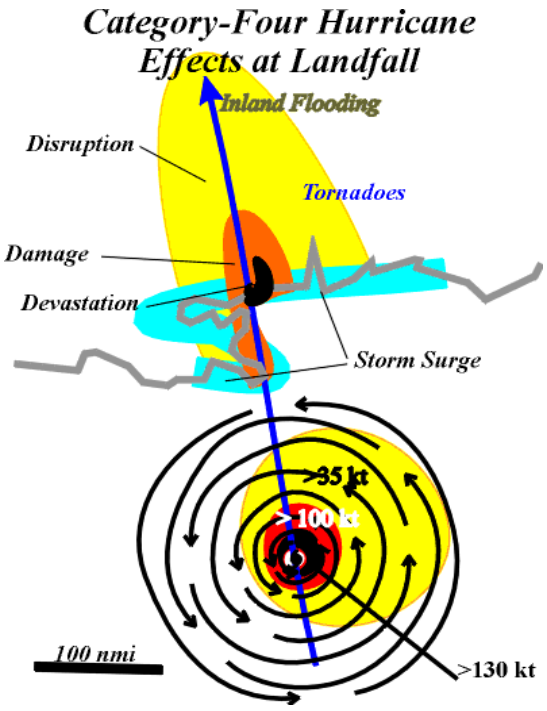
The hurricane threat is real. Every year hurricanes destroy hundreds of millions to several tens of billions of dollars worth of property in the United States. Extreme events–once a century–can produce losses that approach a hundred billion dollars. Human casualties have not been large in the U.S. in the 30 years since Hurricane Camille, but Hurricane Mitch's deadly toll in Central America shows that potential still exists for a hurricane-induced disaster that could kill thousands of U.S. citizens. The years 1995-1998 were the four most active consecutive hurricane seasons in the more than 100-year quantitative record. Climatological and oceanographic considerations point to a possible return of the higher levels of activity that characterized 1940-1969. If so, land-use decisions taken during the relatively inactive period 1970-1994 may be inappropriate for the early 21st century.



A hurricane has an intense core embedded in the broader vortex. Although hurricane-force winds and true devastation are confined to the core, widespread gale force winds, storm surge (cyan), tornadoes, heavy rains, and flooding spread the storm's effects over a broader area.

Saffir-Simpson hurricane intensity categories

Category	Central Pressure (millibars)	Wind Speed MPH	Wind Speed Knots	Damage
1	≥980	74-95	64-83	Minimal
2	965-979	96-110	84-96	Moderate
3	945-964	111-130	97-113	Extensive
4	920-944	131-155	114-135	Extreme
5	<920	>155	>135	Catastrophic

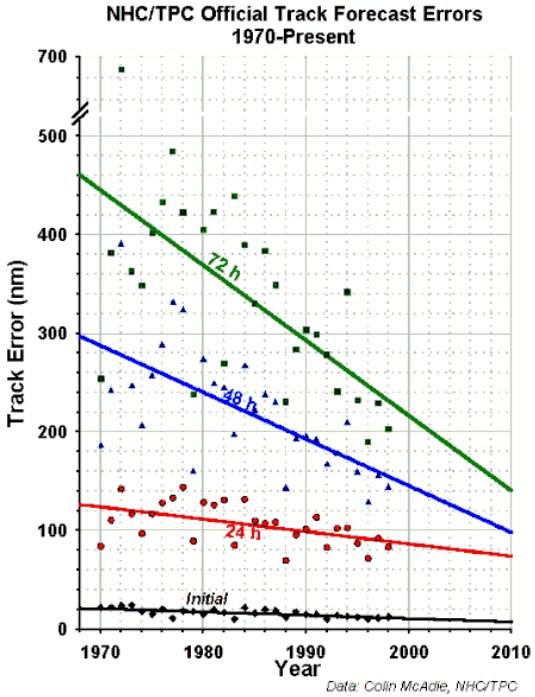
Accurate characterization of the threat is the first step toward a society resilient against hurricanes. Although accurate forecasts are not the whole story, they are a key element of hurricane characterization, and track forecasts are central to the forecast process. When, where, and whether the storm will strike is ***the*** vital concern on a threatened coastline.

