As head of the National Oceanic and Atmospheric Administration, I am proud to be a spokesperson for how we utilize our assets to address pressing questions about Earth and how it functions as a system. NOAA has a distinct mission within the Department of Commerce to aid decision-making at all levels of society, and natural hazards is one area in which NOAA has much to offer. This publication is important to communicating our diverse capabilities. For example, we are now harnessing technology for applications that take us beyond the traditional forecasting of hazards such as tornadoes and hurricanes, to forecasting space weather, helping to protect billions of dollars in technological assets worldwide.

NOAA, the largest agency in the U.S. Department of Commerce, carries out a daily mission of monitoring weather, oceans, coasts, and fisheries, as well as developing forecasts, and distributing information for economic and public benefit. We operate a complex network of observing systems that enable us to meet our mission. Having these technical capabilities, as well as first class Earth scientists of all disciplines, offers enormous possibilities for understanding and mitigating natural hazards.

As we look toward a more encompassing view of the whole Earth system, we will focus expertise on the five areas of natural hazards outlined in this document. NOAA will continue to work with our partners to meet our mission of stewardship and improved understanding of the natural world.

Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (Ret.)
Under Secretary of Commerce for Oceans and Atmosphere and
NOAA Administrator

*Gulf rising rapidly; half the city now under water.*

Isaac Cline, Weather Bureau meteorologist
Last message to reach the outside world, 3:30 P.M., September 8, 1900



## September 8, 1900

# It was a mighty storm . . .

Early reports about the incoming storm had been sketchy. A hurricane had passed over Cuba and was heading North. Storm-warning flags waved quietly above the Weather Bureau building in Galveston, Texas, on Thursday. Few took notice. The telegraph and telephone failed a few hours after the winds began to increase in strength.

*The battle for our lives, against the elements and the terrific hurricane winds and storm-tossed wreckage, lasted from 8 P.M. until near midnight. This struggle to live continued through one of the darkest of nights with only an occasional flash of lightning which revealed the terrible carnage about us.*

Isaac Cline
Galveston, Texas

In a horse-drawn cart, Weather Bureau meteorologist Isaac Cline delivered his forecast to those he met on the streets and at the beach. He urged citizens to go to higher ground. Higher ground was about 9 feet above sea level. The storm surge would be almost 16 feet.

Friday evening, after dark, chaos enveloped Galveston. Dr. Cline lost his wife to the turbulent waters that night. At least 8,000 others joined her. The 1900 Galveston hurricane was the deadliest natural disaster in U.S. history.


“Galveston; Among the Wreckage.” (Stereoview, 1900.)

# Challenges
## *for the 21st Century*

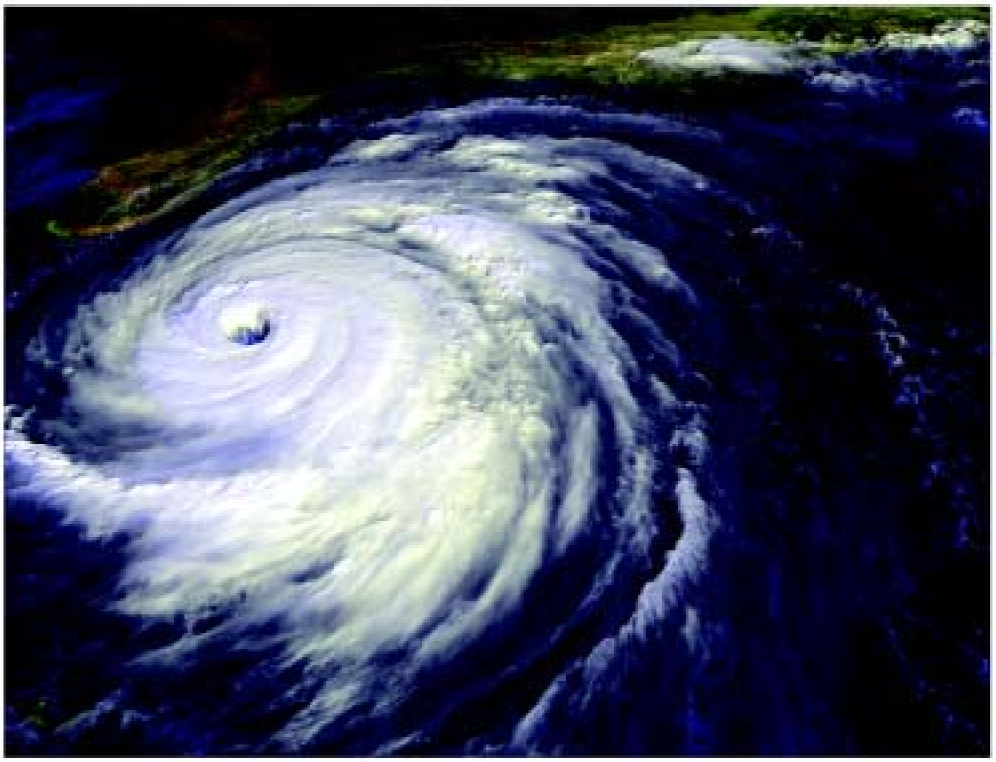
• Hurricanes • Thunderstorms • Tornadoes • Winter storms • Heat • Drought • Floods • Winds • Solar flares • Geomagnetic storms • Tsunamis • Volcanic plumes • Wildland fires • Airborne pollution • Ozone variation • Algal blooms • Hypoxia • Marine mammal strandings • Species decimation • Oil spills • Toxin release • Terrorism

Today, satellites provide continuous, global surveillance that determines the location, size, and intensity of developing storms. Specialized aircraft fly into hurricanes to measure wind, pressure, temperature, and humidity, and to pinpoint the exact location of the storm's core.

Land-based weather networks monitor storm movement. Predictive computer models are used to forecast weather variables. People receive advance warnings. Events comparable to the 1900 Galveston, Texas, storm are handled differently today.

Despite technological advances, millions of Americans remain in harm's way as the Nation's coastal populations grow. More than 3,600 people a day move to coastal locations. Most of our citizens have not experienced a major hurricane, leading to a false impression of a hurricane's potential. The same is true for other natural and technological hazards.

hazards challenges





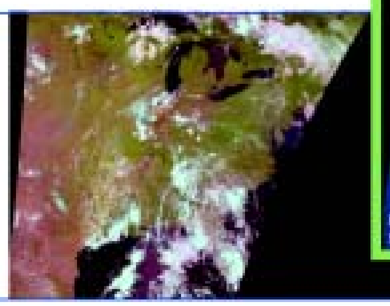
In recent years, natural and technological hazards have been costly, causing many hundreds of deaths and tens of billions of dollars in damages. The impacts are not only in human suffering and property loss, but also loss of livelihood, economic deterioration, and environmental destruction.

**The National Oceanic and Atmospheric Administration (NOAA)**—in partnership with other organizations and emergency management responders—provides a coordinated suite of hazards-related services for the Nation.

NOAA's increased environmental data-gathering efforts have led to breakthroughs in prediction and preparedness, enhancing the safety, and security, of our citizens.

**NOAA-17** (NOAA-M) was launched by NASA for NOAA in June 2002. Its sensors improve weather forecasting and monitor environmental events such as El Niño, fires, and floods. The first image from the satellite (below) showed cloud cover over North America. NOAA and NASA work in partnership to study Earth's interrelated systems.






NOAA operates the Nation's civil geostationary and polar-orbiting environmental satellites. NOAA also manages the largest collection of atmospheric, geophysical, and oceanographic data in the world. These activities are critical to monitoring the environment, and also analyzing hazards potential.

## Satellite Observing Systems

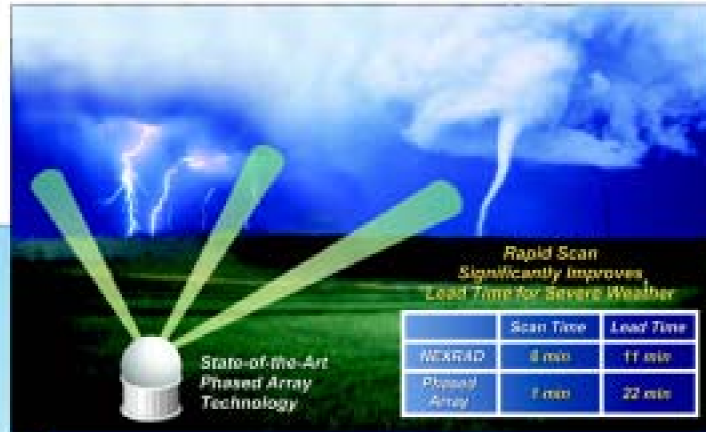
**Geostationary operational environmental satellites (GOES)** support national and regional short-range warnings and now-casting capability.

Positioned over the Equator at approximately 25,000 miles above Earth, these satellites provide continuous monitoring of Earth's atmosphere and surface over the Western Hemisphere. Imagery from these satellites are used to monitor potentially severe weather conditions. Infrared channels can help to detect forest fires, sea surface temperature, fog formation, and volcanic plumes.

**Polar-orbiting operational environmental satellites (POES)** support global long-range forecasting and environmental monitoring. These satellites are North–South orbiting at 500 miles above Earth, viewing the entire planet every six hours.

Data from POES support a broad range of applications including climate research, ocean dynamics studies, drought and forest fire detection, and vegetation analyses. Data from the U.S. Air Force's Defense Meteorological Satellite Program (DMSP) are archived by NOAA and are used to monitor cloud density, city lights, fires, and energetic particles from the sun (which cause aurora and other upper atmosphere phenomena).

