NOAA / NESDIS Center for Satellite Applications & Research (STAR)

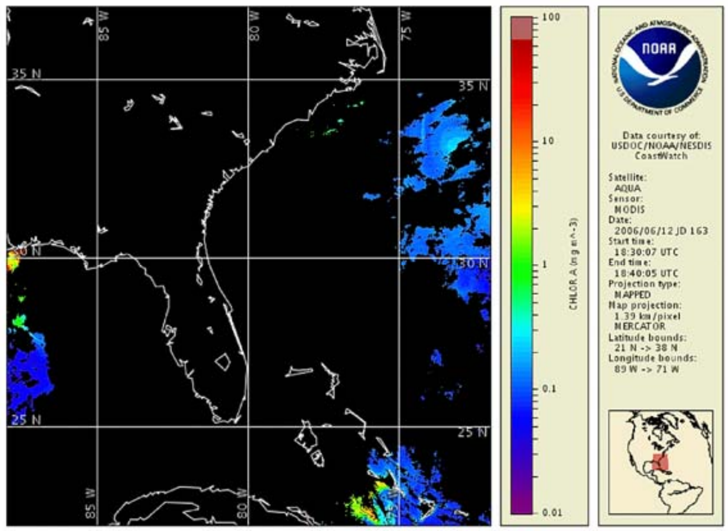
Accomplishments of STAR in 2006

Submitted for NOAA's 2006 Report on Accomplishments [1]

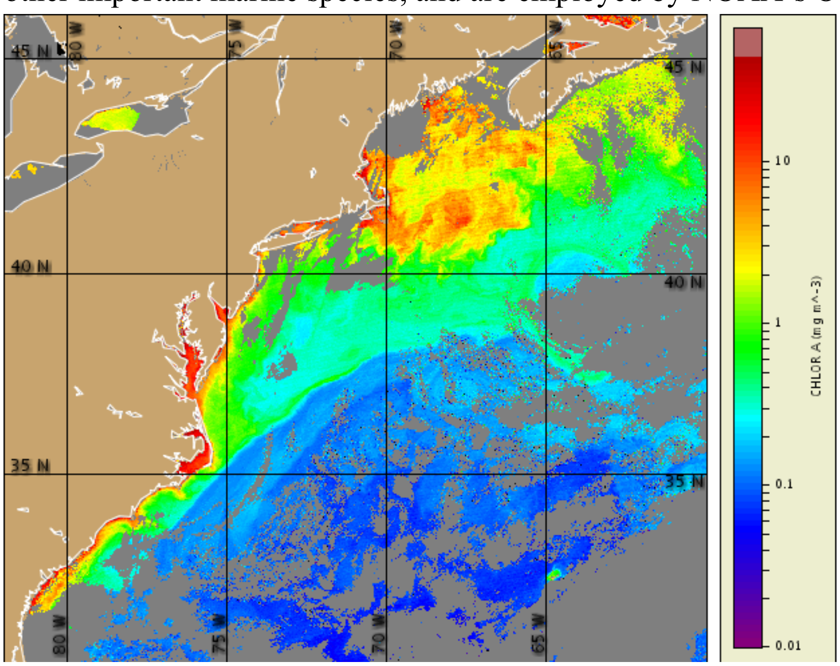
January 9, 2007

1. Ecosystems

Ocean biology products



The National Environmental Satellite, Data, and Information Service (NESDIS) began to process and distribute ocean biology products for coastal U.S. waters, using satellite observations in June 2006. Products, such as chlorophyll concentration, represent the first satellite-derived biological products generated by NESDIS for coastal and open ocean waters. These are useful in detecting and monitoring harmful algal blooms, assessing regional water quality, and locating suitable habitat for fish and other important marine species, and are employed by NOAA's Ocean Service and Fisheries Service.



The experience prepares NOAA for the time when it will assume operational responsibility for generating and distributing ocean biology products in the global ocean after 2010. Information on water quality, fish and other marine species will be available around the clock, for all oceans, as the satellite never sleeps. This achievement was accomplished by the Center for Satellite Applications and Research (STAR) and Office of Satellite Data Processing and Distribution (OSDPD).

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[1] NOAA report is at (must be one word without any spaces): http://www.corporateservices.noaa.gov/%7Enbo/FY08%20Rollout%20Materials/1_31_07_ROLLOUT/Blue_Book/Chapter_1_Final.pdf

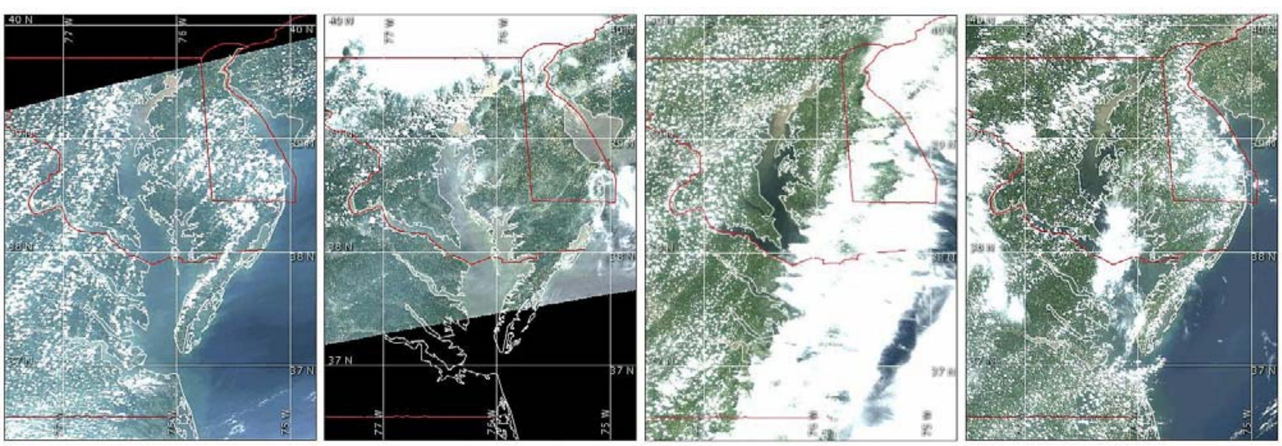
Scientists compared on-site measurements of water color and quality with satellite views after record rainfall discolored Chesapeake Bay waters

The Chesapeake Bay watershed starts in New York and drains into the Atlantic Ocean near Norfolk, Virginia. Heavy rainfall can wash detrimental loads of sediments and nutrients into the Bay. These inputs degrade the health of the Bay's ecosystem.

