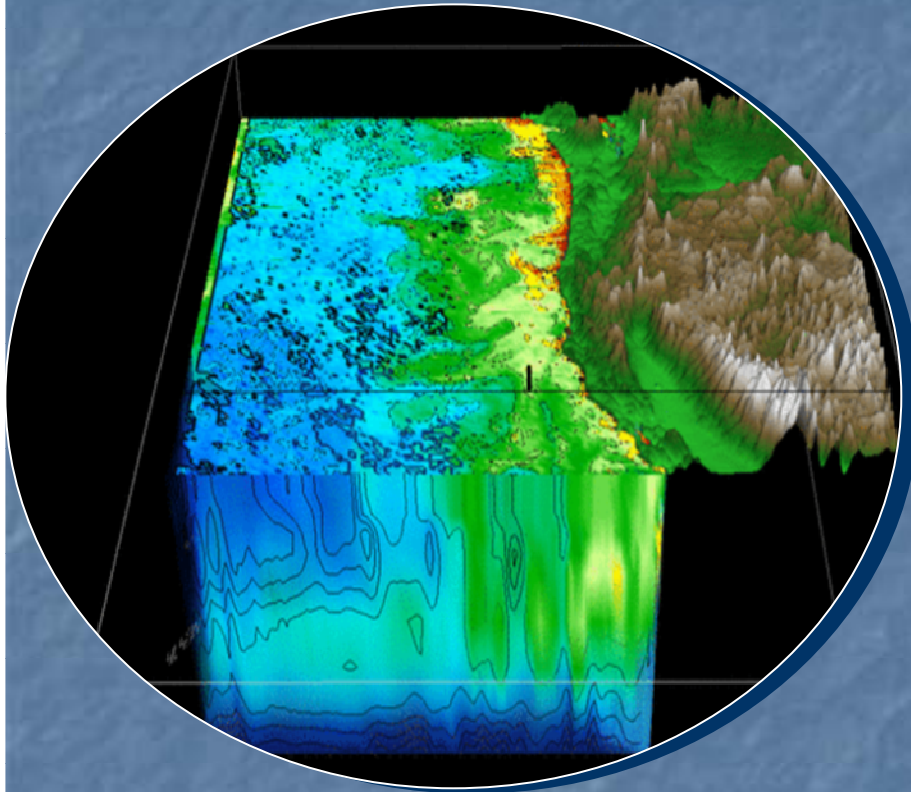
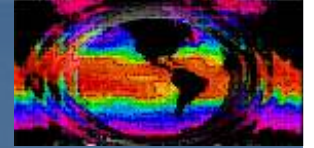
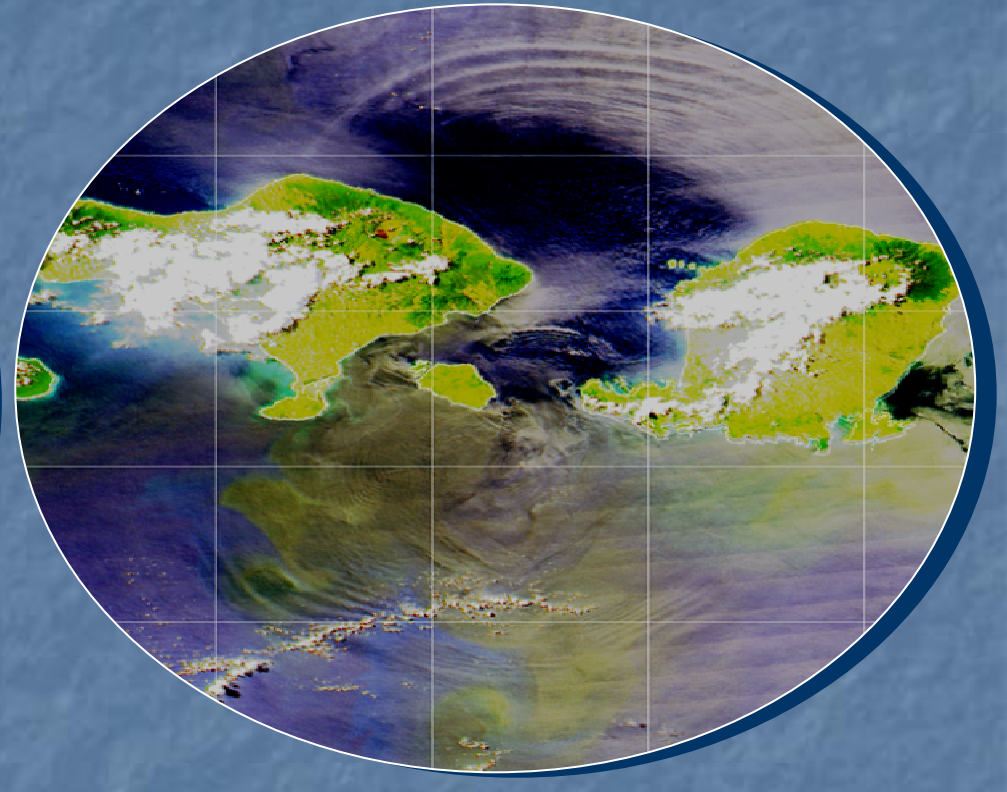




# Characterizing Processes with MODIS Ocean products .



**West Coast  
Oceanography**

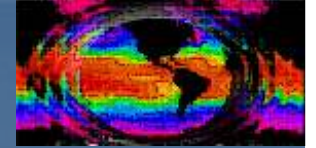


**Lombok Strait**

8t MODIS Science Meeting  
Baltimore Jan 4, 2006

Robert Arnone

Naval Research Laboratory,  
Oceanography Division Code 7330, SSC. MS



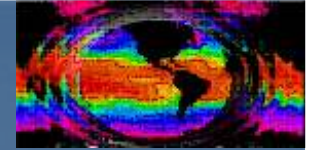
# MODIS Ocean Products

## Developing Future Ocean Capability

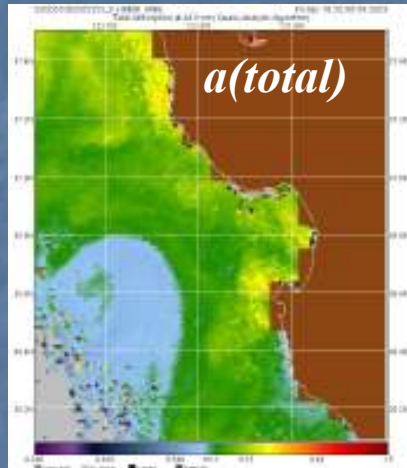
- **Advanced ocean color products / algorithms**  
Extending new products for Coastal Processes
- **High resolution 250 m for Coastal Products**  
Detecting coastal jets, coastal plumes, estuaries and harbors
- **Satellite products and Model fusion in the Gulf of Mexico**  
Pathway toward data assimilation
- **West Coast Bio-Optical Physical Coupling**  
Underneath the satellite product – 3d view.
- **Predicting and Forecasting the Ocean Process**  
Particle tracking



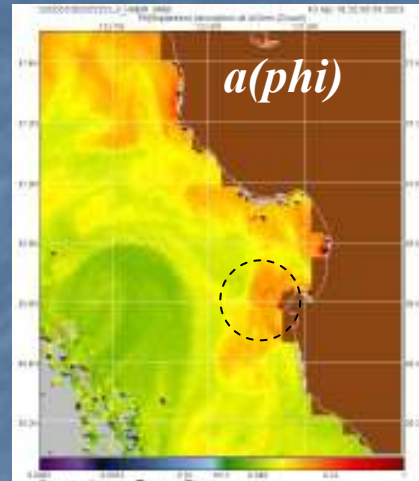
# Recent Advances in Remote Sensing Inherent Optical Properties (IOP)



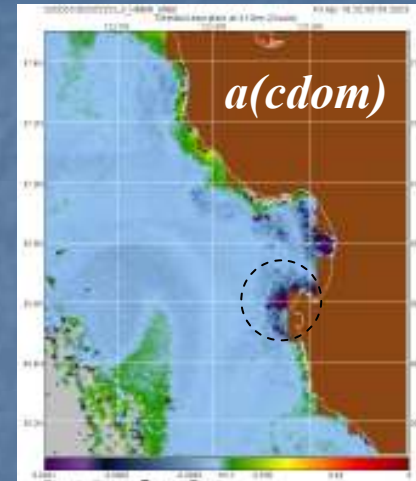
## Monterey Bay – Ocean Color



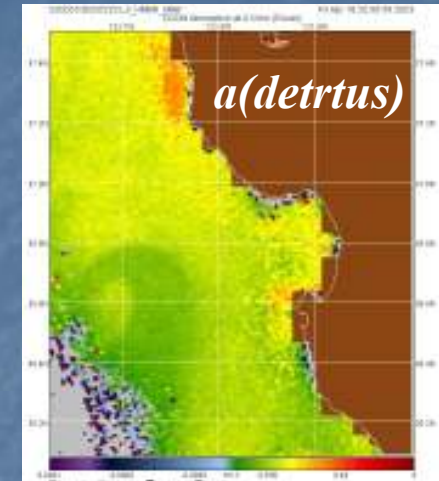
Total Absorption



Phytoplankton



Colored Dissolved Organic Matter

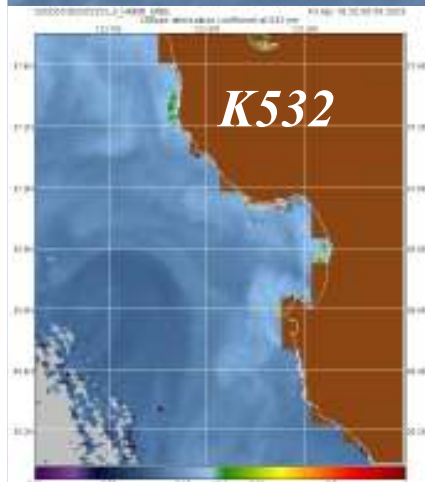


Detrital

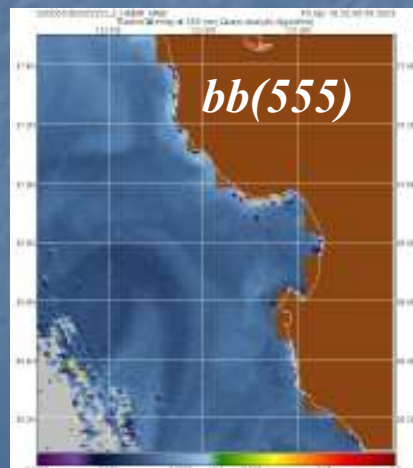
=

+

+



Diffuse Attenuation Coefficient

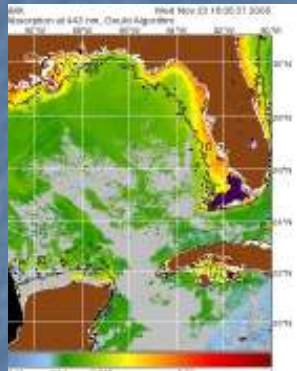
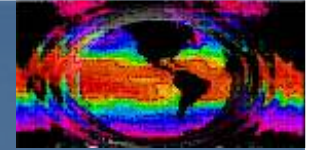


Backscattering (Spectral) - particles distribution

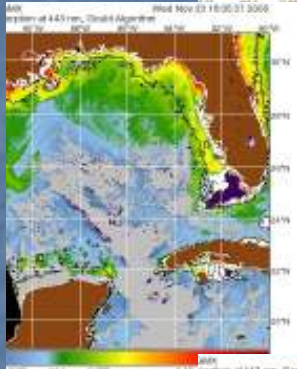
- Uncoupling the Surface Color Signature
- Understanding Coastal Processes require IOP's -
  - Differences represent in-water processes
  - Limitation is “Color” Represents the “near –surface” (first Attenuation Coefficients)
- Rich data sources - available 2+ times day



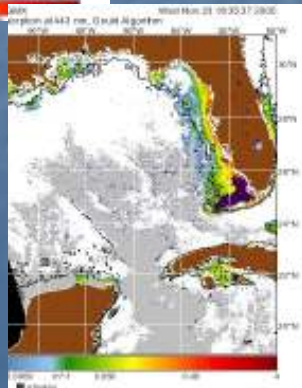
# Identifying Coastal Processes Using IOP – Absorption Budget Water Mass Classification



Phytoplankton Absorption (green)

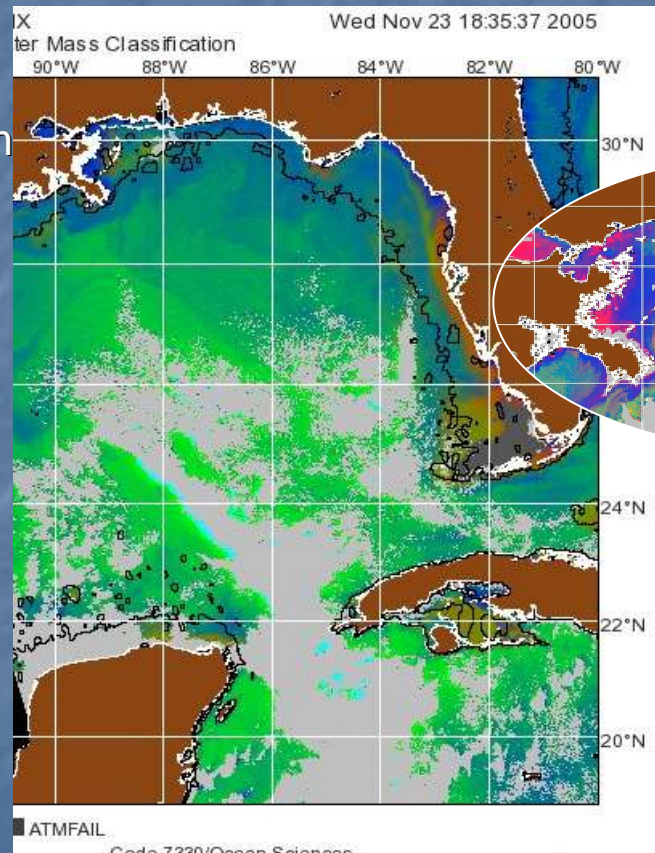


CDOM Absorption (blue)

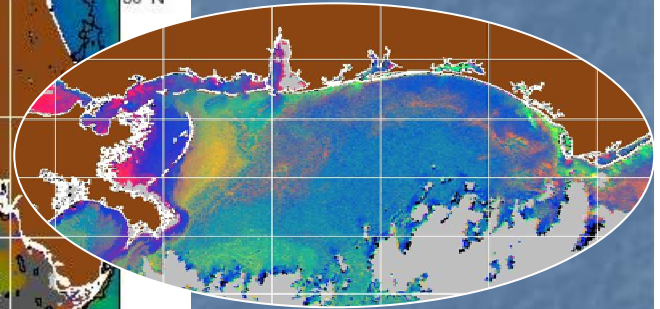


Detrital Absorption (red)