**Radar Observations.** NOAA operates 121 Doppler weather radars, and partners with the Department of Defense and the Federal Aviation Administration to operate an additional 38 radars. Doppler radars enable forecasters to observe precursors of tornadoes and violent thunderstorms, and track tropical storms. These radars also provide estimates of wind speed and rainfall amounts. NOAA researchers and partners are now adapting SPY-1 radar technology (currently deployed on U.S. Navy ships) for use in spotting severe weather. The phased array radar system technology has the potential to vastly improve the NEXRAD system (high resolution Doppler radar).






## *In-Situ* Observing Systems

*In situ* (on-site) observations are those collected from individual locations on the ground, in the ocean, or in the air. A rain gauge at a commercial airport, a ship report of wave height, measurements from a geomagnetic observatory, or flight reconnaissance reports of wind speed and barometric pressure, are examples of *in situ* environmental monitoring.

*In situ* observations are necessary for the calibration of satellite sensors, to adjust satellite drift, and to filter atmospheric data transmission distortions. Clouds and airborne particles in the atmosphere limit the instruments' clear vision of the atmosphere near Earth's surface.

*In situ* data platforms are often used in tandem with satellites, providing geographic referencing. Automated Surface Observing Systems provide minute-by-minute observations and generate information for safe and efficient aviation operations, and are used by the public to plan day-to-day activities. The GOES Data Collection System can receive transmissions such as those from buoys, sensors onboard aircraft, and river gauges, and relay the information back to the owner of the platform. This allows for near real-time use of data.

**NOAA monitors and assesses:** • Current & changing weather conditions • Paths of severe weather • El Niño & La Niña • Atmospheric ozone distribution • Sea surface temperature • Ice hazards in oceans & lakes • Vegetation conditions • Coral bleaching • Coastal ecosystems health • Wildfire movement • The Space environment

**U.S. Top Twelve Deadliest Natural Disasters:** • Galveston Hurricane (1900) • Lake Okeechobee Hurricane (1928) • Johnstown Flood (1889) • Chenier Caminanda Hurricane (1893) • Peshtigo Fire (1871) • Sea Islands Hurricane (1893) • San Francisco Earthquake & Fire (1906) • Georgia & South Carolina Hurricane (1881) • Tri-State Tornado (1925) • Atlantic-Gulf Hurricane (1919) • New England Hurricane (1938) • Labor Day Hurricane (1935)



NOAA provides weather, water, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas. NOAA is the sole United States official voice for issuing warnings during life-threatening weather situations. NOAA also provides watches and warnings for non-weather hazards.

*NOAA's improved technology and forecasting reduces the impact of natural hazards.*

## Hazards Warnings, Watches, and Advisories

NOAA "warnings" and "watches" are the two messages most familiar to U.S. citizens. A warning indicates that a hazardous event is occurring or highly likely. A watch indicates that conditions favor the occurrence of a certain type of hazardous event. Advisories are issued for significant (weather) situations that cause inconvenience but do not meet warning criteria for a major event.

NOAA issues nearly 30,000 warnings, advisories, and statements annually from its nationwide Weather Forecast Offices. NOAA also issues hundreds of river stage and flood statements yearly from River Forecast Centers.

Clean up, West Palm Beach.
(Autochrome, 1928.)

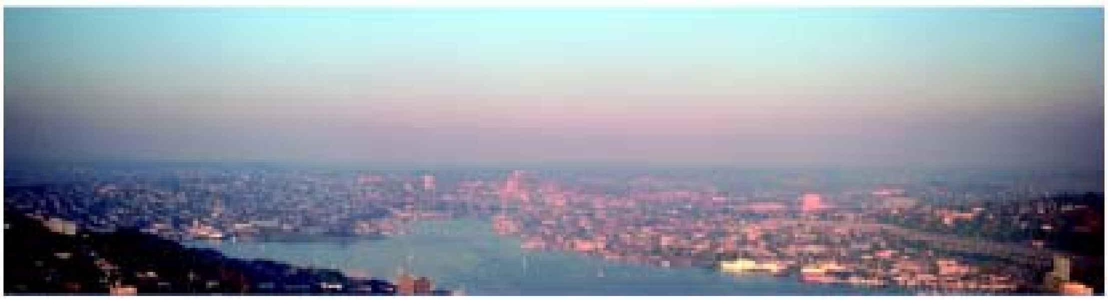
2

Lake Okeechobee Hurricane, 1928
Lake Okeechobee, and surrounding Palm Beach County, Florida
2,500+ deaths
Second deadliest U.S. natural disaster

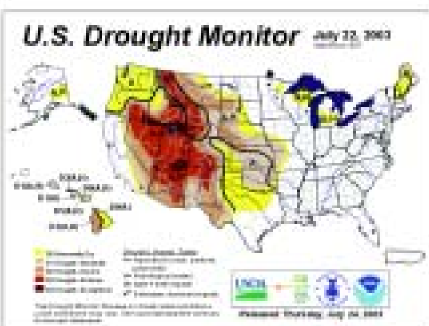
**Note about death tolls:** Death tolls for early U.S. disasters vary according to regional tradition and culture. Prior to the mid-1900s, fatality counts often did not include minorities, migrant workers, transients, recent immigrants, infants, or poor people, especially in rural areas. Mass graves or mass cremations (both health measures) hindered careful counting of the dead. Accurate casualty figures may never be known for most of the early events listed in this publication.

**Extreme heat is currently the deadliest U.S. natural hazard.** The 10-year average for heat-related deaths is 235, nearly three times more than the second deadliest, floods. Heat fatalities from 1993 to 2002 were:

| | | | |
|---|---|---|---|
| 1993 | 20 | 1998 | 173 |
| 1994 | 29 | 1999 | 502 |
| 1995 | 1021 | 2000 | 158 |
| 1996 | 36 | 2001 | 166 |
| 1997 | 81 | 2002 | 167 |








Drought map for the week of July 22, 2003. Yellow areas are “moderately dry;” dark brown areas are “exceptionally dry.” The Drought Monitor is a synthesis of multiple indices which represent a consensus of academic and U.S. government partners, including NOAA. Close monitoring of drought conditions leads to more useful seasonal forecasts.

### Excessive Heat and Drought

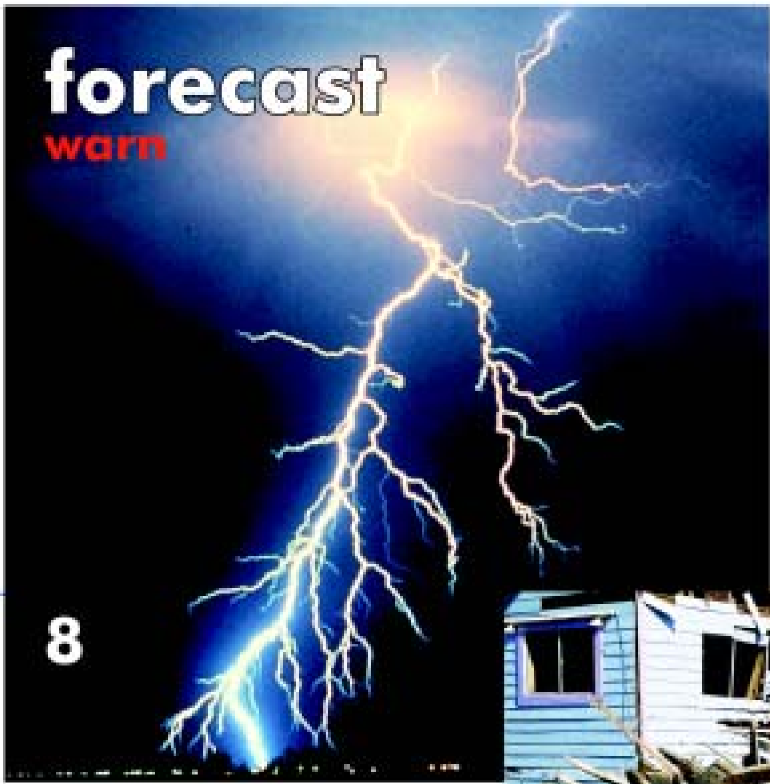
The parameters of an extreme heat watch, warning, or advisory can vary by location, humidity levels, and duration of the forecast. Excessive heat results from a combination of high temperatures (significantly above normal) and high humidity over prolonged periods of time. NOAA has devised the “Heat Index,” which is a measure of how hot it really feels when the relative humidity is added to the actual air temperature.

Stagnant atmospheric conditions of a heat wave trap pollutants in urban areas. This adds to the dangerous stresses of hot weather. NOAA issues heat outlooks, watches, and warnings to assist county and city officials in preparing and responding to excessive heat threats.

Drought occurs when a persistent lack of moisture has adverse impacts on plants, animals, or people. It develops slowly and impacts greatly. NOAA, in collaboration with State climatologists, Regional Climate Centers, universities, and other agencies, monitors drought conditions over the U.S., issuing short-term and long-term forecasts.

### Winter Storms

A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. A winter storm can range from a moderate snow or freezing rain over a few hours to blizzard conditions lasting several days. Extremely cold temperatures, snow accumulation, and sometimes coastal flooding, can cause long-term hazardous conditions. The economic impact of winter storms is high—a single event may incur billions of dollars in damage (see page 30). NOAA issues winter storm warnings, wind chill advisories, and other winter weather forecasts.




**Advanced Prediction of Severe Storms:** Forecasters look for the development of temperature and wind flow patterns in the atmosphere which can cause enough moisture, instability, and wind shear for tornadic thunderstorms. As the event gets closer, the forecast narrows down to a more precise threat area.

### Thunderstorms

The typical thunderstorm is 15 miles in diameter and lasts an average of 20 to 30 minutes. Of the estimated 100,000 thunderstorms that occur each year in the United States, only about 10 percent are classified as severe.

NOAA considers a thunderstorm severe if it produces hail at least three-quarters of an inch in diameter, has winds of 58 miles per hour or higher, or produces a tornado.

