The GREATEST STORMS on Earth

BY ED BROTAK

Even in the mildest of tropical storms, dangerous flight conditions prevail.

U.S. National Aeronautics and Space Administration

When Hurricane Irene came ashore on the Outer Banks of North Carolina, U.S., on Aug. 27, 2011, the small airport servicing Cape Hatteras reported wind gusts to 74 kt and visibility at times of less than 1 mi (1.6 km) in very heavy rain. As Irene moved up the East Coast, it weakened. By the time it came ashore again the next day just south of New York City, Irene had been downgraded to a tropical storm. Throughout the day, the winds at John F. Kennedy International Airport (JFK) gusted to 50 kt, and, at times, visibility fell below 2 mi (3.2 km) in heavy rain.

Even though Irene had lost strength, its effects on aviation operations were significant. The New York airports and others in the storm's path were closed for an extended period during the busy Labor Day weekend. Airlines canceled 12,000 flights. Aircraft were moved to safer locations. It took days for airport operations to get back to normal. United Airlines and Continental Airlines alone reported total losses of $40 million.

Hurricanes present two obvious problems to the aviation industry. First, flying conditions even in minimal storms are dangerous, with the combination of strong winds, heavy rain and low ceilings. Takeoffs and landings are risky, and airports usually close with the approach of a storm. Second, there is the potential for physical damage, both to aircraft on the ground and to airport structures.

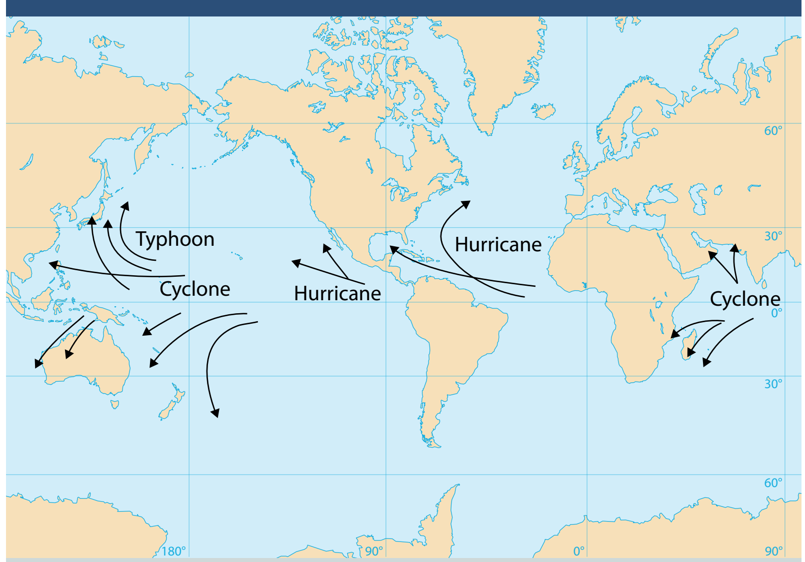
Based on statistics alone, it is unusual for a major hub to be hit by a severe hurricane. This is not the case with smaller, regional airports, which are far more numerous. In August 2004, Hurricane Charley came ashore in southwestern Florida with winds of more than 113 kt. Although inland, the town of Lake Wales took a direct hit from the storm, and every building at the local airport was either destroyed or badly damaged. It has taken years to rebuild.

Tropical Cyclones

Hurricanes are one type of tropical cyclone — a low pressure area that develops only over water with a temperature of at least 80 degrees F (26.7 degrees C). Tropical cyclones, called by various names, are common around the world, primarily on the west side of ocean basins (Figure 1). Many tropical cyclones develop from tropical waves, low-level disturbances that are embedded in the easterly trade winds. A few tropical cyclones develop from cold fronts or other midlatitude systems that move over warm ocean waters.

Officially, the Atlantic hurricane season begins June 1 and ends Nov. 30; however, there have been storms outside of the "official season." The peak of the hurricane season

Tropical Cyclones



Source: Ed Brotak

Figure 1

Radar Chart From Hurricane Irene

Note: Radar shows Hurricane Irene moving across coastal North Carolina. Variations in color indicate corresponding variations in storm intensity. Orange and yellow indicate the strongest winds and heaviest rainfall, compared with the surrounding areas of green and blue.