Organic/ Inorganic



Open Ocean and Coastal Water Processes are different



Controlling Absorption Processes  
-CDOM  
-Phytoplankton  
-Detritus

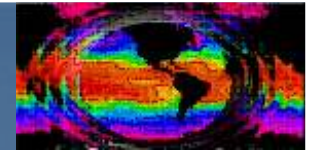
Inputs to bio-physical models

Gould, Green et al.,



# Real Time – Ocean Products

## MODIS Terra and Aqua SeaWIFS, Real Time (3-4 hours)

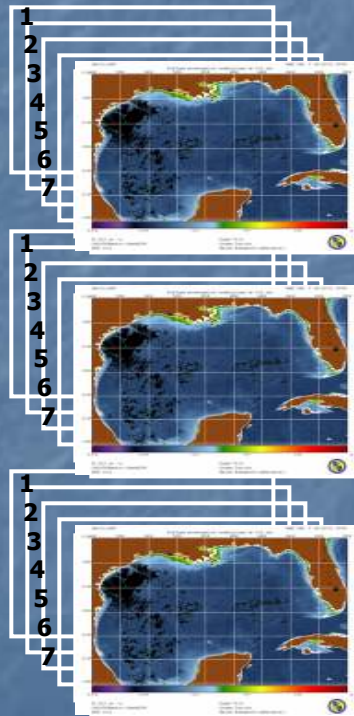
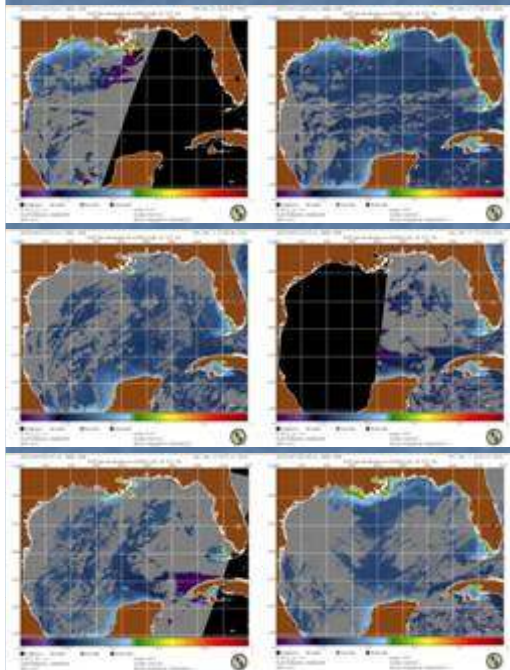


Level 5 Coming

**Level 3**  
Calibrated, Atmospheric Correction,  
Geophysical Product  
Geo-registered,  
**daily composites**  
**1 km resolution**

**Level 4**  
**Latest Pixel Composite**  
**Weekly, Monthly**  
**1 km**

**Level 4**  
**Latest Pixel Composite**  
**Blend**

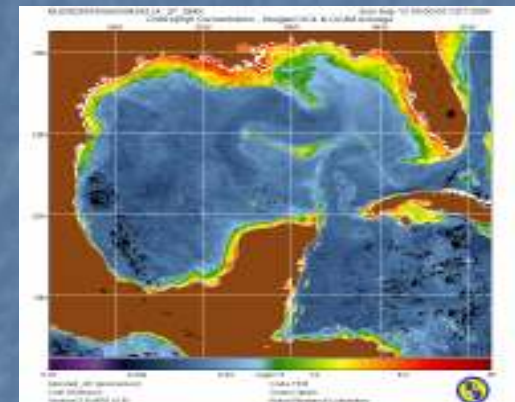


SeaWIFS

Modis Aqua

Modis Terra

Best Image of the day  
"Now cast"



Daily product of the  
Latest Pixels

Chlorophyll  
bb555  
a(cdom) 490  
atotal(490 ....

~170/ day

Chlorophyll  
Absorption  
bb  
K532 , latency ..

~ 35 / day

- > Chlorophyll
- > atotal 443
- > adg
- > bb555
- > aphi
- > sst day
- > sst night

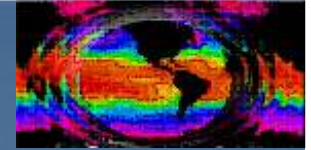
~ 7 day

ReaSon





# Fusing the MODIS products with Circulation Models



## Near Surface Observations:

Time

MODIS – Terra –SST /Ocean Color  
MODIS – Aqua – SST /Ocean Color  
SeaWiFS – Ocean Color  
3+ times / day

## Products

RRS – 412, 443,490,510,555,670	K532,
<b>Chlorophyll</b> (OC4, Carder)	<b>absorption</b> (total, $\lambda$ ) (A, C,QAA)
aphi443 (Carder, OAA, Gould, Stumpf)	adg412 (Carder, QAA, Stumpf)
adg443(Carder, QAA,)	ad412 (Gould)
acdom (Gould)	<b>bb555</b> (Arnone, Carder, QAA)
C555 (carder, Arnone, QAA)	c670 (Carder)
Horizontal Vis (QAA, Arnone)	Vertical Vis (QAA, Arnone)
Particulate Organic matter	Particulate Inorganic Matter (Gould)
Total Sus Sed (Gould)	Water Mass (Gould)
Cloud Albedo	L2 Flags
<b>True Color</b>	
250M – True Color	c670 (G&A)

## **SST**

Physical Ocean Models –  
Navy Coastal Ocean Models (NCOM)

## Products

- salinity, temperature, density
- velocity (u,v), Sea Surface Height

## - Nowcast – 12, 24 ,48 hour forecast

Dong Ko et al

- Resolution 6 km
- 41 hybrid sigma/z levels
- River fluxes (non-real time)
- Driven by wind fields and heat fluxes

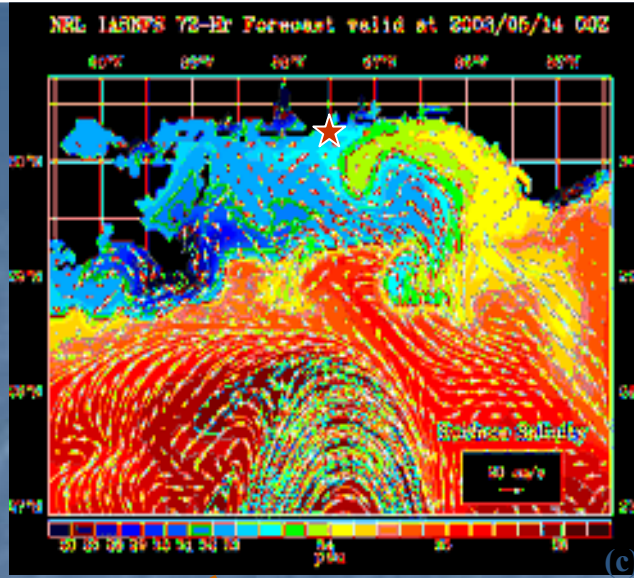
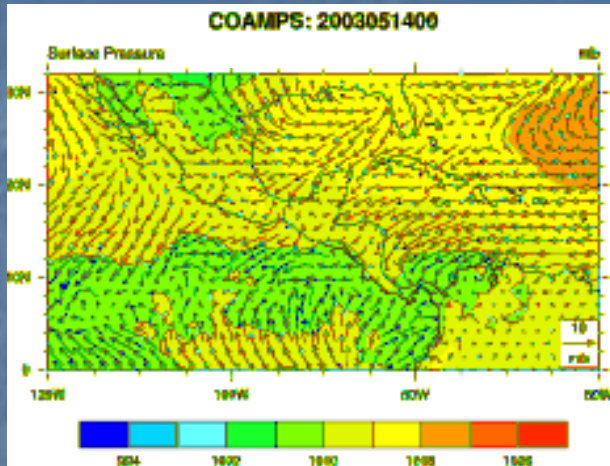
Assimilation

Altimetry SSH  
SST – (9 km) (MODIS 1km)  
Synthetic BT (MODAS)

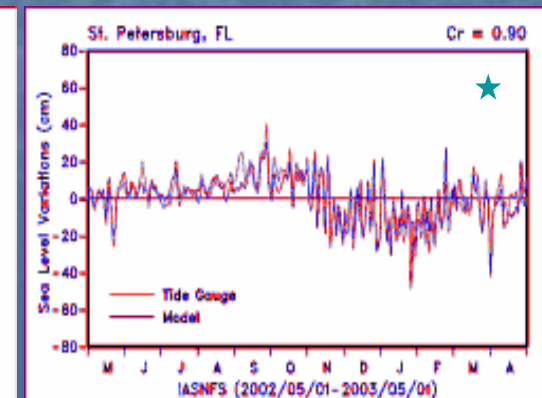
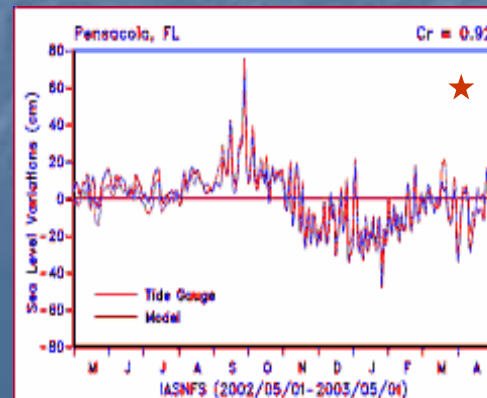
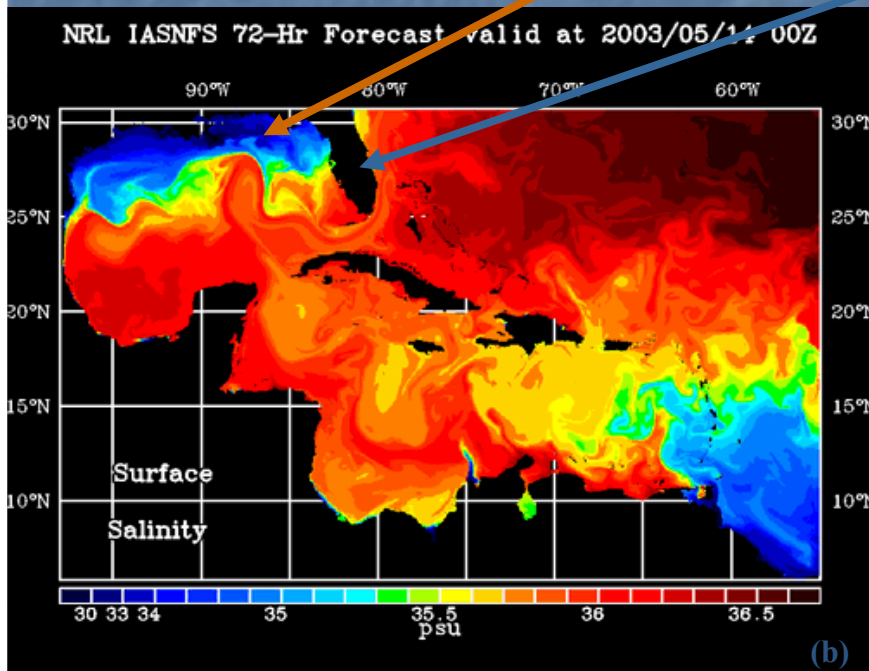
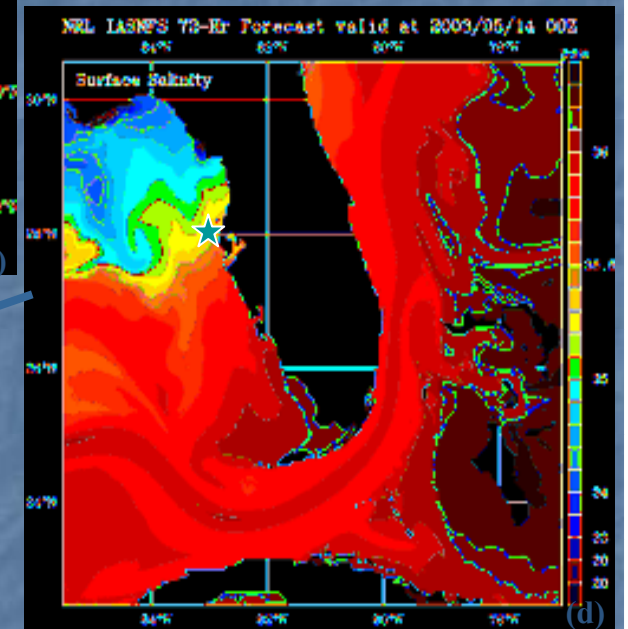
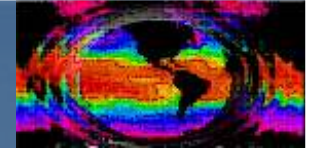
Forced by COAMPS



# Coastal Forecasting

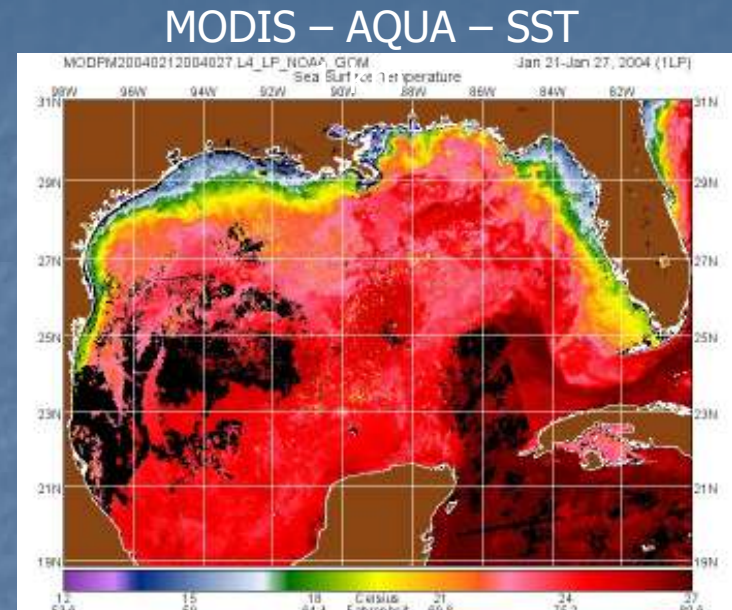
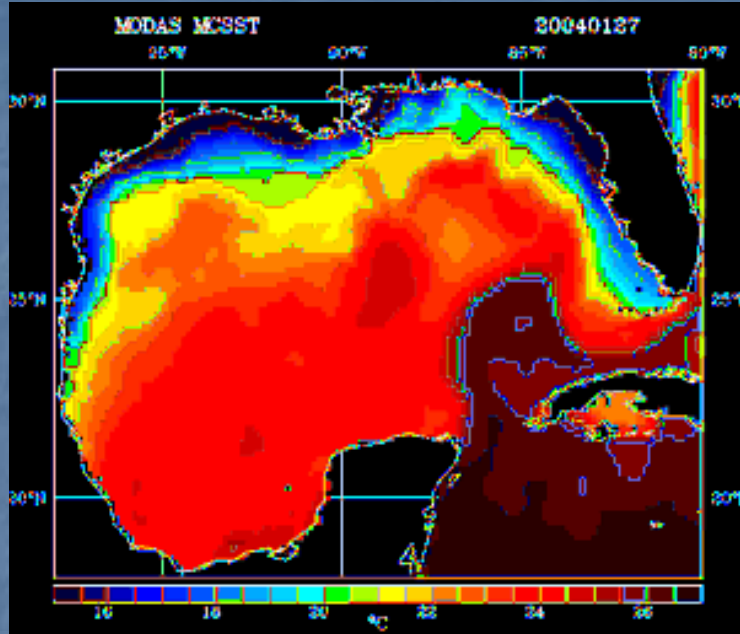
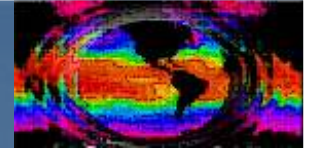