Lightning occurs in all thunderstorms. The rapid heating and cooling of the air near the lightning channel causes a shock wave resulting in thunder.

### Tornadoes

A tornado is a violently rotating column of air extending from a thunderstorm to the ground. The most dangerous ones have rotating winds of 250 miles per hour or more. These are capable of causing extreme destruction.

Although violent tornadoes comprise only 2% of all tornadoes, they are responsible for nearly 70% of tornado-related fatalities.

There are no areas immune to tornadoes. They have been reported in mountains and valleys, over deserts and swamps, from the Gulf Coast into Canada, in Hawaii, and even Alaska. More than 1,000 tornadoes are reported annually nationwide, and as tornado detection systems improve, more are being reported each year.

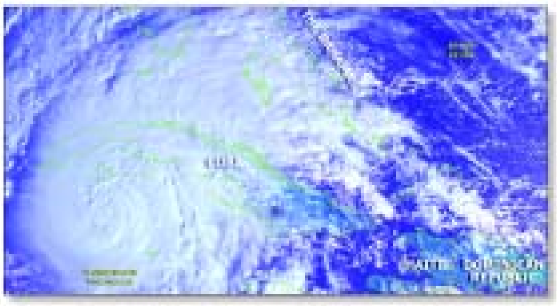
During the first 10 days of May 2003, a record 300 tornadoes were reported in eight States. Close cooperation among NOAA forecasters, local media, and emergency responders helped to minimize fatalities.

“Last trains in and out of Harrisburg.”
(Photograph, 1889.)

3

Johnstown Flood, 1889
Johnstown, Pennsylvania, and surrounding areas
2,200+ deaths
Third deadliest U.S. natural disaster

Hurricane Michelle, 2001.



**Tracking Hurricanes:** NOAA's geostationary satellites provide continuous surveillance that determines the location, size, and intensity of developing hurricanes. Both NOAA and the U.S. Air Force Reserve use specially-equipped aircraft to fly into hurricanes. Instruments measure wind, pressure, temperature, and humidity, and pinpoint the exact location of the storm's center.


### Hurricanes

Hurricanes and tropical storms are cyclones with tropical origins. When a tropical storm has winds which reach a constant speed of 74 miles per hour or more, it is called a hurricane. Each year, on average, 10 tropical storms (of which six become hurricanes) develop over the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico. Many of these storms remain over the water. An average of five hurricanes strike the U.S. coastline every three years. Of these five, two will be major hurricanes (with winds exceeding 110 miles per hour).

More dangerous than the high winds of a hurricane is the accompanying storm surge, a dome of ocean water that can be 20 feet high at its peak and 50 to 100 miles long. The surge can devastate coastal communities as it sweeps ashore. This is what destroyed Galveston, Texas, in 1900. In recent years, the fatalities associated with storm surges have been greatly reduced as a result of better warning and preparedness within coastal communities.

As hurricanes approach, forecasters along U.S. coasts monitor storm movements using NOAA's land-based Doppler weather radar network. NOAA's National Hurricane Center and Central Pacific Hurricane Center follow these storms and provide detailed forecasts, watches, and warnings.

The Chandeleur Islands, part of Louisiana's island barrier system, were once home to thriving, multi-ethnic communities. The 1893 hurricane and storm surges destroyed most of these settlements. Hurricane Georges (1998) also decimated the island chain. Since that time, NOAA and the Louisiana Department of Natural Resources have worked together on shoreline restoration projects.

4

Chenier Caminanda Hurricane, 1893
Coastal Louisiana
2,000+ deaths
Fourth deadliest U.S. natural disaster

**Flood Forecasting.** NOAA's flood forecasting relies almost entirely upon automated data as opposed to manual observations. Most of the river data NOAA uses for its flood forecasting services are provided by other Federal and local cooperating agencies. Real-time data are transmitted from field sites using a variety of techniques that include line-of-sight radio, microwave, and satellite. The data are screened for quality before being placed into computer models. Each geographic region has models configured to its own parameters. River flood forecasting involves a skilled balance of experience, analyses of current conditions, and analyses of model results. This leads to site-specific warnings, watches, and advisories.




*NOAA provides site-specific flood warnings, watches, and advisories.*

### Floods

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. As much as 90% of the damage related to all natural disasters (excluding droughts) is caused by floods and associated debris flows. Most communities in the U.S. can experience some kind of flooding.

Melting snow can combine with rain in the winter and early spring; severe thunderstorms can bring heavy rain in the spring and summer; or tropical cyclones can bring intense rainfall to the coastal and inland States in the summer and fall.

### Flash Floods

Flash floods occur within six hours of a rain event, after a dam or levee failure, or following a sudden release of water held by an ice or debris jam.

Urbanization increases runoff two to six times over what would occur on natural terrain. Streets can become swift moving rivers, while basements and viaducts can become death traps.

Fleeing the Peshtigo Fire.
(Printed wood engraving, 1871.)

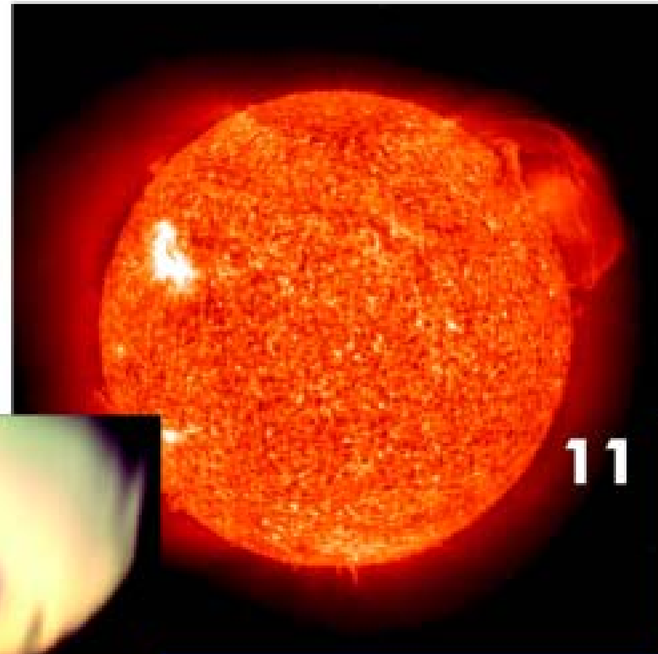
5

Peshtigo Fire, 1871
Peshtigo & Green Bay, Wisconsin area wildfires & firestorm
1,600+ deaths
Fifth deadliest U.S. natural disaster

### Landslides

Landslides and debris flow are typically associated with periods of heavy rainfall or rapid snow melt, and tend to worsen the effects of flooding that often accompany these events. They may also be associated with volcanic events. Pyroclastic flows, hot ash, fallen trees, ground water, and rain water create destructive mudflows and flooding.

Wildfires can also lead to destructive debris-flow activity. In July 1994, a severe wildfire swept Storm King Mountain in Colorado, denuding the slopes of vegetation. Heavy rains two months later resulted in numerous debris flows, one of which blocked Interstate 70 and threatened to dam the Colorado River.





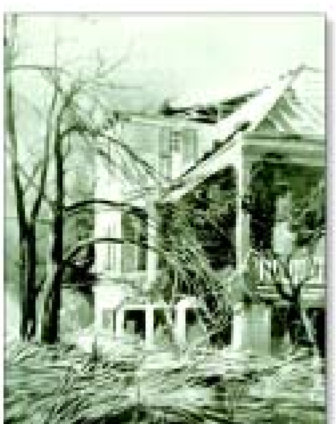
## Space Weather

Space weather has a significant effect upon energy providers, communication, transportation, and space exploration. For example, the Sun periodically generates geomagnetic solar storms that have caused massive power outages. Potential costs associated with power system disruptions due to geomagnetic storms have been estimated at $3 to $6 billion.

Instruments aboard NOAA's polar-orbiting satellites are used to provide a space weather storm warning system. The space environment monitor aboard NOAA's geostationary satellites is designed to provide real-time measurement of space weather, flares, solar radiation storms, radio blackouts, and geomagnetic storms. Researchers and data modelers work together to improve information analyses.

NOAA issues daily forecasts, alerts, warnings, and watches about disturbances in the solar-terrestrial environment. These are distributed by Internet, NOAA Weather Wire, email, and in technical reports. At times of high solar activity, NOAA's space environment Web pages record more than one million queries per day.

"Effects of the Storm upon an Old Mansion on Station Creek." (Illustration by Daniel Smith, 1894.)



6

Sea Islands Hurricane, 1893
Coastal Georgia and South Carolina
1,000-3,000 deaths
Sixth deadliest U.S. natural disaster


EXTRA THE DAILY NEWS EXTRA

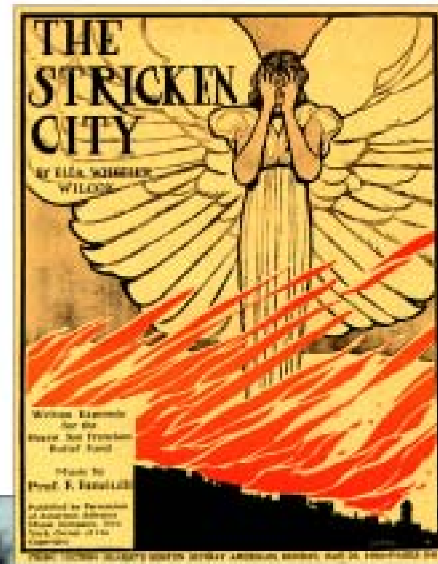
# HUNDREDS DEAD!

Fire Follows Earthquake, Laying Downtown Section in Ruins--City Seems Doomed For Lack of Water

KNOWN DEAD

Portion of a newspaper (above) published at an alternate site after the downtown location lost power.


