Improved Hypoxia Modeling for Nutrient Control Decisions in the Gulf of Mexico (Hypo-G)

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Problem Definition

What is Hypoxia?
Low oxygen is primary problem for estuaries and coastal waters. Hypoxic waters have dissolved oxygen concentration of less than 2-3ppm.

What causes Hypoxia?
Variety of factors, including excess nutrients, primarily nitrogen and phosphorus, and water body stratification due to saline or temperature gradients cause this condition

What is the source?
Fertilizers from agriculture, golf courses, and suburban lawns, erosion of soil; nutrients discharges from sewage treatment plants; and deposition of atmospheric nitrogen

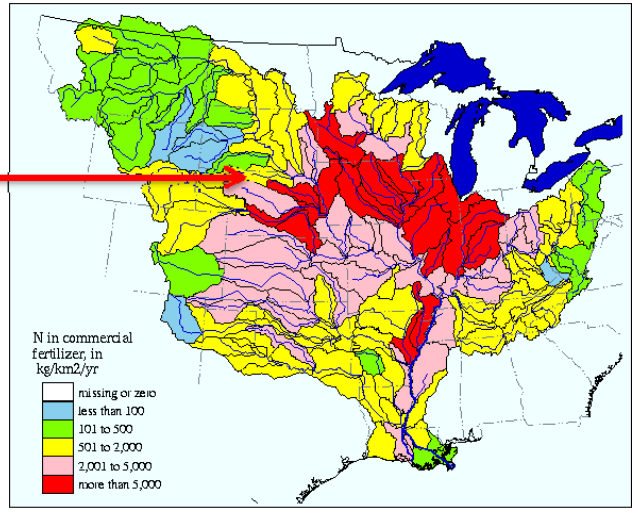
What is the impact?
Fish kills, which deplete valuable fisheries and disrupt ecosystems

Gulf of Mexico – Hypoxic Zone and Nutrient Sources

Network of rivers feeding into Gulf of Mexico

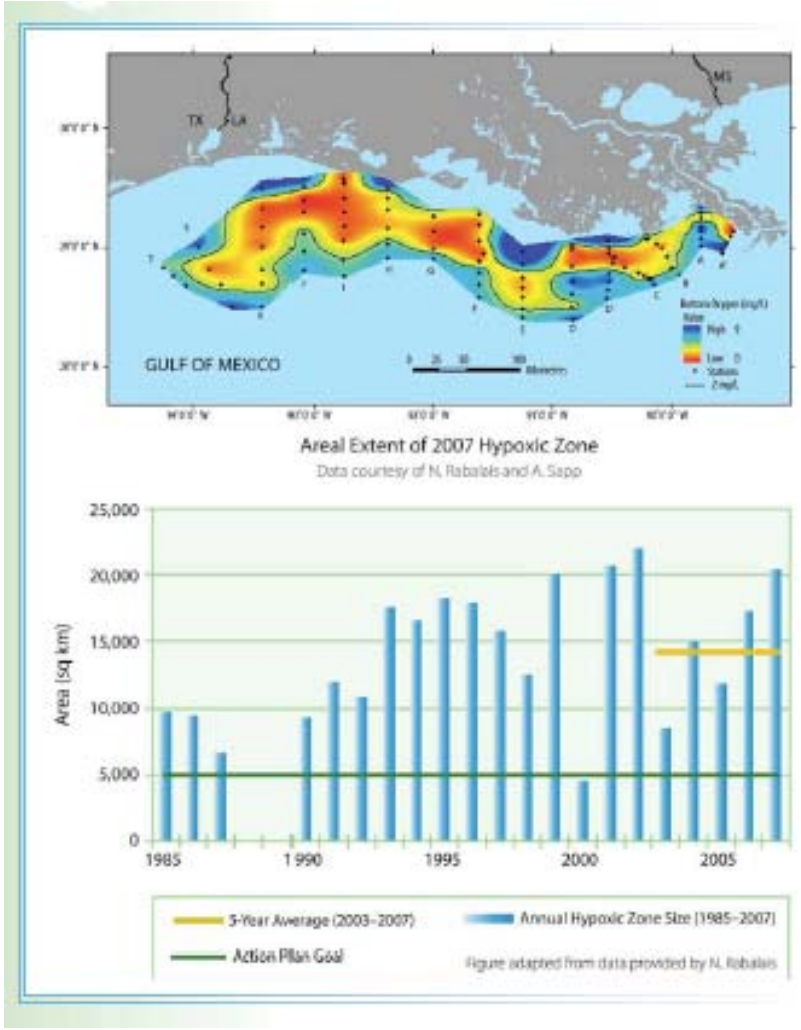
Nutrient Fluxes:

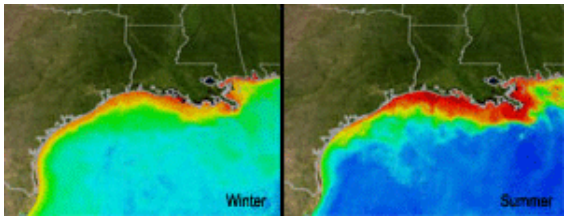
- **Wet and dry deposition over river basins; fertilizer usage; runoff into rivers; transport to Gulf**
- **Direct wet and dry deposition to Gulf**



Hypoxic Zone

- Kills all oxygen-dependent sea creatures within its zone
- The size of the hypoxic zone varies each year. In 2007, the measured hypoxic area was 20,000 square km
- The goal is to reduce the hypoxic area to less than 5000 square km





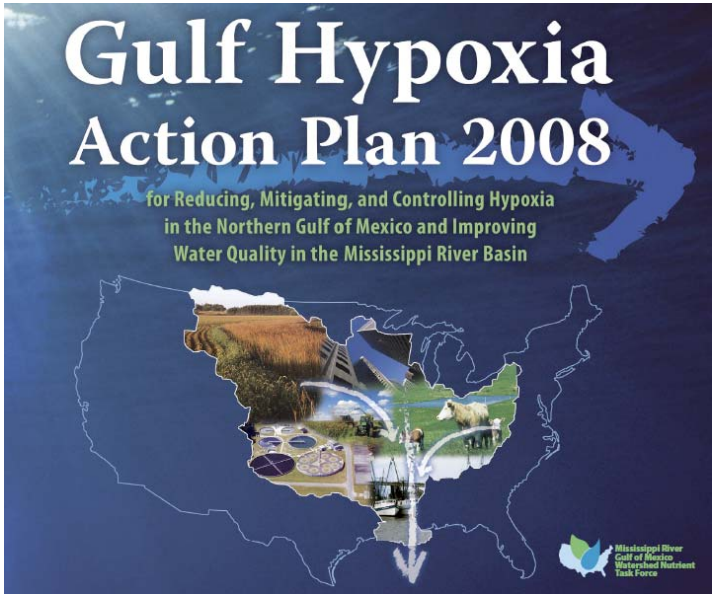
Reference: Gulf Hypoxia Action Plan 2008