## Intra-Americas Sea Nowcast/Forecast System





# Assimilation of SST into Navy Coastal Ocean Model

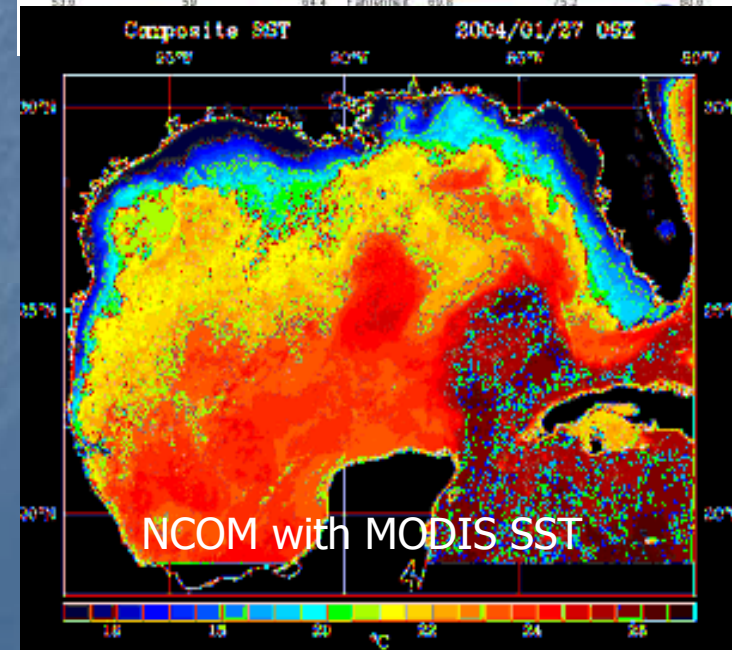


Currently Uses – 9 km Global SST (AVHRR)  
NAVOCEANO

Existing NCOM Model SST Field

Intra-American Sea Forecasting System

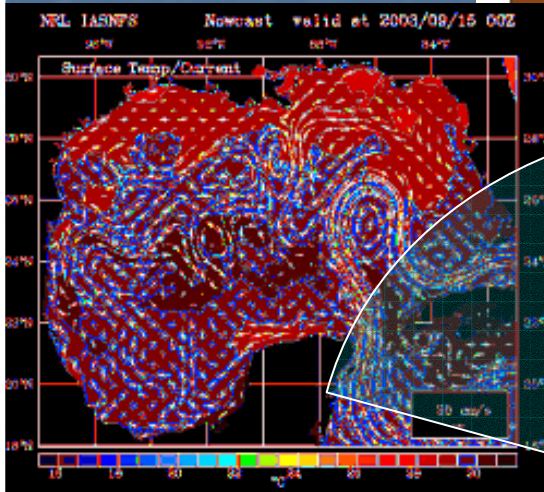
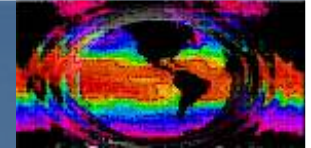
Improved NCOM Model in coastal  
areas , resolves the fine scales  
Coastal features.



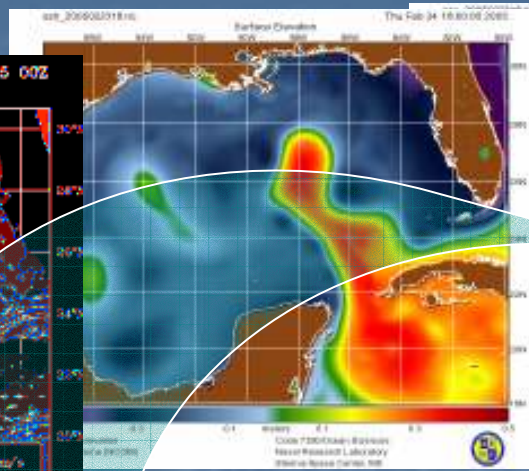




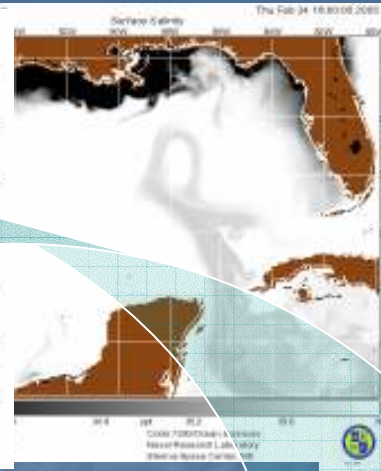
# Fusing the Satellite Optical Products and Physical Models



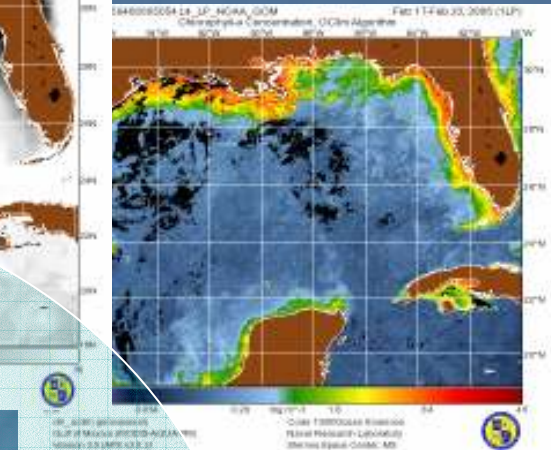
Currents – NCOM  
“Intra Americas Seas”



SSH- NCOM

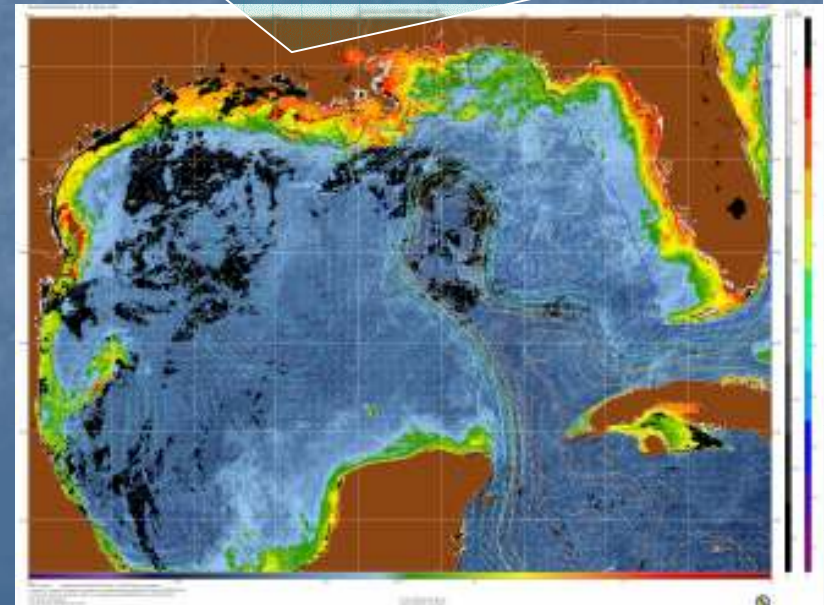


Salinity



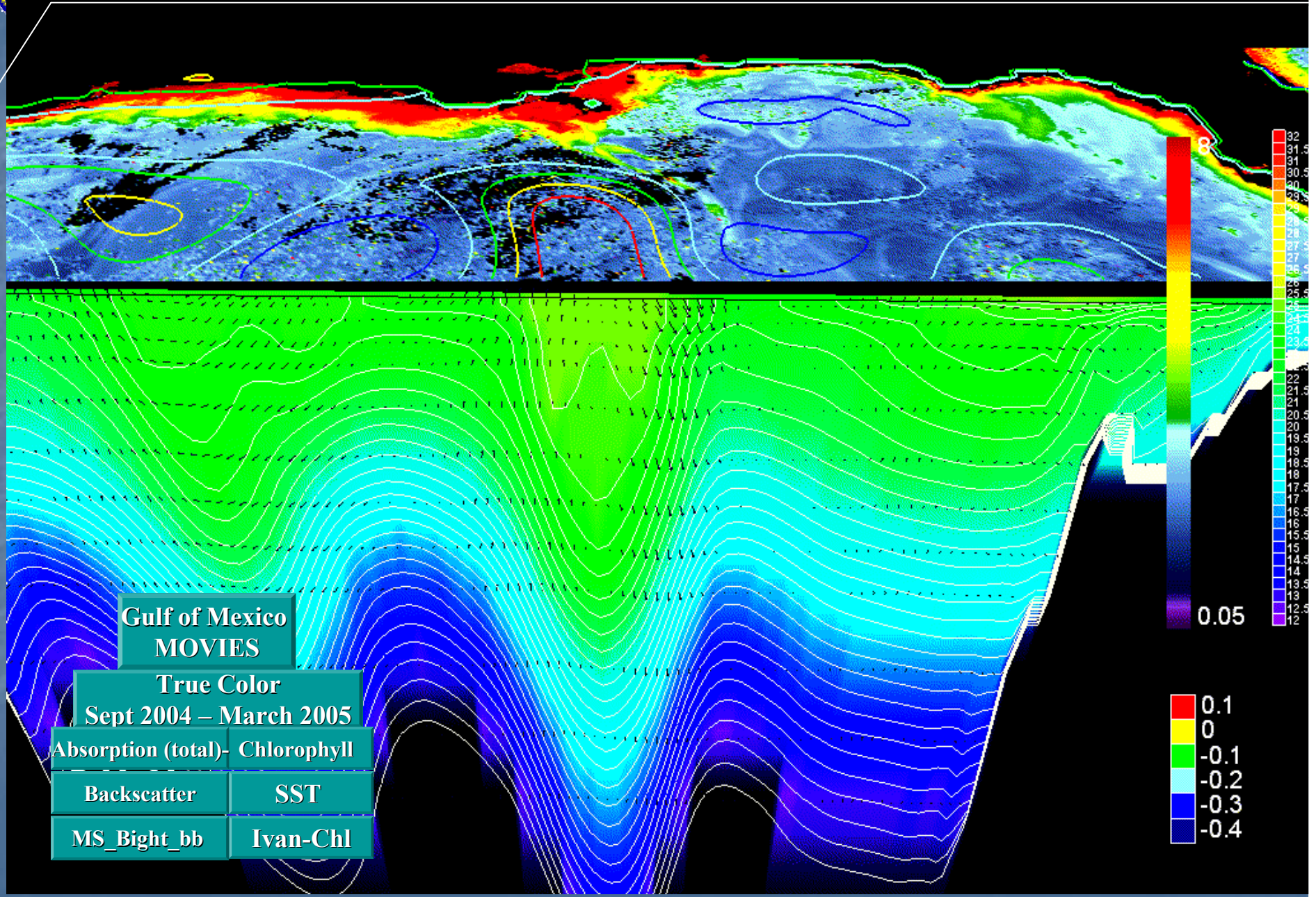
SeaWiFS, MODIS Chlorophyll  
Absorption, Scattering, Diver visibility etc

- Automated Scripts to generate combined
- Remote sensing and model regional products
- Pre-operational at NRL – “Real time Room”
- Integrated with NASA and NOAA





March 19, 2002 - 00:00



**Gulf of Mexico  
MOVIES**

**True Color  
Sept 2004 – March 2005**

**Absorption (total)- Chlorophyll**

**Backscatter SST**

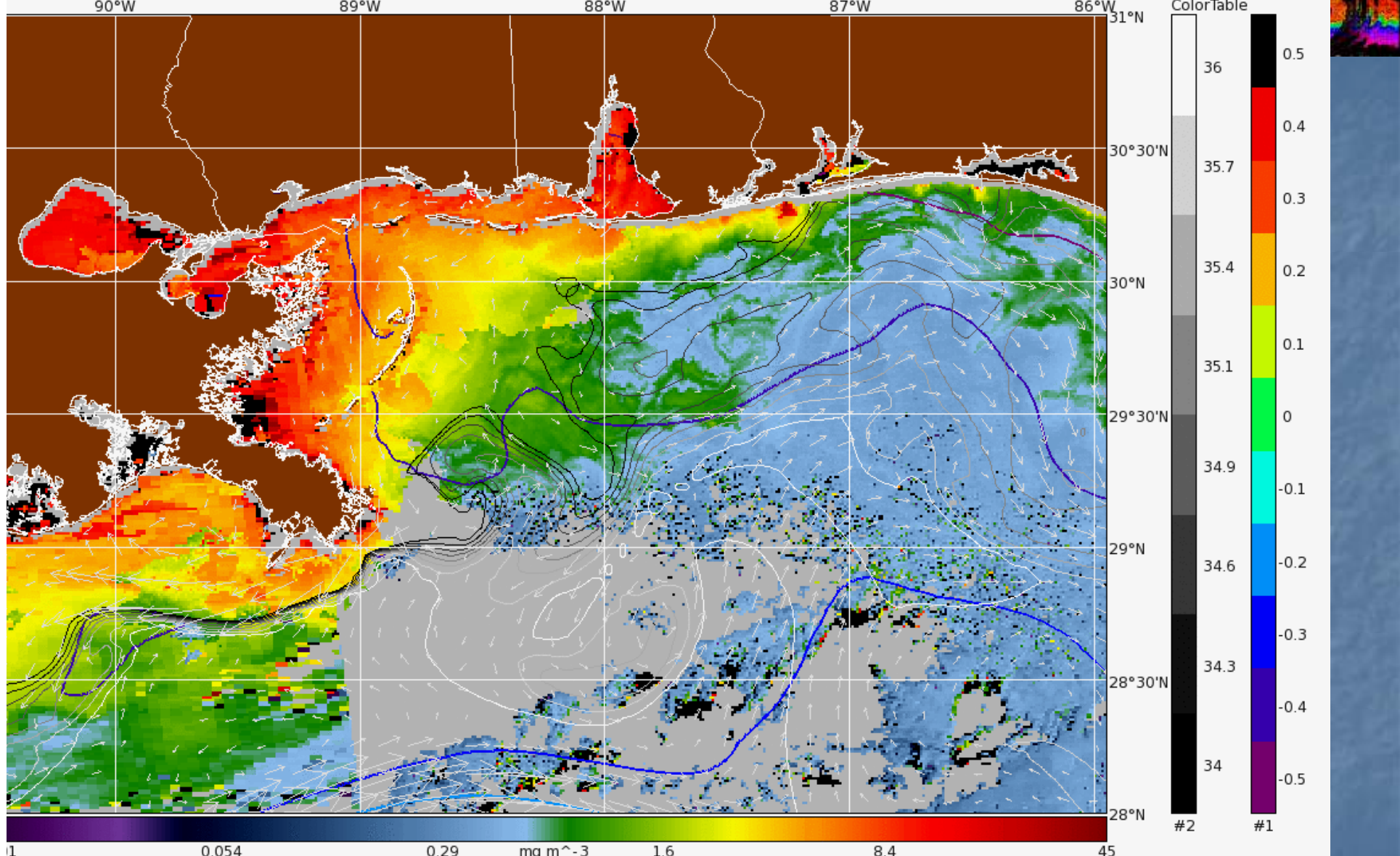
**MS\_Bight\_bb Ivan-Chl**

0.1  
0  
-0.1  
-0.2  
-0.3  
-0.4

MODPM20053492005355.L4\_LP\_NOAA\_GMX  
MODPM20053492005355.L4\_LP\_NOAA\_GMX

Chlorophyll-a Concentration, OC3m Algorithm

Dec 15-Dec 21, 2005 (1LP)  
Dec 15-Dec 21, 2005 (1LP)



1 0.054 0.29 mg m<sup>-3</sup> 1.6 8.4 45  
HIGHLINT CLDICE LAND ATMFAIL  
0.3 m/s /projects/reason/IASNFS/2D/ssu\_2005122118.nc, timestep 0  
Contour #1: Surface\_Elevation in meters from /projects/reason/IASNFS/2D/ssh\_2005122118.nc  
Contour #2: Surface\_Salinity in ppt from /projects/reason/IASNFS/2D/sss\_2005122118.nc  
:hl\_oc3m (provisional) Code 7330/Ocean Sciences  
Gulf Of Mexico (MODIS-AQUA-PM) Naval Research Laboratory  
Version 3.0 (APS v3.0.5) Stennis Space Center, MS





