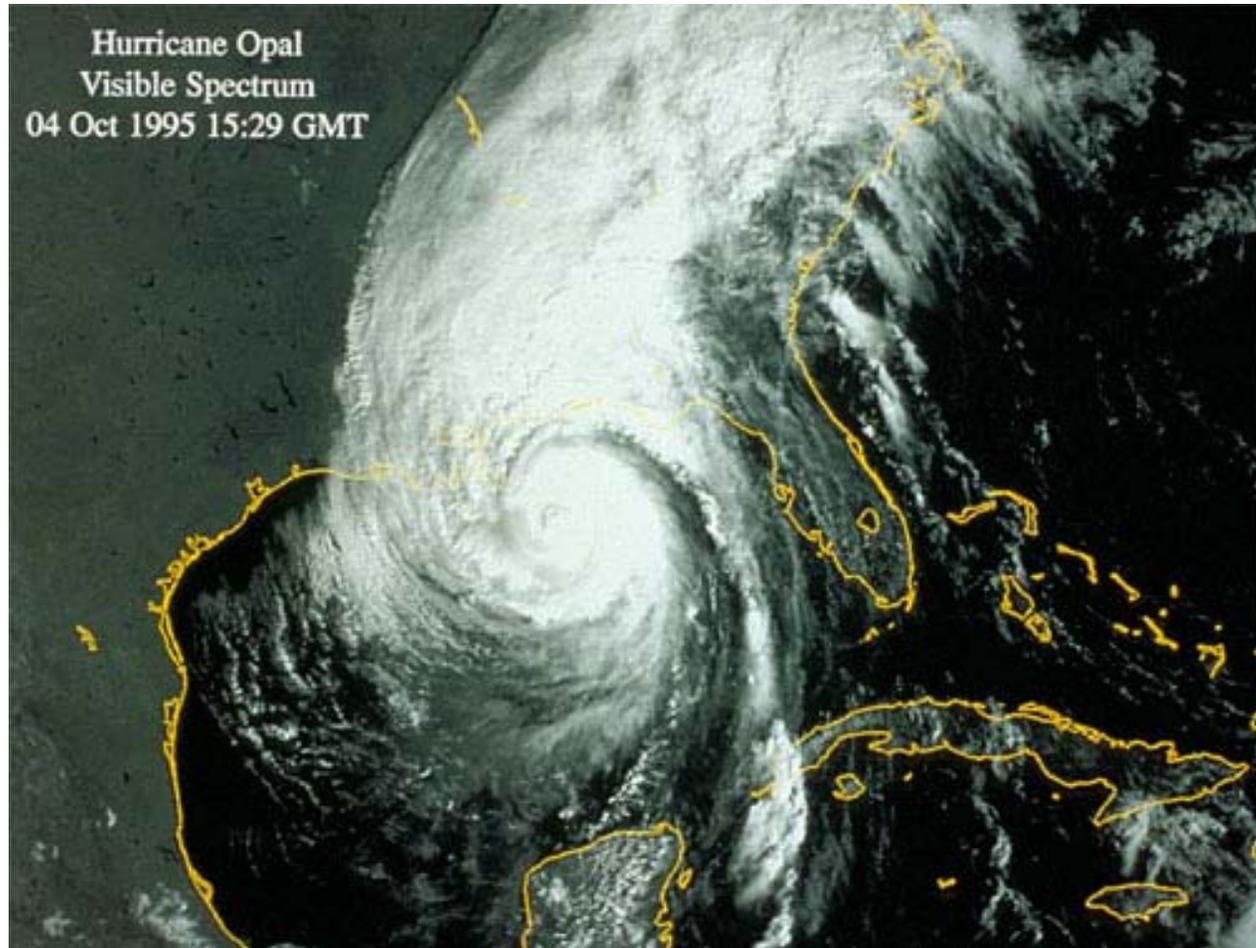


Weather

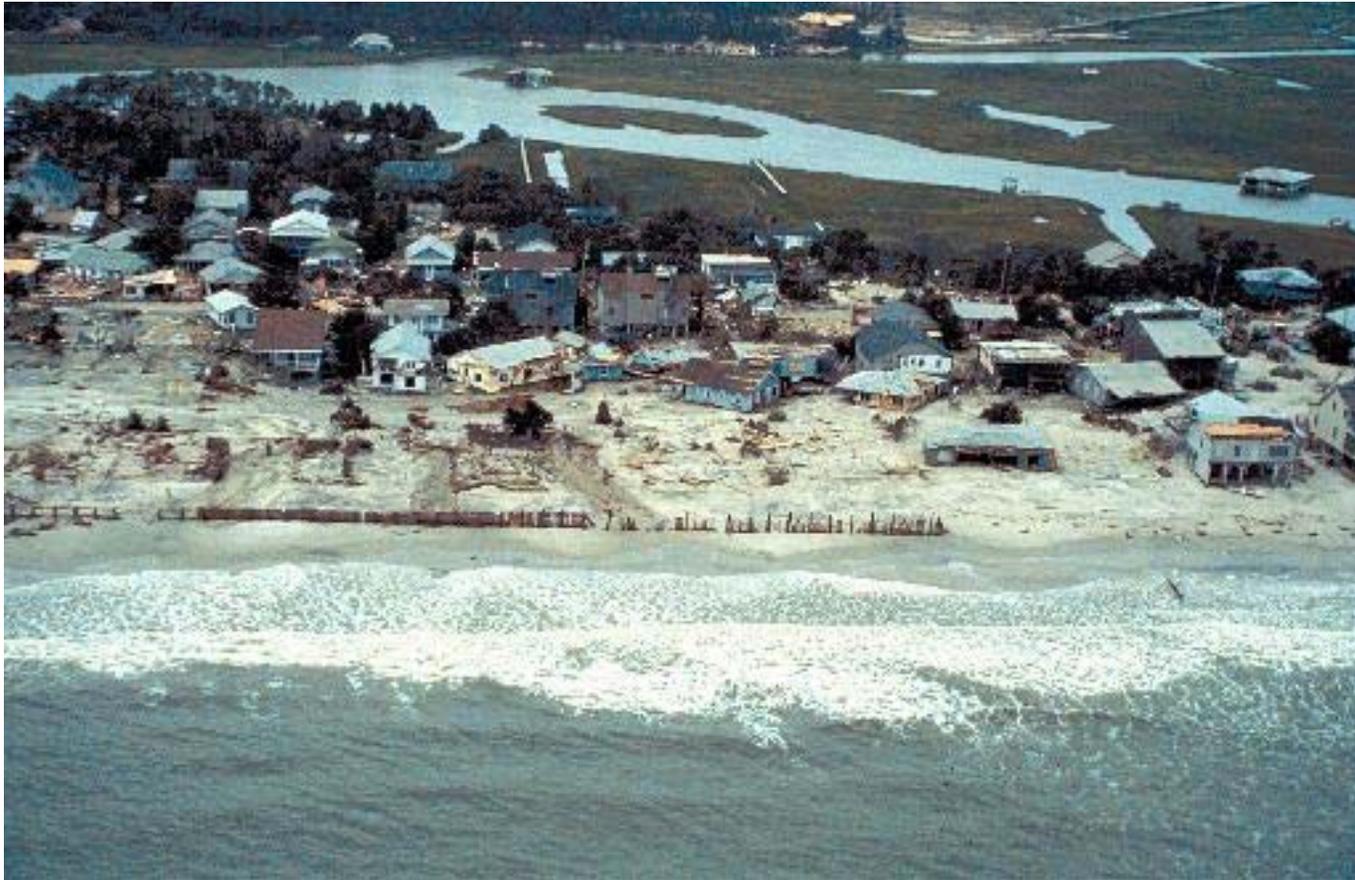
Hurricanes

# Satellite Photo of Hurricane Opal

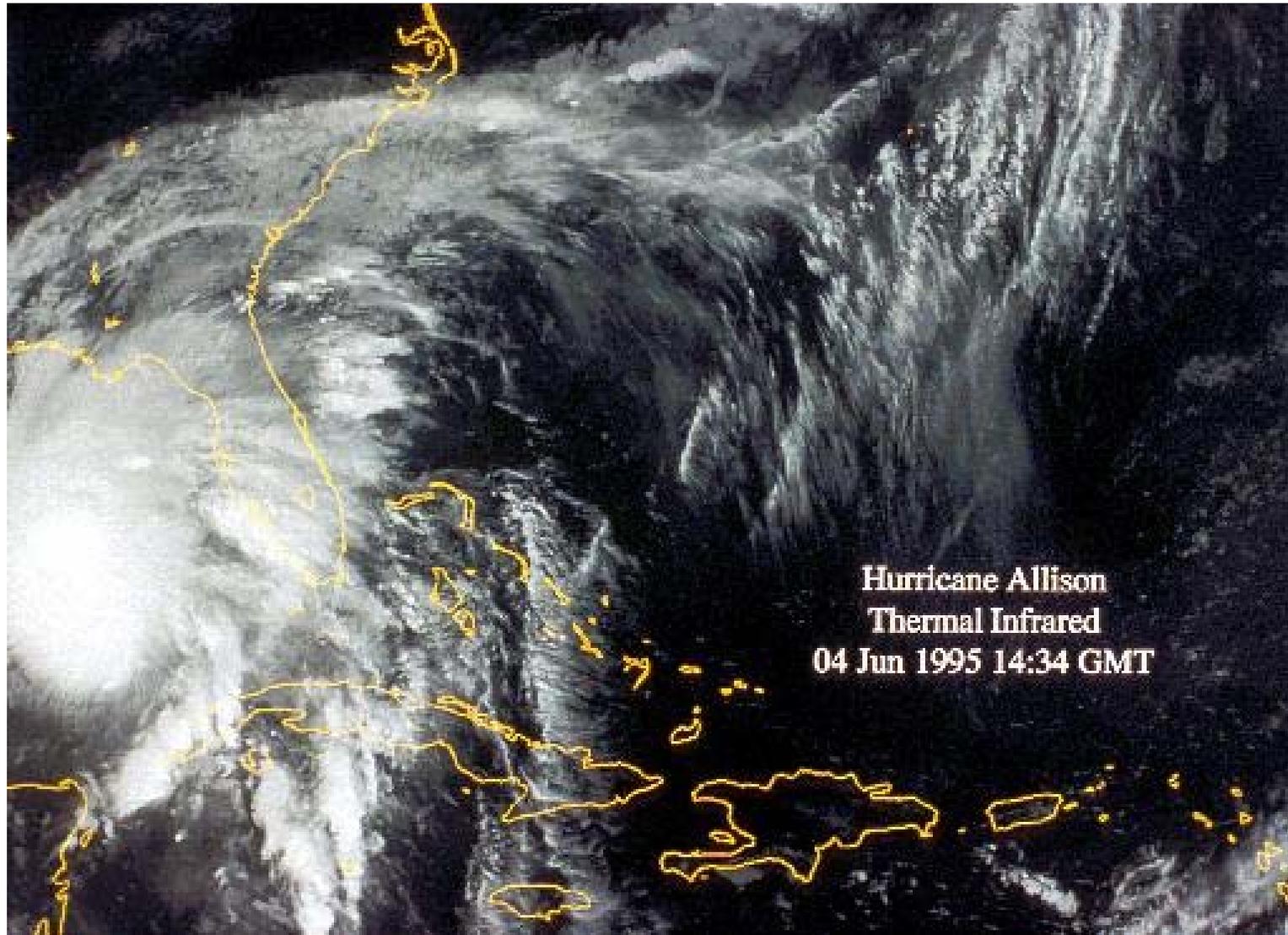


Courtesy NOAA, Image Source: [Earth Science World Image Bank](#)

# Hurricane Hugo Destruction



# Hurricane Allison



Courtesy NOAA, Image Source: [Earth Science World Image Bank](#)

