Water Pollution and Algal Blooms in the Coastal Waters of the U.S.

edited by

David L. Alles

Western Washington University

e-mail: alles@biol.wwu.edu

Last updated 2008-2-27

Note: In PDF format most of the images in this web paper can be enlarged for greater detail.

Introduction

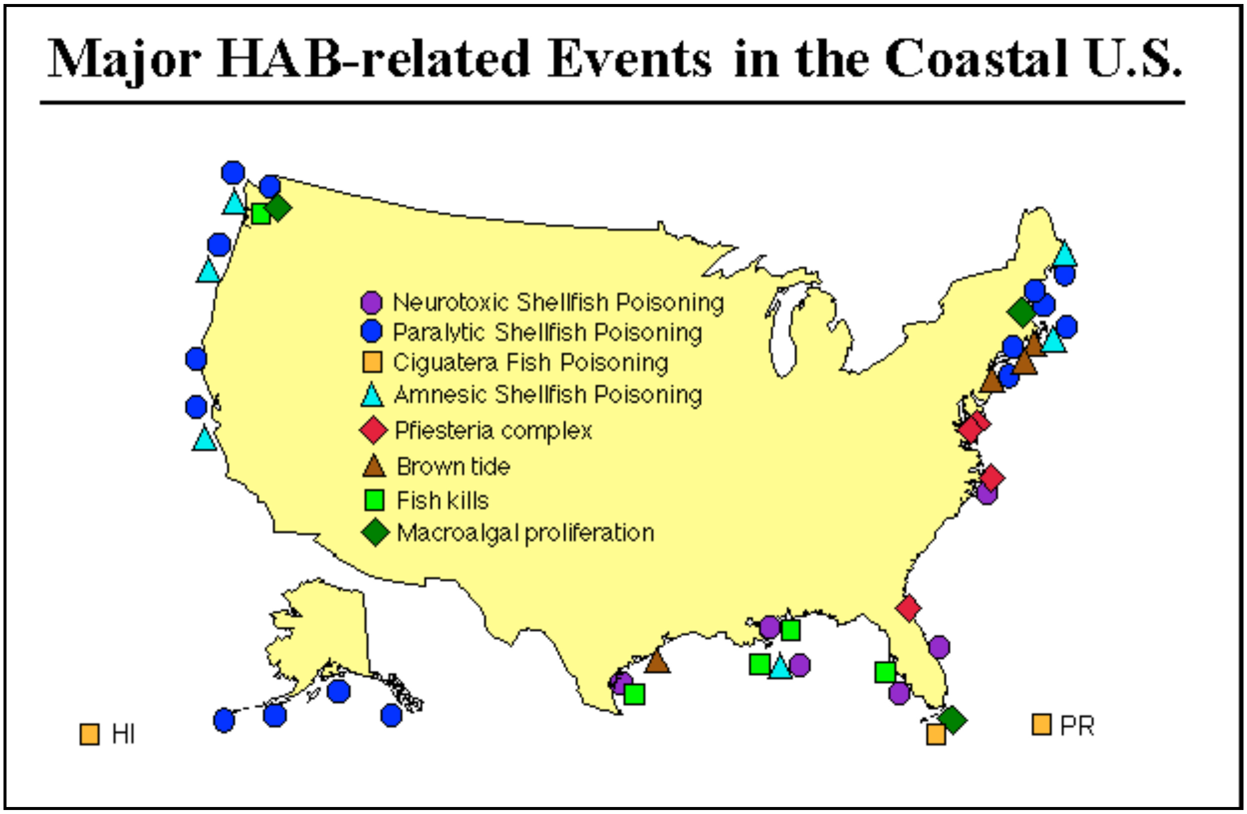
Increasingly streams and rivers of the U.S. are carrying nutrient runoff from the farms and cities of America to the sea. These nutrients, mainly nitrogen and phosphorous, have in turn fueled the explosive growth of algae and cyanobacteria, collectively known as phytoplankton, in the coastal waters of the U.S..

The sources of these nutrients are primarily agricultural fertilizers, farm animal waste, and human waste being flushed into our rivers. Given that the population of the United State has grown from 2.5 million in 1775 to 300 million today, even without the growth of agricultural related runoff, it's clear why our impact on coastal ecosystems has grown to crisis dimensions.

The resulting massive phytoplankton blooms from this nutrient runoff create a variety of environmental problems. In some coastal areas, such as the Gulf of Mexico off the delta of the Mississippi River, blooms of normally harmless phytoplankton are so extensive that, as they die and decompose, removing oxygen from the water (in the process known as hypoxia), fish and marine invertebrates are suffocated and killed over vast areas called "Dead Zones". In other coastal areas, such as Florida Bay, and the Albemarle and Pamlico Sounds of North Carolina, excessive nutrient runoff encourages the growth of harmful species of algae producing "red tides" of algae that can poison fish and marine mammals.

Harmful algal blooms, known as HABs, are becoming increasingly common in all U.S. coastal waters endangering both marine life and humans. Today, remote sensing by satellites allows us a first hand view of the magnitude of this problem.

For more on phytoplankton blooms go to:
http://fire.biol.wwu.edu/trent/alles/PhytoplanktonWeb.pdf