## MODIS 250 meter Coastal Processing

### Processing: (Being upgraded)

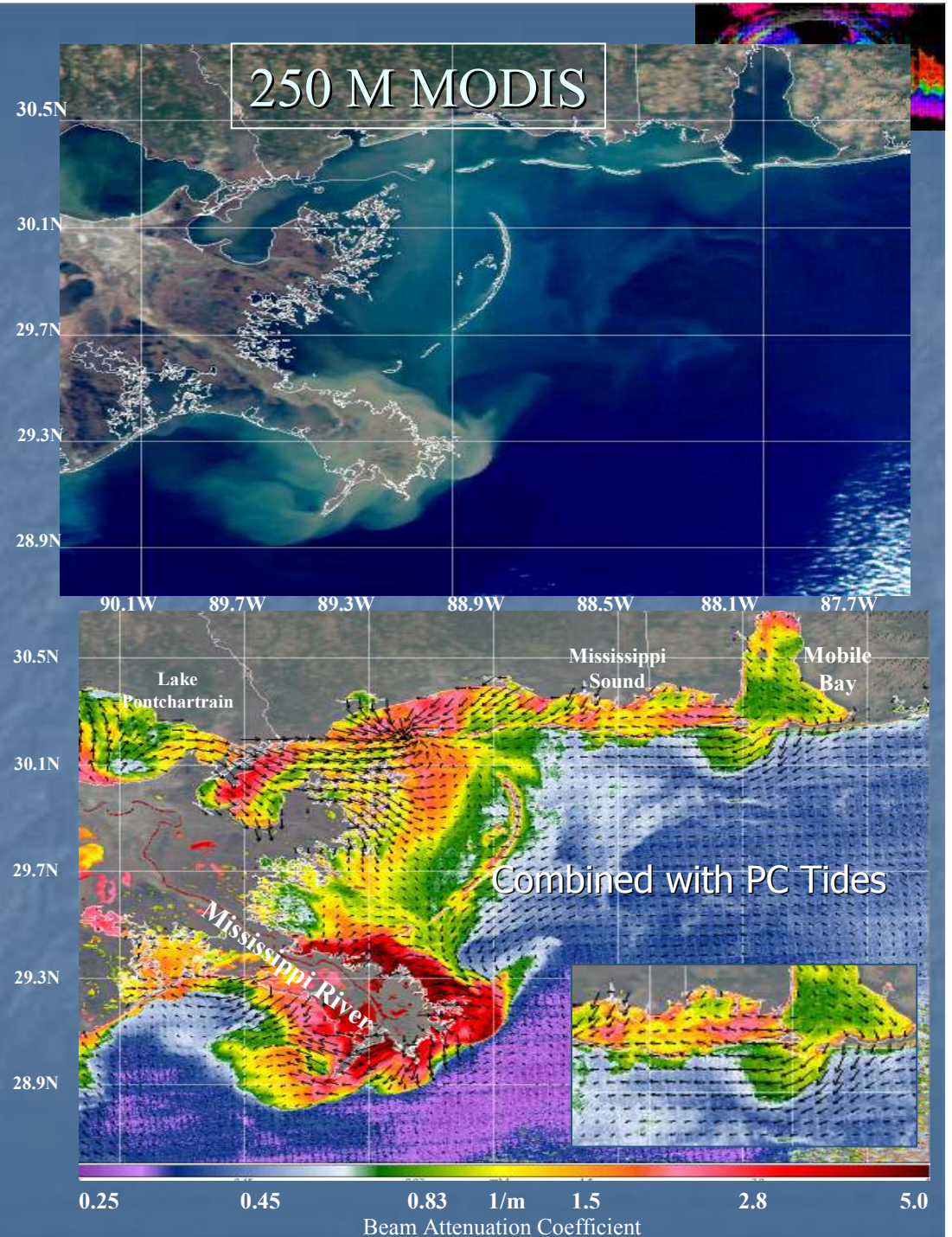
- L0 → L1B: MCST Calibration performed by Goddard DAAC or HRPT stations.
- Raleigh Correction:
- Atmospheric Correction:
- Cloud Detection:
- Land Detection:

NDVI Threshold or land mask

### Ocean Products:

- Beam Attenuation (c645):
  - Gould/Arnone algorithm.

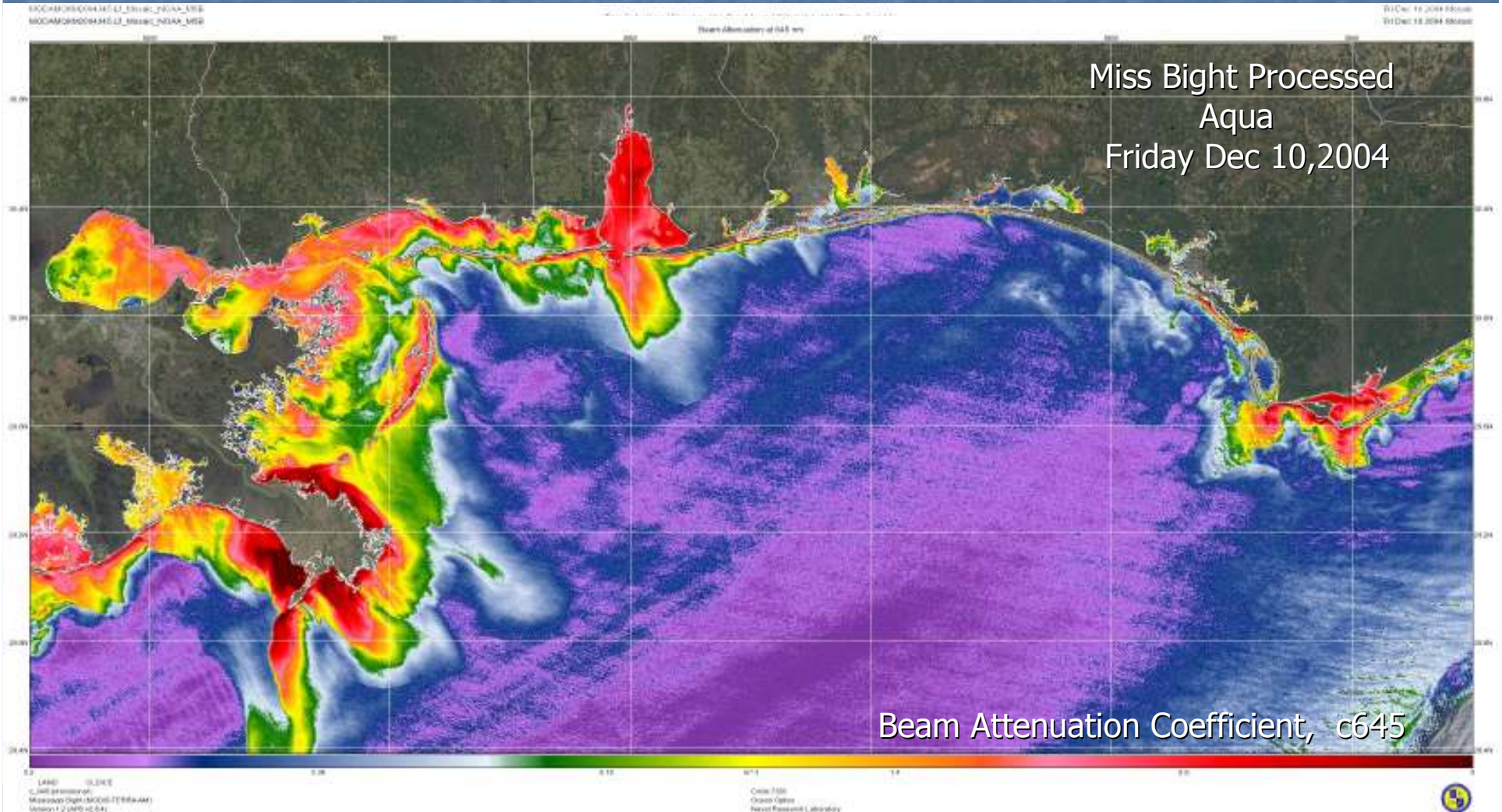
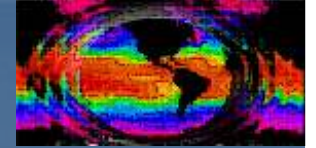
SeaDAS Processing Software





250 M MODIS – Terra –  
Rayleigh corrected  
and Edge sharpening

Extracting Quantitative  
Ocean Properties In Coastal regions  
Monitoring Estuaries and Harbors

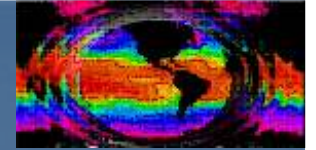




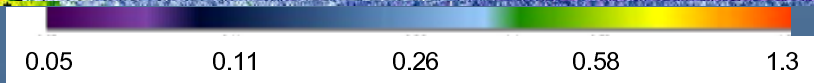
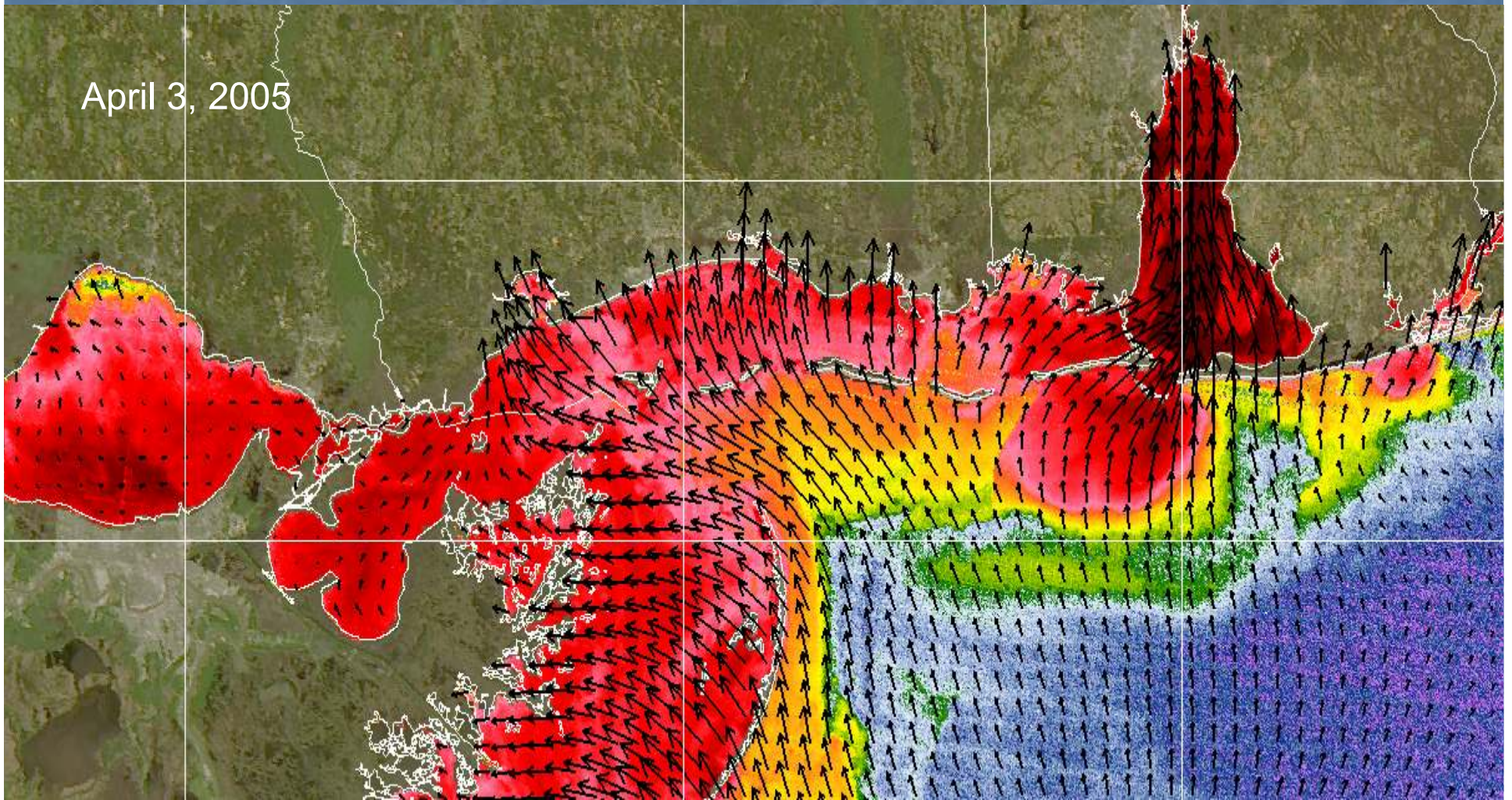
# Monitoring Coastal Optics

## Tidal responses to the "Beam Attenuation Coefficient"

- Note the Consistent between the products



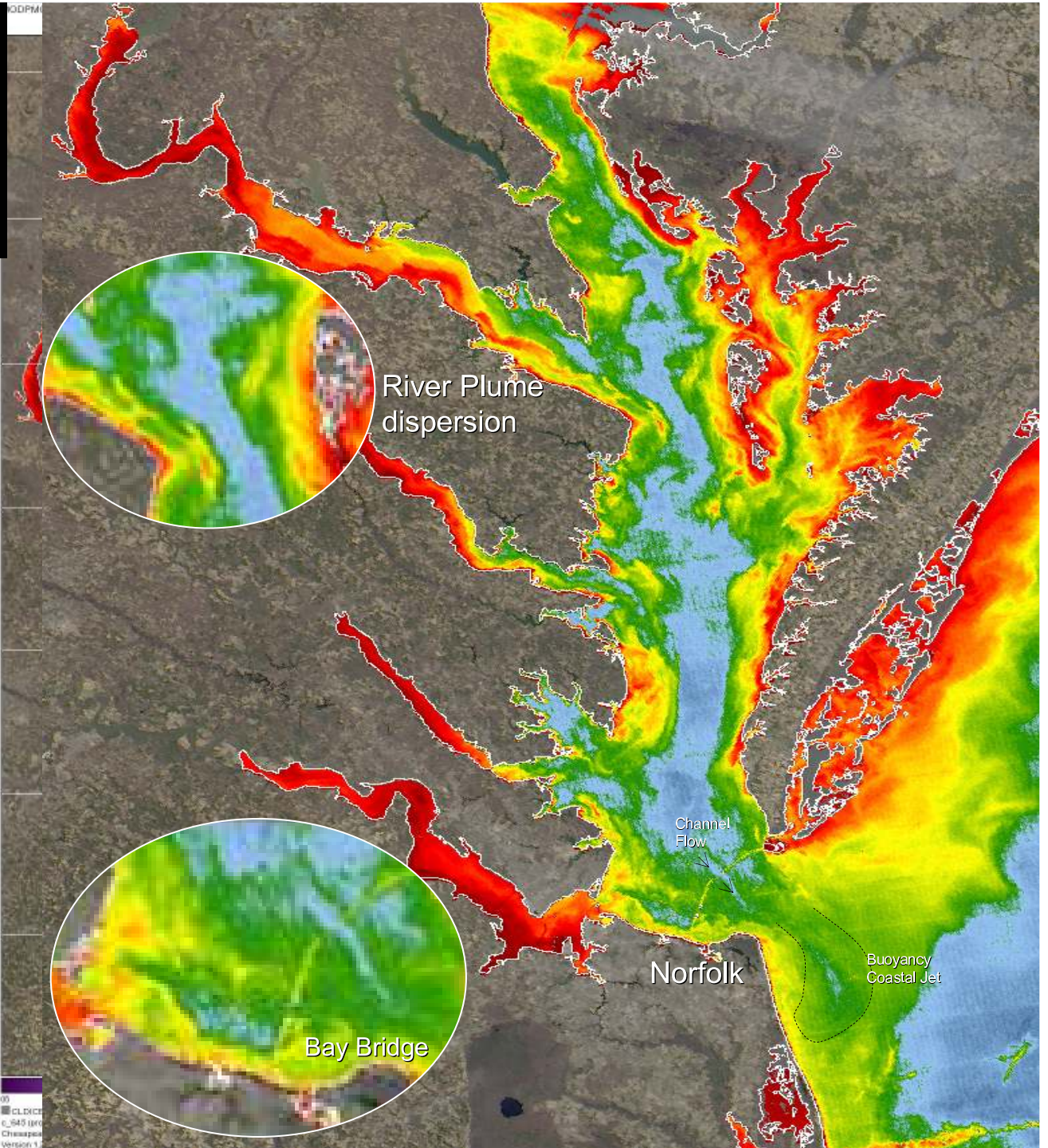
April 3, 2005



Beam Attenuation Coefficient

**Comparison of Spatial resolutions Chesapeake Bay  
March 13, 2004  
Monitoring the Estuarine and Riverine Environment**

