*Hurricane track forecasts have improved substantially due to Vaisala Dropsonde measurements.*

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# A day in a hurricane specialist's life

## Tropical cyclones: The value of Vaisala Dropsondes and lightning data

*15:30 EDT Miami, Florida, USA: a hurricane specialist shows up for the evening shift at the National Hurricane Center (NHC). Hurricane Aidan* is located in the Gulf of Mexico with maximum sustained wind speeds of 135 miles per hour (mph) (217 kilometers per hour) and a minimum central pressure of 941 hectopascals. Aidan has been rapidly intensifying all day. The storm was only a category one hurricane less than 24 hours ago with maximum sustained wind speeds of 90 mph (145 kilometers per hour).*

This is a critical shift for the hurricane specialist. Hurricane Aidan is within 48 hours of landfall somewhere in the northwest Gulf of Mexico along the U.S. coast. It is currently an extremely dangerous category 4 storm with maximum sustained wind speeds of 135 mph (217 kilometers per hour) on a scale of one to five on the Saffir-Simpson Scale. A category five hurricane has maximum sustained wind speeds greater than 155 mph (249 kilometers per hour).

Most numerical weather prediction models used by NHC are projecting landfall near Houston, Texas, the fourth largest city in the U.S. However, two numerical weather prediction models are projecting landfall 300 km east of the Houston area. The specialist needs to issue a hurricane watch when hurricane conditions are expected on the coastline within 36 hours. The specialist is also responsible for issuing tropical storm watches and warnings. A tropical storm watch has already been issued for a large portion of the U.S. coastline in the northwest Gulf of Mexico. A tropical storm warning is issued when tropical storm conditions are expected on the coastline within 24 hours. However, there is a fairly strong outer rainband forming to the north of the center of Aidan. The specialist may need to upgrade the tropical storm watch to a warning during this shift.

### Decisions of great importance

The hurricane specialist must answer the following questions during his shift. Is Aidan going to make landfall near Houston? When should he issue a hurricane watch and where? When should he issue a tropical storm warning and where? Will Aidan reach category five intensity or will the rapid intensification stop shortly?

Tropical cyclone watches and warnings are coordinated through channels including federal, state, county, and local authorities, television, cable, and radio outlets, the internet, and recorded telephone messages. Upon receipt of this information, emergency managers will start making decisions on which coastal areas to evacuate and provide emergency services. Hurricane specialists understand the financial impact of issuing a watch or warning for a metropolitan area the size of Houston.

### Into the eye of the storm

*An Air Force WC-130J reconnaissance plane, better known as a hurricane hunter, has just finished flying through the center of the storm, launching three Vaisala-NCAR Dropwindsondes along the way. The first dropwindsonde (or, simply, dropsonde) was launched into the northeast eyewall of Aidan, the second into the eye, and the third into the southwest eyewall. The first dropsonde measured maximum sustained wind speeds near the surface of 145 mph (233 kilometers per hour). The second dropsonde, launched into the eye of the storm, measured a minimum central pressure of 930 hectopascals. The third dropsonde measured maximum sustained wind speeds near the surface of 140 mph (225 kilometers per hour). Aidan is continuing to rapidly intensify. Unfortunately, the next scheduled hurricane hunter will not be in the storm for another 12 hours.*

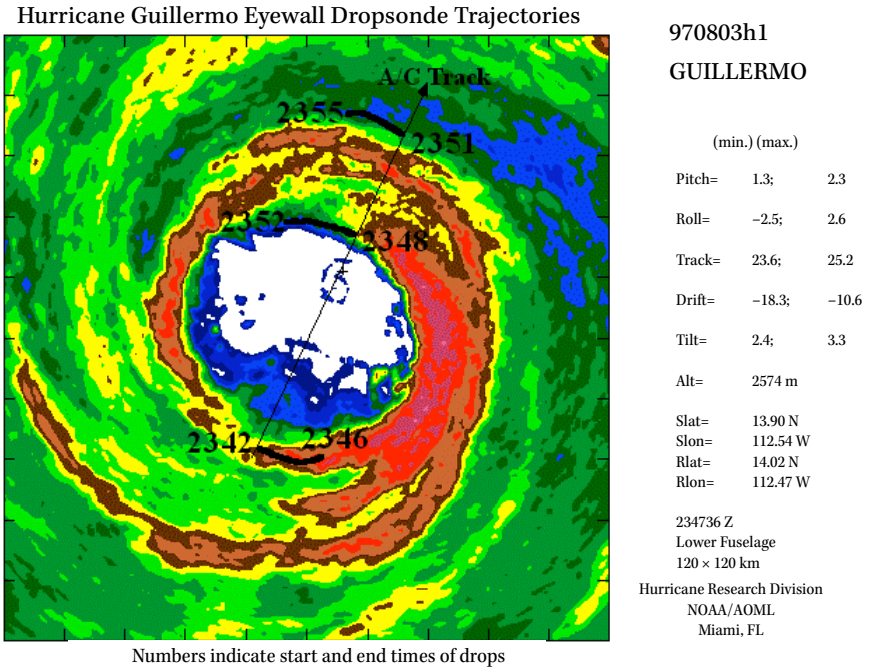
In the mid-1990s, the National Center for Atmospheric Research (NCAR), with funding support from the National Science Foundation, the National Oceanic and Atmospheric Administration (NOAA), and the German Aerospace Research Establishment (DLR) developed the first dropsondes that took advantage of the Global Positioning System (GPS) technology. The Vaisala-NCAR GPS Dropsonde, or RD93, was first manufactured in 1997 after a technology transfer license agreement with NCAR was executed. Vaisala-NCAR Dropsondes provide the only direct profile measure of wind speed and direction, pressure, temperature, and humidity within the core of a hurricane. These measurements are critical for measuring its current intensity and understanding the surrounding environment that influences the development and track of the storm.