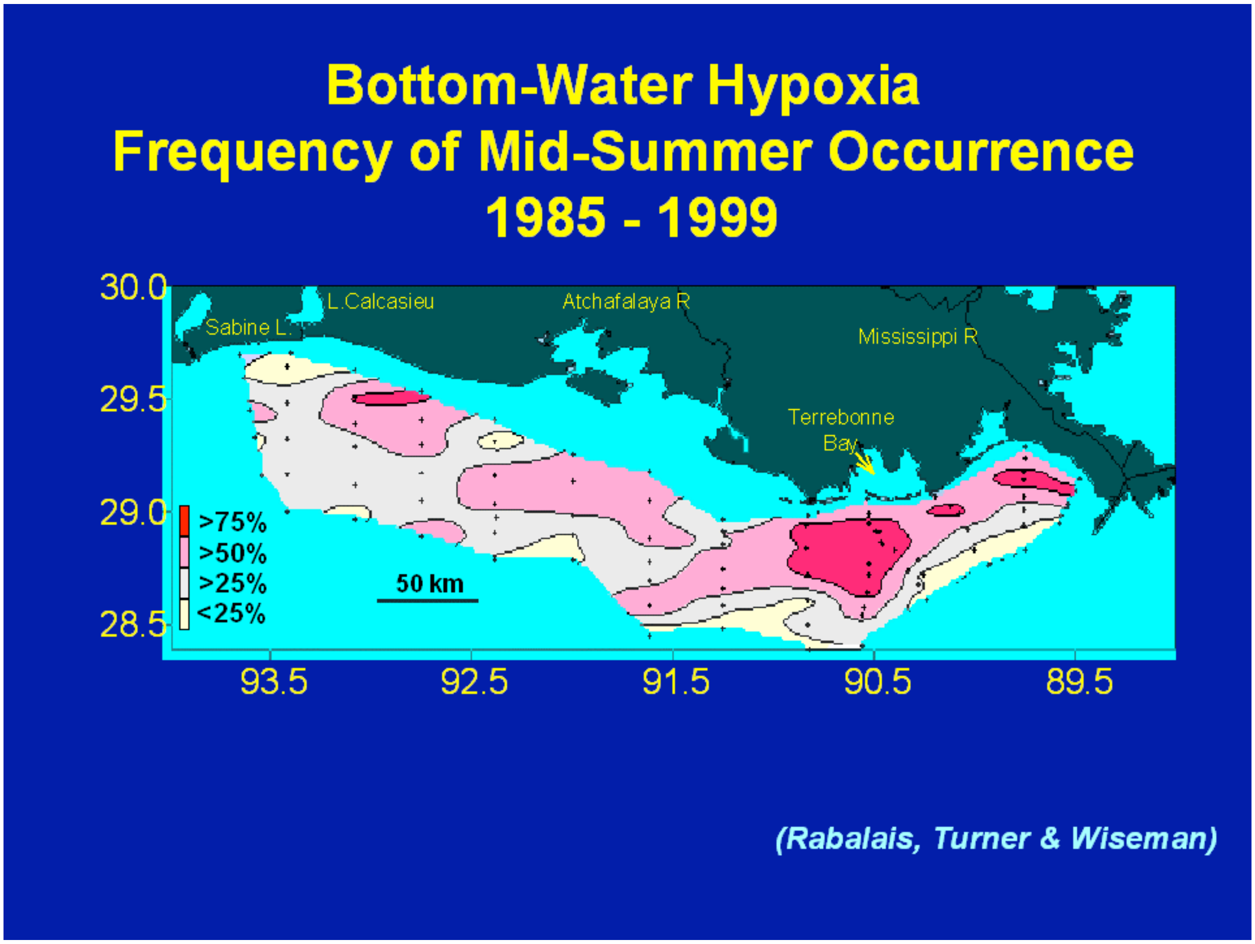


Web Reference
http://www.whoi.edu/redtide/

Every summer, an environmental phenomenon occurs off the coast of Louisiana, covering over 7,000 square miles of the Gulf of Mexico at times. The Gulf of Mexico "Dead Zone", or hypoxic zone, is an expanse of oxygen-depleted waters that cannot sustain most marine life. This hypoxic zone is caused by excessive amounts of nitrogen pollution delivered to the Gulf by the Mississippi River. The vast size of the Dead Zone and the severity of its impact are largely a consequence of human activity—such as river course and landscape alterations, industry, municipal waste treatment and agriculture—throughout the Mississippi River Basin. Human activity has resulted in enormous increases in the amount of dissolved inorganic nitrogen delivered to the Gulf by the Mississippi River. Current estimates suggest that three times as much nitrogen is being carried into the Gulf today as compared to any previous time on record.

The Mississippi River Delta

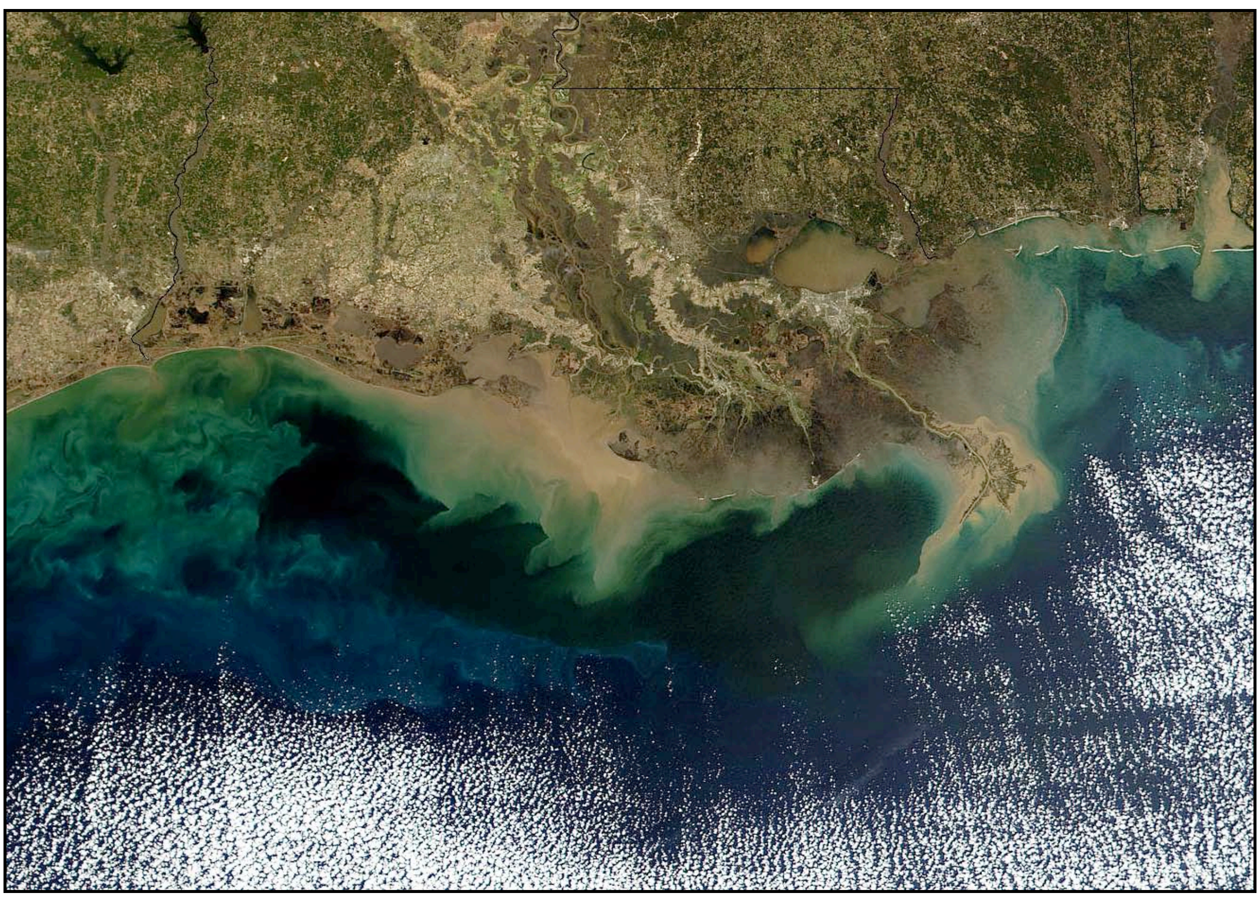
This true color image, acquired from the MODIS instrument on board NASA's Terra satellite on **March 5, 2001**, shows the murky brown water of the Mississippi mixing with the dark blue water of the Gulf of Mexico. The river brings enough runoff and sediment from its 1,250,000 square miles (3,250,000 square km) basin to extend the coast of Louisiana 300 feet (91 m) each year. To the left of the Mississippi River delta is the Atchafalaya River, a “distributary” of the Mississippi that carries about 30% of the river’s total flow.