New Capabilities for  
Managing Coastal Resources

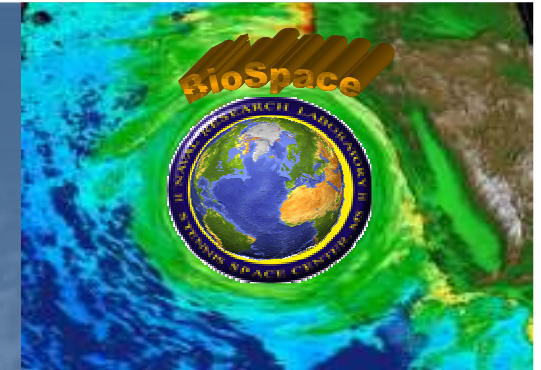


(Franz, McClain, Martinolich, Casey)





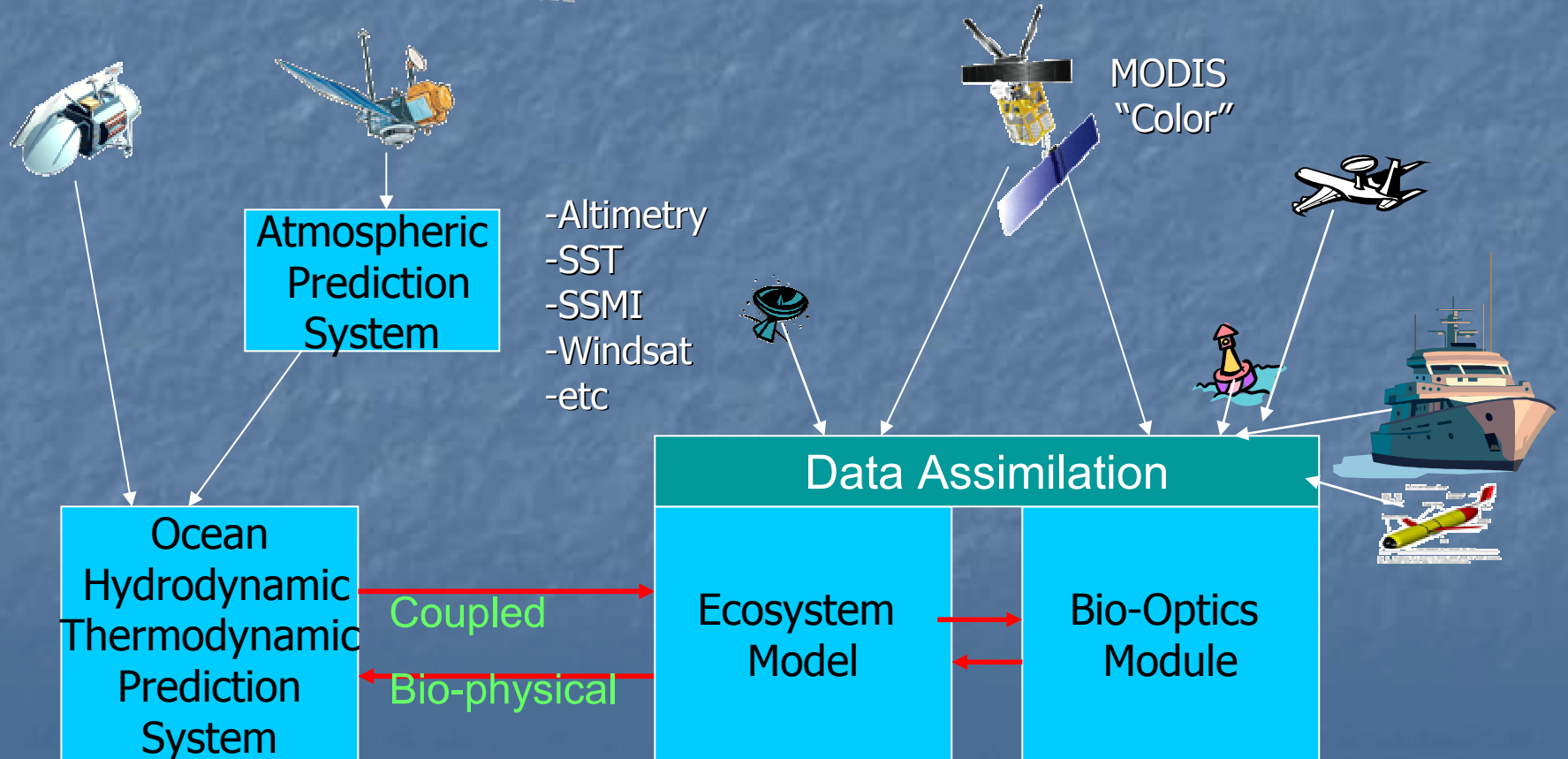
# West Coast – Bio-Optical Models



Goal: Real-time Coupled Ocean Prediction Systems

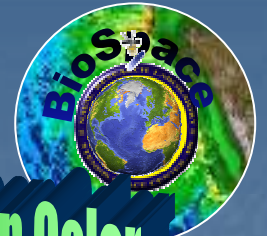
## Remote Sensing-Physical

## Remote Sensing: Bio-optical





# Satellite Derived Light Field



Remote Sensing: Ocean Color

MODIS

Processing

Inherent Optical Properties (IOP)

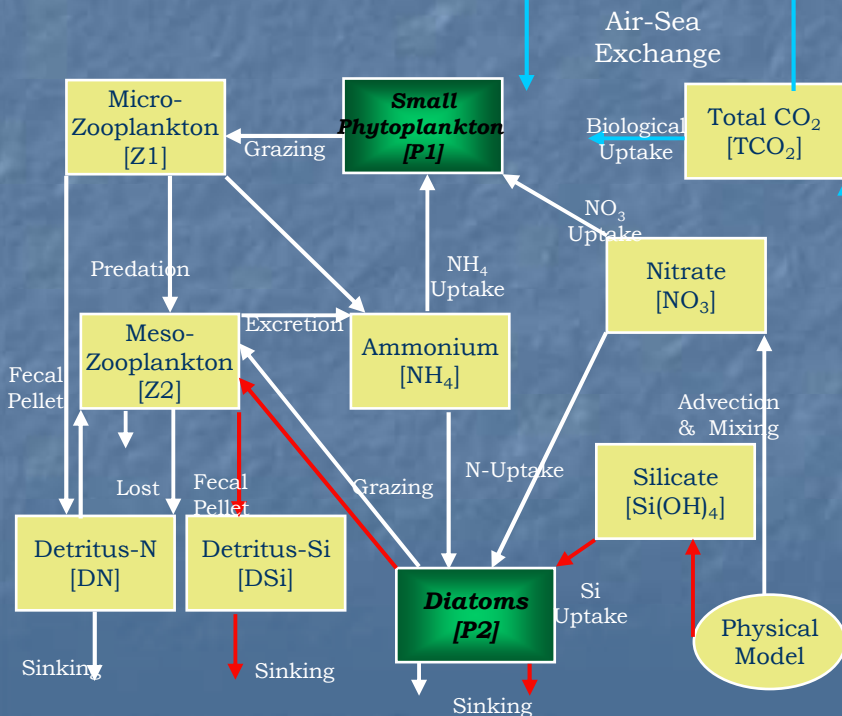
3-d light field

Optical Model  
Hydrolight/  
Ecolight/  
Lee\_et\_al (2005)

Surface Light

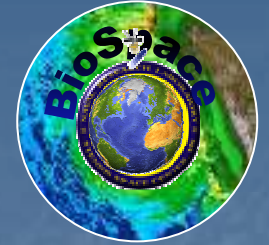
Constraining Ecosystem Models with  
Inherent Optical Properties

*Physical-Biogeochemical Model: Fei Chai*

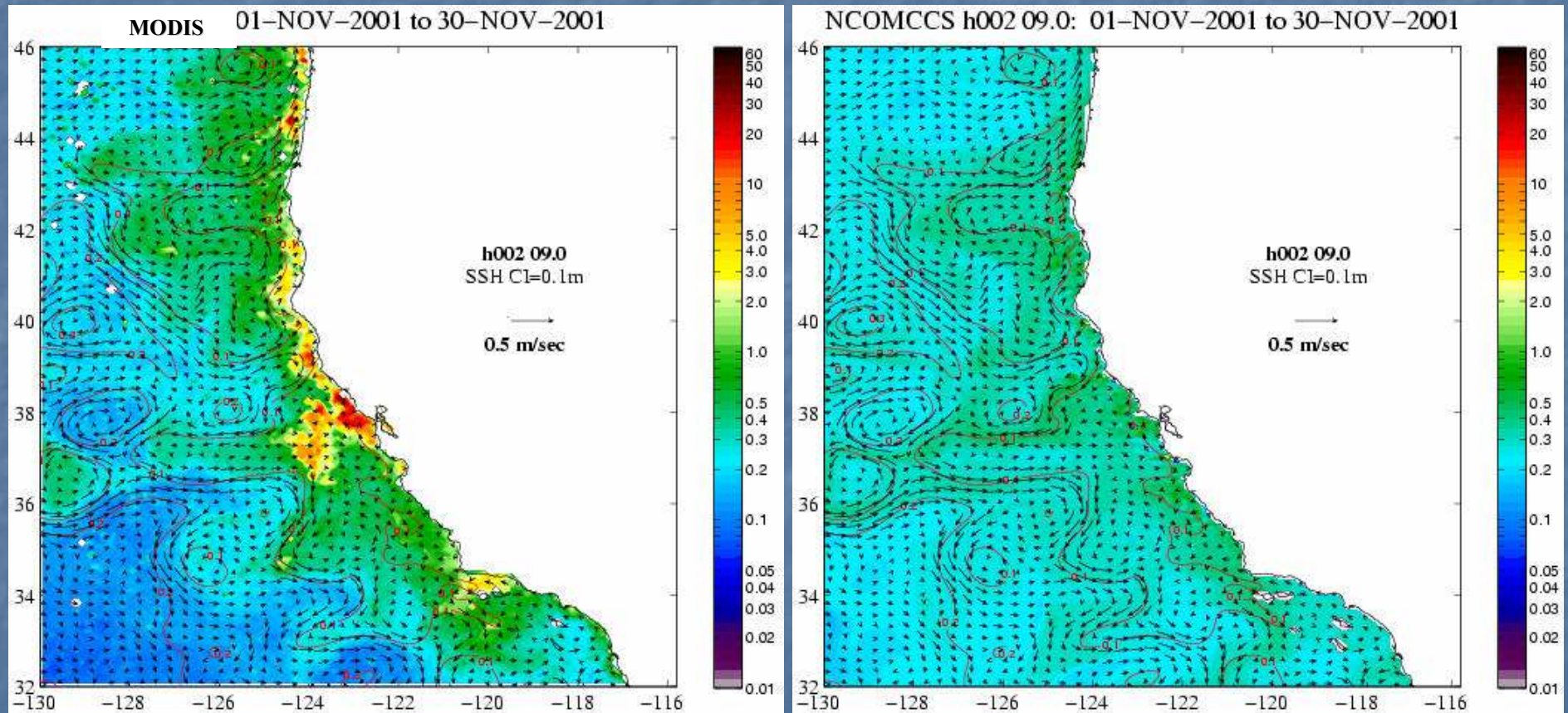




# Biological Model Simulations vs. Satellite Chlorophyll



Combined Small and Large Phytoplankton within  
satellite optical depth ( $1/e$ )

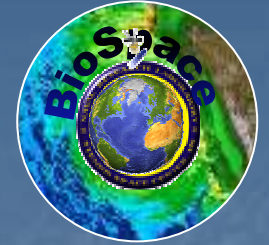


MODIS Chlorophyll

Model Chlorophyll



# Model Simulations vs. MODIS IOP

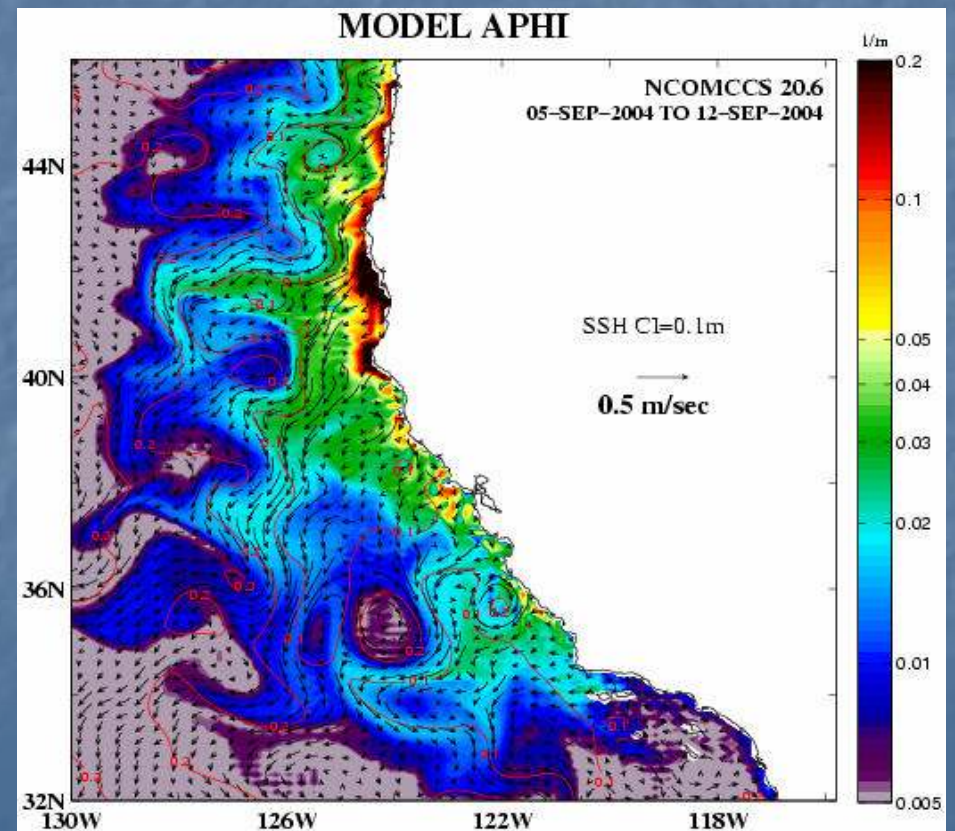
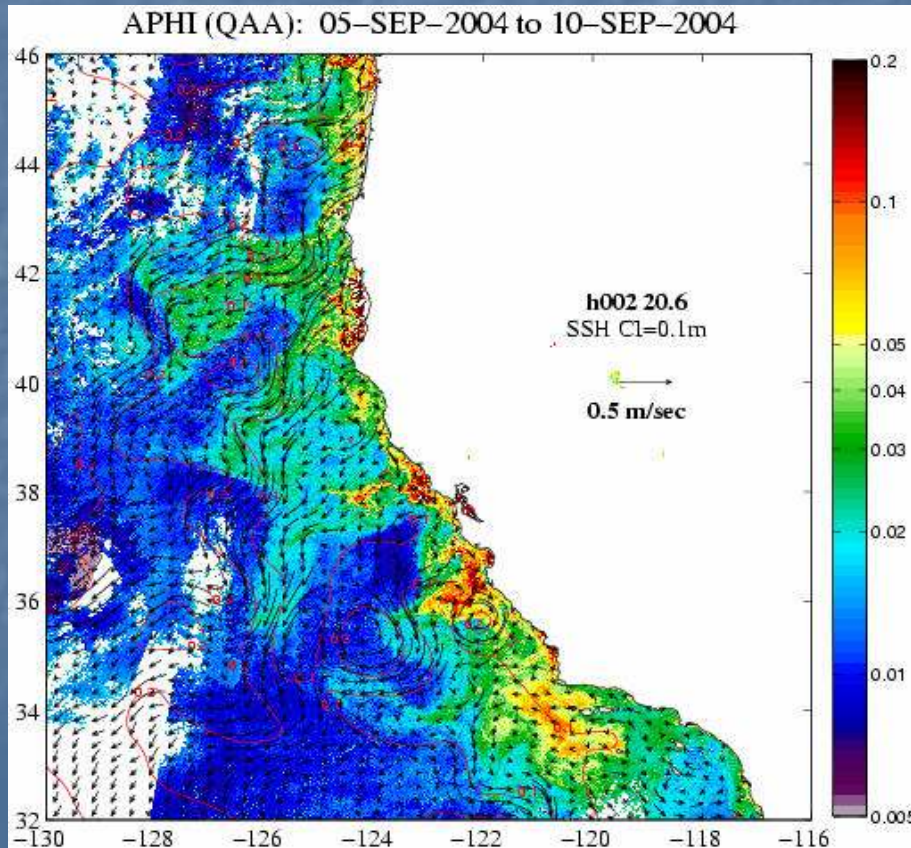