EPA Gulf Hypoxia Monitoring and Modeling Goals

Develop consensus modeling framework targeting Gulf hypoxia

- **Reduce uncertainty and enhance credibility of model estimates of nutrient load reductions required to meet Action Plan goals**

- **Provide defensible options to guide restoration and decision-making**

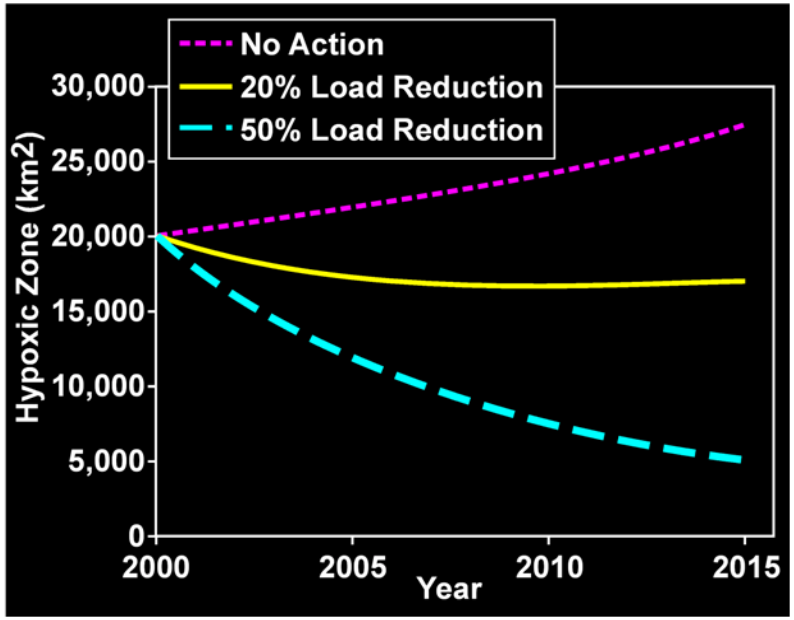


Objectives of EPA Program

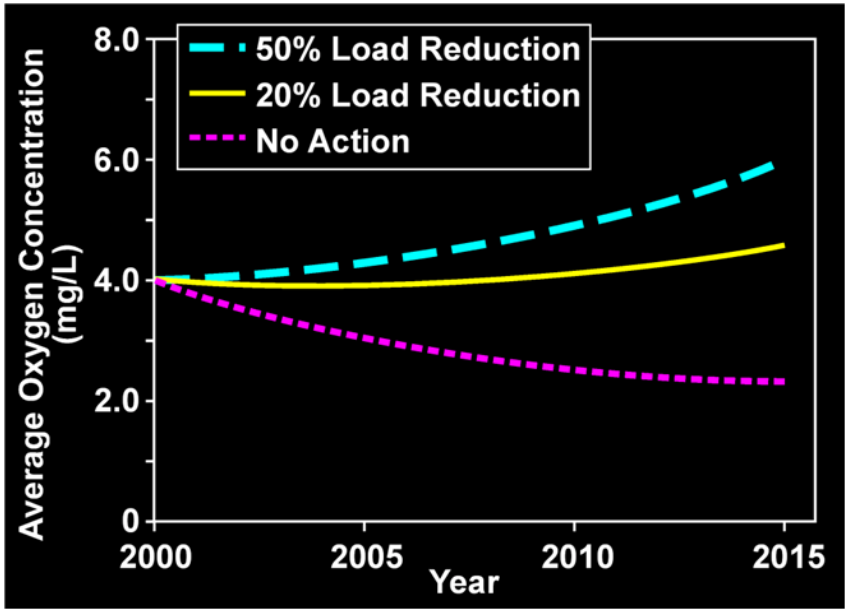
- Establish an integrated multimedia, mathematical modeling framework that incorporates monitoring, condition assessment, diagnosis, and research
- Support the framework with a statistically-based, seasonal field monitoring design and targeted research
- Integrate physical, chemical, biological components with external and internal nutrient loads
- Establish stressor-response relationships for nutrient loads & concentrations, Chlorophyll-a (Chl-a), and Dissolvable Organics (DO)
- Examine these relationships using forecasting to provide bases for biologically-based, nutrient criteria for ambient nutrients, Chl-a, and DO
- Develop predictive capability to forecast the benefits of risk reduction options and the time to realize the benefits
- Provide managers with defensible methods, tools, and options to aid and guide the environmental decision-making process

MARB Nutrient Loading Targets

Establish a nutrient loading target for the Mississippi and Atchafalaya River Basin (MARB), protective of the Gulf for restoring habitat and sustaining marine life populations