# Hurricane Mitch



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# Hurricane Mitch Destruction



# Hurricane Mitch Destruction



© Michael Collier, Image Source: [Earth Science World Image Bank](#)

# Hurricane Isabel



© MODIS, NASA, Image Source: [Earth Science World Image Bank](#)

# Hurricane Isabel's Eye



# Hurricane Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# Pumping Water Out of New Orleans



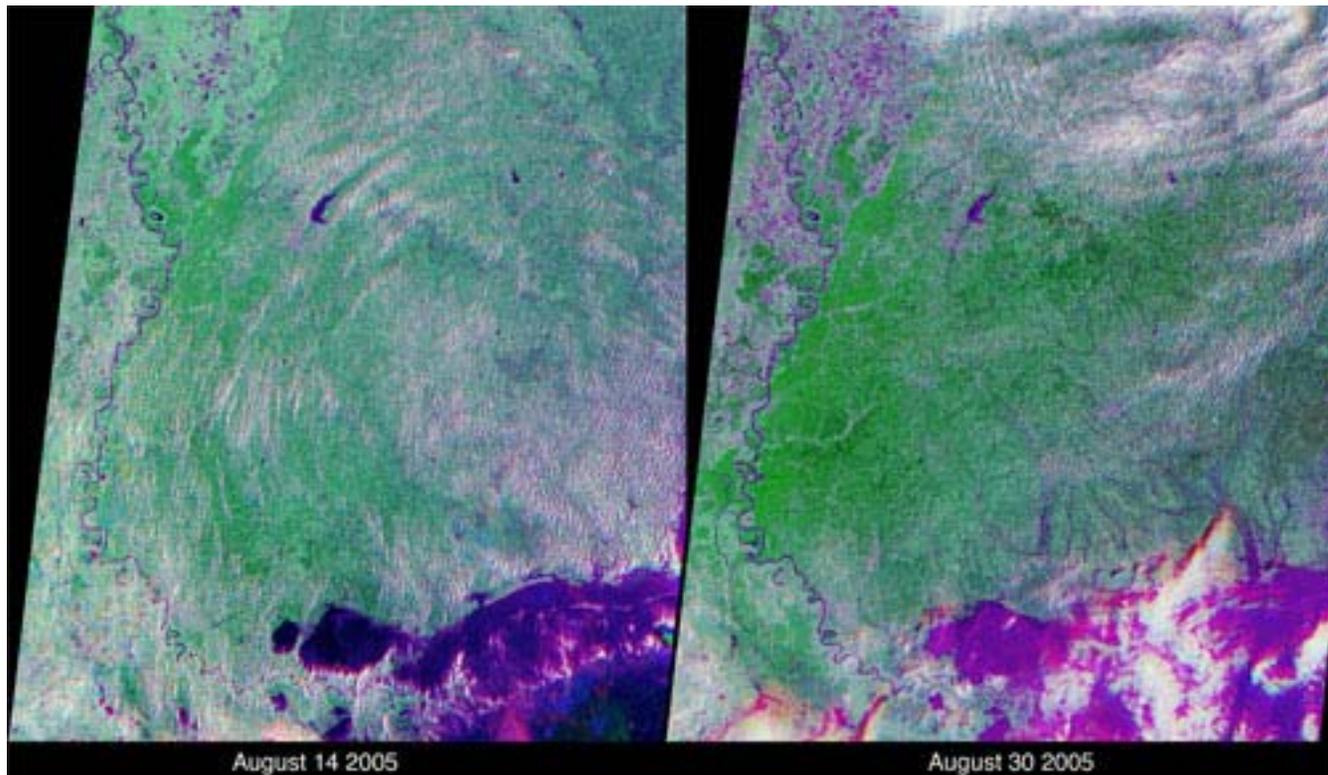
September 15, 2005



September 7, 2005

Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# Flooding After Hurricane Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# Katrina's Aftermath From Space



