

BY ED BROTA

Heavy snowfall and high wind from monster storms called bomb cyclones periodically disrupt aviation operations.

Winter Hurricanes

On Oct. 29, 2011, U.S. weather maps showed a benign-looking 1007-millibar (29.74-in Hg) low pressure area off the coast of North Carolina at 1200 coordinated universal time (0800 local). As the low moved up the East Coast, it began to deepen explosively. With abnormally cold air being pulled in from Canada, rain changed to snow at many locations.

Some reporting stations recorded snowfall rates of 2 to 4 in (5 to 10 cm) per hour and visibilities at local airports dropped to near zero. The town of Peru in extreme western

Massachusetts received 32 in (81 cm) of snow, a record for so early in the season. Locations that escaped heavy snow still had to deal with strong winds.

Nantucket, Massachusetts, observations reported sustained winds of 40 kt with gusts to 60 kt. Aviation operations along the entire northeastern corridor were dramatically affected. At Newark (New Jersey) Liberty International Airport (EWR), heavy rain changed to heavy snow during the day and visibilities dropped to 1/4 mi (400 m). For a time, all flights were canceled. John F. Kennedy International Airport (JFK)

and LaGuardia Airport in New York City had five-hour delays. By the morning of Oct. 30, a powerful 977-millibar (28.84-in Hg) low sat just south of Nova Scotia. The pressure had fallen 30 millibars (0.90 in Hg) in 24 hours.

Consecutive ‘Bombs’

Less than a year before this storm, an even more powerful one had affected the same U.S. region. Having left snow as far south as Georgia and Alabama on Dec. 25, 2010, an already potent low pressure area (992 millibars [29.29 in Hg]) started moving up the coast on Dec. 26. By the next morning, a 962-millibar (28.41-in Hg) low sat just off of Cape Cod, Massachusetts.

All three major airports servicing New York City — Kennedy, LaGuardia and Newark — were closed on Dec. 27 and did not reopen until the morning of Dec. 28. More than 1,400 flights were canceled. At the height of the storm, JFK reported a visibility of zero in heavy snow with winds gusting to 49 kt.

Across the Hudson River, EWR reported visibility of 1/8 mi (200 m) for hours with snow accumulating at rates of 2 to 3 in (5 to 8 cm) per hour. Winds gusted to 39 kt. Newark wound up with 24 in (61 cm) of snow and JFK with 16 in (41 cm). Farther up the coast in Massachusetts, winds continued to increase through the night and into the morning of Dec. 27. Nantucket reported gusts of 50 kt from the southeast ahead of the low and from the northwest following the storm’s passage. Logan International Airport in Boston measured 18 in (46 cm) of snow. Meteorologists call such extreme winter storms *bomb cyclones* or simply *bombs*.

Fred Sanders, a professor of meteorology at the Massachusetts Institute of Technology, coined the term *bomb* in 1980 to classify rapidly

developing extratropical cyclones. These are the extreme winter storms. To officially qualify as a bomb, a low must deepen at least 24 millibars in 24 hours. Meteorologists even call the development/intensification process *bombogenesis*.

Phenomenal Origin

These super storms develop in the colder months at higher latitudes, usually those from 40 degrees toward the North Pole. They are the result of intense temperature contrasts and powerful jet streams. They also are often associated with copious amounts of precipitation, and, because these are cold-season phenomena, the precipitation is often in the form of snow. Regardless of amounts or types of precipitation, bombs are always prolific wind-makers. Winds of 50 kt are common, and winds in excess of 100 kt have been recorded.

In aviation, these storms produce a wide variety of problems and hazards. The dangers of heavy snow to aviation operations are well documented and include reduced visibility, aircraft icing and slick runways. The strong winds often pose an even greater threat. Besides the high sustained winds at the surface, excessive gusts are also common.