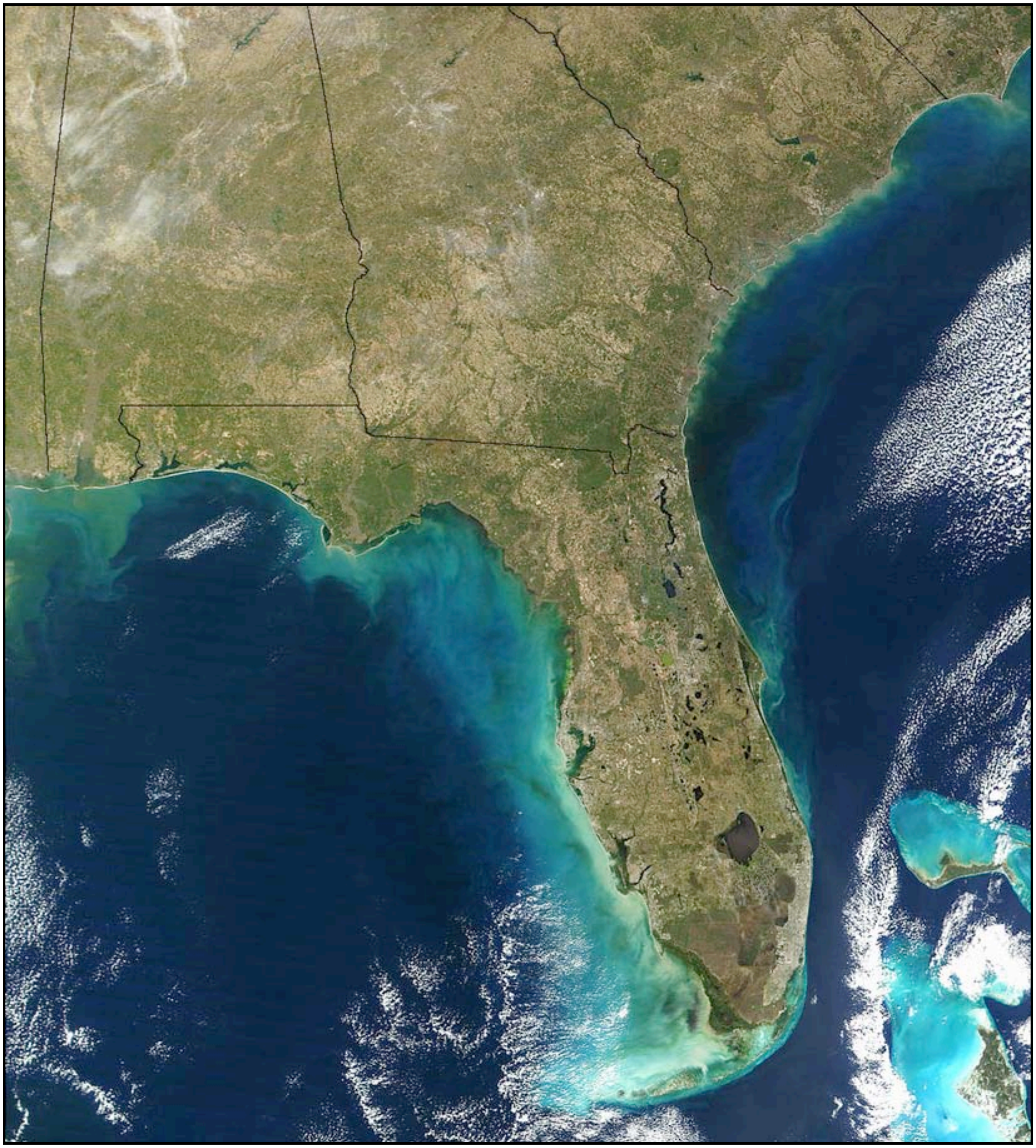


On the next page are:

Top: This **January 4, 2003**, MODIS/Terra image shows the area of the hypoxic Dead Zone between the main delta outlet and the Atchafalaya River distributary.

Bottom: In this MODIS/Terra satellite image of Texas and Louisiana from **January 15, 2002**, the Gulf of Mexico is awash in a mixture of phytoplankton and sediment.