By observing the color and strength of light leaving the water, satellite instruments can monitor the quality of the water, the presence of marine organisms, especially plankton, and properties of water associated with particular species.

In the Chesapeake Bay, drainage of fresh water from rivers profoundly affects the ecosystem of this normally brackish Bay. Sometimes plumes of fresh water are associated with sediment washed from the land; the sediment is rendered visible by a unique gray color which is observable from space. At other times, river water exhibits a brown or orange tint from dissolved material like decaying leaves or tannins. This tint can be measured by an index known as "chromophoric dissolved organic matter (CDOM)" – a measure of organic matter associated with the color of light exiting the water.

Between July 5 and 7, 2006, a team from the Marine Optical Characterization Experiment (MOCE – organized by the Ocean Sensors Branch of NESDIS-STAR) took samples from the upper portion of the Chesapeake Bay near Baltimore and the Bay Bridge. The team documented a discharge of fresh water having high amounts of sediment into the Bay, which then advanced down the Bay following record-breaking rainfall in the Chesapeake Bay watershed. This *plume* of fresh water was potentially devastating to marine species. The team collected measurements of total suspended matter, chlorophyll-a, CDOM, and the color of the light coming from the subsurface water, to better enable the detection of fresh water and its associated pollution in the future. The purpose of developing such satellite-based techniques for observing the quality of the water is to maintain and protect the health of the watershed ecosystem.



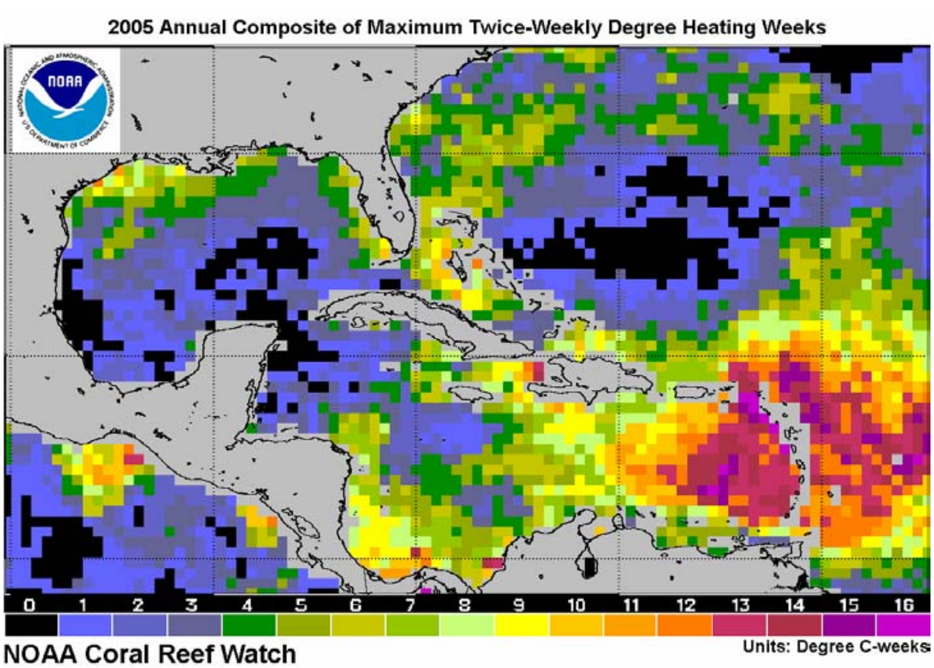
CoastWatch true color images from July 4 to 9, 2006, illustrate the progression of the fresh water plume down the Chesapeake Bay.

Gold Medal awarded for support of NOAA's Harmful Algal Bloom Forecasts

The Harmful Algal Blooms (HABs) Forecasting System indicates the location, extent, and possible development or movement of HABs in the Gulf of Mexico. HABs are population explosions of certain species of algae that are harmful to fish or to humans. The forecasting system uses satellite images, field observations, and data from buoys to provide the frequent, extensive observations needed to assess the location and movements of HABs. Conditions are posted to a web page twice a week during the HAB season. The HAB *Bulletin* offers additional analysis to state and local resource managers. Several NOAA employees received a Gold Medal Award from the U.S. Department of Commerce for collaborative work in using ocean color/ocean biology products from satellite data to support NOAA's Harmful Algal Bloom (HAB) Forecast System.

An early alert of bleaching conditions in the Caribbean Sea from Coral Reef Watch

In the fall of 2005, major bleaching of coral reefs occurred in the Caribbean Sea. The Satellite Bleaching Alert system (of NOAA's Coral Reef Watch) provided early warnings of the onset of this event. This system of products automatically monitors for the thermal stress that gives rise to coral bleaching. Record high thermal stress was observed, and an international effort to document the extent of the bleaching began. The bleaching resulted from the most intense high temperature stress ever seen in the Caribbean Sea (in both the 20-year satellite record and the 100-year instrumental record).



Maximum values of the index for Degree Heating Weeks (DHW), an indicator of accumulated thermal stress, in 2005. Each DHW represents one week of temperatures that are 1ºC above the highest monthly average temperature at a location. DHW values are accumulated over 12 weeks. DHW values over four are virtually always accompanied by bleaching and levels over eight result in mass coral bleaching, onset of mortality of corals, and inability of coral reefs to recover. This product is produced by NOAA Coral Reef Watch.