Typically, gusts can run 20 kt or greater than the mean wind. This is indicative of strong vertical wind shear. Higher winds just above the surface are mixed down in the gusts. For the December 2010 storm, a sounding taken just outside New York City in the evening of the 26th showed winds of 50 kt just 1,000 ft above the surface, with winds increasing to 77 kt at 3,600 ft.

For the October 2011 storm, vertical wind profiles taken near Nantucket indicated winds of 60 kt within 1,000 ft above ground level. Winds of this strength at a terminal make takeoff and

landing extremely difficult, especially if there is a crosswind. Just above the ground, the extreme wind shear generates severe turbulence. Airplane crews in flight having to deal with strong headwinds face significant delays in their arrivals.

What causes a low to “bomb out”? The answer is that the same atmospheric processes that produce typical extratropical cyclones are at work, but they are in overdrive. To briefly review the physics involved, atmospheric pressure is just the weight of a column of air above a point. Surface pressure will fall when air is removed from above a point. This occurs when the wind speed increases with height or when air is spread out over a larger area. This is called *divergence*.

So, to explain what is happening at the surface, we must look aloft. Divergence aloft is found in certain regions of the jet stream and ahead of upper-level troughs of low pressure. On the east side of these troughs in the Northern Hemisphere, the airflow is spread out, creating the divergence needed to lower the surface pressure (Figure 1). With a favorable jet stream configuration, development can be rapid. Exacerbating the problems caused by these storms is the fact that they tend to slow down when they are intensifying rapidly. They can even become stationary. The problems associated with these storms can last for a day or more at some locations.

As previously noted, strong wind associated with these storms is a major risk factor to aviation operations. This wind is generated by differences in pressure, with air always trying to go from higher to lower pressure. The greater the difference in pressure, the faster the winds. On a surface weather map, this is indicated by the pressure gradient, that is, the distance between the isobars or lines of equal pressure. If

these lines are close together, we have a tight pressure gradient, and strong winds can be expected.

Low pressure areas, especially ones that are deepening rapidly, have very tight pressure gradients and resulting strong winds.

Familiar Features

People often consider these storms as “winter hurricanes,” and at times they can resemble tropical cyclones. They can have eye-like features, small clear areas at the center of the storm. They can also have active convection. The December 2010 storm featured “thundersnow” (ASW, 10/10, p. 18) in the New York/New Jersey metropolitan region. Convective bands also were noted, similar to the so-called “spiral bands” in tropical cyclones. For bombs, the bands have been associated with the strongest winds and heaviest snowfalls. These storms are always associated with surface fronts and strong jet stream winds aloft.

Although surface winds may not be quite as strong as in the strongest tropical cyclones, the lows in the case of bomb cyclones cover a much bigger area. Tropical cyclones are relatively small, averaging a few hundred miles across, but the diameter of the winter storms is often much larger, at times approaching 1,000 mi (1,600 km).

Typically, bomb cyclones begin to develop over water. Warm currents typically found off