## Phytoplankton Absorption ( $a_{\text{Phi}}$ )

Differences in Magnitudes require “constraining” the ecosystem models with the IOP

NCOM with  $a_{\text{Phi}}$  from MODIS

NCOM with Model  $a_{\text{Phi}}$

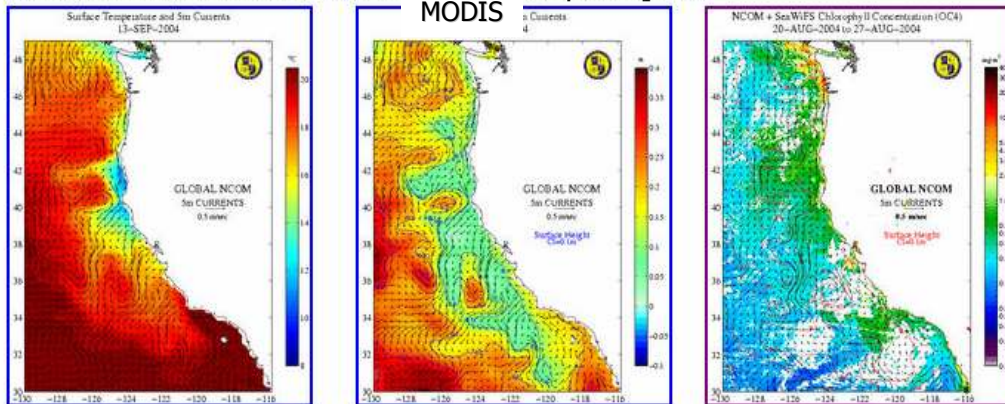


Lee et al., (QAA), Kindle et al.,

## Near Real-Time Depiction of the California Current System: RECENT IMAGES

Today is Monday, September 13.

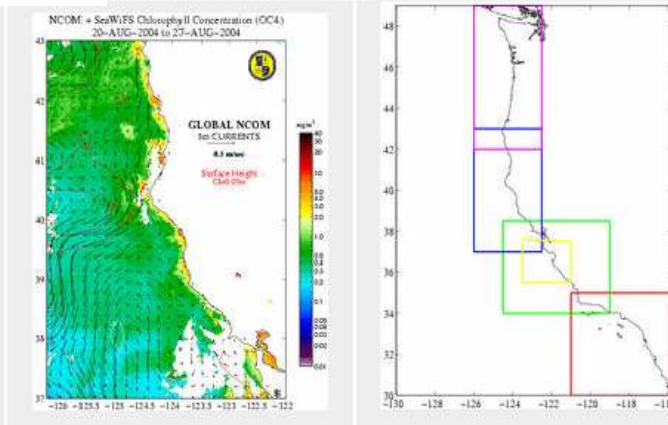
### Global NCOM Model Results and MODIS 5-Day Composite



### Coastal Regions: NCOM + MODIS

- [Washington/Oregon](#)
- [Northern California](#)
- [Central California](#)
- [Southern California](#)
- [Monterey Bay](#)

Real Time  
Web page



Back to [Near Real-Time Depiction of the California Current System Homepage](#)

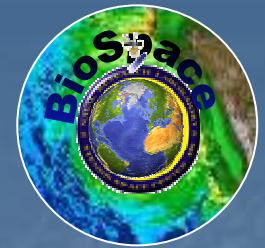
### ARCHIVED IMAGES



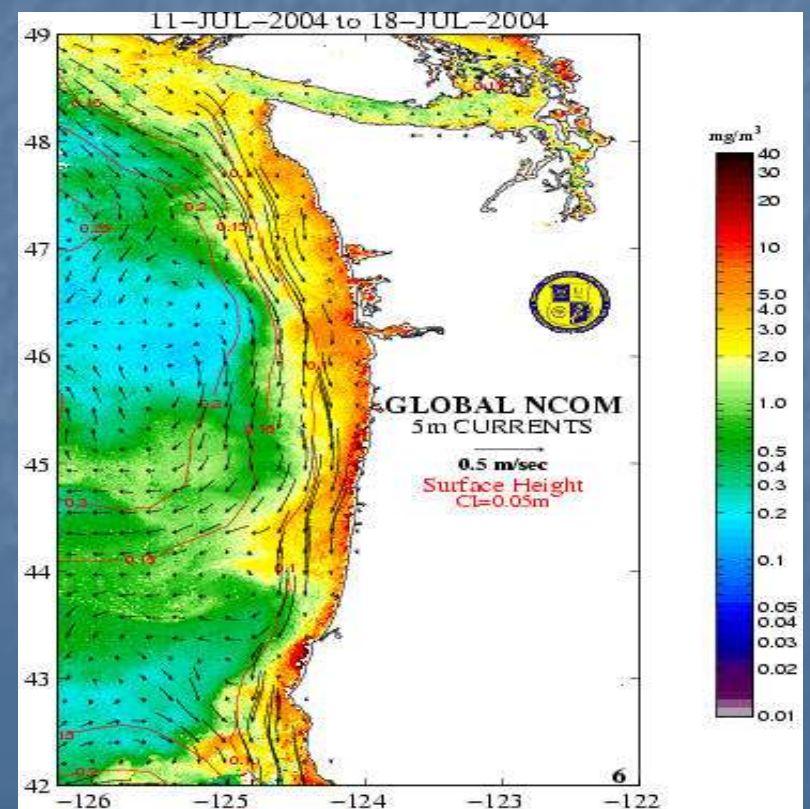
Point of Contact

Project Principal Investigator - [Dr. John Kindle](#)

Send questions and comments to: [Webmaster](#)

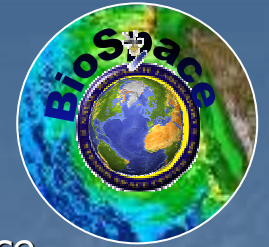


## Real time Updates of Biological Models And MODIS Ocean Products Large and Fine Scales



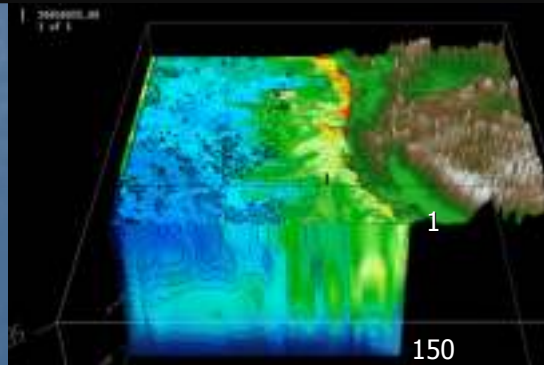
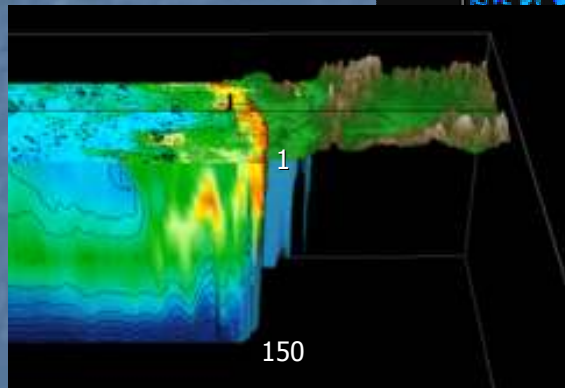
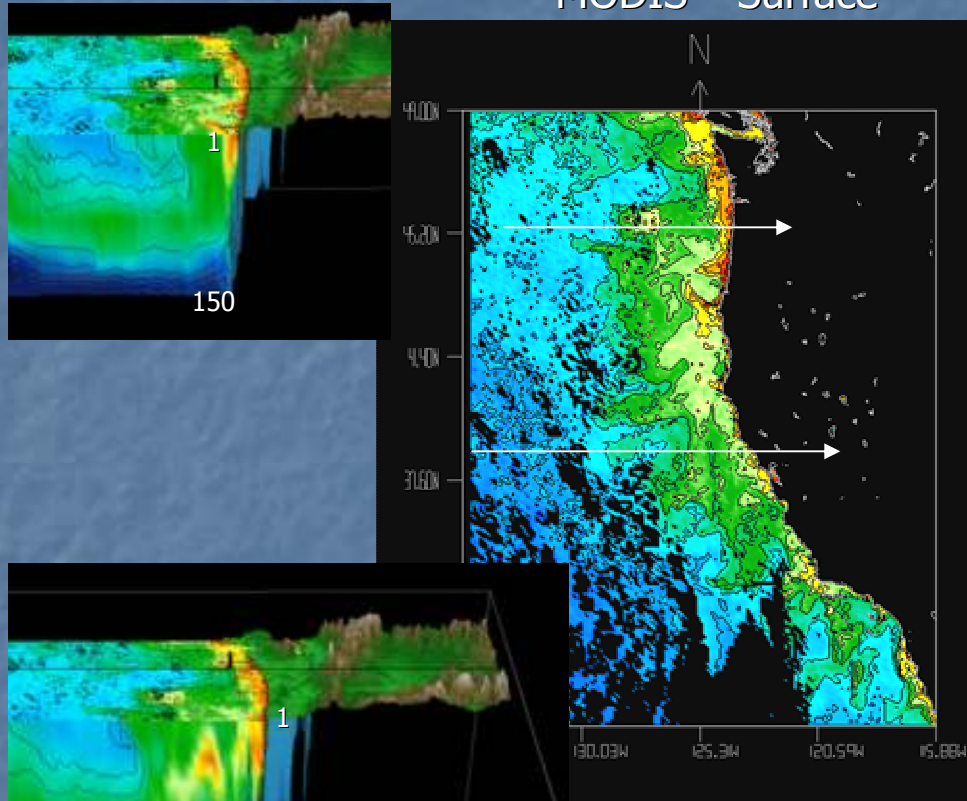


# Looking below the Surface Satellite Ocean Color Combining the Biological Model with MODIS Surface Chlorophyll



MODIS – Surface

Model – Surface



*Subsurface Chlorophyll  
Light Field  
West Coast*

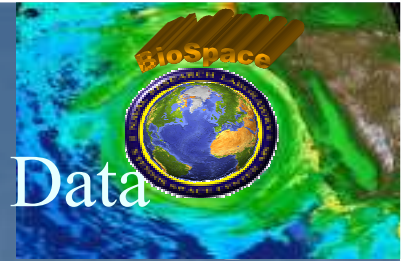
West Coast  
3d-Chlorophyll

Monterey Bay  
MODIS  
3d-Chlorophyll

Courtesy of Penta and Kindle



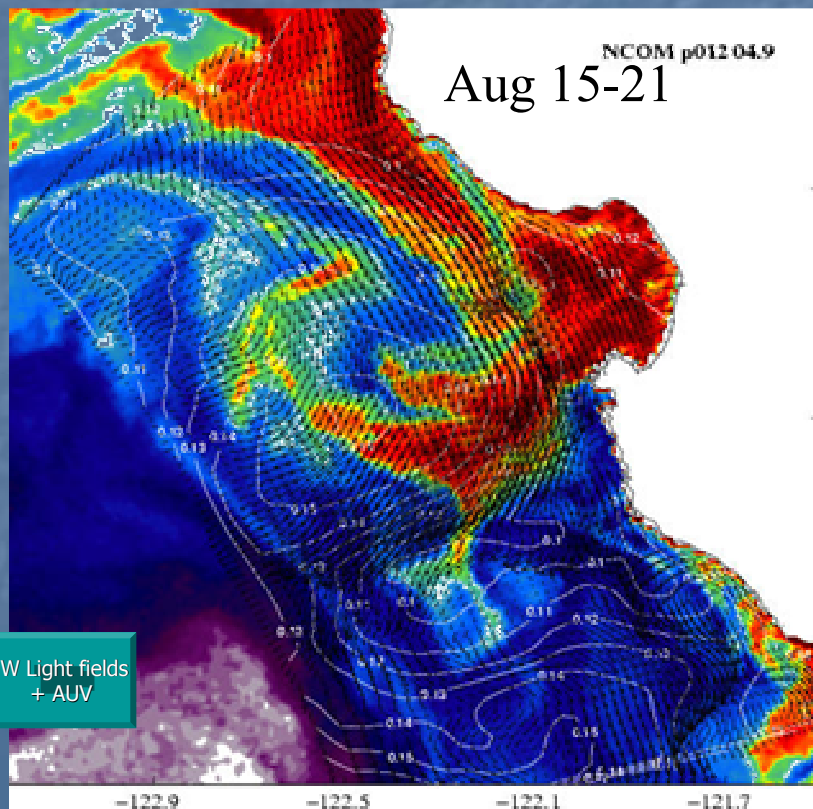
# Coastal Modeling at Fine Scales Requires Joint Assimilation of Physical & Bio-Optical Data