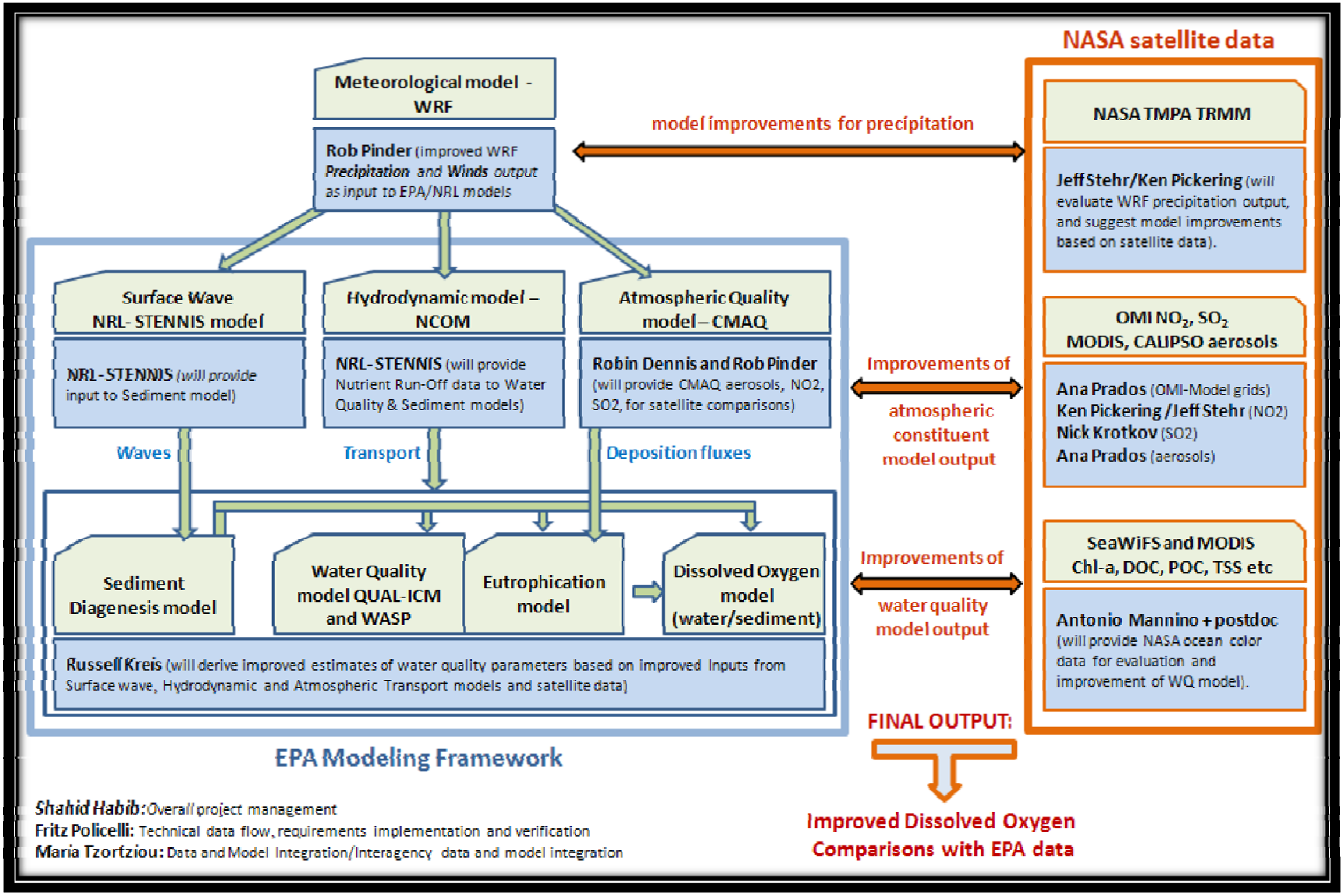


Conceptual Relationship Between Maximum Hypoxic Zone Size and Load Reduction



Conceptual Relationship Between Average Oxygen Concentration and Load Reduction

EPA Gulf of Mexico Modeling Framework and Possible NASA Interfaces – Hypo-G



EPA Modeling Framework and NASA Satellite Data Decision Making

NASA Sensors in Operation
- TRMM precipitation
- MODIS Aerosol (AOT)
- CALIPSO Aerosol
- MODIS Ocean Color
- SeaWIFS Ocean Color
- OMI NO_2 and SO_2

NASA Sensors - Future
- GPM Precipitation
- NPP/VIIRS Ocean Color and AOT
- Glory Aerosol Classification

Data and Products

Decision Making
- *Scenario Analysis*
- *Best Practices analysis*
- *Model Validation*

Decision Support Systems
- Atmospheric Model-WRF
- Chemical Model-CMAQ
- Hydrodynamic Model-NCOM
- Sediment Model
- Water Quality Model-QUAL-ICM and WASP
- Surface Wave Model

Benefits

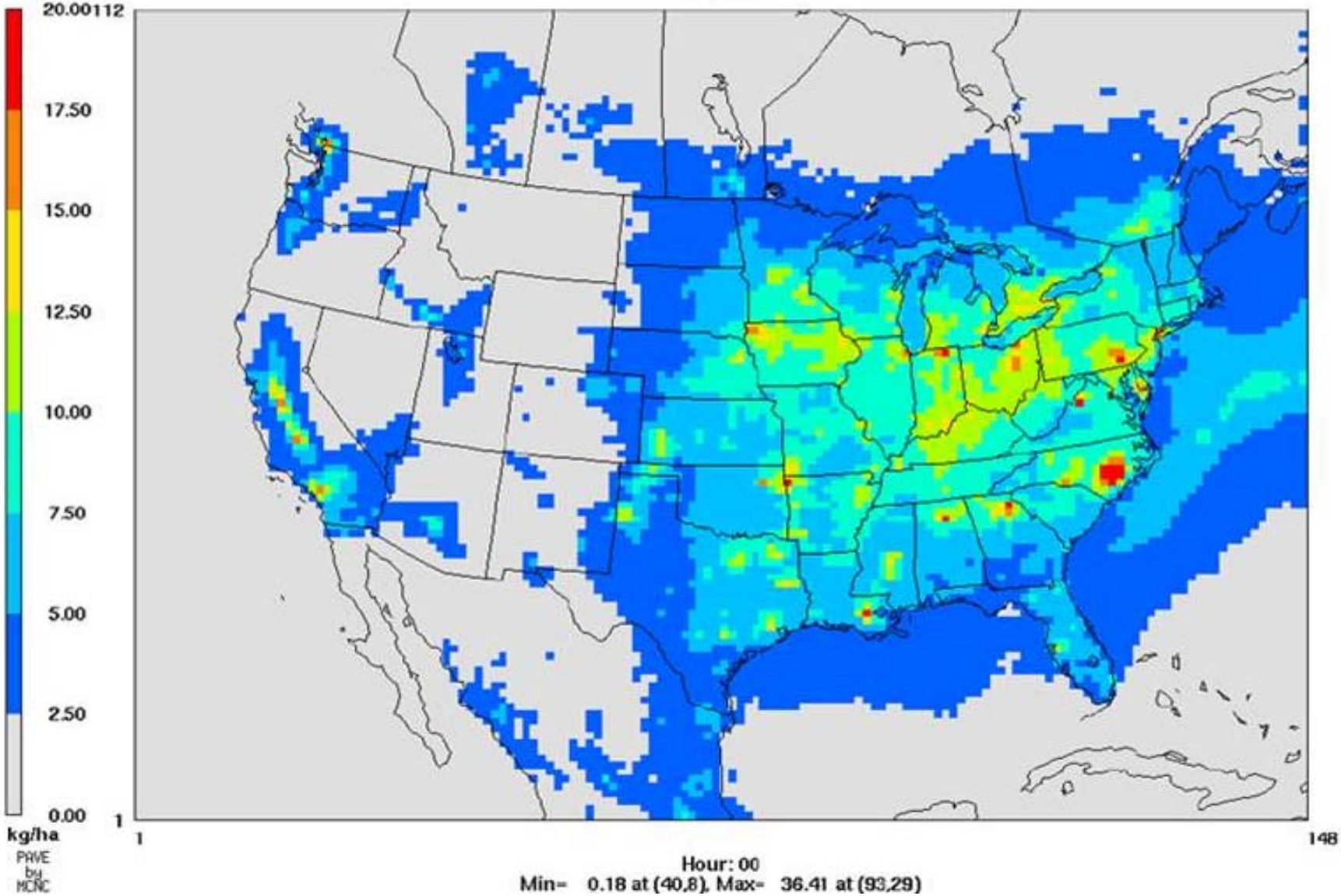
- *Improved Dissolved Oxygen Maps*
- *Improved decisions on Nutrient management*
- *Improved water quality, health fish and ecosystem*

