A Study of Long-Term Trends inEnvironmental Parameters along the Louisiana/Mississippi Outer Continental Shelf Using Ocean Color Remote Sensing Data

Eurico D'Sa
Department of Oceanography/Coastal Studies Institute
Louisiana State University

Acknowledgments: Dong-Shan Ko, Steve Di Marco, M. Korobkin, P. Naik, & S. Singh

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Bureau of Ocean Energy Management, Regulation and Enforcement

Outline

NOAA -CSCOR

- Introduction
- Methods and data:
  - Study area
  - Field bio-optical data
  - Satellite ocean color data
    - Chlorophyll (phytoplankton biomass)
    - CDOM (colored dissolved organic matter)
    - SPM (suspended particulate matter – organic/inorganic)
  - 3-D NCOM modeling (NASA funding)
- Trends in satellite derived environmental parameters: Chlorophyll, CDOM and SPM
  - Optical properties in the NGOM
  - SPM response: during frontal passage and Hurricane Ike
  - CDOM response: seasonal and during Hurricane Rita
  - Long-term trends: phytoplankton chlorophyll

Objectives

1) assess the performance of ocean color algorithms (e.g., CDOM)
2) examine satellite derived environmental parameters (e.g., chlorophyll, CDOM, SPM) in response to hazard events
3) analyze long-term time series ocean color data to examine trends in OCS region

Background

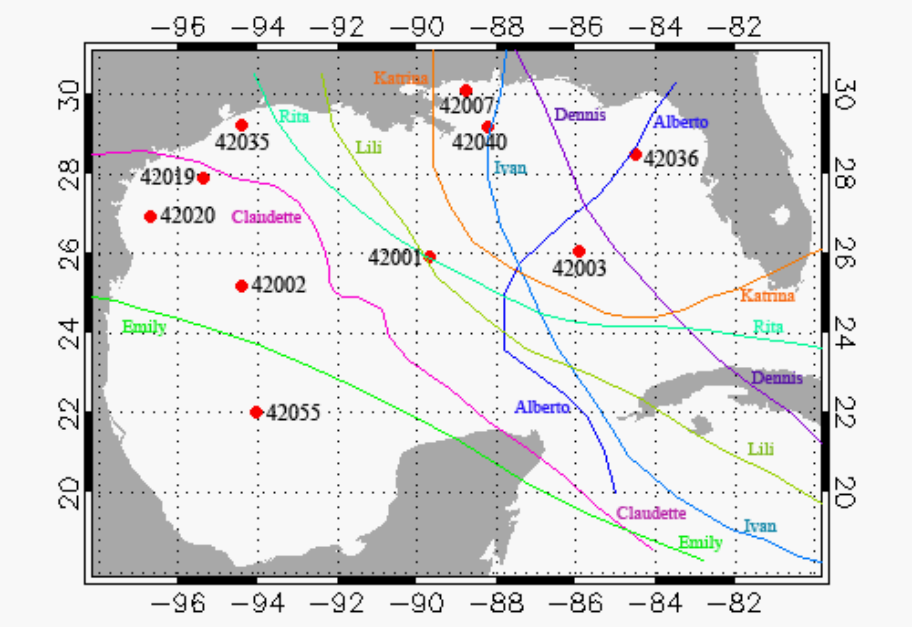
- Mississippi River ranks 2nd globally in terms of drainage basin and river discharge
- Discharge from the Mississippi-Atchafalaya River strongly influences physical, biological and geological properties along the Louisiana coast

NOAA -CSCOR

Background

Economic importance

- oil & gas
- ~1/3 of US fisheries yield



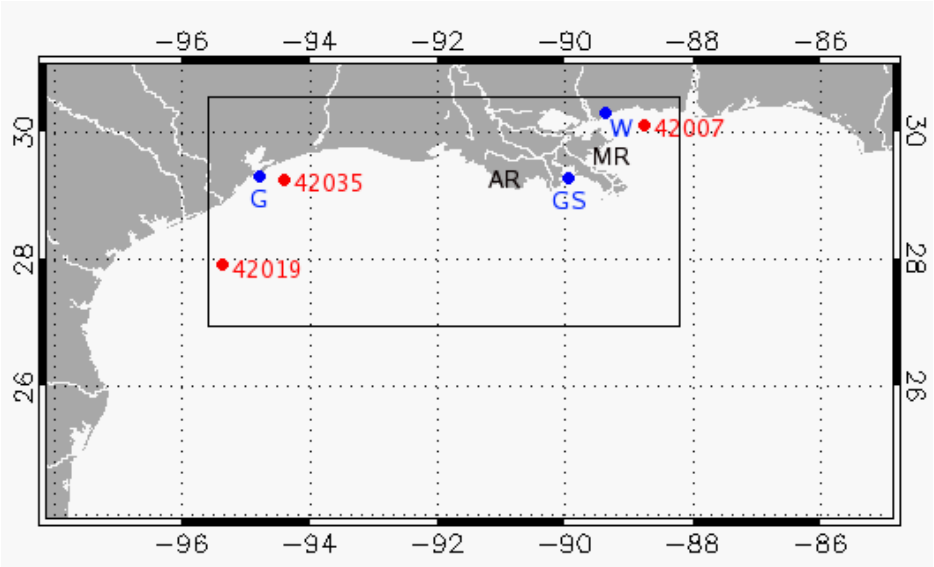
Major issues

- Eutrophication and hypoxia
- Effects of energetic events
  - storms
  - hurricanes
- Pollutants

Methods and Data

- Study area
  - Field bio-optical measurements

- Remote sensing
  - Ocean color data from
    - SeaWiFS
    - MODIS
  - Ocean color products
    - Phytoplankton Chl
    - CDOM absorption
    - SPM concentrations



- Analysis
  - Ocean color data: short- and long-term trends in combination with physical variables
  - Wavelet analysis

Ocean color algorithms

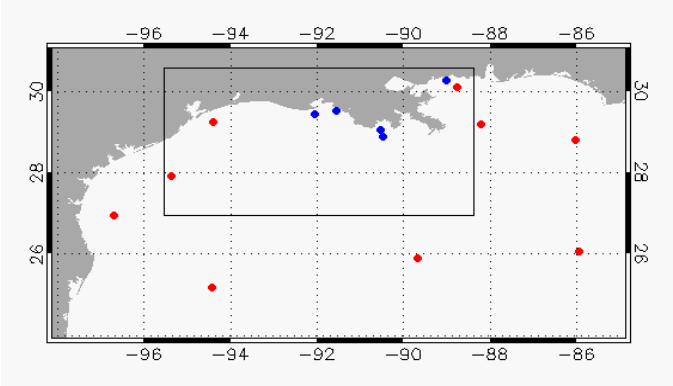
Phytoplankton chlorophyll
SPM concentrations
CDOM absorption

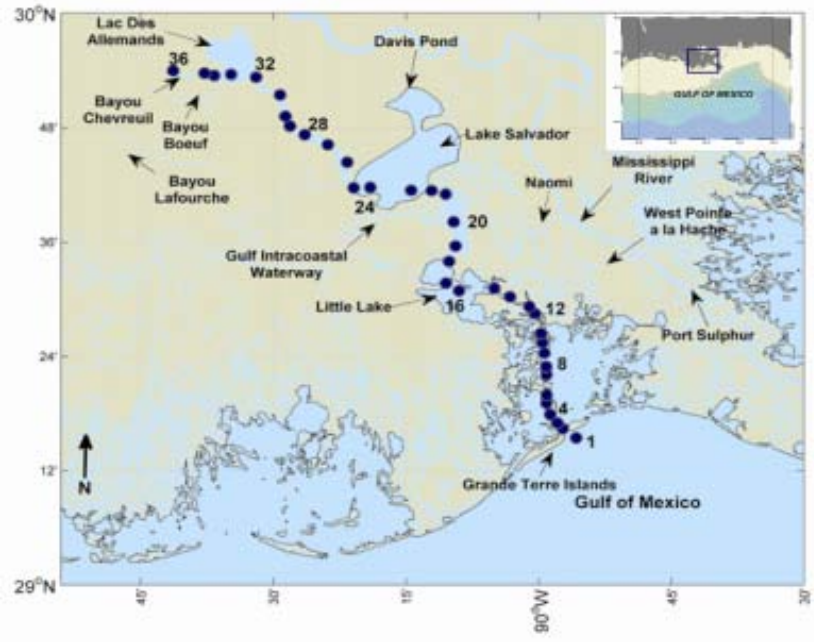
Phytoplankton Chlorophyll – standard NASA OC3/OC4 algorithm

Regional Suspended Particulate Matter (SPM) algorithm

Regional CDOM absorption algorithm

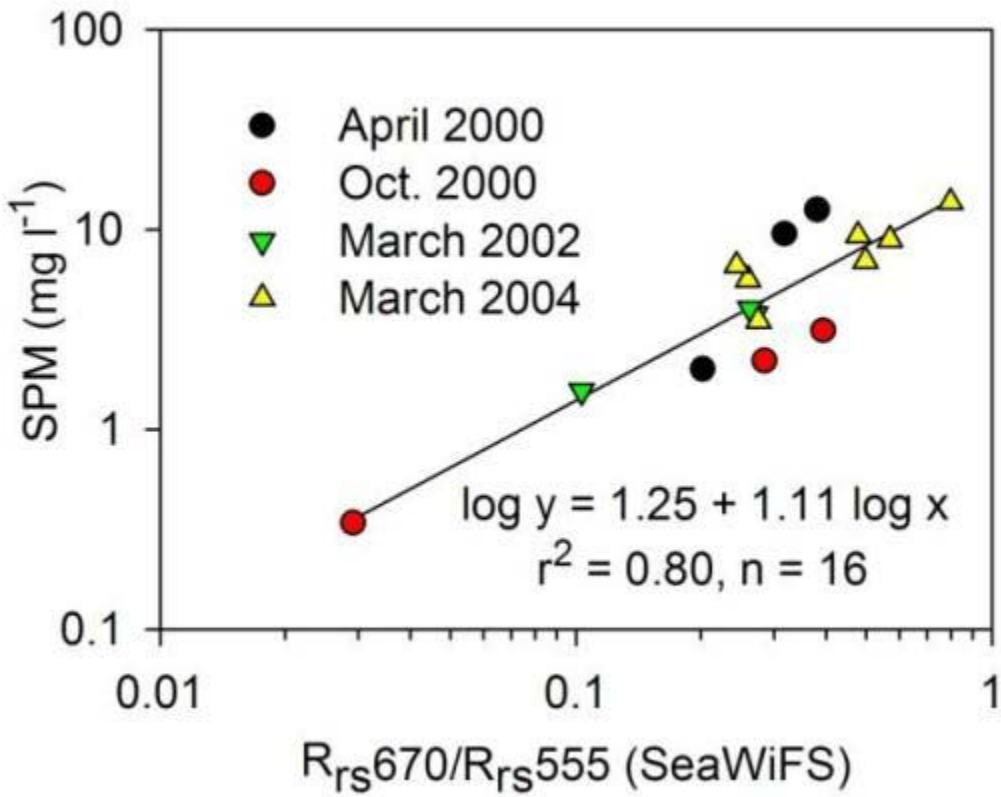
Field Studies





SeaWIFS SPM Algorithm

$$SPM = 17.783\ (R_{rs}670/R_{rs}555)^{1.11}$$



D'Sa et al. 2007

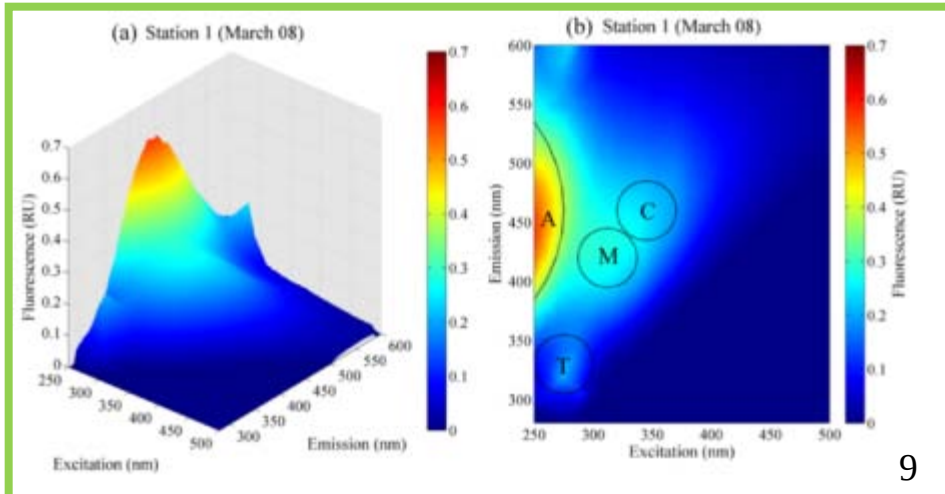
CDOM Absorption and Fluorescence Measurements

CDOM Absorption – optically active fraction of dissolved organic matter (m^{-1})

CDOM Fluorescence – when CDOM is irradiated with light, it releases the absorbed energy in form of emission intensity or fluorescence

Has been used to identify sources of dissolved organic matter in Barataria Basin (Singh et al. 2010)

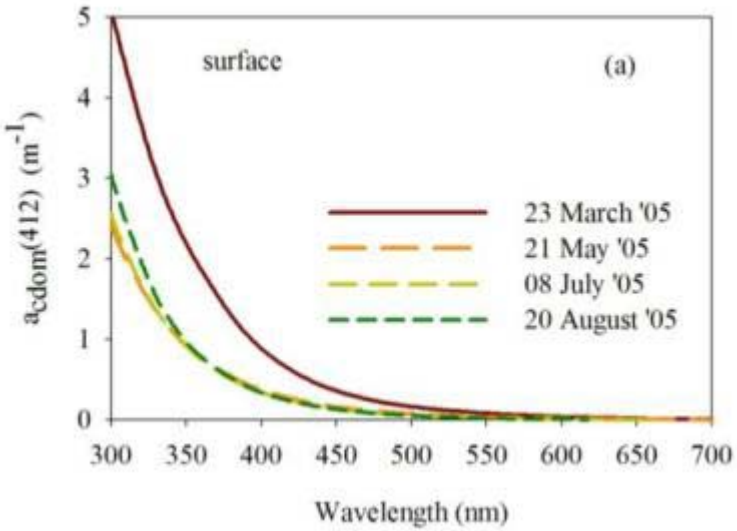
•EEMs
Excitation Emission Fluorescence
Excitation range (250 – 500 nm)
Emission range (280 – 600 nm)

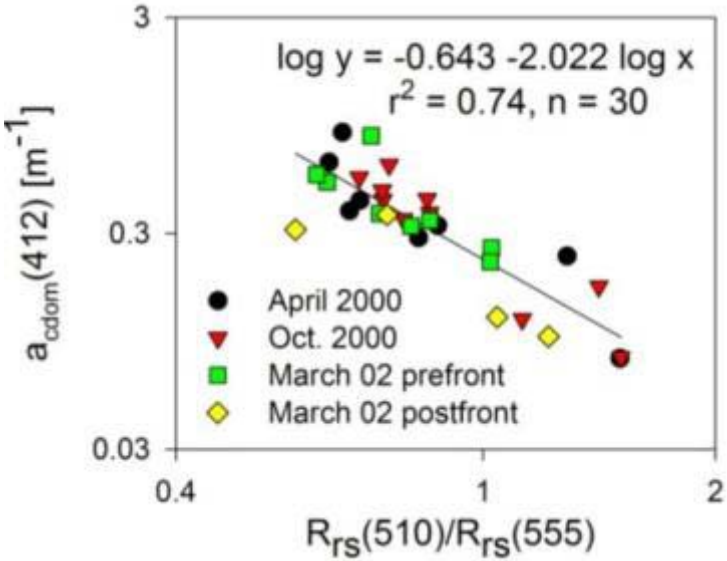


CDOM field data and algorithm

CDOM absorption spectra

D'Sa et al. 1999; 2001
Miller et al. 2003 – Cont. Shelf Res.