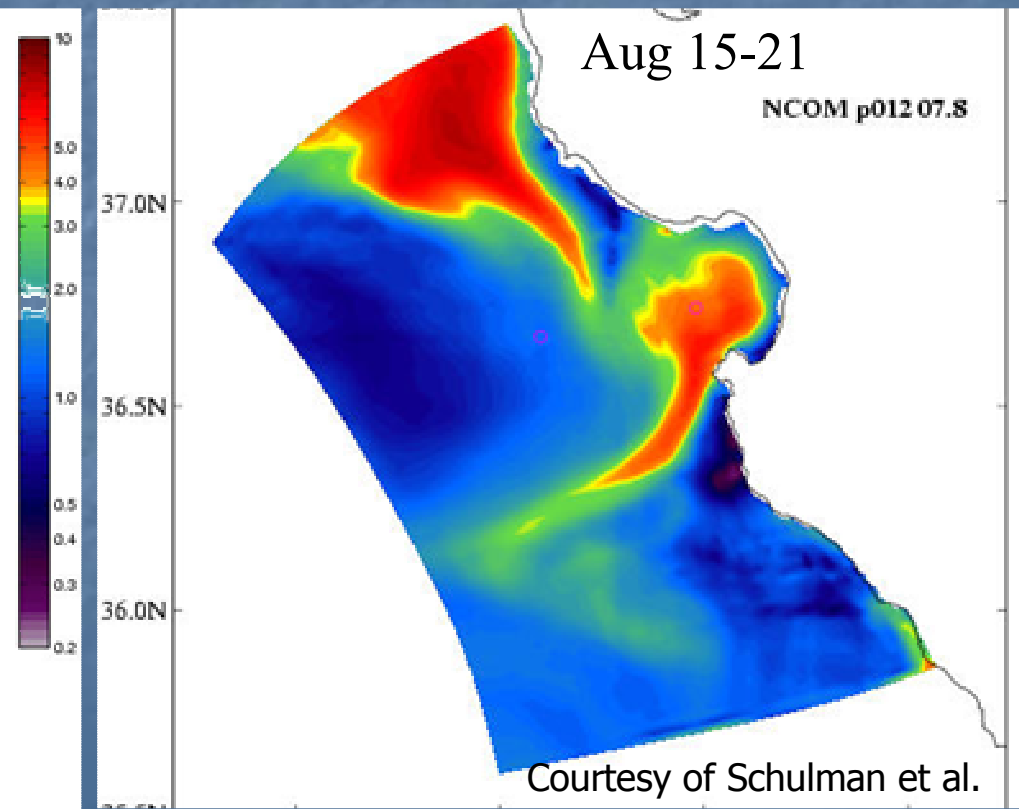
- Satellite Observations: Ocean Color, SST, Altimeter, SAR

MODIS – IOP products

→ HF Surface Radar Currents → Autonomous Platforms, → Moorings



**MODIS Observed Chlorophyll**

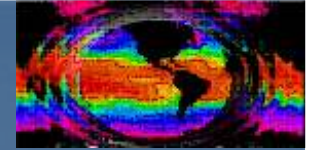


**Predicted Model Chlorophyll**

Courtesy of Schulman et al.



# “ Forecasting Ocean Properties using MODIS Products ”



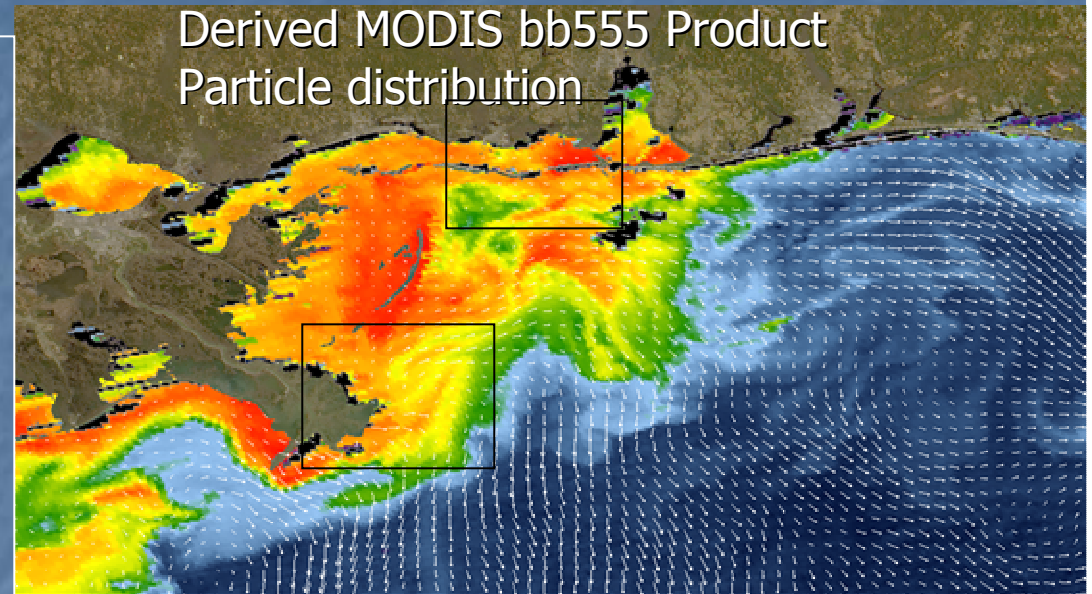
## “Particle Tracking”

### Applications :

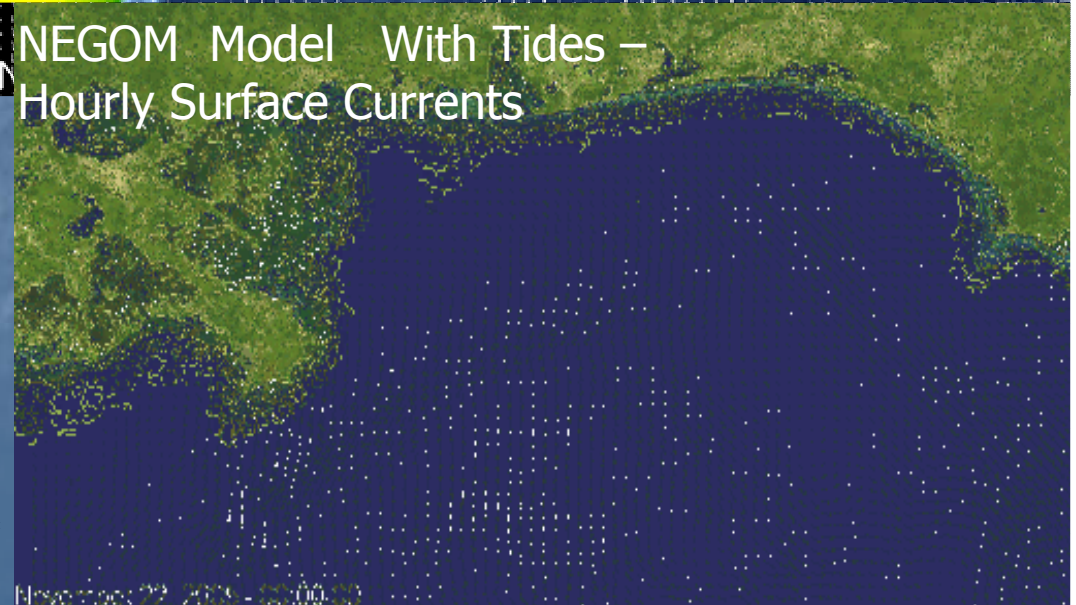
Movements of Different River Plumes  
Movements of Harmful Algal Blooms  
Dispersion Coastal Jets

How physical processes affect Ocean Color.

Define the Chlorophyll Blooms or Color response.



NEGOM Model With Tides –  
Hourly Surface Currents



### Chlorophyll

Different from  
Particle Backscattering

**Preliminary  
Under Development**

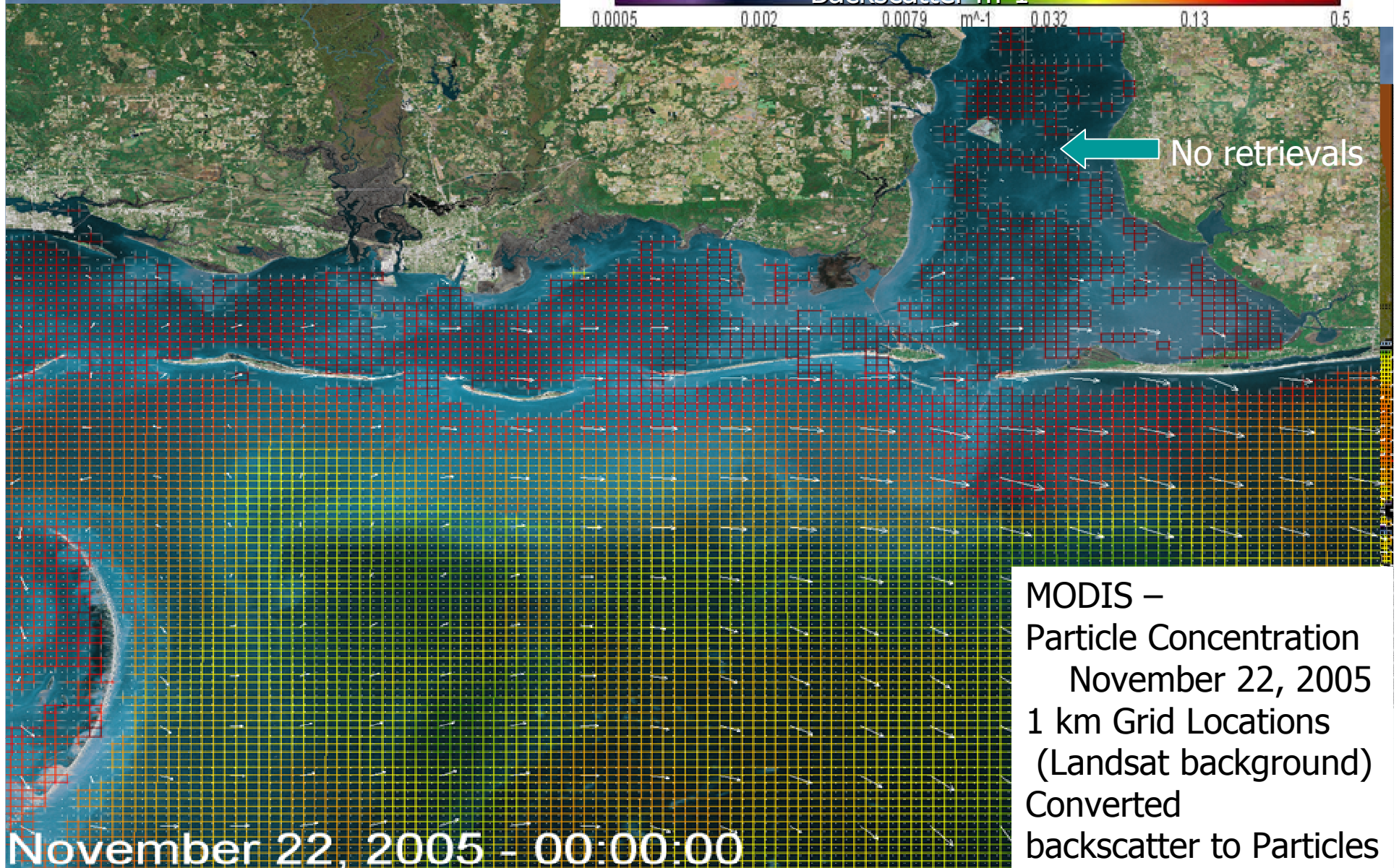
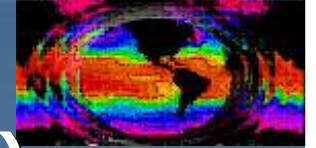
Courtesy of:  
Flynn, Parsons, Zimmer, Scott, Peggion

November 27, 2004 - 05:00:00





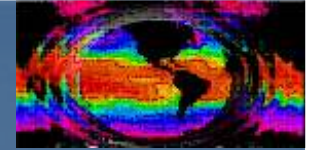
# Develop the particle field from the Backscatter image. (Particle Concentration)



MODIS –  
Particle Concentration  
November 22, 2005  
1 km Grid Locations  
(Landsat background)  
Converted  
backscatter to Particles



# Forecasting Satellite Imagery



Seed the Model  
with Particles from MODIS  
Nov 22 2005,

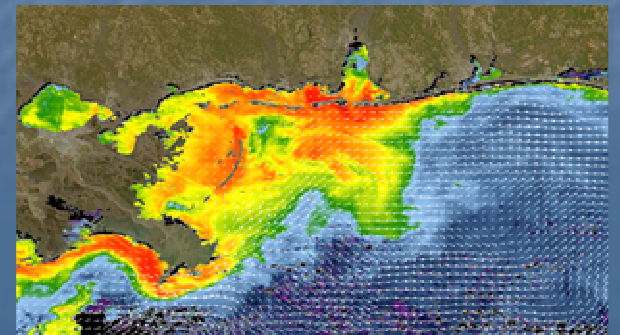
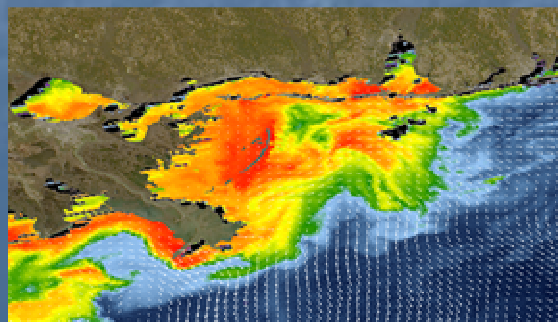
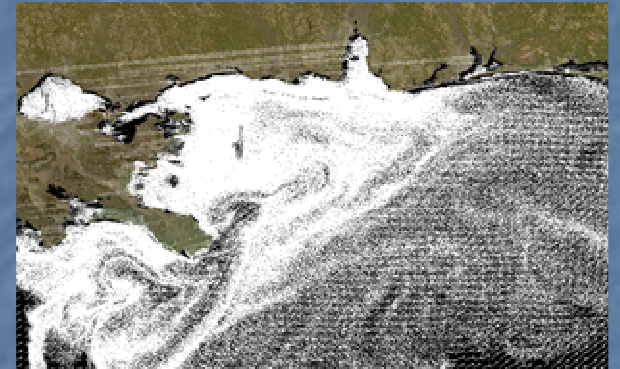
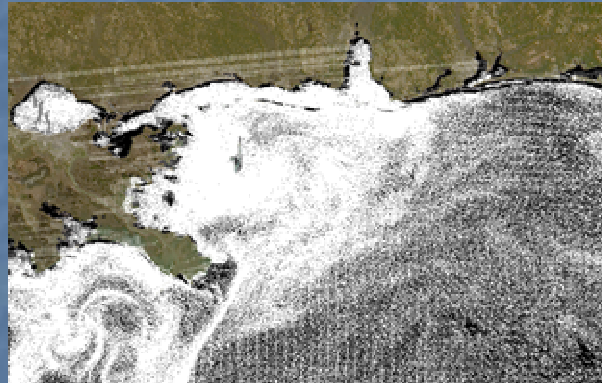
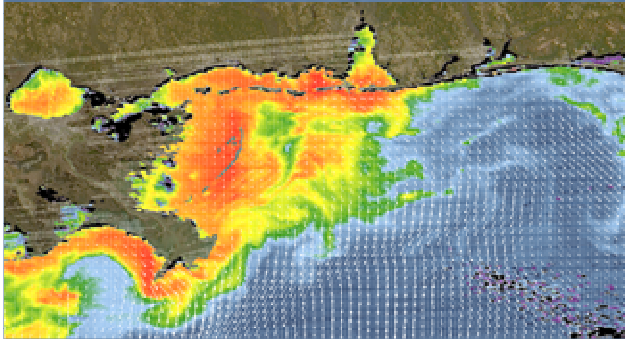
Advect the particles forward  
Hourly steps  
Conservative tracers