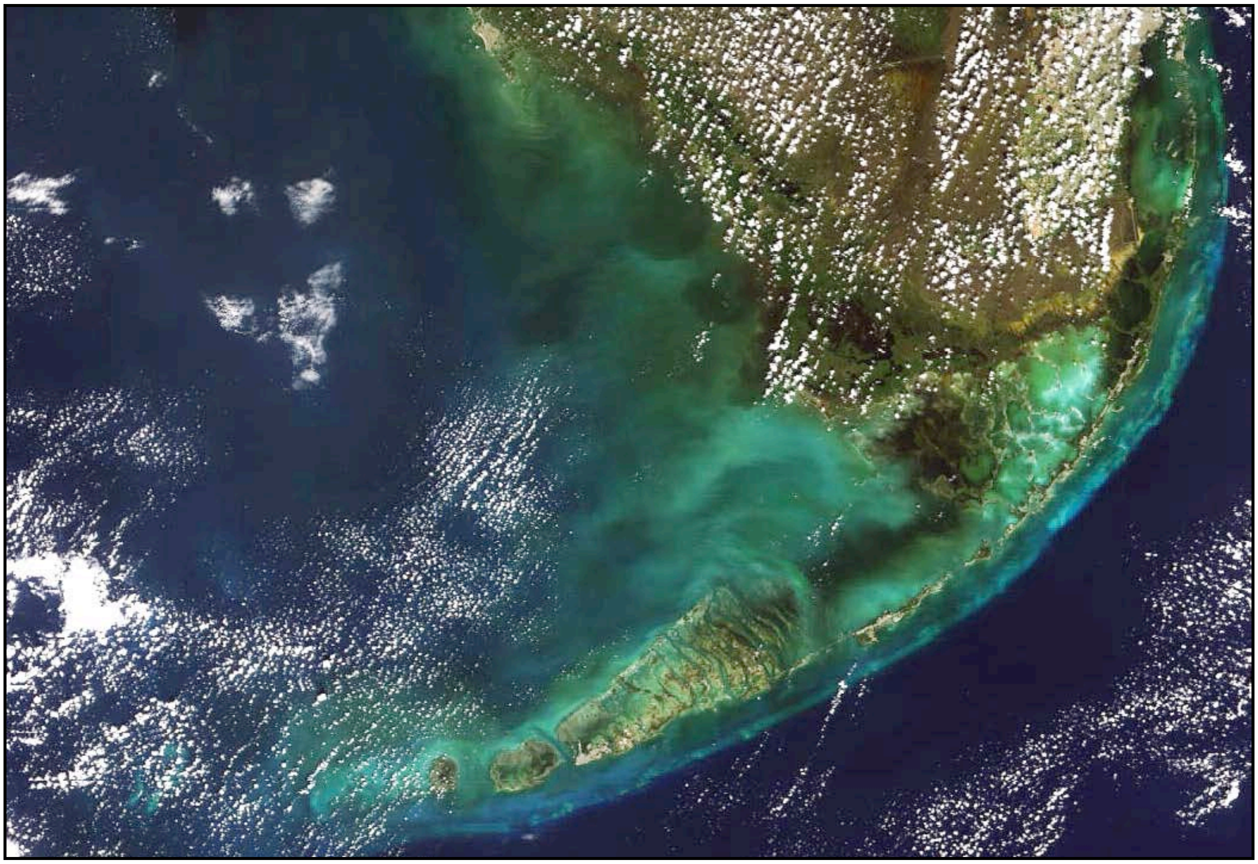


In this MODIS/Terra image from **January 9, 2002**, phytoplankton can be seen growing in the nation's southeast coastal waters; their characteristic blue-green swirls are especially visible off the west coast of Florida.

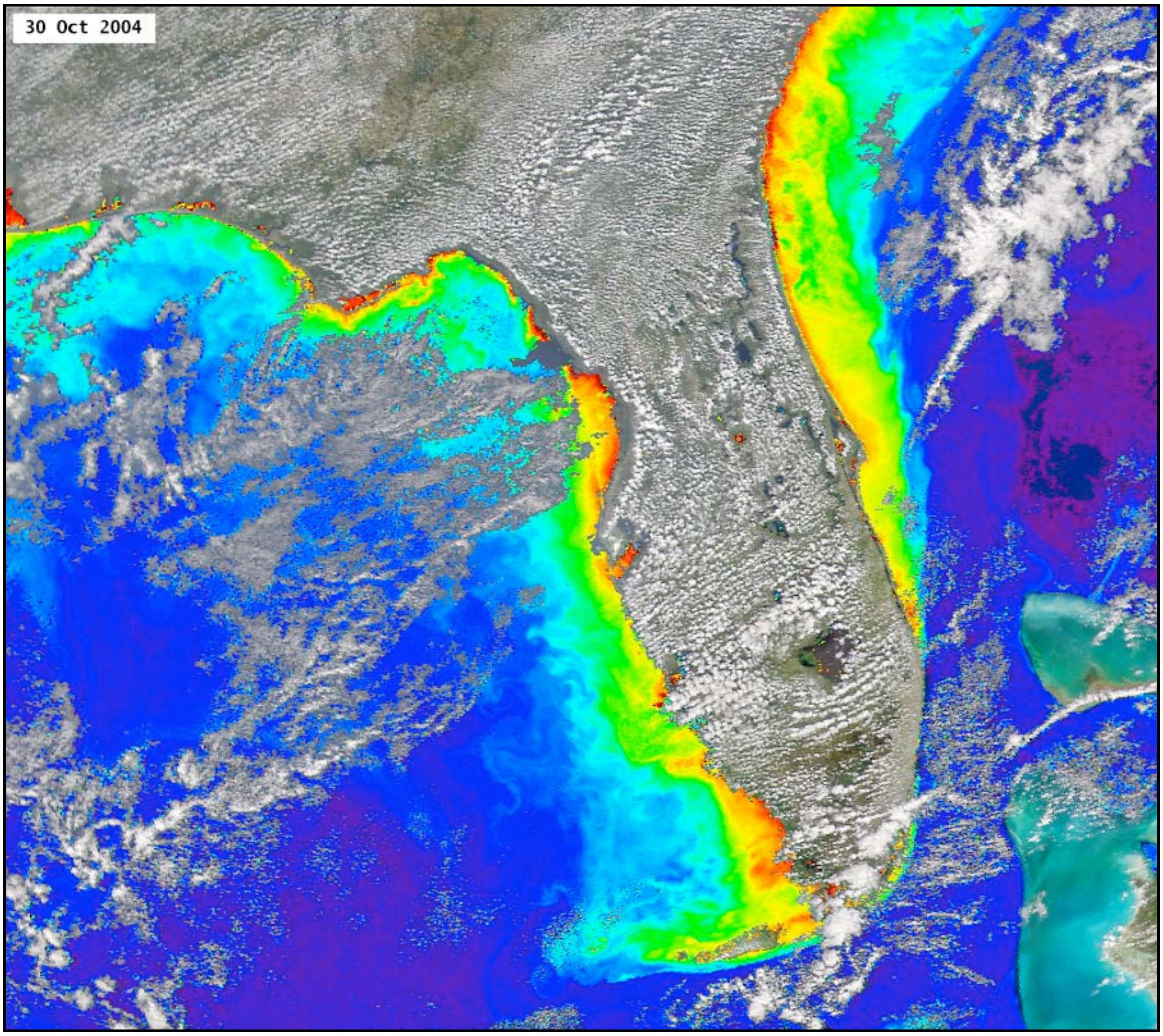
This true color MODIS/Terra image from **February 17, 2002**, shows black water in Florida Bay. When scientists from the University of South Florida Institute for Marine Remote Sensing examined data collected by divers from the dark water area in the Florida Keys, they discovered a 70 percent decrease in stony coral cover, a 40 percent reduction of coral species, and a near-elimination of sponge colonies at two reef sites after the dark water passed. By examining satellite images and field survey data, they concluded that the coral reef ecosystem had been stressed by a red tide of algal blooms and toxins contained in the dark water. Recent evidence also points to these phytoplankton blooms being fed by increased nutrient input from agricultural and urban run-off.