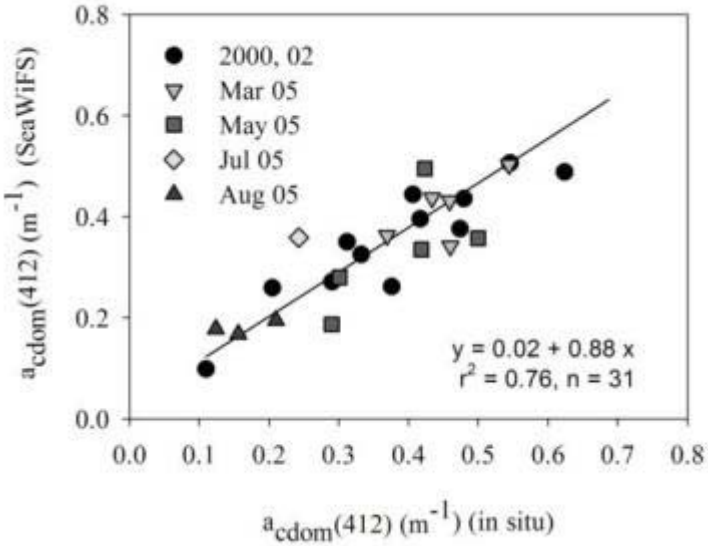
Regional CDOM algorithm

- $a_{cdom}(412)$

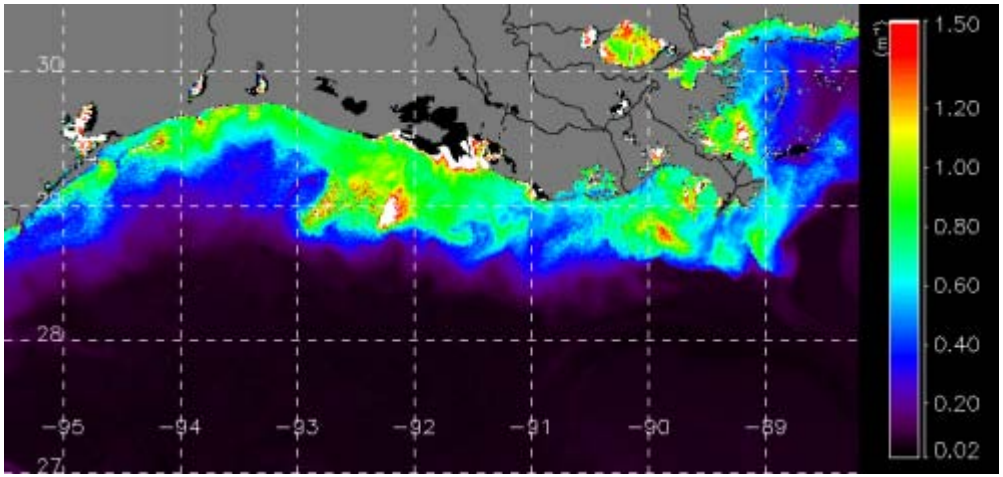
- $= 0.227(R_{rs}(510) / R_{rs}(555)^{-2.022}$