NOAA Coral Reef Watch collected over 1500 observations in the wider Caribbean region, from 100 observers in 22 countries, states, and territories. Many sites reported from 90 to 100% of their corals bleached, and 50% or more mortality of corals.

Products that warn of coral bleaching available through Google Earth

Coral reef managers and scientists around the world can now receive the latest data on thermal stress that can cause bleaching of coral reefs, in the flexible new format of Google Earth. It is an excellent visualization tool that helps to enliven the data of NOAA's Coral Reef Watch. Positive feedback from users has led to several improvements including *placemarks* for "virtual stations" where there is thermal stress: Users can set a location in Google Earth, like a push-pin on a wall map, where they will monitor stress on coral reefs. Perhaps the greatest benefit of these Coral Reef Watch products is that coastal managers will have advance warning of one to three weeks for bleaching events, allowing them to prepare for and respond to coral bleaching.

Coral Reef Watch curriculum now available online

The Remote Sensing and Coral Reefs curriculum is available to a national audience via the website of NOAA's Coral Reef Watch. In the summer of 2004, 5th grade teacher Margaret "Peggy" Koenig created a curriculum unit for NOAA Coral Reef Watch. The set of 7 lesson plans focuses on the application of remote sensing to monitoring of coral reefs and was designed for advanced students in fourth to sixth grades or in middle school classrooms. While designed to be taught in sequence, many of the lessons can stand alone as individual classroom activities.

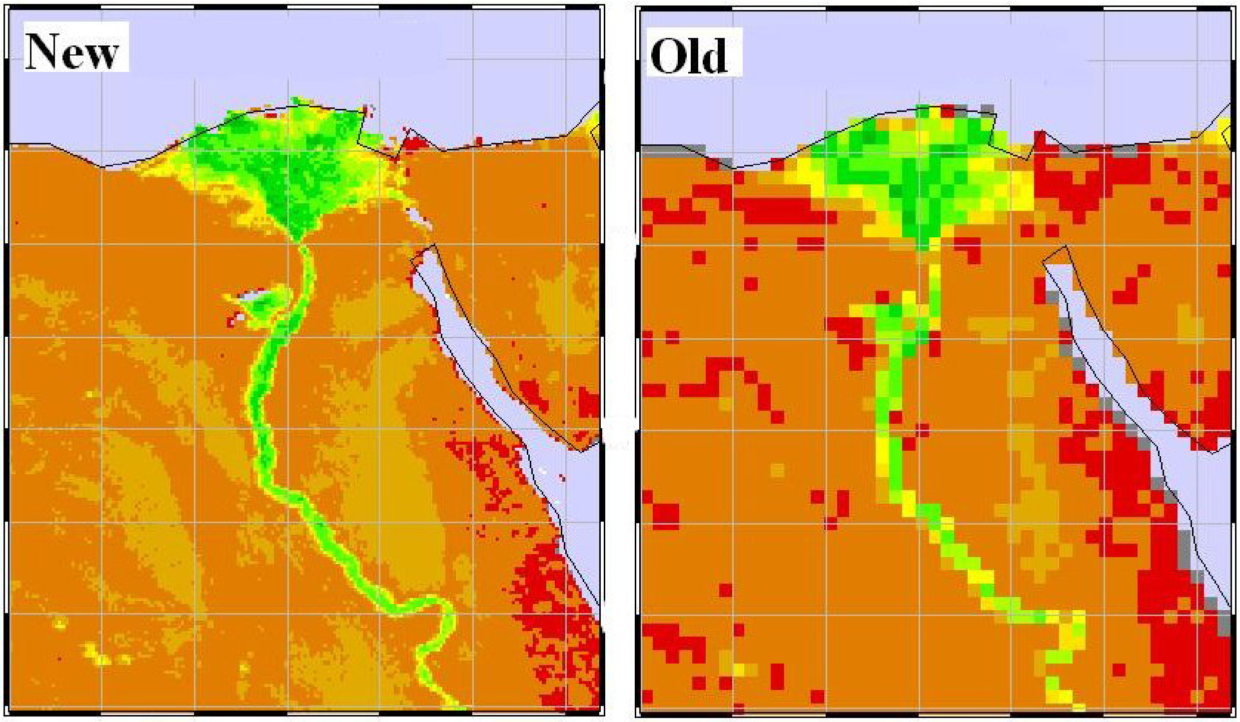
2. Climate

A more detailed Global Vegetation Index

An improved dataset for the world's landscape was developed from the 25-year long archived set of reflectance data from the Advanced Very High Resolution Radiometer (AVHRR) instrument on NOAA's polar-orbiting satellites. This land surface and vegetation dataset was developed from daily reflectance data in the visible, near-infrared, and infrared regions of the spectrum of electromagnetic radiation. The parameters were accumulated over a 7-day period, corrected to reduce noise, and then used to calculate vegetation indices, including the Global Vegetation Index (GVI). *See an example of the Vegetation Index below.*

Among other vegetation datasets, the GVI is unique for having the best space and time resolution and the largest number of parameters and products. For most of the parameters, indices, or products, there are no equivalents in the conventional climate record or in other satellite-based data. So the satellite data is a direct observation of vegetation conditions, unlike anything else in the climate record. NOAA-NESDIS scientists and users have double-checked the accuracy of these Vegetation Indices.

The GVI is useful for detecting long-term trends in vegetation cover, and for monitoring droughts, temperature and moisture effects on the land, health of vegetation, and for monitoring degradation of land, including deforestation and desertification. The index has also been used to indirectly monitor mosquito-borne epidemics and invasive species; and to assess the ways that the land surface responds to the rainfall and temperature patterns caused by El Niño.