Satellite Data

Satellite products	Satellite Sensor	Product Resolution	Frequency	Expected Benefits
NO_2	OMI	0.25^ox0.25^o	Once per day	Apply satellite data of atmospheric SO2, NO2 concentrations and aerosol levels for improving estimates of both wet and dry deposition
SO_2	OMI	0.25^ox0.25^o	Once per day	
Aerosols Vertical Profile	CALIPSO	Vertical: 30-60 m	Approx. once per day	
Aerosols Optical Thickness	MODIS	10 x 10 km	Twice per day	
Precipitation	NOAA Multisensor Precipitation Estimator	4 km x 4km	Hourly	Contribute to an improved estimation of the wet deposition of nutrients within the model framework, especially for nitrogen compounds.
Precipitation	TRMM/TMI and PR multisensor calibrated product –TMPA	0.25^O x 0.25^O	Every 3 hour near real time	
Ocean Color (Chl-a, POC, DOC, TSS, CDOM)	MODIS – Aqua	~ 1 km Nadir	Every 1-2 days	Validate the calculation of photosynthetically active biomass within the modeling framework as well as particulate and dissolved organic carbon.
Ocean Color (Chl-a, POC, DOC, TSS, CDOM)	SeaWIFS	~ 1.1 km Nadir	Every 1-2 days	