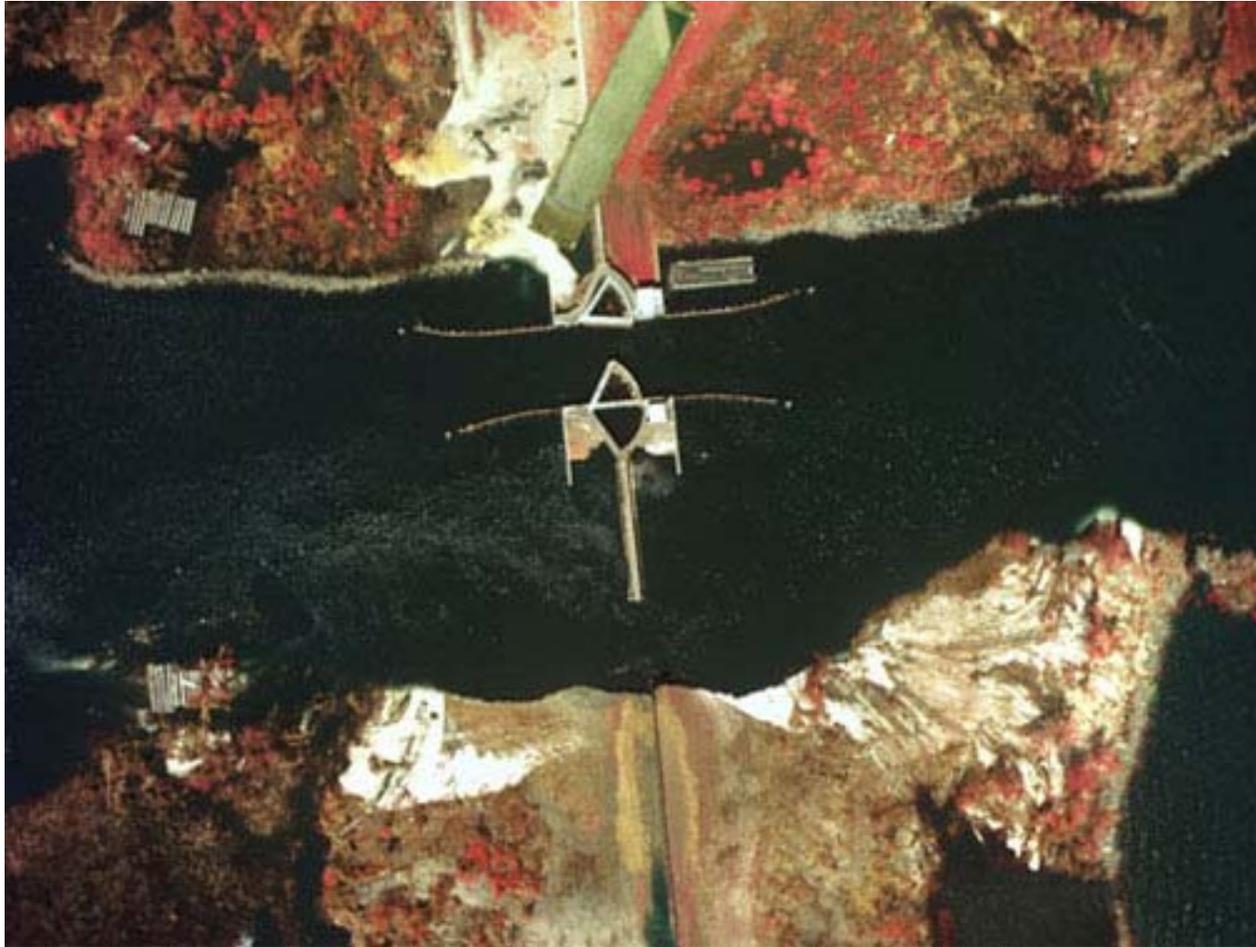
Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# After and Before The Storm

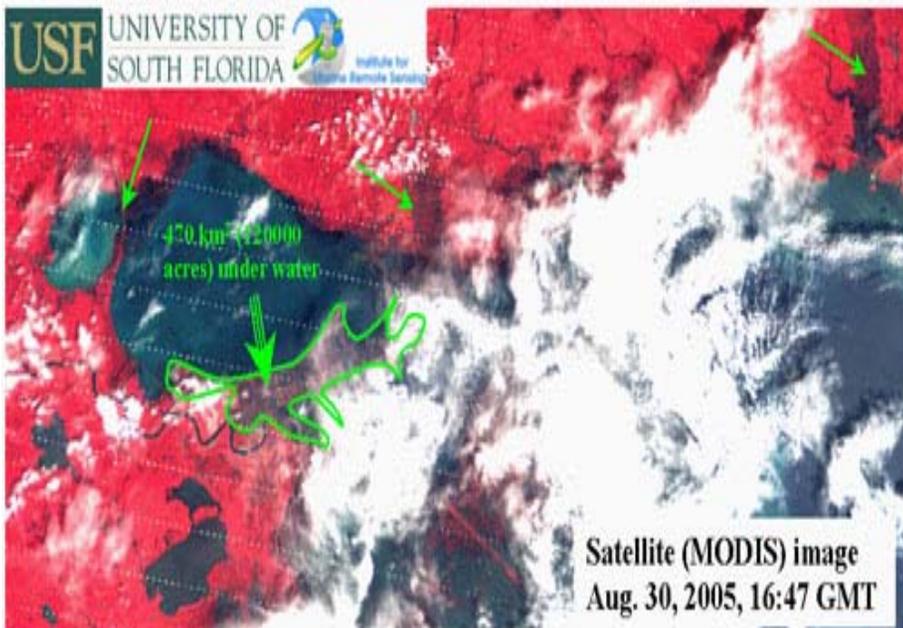
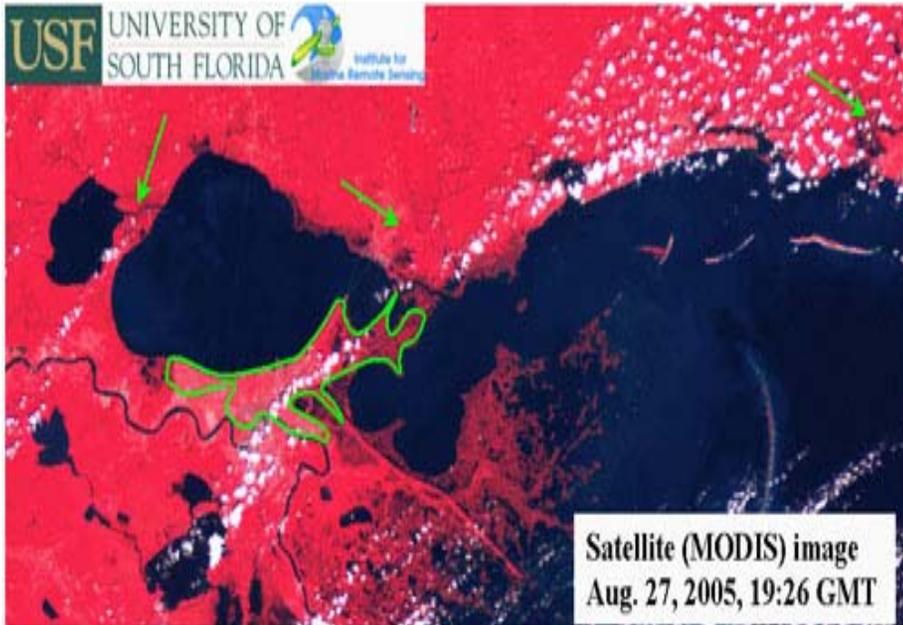