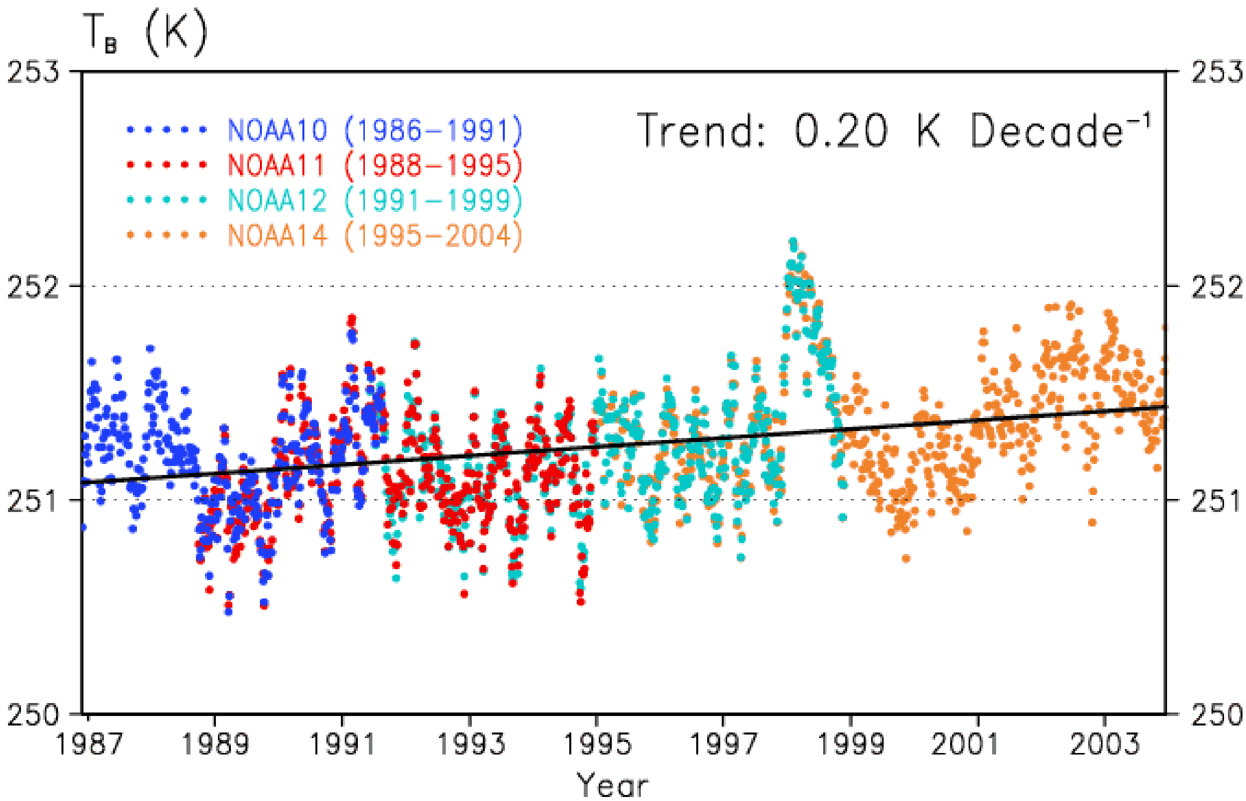


Normalized Difference Vegetation Index – Nile Delta

Microwave Sounder observes the temperature trend of the atmosphere

The global-average air temperature at the surface of the Earth is believed to be warming at about 0.17 degree Kelvin (K) per decade. The question of whether the main part of the atmosphere (the troposphere) is warming or cooling is debated in the scientific community, largely because the observed temperature from the Microwave Sounding Unit (MSU) on NOAA polar-orbiting satellites has shown a nearly zero trend in some previous studies. This debate is directly related to the debate on changes in global temperature.

Calibration errors are a major source of uncertainty in determining the temperature trends observed by the MSU instruments, especially when these are on different satellites in different orbits. To reconcile this problem, scientists in the Center for Satellite Applications and Research (STAR) have re-calibrated MSU instruments on four different NOAA satellites, using the technique of *simultaneous nadir overpasses*, and produced a new set of data that are well-intercalibrated for climate studies *(see figure below)*. The new dataset has diminished the bias of this instrument going from one satellite to another, to only 0.05 to 0.1 degree Kelvin, wherever satellite observations overlap. After re-calibrating MSU, the globally averaged temperature trend of the troposphere over the ocean is 0.20 degree K per decade, from 1987 to 2003. This trend value suggests that the troposphere is warming slightly faster than the surface of the Earth.



Time series and trend of atmospheric temperature.