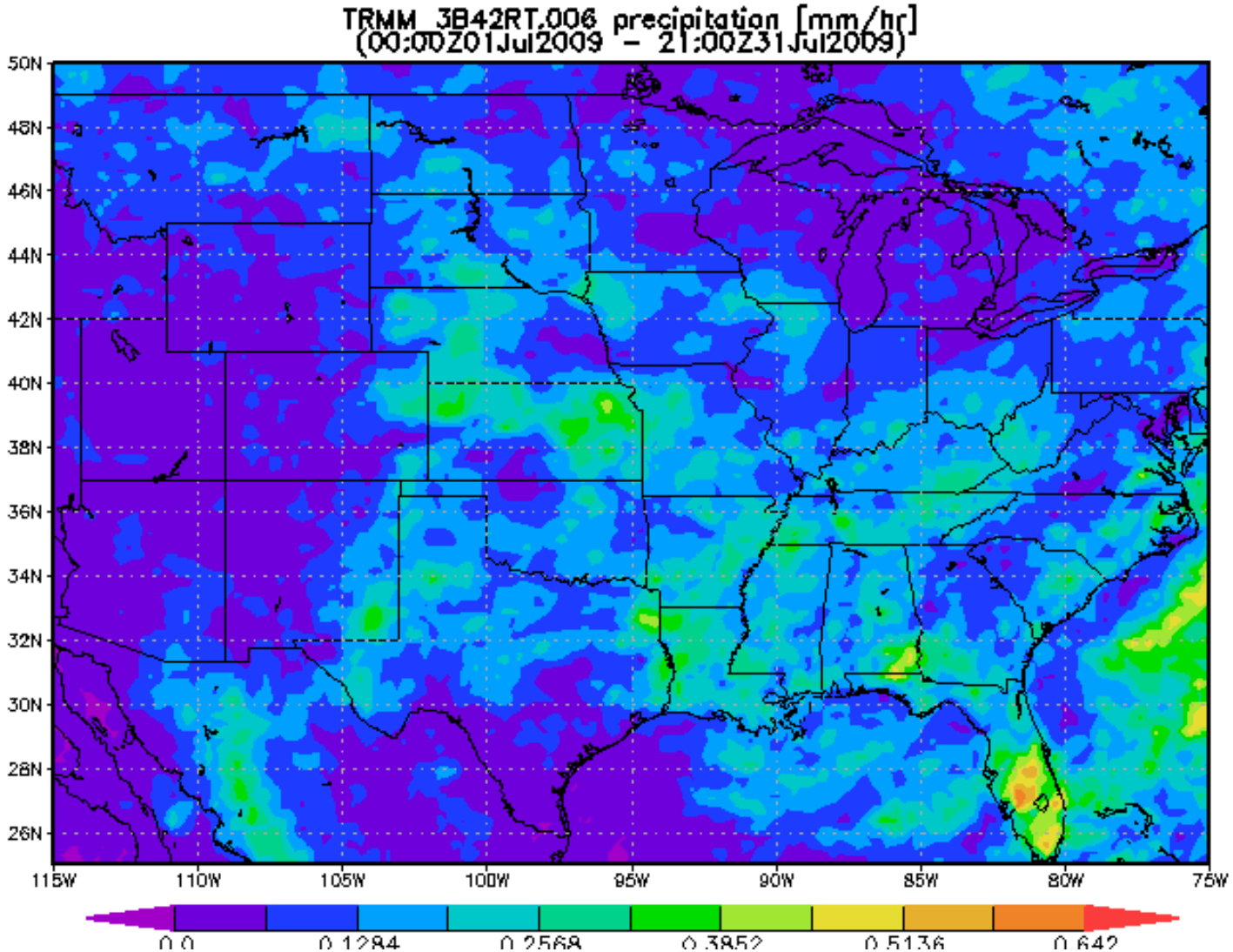
Nitrogen Deposition

Total Nitrogen Deposition (Kg-N/HA)– CMAQ Model Output for Year 2001



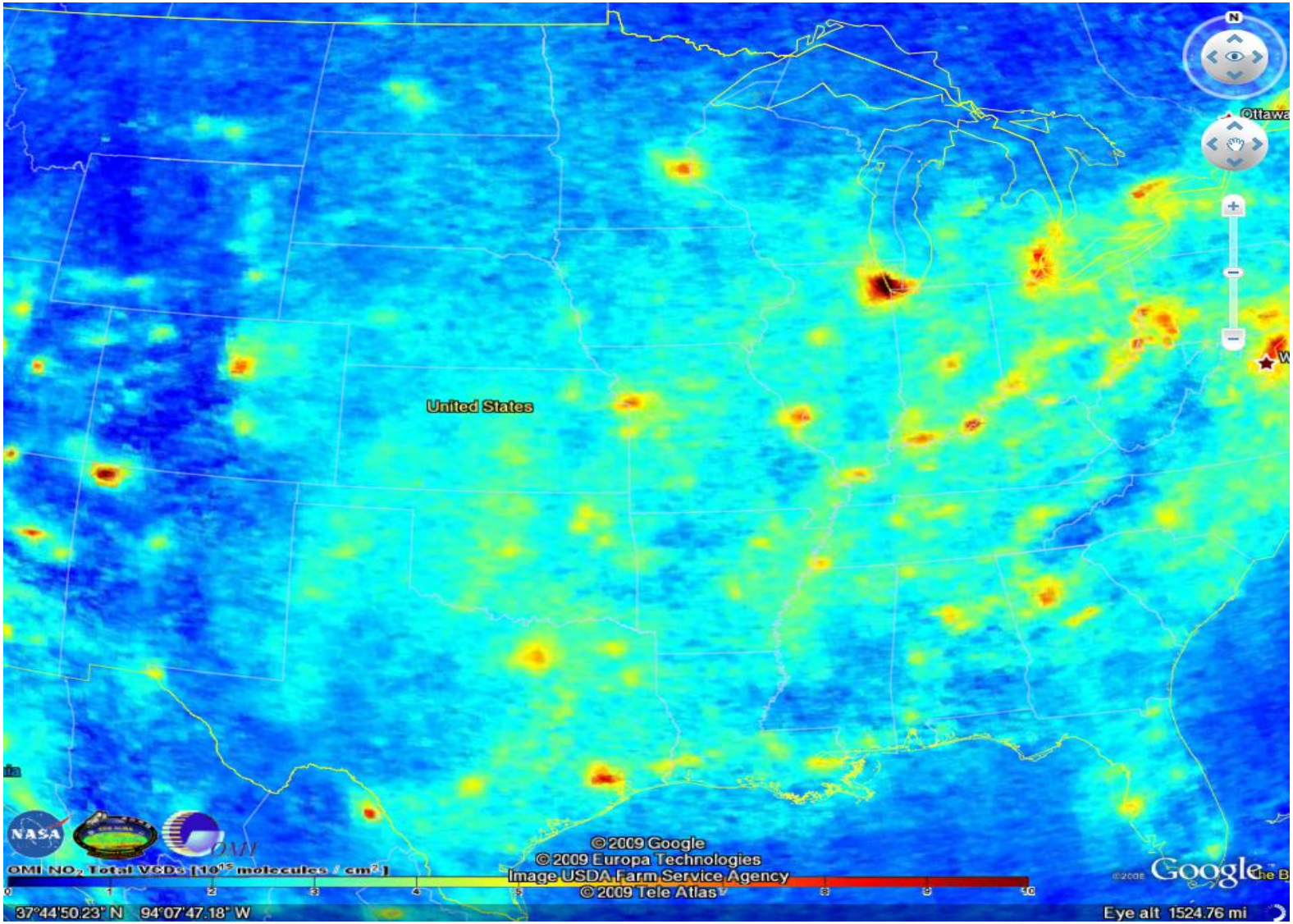
Example: Atmospheric Satellite Products

TMPA (TRMM Precipitation) Monthly Mean (JULY 2009) (0.25° x 0.25°)