Source: U.S. National Oceanic and Atmospheric Administration

Figure 2

occurs in the latter part of August and the first half of September, when ocean temperatures are warmest.

When a tropical cyclone moves over land or colder water, it weakens and dissipates. This is why hurricanes don't occur off the West Coast of the United States and Canada — the water is too cold.

The average diameter of a hurricane — the entire circulation of the storm, not just the hurricane-force winds — is about 250 mi (402 km). The hurricane-force winds usually are found close to the center of the storm.

Hurricanes vary in size, however. Irene was a large storm, nearly 400 mi (644 km) across. Hurricanes typically are asymmetric, with a large wind field to the north and east of the center, in the Northern Hemisphere. For aviation interests, dangerous conditions can persist for many hours, and poor flying conditions can spread well ahead to the north and east of the storm center. Numerous hubs can be affected at the same time.

Unlike typical winter storms, which have large areas of consistent or "stratiform" precipitation aligned along fronts, tropical cyclones have no fronts and the precipitation occurs in bands of convection. Bands of showers and thunderstorms, similar to midlatitude squall lines, move within the cyclonic circulation. These somewhat curved "spiral bands" contain the strongest winds and heaviest rainfall. Farthest from the center are the "outer rain bands." As each band moves through, it is accompanied by rain and wind. Then, as it passes, the rain and winds slack off. Closer to the center, the frequency and strength of the bands increase (Figure 2).

Around the center of the storm is the "eye wall," a partial, or sometimes complete, ring of showers and thunderstorms surrounding the eye. This is where the strongest winds and heaviest rainfall are concentrated.

The eye is the relatively calm center of the storm. Sinking air inhibits cloud production. Strong storms can have clear, cloudless eyes. During a storm's passage, the eye provides a lull in the extreme weather.

To accurately forecast short-term weather conditions in a tropical cyclone, check the weather radar.

Tropical convection differs from the typical midlatitude showers and thunderstorms. It develops in a deep tropical air mass that is warm and moist throughout its vertical profile. Lapse rates aren't that steep, and instability isn't that great. The tropopause, which acts as a lid on convection, is much higher in the tropics. Convective cells can reach great heights, more than 60,000 ft, but with the lack of temperature contrast, the updrafts aren't strong. Overall, tropical convection is less turbulent than midlatitude convection.

Making Landfall

All this changes if and when the convection moves over land. Increased friction produces more physical turbulence. Lapse rates and instability tend to increase. The convection becomes stronger, sometimes strong enough to generate tornadoes, primarily in the right forward quadrant of the storm.

Strong winds are what most people expect when they think of tropical cyclones, but in fact, a wide range of wind speeds can accompany a tropical system. If winds in a tropical cyclone are between 26 and 33 kt, it is called a *tropical depression*. Winds of 34 to 63 kt are associated with a *tropical storm*. Winds greater than 64 kt qualify a storm as a *hurricane*. In an average year in the Atlantic Basin, there are 11 systems of at least tropical storm strength, including six full-fledged hurricanes. Even with hurricanes, there is considerable variability. To make it easier for the public to quickly understand the strength of a storm, hurricanes are ranked from 1 to 5 using the Saffir-Simpson Scale (Table 1).

Major hurricanes with winds of 96 kt or more — those in Category 3 or higher — occur, on average, twice a year. Category 5 storms, with winds of 135 kt or more, are the strongest and do not occur every year.

The strong winds associated with tropical cyclones produce major problems for pilots in controlling aircraft, especially during takeoffs and landings. Even the winds produced by a tropical depression create difficulties. Making matters worse is the gusty nature of the winds. The convective downdrafts in showers and thunderstorms bring the stronger winds aloft down with them.

Vertical Profile

A few things should be noted about the vertical wind profile of a tropical cyclone. As in all types of winds, friction near the surface slows the wind speed considerably. At 1,600 ft above the ground, wind speeds can be 20 percent higher than they are at the surface. This equates to a one-category increase in storm strength. But higher up, winds decrease. This is not the case with extratropical cyclones, the typical winter storms, which are tied in with the upper-level jet stream and become stronger with height (*ASW*, 2/12, p. 47). Tropical cyclones are more low-level systems and weaken above 10,000 ft.

Rainfall Rates

Heavy rain is another characteristic of tropical cyclones that affects aviation. Rainfall rates of several inches per hour are common and significantly reduce visibility. In addition, serious ponding occurs on runways. Fresh water flooding is a concern in areas prone to such occurrences.