Better track forecasts have unquestionably saved lives, but are they good enough? The arts of forecasting intensity, rainfall, and surface winds that determine damage patterns ashore and raise devastating seas are still in their infancy. Advancement requires new scientific insight leading to accurate numerical modeling of the following aspects:

- The oceanic energy source
- Interaction with the surrounding atmosphere
- The hurricane's internal dynamics

A serious concern is the meteorological phenomenon called "rapid intensification" that can transform a hurricane from a Category 1 or 2 to a Category 4 or 5 in less than a day. The transformation is dangerous because it is the only process that creates "major hurricanes"–the strongest 20% with winds blowing harder than 100 kt (115 mph) that account for 80% of the damage. Rapid intensification is also essentially impossible to forecast.

Hurricane Opal of 1995 illustrates this problem. It intensified from a Category 3 to a Category 4 storm during the night of October 3rd. People on the U.S. Gulf coast faced the possibility of an unprecedented disaster when they awoke the following morning. Only the equally abrupt, and equally unforecast, weakening just offshore prevented the possibility from becoming a reality.



Improvements in observations and modeling have produced substantially better hurricane track forecasts. Since 1970, the average 24-h forecast error has decreased from more than 125 miles to less than 90 miles. If the 30-year trend of improvement in 48-h forecasts continues, by 2010 they will be as accurate as 24-h forecasts were in 1990.

Historically, steady improvement of track forecasts shows what can be done; limitations of current intensity, rainfall, and surface wind forecasts show what needs to be done.

Hurricane Research and the U.S. Weather Research Program. The USWRP is a multi-agency program that focuses the efforts of NOAA, NASA, NSF, and ONR on the scientific problems of hurricanes at landfall, quantitative precipitation forecasts, and the optimum suite of meteorological observations. Its Hurricanes at Landfall (HaL) focus is a means to provide resources and organization for this essential research.

The 1998 hurricane season. HRD's ambitious 1998 airborne research campaign was carried out in conjunction with NASA's Third Convection and Moisture Experiment (CAMEX3). It was preliminary to a five-year (2000-2004) program of observation and analysis to be conducted under the USWRP and the World Weather Research Programme (WWRP). The initial 1998 collaboration resulted in unprecedentedly detailed observation of Atlantic hurricanes. Aircraft from both agencies flew a combined total of 66 scientific sorties and deployed more than 1500 dropsondes in Hurricanes Alex, Bonnie, Danielle, Earl, Georges, Hermine, and Mitch. Participation by jet aircraft provided extensive in-situ observations above the middle troposphere for the first time since the 1960s. Several of the flights were coordinated with overpasses of the Tropical Rain Measuring Mission (TRMM) satellite to provide ground truth.

In 1999 and 2000 we will emphasize analysis of our data, followed by another intensive observing season in conjunction with CAMEX4 in 2001, and three more years of analysis. The new observations and analyses promise a revolution in understanding and forecasts of tropical cyclones.

HURRICANE SCIENCE FOR THE 21ST CENTURY

One of the two WP-3D research aircraft operated by NOAA's Aircraft Operations Center. These airplanes and the newly commissioned Gulfstream IV jet provide unequaled facilities for hurricane science.

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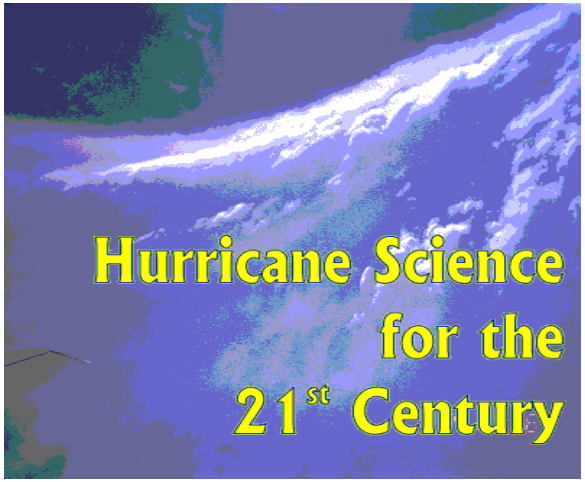

The eyewall of Hurricane Olivia, seen from within

NOAA's Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) is the only organization in the world that routinely designs and executes scientific research flights into hurricanes. Its missions are advancement of basic physical understanding, leading to better forecasts of:

- Hurricane motion
- Hurricane intensity
- Hurricane structure with emphasis on surface winds at landfall
- Hurricane climatology and human impacts
- Tropical convection and rainfall

In pursuit of these objectives, researchers collaborate closely with the National Weather Service, especially the Tropical Prediction Center, other NOAA laboratories, federal agencies, and university scientists worldwide.