Courtesy NOAA, Image Source: [NOAA Photo Library](#)

# Gulf of Mexico After Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)



Flooding after Hurricane Katrina: before (Aug. 27, 2005) and after (Aug. 30, 2005) comparison. Red: land; white: clouds; other colors: water. Green arrows point to severe flooding. Green outlines around New Orleans show extensive flooding area. More daily images can be found at the USF Institute for Marine Remote Sensing (<http://modis.marine.usf.edu/weekly/mriver/mriver.index.html>).

Courtesy NOAA,  
Image Source: [NOAA Photo Library](#)

# After and Before Hurricane Katrina Hit Louisiana



August 30, 2005



August 27, 2005

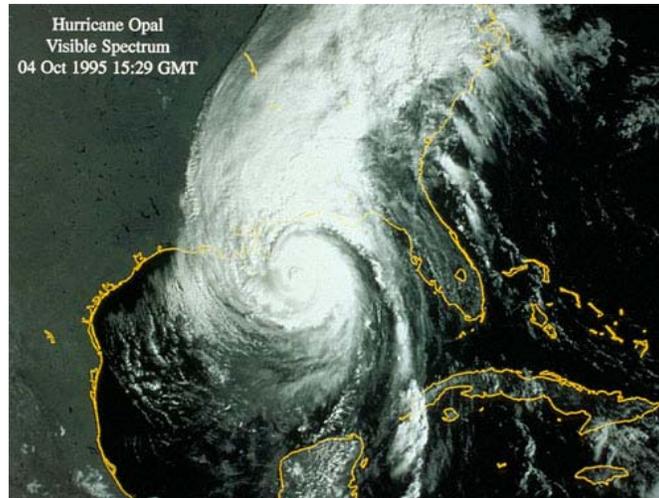
Courtesy NOAA, Image Source: [NOAA Photo Library](https://www.noaa.gov/photo-library)



Weather

Hurricanes

# Satellite Photo of Hurricane Opal



Courtesy NOAA, Image Source: [Earth Science World Image Bank](#)

This satellite visible spectrum image is of Hurricane Opal in October of 1995. The 1995 Atlantic hurricane season was the second most active season in recorded history. During 1995, 12 named tropical cyclones formed in the Atlantic before the end of August, and by the end of the season 19 tropical cyclones had received names. 11 of the 19 reached hurricane strength. The 1886 to 1994 seasonal average is 8.4 tropical storms with 4.9 reaching hurricane strength.

Opal was first detected as a tropical wave moving off the African coast on September 11. The wave moved westward through the Atlantic and Caribbean and merged with a broad low pressure area over the western Caribbean on September 23. The combined system then developed into a tropical depression near the east coast of the Yucatan Peninsula on September 27. The depression drifted slowly northward, becoming Tropical Storm Opal as it reached the north coast of Yucatan on the 30th. Opal then moved slowly westward into the Bay of Campeche, where it became a hurricane on October 2. A gradual north-northeastward turn started later on the 2nd, with acceleration on the 3rd and 4th. Opal continued to strengthen, and a period of rapid strengthening late on the 3rd and early on the 4th made it a Category 4 hurricane. Weakening followed, and Opal was a Category 3 hurricane when it made landfall near Pensacola Beach, Florida late on the 4th. Opal continued quickly north-northeastward and became extratropical over the Ohio Valley on the 5th. The cyclone was last seen over the eastern Great Lakes on October 6.