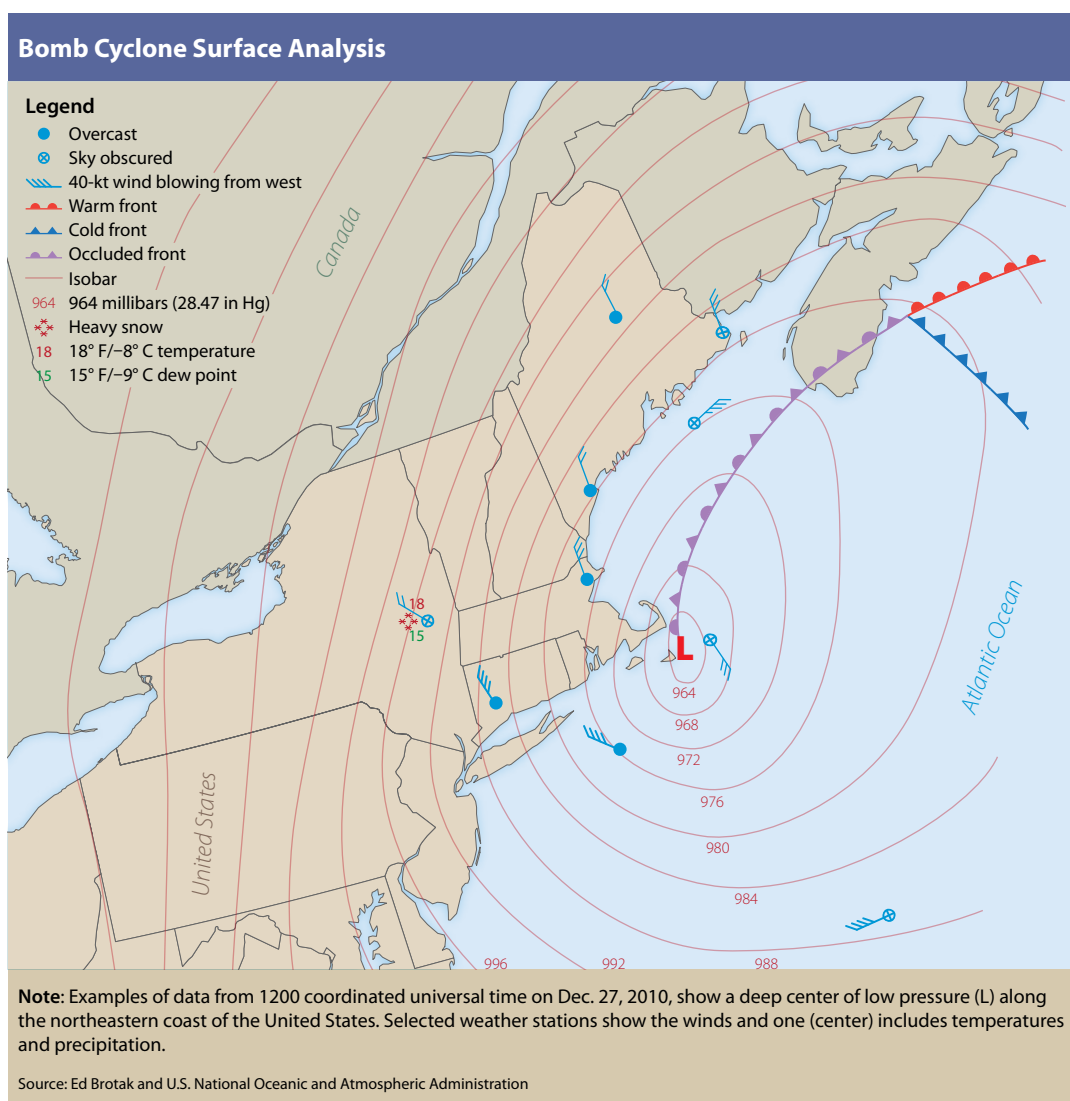


Figure 1

the east coasts of continents are active breeding grounds. The mild air over the warm waters contrasts greatly with the bitterly cold arctic air that moves off the continents at high latitudes. The extreme temperature difference between air masses — in addition to energy derived from condensation in the clouds — fuels the cyclone. So bombs are technically extratropical, not tropical, because they get their energy from the contrast of air masses, not just from warm tropical waters.

Interestingly, tropical cyclones occasionally can turn extratropical in the late fall, especially at higher latitudes. Sometimes, tropical cyclones will “bomb out” and become major storms again. This commonly occurs in the

Pacific Ocean in October and November when typhoons in the western Pacific become major winter-type storms in the North Pacific.

International Locations

Areas most commonly affected by these storms in the Pacific Basin include eastern Asia from Japan northward, coastal Alaska and British Columbia, and occasionally the Pacific Northwest of the United States. On the Atlantic side, the affected areas tend to be the U.S. East Coast from North Carolina northward, through the Canadian Maritimes, coastal areas of Greenland and Iceland, and sometimes as far east as Western Europe.