D'Sa and Miller 2002
D'Sa et al. 2006

SeaWiFS Salinity from CDOM

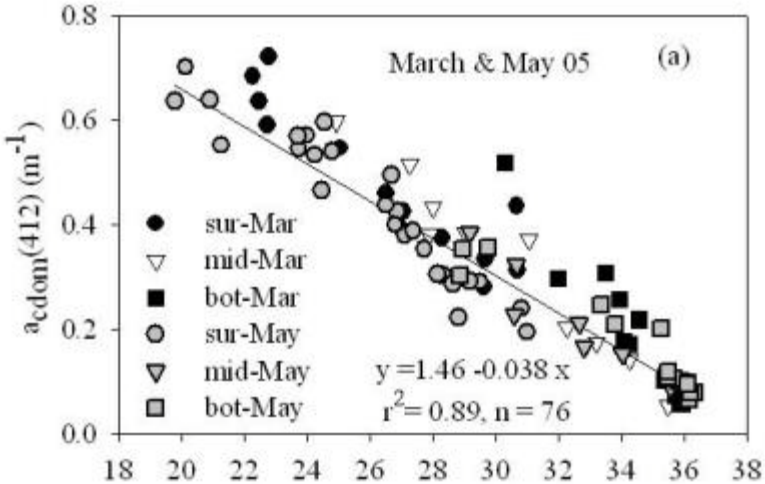


CDOM – 3/23/2005



CDOM algorithm performance

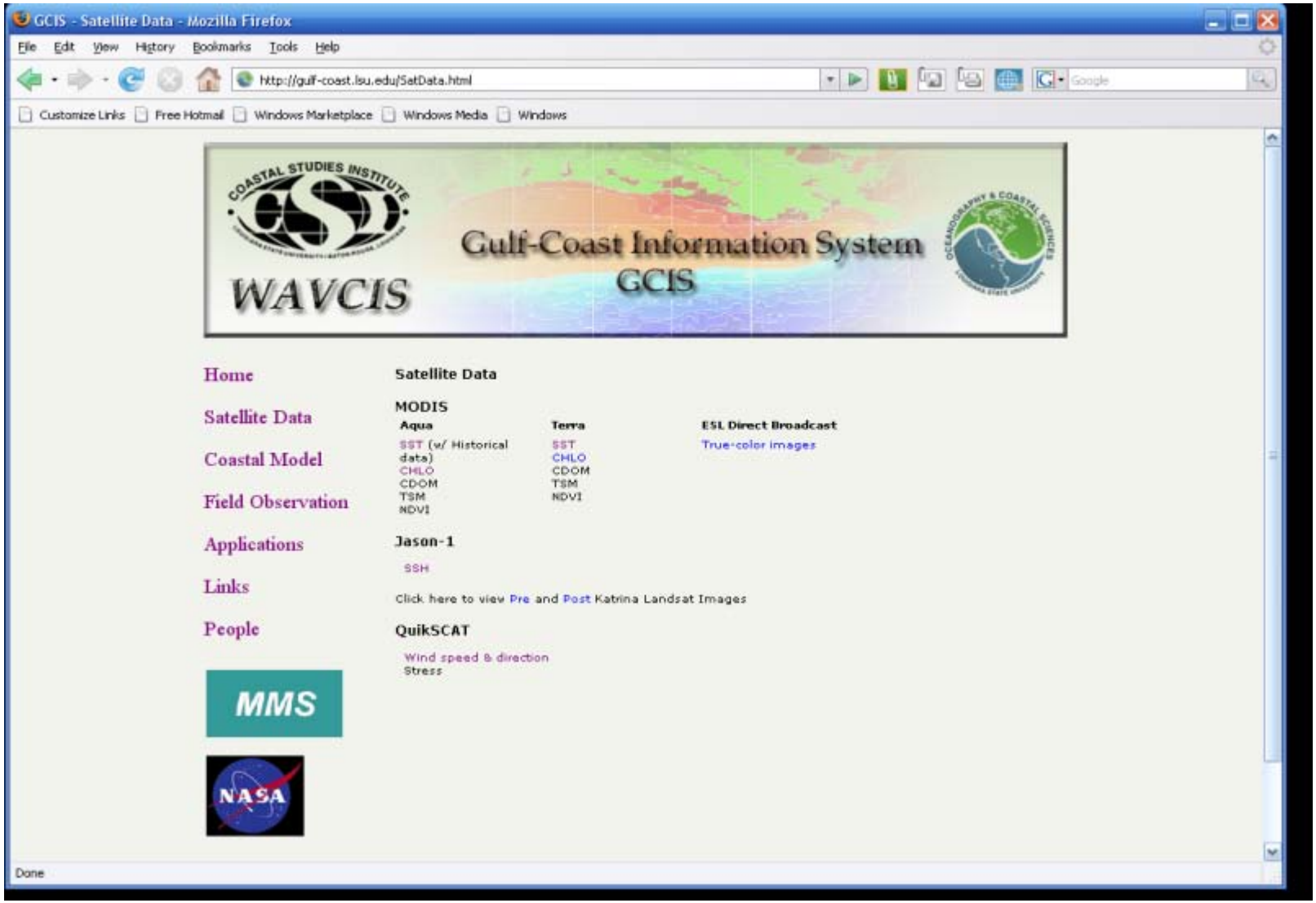
CDOM absorption vs salinity



D'Sa and DiMarco 2009

Web Based Access to Satellite Data Products

http://gulf-coast.lsu.edu



Satellite Ocean Color and Other Data Products

Home

Satellite Data

Coastal Model

Simulation

GIS

Field Data

Links

People

Satellite Data

MODIS

Aqua	Terra
SST	SST
CHLO	CHLO
CDOM	CDOM
TSM	TSM
NDVI	NDVI

SeaWiFS

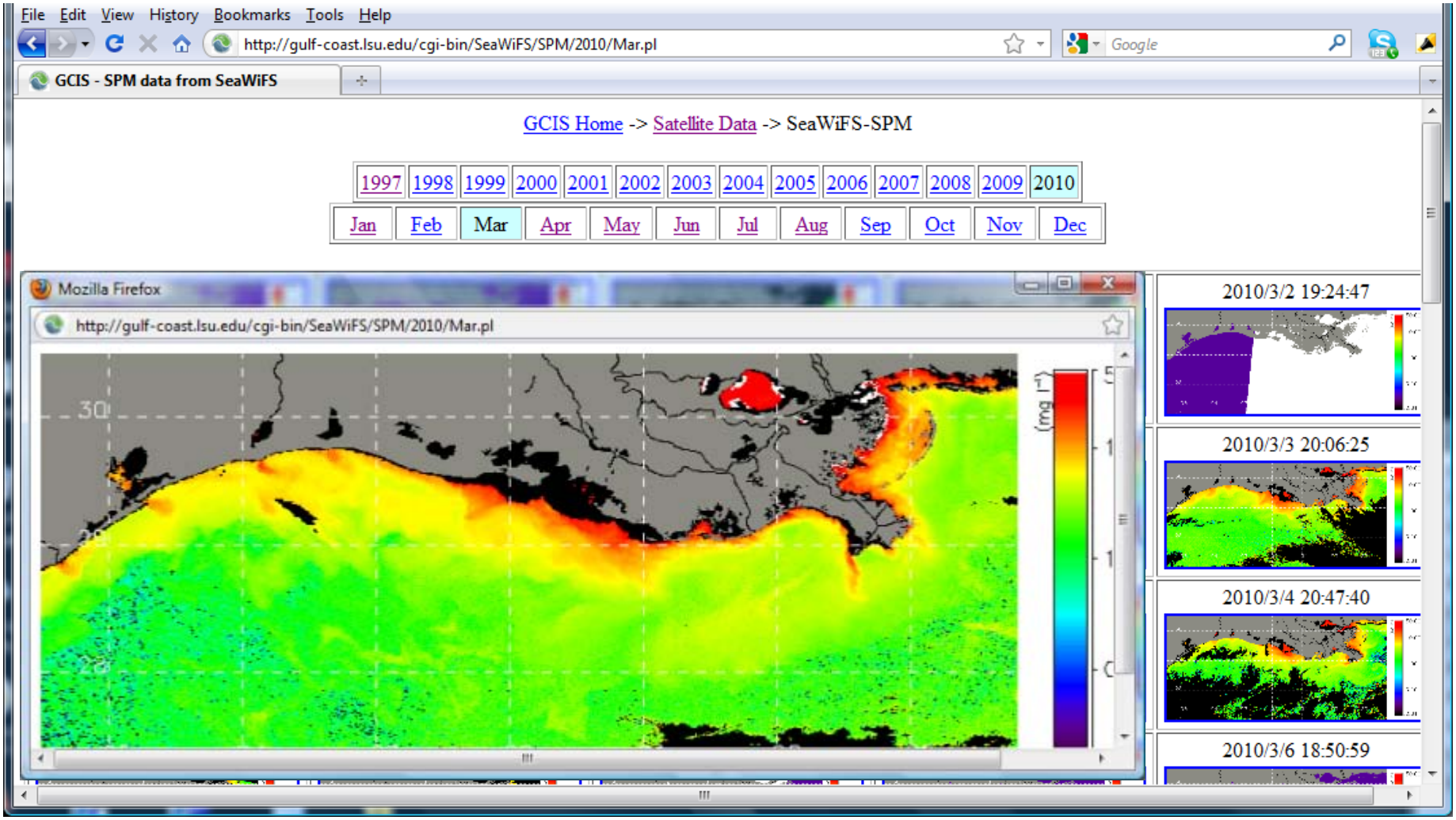
CDOM
SPM
CHLO

Jason-1

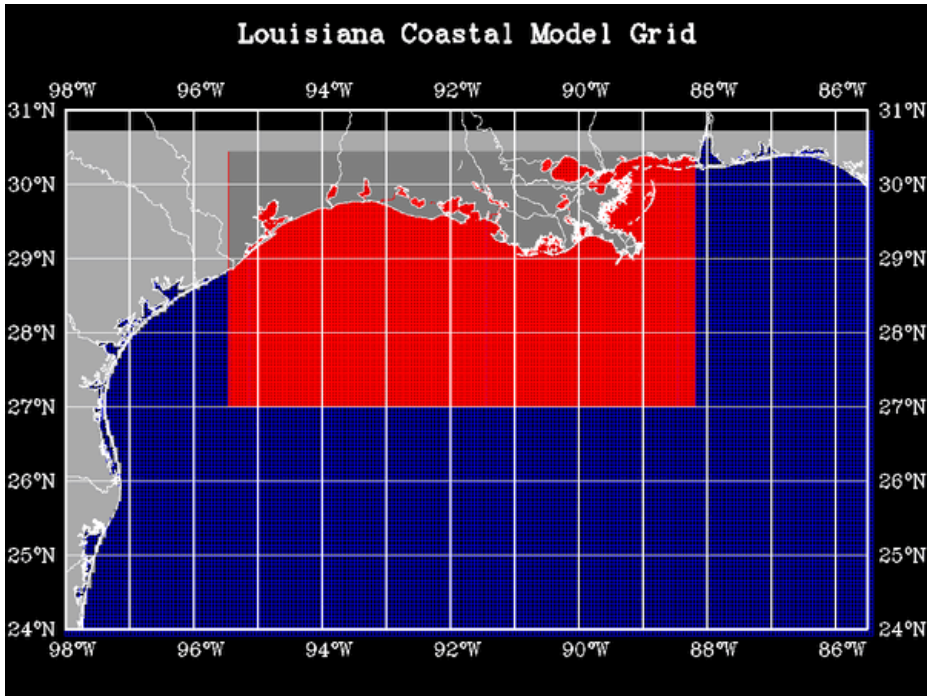
SSH

QuikSCAT

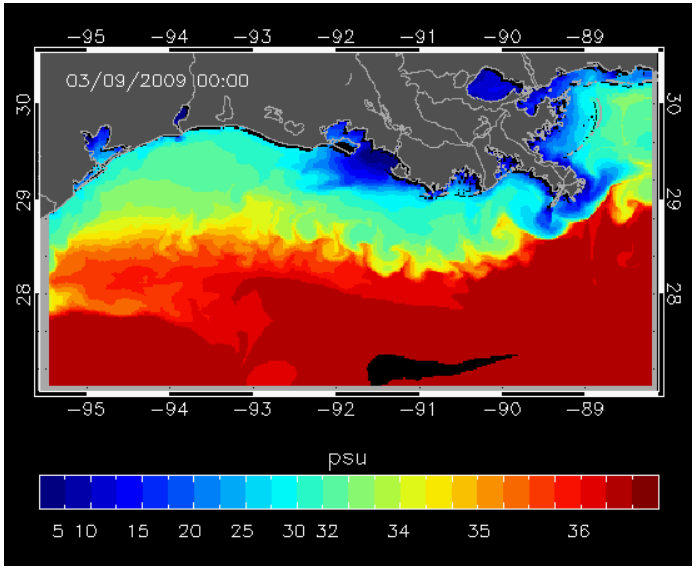
Satellite Data – SPM



Satellite Ocean Color Data Combined with Outputs of a Nested 3-D MsLaTex Coastal Model (NASA Project)



Salinity



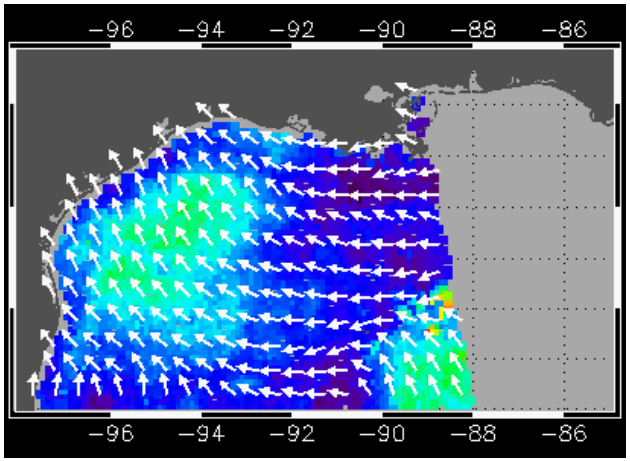
- Longitude: 95.5 W – 88.2 W; Latitude : 27.0 N – 30.5 N
- Horizontal Resolution: 1/64 Degree (~ 1.9 Km)
- Vertical Resolution: 36 Layers (19 Layers on the shelf)
- Number of Grids: 372 x 200

Satellite Ocean Color for Event-Based and Long-Term Studies

- Effect of cold fronts
- Hurricane Ike – coastally trapped wave; SPM and chlorophyll response
- CDOM and salinity response during Rita
- CDOM seasonal variability
- Long-term phytoplankton chlorophyll variability using wavelet analysis

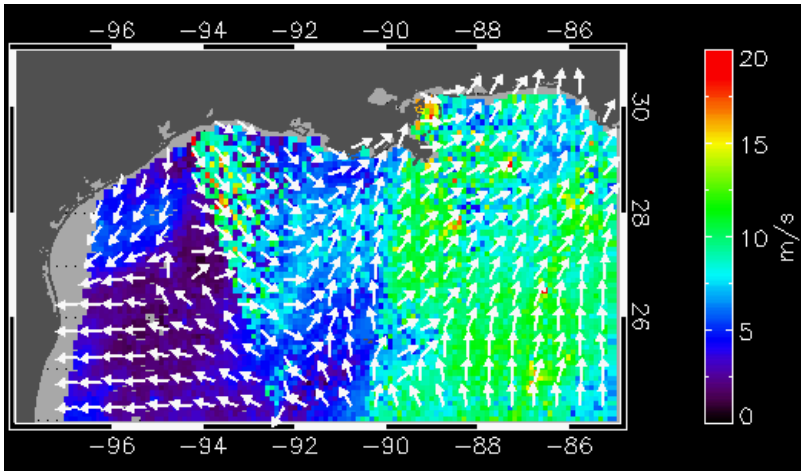
SPM Dynamics during Frontal Passage

D'Sa and Ko 2008

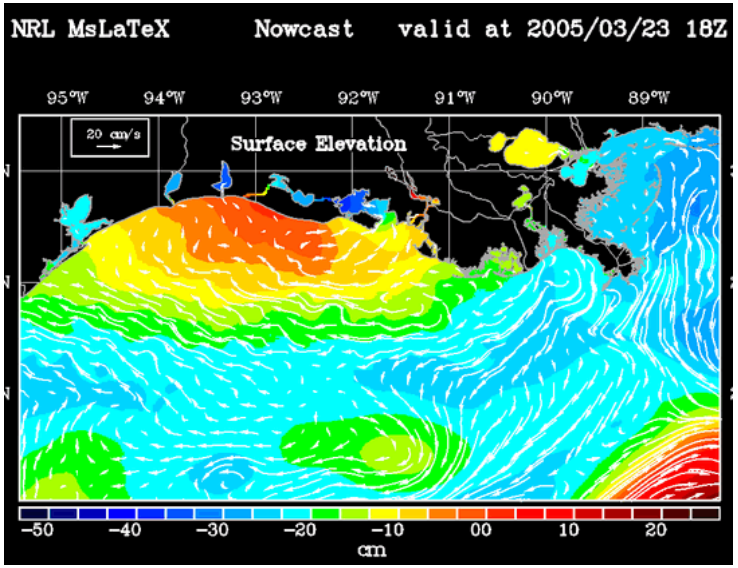


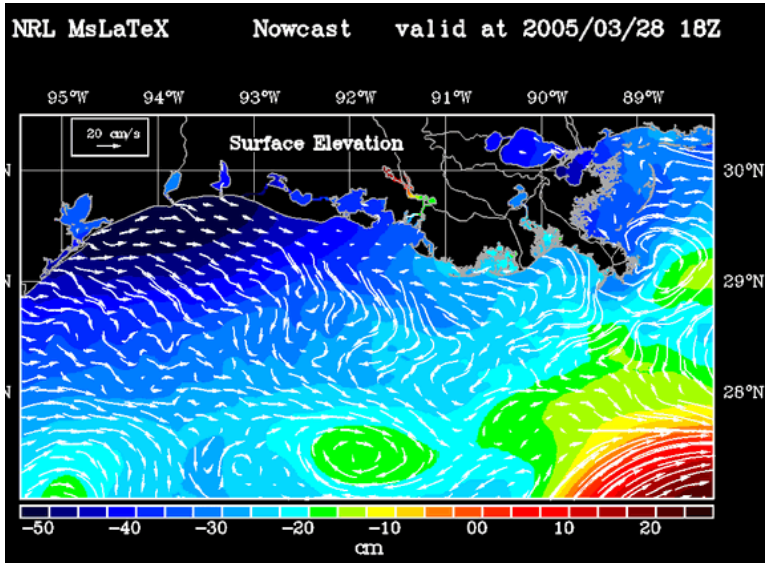
March 23, 2005

QuikSCAT Winds



March 28, 2005

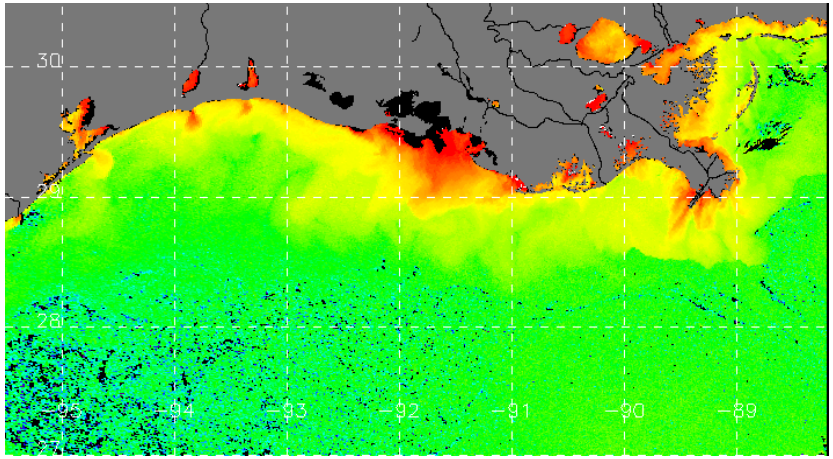




NCOM – sea level & currents

SPM Dynamics during Frontal Passage

D'Sa and Ko 2008



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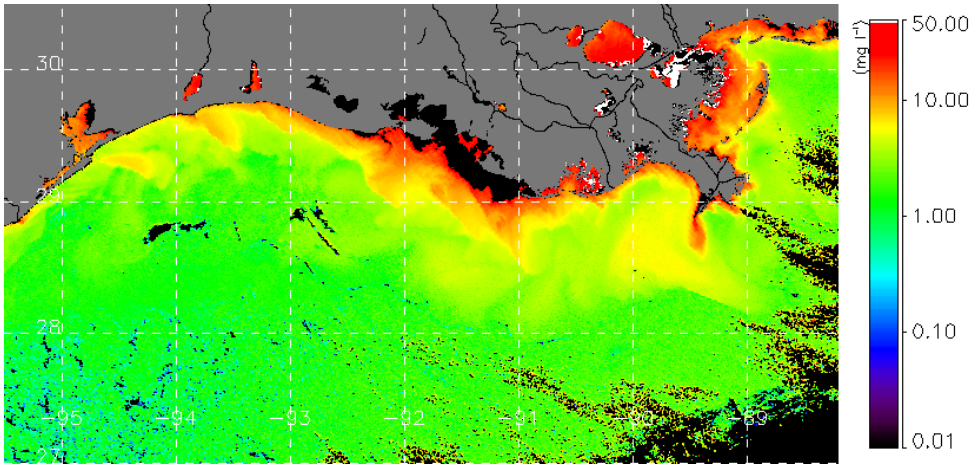
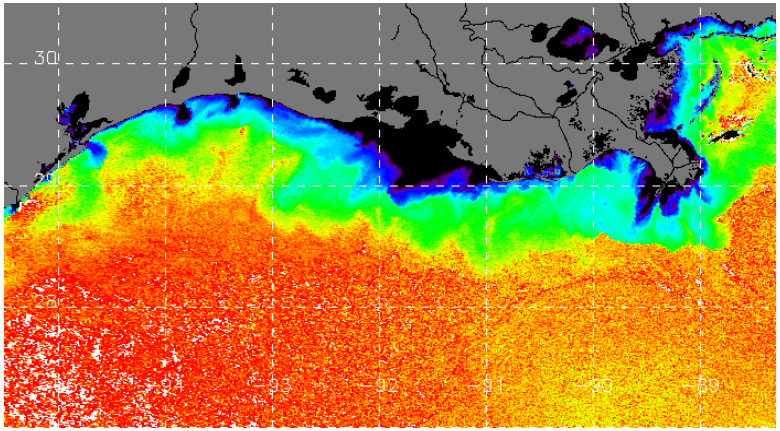


