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Forecasting Hurricanes: Role of the National Hurricane Center

The National Hurricane Center (NHC), part of the National Weather Service (NWS) within the National Oceanic and Atmospheric Administration (NOAA), is responsible for forecasting tropical cyclones, including hurricanes in the Atlantic Ocean and the eastern Pacific Ocean. The NHC provides estimates of the path of a tropical cyclone (i.e., hurricane track), the intensity, and the size and structure of the storm, as well as predictions of storm surge, rainfall, and even tornadoes. Depending on the status of the tropical cyclone, this information may be used to create a hurricane watch or a hurricane warning and public advisories, which are issued on an increasingly frequent basis if a storm strengthens and approaches the U.S. coastline.

How the Process Works

A hurricane forecast involves many components and uses a broad array of resources and capabilities within NOAA and the NWS, all of which must be coordinated and interpreted by the NHC. The process begins with observations: satellites, aircraft, ships, buoys, radar, and other sources provide data used to create storm-track and intensity predictions. Most Atlantic hurricanes, for example, begin to form just west of the African continent over the ocean. NOAA weather satellites primarily provide the remote-sensing observations during the early stages of tropical storm development in the eastern Atlantic. NOAA's Geostationary Operational Environmental Satellites (GOES) are stationed over the same location spanning North America (two satellites make up the active GOES constellation, often referred to as GOES East and GOES West) and provide continuous data as the storms form and intensify during their journey across the Atlantic from Africa to North America.

Approaching the Coast

If an Atlantic hurricane is judged to pose a threat to the U.S. coastline, NOAA hurricane aircraft and U.S. Air Force aircraft (often referred to as Hurricane Hunters) fly directly into the storm to collect real-time data from inside the cyclone. Within the NHC, it is the responsibility of the Chief, Aerial Reconnaissance Coordination, All Hurricanes (CARCAH) unit, to coordinate all tropical cyclone operation reconnaissance in accordance with the National Hurricane Operations Plan. Data collected from the Hurricane Hunters and other aircraft (e.g., the NASA Global Hawk) are checked at CARCAH and provided to NHC forecasters. If the storm gets closer, approximately 280 miles from the coast, land-based radars begin to provide the NHC with precipitation and wind-velocity data. Additional ground-based measurements are provided by the Automated Surface Observation Systems instruments when the storm is close to shore or makes landfall.

Analyzing the Data

The NHC gathers all the observational data collected as a tropical cyclone approaches the U.S. coastline and uses the data to generate a series of hurricane forecast computer models. The principal purpose of hurricane forecast models typically is to predict the hurricane track and intensity over a period of three to five days. Essentially, the model uses the observational data to understand the state of the atmosphere and then uses mathematical equations to produce forecasts. Not all hurricane forecast models are the same; they may differ in how they process information, such as when observations are fed into the model, which equations are used, how the solutions to the equations are used to make forecasts, and other factors. These differences explain why NHC hurricane forecasts may differ from those of other countries or institutions that also produce hurricane forecasts (e.g., the European Center for Medium-Range Forecasts produces Atlantic hurricane forecasts, as do some research institutions within the United States, such as the National Center for Atmospheric Research).

Forecasts and Warnings

Using the results from hurricane forecast models, different components within and outside the NHC contribute to the hurricane forecast process. These include the Tropical Analysis and Forecast Branch (TAFB), the Hurricane Specialist Unit (HSU), and the Hurricane Liaison Team (HLT). Of these, the HSU produces the final, official public forecast products, issued every six hours after a storm forms and more frequently if a hurricane watch or a hurricane warning is issued. (A *hurricane watch* is an announcement that hurricane conditions are possible within a specified coastal area, usually issued 48 hours in advance of the onset of tropical-storm-force winds. A *hurricane warning* is issued when hurricane conditions—sustained winds 74 miles per hour [mph] or greater—are expected somewhere within the specified coastal area.) The HSU also provides briefings on tropical storms to emergency managers and the public and cooperates with meteorological services in other countries (e.g., Mexico, as well as Central American and Caribbean countries). The TAFB supports the HSU by providing tropical cyclone position and intensity estimates, conducting media interviews, and assisting in tropical cyclone operations.

The HLT is sponsored through the Federal Emergency Management Agency (FEMA) and is comprised of federal, state, and local emergency managers, FEMA personnel, and NWS forecasters and hydrologists. On or before the beginning of hurricane season (for the Atlantic, June 1 to November 30), the NHC director requests that FEMA activate the HLT, which remains active throughout hurricane season. If a tropical cyclone in the Atlantic or eastern Pacific basin threatens either the United States or its territories, then the NHC can request that NWS

meteorologists or hydrologists be assigned to the HLT until the storm threat has passed.