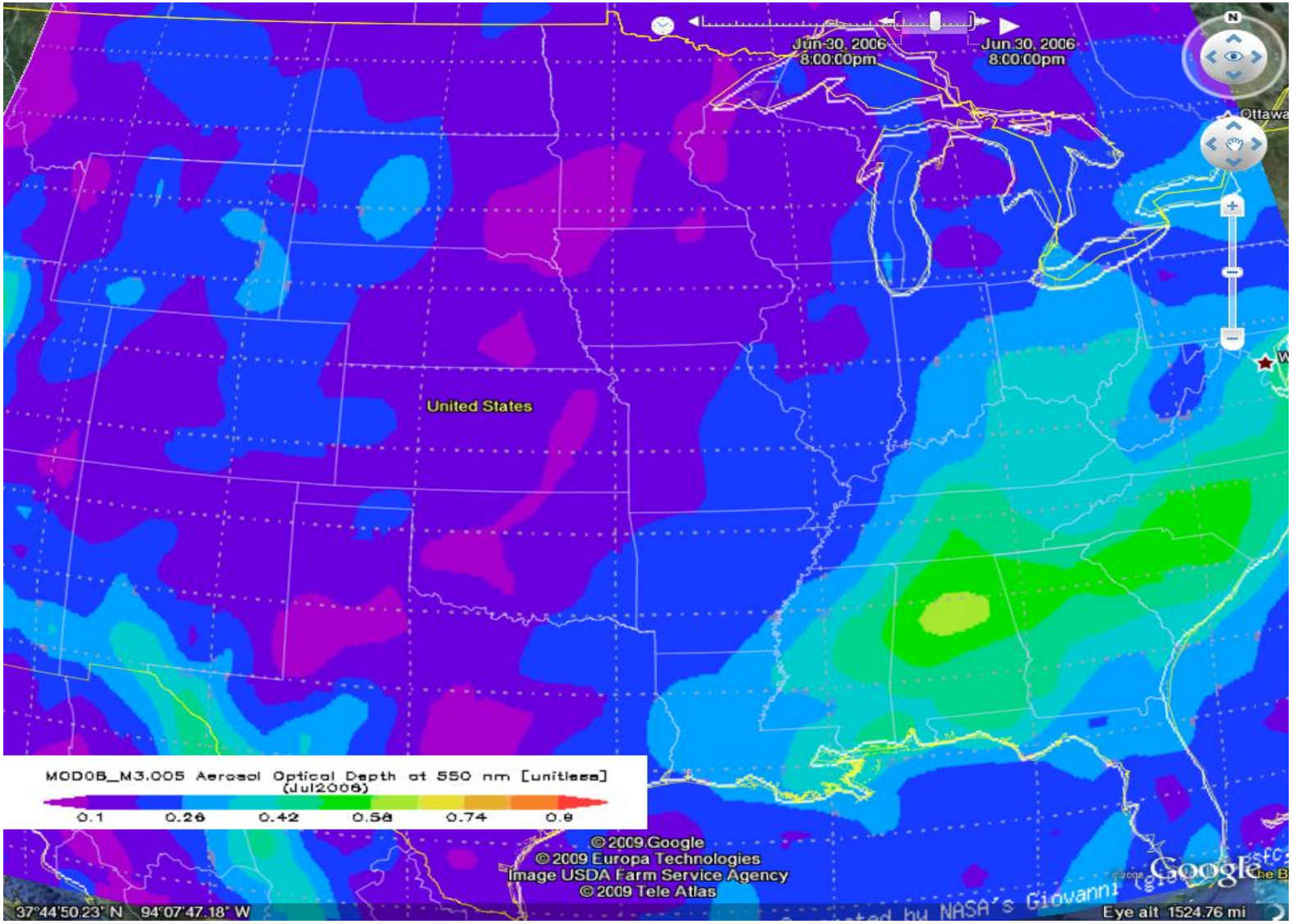
Example: Atmospheric Satellite Products

OMI NO_2 Monthly Mean (JULY 2006) (0.05°x0.05°gridded data)



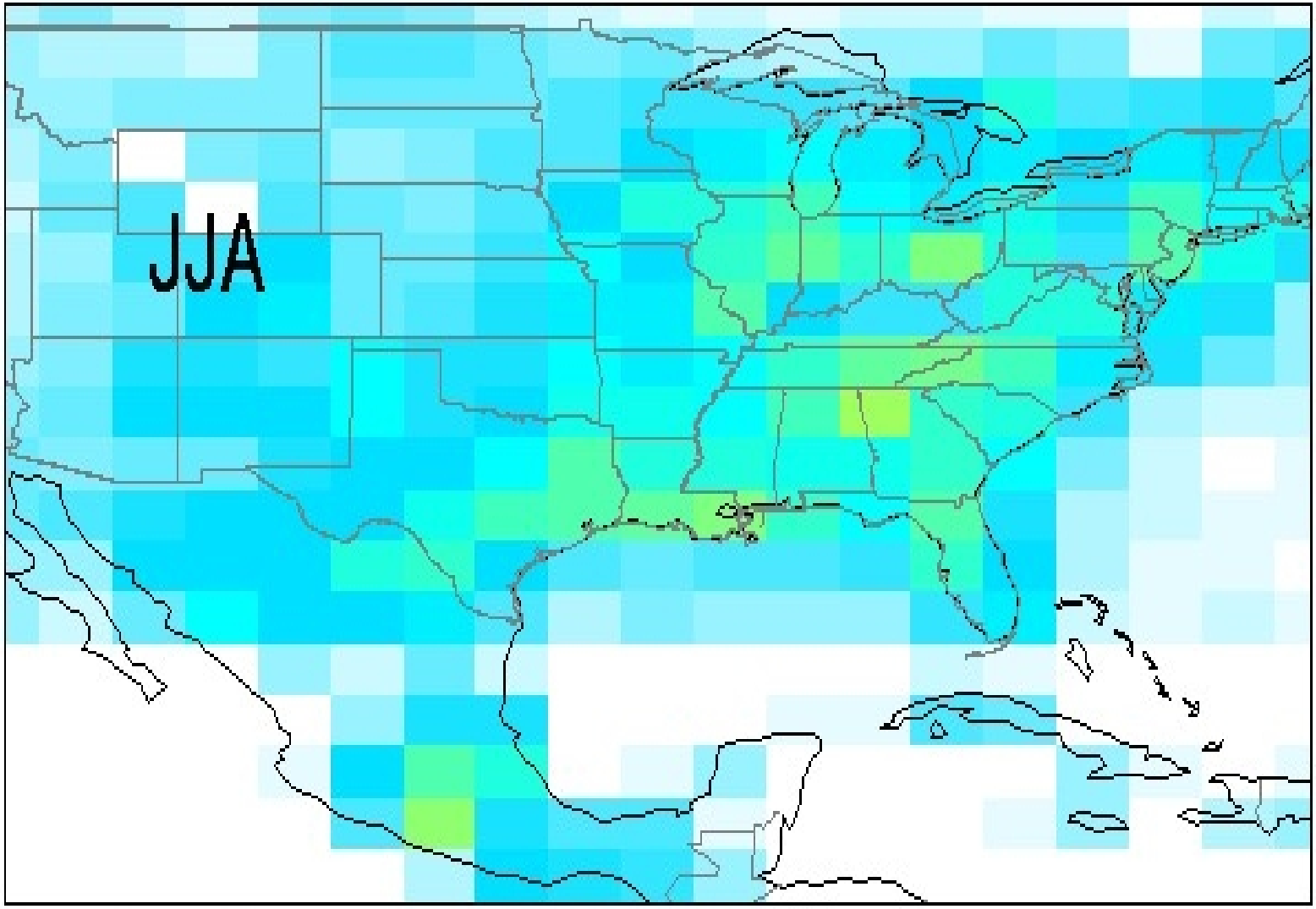
Example: Atmospheric Satellite Products

Terra MODIS AOD Monthly Mean (JULY 2006)