3. Weather and Water

Forecasters agreed on requirements for surface wind vectors over the ocean

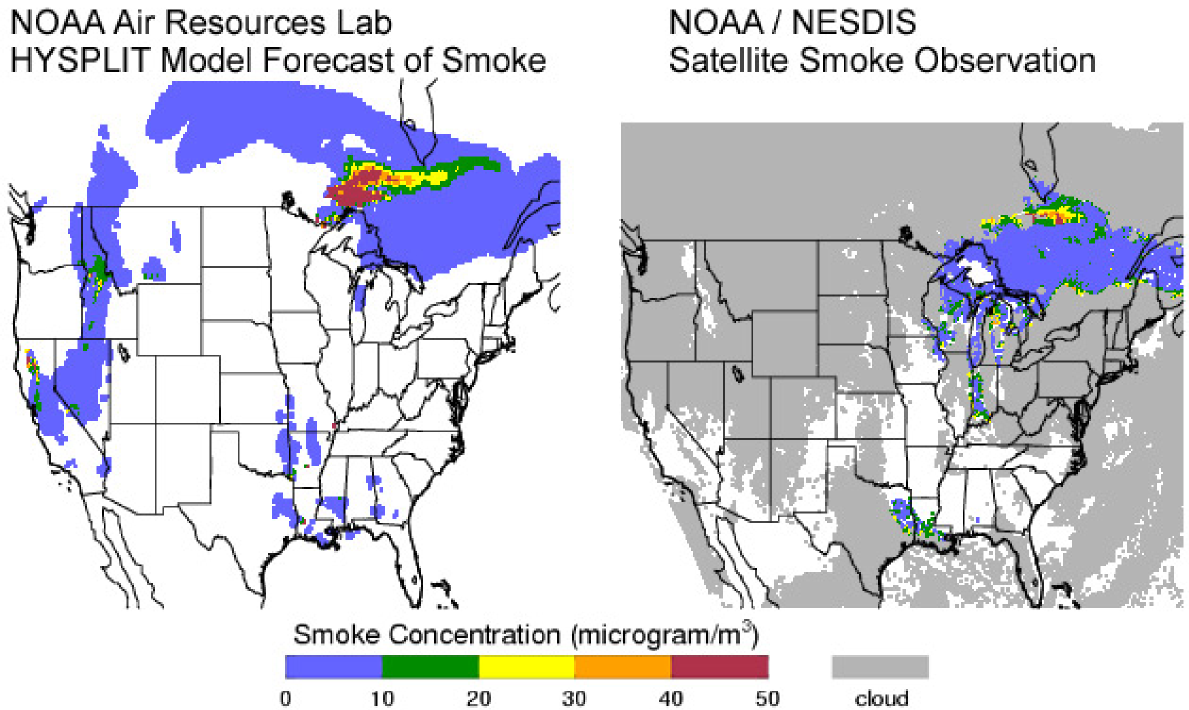
Satellite wind vectors over the ocean surface are a staple product for local and marine weather forecasting. Satellites can offer better coverage in space and time that enables more accurate forecasting. The community of forecasters met in Miami at a workshop on NOAA Operational Satellite Ocean Surface Vector Wind Requirements, at the National Hurricane Center in June 2006. The meeting united a broad spectrum of folks representing the operational weather forecasters, the research community, and remote-sensing engineers to choose NOAA's requirements for the ocean surface wind vector. Much has been learned and much has changed over the past ten years with respect to the need for surface wind observations by satellites in weather forecasting. Because of this meeting, there is now greater acceptance of these satellite winds by the forecasters. In the long term, it pushes NOAA to deliver these wind products to operational forecast centers, and to improve the forecasts of hurricane intensities and intensity of winter storms.

Requirements For Ocean Surface Winds

- Observations in all weather (i.e., winds are accurate in rain)
- The accuracy of a wind observation sustained over one minute, at a height of 10 meters above the ocean, will be given by:
  - from 0 to 4 knots: speed will be ±2 knots
  - from 4 to 10 knots: speed will be ±2 knots, and direction ±20 degrees
  - from 10 to 165 knots: speed will be ±2 knots, and direction ±10 degrees
- time interval between measurements at a point on the ocean surface: every 6 hours
- Lag time before product is available: 45 – 60 minutes after measurement
- Spacing between different wind observations: 2.5 km x 2.5 km
- Wind observations to within 2.5 km of the coast
- Wind fields must be delivered to the operational centers and data systems
- Product documentation, tutorial, and training

Verifying forecasts of smoke and air quality with satellite products

The National Weather Service (NWS) offers experimental forecasts of the location and concentration of smoke using a model called Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT), developed by the NOAA Air Resources Laboratory (ARL). In 2006 NWS asked the National Environmental Satellite, Data, and Information Service (NESDIS) to provide observational support for verifying the accuracy of smoke forecasts in near real time. To fulfill this request, NESDIS scientists developed a procedure based on pattern recognition to identify *smoke plumes*, or clouds of smoke, using fire and aerosol information from geostationary satellite data. The amount of overlap between observed and forecast smoke concentrations is used to calculate a forecast skill, as a figure of merit score.



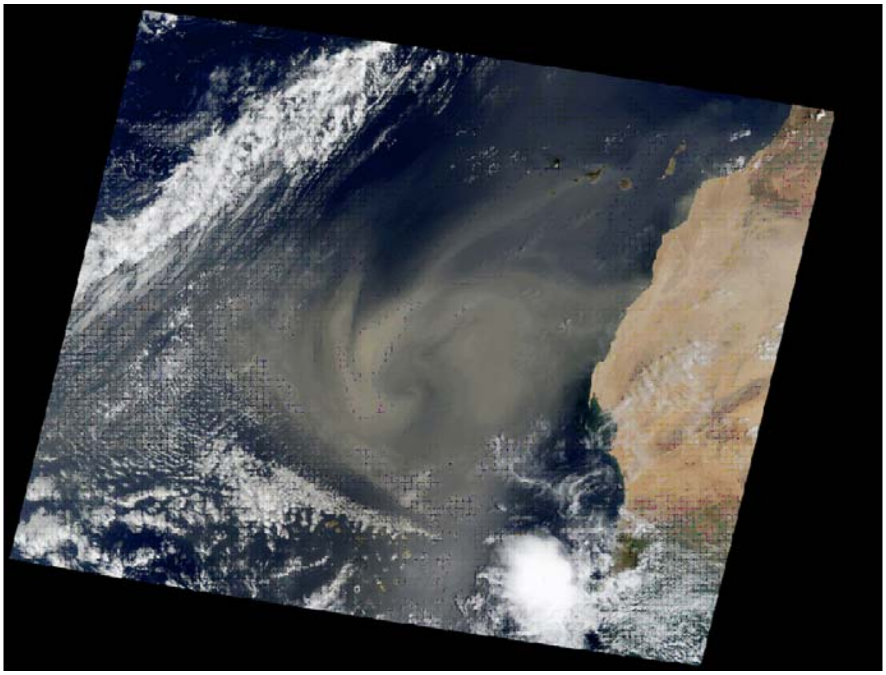
Comparison A prediction of HYSPLIT smoke analysis concentration from the HYSPLIT model (left) is compared with a smoke observation from GOES-12 smoke observation (right), for September 9, 2006, 16 UTC at mid-day. Observed plumes from the GOES-12 Imager are well forecast by the HYSPLIT model in eastern Canada. Forecast skill (figure of merit scores) for 1, 5, and 20 μg/m^3 contours for this episode were 45%, 17%, and 16% respectively. Forecast skill can only be calculated for the cloud-free regions. The presence of clouds in the satellite field of view prevented the observation retrieval of smoke aerosols by satellite observations over the central part of Canada and the western United States (entire region in gray).