Bomb cyclones also develop over the Mediterranean Sea in the colder months. And powerful extratropical cyclones are not limited to the Northern Hemisphere. New Zealand and southern Australia, as well as southern South America, can be affected. A bomb that hit southern Brazil and Uruguay in August 2005 produced winds of 80 kt, with a peak gust of 100 kt.

But warm water is not essential for bombogenesis, and strong cyclones also can develop over the interiors of continents. Inland cyclones, often deprived of a significant moisture source, have less precipitation. Therefore, the aviation problems associated with rain and, especially, heavy snow are often greatly reduced. However, the hazards produced by strong winds are still present.

On Oct. 25, 2010, an already-potent low pressure area moved into the U.S. western Great Lakes. Fueled by a 165-kt jet stream and a 40-degree F (20-degree C) temperature difference across the cold front, the low “bombed out.” By late on the following day, a 955-millibar (28.21 in Hg) low was located over extreme northeastern

Minnesota. This was the lowest recorded pressure ever in the central United States and is comparable in pressure to a Category 3 hurricane.

The magnitude of the storm is illustrated (p. 47) by the fact that five U.S. states and considerable portions of southern Ontario and Manitoba in Canada experienced wind gusts exceeding 60 kt. At Chicago’s O’Hare International Airport, winds increased throughout the day on Oct. 26 and continued blowing hard on the 27th. Sustained winds of 20 kt with gusts to 44 kt were recorded. Hundreds of flights were canceled at O’Hare alone. Pierre Regional Airport in South Dakota endured winds gusting to more than 40 kt for a 32-hour period.

These winter storms are even stronger at higher latitudes. The Bering Sea and Gulf of Alaska have many powerful cyclones in the winter, but on Oct. 25, 1977, a low-pressure area rewrote the record books. Dutch Harbor in the Aleutians recorded a pressure of 926 millibars (27.35 in Hg), the lowest pressure ever recorded in North America for an extratropical system. Winds at nearby Adak gusted more than 80 kt for 12 hours with a peak gust of 110 kt.

Cyclones in the North Atlantic Ocean have gotten even stronger. The storm that severely damaged the luxury liner Queen Elizabeth II in 1978 had a central pressure drop of 60 millibars (1.77 in Hg) in 24 hours. In January 1993, a storm in the North Atlantic had a central pressure of 913 millibars (26.96 in Hg). If it had been a tropical system, it would have qualified as a Category 5 hurricane, the strongest storm ranking.

Bombs, by their nature, can develop very quickly. Fortunately, today’s computer forecast models are pretty good at spotting major cyclone development

days or sometimes even a week in advance. These models work best for the upper levels of the atmosphere, so the upper-level troughs which produce the surface cyclones are usually well handled. In particular, the model looks for injections of very cold air into existing troughs. This will intensify the trough and the jet stream winds.

The roles of moisture and other low-level features are also dealt with more efficiently now than a few decades ago. In fact, it was a bomb off the Mid-Atlantic coast — the infamous Presidents’ Day Snowstorm of February 1979, which dropped an unforecast 20 to 30 in (51 to 76 cm) of snow — that prompted much of the research that identified this class of storms and refined the techniques to forecast them.

Forecasts are not perfect, and occasionally, a storm will be missed. Warnings for the December 2010 blizzard were sent out only 24 hours in advance. The various forecast models all predicted major *cyclogenesis*, the process of development or intensification of a cyclone, but some predicted that the storm would move up the East Coast while others took it harmlessly out to sea. In situations where forecast models don’t agree, meteorologists are left in a quandary as to which model to believe.

A bomb-induced snowstorm in the U.S. northeastern megalopolis during any Christmas–New Year holiday week — or similar major air travel period in a densely populated region in any country — can be expected to have major consequences. U.S. forecasters decided to wait in the 2010 example until the models came into better agreement, which, in this case, left little lead time for warnings. 🌀

Edward Brotak, Ph.D., retired in 2007 after 25 years as a professor and program director in the Department of Atmospheric Sciences at the University of North Carolina, Asheville.