The Front

NOAA's National Weather Service July 2011

Thunderstorm Formation and Aviation Hazards

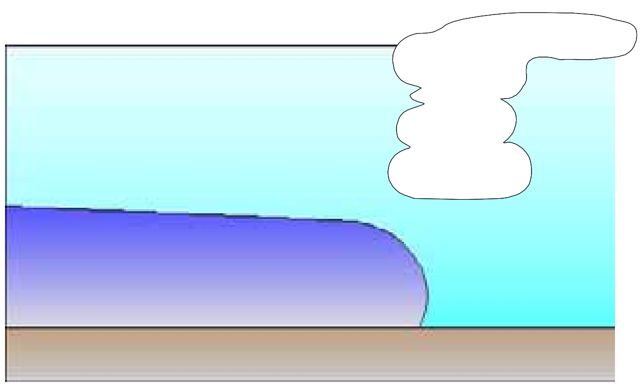
By Ken Harding, Meteorologist in Charge, WFO Topeka, KS

Thunderstorms are one of the most beautiful atmospheric phenomenon. As a pilot, however, thunderstorms are one of the most hazardous conditions you can encounter. All thunderstorms can produce severe turbulence, low level wind shear, low ceilings and visibilities, hail and lightning. Each of these hazards can be difficult to cope with; if all these conditions arrive at once, it can be disastrous. Understanding basic thunderstorm formation and structure can help you make safe decisions.

Thunderstorms are formed by a process called convection, defined as the transport of heat energy. Because the atmosphere is heated unevenly, an imbalance can occur which thunderstorms attempt to correct. Three things are needed for convection to be a significant hazard to flight safety: moisture, lift and instability.

- **Moisture**—Sufficient moisture must be present for clouds to form. Although convection occurs in the atmosphere without visible clouds, think thermals on a warm afternoon, moisture not only is the source of a visible cloud, but also fuels the convection to continue. As the warm air rises, it cools, and the water vapor in the air condenses into cloud droplets. The condensation releases heat, allowing the rising air to stay buoyant and continue to move upward.

- **Lift**—There are many ways for air to be lifted in the atmosphere. Convection, or buoyancy, is one method. Other meteorological methods include fronts, low pressure systems, interactions between thunderstorms, and interactions between the jet stream and the surface weather systems. Air also can be lifted by mechanical lift, such as when it is forced up and over a mountain range. Regardless of how the air is lifted, if the lift is enough to make the air warmer than the surrounding air, convection can continue.



Frontal lift

Inside

When's the Next *Front?*

Would you like an email when a new edition of **The Front** *is published? Write melody.magnus@noaa.gov.*