Web Reference

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=14783

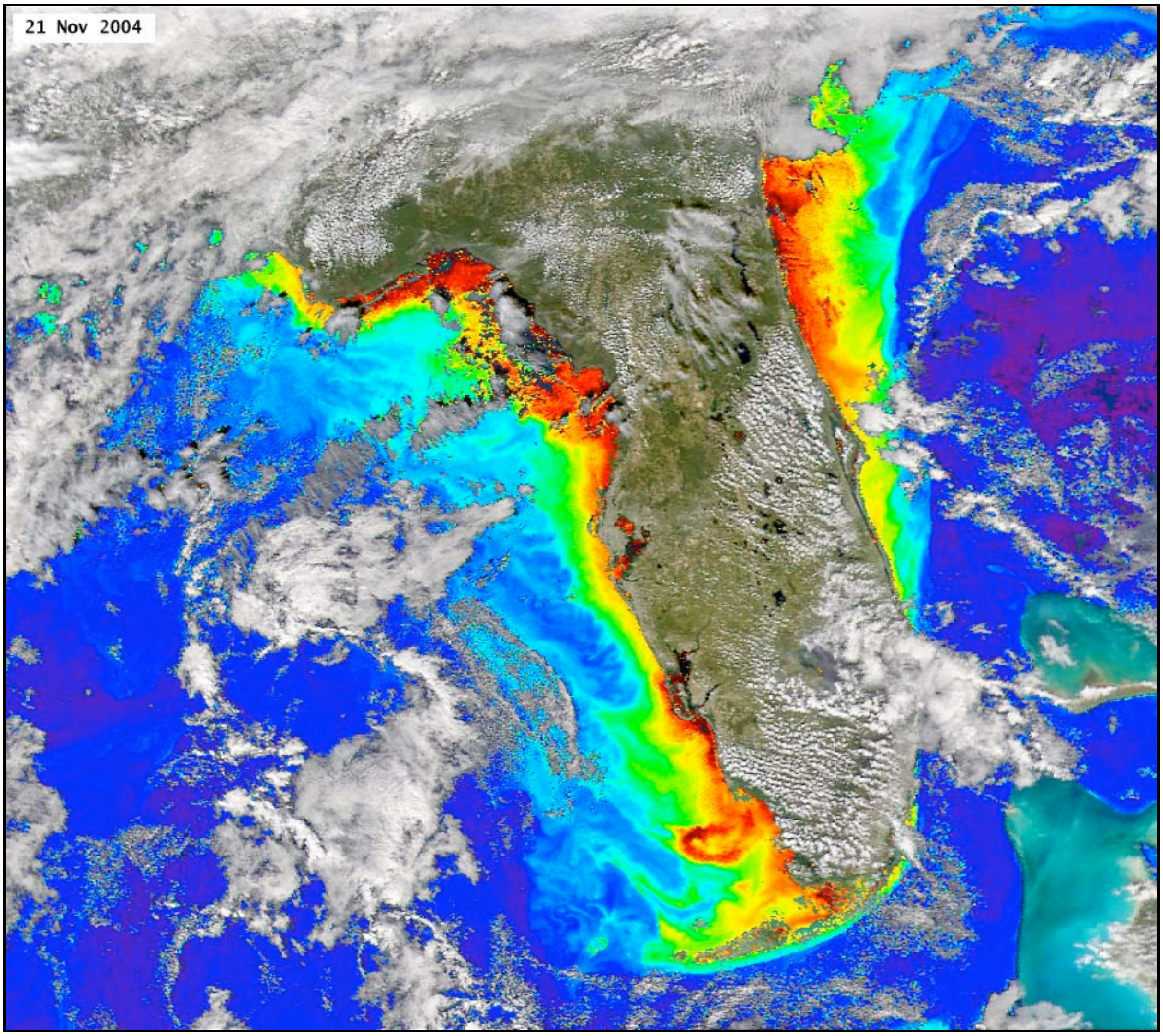


Hurricanes and heavy rains in 2004, flushed extreme levels of nutrients mixed with sediment into the sea, bringing red tide once again to Florida Bay. This true color MODIS/Terra image is from **October 22, 2004.**