The strongest winds in a hurricane are located within a ring of intense weather near the center of the storm known as the eyewall. The eye of the storm is located in the center of a hurricane and may contain little cloud cover and relatively calm winds. The minimum central pressure of a hurricane is found in the eye and is another measure of storm intensity.

### Strongest winds at 500 meters

*As the hurricane hunter flew in and around the center of the storm, it was taking continuous measurements of the wind at flight level, approximately 10,000 feet (3,048 meters). These measurements showed that the eastern eyewall of the storm contained the highest sustained wind speeds.*

In the late 1990s, hundreds of Vaisala-NCAR Dropsondes were launched into hurricanes. Scientists at NHC and the Hurricane Research Division (HRD) quickly confirmed that the strongest winds within a hurricane are not at the surface, but at an altitude of approximately 500 meters (or 1,640 feet). Dropsonde measurements of wind speed from 10,000 feet (3,048 meters) to the surface allowed forecasters to better understand the relationship between flight-level winds and surface wind speeds. Since dropsondes only provide a single vertical profile of wind speeds near the surface, specialists at NHC depend on continuous flight-level measurements of wind speed as hurricane hunters fly in and around the center of the storm. Properly translating flight-level wind speeds to surface




*Radar reflectivity image from aircraft showing the eyewall and eye of Hurricane Guillermo (1997). The eyewall is shown by the ring of stronger reflectivities (red and purple colors) surrounding the eye (blue and white colors). The paths of three Vaisala-NCAR dropsondes are shown by the thick black lines. The hurricane hunter aircraft track is shown by the thin black line. The launch and end times show the horizontal path of the dropsondes as they rotated counterclockwise around the center (eye) of the storm. Image: National Hurricane Center.*

wind speeds is another critical way to monitor the storm.

The confirmation that the highest wind speeds in the eyewall of a hurricane occur above the surface is very important for emergency managers. If a hurricane is going to make landfall near a large city with numerous high rise buildings, people should not seek shelter on the upper floors of those buildings. Hurricanes are actually a category stronger on the Saffir-Simpson scale on the 25th floor of a high rise building than they are on the ground. Most of the damage caused on the upper floors of high rise buildings during hurricane landfalls is due to windows being blown out.

*As the hurricane hunter is returning to its base, it flies through a rainband developing on the north side of Hurricane Aidan. As it flies through the rainband, the Stepped Frequency Microwave Radiometer (SFMR) is taking continuous remote measurements of surface wind speed and measures surface wind speeds just under tropical storm strength. However, flight-level wind speeds measured by the aircraft show sustained winds of moderate tropical storm strength.*

The SFMR estimates surface wind speeds based on the state (or amount of foam) of the ocean surface. Surface wind speed estimates from the SFMR need to be calibrated using Vaisala-NCAR Dropsondes. Similar to flight-level wind measurements, SFMR provides continuous estimates while the aircraft is in the storm. Surface wind speeds are critical to forecasters in gaining a better understanding of storm development and current intensity.