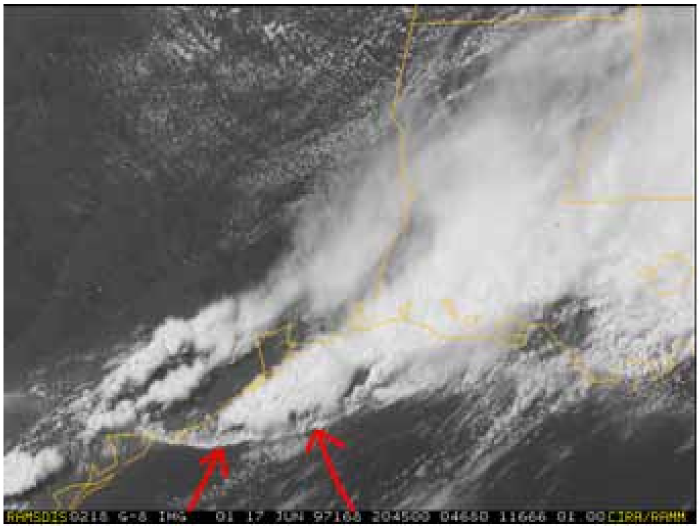
The Front

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

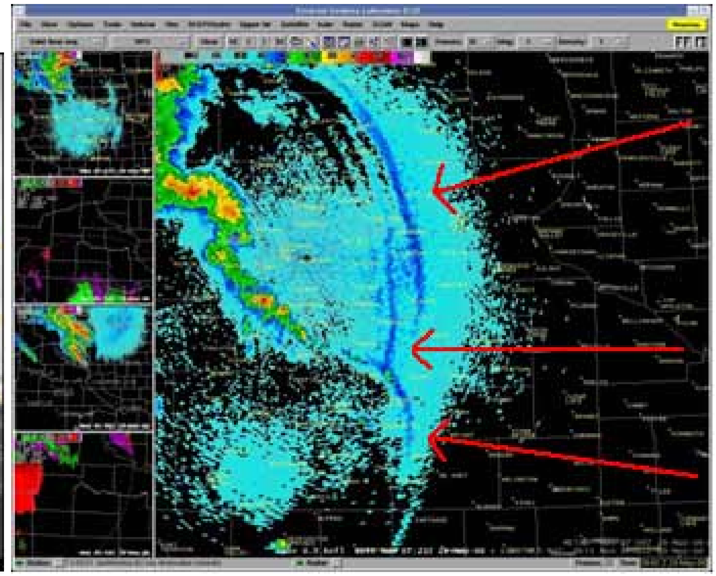
Mission Statement

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

Next, We'll look at the thunderstorm outflow boundary, which can have a significant impact on aviation. This boundary marks the leading edge of rain-cooled air flowing out from mature thunderstorms. These outflow boundaries can move many miles away from thunderstorms and may be associated with clouds.

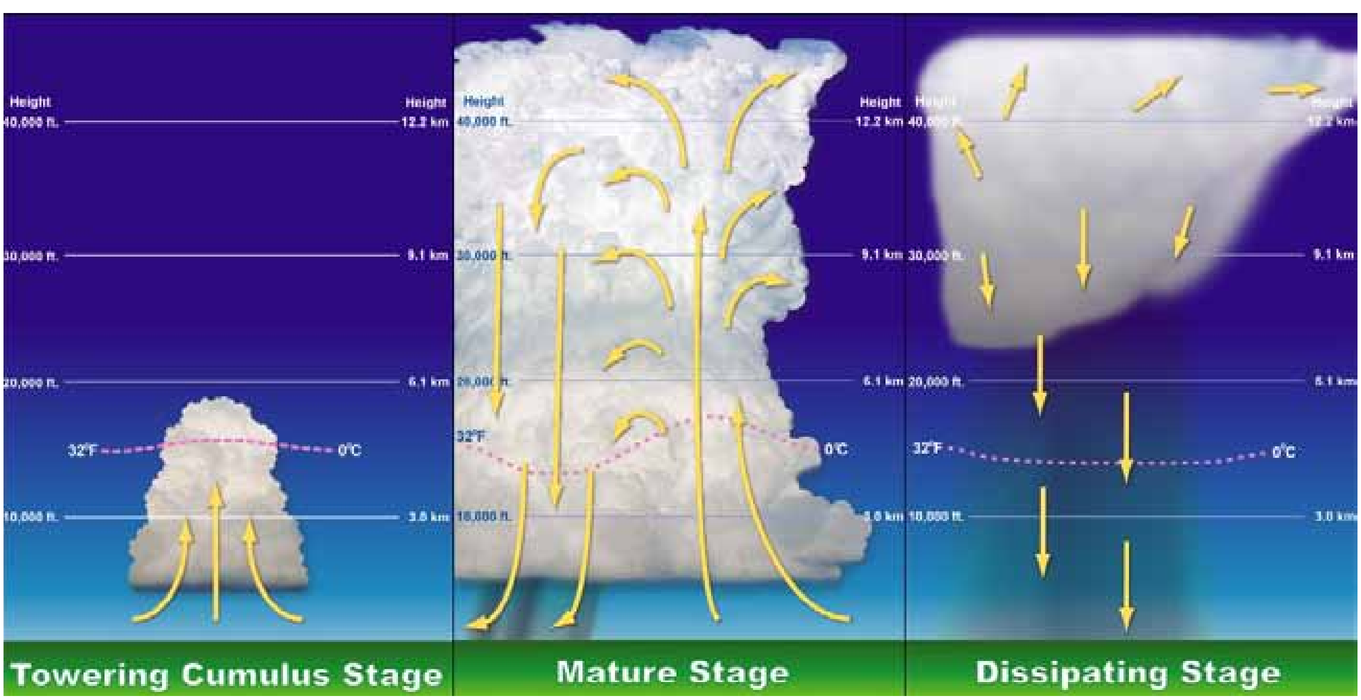


Satellite picture of outflow boundary



WSR-88D detection of multiple outflow boundaries

♦ Instability—In general, as you increase in altitude, the air temperature cools up to the top of the troposphere. Of course, around fronts, mountains and in shallow layers near the ground, this is not always the case. How fast air cools is a measure of atmospheric stability. Meteorologists refer to this vertical change in temperature as the lapse rate. Outside of extremes, the temperature generally decreases from between 2.7°F - 5.4°F per 1000 feet. If the actual rising air cools slower than the lapse rate, the air remains relatively warm compared to the surroundings, and it continues to rise.