Hurlbert Field, Florida reported sustained winds of 84 mph with a peak gust of 144 mph, and gusts to 70 mph occurred as far inland as northwest Georgia. However, the main impact from Opal was from storm surge. A combination of storm surge and breaking waves inundated portions of the western Florida Panhandle coast to a

# Hurricane Hugo Destruction



© Society for Sedimentary Geology, Image Source: [Earth Science World Image Bank](#)

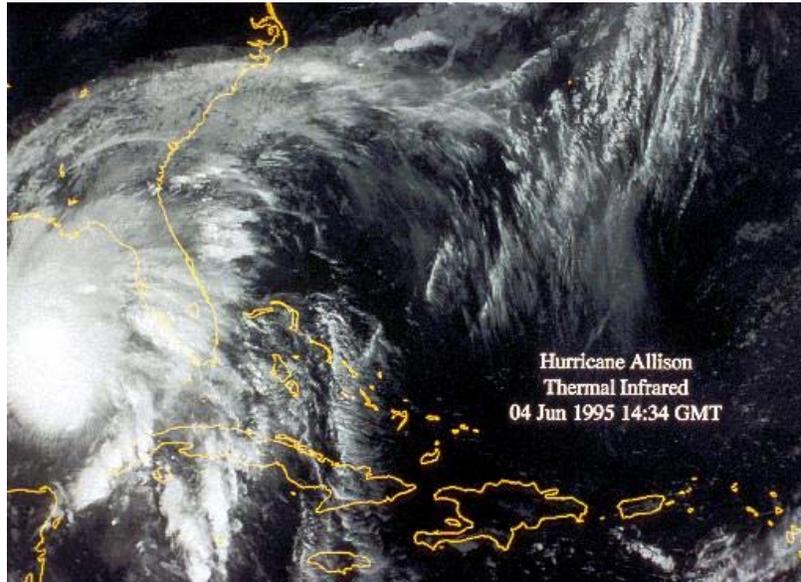
A view of the destruction caused by Hurricane Hugo in September 1989 on Pawley's Island, South Carolina. At the time there was a law that said that they could not be rebuilt. This law was later waived as a result of political pressure.

This classic Cape Verde hurricane was first detected as a tropical wave emerging from the coast of Africa on September 9. Moving steadily westward, the system became a tropical depression the next day, a tropical storm on the 11th, and a hurricane on the 13th. Hugo turned west-northwest on September 15 as it became a Category 5 hurricane. It was still a Category 4 hurricane when the center moved through the Leeward Islands and St. Croix, USVI, and the 18th. Turning northwestward, the center passed across the eastern end of Puerto Rico on September 19. This general motion would continue with some acceleration until Hugo made landfall just north of Charleston, South Carolina on 22 September. Strengthening in the last twelve hours before landfall made Hugo a Category 4 hurricane at the coast. After landfall, the storm gradually recurved northeastward, becoming extratropical over southeastern Canada on September 23.

The Naval Air Station at Roosevelt Roads, PR reported sustained winds of 104 mph with gusts to 120 mph, which were the highest winds reported from the Caribbean. A ship moored in the Sampit River in South Carolina measured sustained winds of 120 mph. High winds associated with Hugo extended far inland, with Shaw Air Force Base, South Carolina reporting 67 mph sustained winds with gusts to 110 mph and Charlotte, North Carolina reporting 69 mph sustained winds and gusts to 99 mph.

Storm surge from Hugo inundated the South Carolina Coast from Charleston to

# Hurricane Allison



Courtesy NOAA, Image Source: [Earth Science World Image Bank](#)

This is a thermal infrared image of Hurricane Allison, the first named storm of the 1995 season. The 1995 Atlantic hurricane season was the second most active season in recorded history. During 1995, 12 named tropical cyclones formed in the Atlantic before the end of August, and by the end of the season 19 tropical cyclones had received names. 11 of the 19 reached hurricane strength. The 1886 to 1994 seasonal average is 8.4 tropical storms with 4.9 reaching hurricane strength.

# Hurricane Mitch



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

This powerful hurricane began developing over the southwestern Caribbean Sea on 22 October. It drifted westward and became a tropical storm later that day, then turned northward and became a hurricane by the 24th. Mitch then turned westward again and rapidly strengthened, becoming a Category 5 hurricane with a central pressure of 905 mb on the 26th. After passing over Swan Island on the 27th, a weakening Mitch moved slowly southward near the coastal Islands of Honduras. It made landfall over northern Honduras on the 29th as a Category 1 hurricane. Mitch gradually turned westward after landfall, and the surface center dissipated near the Guatemala-Honduras border on 1 November.

The remnant circulation aloft reached the Bay of Campeche on 2 November and began developing again. The re-born Mitch became a tropical storm on 3 November, then moved northeastward across the Yucatan Peninsula on the 4th. Mitch crossed south Florida as a tropical storm on the 5th and then became extratropical later that day. The extratropical cyclone remained strong as it crossed the Atlantic, eventually affecting the British Isles and Iceland on the 9th and 10th.

Mitch ravaged the offshore islands of Honduras with high winds, seas, and storm surge. However the greatest impact was widespread heavy rains and severe floods in Honduras, Nicaragua, Guatemala, and El Salvador. Mitch caused an estimated 9,000 deaths in Central America with another 9,000 missing. Thirty-one people died when the schooner *Fantome* sank as it encountered the high winds and seas associated with the hurricane. Two people died in the Florida Keys when a fishing boat capsized. Mitch caused tremendous property, infrastructure, and crop damage in Central America, and an additional \$40 million in damage in Florida.