March 28, 2005

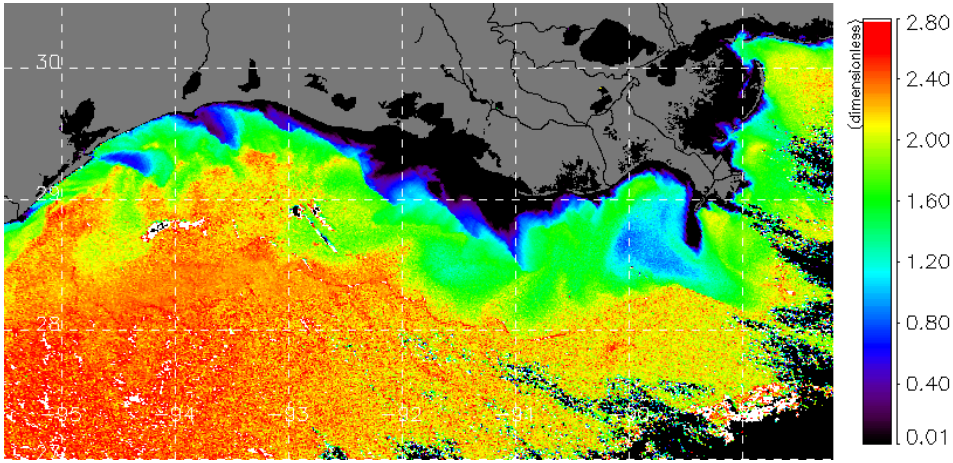
SPM Size Distribution during Frontal Passage

Gamma (γ) function derived from the slope of spectral backscattering is sensitive to particle size distribution