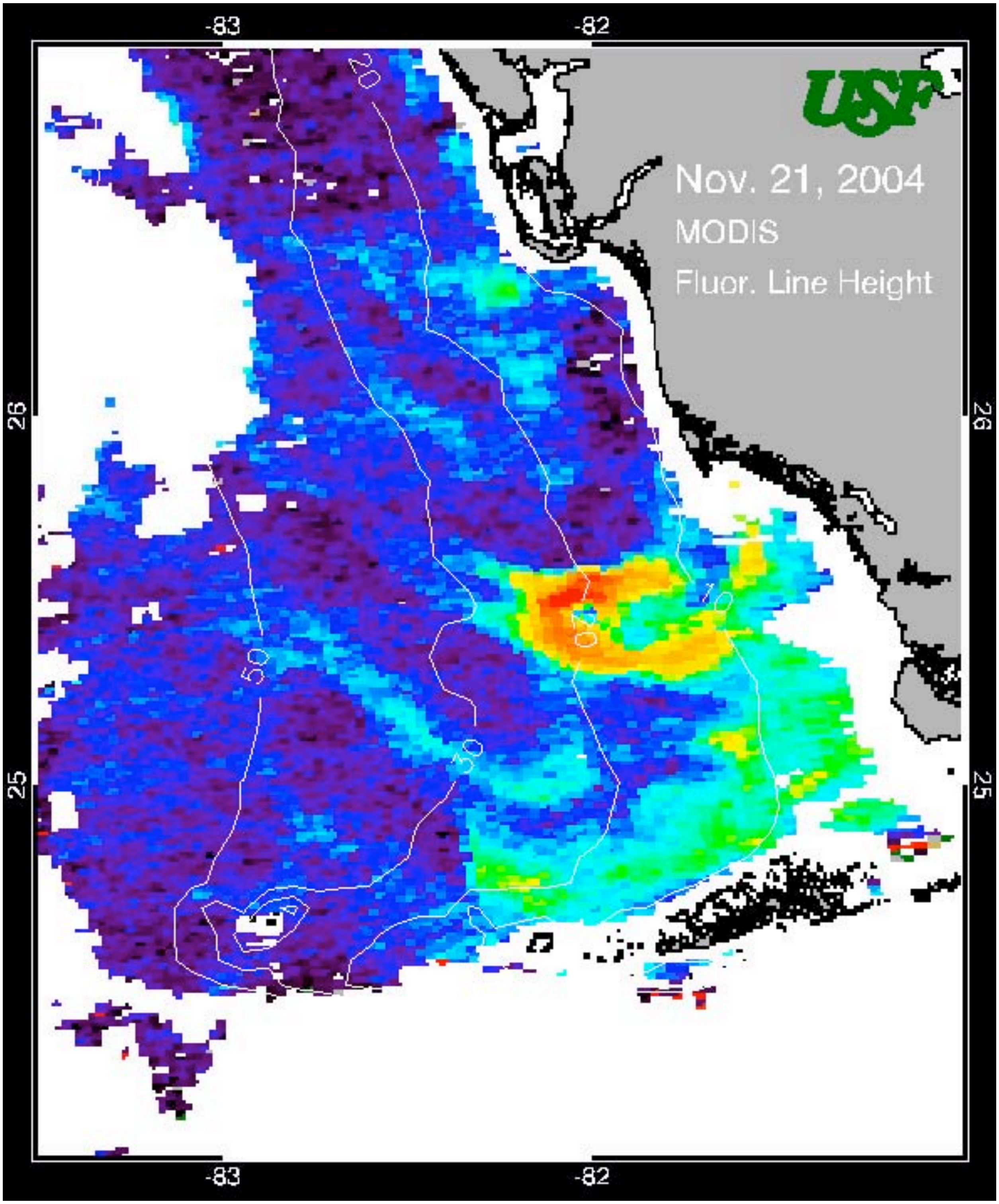
Chlorophyll Concentrations off Florida October 30, 2004

In mid-November 2004, scientists began to notice a phytoplankton bloom developing in the Gulf of Mexico, and ground tests confirmed the presence of red tide. By December 8, the bloom had spread to cover 400 square miles. The images on this and the following pages show chlorophyll concentrations in the Gulf of Mexico off southwestern Florida on October 30 and November 21, 2004, as well as chlorophyll fluorescence on November 21. Highest concentrations of chlorophyll and highest levels of fluorescence are red; lower values are green and blue. The chlorophyll image above was taken by the SeaWiFS instrument on the OrbView-2 satellite.



In this **November 21, 2004,** SeaWiFS image the red tide is clearly visible as the oval-shaped red area off the southwest coast of Florida. The high chlorophyll concentrations occur between Charlotte Harbor and the Florida Keys, which matches the location of the bloom.

This true color MODIS/Terra image from **November 21, 2004**, shows a plume of very dark water flowing into the Florida Bay from the north.

