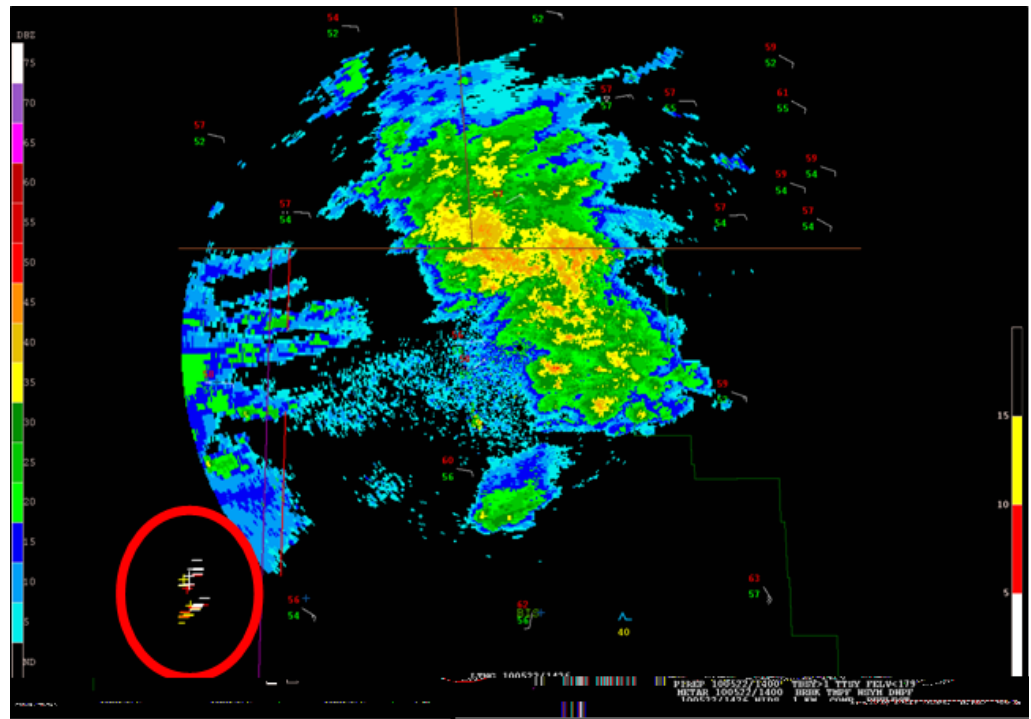


Figure 5: Shown is Bismarck, ND, composite reflectivity valid 1426Z on 5/22/2010 with 0-5 minute (white), 5-10 minute (red), and 10-15 minute (yellow) lightning data, surface observations, and PIREPs. The lightning plots on the lower left hand side of the image are outside the radar antenna's range (red circle).

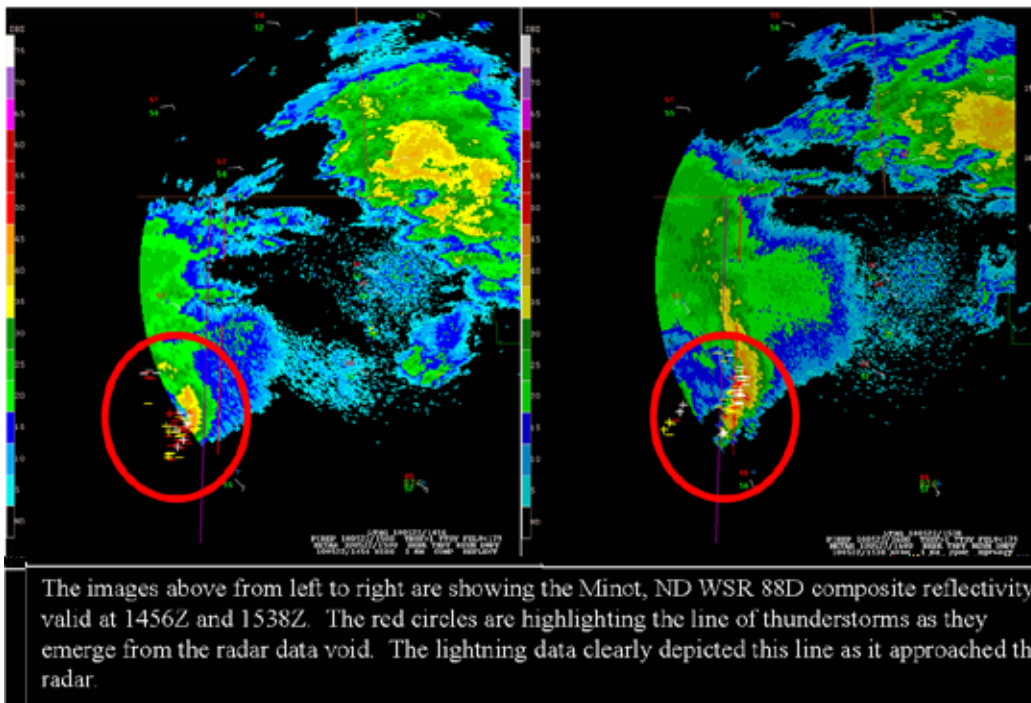


Figure 6: Shown is Minot, ND, WSR-88D composite reflectivity valid 1456Z (left image) and 1538Z (right image) with 0-5 minute old (white), 5-10 minute old (red), and 10-15 minute old (yellow) lightning data, surface, and PIREPs overlaid.

data, surface observations, and PIREPs as overlays.

In summary, NWS meteorologists work closely with the airspace managers and controllers and are aware of these data voids.

NWS provides training to controllers on seasonal weather hazards and potential remote sensing issues.

NWS meteorologists also provide face-to-face consultation with controllers, alerting them to current and forecast icing, turbulence, and convective hazards.

Your knowledge of the risks and problems with using remote sensing sources increases your understanding of weather data limitations. These limits are why we continue to ask for your PIREPs, a vital source for enhanced flight safety. ➔