Low -gamma (γ) => larger particles

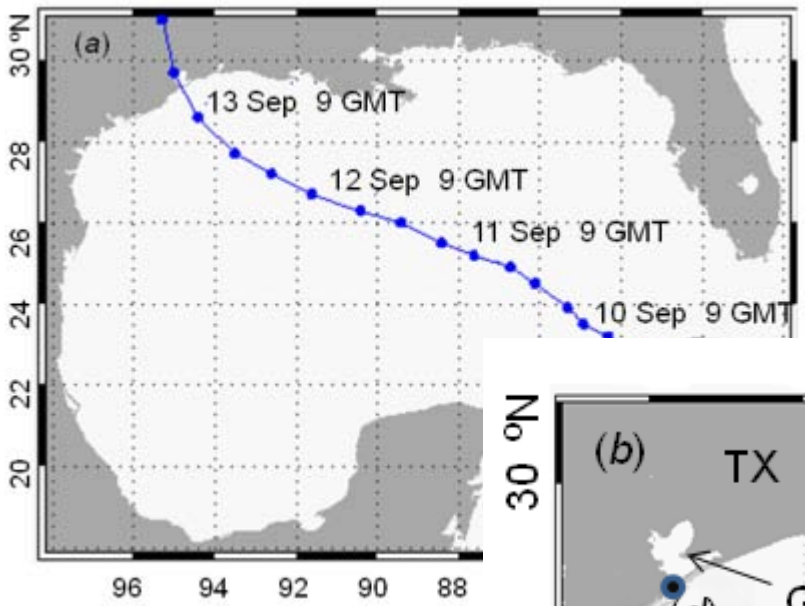


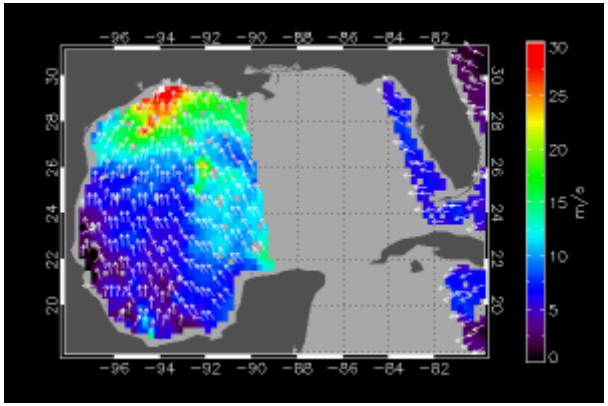
March 23, 2005

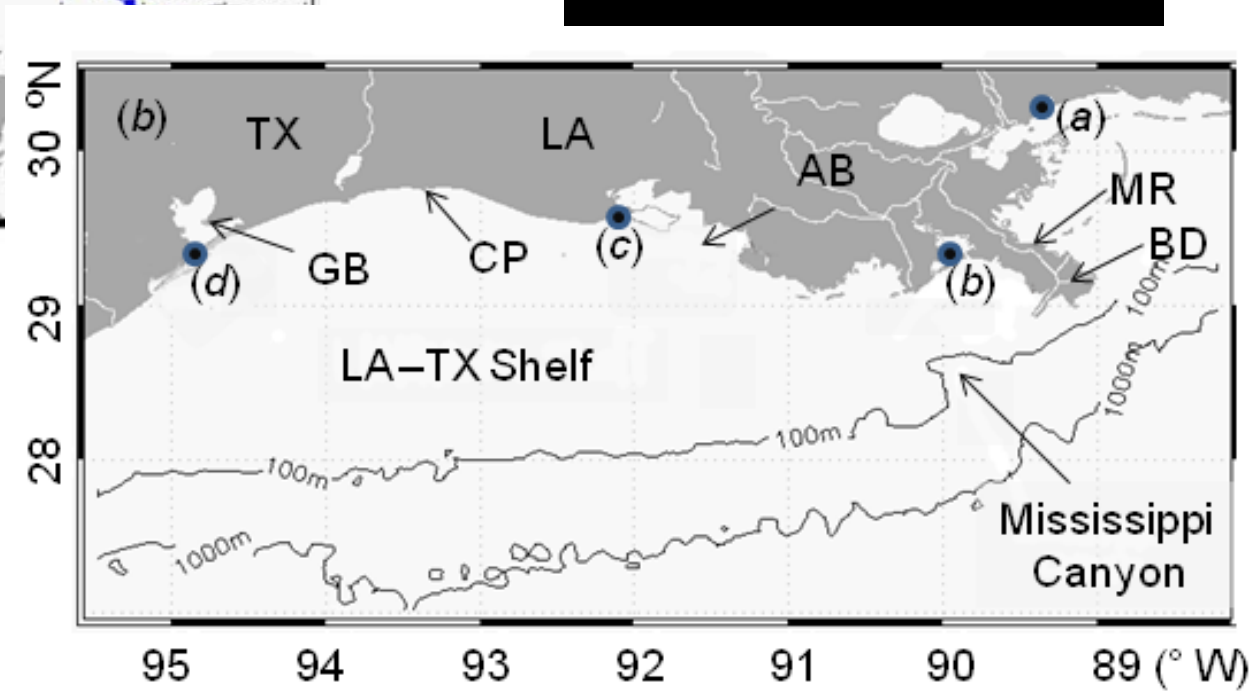


March 28, 2005

Coastal Response to Hurricane Ike

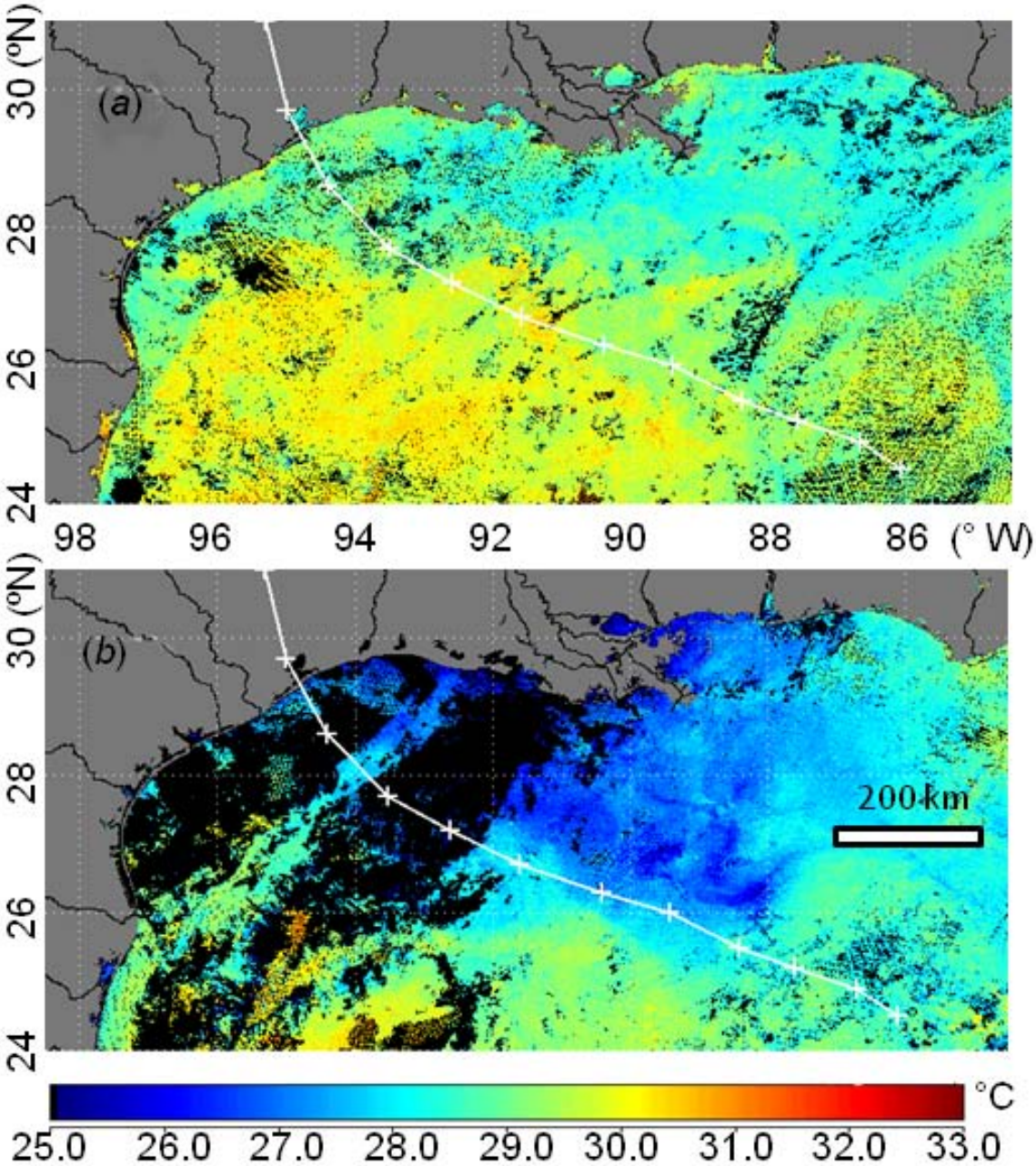






D'Sa et al. 2011

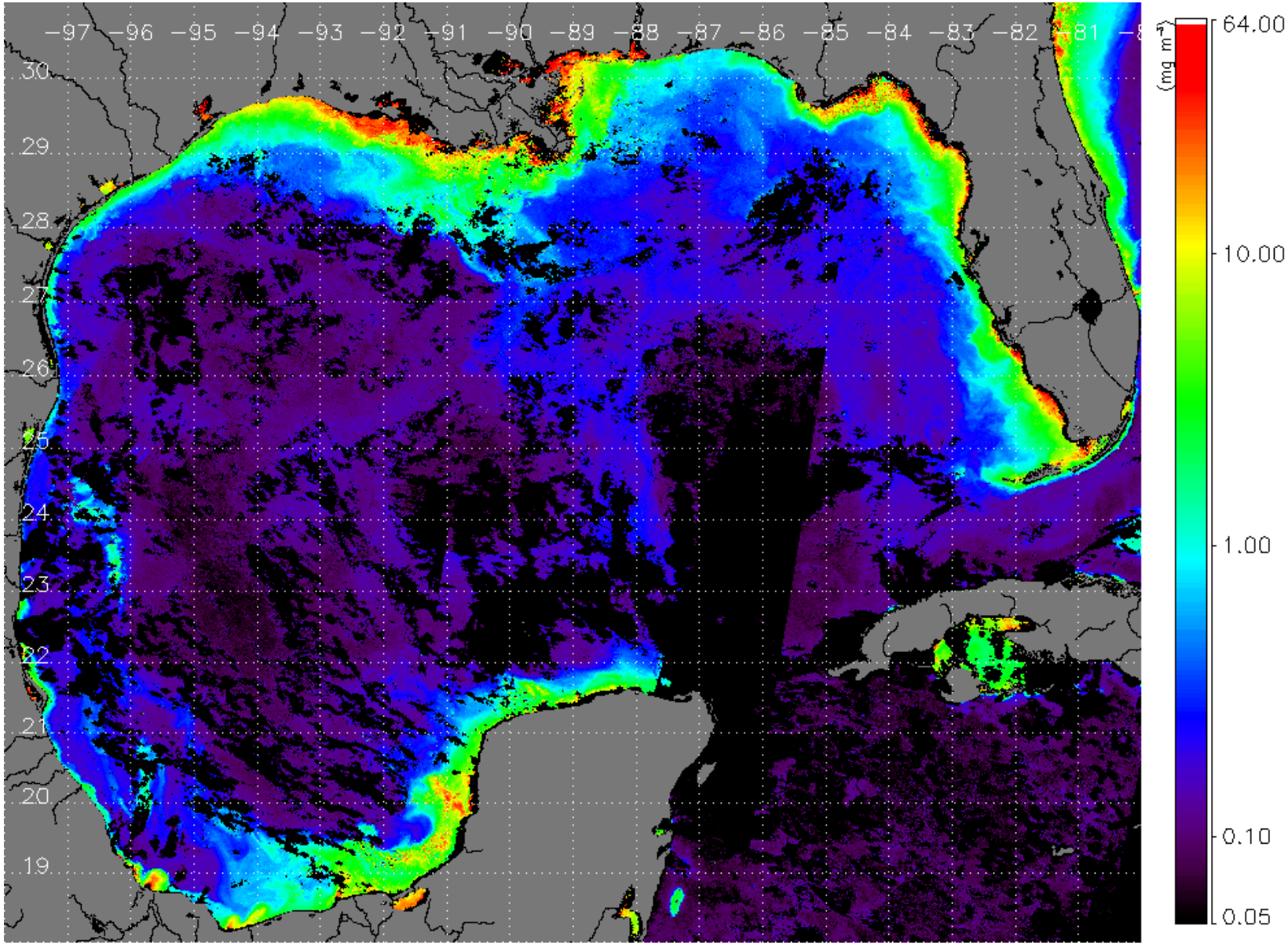
Hurricane Ike Effect on SST



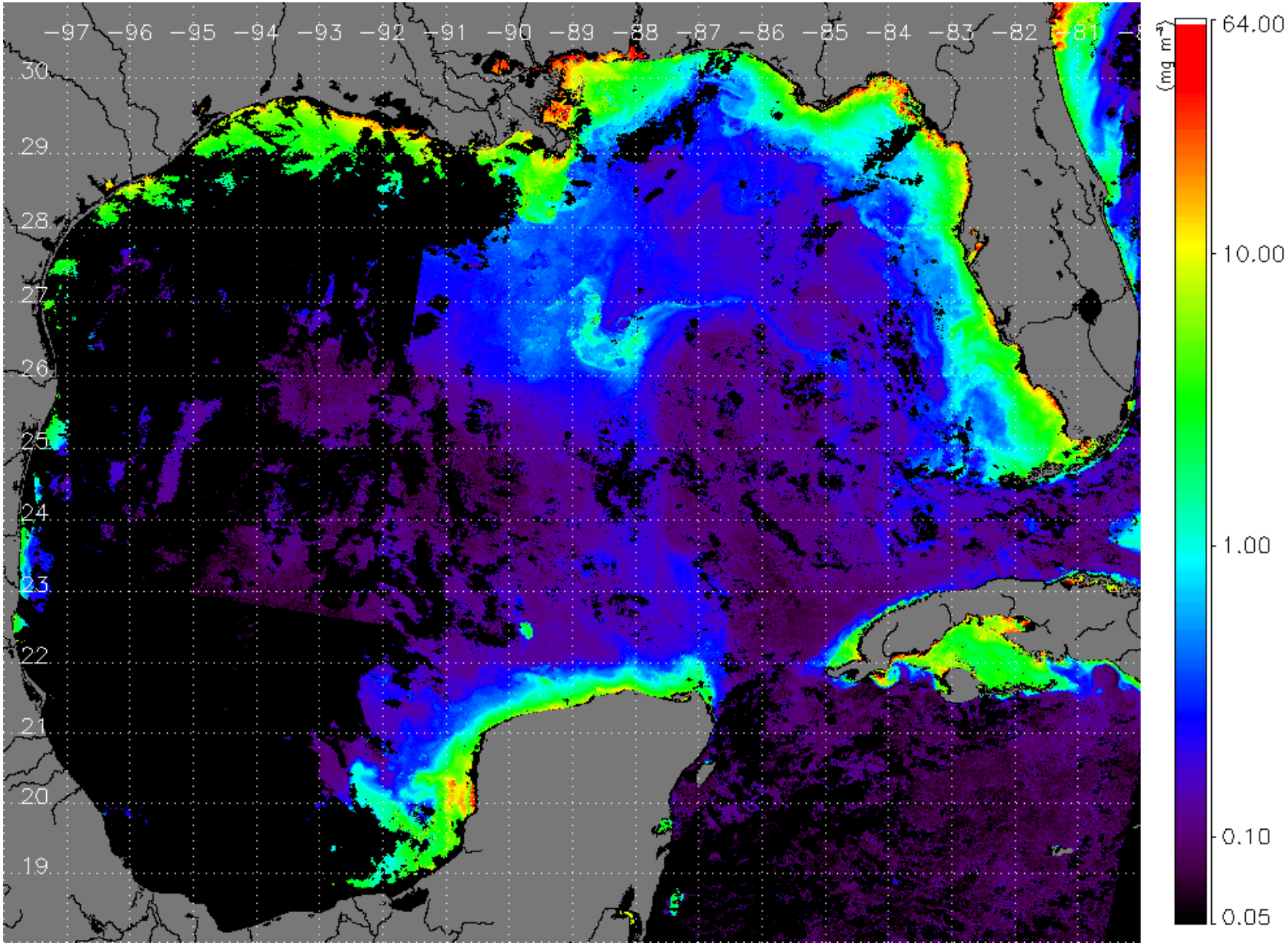
Avg 5-day
(Sep 6 – 10, 2008)

Avg 5-day
(Sep 14 – 18, 2008)

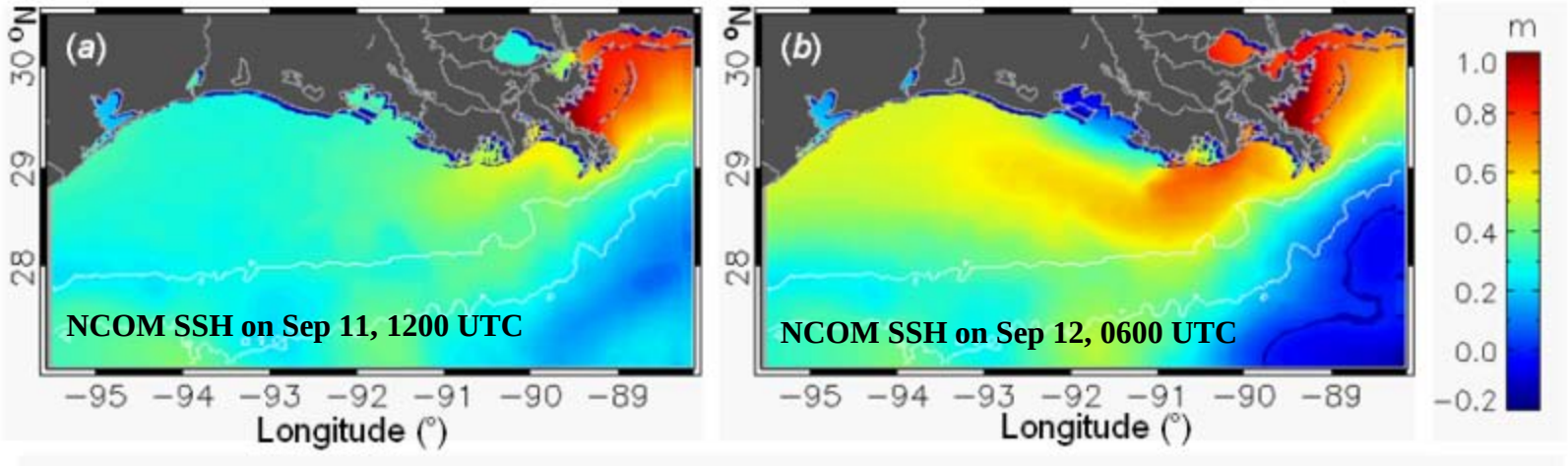
Chlorophyll in the Gulf of Mexico before Ike (Sep 6 – 10)



Chlorophyll in the Gulf of Mexico after Ike (Sep 14 – 18)



Hurricane Ike – Coastally Trapped Barotropic



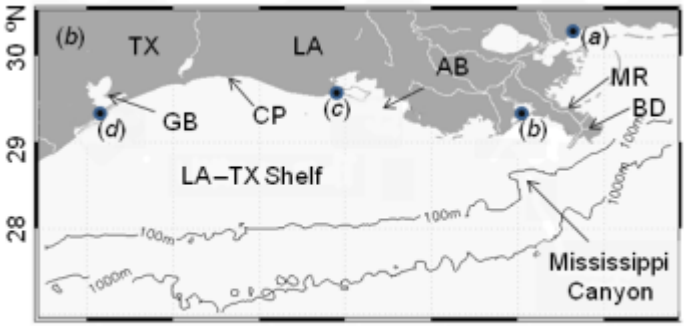
More than one maxima and reported earlier-than-expected surge appears to be due to a coastally trapped wave (CTW)

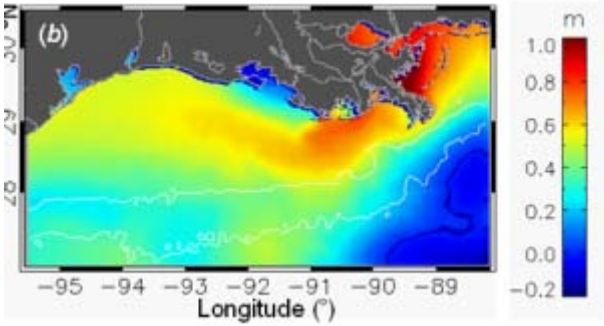
CTW is a rapidly moving disturbance that takes the form of a wave field and travels along the coastline

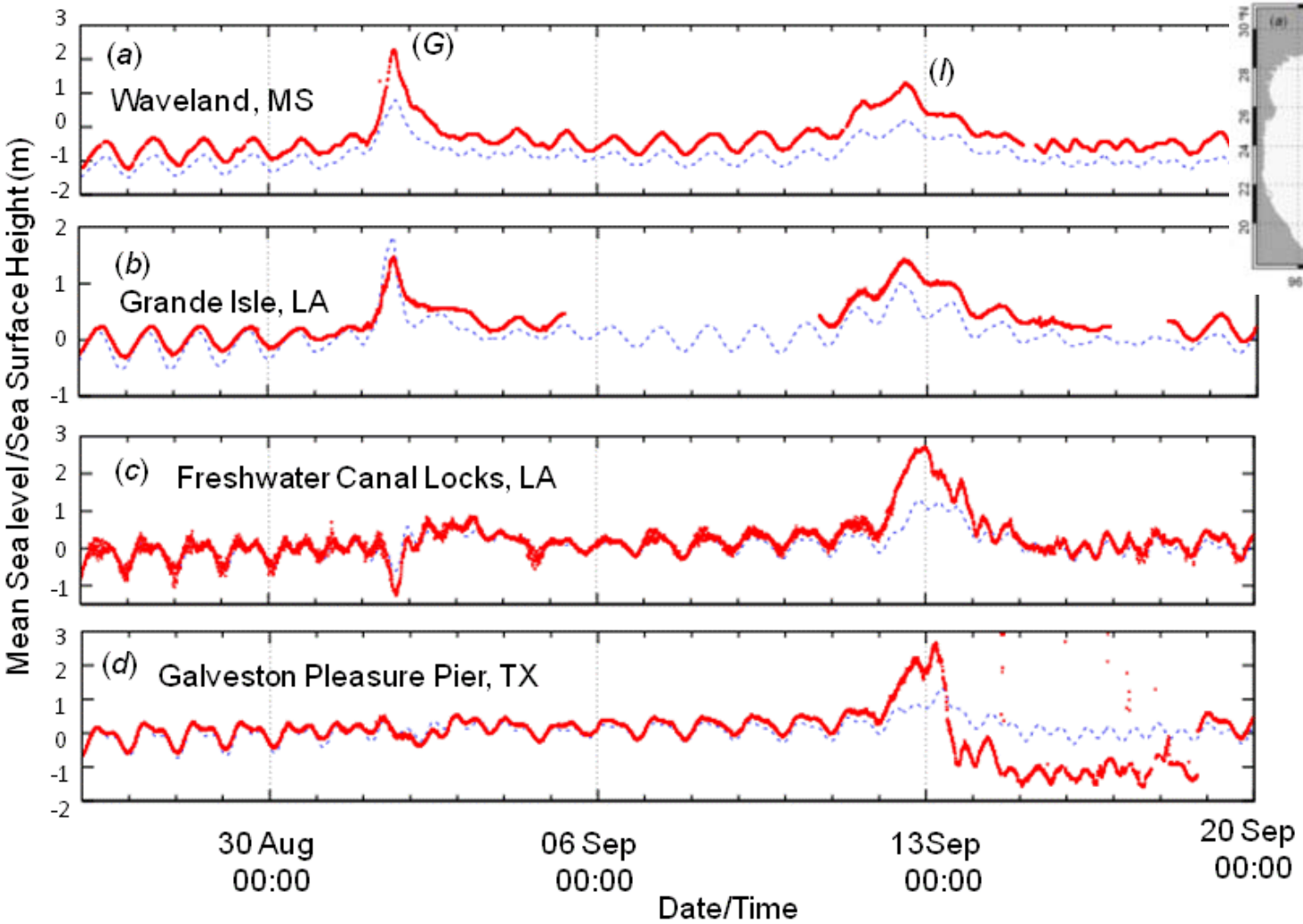
CTW form as hurricane winds force the ocean water against the coast and create a bulge of high sea level

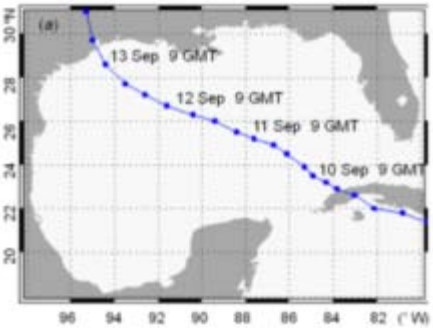
CTW have been shown to amplify the storm surge (Morey et al. 2006)

Mean Sea Level vs SSH (Model)





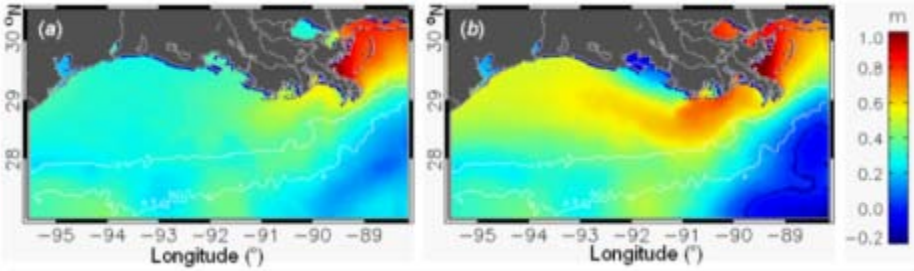




Hurricane Ike – Coastally Trapped Barotropic Kelvin Wave

Time-distance plot of SSH simulated by NCOM along 28.5 N lat. suggests the appearance of a large wave at the Mississippi Canyon (~90W longitude) on Sep 12