Postcard that shows the burning of San Francisco, mailed by a survivor. (Color lithography, 1906.)



1906 sheet music published for the Hearst San Francisco Relief Fund. (Color folio, 1906.)




“The City in Flames.” April 18, 1906, 10 A.M.; five hours after the earthquake. (Panoramic photograph, 1906.)

7
San Francisco Earthquake and Fire, 1906
San Francisco, California
700-3000 deaths
Seventh deadliest U.S. natural disaster

## Tsunami Warnings

Tsunamis are ocean waves most often generated by earthquake-induced movements of the ocean floor. Landslides and volcanic eruptions can also generate a tsunami. If a major earthquake is felt, a tsunami could reach the beach in a few minutes, even before a warning is issued. As the waves approach the coast, their speed decreases and their amplitude increases. The waves can be very destructive and cause many deaths or injuries.

As part of an international cooperative effort to save lives and protect property, NOAA operates two tsunami warning centers. The Alaska Tsunami Warning Center in Palmer, Alaska, serves as the regional Center for Alaska, British Columbia, Washington, Oregon, and California. The Pacific Tsunami Warning Center in Ewa Beach, Hawaii, serves as the regional Center for Hawaii, and is an international warning center for tsunamis that pose a Pacific-wide threat.

## Volcanic Ash Advisories

The United States is third in the world, after Japan and Indonesia, for the number of active volcanoes. Most of our Nation’s volcanoes are in Alaska. However, the U.S. may experience effects from volcanoes which erupt in other geographic regions.

Volcanic ash consists of fine, glassy rock fragments that can affect people and equipment hundreds of miles away from an eruption. It poses an ever-increasing threat to aviation safety as transportation expands throughout the Pacific rim.

Airborne ash can diminish visibility, damage flight control systems, and cause jet engines to fail. NOAA meteorologists track volcanic eruptions throughout the world and monitor all available satellite images for ash plumes. In collaboration with the Federal Aviation Administration, the International Civil Aviation Organization, and other ash advisory centers worldwide, NOAA develops volcanic ash advisory statements. Pilots are warned to avoid routes with a high probability of danger.



*There will always be a person in the loop—someone to oversee the data pouring in from satellites, reconnaissance aircraft, radar, surface observing systems, numerical models and the like. Even with the precision of these inputs, there will be times when science melds with skill, a feeling in the gut, a decision based on experience.*

Miles Lawrence
NOAA hurricane specialist
Tropical Prediction Center, Miami, Florida, 2000

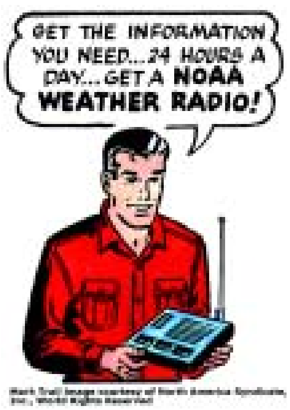
Tybee Island, Georgia, on a quiet day. The 1881 and 1893 hurricanes landed in this geographic region.

8

Georgia and South Carolina Hurricane, 1881
Coastal Georgia and South Carolina
700+ deaths
Eighth deadliest U.S. natural disaster

NOAA Weather Radio stations coverage across the conterminous U.S.

# NOAA Weather Radio
...the Voice of the National Weather Service




## Broadcasting Information

Three systems were created with the goal of disseminating weather information. Each has been expanded to include information on other life threatening situations, including both natural and technological disasters. These systems operate 24 hours a day, every day.

### NOAA Weather Radio

NOAA Weather Radio (NWR) is the "Voice of the National Weather Service." NWR provides continuous broadcasts of the latest weather information, and warnings of severe weather and other life-threatening hazards from 122 local Weather Forecast Offices. Broadcasts are specifically tailored to needs of people within the service area.

During an emergency, NOAA National Weather Service forecasters will interrupt routine weather radio programming with special messages describing the threat, and actions that should be taken. The messages are accompanied by digital coding. This code activates special receivers programmed by the user to alarm only for specific events and for specific areas.

These receivers may have a loud siren, and visual displays that indicate the immediacy of the threat and identifies the specific threat. Some receivers can also drive external devices such as strobe lights, pagers, and personal computers, to alert people with special needs.

NWR broadcasts from more than 800 stations located in the United States, adjacent coastal waters, Puerto Rico, U.S. Virgin Islands, Guam, and Saipan, on seven frequencies. This reaches approximately 95% of the U.S. population. A few stations also broadcast on-line.

Working with other Federal agencies and the Federal Communications Commission's Emergency Alert System, NWR is an "all hazards" radio network. It is the best single source for the most comprehensive weather and emergency information available to the public.

# WEATHER WIRE

transmitting the **power** of prediction

## Emergency Managers Weather Information Network

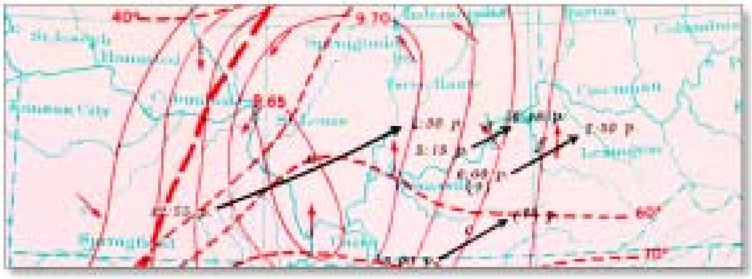
The NOAA Emergency Managers Weather Information Network (EMWIN) is a wireless computer data broadcast system. EMWIN provides real-time warnings, forecasts, graphics, satellite imagery, and other data to the emergency management community, television stations, and various government and private institutions.

## NOAA Weather Wire Service

The NOAA Weather Wire Service (NWWS) is a satellite-based telecommunications network. It is designed to disseminate weather watches, warnings, and other products (more than 6,000 in all) in the shortest possible time and with the highest possible reliability.

NOAA's Advanced Weather Interactive Processing System integrates incoming weather data for distribution through NWWS. Weather, hydrologic, and all-hazards warnings receive the highest priority. NWWS delivers warnings to users in 10 seconds or less from the time they are issued, making it the fastest delivery system available for these time-sensitive products. It is comprised of 20 transmitting sites known as uplinks. Each site has automatic dial backup in case of failure of any part of the system, whether it is satellite or terrestrial.

Detail of storm track from *Monthly Weather Review*, April 1925.



9

Tri-State Tornado, 1925
Indiana, Illinois, and Missouri
700+ deaths
Ninth deadliest U.S. natural disaster




During the occurrence of an extreme event or disaster, NOAA manages real-time data and communicates hazard information and warnings. This information assists first responders in their task of emergency management. In the recovery period after an event, NOAA documents what happened with the goal of understanding physical processes and improving modeling, forecasting, and warnings.

### Saving Lives: International Search and Rescue Program

Cospas-Sarsat is an international, humanitarian search and rescue system that uses United States and Russian satellites to detect and locate emergency beacons indicating distress. The beacon transmitters are carried by individuals, or aboard aircraft and ships. To date, more than 17,000 lives have been saved worldwide.


The search and rescue program has been used extensively during weather emergencies, especially for locating crafts disabled by severe storms. The system consists of a network of satellites, ground stations, mission control centers, and rescue coordination centers across the planet. The system operates 24 hours a day, every day, and includes 36 nations.

The United States Mission Control Center, operated by NOAA, serves as the focal point of United States' alert data. These data are forwarded to the U.S. Air Force and Coast Guard who perform the rescues. The program is jointly funded by NOAA, U.S. Coast Guard, U.S. Air Force, and National Aeronautics and Space Administration.

*People from countries around the world can reap the benefits this technology provides. The ultimate objective is to eliminate search from the search and rescue operation.*

Vice Adm. Conrad C. Lautenbacher, Jr. USN (ret.), NOAA Administrator
at the 20th Anniversary of Cospas-Sarsat, October 2002



## Saving Lives: Personal Locator Beacons

In 2002, the Federal Communications Commission approved a request by NOAA for frequency access by personal locator beacons in the U.S. This contributes to emergency safety for those who enjoy wilderness activities.

The personal locator beacons have advanced features including global positioning system technology, making it easier and quicker for NOAA satellites to pick up distress signals and relay an accurate location to rescuers. The beacons are small and lightweight. They are available at stores that sell marine and outdoor gear. The new system was announced at the 20th anniversary celebration of Cospas-Sarsat (October 2002), and became operational in July 2003.

Personal locator beacons made by various manufacturers.

# 10, 11, 12

"Dedicated to the memory of the civilians and war veterans whose lives were lost in the hurricane of September Second 1935."
Detail of Islamorada Hurricane Monument (Key West) showing palm trees and waves in the storm. (Works Progress Administration, 1937; carved coral, bas-relief sculpture.)

Atlantic-Gulf Hurricane, 1919
Florida Keys, Texas (and Cuba)
600-900 U.S. deaths
Tenth deadliest U.S. natural disaster

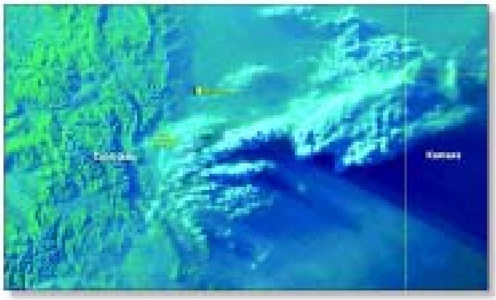
New England Hurricane, 1938
600-700 deaths
Eleventh deadliest U.S. natural disaster

The Labor Day Hurricane of 1935
Florida Keys
400+ deaths
Twelfth deadliest U.S. natural disaster

*No single federal, state, local, tribal, or volunteer agency alone can handle all wildland fires that may occur in its jurisdiction. At the Center, branches of seven federal agencies work together to exchange support, protection responsibilities, information, and training, providing an efficient method for protecting lives, property, and natural resources.*

Larry Van Bussum, NOAA National Weather Service liaison
National Interagency Fire Center, Boise, Idaho





Heat signatures and smoke plumes visible from the Hayman Fire in Colorado, June 2002. NOAA scientists create imagery from GOES, POES, and other satellites. These high-resolution visuals are used by emergency response teams and also by the news media.