Scientists discover that African dust may be hampering hurricane activity

The active Atlantic hurricane seasons in 2004 and 2005 and warming ocean temperatures led many researchers to look toward global warming to explain year-to-year changes in tropical storm activity. However, University of Wisconsin-Madison and National Environmental Satellite, Data, and Information Service (NESDIS) scientists have found a new cause for the year-to-year variability of these tropical storms: dust storms from Africa.

Published October 11, 2006, in *Geophysical Research Letters*, these scientists reported that large dust clouds from the Saharan desert may suppress hurricane formation and growth in the Atlantic Ocean. Using a new dust detection algorithm for the data of the Advanced Very High Resolution Radiometer (AVHRR) instrument on the NOAA polar-orbiting satellites (a record that is 25 years long), these scientists discovered that few hurricanes formed in years with large amounts of Saharan dust over the Atlantic, while more tropical storms and stronger storms appeared in years with little dust activity.

In addition to explaining the long-term change in hurricane activity in the Atlantic Ocean, Saharan dust storms, which were numerous in the summer of 2006, may also explain why so few tropical storms formed in 2006, defying the predictions of many in NOAA for a very active season of storms. Furthermore, if it is possible to incorporate dust into weather forecast models, then the accuracy of seasonal predictions of hurricane activity would be boosted. The embarrassment of a “failed” hurricane season like the 2006 season might be averted. Research is still needed to understand why some years have few dust storms and others years have many.

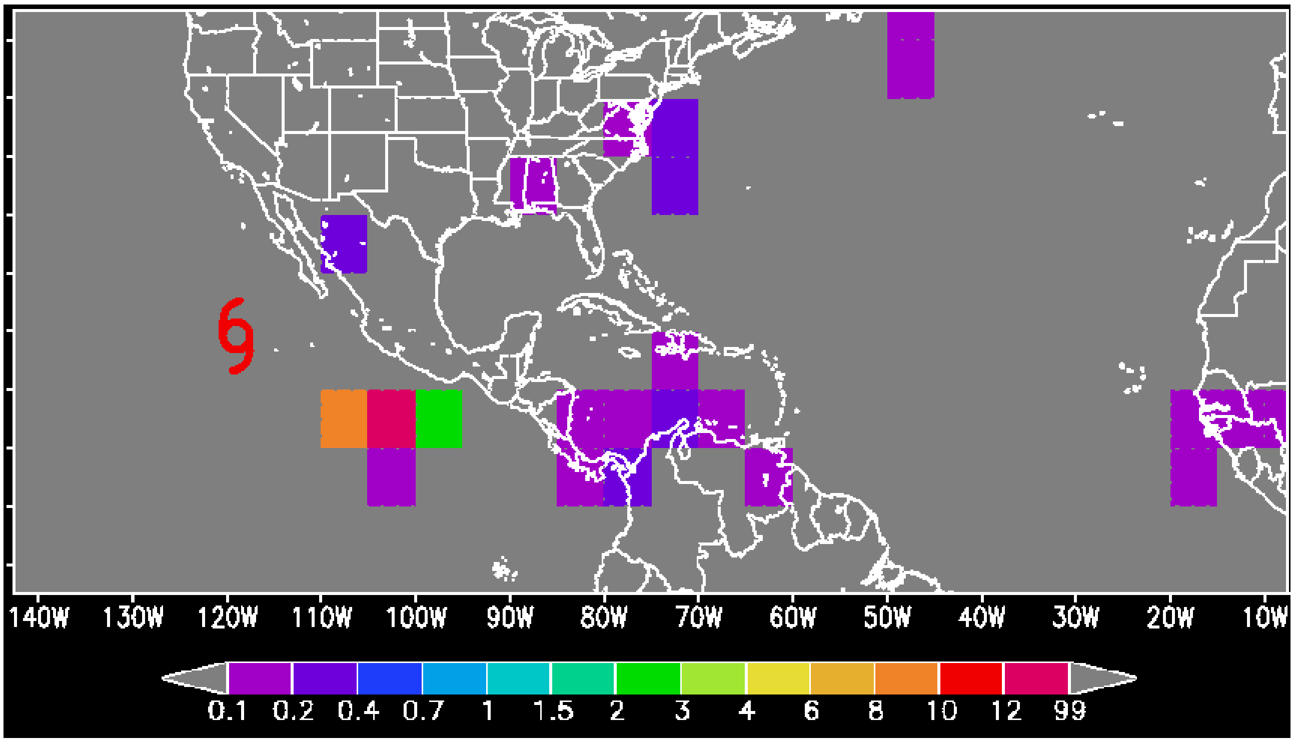


Satellite Image of Dust Storm over the North Atlantic

New product for formation of tropical cyclones operational for 2006 hurricane season

The prediction of where and when a tropical cyclone will form is a very difficult task. Little guidance is available to the National Hurricane Center (NHC) from computer models. In response to this need, scientists in NESDIS-STAR and the Cooperative Institute for Research in the Atmosphere created a new product for *Tropical Cyclone Formation Probability* (TCFP). The product combines the vertical shear of the wind, the sea surface temperature, and images in the water vapor channel from the GOES-East satellite to determine the probability that a tropical cyclone will form within the next 24 hours. The product also indicates the climatological probability of cyclone formation for a given region, so that areas where formation of a storm is more likely than it normally is can be identified. The product covers the area of forecast responsibility of the National Hurricane Center, and includes the Atlantic and eastern North Pacific Oceans. STAR’s product became operational in the NESDIS Office of Satellite Data Processing and Distribution in time for the 2006 hurricane season. The probabilities of formation are updated every six hours, and are available at: www.ssd.noaa.gov/PS/TROP/genesis.html along with all the information used to create the product.

