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EXTREME *Weather* MAKERS

Hard-to-forecast anafronts generate unusual combinations of threats.

BY ED BROTAK

Sudden, drastic weather changes at Dallas/Fort Worth International Airport during two days in November 2006 seemed to defy the usual explanations. At 1800 the first day, the temperature was 72° F (22° C), winds were from the south-southeast at 20 kt gusting to 26 kt, skies were broken at 3,000 ft, and the visibility was greater than 10 mi (16 km). Within minutes, the wind shifted abruptly to the north-northwest at 20 kt gusting to 27 kt, the temperature fell precipitously into the 40s (4.4° to 9.4° C), and the skies became overcast. Soon, rain began to fall, becoming heavy. Ceilings lowered to below 1,000 ft and visibility dropped to 4 mi (6.4 km).

During the night, a thunderstorm moved over the airport. The temperature continued to fall, by morning going below 32° F (0° C). The rain started to freeze, causing icing conditions. Flight crews descending through 4,000 ft above ground level (AGL) encountered an air temperature of 49° F (9.4° C) and wind from the southsouthwest at 26 kt. At 2,800 ft AGL, the temperature was 22° F (minus 5.6° C) with icing conditions, and the wind was from the north-northwest at 26 kt. It was a classic example of an *anafront,* an exceptional type of cold front.

All fronts — the boundary layer between two types of air masses — have denser, relatively cold air near the ground and lighter, relatively warm air aloft. Their passage poses familiar problems in aviation. Low clouds producing low ceilings; precipitation resulting in poor visibilities; strong winds that quickly change direction; and dramatic changes in temperature, humidity and air density are all common.

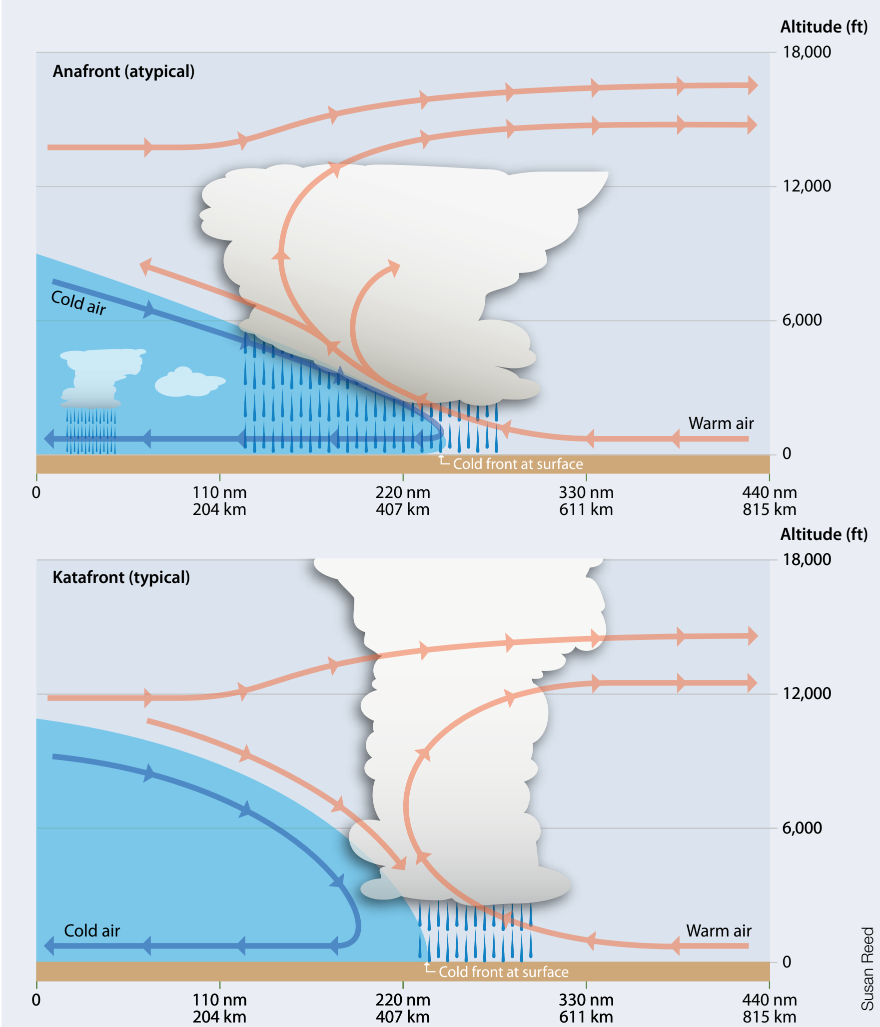
Although such weather conditions often are associated with cold fronts, the situation usually improves rapidly after the cold front passes.[1] When an anafront passes, the conditions initially seem similar to other cold fronts, just more extreme. The apparent similarities quickly end, however, and the challenges for flight crews begin.