Three Stages of Thunderstorms

Shown above are all three stages of thunderstorm development.

Towering Cumulus Stage: This is the stage of a thunderstorm once convection has begun and a cloud is visible. These building clouds are made entirely of liquid water. This stage is characterized by upward motion throughout the entire cloud. Aviation hazards from this stage include turbulence and icing. Even though the cloud is composed of all liquid, some of the liquid is "supercooled," in other words, liquid water can exist at temperatures below the normal freezing point.

Mature Stage: This stage is characterized by the production of precipitation. Both updrafts and downdrafts are present. Lightning is being produced. The mature thunderstorm contains water, supercooled water and ice.

Dissipating Stage: During this final stage, the updraft has ceased and the storm is dominated by downdrafts. Precipitation may still occur, but will decrease with time as moisture is depleted. This dissipating thunderstorm contains mostly ice.

You can visually estimate the potential for convection to continue by looking at the texture of the thunderstorms. If the cumulus tops are crisp and well defined—often looking like a cauliflower, the storm will continue to grow. The crisp texture occurs because the cloud is mostly made up of water drops with little ice. As the storm becomes more vertical, these water drops will change phase and freeze. This change will release heat, fueling the continued growth of the cloud.

Crisp clouds, (left) vs. fuzzy clouds (right) help you determine if a thunderstorm is growing.

If the clouds appears fuzzy, it is likely because they are now composed mostly of ice crystals As a result, the storm has much less energy available to grow significantly taller.

Individual thunderstorms generally last less than one hour; however, if the storms are being continually forced by a moving front outflow boundary or from the same terrain feature and area, thunderstorms can continue for many hours.

A special case of thunderstorms are known as supercell thunderstorms. Supercell thunderstorms have a structure, driven primarily by the changing wind speed and direction with height that allows the updrafts and downdrafts to remain separated. Thus, the storm can remain in the mature phase for extended periods—several hours or more. These supercell thunderstorms are often times associated with damaging winds, frequent lightning, large hail, severe to extreme turbulence, and low level wind shear.

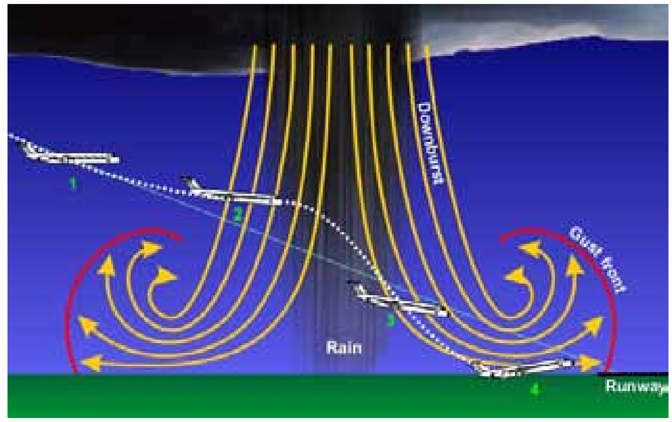
Supercell thunderstorm

Intense lightning

Hazards Associated with Thunderstorms

It is wise to avoid thunderstorms, as a flight instructor once said "A thunderstorm is never as bad inside as it looks from the outside—it is worse." Thunderstorms contain many hazards to aviation such as the following:

Lightning: By definition, all thunderstorms contain lightning. Although the NWS will mention lightning as a hazard in some warning products, lightning is not a criteria used to determine if a thunderstorm is severe. As an aviator, you should be aware that lightning can strike more than 10 miles from a thunderstorm. Lightning can strike the ground, another cloud or discharge into clear air.

