The Front

NOAA's National Weather Service | February 2014

Daily Wind Changes in the Lower Levels of the Atmosphere

Jeff Halblaub, Meteorologist, NWS Hastings, NE

On most days, winds change substantially between the surface and the lowest few thousand feet above ground level (AGL). These changes are part of the daily cycle driven by the sun. The atmosphere behaves like a fluid. The layer of fluid in contact with an underlying surface is called the boundary layer. The atmospheric boundary layer moves through a daily cycle based on heat from the sun.

This cycle of daytime heating and nighttime cooling explains why, under most circumstances, higher winds are confined above the surface at night. As low-level temperatures warm during the morning hours, those higher winds gradually drop down to the surface, resulting in daytime gustiness.

A well-mixed boundary layer results in substantial turbulence. This turbulence is magnified when cumulus clouds form posing challenges to Visual Flight Rules (VFR) operation. When flying above the boundary layer, which is generally much smoother, there is an abrupt increase in turbulence during descent into the boundary layer. This turbulence continues down to the runway.

Pilots frequently must deal with daytime gustiness during takeoffs and landings. These gusty surface winds usually begin in the late morning hours, peak in the afternoon, and end by early evening. Winds in the low-levels become much more uniform at night and in predawn hours. Departures into a strong temperature inversion can result in smooth flight conditions. There is, however, the occasional threat of low-level wind shear and turbulence at the transition between the cool surface air and the higher winds just a couple thousand feet AGL. This threat is especially strong if there is a sharp change in wind direction.

During the night, the loss of the sun's radiation causes the earth's surface to lose the heat it builds up during the day. This cooling creates a shallow, stable layer of air near the ground, resulting in a temperature inversion. In an inversion, the temperature in the layer above the ground is actually warmer than it is near the surface.

The increased stability limits the transfer of temperature, humidity, and wind down to the surface from the rest of the atmosphere above. The term for this is called decoupling, where this layer is no longer "aware" of what is occurring above it. The winds above the inversion can be strong while in the stable layer below, winds are calm or light.

Inside

When's the Next ***Front?***

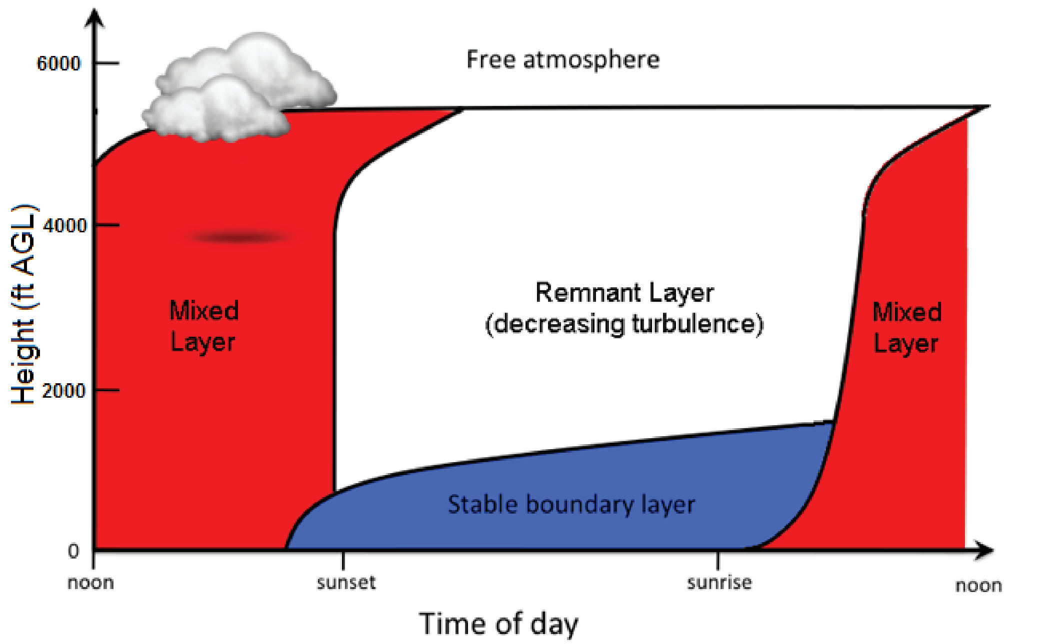
Would you like an email when a new edition of **The Front** *is online? Email* Melody.Magnus@noaa.gov. *Your subject line for the email should be "Subscribe to The Front."*