*At the same time as the Air Force hurricane hunter is flying through Aidan, a NOAA Gulfstream IV aircraft is flying at 40,000 feet (12,192 meters) and launching dropsondes in the environment surrounding the hurricane.*

The Gulfstream IV aircraft launches dropsondes at a much higher altitude than the Air Force hurricane hunter and outside of the hurricane in order to provide numerical weather prediction models with the information they need to improve forecasts. Vertical measurements of wind speed and direction, pressure, temperature, and humidity are immediately sent to the National Center for Environmental Prediction (NCEP) and assimilated into NCEP and other numerical weather prediction models. NCEP is located in Camp Springs, Maryland and provides worldwide forecast guidance products. Research has shown that hurricane track forecasts have improved substantially due to Vaisala-NCAR GPS Dropsonde (RD93) measurements in the environment surrounding the hurricane.

## Lightning activity reveals hurricane intensity

*As the hurricane specialist waits for the next set of numerical weather prediction model data, including the recent dropsonde measurements assimilated from the hurricane environment, he notices some changes in the lightning activity within Aidan. The outer rainband to the north of the storm is now producing very high lightning rates.*

Most of the lightning produced by a hurricane occurs in the outer rainbands of the storm however not all outer rainbands produce lightning. High lightning rates within outer rainbands of a hurricane indicate strong convection that will allow strong winds above the ground to reach the surface in downdrafts. Vaisala-NCAR Dropsonde measurements in the outer rainbands of hurricanes have shown that the highest winds are not at the surface, but also near 500 meters (1,640 feet). Therefore, high lightning rates in the outer rainband of a hurricane may indicate that stronger winds aloft may reach the surface.

*The hurricane specialist has also been monitoring an abrupt increase in lightning activity in the eyewall of Aidan over the past nine hours. This increase in eyewall lightning activity has decreased considerably over the last three hours.*

Research currently being performed at Vaisala and NHC has shown that numerous hurricanes have produced an abrupt increase in eyewall lightning near peak intensity after a rapid intensification period. This abrupt increase will usually cease after 6 – 9 hours. Rapid intensification ends at about the time the lightning rate ceases in the eyewall.

*The latest numerical weather prediction model results using the dropsonde data from the environment outside of the hurricane have just come in. All models now have tracks that take the storm 300 km east of Houston during landfall. The numerical weather prediction models also predict landfall in 36 hours due to an unexpected increase in forward motion that was not shown in previous model runs. It is time to issue the 23:00 EDT advisory for Hurricane Aidan.*

The hurricane specialist now needs to process all of this information and come up with the appropriate track and intensity forecast. Let's now go back to the original list of questions the hurricane

specialist must answer in order to issue the 23:00 EDT advisory for Hurricane Aidan.

## Is Aidan going to make landfall near Houston?

Vaisala-NCAR Dropsonde data collected in the environment surrounding Hurricane Aidan has provided critical information regarding expected landfall. It is going to be a close call, but the official forecast issued by the hurricane specialist will take the center of Aidan over land 300 km east of Houston.

## When should he issue a hurricane watch and where?

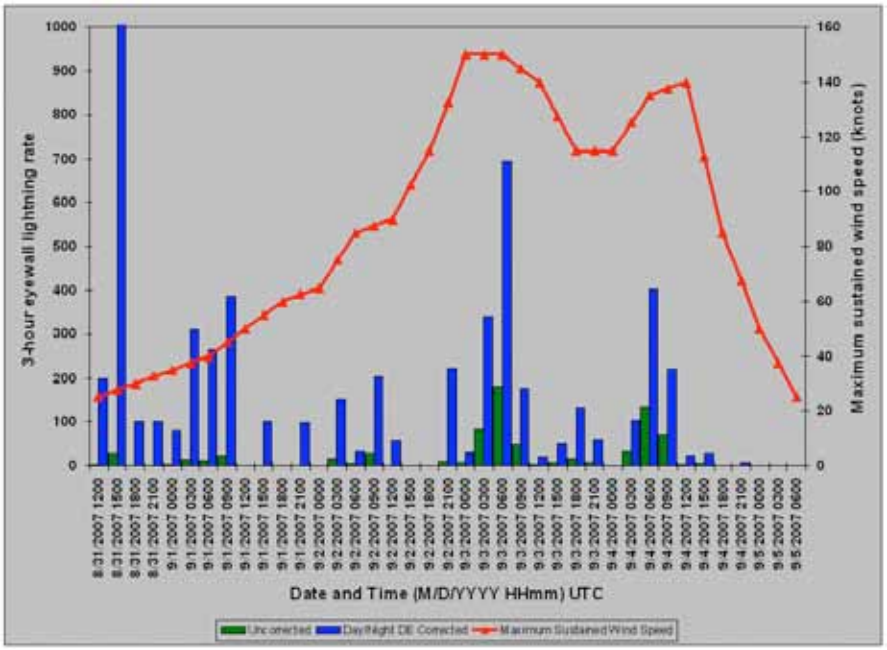
Once again, Vaisala-NCAR Dropsonde data collected in the environment surrounding Hurricane Aidan has provided critical information on when and where to issue the hurricane watch. Since the storm should increase its forward motion, the hurricane specialist issues a hurricane watch for areas east of Houston indicating that hurricane conditions are possible at locations within the watch area within 36 hours.