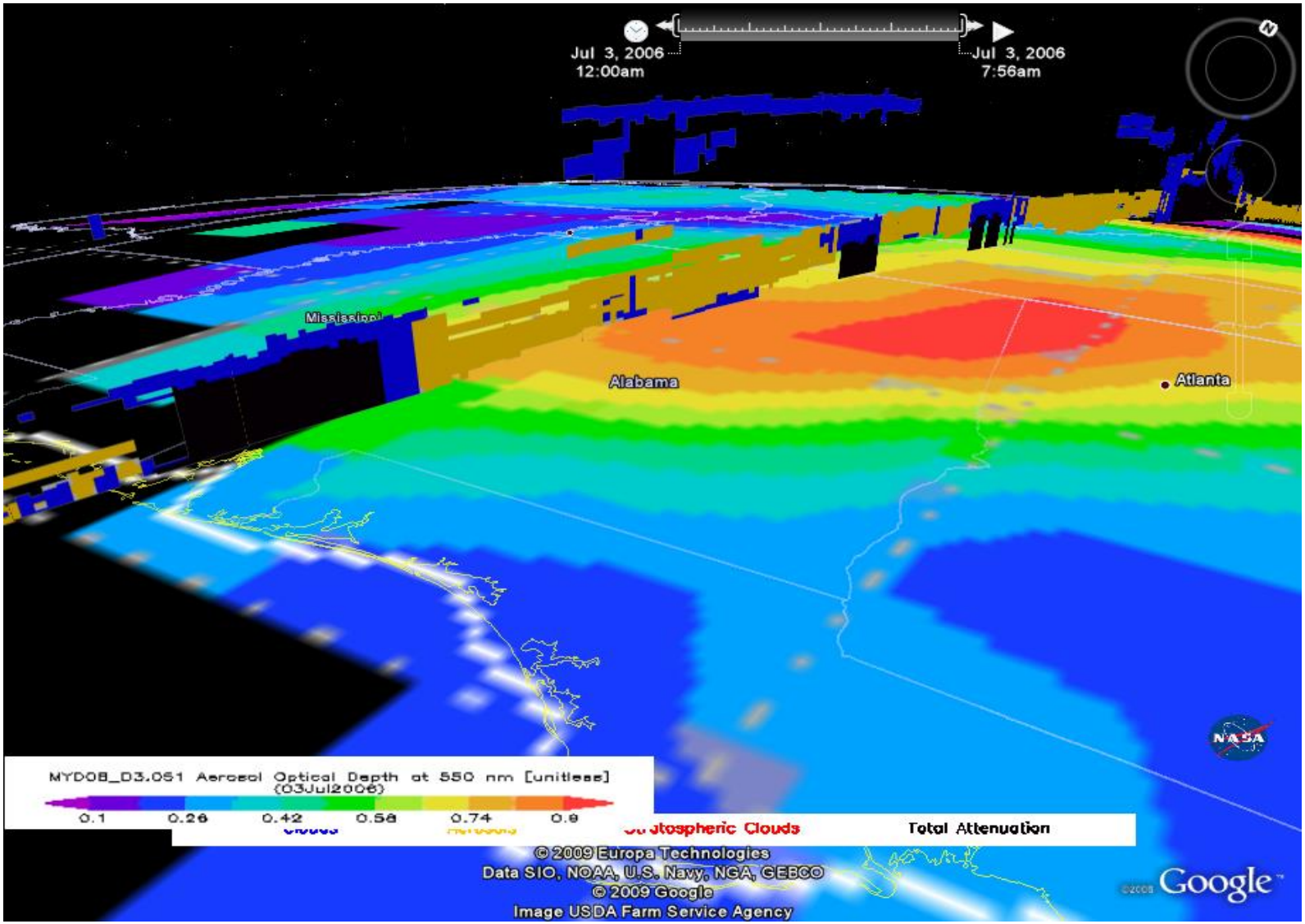
Example: Atmospheric Satellite Products

OMI Boundary Layer SO_2 Seasonal Mean (June-July-August 2006)