# Hurricane Mitch Destruction



© Michael Collier, Image Source: [Earth Science World Image Bank](#)

Shown here is the devastation along the Rio Choluteca in Tegucigalpa, Honduras after Hurricane Mitch in January of 1999.

# Hurricane Mitch Destruction



© Michael Collier, Image Source: [Earth Science World Image Bank](#)

Shown here is the devastation along the Rio Choluteca in Tegucigalpa, Honduras after Hurricane Mitch in January of 1999.

# Hurricane Isabel



© MODIS, NASA, Image Source: [Earth Science World Image Bank](#)

Astronaut Ed Lu captured this broad-view photograph of Hurricane Isabel from the International Space Station on September 13, 2003, at 11:19 UTC. At the time, Isabel was located about 450 miles northeast of Puerto Rico and packed winds of 150 miles per hour with gusts up to 184 miles per hour.

# Hurricane Isabel's Eye



© MODIS, NASA, Image Source: [Earth Science World Image Bank](#)

Astronaut Ed Lu snapped this photo of the eye of Hurricane Isabel from the International Space Station on September 13, 2003 at 11:18 UTC. At the time, Isabel was located about 450 miles northeast of Puerto Rico. It had dropped to a Category 4 hurricane on the Saffir-Simpson Hurricane Scale, packing winds of 150 miles per hour with gusts up to 184 miles per hour. After originating in the eastern Atlantic west of the Cape Verde Islands, Isabel became the second major hurricane of the 2003 Atlantic season when it was declared a Category 3 storm by the National Hurricane Center on September 8. Over the next four days, Isabel strengthened into an extremely powerful Category 5 hurricane with winds estimated at 160 mph before dropping to a Category 4 hurricane on September 13. This photo shows the structure of Isabel's eye wall.

# Hurricane Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

## Pumping Water Out of New Orleans

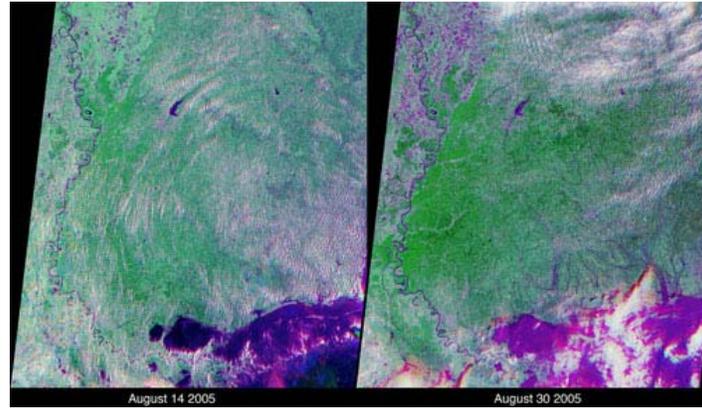


Courtesy NOAA, Image Source: [NOAA Photo Library](#)

The floods that buried up to 80 percent of New Orleans had noticeably subsided by September 15, 2005, when the top image was taken by the Landsat 7 satellite. In the two and a half weeks that had passed since Hurricane Katrina flooded the city, pumps had been working nonstop to return the water to Lake Pontchartrain. As portable pumps were brought in to supplement the permanent pumps already hard at work, as much as 380 cubic meters (380,000 liters or 23,190,000 cubic inches) of water were being pumped out of New Orleans every second, according to the U.S. Army Corps of Engineers.

The progress in draining the city is evident when the September 15 image is compared with an image taken one week earlier. In the lower image, taken by the Landsat 5 satellite on September 7, black flood water covers much of the city. By September 15, the dark flood water had all but disappeared, lingering only in a few sections of the city. The September 7 image does not show the full extent of the flooding. Taken more than a week after the hurricane struck New Orleans, the image shows a flooded city that had already started to drain. In a similar (but cloudy) image taken on August 30, the flood water in St. Bernard Parish, image right, extends almost to the Mississippi River. Credit: Images provided courtesy of the United States Geological Survey Center for Earth Resources Observation & Science (CEROS).

# Flooding After Hurricane Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

These views of the Louisiana and Mississippi regions were acquired before and one day after Katrina made landfall along the Gulf of Mexico coast, and highlight many of the changes to the rivers and vegetation that occurred between the two views. The images were acquired by NASA's Multi-angle Imaging SpectroRadiometer (MISR) on August 14 and August 30, 2005. These multiangular, multispectral false-color composites were created using red band data from MISR's 46° backward and forward-viewing cameras, and near-infrared data from MISR's nadir camera. Such a display causes water bodies and inundated soil to appear in blue and purple hues, and highly vegetated areas to appear bright green. The scene differentiation is a result of both spectral effects (living vegetation is highly reflective at near-infrared wavelengths whereas water is absorbing) and of angular effects (wet surfaces preferentially forward scatter sunlight). The two images were processed identically and extend from the regions of Greenville, Mississippi (upper left) to Mobile Bay, Alabama (lower right).

There are numerous rivers along the Mississippi coast that were not apparent in the pre-Katrina image; the most dramatic of these is a new inlet in the Pascagoula River that was not apparent before Katrina. The post-Katrina flooding along the edges of Lake Pontchartrain and the city of New Orleans is also apparent. In addition, the agricultural lands along the Mississippi floodplain in the upper left exhibit stronger near-infrared brightness before Katrina. After Katrina, many of these agricultural areas exhibit a stronger signal to MISR's oblique cameras, indicating the presence of inundated soil throughout the floodplain. Note that clouds appear in a different spot for each view angle due to a parallax effect resulting from their height above the surface.