Compare with  
MODIS  
Nov 23, and 24, 2005

Nov 22, 2005  
Backscatter Seed

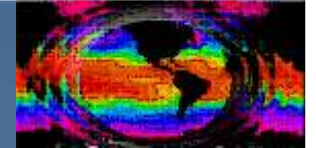
24 hour forecast  
Nov 23, 2005

48 hour forecast  
Nov 24, 2005

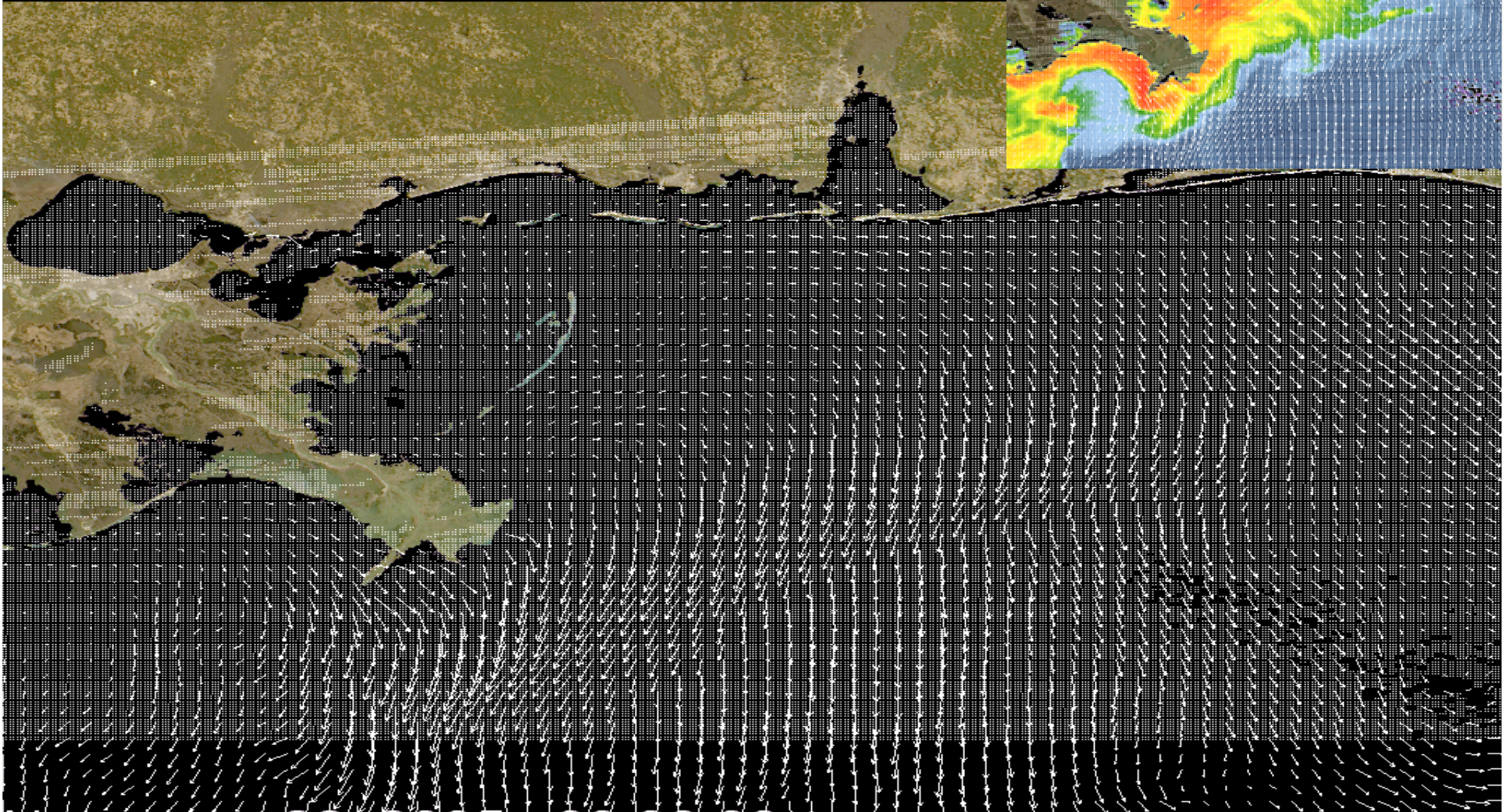
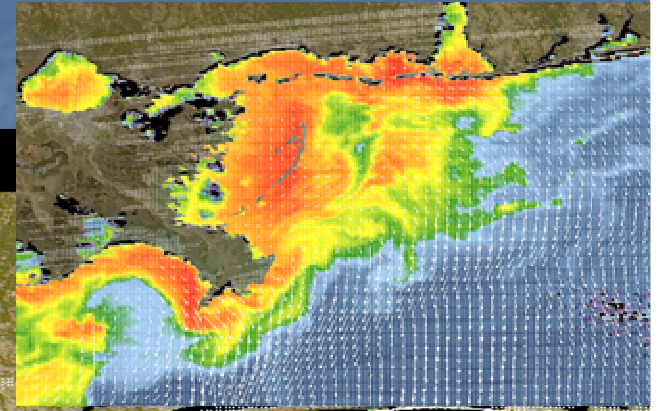




Forecasting the MODIS Particles. (Animated)  
Advection of the Nov 22 backscattering image  
-NEGOM- surface currents  
hourly prediction (2 hour Step)

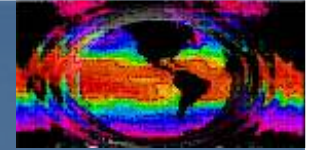


Initialization Particle Field

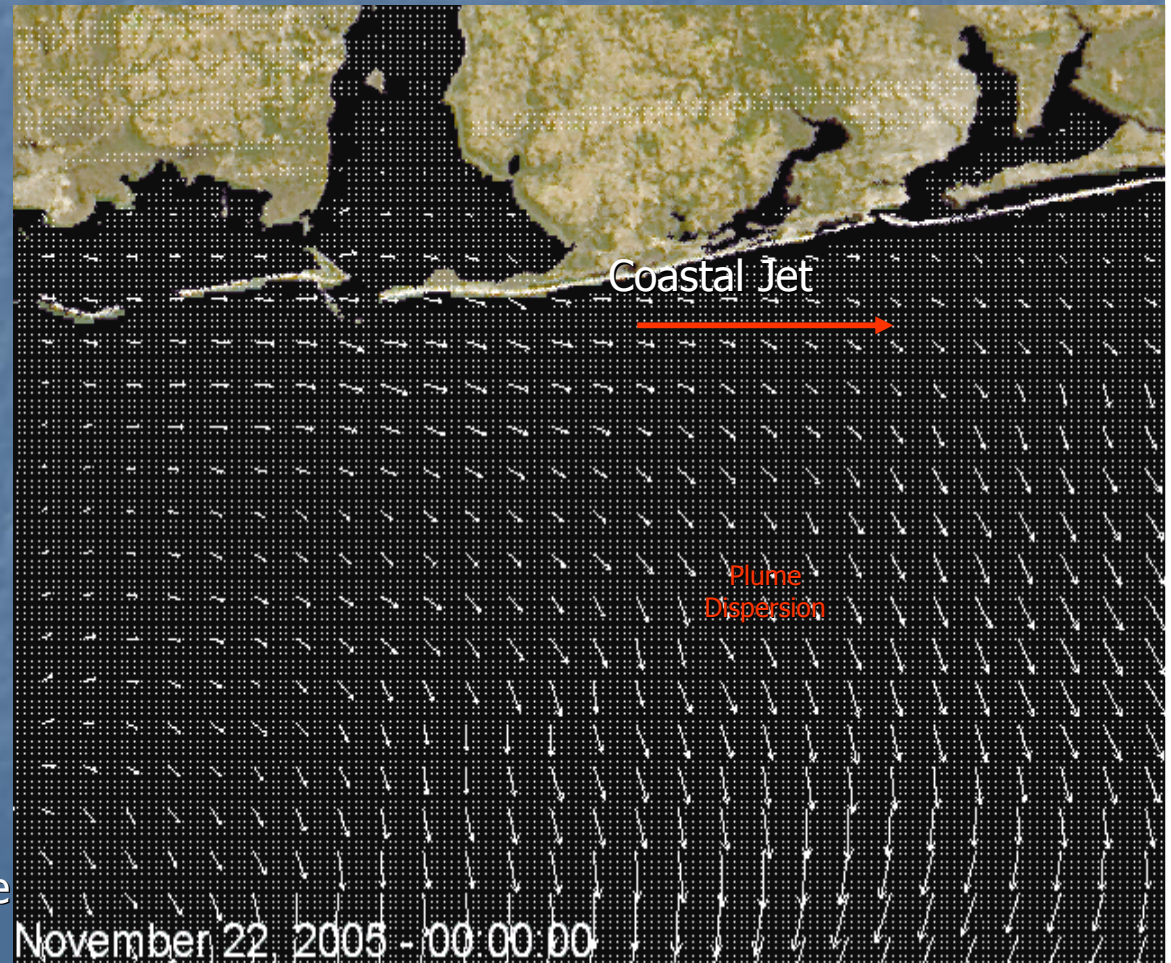
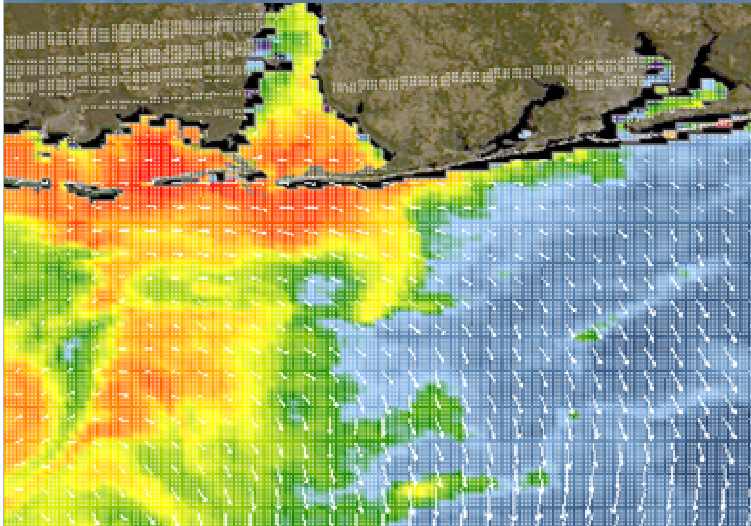




Forecasting the MODIS Chlorophyll Particles. (Animated)  
Advection of the Nov 22 image to Nov 24  
-NCOM – surface currents  
hourly prediction (2 hour Step)



## Mobile Bay Plume Dispersion

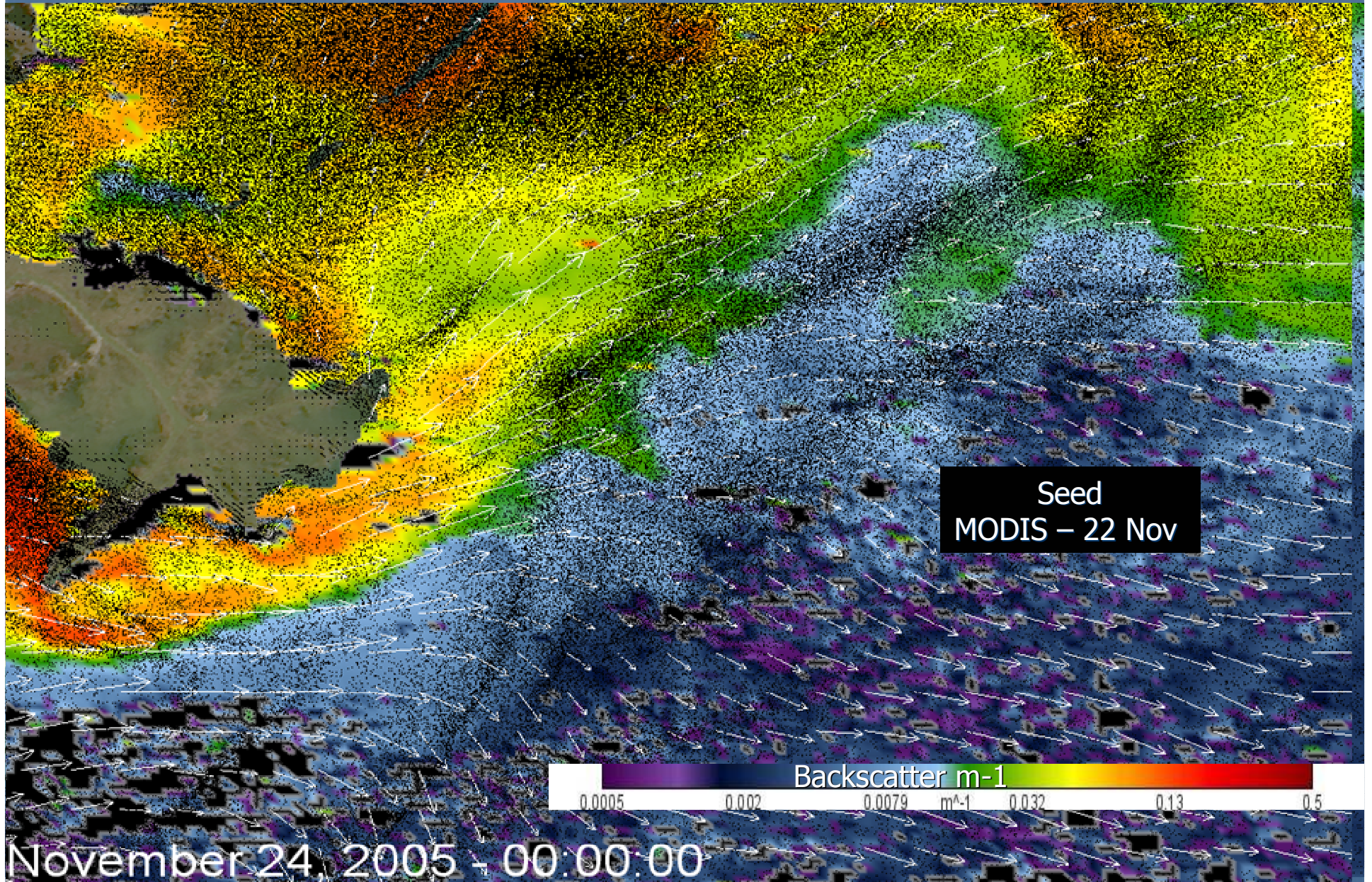
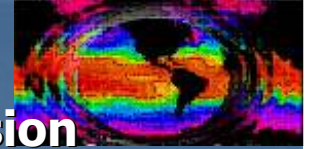


Note:  
Tidal Oscillations  
Eastward Propagation of Plume  
Imagery - ~ 1400 Local time  
Doesn't capture the tidal response



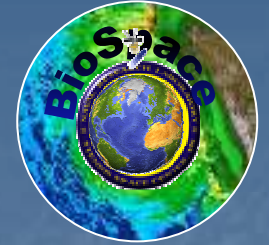
## Following the MS Plume Advection field

Non Conservative Particles -- Limited particle settling / dispersion





# MODIS Applications for Coastal Processes



## Summary –

- **Advanced ocean color products / algorithms**  
Extending new products for Coastal Processes
- **Satellite products Linked with Physical Ocean Models**  
Pathway toward data assimilation , SST and Ocean Color
- **High resolution 250 m MODIS Products**  
New Capability for monitoring coastal jets, river plumes, estuaries and harbors
- **Coupling MODIS Ocean Color with Biological Models**  
Underneath the satellite product – 3d view.  
MODIS can provide products to constraint ecosystem models
- **Predicting and Forecasting the Ocean Processes**  
Particle tracking of MODIS fields