Saffir-Simpson Hurricane Scale

Category	Winds	Surge	Central Pressure
1–Minimal	64–82 kt	4–5 ft (1.0–1.5 m)	greater than 980 mb or 28.94 inHg
2–Moderate	83–95 kt	6–8 ft (1.8–2.4 m)	965–979 mb or 28.50–28.91 inHg
3–Extensive	96–113 kt	9–12 ft (2.7–3.7 m)	945–964 mb or 27.91–28.47 inHg
4–Extreme	114–135 kt	13–18 ft (4.0–5.5 m)	920–944 mb or 27.17–27.88 inHg
5–Catastrophic	greater than 135 kt	greater than 18 ft	less than 920 mb or 27.17 inHg

Source: U.S. National Oceanic and Atmospheric Administration

Table 1

Airports along the immediate coast can be endangered by storm surges. These wind-driven high tides can range from a few feet (1 m) up to 30 ft (9 m). On top of the surge of ocean water are waves that can crest more than 20 ft (6 m) higher. The pounding waves are capable of destroying buildings and often do more physical destruction than any other element of a storm.

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A storm surge is a direct result of strong winds that physically push the water onshore. The highest surge occurs where the center of the storm crosses the coast and just to the right of that point. There is some heightening of sea level and storm surge due to the lower pressure in the eye of the storm. But most of this maximum surge where the center of the storm crosses the coast is due to the proximity of the strongest winds at the eye wall. The actual height of the storm surge is influenced by a variety of factors: the strength of the storm, the size of the storm, and, most importantly, the normal high and low tide cycle. In areas with large tidal variations, this can mean the difference between little or no damage and a catastrophe.

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Forecasting

Forecasts for Atlantic tropical cyclones come from the U.S. National Hurricane Center (NHC) in Miami.[1] Meteorologists at the NHC forecast a storm's movement and intensity by using computer models and applying their own knowledge and experience to modify the results.

Even before a full-fledged tropical cyclone has developed, the NHC tracks disturbances in the tropics using satellite imagery and issues regular updates on the likelihood of intensification. Once a tropical depression forms, the NHC sends out regular advisories every six hours describing the current status of the storm and providing a five-day forecast of its movement and intensity. When a system reaches tropical storm strength, it is given a name — a practice adopted to aid in storm-related communication. If a storm is particularly destructive, its name is retired.

Watches and Warnings

If a storm is forecast to threaten land, the NHC sends out a tropical storm watch or hurricane watch and, if need be, a subsequent upgrade to a tropical storm warning or hurricane warning. A watch means that tropical storm/hurricane force winds *may* affect a given area within 48 hours. A warning means that tropical storm/hurricane force winds *are expected* somewhere within the given area in 36 hours or less.

Forecasting the movement of a tropical cyclone involves forecasting the "steering currents" — the prevailing winds that surround a storm and direct its movement. As powerful as these storms may get, they are still just small eddies flowing within the "rivers" in the larger atmosphere. Today's advanced computer models are good at predicting these steering currents and the tropical cyclones embedded in them. For example, they correctly forecast Irene's march up the East Coast.

Forecasting the strength of tropical cyclones is more challenging. There are many variables. Rapid intensification is the most dangerous scenario. Fortunately, this seldom occurs near land. However, Florida Hurricanes Andrew in 1992 and Charley in 2004 show that this type of intensification can occur. Major hurricanes often go through cycles of intensification and weakening tied to internal structural changes that are not well understood.

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Note

1. Online at <www.nhc.noaa.gov>. In other parts of the world, various government agencies and private companies provide similar forecasts.

Further Reading From FSF Publications

Brotak, Ed. "Forecasting Thunderstorms." *AeroSafety World* Volume 7 (May 2012): 14–18.

Brotak, Ed. "Winter Hurricanes." *AeroSafety World* Volume 7 (February 2012): 47–50.

Brotak, Ed. "Dusty and Gusty." *AeroSafety World* Volume 6 (September 2011): 42–46.

Brotak, Ed. "Convectional Wisdom." *AeroSafety World* Volume 6 (June 2011): 12–16.

Brotak, Ed. "Thundersnow." *AeroSafety World* Volume 5 (October 2010): 18–22.