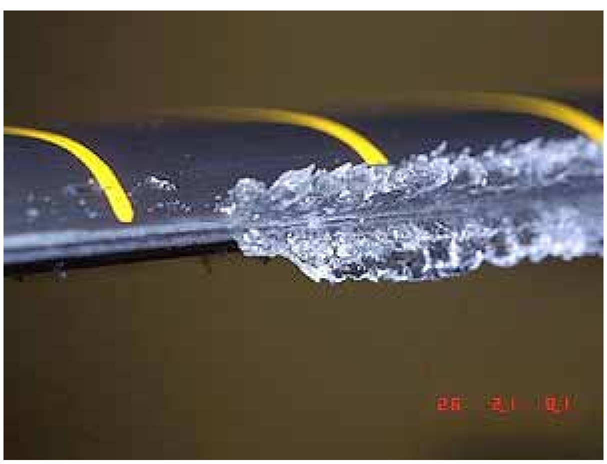


Microburst encounter

Turbulence: Pilot reports from aircraft encountering thunderstorms have noted up and down drafts exceeding 6000 feet per minute. Turbulence exceeding the performance capability of most aircraft can be found in and around thunderstorms.

Wind Shear: Thunderstorm outflow can cause extreme changes in wind speed and direction near the surface during critical phases of flight. Microbursts are possible with many thunderstorms, as is heavy rain. Often virga and blowing dust on the surface are your only clues to the presence of a microburst.

Icing: Because thunderstorms are driven, in part, from the conversion of liquid water to ice, pilots can expect to find airframe icing in all thunderstorms. Although all forms of icing are possible, clear icing, caused by larger drops of supercooled water, is the most common. Ice accumulation can be rapid. Supercooled water and clear icing can extend to great heights and to temperatures as low as -20^{o} C.



Example of icing on plane

The FAA publication, **Thunderstorm Avoidance Tips** puts it succinctly: "To rely solely on Air Traffic Control (ATC) as a source for weather avoidance is not entirely prudent. It is the pilot's responsibility to obtain a preflight weather briefing. Any ATC reported weather information, along with periodic contacts with Flight Watch while airborne, will supplement what was learned during the preflight briefing. The ATC reports of precipitation areas are of value because they can give you a global view of what is in the area. Pilots who have onboard weather radar or lightning detection systems can benefit from the big picture that ATC can paint and can use the aircraft's onboard systems to pick the best tactical route to avoid severe weather."

Source for More Pilot Information

The NWS Aviation Weather Center is one of your best sources for weather information. On the **Aviation Weather Center Website**, you can find preflight information on thunderstorms and other weather that may impact your flight. Before talking with Flight Service for your weather briefing and filing a flight plan, educate yourself on the potential for thunderstorm, and identify current SIGMETS and AIRMETS that may pertain to your route. Spend some time learning about thunderstorms, study the current and forecast weather. The time you put into weather study will greatly help your weather situational awareness. ✈

Knowing the TAF: News You Can Use

By Mike Graf, NWS Aviation Services Branch

The Terminal Aerodrome Forecast (TAF) is an aviation forecast for the terminal area. The area is defined as the 0-5 mile radius around the center of the airport. Guidance for how a TAF is composed is available from the International Civilian Aviation Organization (ICAO) Annex 3, Amendment 76; however, each country interprets this guidance a little differently. This interpretation generates a slightly different looking TAF, depending on what country is producing it.

Lets look at some examples of these differences by reviewing international TAFs and U.S. Military TAFs and then comparing them to the typical U.S. TAF format. The differences may surprise you. Below are TAFs from other countries, one U.S. military TAF and one typical U.S. TAF.

Keflavik, Iceland…International TAF
BIKF 201045Z 2012/2112 15012KT 9999 FEW025 BKN035
BECMG 2020/2022 VRB02KT
BECMG 2109/2112 33010KT

This TAF from Keflavik uses the Becoming Group, BECMG, which is not used in the United States except in military TAFs. The BECMG group allows a forecaster to infer a gradual or not so gradual change over a period of usually 2 hours. For example, on the Iceland TAF above, the wind, as of 2200 UTC, is variable at 2 knots. On the last line, the BECMG group indicates that sometime between 0900 and 1200 UTC on the 21st the winds would change. As of the 1200 UTC, the winds would be from the northwest at 10 knots.

Another common feature of international TAFs is the BECMG group usually includes only the weather element that changes. You see this in the second and third lines where only the wind is forecasted to change and the rest of the TAF carries 9999 FEW025 BKN035 throughout the life of this TAF.

Cairo, Egypt…International TAF
HECA 201000Z 2012/2118 34012KT CAVOK
TEMPO 2100/2106 VRB03KT 3000 BR NSC

The Cairo TAF makes use of several features we do not use in a U.S. TAF. In the first line is a remark Ceiling and Visibility OK, CAVOK, which is approximately Visual Flight Rules (VFR). Also in the second line is the sky condition, NSC, which stands for no significant clouds. Similar to a sky clear, SKC, or scattered clouds, assuming the clouds are not convective.