The Front

Program Manager:
Michael Graf
Managing Editor:
Melody Magnus
Editor: Nancy Lee

Mission Statement

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



Boundary layer evolution during a diurnal cycle (adapted from Stull, 1988)

Stull, R. B., 1988: An Introduction to Boundary Layer Meteorology.

This change in wind character can occur over a very short depth of 100 feet or less.

After sunrise, the sun's radiation begins warming the earth's surface. As this occurs, parcels (or bubbles) of warm air begin to rise within the cool layer. These parcels can be compared to the initial stages of a pot of water on the stove. As the pot becomes hotter, bubbles form at the bottom. They become warmer than the rest of the water and begin rising one by one to the top of the water. As the water gets hotter, more bubbles form until the water is boiling.

A similar event occurs in the lower atmosphere. The first few parcels rise into the warmer air left from the previous afternoon. The parcels can only rise so far before they reach equilibrium with the temperature of the surrounding environment. Just like the pot on the stove, as the sun continues to warm the ground, the parcels become warmer, allowing them to rise through the lowest few thousand feet AGL and mix deeper into the lower levels of the atmosphere (see figure above). This process continues until the previous afternoon's warmth is completely replaced and deep mixing occurs between the earth's surface and a few thousand feet AGL. This process results in an evolution of the progressively expanding boundary layer during the daytime hours.

As mixing occurs, the boundary layer becomes coupled (or "aware") to what is occurring in the rest of the lower atmosphere. As a result, temperature, humidity, and wind are thoroughly "mixed" throughout the lowest few thousand feet AGL.

If there is sufficient moisture, cumulus clouds form at the top of the boundary layer. These clouds can further increase the magnitude of the turbulence. Typically, cooler temperatures, drier air, and higher winds mix downward to the surface. This mixing is why winds are usually gustier at the surface during the daytime. The result is called thermally-induced turbulence, which extends through the depth of the boundary layer. Thus, when aircraft are flying above the boundary layer and descend into it, there is an abrupt increase in turbulence. This change also explains why winds in the lowest 3000 to 5000 feet gradually make their way to the surface during the late morning hours.

As the sun's radiation wanes late in the day, the temperature of the earth's surface begins to fall. Stability increases and cooling air parcels can no longer rise into the warmer surroundings. A key sign of this change is that any cumulus clouds that might have formed begin to decrease in coverage and eventually dissipate. Surface wind speeds drop and gustiness comes to an end as the cooling layer near the surface decouples from the remnants of the afternoon boundary layer. Without the mixing, winds within this remnant layer gradually become less turbulent and begin to behave like the rest of the atmosphere, usually increasing in speed with height AGL. With much lighter or even calm winds within the newly formed boundary layer, the interface with the increasing speeds aloft can create wind shear, referred to as mechanical turbulence.

There are days when other factors alter this diurnal trend such as low pressure systems or a strong pressure gradient. Extensive cloud cover and temperature inversions near fronts can also significantly limit the depth of the boundary layer. In areas with lush, green vegetation, the average depth of the boundary layer is lower versus arid or desert regions. Because the earth heats up more over dry, rocky soil, the average boundary layer is much higher, from 8,000 to 12,000 feet.

As a pilot, being aware of the local regime or weather pattern (high pressure location/frontal positions) and looking at the METARs over the past 24 hours will help you begin to anticipate the local nuances for your preferred airfield. For example let's look at Avoca, Wilkes-Barre Scranton, PA.