The figure below shows an example of the operational TCFP product from the web page. This figure shows the departure of the formation probability from the climatological value. It highlights regions in orange and red where storm formation is more likely than normal. The plot also shows the locations of existing tropical cyclones, since these are areas where formation of a second storm is unlikely. On this day in July 2006, Tropical Storm Carlotta was located in the Pacific Ocean west of Mexico, where the red cyclone symbol is placed. The red square between 10 and 15° N latitude and between 100 and 105° W longitude shows where formation of a tropical cyclone was much more likely than average. Hurricane Daniel formed in this region the next day.

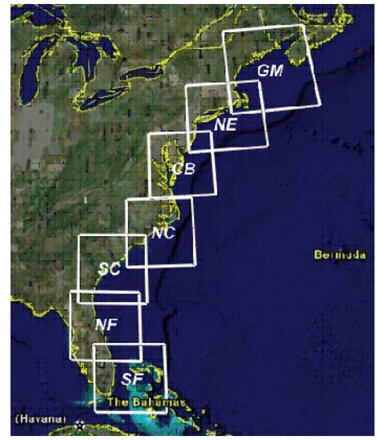


The new product for tropical cyclone formation probability on 16 July 2006. The product shows areas where tropical cyclone formation is more likely than average in 5 degree by 5 degree boxes over the Atlantic and eastern North Pacific Oceans. Existing tropical cyclones are located by red tropical cyclone symbols.

4. Commerce and Transportation

NOAA CoastWatch Launches the East Coast Node

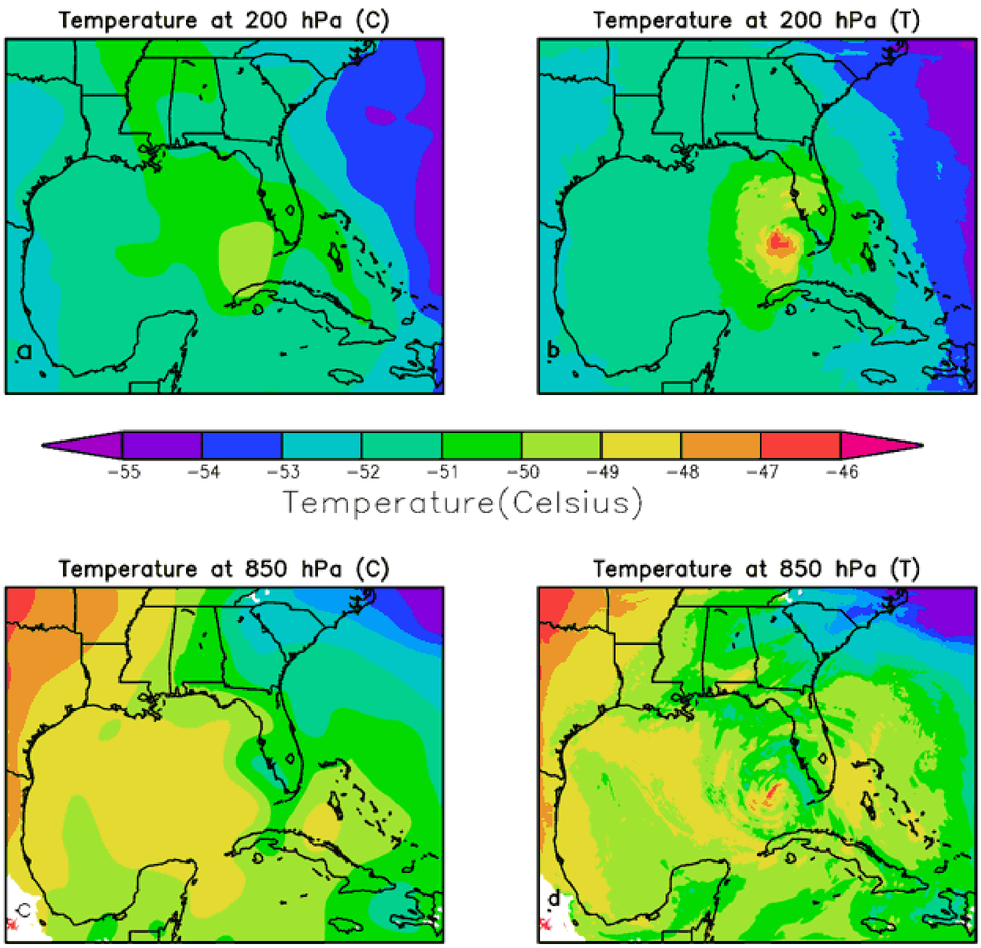
The National Oceanic and Atmospheric Administration (NOAA) CoastWatch provides ocean remote sensing data for six regions covering the entire coast line of the United States, including the Great Lakes. In June 2006, NOAA CoastWatch launched its newest region, the East Coast Node, at the Chesapeake Bay office of NOAA in Annapolis, Maryland. The new node provides diverse data from multiple satellites; the data include sea surface temperature, ocean surface winds, and levels of chlorophyll-a in the water; and the products are available on the internet. Scientists, resource managers, and fishers use this data to forecast atmospheric events, predict harmful algal blooms, and detect the presence and distribution of fish and marine mammals along the eastern seaboard of the United States. With CoastWatch products, fishermen are able to find fish in less time; public health authorities have advance warning of toxic waters off the shore; and ships receive forecasts of sea-state conditions with less delay.