### Responding to Wildfires

The objective of NOAA's Fire Weather Program is to provide meteorological support to land management agencies for the protection of life and property. This support includes warnings, forecasts, on-site services during wildland fires, and meteorological training for fire fighters.

NOAA forecasters monitor meteorological conditions continuously during the fire season, using their knowledge of weather to assist authorities with fire suppression strategies and related safety issues. Weather information comes from NOAA satellites, local NOAA offices, and from NOAA's Incident Meteorologists, who join firefighting teams near the front lines of the blaze. These meteorologists provide accurate, site-specific weather forecasts. Portable weather equipment is set up at base camps, along with electronic access to local forecast offices.

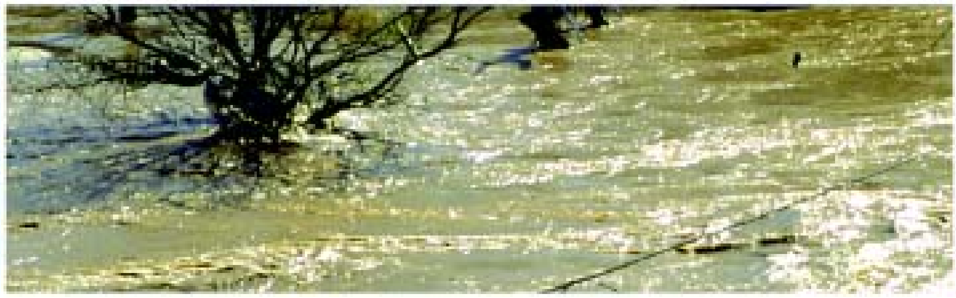
Meteorologists maintain communication with the fireline. These specialists receive training in microscale forecasting, fire behavior and fire operations, thus making them key members of the broader fire management team.

NOAA also tracks drought conditions and dry thunderstorms (which produce significant lightning) to identify geographic areas at risk of fire. The information is used to determine allocation of resources when firefighters are in high demand.

Satellite data are used to detect fires, identify hot spots, and track smoke plumes. Computer models determine air quality forecasts, important for the medical community's response to fire-related symptoms. All fire location data are available through Web-based geographic information systems. The data may be viewed with other relevant information, on customized maps.

*National implementation of the Advanced Hydrologic Prediction Service will save lives and an estimated $240 million per year in flood losses, and will contribute an additional $520 million per year in economic benefits to water resources users.*

*Use and Benefits of the NWS River and Flood Forecasts,* National Hydrologic Warning Council, April 2002.





## Responding to Flooding

Flooding may occur days or weeks after a tropical cyclone or winter storm. Wildfires can strip steep hillsides of vegetation, increasing the likelihood of flash floods and mud slides until vegetation returns.

As extreme events unfold and local emergency response is initiated, local NOAA Weather Forecast Offices provide forecast and warning information on potential floodwater inundation.

The Advanced Hydrologic Prediction Service (AHPS) is based on computer models of rainfall, water runoff, and river channel flow data, plus the historical record of these parameters for given forecast points and small watersheds. The models extend the current one- to three-day river stage forecast lead times to weeks and months in advance. These types of data are essential for risk-based decision making in the local response community.

## Responding to Spill Incidents

NOAA is the focal point for spill preparedness and response, hazardous waste site investigation, and environmental damage assessment. NOAA guides local agencies in environmental restoration when events occur in coastal zones or in navigable waters. This includes monitoring species populations and modeling coastal ecosystems. NOAA provides rapid assessment of injuries to marine life from catastrophic oil spills and at Superfund sites such as Commencement Bay in Puget Sound.

NOAA's software, databases, and other tools help emergency organizations respond to hazardous materials accidents and resolve contamination problems. NOAA computer models analyze oil spill trajectory and air dispersion of chemicals. An Incident News Web site provides timely information to the public about current response operations for spill incidents.


Preparedness anticipates hazards and takes appropriate countermeasures in advance, such as issuing warnings, stockpiling supplies, or establishing evacuation routes. Mitigation involves long-term actions to prevent or reduce a hazardous effect from occurring, such as building structures that can withstand the force of winds or earthquakes.

Traditionally, local governments have emergency response teams or committees which draft hazard response plans after considering data, statistics, or environmental indicators. NOAA data and analyses are used in these planning efforts.


Effective preparedness and mitigation procedures include:

- Identifying users and their needs
- Use of historical data collections
- Data modeling and other assessment techniques
- Data distribution
- Partnerships at all levels

**Historical environmental data are used to:** • Conduct risk & vulnerability assessments • Provide short-term warnings • Provide short- & long-term forecasts • Promote safe navigation • Manage & protect living marine resources • Manage & protect coastal & ocean environments

Dust Bowl, 1931-1939
Worst drought in U.S. history, covering 75% of the country, and affecting 27 States severely.

"Children of migrant agricultural workers in California."
(Dorothea Lange, FSA photograph, 1937.)

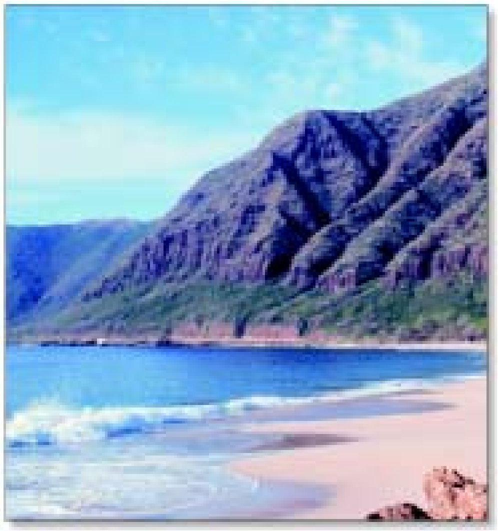


Dust storm approaching Stratford, Texas.
(Photograph, 1935.)

## Historical Data Collections

NOAA provides long-term stewardship for the Nation's environmental data. These historical data collections are broad in scope. Long-term data can be used to establish the past record of hazardous event occurrences, and contribute to awareness of future risk.

Weather observations have been manually recorded at hundreds of U.S. locations since the 18th Century, providing a 200-year record of the Nation's environment. Hydrographic and fish surveys provide a history from the mid-1800s. Data collected by remote sensing systems, such as radar and satellites, have been providing records for the past 40 years. Proxy data gathered from the natural record comes from sources such as ice-core samples, ocean sediments, fossil pollen, coral skeletons, and tree rings. Proxy data extend the understanding of the climate far beyond the instrumental record.

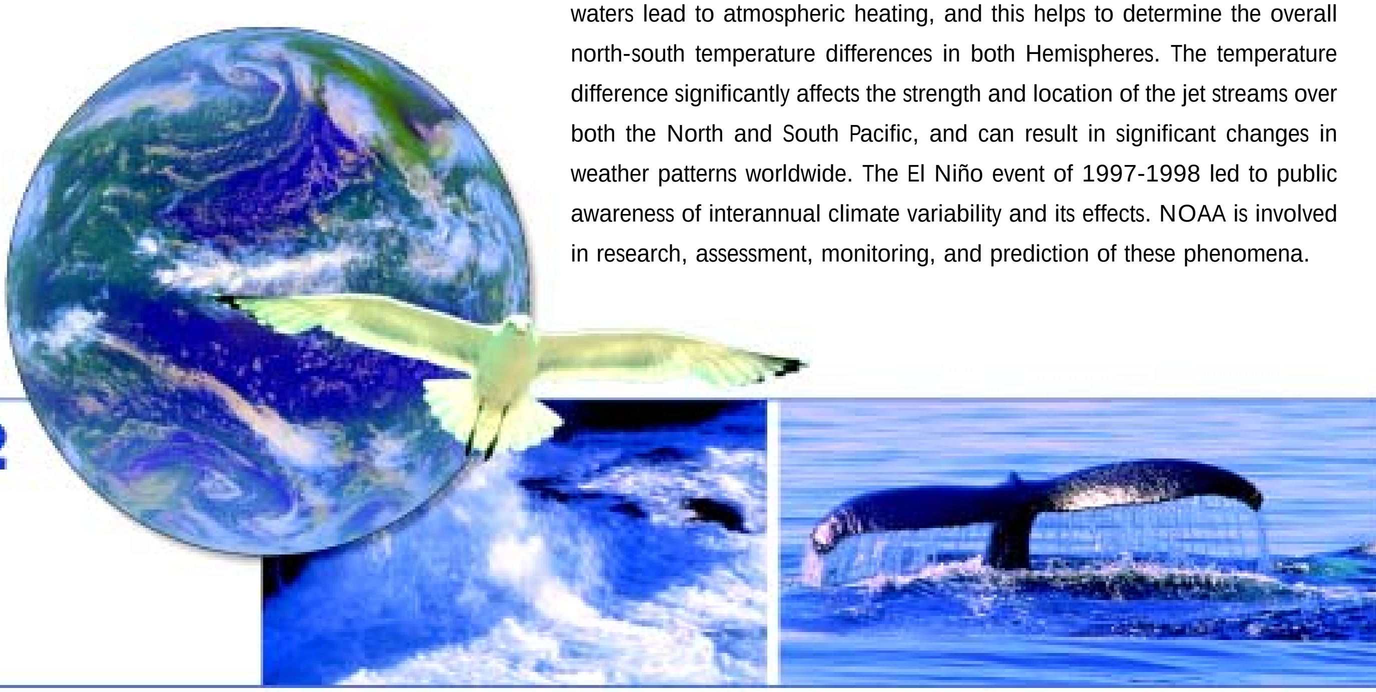


### Coastal Data

Coastal hazards may include hurricanes, tsunamis, erosion, oil spills, harmful algal blooms, and pollution. Many coastal issues involve the entire watershed area on the land side, coastal seas including estuaries and bays on the ocean side, and the wetlands between them. Understanding this land–aquatic interface is becoming increasingly important due to rapid population growth in coastal areas. NOAA provides historical data, plus new scientific discoveries and technology, to the nation's coastal resource managers.