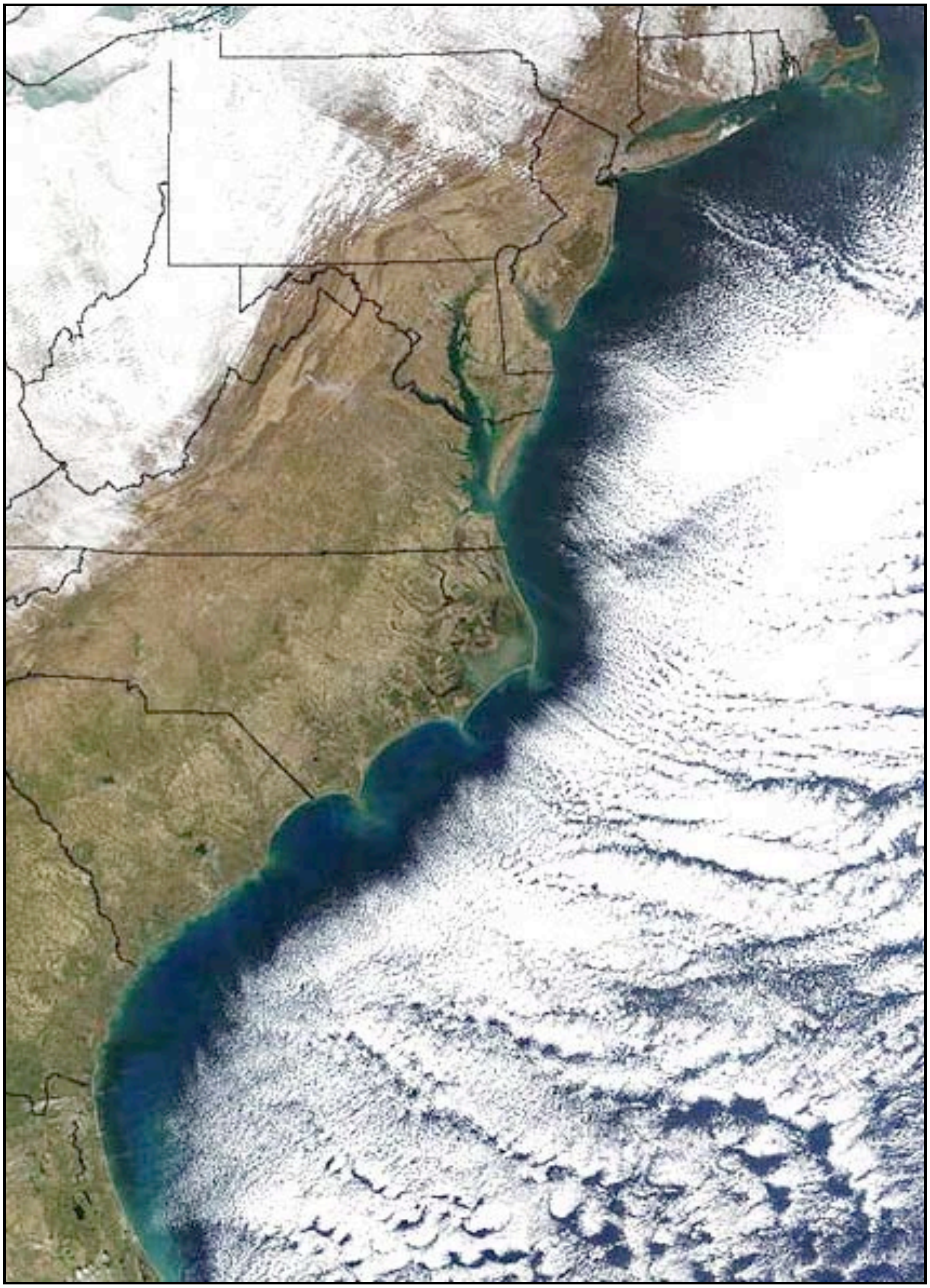


This image shows fluorescence measured by the MODIS/Terra instrument on **November 21, 2004**. Areas with high fluorescence are red and orange, while lower fluorescence values are blue. The region of highest fluorescence corresponds well with the bulge of high chlorophyll concentrations recorded by SeaWiFS on the same day, providing further evidence that the feature is in fact the ongoing red tide.

A challenge scientists face when interpreting satellite images of red tides is that what may appear to be high levels of chlorophyll could in fact be chlorophyll and *something else*. Shallow coastal areas are rich in sediment and organic matter deposited by rivers and stirred up by tides. So chlorophyll may be present, but it is mixed in with these other substances that influence the color and intensity of the light reflected by the ocean. This effect is visible in the SeaWiFS image from October 30. Though the obvious sign of the red tide had not yet developed—note the red bulge detected offshore on November 21 is missing—coastal waters were still reflective enough to suggest high chlorophyll concentrations along the coast.

One way to determine whether a satellite has detected sediment and organic matter or chlorophyll is to look at fluorescence signals. When algae absorb light, not all of it is converted to energy; some is converted to heat, and some is released as light. The re-emitted light, called fluorescence, is not the same wavelength as sunlight that is simply reflected by the surface.

Web Reference
http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16754

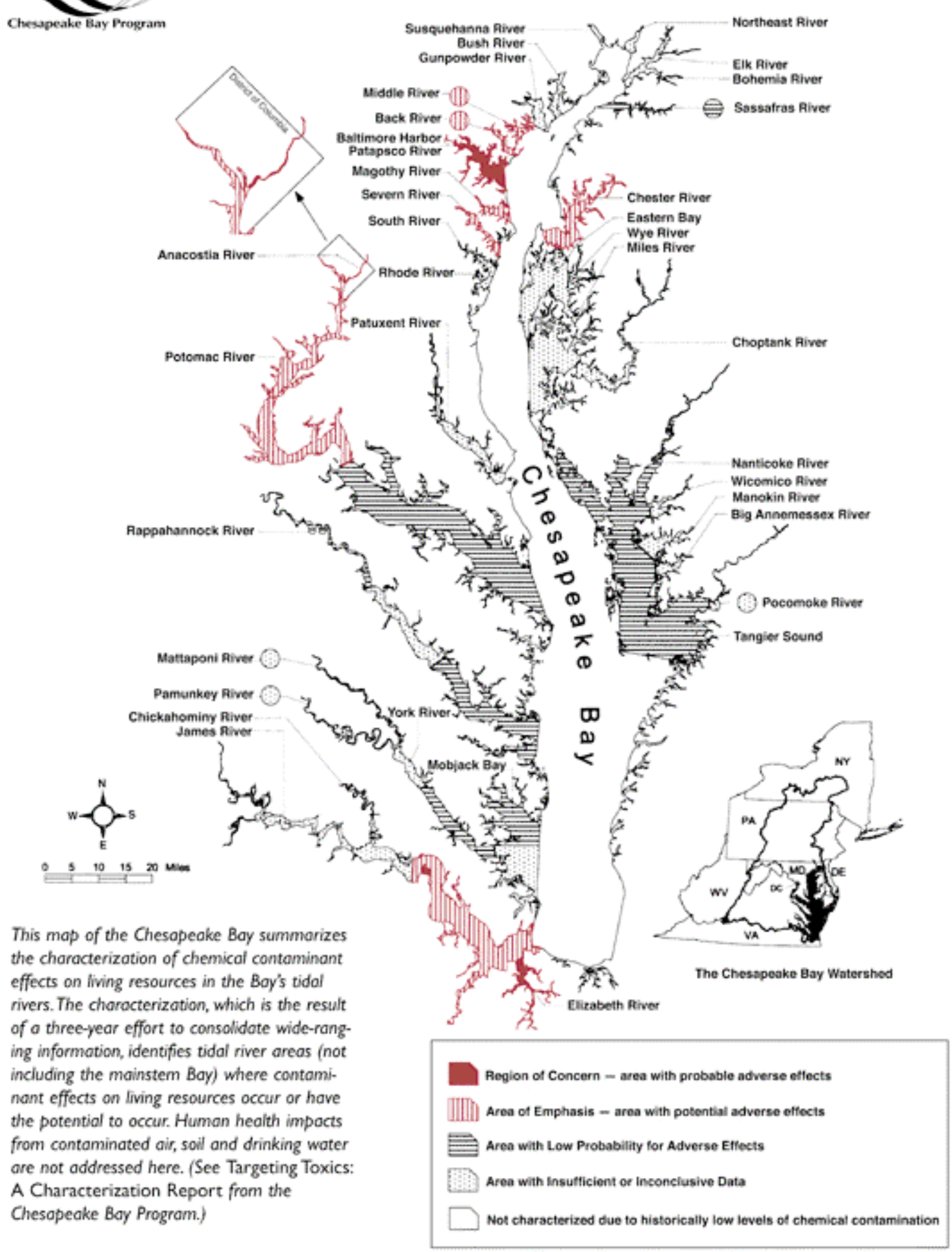


The Eastern Seaboard of the United States, since European settlement, has been the most densely populated coastal region in the U.S.. One result is that nutrient runoff from too many people is compounded by industrial chemical pollution in many of these waters. (MODIS/Terra **February 28, 2002** image courtesy of NASA)

Two areas of special concern are Chesapeake Bay (above center) and the Albemarle-Pamlico Sounds (below center). Both the Albemarle and Pamlico Sounds suffer from massive nutrient runoff from industrial farming in North Carolina, while the rivers feeding Chesapeake Bay have a long history of industrial pollution that has yet to be cleaned up. (**October 11, 2000**, MODIS/Terra image courtesy of NASA)