Berlin, Germany… International TAF
EDDB 201100Z 2012/2112 27015G25KT 9999 SCT020
BECMG 2012/2014 28010KT
PROB30
TEMPO 2014/2018 SHRA
BECMG 2018/2020 25005KT

Many international TAFs occasionally will use two conditional groups at one time. Look at the third and forth line in the Berlin TAF above for example.

Before continuing, lets review two key terms: TEMPO and PROB.

- ♦ **TEMPO:** indicates frequent or infrequent temporary fluctuations in forecast meteorological conditions expected to last less than 1 hour in each instance and, in the aggregate, cover less than half of the period indicated.
- ♦ **PROB:** indicates the probability of occurrence of forecast element(s) during a defined period of time. Only the values 30 and 40 are used to indicate the probabilities of 30% and 40%, respectively. **The U.S. civilian TAFs use only the PROB30 remark. And the PROB30 remarks are not allowed in the first 9 hours of a U.S. TAF.**

Now let's translate these terms to practical usage.

PROB30
TEMPO 2014/2018 SHRA

TEMPO straight-forward: SHRA is valid 1400-1800 UTC and indicates frequent or infrequent temporary fluctuations in forecast showers here, expected to last less than 1 hour in each instance and, in the aggregate cover, less than half of the period indicated. Since this is a 4-hour period the total time of showers should be less than 2 hours. If this was only a TEMPO group, you would look for a greater than 50% chance of the showers.

Note, however, that you have the PROB30 remark preceding TEMPO, which means that there is only a 30 percent chance of the airport getting a shower. Having said that, if they get the shower, then it will be an on-and-off, 4-hour event as defined by the TEMPO rules above.

Moscow, Russia… International TAF
UUWW 201050Z 2012/2112 20005G10MPS 9000 BKN020 SCT030CB
TEMPO 2012/2022 VRB18MPS 0800 +TSRAGR SQ BKN004 BKN010CB
BECMG 2022/2024 27007MPS
TEMPO 2022/2105 1100 SHRA BR BKN004 SCT015CB

The international TAF code recently made allowances for metric remarks. The Russian TAFs, for example, use Meters Per Second (MPS) rather than Knots (KT). The conversion is 1 Meter Per Second = 1.9438444924406 Knots. So the first line of the Moscow TAF above could be converted by roughly doubling the MPS value: 20005G10MPS, which converts to 20010G20KT.

Ft Bragg, North Carolina…US Military TAF (the format is the same for Marine/Navy/
Air Force
TAFs, Army TAFs are provided by the Air Force)
KFBG 2011/2109 26006KT 9999 SKC QNH2977INS
BECMG 2012/2013 31009KT 9999 OVC030 620304 50004 QNH2983INS
TEMPO 2100/2103 01015G30KT 8000 TSRA BKN030CB
BECMG 2103/2104 01005KT 9999 FEW050 QNH2993INS T33/2021Z T22/2109Z

In the U.S. military TAFs, you will notice some obvious differences from typical NWS civilian TAFs. Most notable is the inclusion of barometric pressure adjusted to sea level, QNH, as well as Icing and Turbulence forecasts below 10,000 feet and the common use of the BECMG group.

Icing and Turbulence can be decoded by using the information below. This data is helpful if you are near a military installation with a TAF. Here's an example from Air Force Pamphlet 11-238:

If forecasted, the icing group will be prefixed by the number 6 and follows the cloud group in the TAF. Look at the second line in the Ft Bragg TAF to decode, follow these instructions:

Using **620304**:

1. Find the icing designator "6" following the cloud group: **6**20304
2. The next digit gives icing type and intensity: 6**2**0304. See codes in **Table 1**.
3. The next three digits give the base of the icing layer in hundreds of feet: 62**030**4.
4. The last digit provides the icing layer depth in thousands of feet: 62030**4**. Add this value to the base height to determine the top limit of the icing conditions.