The profile view of the common cold front, called a *katafront,* shows air sinking along a steeply sloping frontal surface that sits on top of a fairly deep layer of cold air, and then lifting right along or even ahead of the surface front. This is where the clouds and precipitation occur. For the anafront, air rises along a shallow sloped front that caps a shallow layer of cold air (Figure 1, p. 14). This is similar to a warm front except, in this case, the cold air moves forward, undercutting the warm air.

With the warm air rising along the full length of the frontal surface, precipitation occurs well behind the surface cold front in a process meteorologists call *overrunning.* If the overlying warm air is unstable, thunderstorms can develop by a process called *elevated convection* even though the surface air may be cold and stable. Such thunderstorms can be difficult to forecast because the convection is not surface-based as usual.

During the anafront passage, the surface wind direction changes

Atypical vs. Typical Cold Front Weather



ft = feet; nm = nautical miles; km = kilometers

Note: The direction of frontal movement is left to right in both profile illustrations. Behind an anafront, persistent conditions may include cumulus clouds and thunderstorms; behind a katafront, conditions typically improve quickly. Altitudes and distances shown only provide a rough approximation of the scale.

Source: Ed Brotak

Figure 1

dramatically, often clockwise by 180 degrees. Drops in temperature also can be spectacular, sometimes 30° F (16.7° C) in a short time.

Typically, there is no precipitation ahead of or with the actual passage of the anafront. But the low clouds persist well behind the front, so there is no clearing. This is also where precipitation occurs. In winter, freezing rain often is observed. Despite Fahrenheit temperatures in the single digits, rain falls. This liquid precipitation can be very heavy and a major factor in icing risk. Strangely enough, thunderstorms can occur even with temperatures that low.

With the anafront, if the very shallow cold air layer near the surface has temperatures below freezing, freezing rain is common because the temperatures aloft can be warm. Any frozen precipitation that forms in or falls through this warmer layer aloft quickly turns to rain. The cold air layer below again cools the water to the freezing temperature but is so shallow that the rain does not have a chance to re-freeze into sleet or ice pellets. Instead, it remains liquid until it encounters a cold surface. Then it freezes on contact, producing glaze conditions.

This may occur within several thousand feet of the surface, so icing becomes a low-level hazard. For aircraft in the descent phase, flight conditions may be normal until the airplane flight path penetrates the cold layer of air at the anafront. The flight crew then may encounter unexpectedly severe icing conditions.

The vertical wind structure through the frontal zone also can be problematic. Near the surface, north to northeast winds in the Northern Hemisphere strongly change direction counterclockwise with increasing altitude to become winds from the southwest or even the south as the airplane climbs.[2] Besides directional shear, velocity shear can be a problem with strong north winds or even a low-level jet occurring in the cold air.[3] The practical effect is that during takeoff and landing, pilots could encounter rapid changes in wind direction and speed.

The bad weather conditions experienced behind the anafront can last for many hours — or many days — because anafronts are slow-moving. The front itself is usually parallel to the upper air flow so there is little energy to push the front.

Unlike common cold fronts, the supporting upper-level trough for an anafront is well displaced to the north, often hundreds of miles away. Computer forecast models, which handle upper-level features better than low-level features, therefore don't predict anafronts as well as other cold fronts.