5. Satellite Services

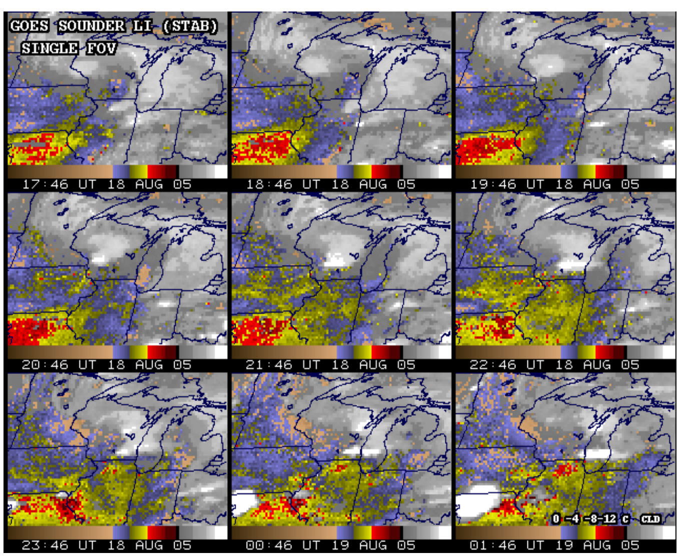
Direct use of satellite "radiance" data from cloudy regions in forecast models improved monitoring of a hurricane

Scientists in NESDIS and the Environmental Modeling Center of the National Weather Service have come a long way in assimilating satellite data into global and regional weather forecast models. Instead of converting what the satellite observes into quantities that the model "knows" how to use, newer models can now assimilate what the satellite actually measures. For example, the Community Radiative Transfer Model can directly use measurements of *radiances*, a property that an instrument on a satellite readily "sees" at a point in space, from a particular direction, and at a moment in time. As a human eye can see the "brightness" of light coming from a particular direction and from a region of the sky, so can an instrument detect the radiance of electromagnetic radiation coming from a particular direction. Radiance observations from cloudy and rainy areas can now be assimilated into the Weather Research and Forecast model. In the figure below, the new technique produces a temperature field in Hurricane Katrina that is more detailed, and that better resolves the warm core of the hurricane. The Joint Center for Satellite Data Assimilation, in which both NESDIS and the NWS participate, uses these satellite observations to enable better forecasts of severe weather.



For the first time, observations of microwave radiances are assimilated into a weather forecast model. Here, the radiance observations are from the Special Sensor Microwave Imager and Sounder instrument on the DMSP satellite. The new data assimilation technique improves the analysis of temperature fields (shown in the right panels) at two levels in Hurricane Katrina, compared with the same fields in the control run, in the left panels.

More detailed GOES sounder products for forecasters



Newer product with more details shows zones of sharp transition from low instability to high instability

The National Environmental Satellite, Data, and Information Service (NESDIS) has retrieved atmospheric and surface properties from vertical profiles of the atmosphere, using measurements from the sounder instrument on the GOES satellites. NESDIS scientists have now implemented a new GOES sounder processing system that produces an entire suite of products at the full resolution of the GOES sounder without loss of quality or timeliness. These products are more detailed and offer better geographic coverage and depiction of atmospheric and surface information for the National Weather Service (NWS) forecasters.

NESDIS delivers the GOES sounder products to its primary user, the NWS, in a variety of formats. For example, the Derived Product Imagery (DPI) format, a color-coded image of derived meteorological information, permits the display of time-lapse loops that animate changes in quantities like atmospheric moisture, atmospheric instability, temperature of the ground surface, and height and amount of clouds.

The additional information and sharper presentation of the high resolution products from the GOES sounder allows field forecasters to provide more timely and more specific severe weather warnings to the public.

Cooperative Institute for Oceanography Evaluated

Established in 2003 by Oregon State University (OSU) and the National Oceanic and Atmospheric Administration (NOAA), the Cooperative Institute for Oceanographic Satellite Studies (CIOSS) develops satellite techniques to study the ocean and improve computer models of the ocean and of the interface between ocean and atmosphere. In October 2006, a formal review was conducted to determine how effectively CIOSS supports NOAA's stewardship of ocean and coastal resources and whether CIOSS serves the public. Preliminary results from the review indicate that CIOSS is admirably advancing understanding of the oceans through its improvements of satellite-based techniques for monitoring the ocean and the ocean-atmosphere interface. In addition, CIOSS has an outstanding outreach program to foster awareness of ocean issues in young people and greatly benefits NOAA and OSU. The reviewers urged that the agreement establishing CIOSS be renewed for another five years.

Signals from GPS satellites probe the atmosphere and assist in forecasting Weather

The Radio Occultation technique uses radio signals from Global Positioning System (GPS) satellites as the signals pass through the edge of the atmosphere. The atmosphere bends radio signals which graze the Earth at a shallow angle, when the signals are nearly tangent to the Earth. A second satellite receives the signals, and can observe slight changes in the time that the signal is received. These timing shifts indicate how much a signal has been bent, which is related to subtle changes in air density, caused by changes in the temperature or moisture of air layers.

These satellite measurements of radio refractivity of the atmosphere (or what is equivalent, measurements of the bending angle of the radio signals) complement conventional satellite measurements of temperature, when both are assimilated in numerical weather prediction models. At the Joint Center for Satellite Data Assimilation, National Weather Service and NESDIS - STAR scientists have developed methods to use these bending angle and refractive index measurements from GPS satellites in the Global Forecast System (GFS) model. Observations from the "German Challenging Microsatellite Payload" (CHAMP) mission have been used successfully to test these methods. New tests with near-real-time data from the "Constellation Observing System for Meteorology, Ionosphere and Climate" (COSMIC) satellite have been promising. The goal is to use the COSMIC data for operational forecasting by April 2007, one year after launch.

Better selection of data for use in a forecast model

The Center for Satellite Applications and Research (STAR) and the National Centers for Environmental Prediction, of the National Weather Service (NWS), are improving the prediction of weather from numerical models, especially the Global Forecast System (GFS). The two centers have tried and tested new techniques that exploit the power of the National Aeronautics and Space Administration (NASA) Atmospheric Infrared Sounder (AIRS) instrument. The GFS model cannot use every single data point, or “field of view (FOV),” of the AIRS instrument, so it uses only one of every nine fields of view. This greatly speeds up the processing of data and cuts the time required to make a forecast. The field of nine points corresponds to a single field of view of another instrument (the Advanced Microwave Sounding Unit). The new technique selects the one best field of the nine that is “least obscured by clouds” in all channels of the AIRS instrument. Since the model cannot use all nine points, it can either take the center point (blue bars in the figure), or it can use the “least cloudy view” (red bars). The figure suggests that the latter choice leads to better forecasts.