Coastal and marine waters support 28.3 million jobs, generate $54 billion in goods and services, contribute $30 billion to the U.S. economy through recreational fishing, and provide a tourism destination for 89 million Americans each year.

**An El Niño episode** is a period of exceptionally warm sea surface temperatures across the eastern tropical Pacific. Normally, the warm ocean waters lead to atmospheric heating, and this helps to determine the overall north-south temperature differences in both Hemispheres. The temperature difference significantly affects the strength and location of the jet streams over both the North and South Pacific, and can result in significant changes in weather patterns worldwide. The El Niño event of 1997-1998 led to public awareness of interannual climate variability and its effects. NOAA is involved in research, assessment, monitoring, and prediction of these phenomena.





### Atmospheric Data

NOAA scientists use historical data to research the atmospheric-aquatic interfaces which lead to ecosystem disasters. For example, atmospheric deposits may intensify contamination from sources such as fertilizers and industrial discharge. Excessive nitrogen deposits can cause red or brown tides, which choke coastal ecosystems.

### Marine Resources Data

NOAA maintains critical fisheries data used in assessing fishery stocks, determining over-fished areas, and conducting habitat restoration projects. NOAA also monitors migratory movements, habitat needs, and population dynamics of protected marine mammals. Historical data show the long-term impact of interactions between human activities and living marine resources.

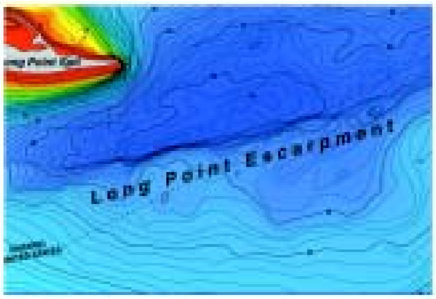
### Seismological Data

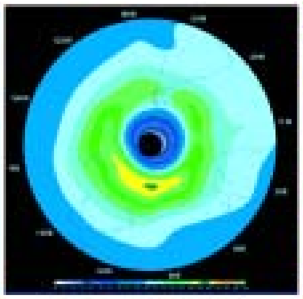
Seismological hazards, including earthquakes and tsunamis, affect both coastal and inland areas. NOAA plays a major role in post-event data collection. NOAA has taken the lead in collecting valuable historical tsunami data for the Pacific Rim and Caribbean.

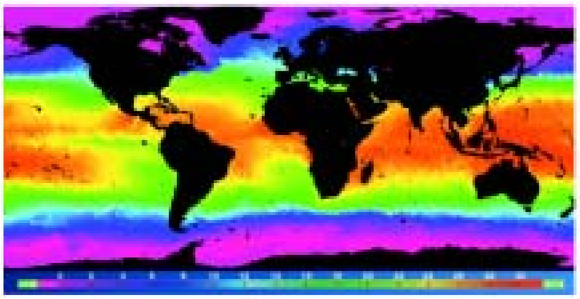
### Weather Data

NOAA's vast weather data collection spans several centuries. Information on daily or long-term regional weather may help in the budgeting of resources from sand bags to snow plows. Emergency agencies depend on these historical data to assess the need for equipment, supplies, and shelter space, and to coordinate volunteer activity.

**Data modeling is used to study:** • Hazardous chemical dispersion • Oil spill behavior • Sediment contaminant distribution • Near-term weather trends • Global warming • El Niño & La Niña • Sea surface temperature • Solar events • Navigational hazards • Ecosystems characterizations • Ocean ice analyses • Endangered marine mammals • Fish habitats • Wildfire destruction of biomass







## Data Modeling for Hazards Analyses

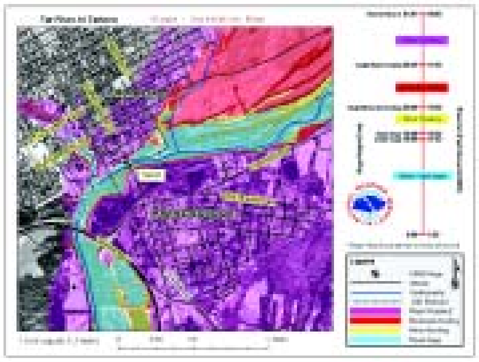
The needs of hazards researchers, local and regional governments, and disaster preparedness organizations have become more complex as data access has improved. For example, those researching the movement of hurricanes may need wind measurements from land and sea, satellite data and images, water-level measurements, and detailed weather data.

NOAA develops computer models that incorporate diverse types of data. The models are used within NOAA and in the hazards community for data analyses and forecasting. These are frequently used in combination with satellite and *in situ* observing systems.

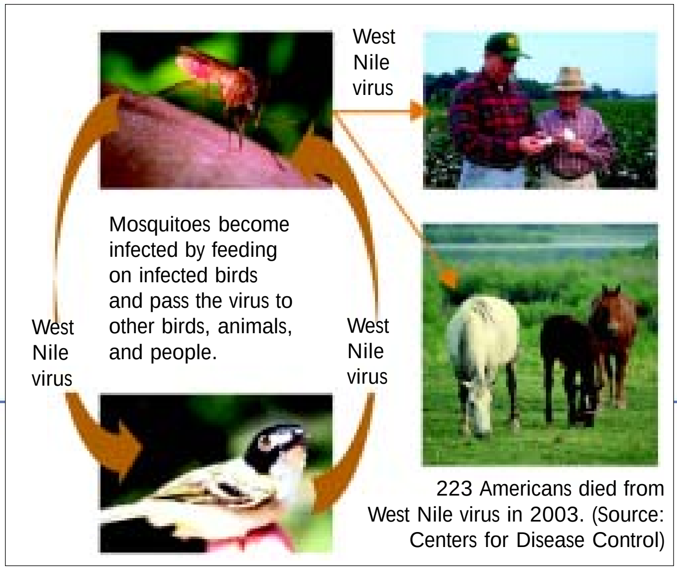
The 1997–1998 El Niño event, one of the most intense of the 20th Century, was successfully predicted by NOAA. Oceanic and atmospheric data from NOAA's observing systems were utilized in the dynamical and statistical models that led to the prediction of the El Niño temperature anomaly.

Advances in information technologies make it possible to perform disaster modeling that simulates a wide variety of scenarios. Each adds significant value in monitoring events and characterizing infrastructure, high-hazard areas, and disaster zones.

The growing number of these models may present challenges to users. NOAA provides training materials and on-site assistance for many of the products. Careful planning is put into product design, providing flexibility for various uses.



NOAA develops models and map products using multi-layered environmental and cultural data. This visual information is useful in assessing geographic risk, and in developing mitigation plans.




223 Americans died from West Nile virus in 2003. (Source: Centers for Disease Control)

The West Nile virus transmission cycle is a complex interaction among species, ecosystems, and climate variables. NOAA and its partners are using novel techniques to investigate West Nile virus and other climate-health issues. These studies involve rapid exchange of information at all levels of research, and across many scientific disciplines.



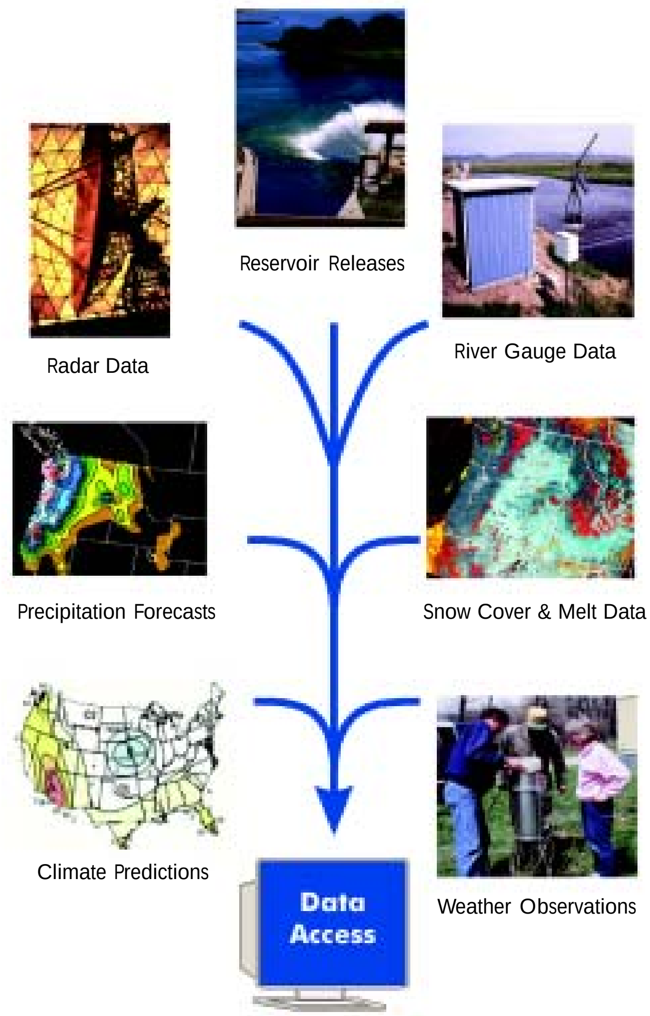
## Data Distribution

NOAA products and systems enhance data utilization at all levels—from the data manager to the first responder. Creative uses of new technology, combined with NOAA data, have led to breakthroughs in hazards detection, assessment, and mitigation standards.