It traveled from 90–95 W in ~ 8 hrs => speed 17 m s^{-1}



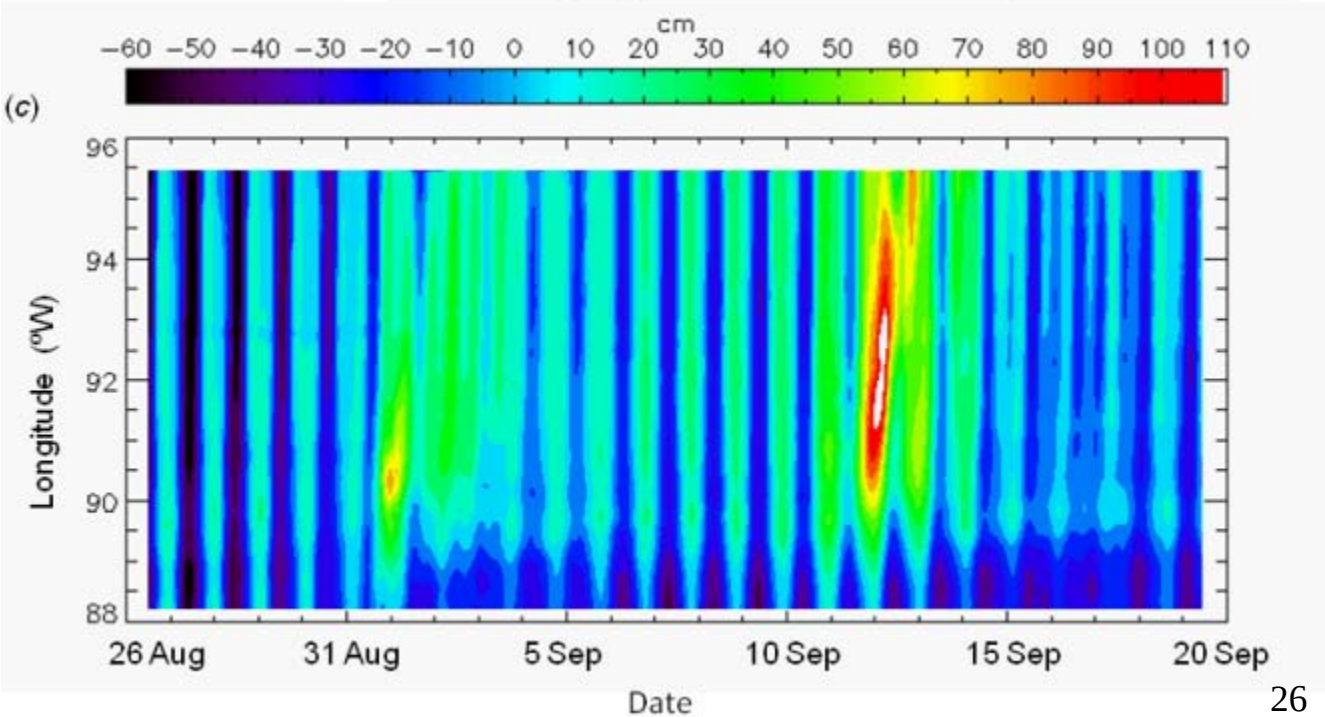
Assuming H = 30m

Speed of CTW

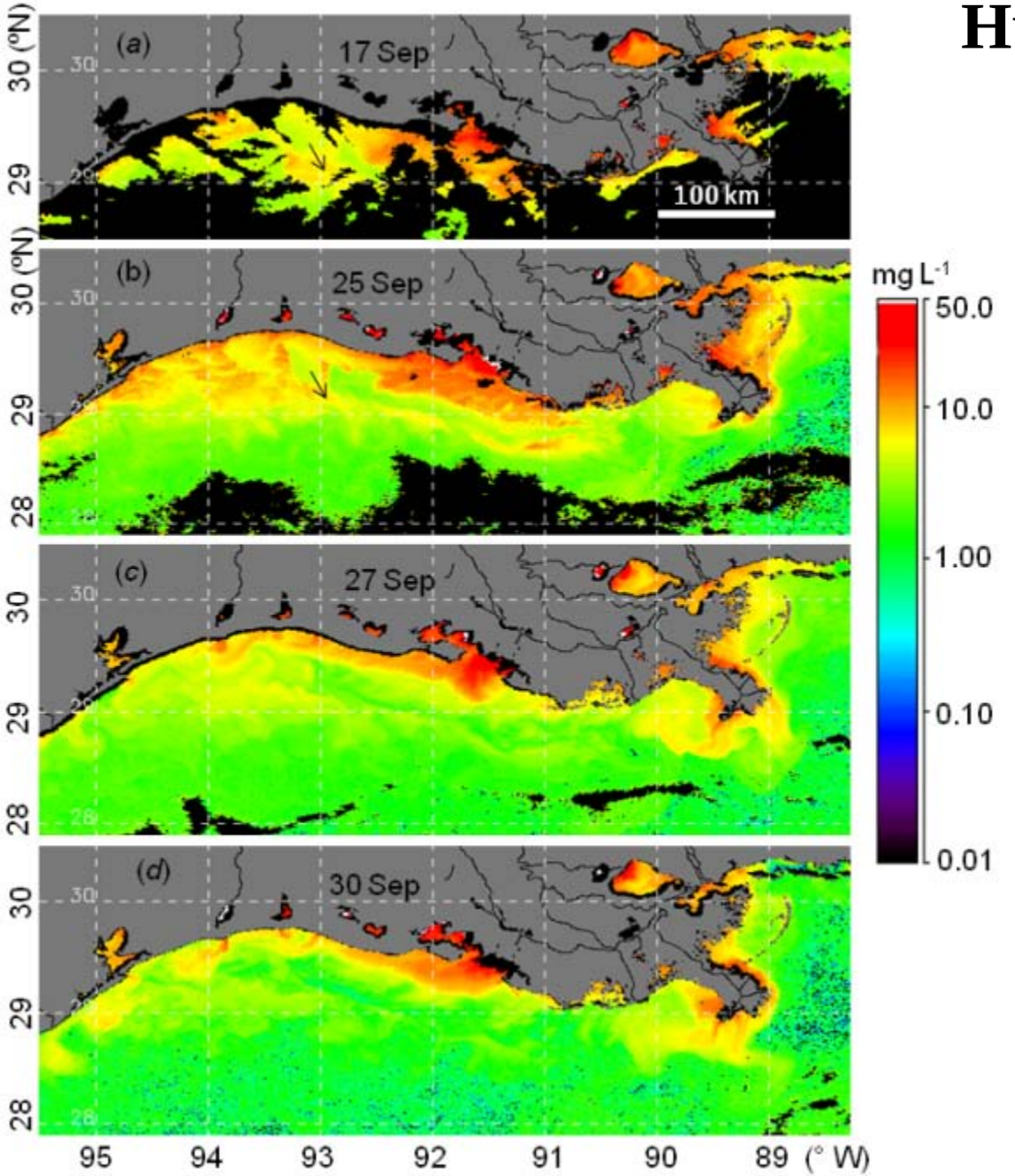
$\sqrt{gH}$ = 17 ms^{-1}

Hypothesis: Forerunner wave

Sediment resuspension



Hurricane Ike Effects on Coastal SPM



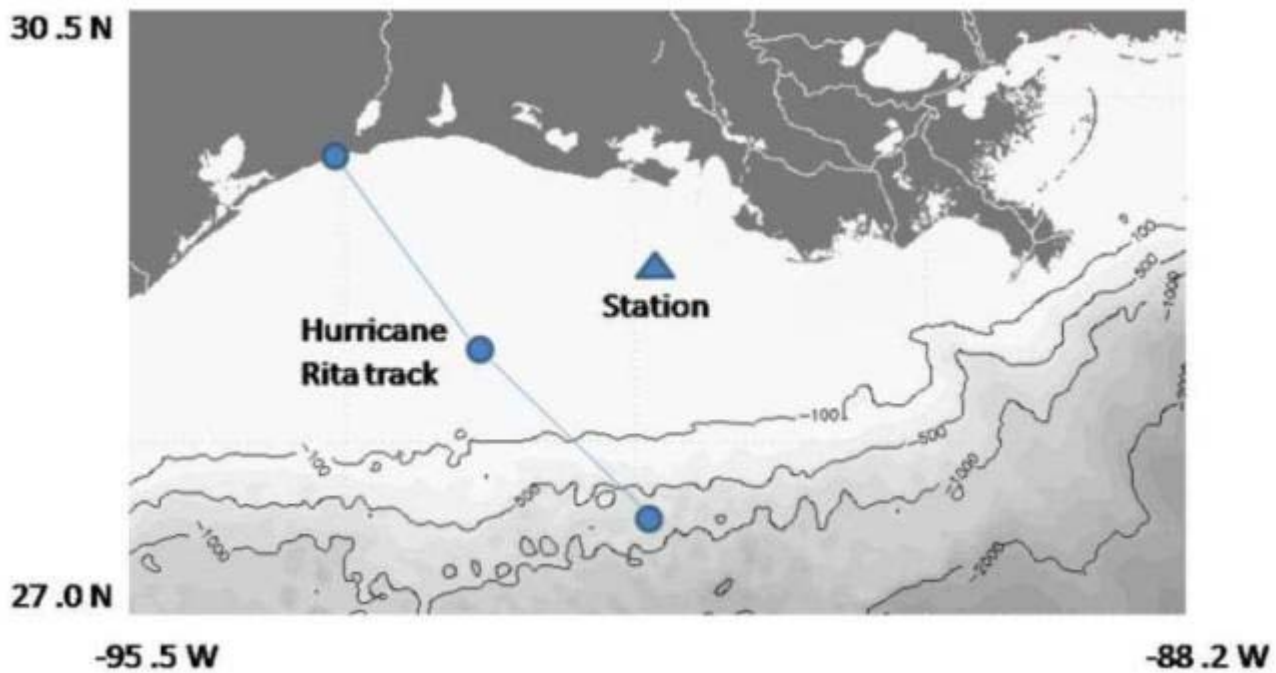
- SPM from SeaWiFS for Sep 17, 25, 27, 30
- Two wind events 15, 21
- Plumes of elevated SPM
- Discharge of inundated waters
- Elevated SPM band
- River discharge increased by 12% (Sep 25 – 29)

D'Sa et al. 2011

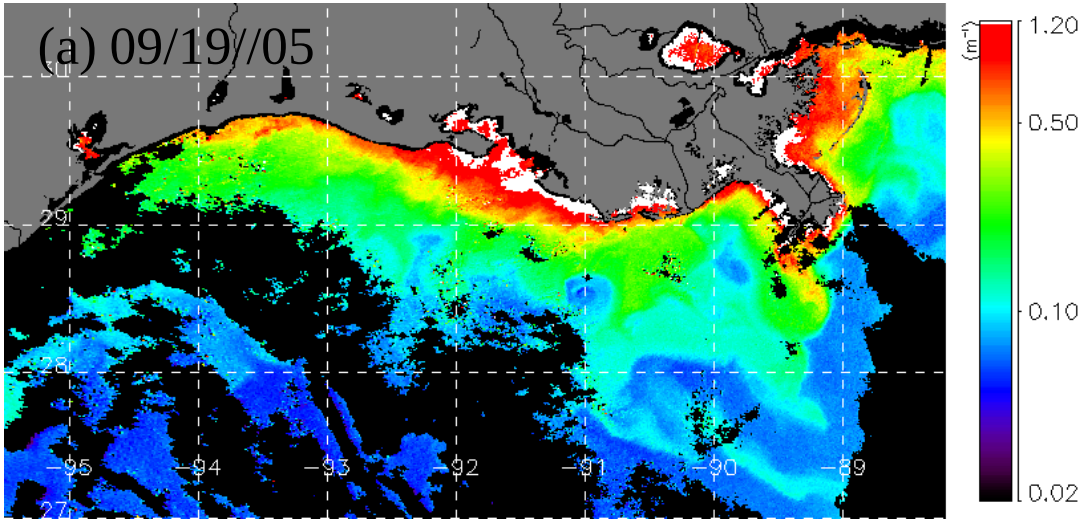
CDOM Dynamics during Hurricane Rita

SeaWiFS imagery were downloaded from NASA DAAC and processed using using regional CDOM algorithm (D'Sa et al. 2006)

Impact of hurricane Rita on CDOM and salinity distribution in the northern GOM were examined from satellite data



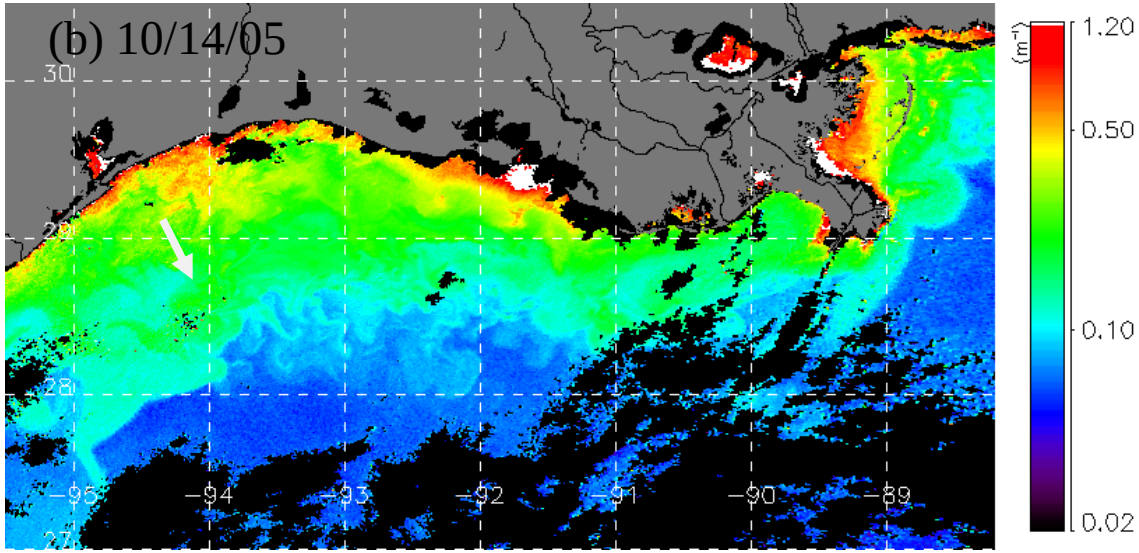
SeaWiFS CDOM Absorption – Effects of Hurricane Rita