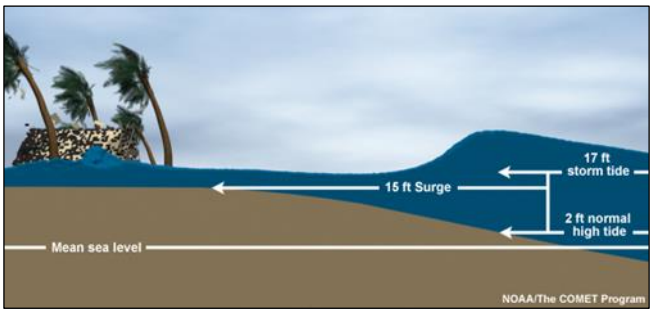
The HLT serves as a liaison between the NHC forecasters and local emergency managers facing a threat of tropical cyclones. A main function of the HLT is to communicate the level of the threat to federal, state, and local officials. Neither the HLT nor the NHC assumes any responsibility for issuing evacuations, however; those decisions are left to state or local officials.

Forecasts and warnings generally are coordinated between the NWS national centers and the local forecast offices. When the NHC issues its forecast, local NWS Weather Forecast Offices use the information for their own forecasts, which take into consideration local conditions.

Storm Surge

In addition to the hurricane forecast models that predict intensity, winds, and precipitation, other forecast models are designed specifically to forecast storm surge. *Storm surge* is defined as an abnormal rise in sea level accompanying a hurricane or other intense storm. It generally refers to the difference between the measured level of the sea surface during the storm compared to what the sea level would have been without a storm. (See **Figure 1**.) Storm surge, combined with high precipitation from a hurricane, can create dangerous flood conditions for coastal communities during tropical cyclones and other intense storms. (Superstorm Sandy, for example, produced a storm surge that inundated the heavily populated coastline in New Jersey and New York to cause enormous damage, despite the storm itself being a relatively weak hurricane immediately prior to landfall.)

Figure 1. Storm Surge



Source: National Hurricane Center at http://www.nhc.noaa.gov/surge/ssu.php.

The Storm Surge Unit, part of the NHC, models and predicts storm-surge vulnerability over the U.S. Atlantic and Gulf coasts, Hawaii, Puerto Rico, and the U.S. Virgin Islands. The Storm Surge Unit typically commences its operations when a hurricane warning is issued and continues 24 hours per day if the hurricane threatens to make landfall until the storm surge threat subsides.

Challenges

Hurricane forecasts have improved in recent decades. In 1992, hurricane forecasts extended out only three days; today, the forecasts typically extend for five days. Over that same time span, the ability to forecast hurricane tracks also has improved, increasing the likelihood of more accurately predicting landfall location. That increased accuracy provides useful information to local, state, and federal emergency managers faced with decisions about evacuating coastlines and with staging emergency equipment and supplies. Better instruments aboard weather satellites, such as the GOES series and the polar-orbiting weather satellites, have contributed to those improvements, together with more sophisticated hurricane forecast models and vastly improved computing capabilities.

Flooding resulting from intense precipitation during hurricanes could be responsible for the majority of fatalities caused by a storm. Some studies show, however, that the amount of rainfall produced by a storm may not necessarily be related to the intensity of the hurricane. Intense precipitation and flooding during Hurricane Harvey, for example, continued even after the storm made landfall and was downgraded from a hurricane to a tropical storm. Improving the ability to accurately forecast the amount and location of intense precipitation would advance the value of hurricane forecasting significantly.

Perhaps the biggest challenge for the NHC is how to improve the ability to predict hurricane intensity, basically how strong a hurricane will become and when and where it will reach its maximum intensity. In addition, hurricane intensity itself is generally measured as highest sustained wind speeds, referred to as the Saffir-Simpson wind scale (1-5), ranging from sustained winds of 74-95 mph (Category 1) to 157 mph or higher (Category 5). However, that measurement does not take into consideration the storm surge or precipitation-caused flooding, both of which may be among the most dangerous elements of a hurricane. (For instance, intense, concentrated, and multiday precipitation and flooding in and around the Houston, TX, region caused by Hurricane Harvey has been the storm's most destructive and dangerous feature.) Despite not being part of the hurricane-intensity scale, hurricane forecast information typically includes precipitation estimates—as in the case of Hurricane Harvey—and storm-surge estimates, so that affected communities may better prepare for the impending hazard.

Legislation

The 115th Congress recently enacted P.L. 115-25, the Weather Research and Forecasting Act of 2017, which provides direction to NOAA and NWS on a broad range of weather-related activities. The primary aim of the legislation is to improve NOAA's weather forecasts and warnings. Section 104 of Title 1 of P.L. 115-25 is specifically aimed at improving hurricane forecasting. The legislation directs NOAA to provide a plan to implement its project to improve hurricane forecasting within one year of enactment (by April 2018). For more detailed information about P.L. 115-25, see CRS Report R44838, *The Weather Research and Forecasting Innovation Act of 2017: Congressional Direction to NOAA in P.L. 115-25*, by Peter Folger.

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