The Multi-angle Imaging SpectroRadiometer observes the daylit Earth continuously, viewing the entire globe between 82° north and 82° south latitude every nine days. Each image covers an area of about 380 kilometers by 410 kilometers. The data products were generated from a portion of the imagery acquired during Terra orbits 30091 and 30324 and utilize data from blocks 64-67 within World Reference System-2 path 22.

MISR was built and is managed by NASA's Jet Propulsion Laboratory, Pasadena, CA, for NASA's Science Mission Directorate, Washington, DC. The Terra satellite is managed by NASA's Goddard Space Flight Center, Greenbelt, MD. JPL is managed for NASA by the California Institute of Technology.

**Image credit:** NASA/GSFC

**Text credit:** Clare Averill (Raytheon RIS/Jet Propulsion Laboratory), David J. Diner and Barbara J. Gaitley (Jet Propulsion Laboratory)

# Katrina's Aftermath From Space



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

The extent of flooding in the greater New Orleans metropolitan area is clearly visible in this image, acquired from the International Space Station on September 8, 2005, of areas damaged by Hurricane Katrina. Flooded areas are dark greenish brown, while dry areas to the west of the 17th Street Canal and along the banks of the Mississippi River (lower half of image) are light brown to gray. This cropped image (from the parent frame ISS011-E-12527) is oriented with north to the top. Credit: NASA

## After and Before The Storm



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

Seventeen days after Hurricane Katrina flooded New Orleans, much of the city is still under water. In this pair of images from the Advanced Spaceborne Thermal Emission and Reflection Radiometer on NASA's Terra satellite, the affected areas can clearly be seen. The top image mosaic was acquired in April and September 2000, and the bottom image was acquired September 13, 2005.

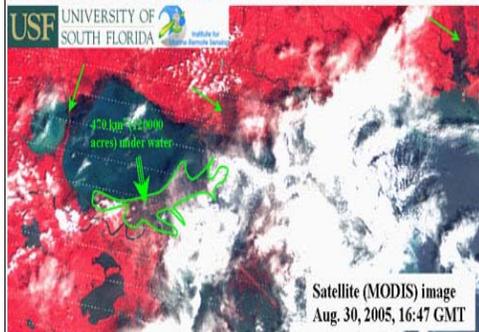
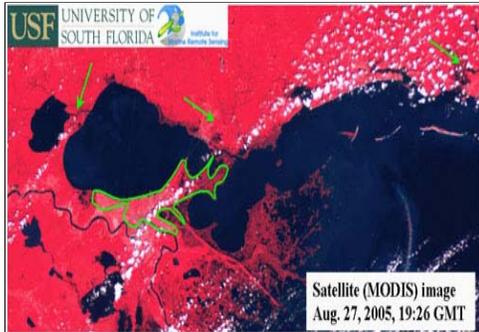
The flooded parts of the city appear dark blue, such as the golf course in the northeast corner, where there is standing water. Areas that have dried out appear light blue gray, such as the city park in the left middle. On the left side of the image, the failed 17th Street canal marks a sharp boundary between flooded city to the east, and dry land to the west. The images cover an area of 10.4 x 7.1 kilometers and are centered near 30 degrees north, 90.1 degrees west. Image credit: NASA/JPL

## Gulf of Mexico After Katrina



Courtesy NOAA, Image Source: [NOAA Photo Library](#)

The image above was taken from NASA's Experimental Advanced Airborne Research Light Detection and Ranging (EAARL) system that has been surveying the coastline of the Gulf of Mexico this week. The aircraft is taking high-resolution observations that can be used to assess the amount of damage to communities and the environment. This activity is being conducted at the request of the U.S. Geological Survey in cooperation with the Federal Emergency Management Agency and the Army Corps of Engineers.



Flooding after Hurricane Katrina: before (Aug. 27, 2005) and after (Aug. 30, 2005) comparison. Red: land; white: clouds; other colors: water. Green arrows point to severe flooding. Green outlines around New Orleans show extensive flooding area. More daily images can be found at the USF Institute for Marine Remote Sensing (<http://modis.marine.usf.edu/weekly/river/river.index.html>).

Courtesy NOAA.  
Image Source: [NOAA Photo Library](#)



# After and Before Hurricane Katrina Hit Louisiana

Courtesy NOAA, Image Source: [NOAA Photo Library](#)



[NOAA Photo Library](#)

Hurricane Katrina strengthened into a powerful Category Five hurricane overnight with sustained winds of 160 mph. The National Hurricane Center put out a special advisory on the hurricane's gain in strength just before 8 a.m. EDT. The boost came just hours after Katrina reached Category 4, with wind of 145 mph, as it gathered energy from the warm water of the Gulf of Mexico.

According to the National Hurricane Center, a Category Five hurricane causes storm surges generally greater than 18 ft above normal, complete roof failure on many residences and industrial buildings. All shrubs, trees, and signs are blown down. Severe and extensive window and door damage can occur. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline occurs and massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required. This is especially essential in the New Orleans area where most of the city lies below sea level and exists with the help of levees and pumps. To date, only 3 Category Five Hurricanes have made landfall in the United States since records began. Credit: NASA/Jeff Schmaltz, MODIS Land Rapid Response Team