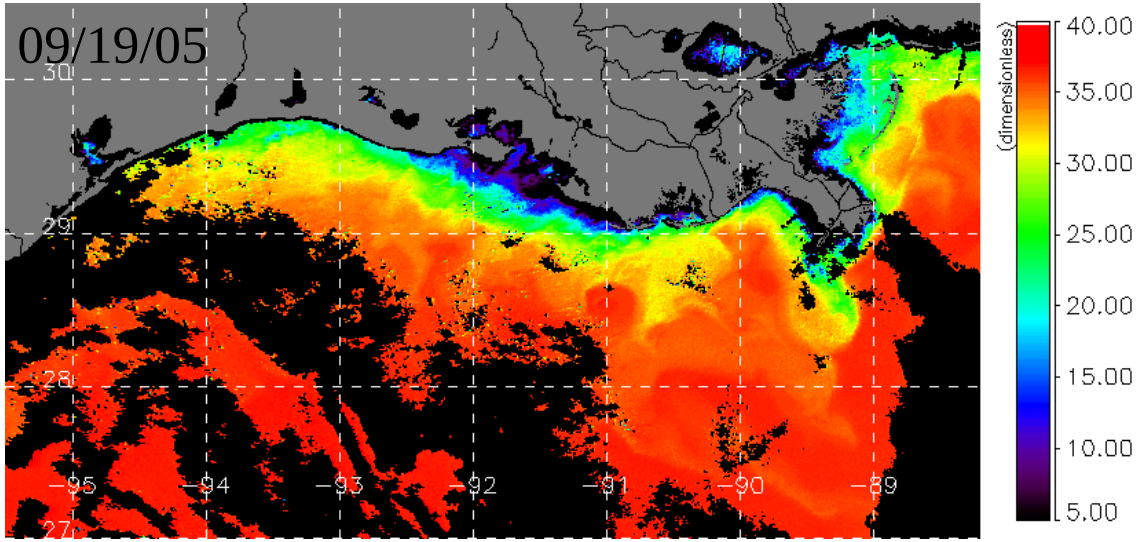
D'Sa and Korobkin 2008

Before Hurricane Rita

After Hurricane Rita

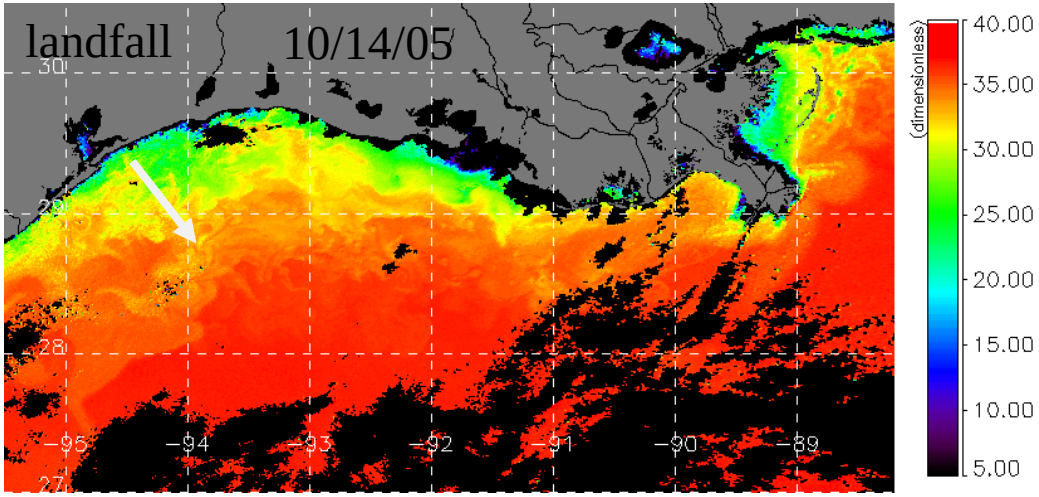


Salinity from Ocean Color – Effects of Hurricane Rita

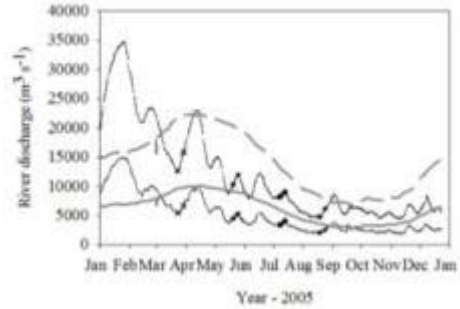


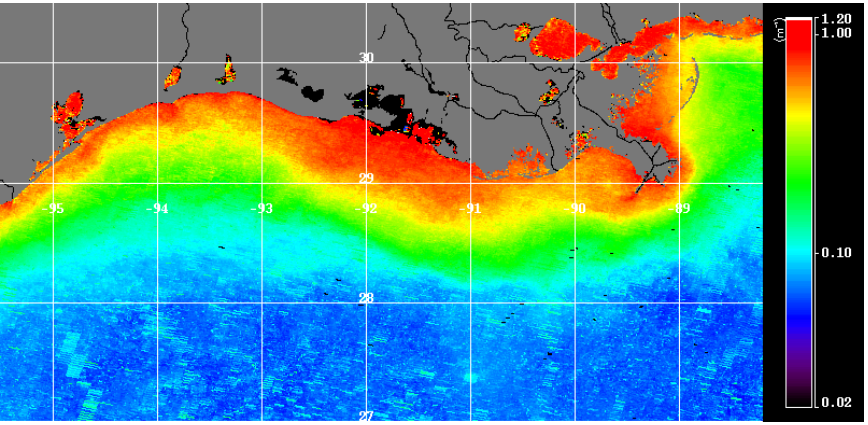
Before Hurricane Rita

After Hurricane Rita

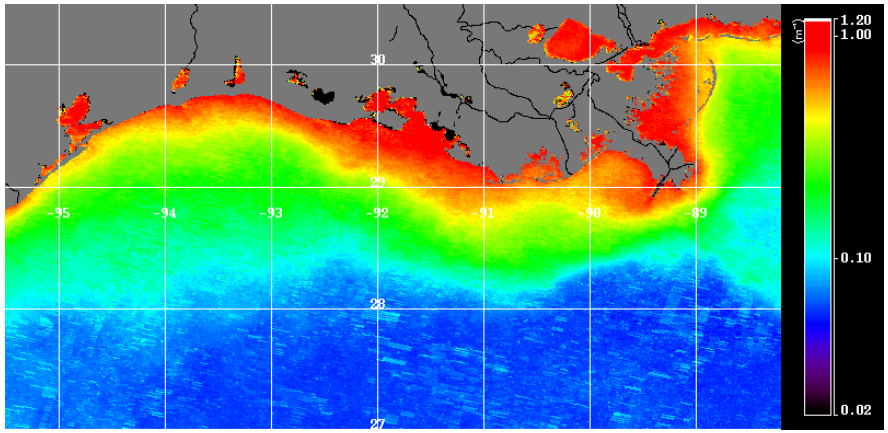


Seasonal CDOM Dynamics 2005

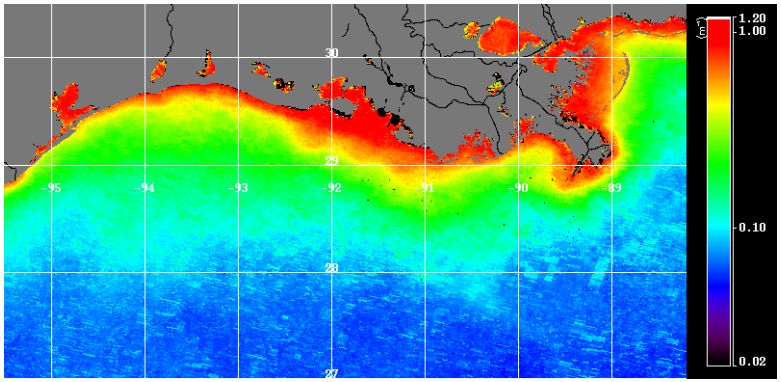




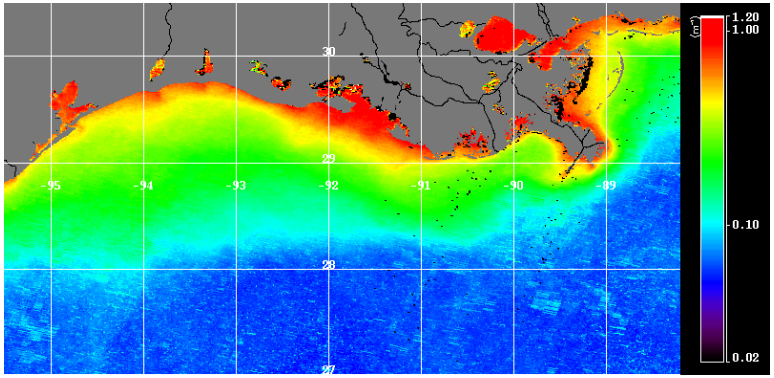
Winter 2005



Spring 2005



Summer 2005

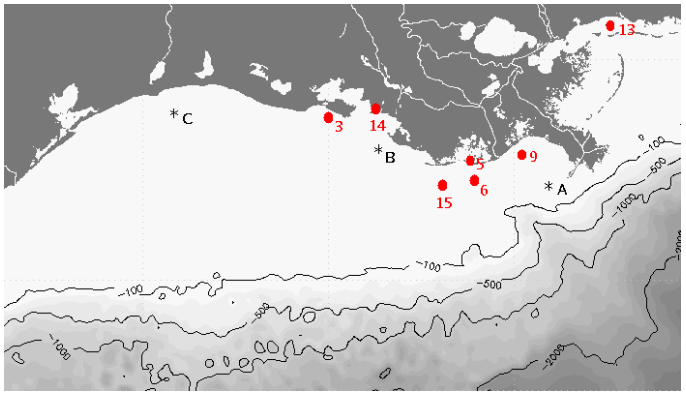


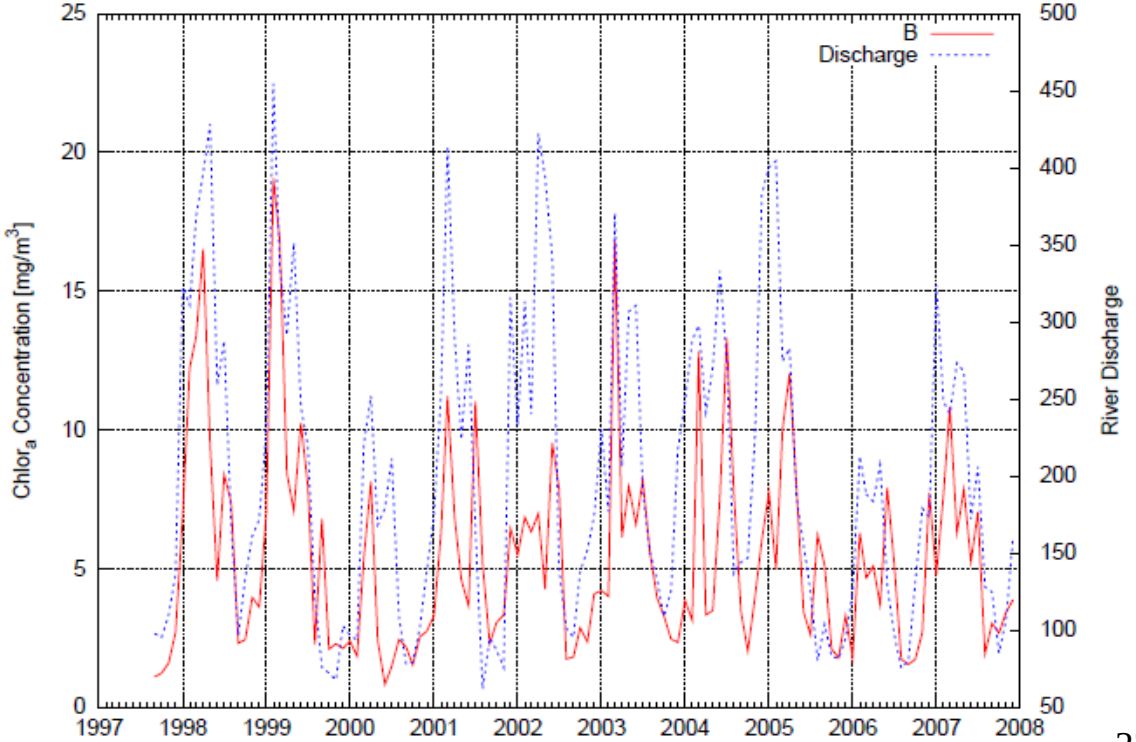
Fall 2005

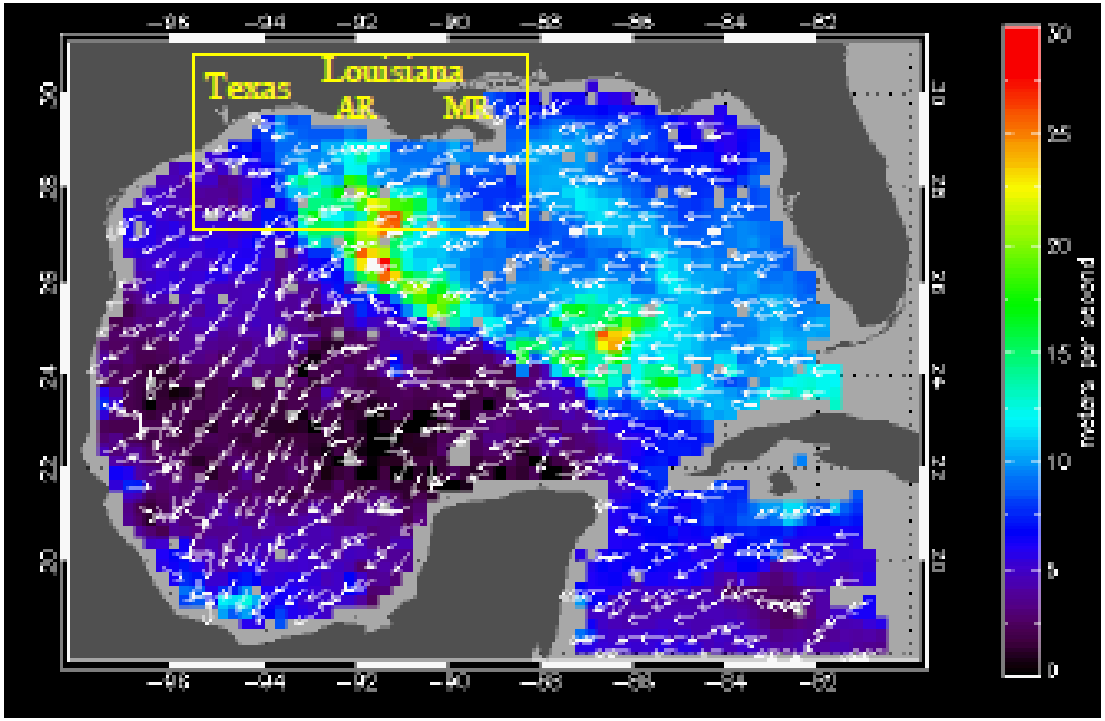
D'Sa and Korobkin 2008

SeaWiFS Chl and River Discharge

- The SeaWiFS ocean color sensor has been operational since September 1997 and has provided global estimates of oceanic Chlorophyll *a* (Chl)
- SeaWiFS derived Chl has been used in GOM to study Chl distribution and dynamics (Walker and Rabalais 2006)
- Seasonal discharge from the Mississippi and the Atchafalaya rivers