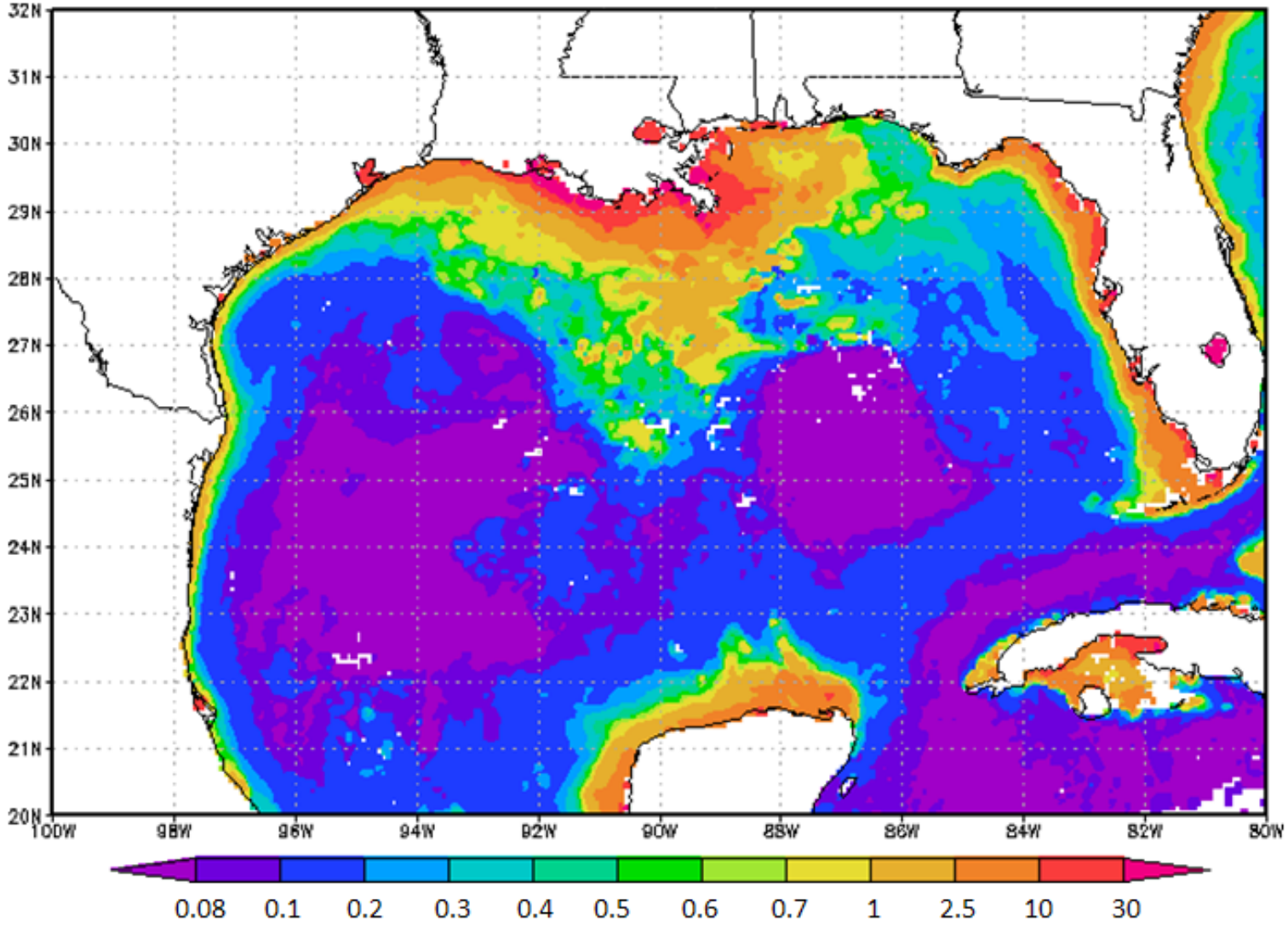
Example: Atmospheric Satellite Products

Calipso Aerosol Vertical Extent Displayed over MODIS AOD



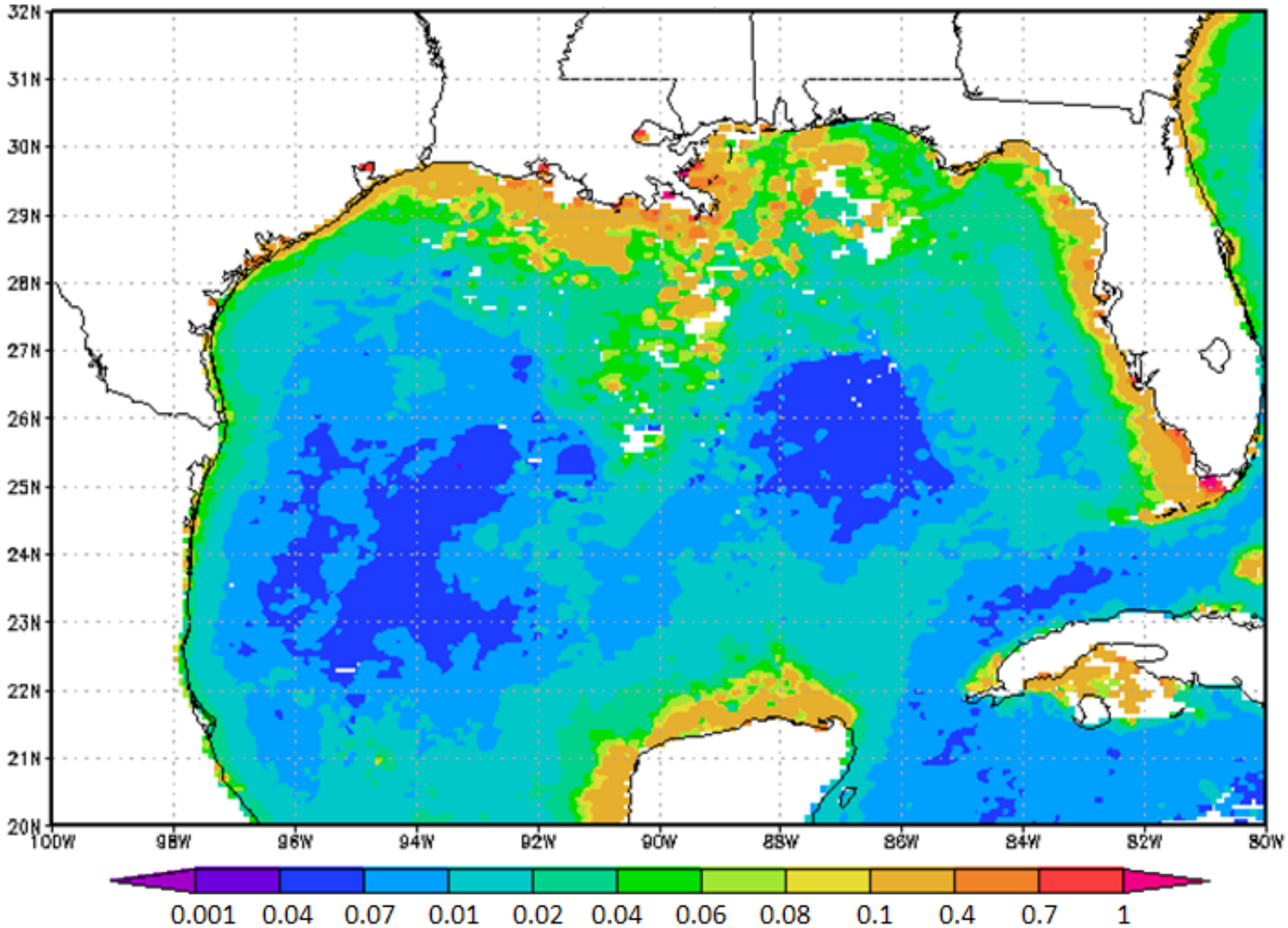
Example: Ocean Color Satellite Products

Chlorophyll a concentration [mg m^{-3}] (July 2009) (MODIS Aqua)



Example: Ocean Color Satellite Products

Dissolved and Detrital Organic Matter Absorption at 443 nm [m^{-1}] (July 2009)
(GSM MODIS Aqua)



Project Tasks

- Obtain model output from EPA (WRF Precip., CMAQ NO2, SO2, aerosol, water quality variables)
- Obtain and preprocess satellite data sets
- Evaluate WRF Precip. using TMPA and NOAA Multisensor data
- Evaluate CMAQ NO2 and SO2 using OMI; aerosol using MODIS AOD and Calipso profiles
- Evaluate water quality model using products generated from MODIS and SeaWiFS (e.g., Chl-a, DOC, POC, TSS)
- Summarize model evaluations and suggested model improvements in an Interim Report to EPA
- Reevaluate modified model as above
- Final Report
- Training of EPA personnel in use of satellite data