## When should he issue a tropical storm warning?

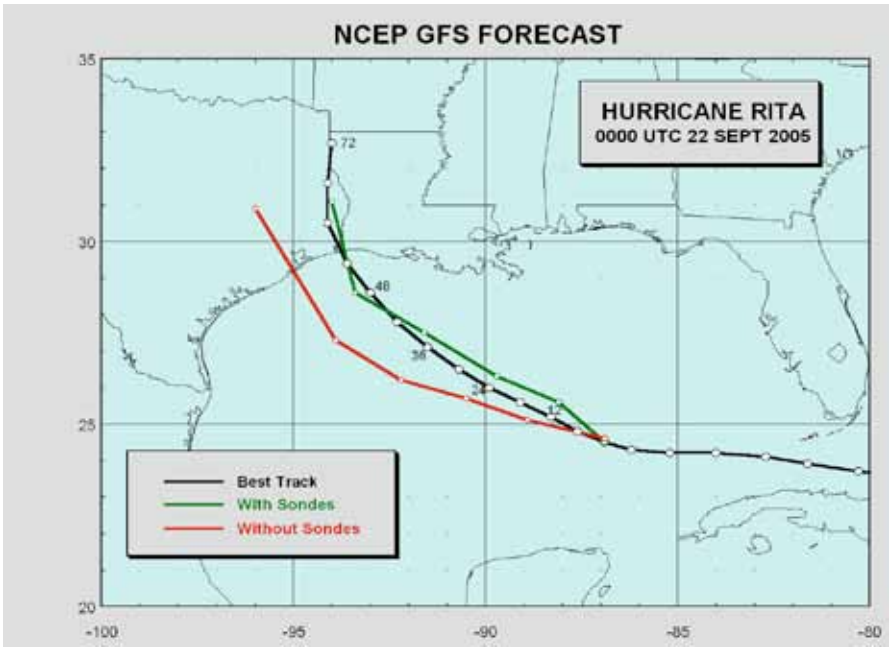
SFMR measurements showed surface wind speeds just under tropical storm strength in the outer rainband developing to the north of Hurricane Aidan. However, the hurricane specialist is concerned that stronger (tropical storm force) winds aloft in that rainband will reach the surface based on the observed high lightning rates within that band. This rainband is moving north at a moderate speed and could reach coastal areas within 24 hours. Therefore, the hurricane specialist issues a tropical storm warning for coastal areas in the path of this northern outer rainband. A tropical storm warning means that sustained winds between 39 and 73 mph (63 and 118 kilometers per hour) are expected to reach the coast in 24 hours or less.

## Will Aidan reach category five intensity or will the rapid intensification stop shortly?

According to the Vaisala-NCAR Dropsondes launched into the eyewall of Hurricane Aidan several hours ago, Aidan was continuing to rapidly intensify. However, over the last nine hours a burst of eyewall lightning has come and gone. In the absence of direct aircraft measurements, the hurricane specialist interprets this lightning burst as a sign that the rapid intensification of Aidan should end. Therefore, his forecast advisory states that the rapid intensification of Aidan has likely ended and the storm should not reach category five intensity during the next 12 hours. ■




*Eyewall lightning and maximum sustained wind speed time series for Hurricane Felix (2007). Eyewall lightning shown by the green and blue bars. Green bars represent raw lightning counts. Blue bars represent lightning counts corrected for day/night detection efficiency changes. The red line represents maximum sustained wind speeds within the storm. Notice the eyewall lightning burst early on 3 September 2007 as rapid intensification of Felix comes to an end.*




*Improvement in Hurricane Rita (2005) track forecast due to assimilation of Vaisala-NCAR dropsonde data in the environment outside of the hurricane into the NCEP Global Forecast System (GFS) numerical weather prediction model. At the time of the forecast, Rita was located in the southeast Gulf of Mexico. The black line shows the actual path of Rita as it made landfall near the Texas/Louisiana, U.S. coastline. The red line shows the forecast without dropsonde data. The green line shows the improved forecast after assimilation of dropsonde data. Image: National Hurricane Center*

***Further information:***
*www.vaisala.com/weather/applications/severeweather/hurricanes*

** Hurricane Aidan is a fictitious hurricane name to illustrate actual mission critical actions at the National Hurricane Center, utilizing Vaisala products.*