Table 1. Icing Intensity Decode	
0	Trace Icing or None (see note)
1	Light Mixed Icing
2	Light Rime Icing In Cloud
3	Light Clear Icing In Precipitation
4	Moderate Mixed Icing
5	Moderate Rime Icing In Cloud
6	Moderate Clear Icing In Precipitation
7	Severe Mixed Icing
8	Severe Rime Icing In Cloud
9	Severe Clear Icing In Precipitation

Note: Air Force code "0" means a trace of icing

In the above example, the icing forecast will read, "light rime icing (in cloud) from 3,000 to 7,000 feet." If forecasted, the turbulence code will be prefixed by the Number 5 and will follow the cloud or icing group. Look at the second line in the Ft Bragg TAF to decode the turbulence group **520004** using these instructions:

1. Look for the turbulence designator "5" that follows the cloud or icing group: **5**20004.
2. The next digit will determine the intensity: 5**2**0004. See **Table 2**.
3. The next three digits will determine the base limit of the turbulence layer in hundreds of feet Above Ground Level (AGL): 52**000**4.
4. The last digit will determine the turbulence layer depth in thousands of feet: 52000**4**. Add this value to the base height to determine the top limit of the turbulence conditions.

Table 2. Turbulence Intensity Decode

CODE	DECODE
0	None
1	Light turbulence
2	Moderate turbulence in clear air, frequent
3	Moderate turbulence in clear air, occasional
4	Moderate turbulence in cloud, occasional
5	Moderate turbulence in cloud, frequent
6	Severe turbulence in clear air, occasional
7	Severe turbulence in clear air, frequent
8	Severe turbulence in cloud, occasional
9	Severe turbulence in cloud, frequent
X	Extreme turbulence

Note: Occasional is defined as occurring less than 1/3 of the time

In the above example, the turbulence forecast will read, "occasional moderate turbulence in clear air from the surface to 4000 feet."

Reagan Airport…Washington DC
KDCA 201137Z 2012/2112 06008KT 4SM -RA BR SCT018 BKN035 OVC050
FM201300 05008KT 6SM -SHRA BKN035 OVC050
FM201500 04009KT P6SM OVC060
FM202000 03007KT P6SM SCT050 BKN100
FM210000 16005KT P6SM FEW050 BKN250

The TAF above is a U.S. TAF. NWS Weather Forecast Offices (WFOs) produce 635 TAFs four times a day at in support of the National Air Space. The TAFs are issued between 20 and 40 minutes before the valid times of 1800/0000/0600/1200 UTC, and include amendments as needed. Below are the major points to remember when planning and using NWS TAFs.

1. BECMG groups are not used.
2. Consecutive conditional groups are not used, i.e., PROB30 followed by a TEMPO group, see example in the Berlin TAF.
3. TEMPO groups may only be 4 hours long.
4. At high impact airports, TAFs are routinely updated (amended) for critical push times; see the following list.

ATL	Hartsfield-Jackson Atlanta Intl	LGA	New York LaGuardia
BOS	Boston Logan Intl	MCO	Orlando Intl
BWI	Baltimore/Washington Intl	MDW	Chicago Midway
CLE	Cleveland Hopkins Intl	MEM	Memphis Intl
CLT	Charlotte Douglas Intl	MIA	Miami Intl
CVG	Cincinnati/Northern Kentucky Intl	MSP	Minneapolis/St. Paul Intl
DCA	Reagan Washington National	ORD	Chicago O'Hare Intl
DEN	Denver Intl	PDX	Portland Intl
DFW	Dallas/Fort Worth Intl	PHL	Philadelphia Intl
DTW	Detroit Metropolitan Wayne County	PHX	Phoenix Sky Harbor Intl
EWR	Newark Liberty Intl	PIT	Pittsburgh Intl
FLL	Fort Lauderdale/Hollywood Intl	SAN	San Diego Intl
HNL	Honolulu Intl	SEA	Seattle/Tacoma Intl
IAD	Washington Dulles Intl	SFO	San Francisco Intl
IAH	Bush Houston Intercontinental	SLC	Salt Lake City Intl
JFK	New York John F. Kennedy Intl	STL	Lambert Saint Louis Intl
LAS	Las Vegas McCarran Intl	TPA	Tampa Intl
LAX	Los Angeles Intl		