Many types of data are integrated into useful information about hazards. The example (right) shows data used to initiate flood warnings and water resource forecasts.

Computer speed and functions will continue to increase with a corresponding decrease in cost. This will enhance the capabilities of forecasters to extract critical information and predict hazards probabilities. This will also decrease the time it takes for vital information to reach the public.

Information technology continues to transform the data distribution process. Effective data distribution and technology transfer are essential in sustainable hazards mitigation.




NOAA's Advanced Hydrologic Prediction Service uses interdisciplinary data to improve flood warnings and water resource forecasts.

StormReady is a grassroots program that prepares communities to survive natural disasters by improving emergency communication and public education. StormReady is designed to complement existing preparedness activities. Locations with NOAA StormReady recognition have established formal hazardous weather plans, and have met a number of criteria which strengthen local efforts. As of October 2003, there were 659 StormReady communities in 46 States.

## Citizen-Assisted Programs

### Cooperative Observer Program

A vital component of NOAA's weather data collection system is one that is made of nearly 12,000 volunteer citizens. The Cooperative Observer Program is the Nation's largest and oldest climate and weather network.

Officially established in 1890, observers submit daily or monthly summaries of their manual weather observations. These important observations are used in support of local forecast and warning services, and for maintaining the historical record.

### Storm Spotters

Storm spotters play a critical role in NOAA's severe weather operations. They are often a community's first line of defense against dangerous storms. To date, NOAA has trained more than 211,000 storm spotters nationwide. They report severe weather at their locations to local National Weather Service Field Offices. Most storm spotters are volunteers, but also include public emergency personnel such as sheriff's deputies, police, and firefighters. Coverage is also provided by volunteer amateur radio operators who are organized into "Skywarn" networks. A central station (liaison net) controls exchange of information among spotters, first responders, and NOAA's National Weather Service.

Weather instrument shelter which may have been used in the early days of the Cooperative Observer Program. (Glass lantern slide, circa 1915.)

*Our government bears essential responsibilities in this struggle:*
*to wage an effective relentless war against terrorists,*
*protect the homeland,*
*and strengthen America's economy.*
*We have acted on those fronts, and will continue to do more.*

George W. Bush
President, United States of America
September 2002

September 11, 2001
New York City, New York
Arlington, Virginia
Somerset County, Pennsylvania
More than 3,000 deaths

*We face challenges every day as forecasters. But when you are charged with protecting recovery crews, it gives you new inspiration to go beyond what you thought you were capable of doing.*

Michael Wylie, NOAA meteorologist
at the World Trade Center recovery effort, September 2001


The events of 9/11/01 were clearly acts of terrorism that threatened national security. These showed our Nation's vulnerabilities, and also our Nation's strengths. National security may also be compromised by weather events, natural disasters, and technological disasters.

### NOAA's Response to 9/11

During and following the events of 9/11, NOAA's well-established Incident Response Plan was put into action.

NOAA directly supported search and recovery efforts at both the World Trade Center and the Pentagon sites, using its mapping and remote sensing tools, at the request of the U.S. Army. NOAA provided aircraft and flight crews to produce three dimensional images of debris fields. NOAA also provided nautical charts and other coastal information to the U.S. Navy, Coast Guard, and other government and port sector officials. Special NOAA enforcement agents were detailed to the FBI, U.S. Marshall Service, and Border Patrol.

NOAA assigned on-site scientific support in preparation for possible oil and hazardous material pollution and flooding resulting from the collapse of the towers. NOAA produced hyperspectral imagery needed in evaluating asbestos fallout.

Multiple mobile weather stations were installed near Ground Zero at the World Trade Center to provide recovery workers with weather and air quality data. NOAA meteorologists provided special forecasts for all three recovery sites.

At the request of the White House, national updates on potential weather and water threats were provided by NOAA to FEMA, highlighting where potential disasters might drain resources from the recovery sites.



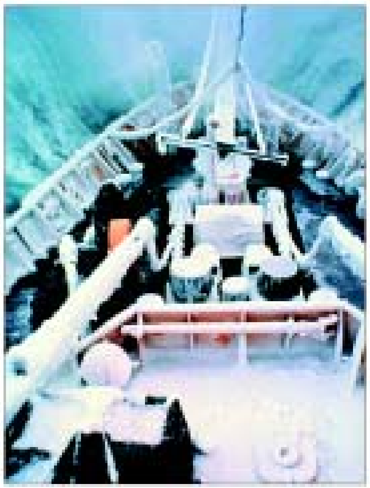
**Severe weather events can disrupt transportation, communications, and critical services to communities.** These communities include the Nation's military personnel and other security forces. Vulnerability to weather events is reduced through proactive measures, including precise forecasting. Precision is increased using highly technical weather modeling that accesses NOAA's important historical data while analyzing incoming, real-time data. NOAA's unique contributions to weather analyses reduce the social, economic, and natural resource risks from severe weather events.


### Chemical, Nuclear, and Biological Disasters

Chemical and nuclear materials may be released in the form of explosives, flammable and combustible substances, poisons, and radioactive materials. Biological disasters may include infectious microbes that are introduced into the population to produce illness or death (such as smallpox or anthrax). Although these have been used in acts of war or terror, most hazardous materials disasters are a result of transportation or industrial accidents such as spills and fires.

During these emergencies, toxins may spread by air, land, or water. NOAA's coastal and ocean modeling show the movement of hazardous materials toward land or marine sanctuaries. Local weather conditions provided by NOAA track surface winds and temperatures, which affect the movement of toxins over land. NOAA's atmospheric models can be used to predict the direction of airborne particles.



### Navigation Safety

NOAA provides navigation and spatial reference services that are essential to the security of the Nation's marine transportation systems. NOAA's Physical Oceanographic Real-Time System (PORTS) Program provides ship masters and pilots with accurate information required to avoid ship groundings and collisions.

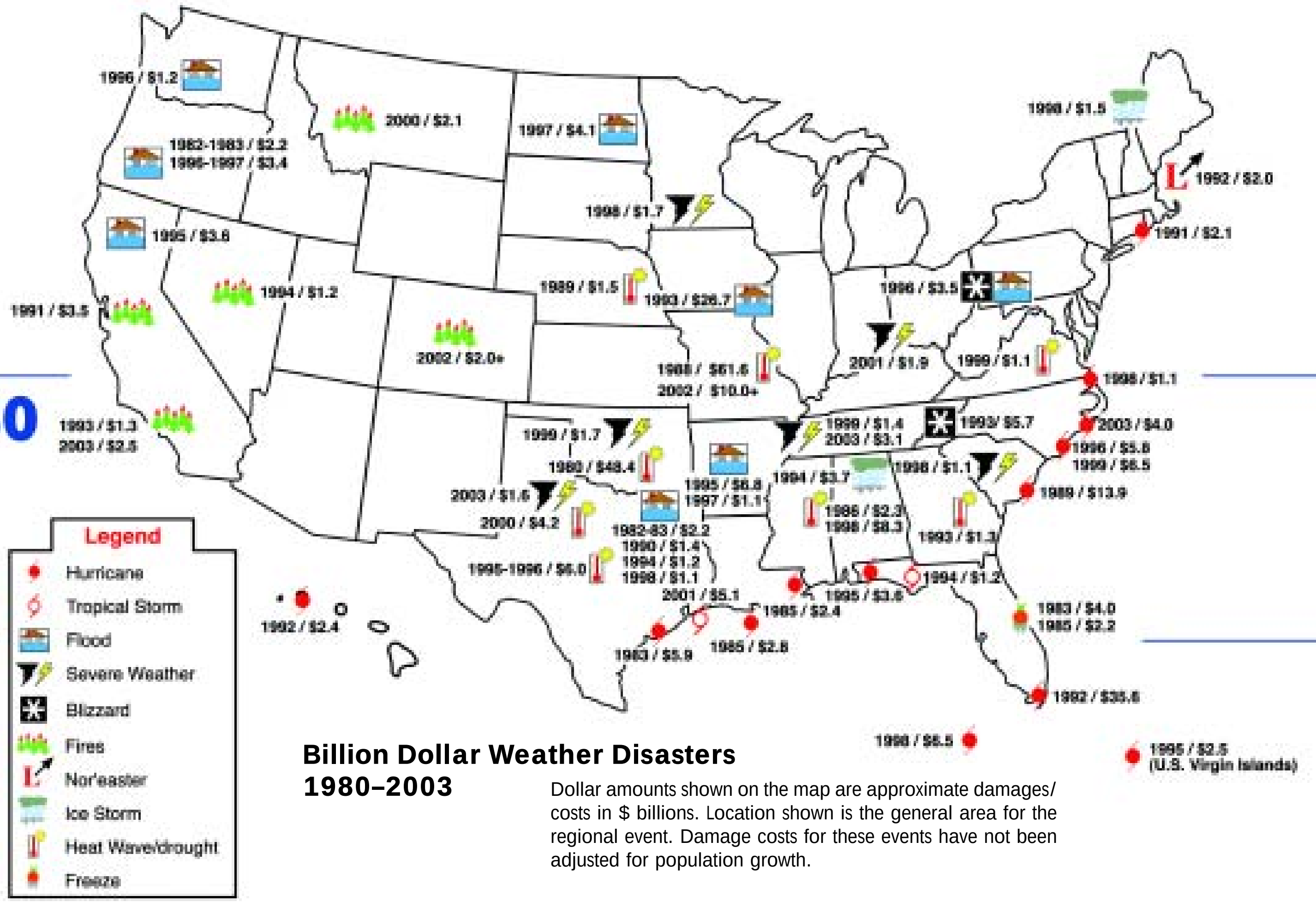
Nautical charts, hydrological surveys, and digital bathymetry models promote safe navigation. NOAA satellite data are used to produce analyses of sea-ice conditions in the Arctic, Antarctic, and Great Lakes. NOAA's National Spatial Reference System provides the framework for latitude, longitude, height, scale, gravity, orientation, and shoreline throughout the United States.