KAVP, under high pressure, typically the winds become calm toward sunset. Later in the evening and overnight, the colder winds from the ridges to the northeast, providing a steady overnight wind, typically something like 05007 kts. Then with sunrise, the northeast winds die off, followed by a few hours of calm winds. By 9 am to 10 am, the influence from the winds aloft due to the heating mechanics discussed above would set up the afternoon wind direction and speed through the rest of the day.

This is just one example for a local airport. By taking time to associate the local weather pattern with the METARs, you'll gradually be able to better anticipate typical wind patterns that might affect your flight.

General Aviation: Identify, Communicate Hazardous Weather

Reprinted with permission from the National Transportation Safety Board

The overwhelming majority of aviation-related deaths in the United States occur in general aviation (GA) accidents. In 2011, there were 1,466 GA accidents, of which 263 were fatal; 444 people were killed. The accident rate per 100,000 flight hours remains substantially higher in GA than in commercial aviation (6.51 for GA compared to 1.5 for on-demand Part 135 operations and 0.162 for scheduled Part 121 operations).

Historically, about two-thirds of all GA accidents occurring in instrument meteorological conditions (IMC) are fatal—a rate much higher than the overall fatality rate for GA accidents. IMC refers to meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling less than the minimums specified for visual meteorological conditions.

A frequent contributing factor to these accidents is hazardous weather. For example, on December 19, 2011, a Piper carrying the pilot and four passengers impacted terrain following an in-flight break up near Bryan, TX. NTSB investigators determined the probable cause of the five-fatality accident was the pilot's inadvertent encounter with severe weather, which caused the left wing to fail. One of the issues identified in the investigation was the presentation of weather radar data in the cockpit, obtained through the pilot's subscription to satellite-based weather services.

The NTSB continues to examine the Federal Aviation Administration's (FAA) weather information dissemination practices in recent investigations as well as the consistency of NWS weather advisory products for the aviation community.

While having weather information available to pilots, air traffic controllers, and meteorologists is crucial, misunderstanding and misuse of this information can prove just as dangerous, if not more dangerous, as not having that information at all. Examples include pilots gaining a false sense of confidence that may lead them unknowingly into adverse weather conditions, or air traffic controllers not effectively using weather information they have to assist pilots in avoiding such conditions.

What Can Be Done . . .

In the almost 50 years of NTSB accident investigations, the Board has determined solutions to weather issues fall into three broad areas:

- Ensuring pilot training and operations
- Creating weather information and advisories
- Collecting and disseminating weather information, particularly by the NWS and the FAA

The first line of defense in preventing a GA weather-related accident are the pilots. Pilots decide when and where to fly the aircraft. Therefore, training on how to obtain and use hazardous weather information is critical. In addition, granting pilots, as well as FAA-contracted weather briefers, access to real-time weather information through weather cameras would further enhance operators' situational awareness.

Another key line of defense is air traffic controllers, who provide weather data to pilots prior to, and during flight. Pilots then use this information to decide when and where to fly. To meet these needs, controllers must have unimpeded access to critical information on key weather scenarios, such as mountain wave activity advisories and real time lightning data.

A mountain wave is the wave-like effect, characterized by updrafts and downdrafts, that occurs above and mainly to the lee of a mountain range when rapidly flowing air encounters the mountain range's steep front in a near-perpendicular fashion within a supportive vertically stable atmosphere (referred to as a mountain wave-supporting environment). Mountain wave activity refers to these updrafts and downdrafts, their associated turbulence, and other wind phenomena that can occur in association with a mountain wave-supporting environment, such as rotors, hydraulic jumps, and down-slope wind events.

Controllers must also be trained and equipped to transmit this critical information expeditiously. Further, because controllers are the primary recipients of pilot reports (PIREPs), the FAA must have the infrastructure and protocols in place to ensure such vital information is conveyed in the national airspace system (NAS).

What is the NTSB doing?