5. All U.S. TAFs are valid for at least 24 hours. The following 32 TAFs are valid for 30 hours.

KATL	William B. Hartsfield Atlanta Intl	KMSP	Minneapolis-St Paul Intl
KBDL	Bradley Intl	KOAK	Metropolitan Oakland Intl
KBOS	Gen. Edward Lawrence Logan Intl	KONT	Ontario Intl
KBWI	Baltimore-Washington Intl	KORD	Chicago-O'Hare International
KCLE	Cleveland Hopkins Intl	KPHL	Philadelphia Intl
KCVG	Covington/Cincinnati	KPIT	Pittsburgh Intl
KDEN	Denver Intl	KSAN	San Diego Intl–Lindbergh Field
KDFW	Dallas/Fort Worth Intl	KSDF	Louisville, Intl Standford Field
KDTW	Detroit Metro Wayne County	KSEA	Seattle-Tacoma Intl
KEWR	Newark Liberty Intl	KSFO	San Francisco Intl
KIAD	Washington Dulles Intl	KSLC	Salt Lake City Intl
KIAH	Houston-George Bush	KSTL	Lambert-St Lewis Intl
KIND	Indianapolis Intl	KSWF	Stewart Intl
KJFK	John F. Kennedy Intl	PANC	Ted Stevens Anchorage Intl
KLAX	Los Angeles Intl	KAUS	Austin-Bergstrom Intl Airport
KMKE	General Mitchell Intl	KSAT	San Antonio Intl Airport

6. PROB groups are not allowed in the first 9 hours of the TAF.
7. The U.S. TAFs allow the use of thunderstorm in the vicinity (TS VCNTY). No other countries use this remark. And with no PROB30 allowed in the first 9 hours of the TAF, forecasters usually insert this remark for low probability convective events.
8. Given Points 6 and 7, it is imperative for you to look at other NWS convective services and products such as:

- NWS Storm Prediction Center: http://www.spc.noaa.gov/
- **Local WFO information:** http://www.weather.gov/
- **Aviation Forecast Discussions:** http://aviationweather.gov/products/afd/

✈

Collaborative Decision Making Meets Volcanic Ash

By Mike Graf, NWS Aviation Services Branch

As technology advances, the use of Collaborative Decision Making (CDM) improves. In a nutshell, CDM happens when users of services have a chance to add their expertise to the decision making process up front. For the process to work effectively, it helps to have tools to view the information seamlessly and on the fly.

One of the new CDM tools is available from the Anchorage **Volcanic Ash Advisory Center** (VAAC). The site allows you to easily view Volcanic Ash Advisories (VAAs) anywhere in the world. The information is a **graphical representation of the VAA** and is available for the current time as well as a 6.12 and 18 hour forecast.

There are nine VAACs that cover the globe. By using this site, the VAACs can easily view their counterpart's products. This ability can improve coordination and collaboration between these offices as they prepare and update products.

Another example involves Airlines. The Anchorage VAAC works with Airlines in its region to understand the impact of a VAA on airline operations. This in turn helps the VAAC understand where to focus its attention with respect to levels and areal coverage during a Volcanic Eruption and the resultant VAA. Below are some examples from the Anchorage VAAC's new Webpage. ✈