In support of aviation safety, NOAA satellite data are used to locate and identify hazardous plumes from explosions and volcanic events. Digital elevation models are used in building terrain-avoidance systems.

### Data Security

Much of society now depends on computers for livelihood and life itself. A technological disaster can shut down access to emergency or other time-critical services. State and local emergency management organizations continue to address this complicated issue. NOAA's goal is to provide continuous data flow, no matter what incident has occurred.

NOAA is duplicating its data services in various parts of the U.S., providing seamless access to real-time and archived weather, geodetic positioning, and satellite data. Although this initiative is related to increased national security against terrorism, the benefits of duplicating critical data services apply to other hazardous events as well.




**Billion Dollar Weather Disasters 1980–2003**

Dollar amounts shown on the map are approximate damages/costs in $ billions. Location shown is the general area for the regional event. Damage costs for these events have not been adjusted for population growth.

The U.S. has sustained 58 weather-related disasters over the last 24 years, with overall damages/costs exceeding $1.0 billion or more for each event. Forty-six of these occurred during or after 1990. The total costs of the 58 events were nearly $350 billion, using an inflation/wealth index.

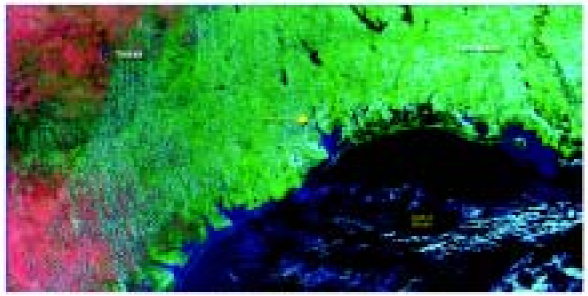
The potential economic impact of future natural and technological hazards affects all U.S. citizens. Hazards do not respect boundaries—geographical, political, or sociological. NOAA's interagency and public–private partnerships work toward the benefit of communities nationwide.

*NOAA's forecasts, warnings, and the associated emergency responses result in a $3 billion savings in a typical hurricane season. Two-thirds of this savings is attributed to the reduction in hurricane-related deaths, and one-third of this savings is attributed to a reduction in property-related damage because of preparedness actions.*

Dr. Hugh Willoughby
NOAA, Atlantic Oceanographic and Meteorological Laboratory, 2001

Weather map, September 1872.

NOAA POES image of the same region, June 2001.





NOAA monitors Earth's atmosphere and surface using satellite and *in-situ* observing systems. The data are integrated into studies of the oceans, lakes, coasts, Sun and Earth's surfaces, and various levels of the atmosphere.

NOAA's research has lead to more timely warnings for extreme weather events and disaster scenarios such as dispersion of toxins and other hazardous materials. NOAA also generates long-term predictions of climate variability.

NOAA provides value-added data services to those who deploy resources before, during, and after disasters occur. Partnerships promote the transfer of vital information to all participants in this process.

**NOAA will continue to use innovative, interdisciplinary approaches to meet the challenges of natural and technological hazards in the 21st Century.**

# *National Oceanic and Atmospheric Administration*
# Contact Information

For more information on NOAA programs and hazards services, please visit:

**http://www.noaa.gov**

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14th Street & Constitution Avenue, NW
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**NOAA Oceans**
http://www.nos.noaa.gov

**NOAA Fisheries**
http://www.nmfs.noaa.gov

**NOAA National Weather Service**
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Front and inside cover: Lightning storm, unknown location. Vice Admiral Conrad C. Lautenbacher, Jr., by Dane Konop.

1. (Background) North Pacific Storm, Winter, 1989. Galveston,1900, street scene after the event; Rosenberg Library Digital Collection, Galveston and Texas History Center. Stereoview, personal collection of C. Ike Ikelman.

2. Montage, NESDIS-A Strategic Approach for the New Millenium, 2001. "City Streets," Census 2000 (Lloyd Wolf, U.S. Census Bureau).

3. Hurricane Floyd satellite image, September 14, 1999 (Hal Pierce, NASA).

4. NOAA-M Logo (NOAA & NASA). First image from NOAA-17. "GOES Next Generation," art by Allan Kung, 2001.

5. NEXRAD tower. Phased Array Radar diagram. Automated Surface Observing System. NOAA Ship KA'IMIMOANA servicing buoy.

6. Ice storm, Burlington, VT, 1998 (FEMA News Photo). Palm Beach Hurricane, 92 Views; American Autochrome Company, Chicago, IL, 1928.

7. Seattle, Washington, pollution and haze, 1980.

8. Lightning storm (C. Clark). Ruins from Mississippi tornado, November 2002 (Kevin Galvin, FEMA News Photo). "Last trains in and out of Harrisburg," History of the Johnstown Flood, Willis Fletcher Johnson, 1889.

9. Hurricane Michelle, November 2001. NOAA Aircraft Operations Center, Hangar 5 (Juan Carlos Pradas-Bergnes, 2002). Chandeleur Islands, LA, 2001.

10. East Grand Forks, MN, April 1997 (David Saville, FEMA News Photo). Clear Fork Creek, WV, July 2001 (Leif Skoogfors, FEMA News Photo). "Peshtigo Fire," Harper's Weekly, November 25, 1871 (University of Wisconsin).

11. Solar prominence, September 18, 1997 (SOHO-EIT Consortium, ESA, NASA). Aurora borealis near Anchorage, AK, 1977 (Dr. Yohsuke Kamide). Solar observatory scientist. Daniel Smith illustration from "The Sea Island Hurricanes. II. The Relief," by Joel Chandler Harris, Scribner's Magazine, Vol. 15, Issue 3, March, 1894.

12. The Stricken City by Ella Wheeler Wilcox (Historic American Sheet Music; Duke University Rare Book, Manuscript, and Special Collection Library; Library of Congress). San Francisco Newspaper, April 18, 1906 (Library of Congress). Postcard, personal collection of Joy Ikelman. Panoramic view from NOAA archives, original source unknown. Many items were created for relief funds, and for personal gain, after this event.

13. Oklahoma tornado, May 3, 1999. Tybee Island photo by William Folsom.

14. Mark Trail image courtesy of Jack Elrod, North American Syndicate Inc., World rights reserved.

15. Thunderstorm out flow from storm core, unknown location, 1982.

16. Cospas-Sarsat schematic and logo.

17. Rocky Mountain National Park, CO (U.S. Department of Interior). Rescue helicopter (Joe Dye, U.S. Coast Guard). The Islamorada Hurricane Monument was designed by Harold Lawson and sculpted by Lambert Bemelmann for the U.S. Works Progress Administration, 1937. Photo courtesy of Historical Preservation Society of the Upper Keys.

18. Wildfire in Florida, June 1, 1998 (Liz Roll, FEMA News Photo). NOAA-15 image, June 12, 2002.

19. Flood waters, unknown location. Oil rig blow out, Timbalier Bay, LA, 1992.

20. After a flood, unknown location. Disaster personnel meet to coordinate Federal, State, and local disaster assistance programs, NY, October 2001 (Andrea Booher, FEMA News Photo).

21. Dust storm approaching Stratford, TX, April 18, 1935. "Children of Migrant Agricultural Workers," Dorothea Lange, Farm Security Administration photograph,1937 (Library of Congress). Waianae Coast, Southwest Oahu, HI.

22. Full Earth, El Nino conditions, 1997 (GOES). Seagull at Stellwagen Banks National Marine Sanctuary (Bob Michelson). Waves, Gulf of the Farallones National Marine Sanctuary (Dan Howard). Humpback whale, Stellwagen Bank National Marine Sanctuary (Dann Blackwood, U.S. Geological Survey).

23. Detail of bathymetry map, Lake Erie. POES composite, Antarctic ozone hole, October 1999 (NOAA & NASA). NOAA-14 composite, sea surface temperature, 1999 (NOAA & NASA). Flood inundation map, Tar River, NC (NOAA).

24. West Nile virus graphics, U.S. Department of Agriculture. Data access chart adapted from a NOAA/NWS brochure.

25. Cumulus formation. Glass "Magic Lantern" slide photo from NOAA's amazing Photo Library.

26. World Trade Center ruins, September 21, 2001 (Andrea Booher, FEMA News Photo).

27. Exterior of the crash site at the Pentagon, September 12, 2001 (Jocelyn Augustino, FEMA News Photo). World Trade Center, September 20, 2001 (Andrea Booher, FEMA News Photo). World Trade Center ruins with U.S. Flag, September 19, 2001 (Andrea Booher, FEMA News Photo).
28. Mississippi River at Memphis, TN, 2000 (Larry Donald, U.S. Army Corps of Engineers). Danger sign at New Bedford, MA, Superfund site. Warehouse fire.
29. Portion of Gloucester, MA, bathymetry map, 1986. NOAA Ship SURVEYOR, ice-covered in the Bering Sea, circa 1979. Monitoring Y2K Events (Greg Mathieson, FEMA News Photo).
30. Billion Dollar Weather Disasters, 1980-2003 (NOAA/NESDIS/National Climatic Data Center).
31. Weather map, September 1872. Aftermath, Tropical Storm Allison, June 2001; NOAA-16 image.
32. U.S. Flag (Rob Wyman, U.S. Coast Guard).

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