Methods and Data

- QuikSCAT Satellite wind data products were obtained from NASA JPL

- The 10 m scatterometer winds were converted to wind stress using the drag coefficient algorithm from Large and Pond 1981

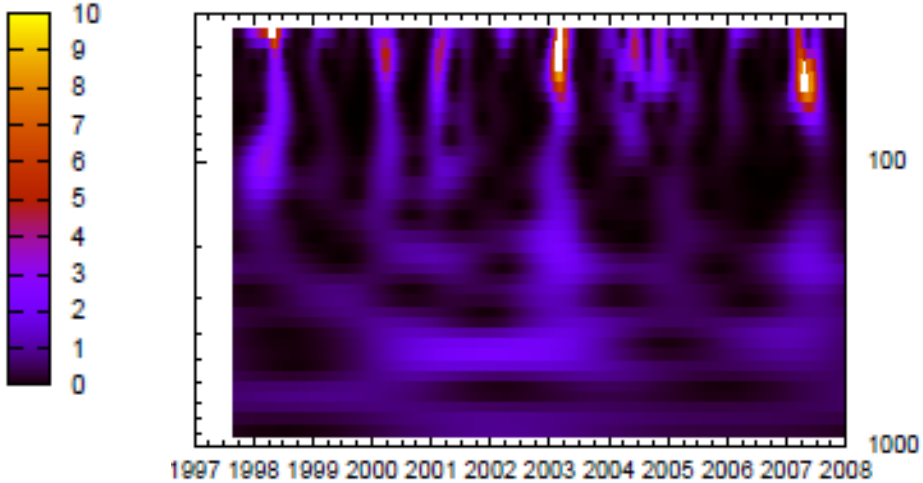
Chlorophyll – Variability Using Wavelet Analysis

- Fourier transform is commonly employed to identify dominant frequencies in a time series of data. However it retains no info on temporal evolution of a signal's spectral characteristics
- The wavelet transform (WT) decomposes a signal into time-frequency space, quantifying not only the dominant modes of variability, but also how they vary in time

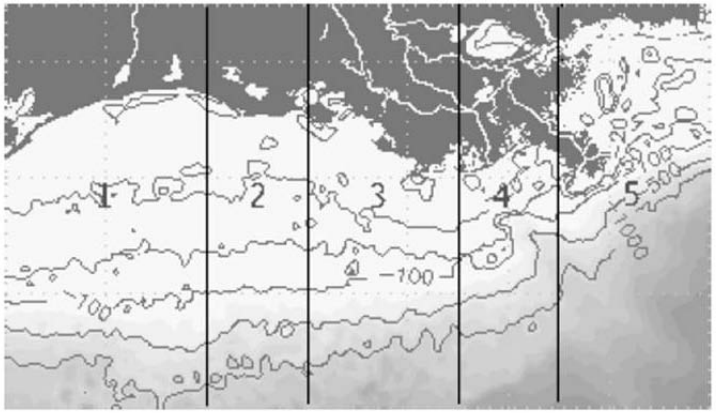
The WT decomposes a signal into a series of wavelets which can be stretched or compressed to encompass different frequencies while also moving the center of the wavelet in time so that it can be applied to all data points in a time series

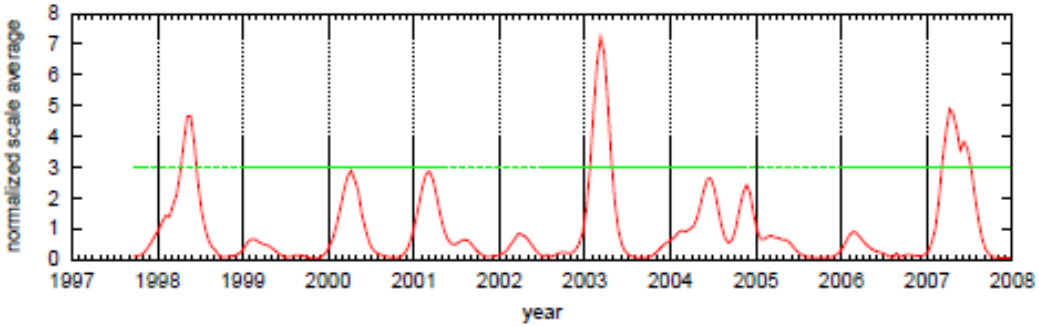
Applying the WT to the chl time series yields the local wavelet power spectrum (original data unit squared or variance $(mg\ m^{-3})^2$

Chl Variability West of MR Delta – 500 m Isobath

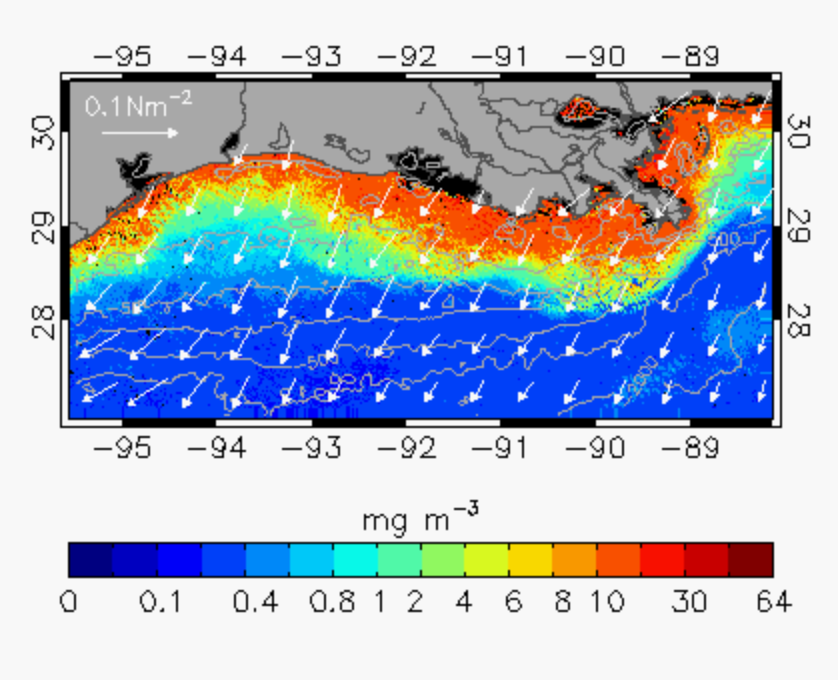


Local wavelet power spectra



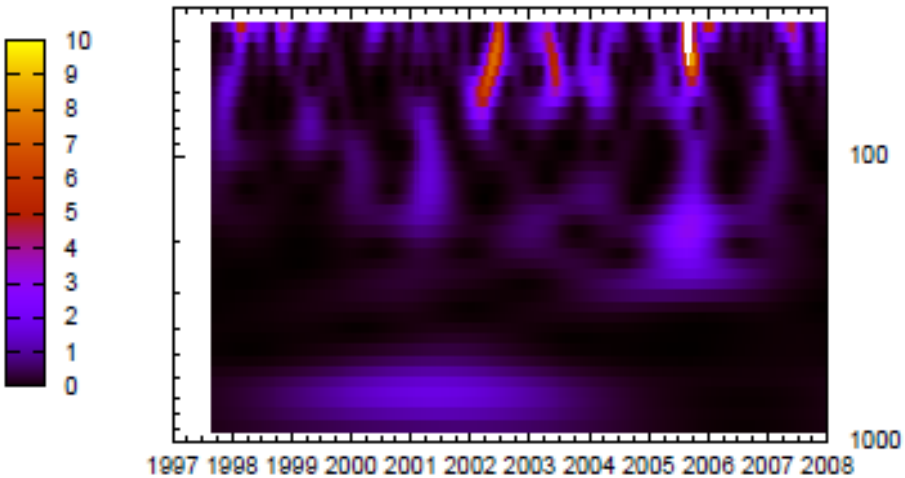


Scale-averaged time series for the period band 30 – 100 days

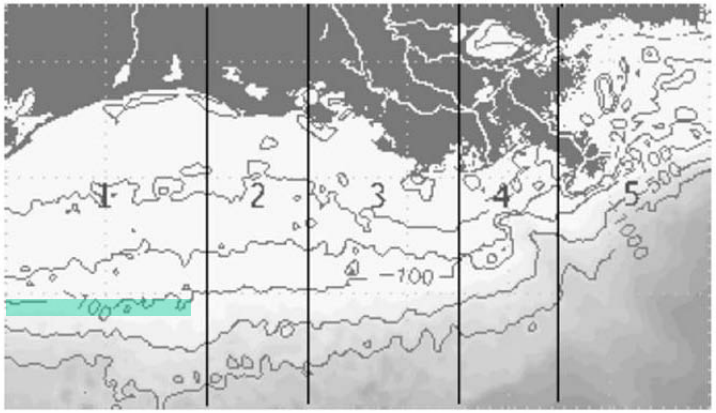


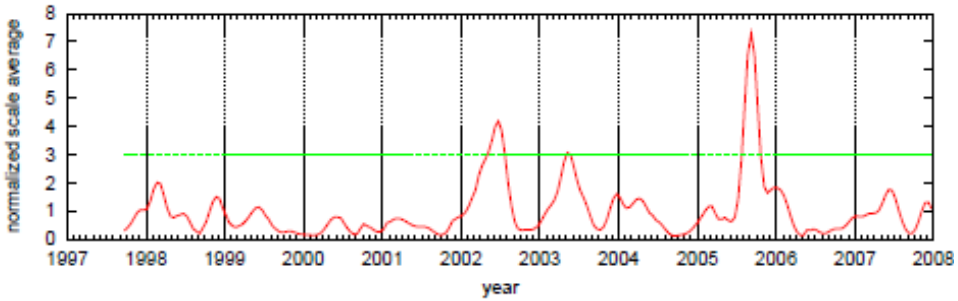
March 2003

Chl Variability West of the Atchafalaya Delta – 100 m Isobath

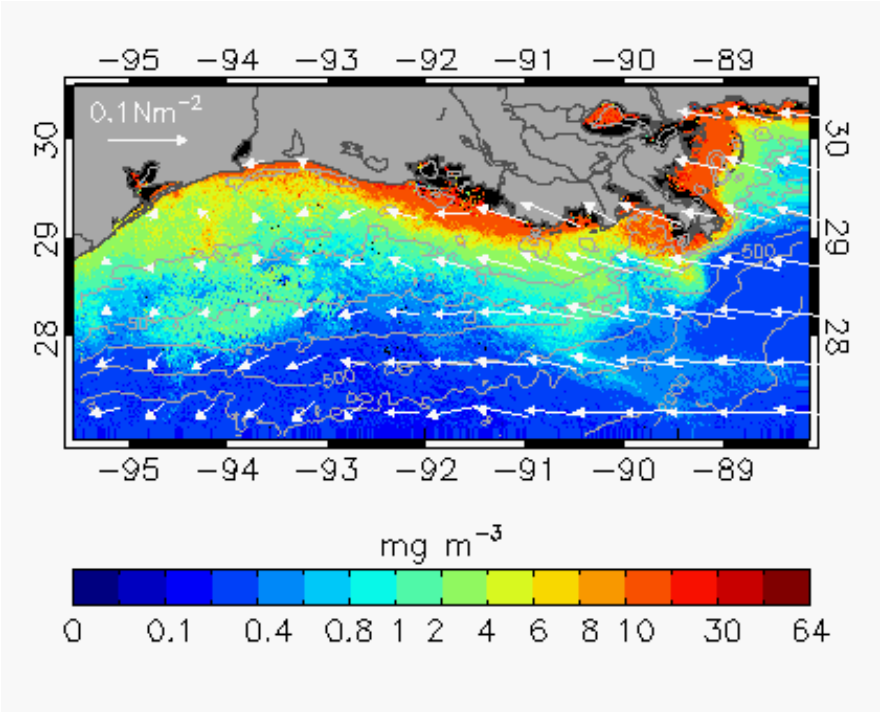


Local wavelet power spectra





Scale-averaged time series for the period band 30 – 100 days



September 2005

Conclusions

- Combining satellite and model data provide considerable insights into interaction of physical and biogeochemical processes

- Both short- and long-term applications of ocean color products have been demonstrated in this study

- In addition to standard ocean color chlorophyll product, SPM and CDOM can support environmental monitoring for decision-making in the northern Gulf of Mexico

- These ocean color products can also be used to support field programs and ecological monitoring over large spatial and temporal scales

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