Chesapeake Bay is fed by some of the most famous rivers in American history, the Potomac River that flows past Washington D.C., the James River flowing from Richmond, Virginia, and the Susquehanna River which drains much of Pennsylvania. Some of the most intensive industrial development in U.S. history occurred near these waters and has left a legacy of chemical pollution. The following page on chemical pollutants in Chesapeake Bay can be enlarged in PDF format to 200% for more details on chemical pollution in the bay. (**December 31, 2003**, MODIS/Aqua image courtesy of NASA)

Status of Chemical Contaminant Effects on Living Resources in the Chesapeake Bay's Tidal Rivers



This map of the Chesapeake Bay summarizes the characterization of chemical contaminant effects on living resources in the Bay's tidal rivers. The characterization, which is the result of a three-year effort to consolidate wide-ranging information, identifies tidal river areas (not including the mainstem Bay) where contaminant effects on living resources occur or have the potential to occur. Human health impacts from contaminated air, soil and drinking water are not addressed here. (See Targeting Toxics: A Characterization Report *from the Chesapeake Bay Program.)*

Chesapeake Bay Monitoring

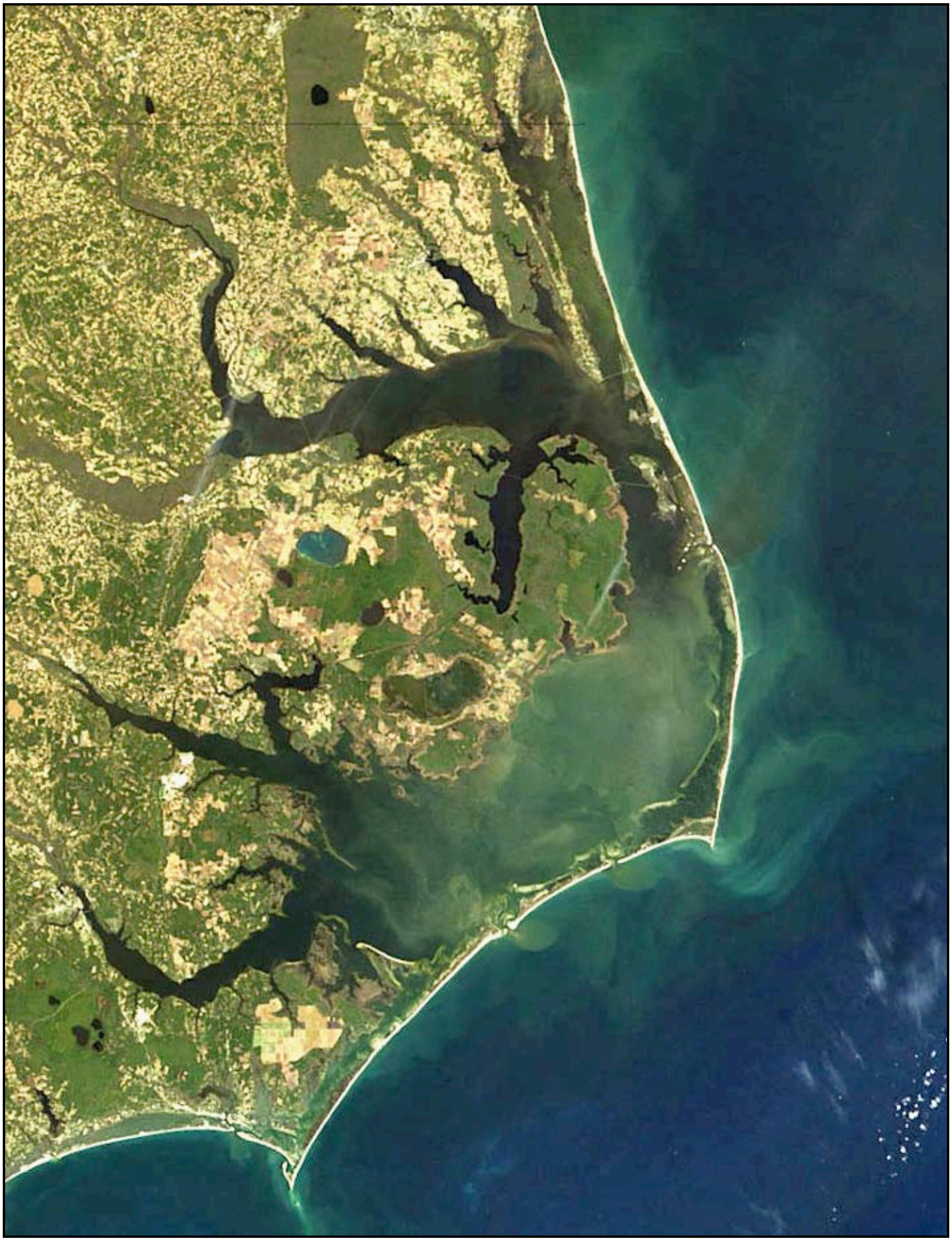
In 2005, NASA sponsored an remote sensing study of Chesapeake Bay by James Acker of NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) in Greenbelt, Maryland. The links below go to or are related to the online study.

Warm Waters in Chesapeake Bay
http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17082

Part 1. Water Pollution in Chesapeake Bay
http://earthobservatory.nasa.gov/Study/ChesapeakeBay/

Part 2: Eyes on the Bay
http://mddnr.chesapeakebay.net/NASAimagery/EyesInTheSky.cfm

Above is a MODIS/Terra image of Albemarle-Pamlico Sounds and the Barrier Islands of North Carolina taken on **October 11, 2000**. Cape Hatteras is the hooked point down and to the right of center, with Cape Lookout at the bottom left. The dark brown and green swirls are phytoplankton blooms.



This MODIS/Terra image of Albemarle-Pamlico Sounds was taken on **November 7, 2004**. What is apparent is that there has been little improvement in water quality during the four years between these images.

For more on U.S. coastal water pollution and algal blooms go to:

Harmful Algal Blooms
http://oceanservice.noaa.gov/topics/coasts/hab/welcome.html

http://earthobservatory.nasa.gov/Study/Redtide/

http://www.bigelow.org/hab/impact.html

http://aquaticpath.umd.edu/toxalg/

For further information on related topics go to:

Global Ecology and Remote Sensing
http://fire.biol.wwu.edu/trent/alles/GlobalEcologyindex.html

Alles Biology Home Page
http://fire.biol.wwu.edu/trent/alles/index.html