U.S. anafronts most commonly occur in the central part of the lower 48 states, between the Rocky Mountains and the Appalachian Mountains. The Plains and Midwest regions of the country are devoid of the topographic barriers that impede the southward flow of the shallow, dense and cold air from Canada that can generate anafronts. Cold fronts that cross mountain ranges, even those at the relatively low height of the Appalachians, have the familiar steep slope because the cold air from Canada behind the fronts banks up and becomes deeper.

The following case study illustrates how meteorologists can identify anafronts from upper-level charts, surface weather maps, radar summary charts and/or satellite imagery: The surface weather map for 1200 coordinated universal time (UTC) on Dec. 9, 2007, showed a cold front moving from the north into southern Texas. The front had pushed through Oklahoma the previous day. A strong, arctic high pressure system was to the north. A nose of higher pressure extended southward from the high pressure area into Texas. This cold air had banked up along the Rocky Mountains and had been driven well south.

The 500-millibar (mb) chart, approximately 18,500 ft above sea level (ASL), showed quite a different pattern.[4] A deep trough and a closed low pressure area off the Southern California coast were producing a strong southwest flow over the southern Plains states. The 850-mb chart (approximately 5,000 ft ASL) showed that the flow was even more southerly and moisture-laden than on the 500-mb chart. This was the warm, moist air overriding the frontal surface.

Freezing rain began in eastern Oklahoma during the morning of Dec. 9 and lasted well into the next day. Thunderstorms were numerous and widespread. Meteorologists recorded these conditions as one of the worst ice storms in Oklahoma history, and they were a nightmare for aviation. The major air carrier airports at Oklahoma City and Tulsa, Oklahoma, reported almost continuous freezing rain or drizzle for 36 hours with thunderstorms occasionally reported, too.

The charts for the morning of Dec. 9 at Oklahoma City showed other conditions significant for aviation. At the surface, the temperature was 27° F (minus 2.2° C), and the winds were from the north at 19 kt. The cold air near the ground was only a few thousand feet thick. Continuing up through this air mass, the temperature exceeded 50° F (10° C) at 4,000 ft.

This meant there was no chance for snow even though the surface temperatures were well below freezing. The wind sharply changed direction counterclockwise with height: north-northeast near the surface and southwest just above that. Thunder was reported at the airport during the day. Surface-based air mass stability indexes like the lifted index showed extremely stable conditions. However, the Showalter Index using conditions at approximately 5,000 ft ASL was minus 1.5, indicating possible convection.[5]

Although these examples come from the United States, anafronts can occur anywhere in the world where a source of very cold air exists. They often, but not exclusively, form on the lee side of mountain ranges for this reason.

Anafronts generate a difficult set of problems for aviation interests. They also are more difficult to forecast accurately than common cold fronts. Meteorologists have resources, such as upper-level soundings, and expertise to explain the whole situation. They enable the industry to anticipate when and where anafronts are likely to occur.

For short-term purposes, a few hours in advance of flight operations, the best option for non-meteorologists is to look at the latest surface analysis chart. Real-time radar depictions also are a good option to see if the precipitation is behind the surface front. For a longer-term perspective, surface forecast maps are good. Anytime a cold front has thunderstorms or freezing rain behind it, an anafront — and all that it entails — can be suspected.

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Notes

1. Common cold fronts occur when a mass of cold, dense and stable air advances and replaces a warmer air mass. Distinguishing characteristics may include the length of the front; frontal surface slope; speed of movement; and precipitation decrease after frontal passage.
2. In the Southern Hemisphere, with cold air to the south, anafronts have southerly winds at low levels that change direction clockwise to a northerly component aloft.
3. A low-level jet is a wind speed maximum of at least 30 kt below 10,000 ft with wind speeds decreasing both above and below that altitude.
4. Upper-level charts, such as the 500-mb chart, graphically represent a compilation of data from radiosonde soundings, observations transmitted from sensors aboard aircraft and satellite data.
5. Any positive number for the Showalter Index — used by meteorologists to assess the potential for thunderstorms to develop — indicates stable air. Values from zero to minus 4 signify marginal instability, values from minus 4 to minus 7 signify large instability, and values of minus 8 or less signify extreme instability, the greatest probability of thunderstorms.