In 2005, the NTSB conducted a safety study to better understand the risk factors associated with accidents occurring in IMC or poor visibility. This report was the fifth on weather-related GA accidents since the NTSB's creation in 1967. The NTSB has also explored hazardous weather issues in numerous GA accident investigations. Based on this body of research, the NTSB has reached out to the various operator and user groups to engage more than 20 stakeholders across several agencies, including the FAA, the NWS, the National Air Traffic Controllers Association, the Aircraft Owners and Pilots Association, Lockheed Martin Flight Services, and the Air Line Pilots Association. To date, stakeholders have held initial meetings, and progress has been encouraging.

The NTSB continues to investigate and research ways to enhance hazardous weather communications. In early 2014, the NTSB intends to complete additional work on mountain wave activity and work on addressing NWS internal and external communications and operational use of PIREP information.

The NTSB is also examining the use of Light Detection and Ranging (LIDAR) information in Las Vegas and the structure of retrieving and disseminating airport runway wind information in the NAS. LIDAR is a method of remotely sensing atmospheric wind information by laser technology. Given the frequent role that weather plays in GA accidents, the NTSB will continue to examine all aspects of weather-related safety issues.


NTSB MOST WANTED LIST

CRITICAL CHANGES NEEDED TO REDUCE TRANSPORTATION ACCIDENTS AND SAVE LIVES

2014

GENERAL AVIATION: IDENTIFY AND COMMUNICATE HAZARDOUS WEATHER

What is the Problem?

The overwhelming majority of aviation-related deaths in the United States occur in general aviation (GA) accidents. In 2011, there were 1,466 GA accidents, of which 263 were fatal. 444 people were killed, and the accident rate per 100,000 flight hours remains substantially higher in GA than in commercial aviation (6.51 for GA compared to 1.5 for on-demand Part 135 operations and 0.162 for scheduled Part 121 operations). Historically, about two-thirds of all GA accidents that occur in instrument meteorological conditions (IMC)[1] are fatal—a rate much higher than the overall fatality rate for GA accidents.

A frequent cause of or contributing factor to these accidents is hazardous weather. For example, on December 19, 2011, a Piper carrying the pilot and four passengers impacted terrain following an in-flight break up near Bryan, Texas. NTSB investigators determined that the probable cause of the five-fatality accident was the pilot's inadvertent encounter with severe weather, which caused a failure of the left wing. One of the issues identified in the investigation was the presentation of weather radar data in the cockpit, obtained through the pilot's subscription to satellite-based weather services.

The NTSB continues to examine the Federal Aviation Administration's (FAA) weather information dissemination practices in recent investigations as well as the consistency of National Weather Service (NWS) weather advisory products for the aviation community. While having weather information available to pilots, air traffic controllers, and meteorologists is crucial, improper understanding and misutilization of this information can prove just as dangerous (if not more dangerous) as not having that information at all. Examples include pilots gaining a false sense of confidence that may lead them unknowingly into adverse weather conditions, or air traffic controllers not effectively using the weather information they have to assist pilots in avoiding such conditions.

1 Meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling less than the minimums specified for visual meteorological conditions.

Photo of post-accident cockpit and engine sections of a Socata TBM 700 aircraft following its encounter with severe icing conditions near Morristown, New Jersey on December 20, 2011.

What can be done?

In the almost 50 years of NTSB accident investigations, NTSB's recommended solutions to weather issues fall into three broad areas:

1. pilot training and operations;
2. the creation of weather information and advisories; and
3. the collection and dissemination of weather information particularly by the NWS and the FAA.

The first line of defense in preventing a GA weather-related accident is the GA pilot; he or she makes the decision of when and where to fly the aircraft. Therefore, appropriate training on how to obtain and use the proper information to address hazardous weather is critical. In addition, granting pilots, as well as FAA-contracted weather briefers, access to real-time weather information through weather cameras will further enhance operators' situational awareness.

for more information, visit: www.ntsb.gov/mostwanted

National Transportation Safety Board

For more information, see the ***NTSB Most Wanted List.***