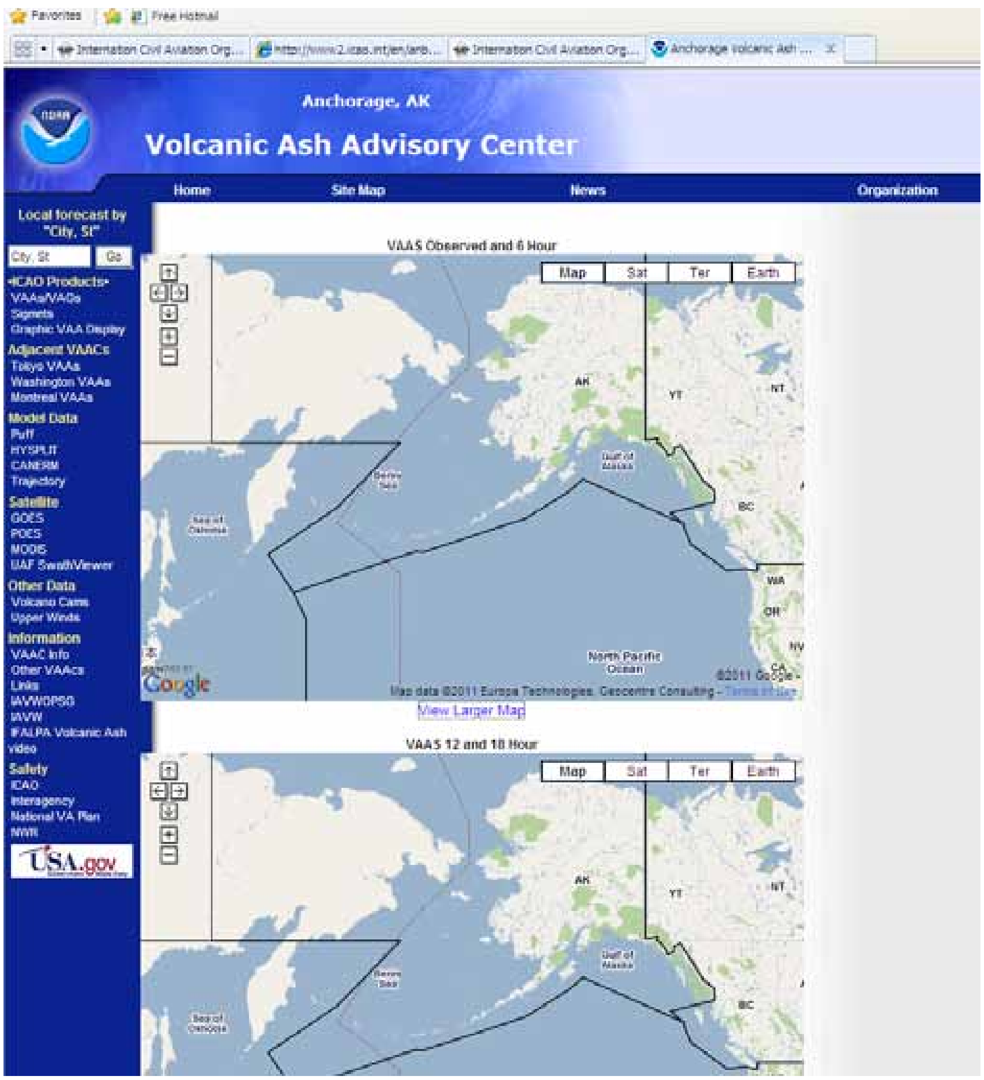


Figure 1. Anchorage area of concern

Figure 2. *Global view*

Figure 3. *Volcanic ash product from the Buenos Aires VAAC*

NWS Seeks Comments on Future Service Delivery Architecture Through July 31, 2011

NWS is currently looking at ways to improve its service delivery architecture to ensure it can meet 21st century data requirements. To meet this goal, NWS is currently trying to determine user requirements to develop a clear road map. The road map, in turn, will help NWS create a future-facing service delivery architecture to better serve your needs.

NWS is requesting comments to better understand current and future service needs. The primary goal is to fulfill the NWS mission to protect life, property and the enhance the national economy. NWS seeks to improve how it meets these goals by disseminating the necessary data using new and emerging technology. Users, such as you, of NWS dissemination services are the most important group affected by this process. User involvement is vital to the success of this effort.

NWS infrastructure includes all dissemination media currently supported, such as the NWS Telecommunications Gateway, NOAA Weather Radio All Hazards, NOAA Weather Wire, Family of Services, NOAAPORT, Emergency Managers Weather Information Network, NWSChat, iNWS, as well as all web-based email and telephone services. As the NWS begins to consider how best to improve and expand these current services through the new NWS Dissemination Architecture, research will be conducted in the following areas:

- **Data Sets:** Types required by users
- **Dissemination Methods:** For example, the use of part of selected datasets through stable, operational Web services (e.g., Simple Object Access Protocol, Representational State Transfer services, Geographic Information System) or through complete datasets, i.e., traditional meteorological formats
- **Best Practices of Existing Dissemination Systems:** For example, NOAA's National Operational Model Archive and Distribution System, which is Web-based and provides both real-time and retrospective format with independent access to climate and weather model data: http://nomads.ncdc.noaa.gov/
- **Operational Level:** For example, requirements to deliver time-critical information, e.g., within 1 minute of issuance, and to improve NWS' ability to prioritize urgent information over non-urgent information
- **Service level:** Expansion of fee-for-service dissemination similar to the Family of Services program, http://www.nws.noaa.gov/datamgmt/fos/fospage.html, adding stringent delivery performance requirements for those customers

User input on these points will help NWS improve its services. If you have any information you believe would help in this analysis, please provide your input by July 31, 2011 to the following address:

Robert Bunge
Chief, Telecommunication Software Branch
Telecommunication Operations Center
301-713-0882 x 114
nwsrearch@noaa.gov

You may also provide online input at:
NWSrearch.ideascale.com

Thank you for helping NWS improve its dissemination systems and apply techniques appropriate for the 21st Century. ✈