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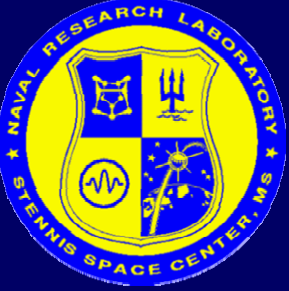
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High Resolution Characterization of Riverine and Coastal Currents

*Dr. Cheryl Ann Blain
Dr. T. Christopher Massey
Mr. Brett D. Estrade*

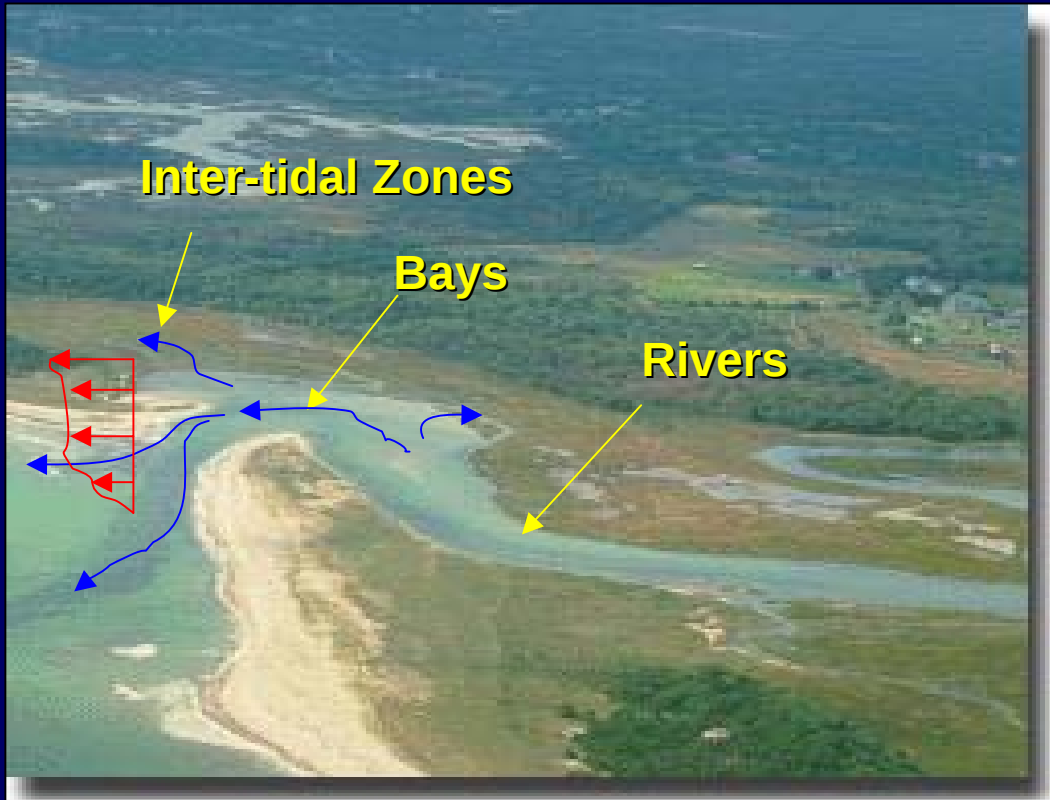
*Oceanography Division
Naval Research Laboratory
Stennis Space Center, MS*

*21-23 June, 2005
73rd MORS Symposium, West Point, NY*

What can we do?

Predictive Capability for Coastal Circulation

- High resolution (meters) currents and water levels in littoral environments that include bays, inter-tidal marshes and rivers

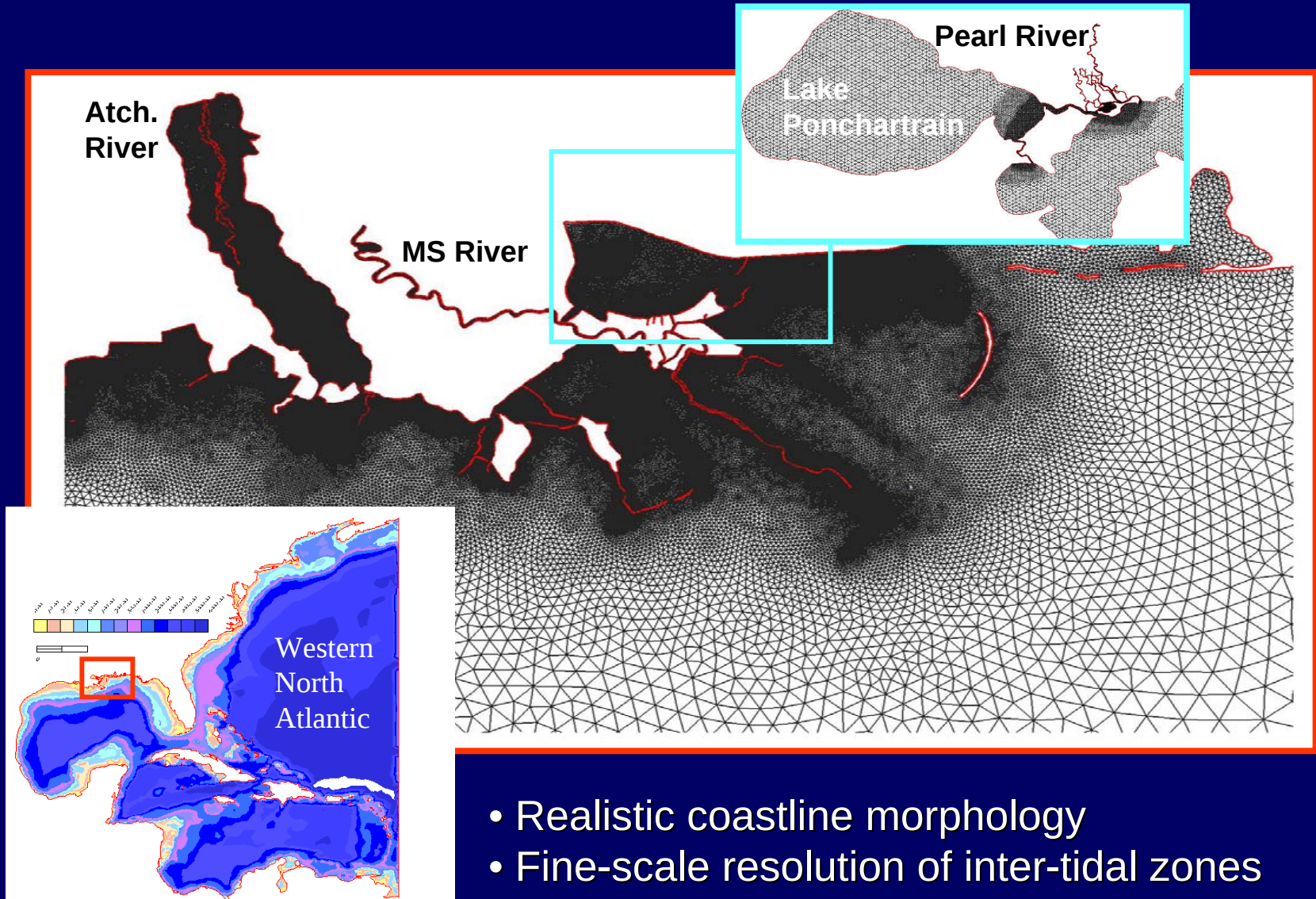


ADCIRC Model

- 3D dynamics
- Forcing from tides, wind, waves, and rivers
- Shoreline inundation/recession
- Utilizes unstructured grids (based on finite elements)
- MPI parallelization



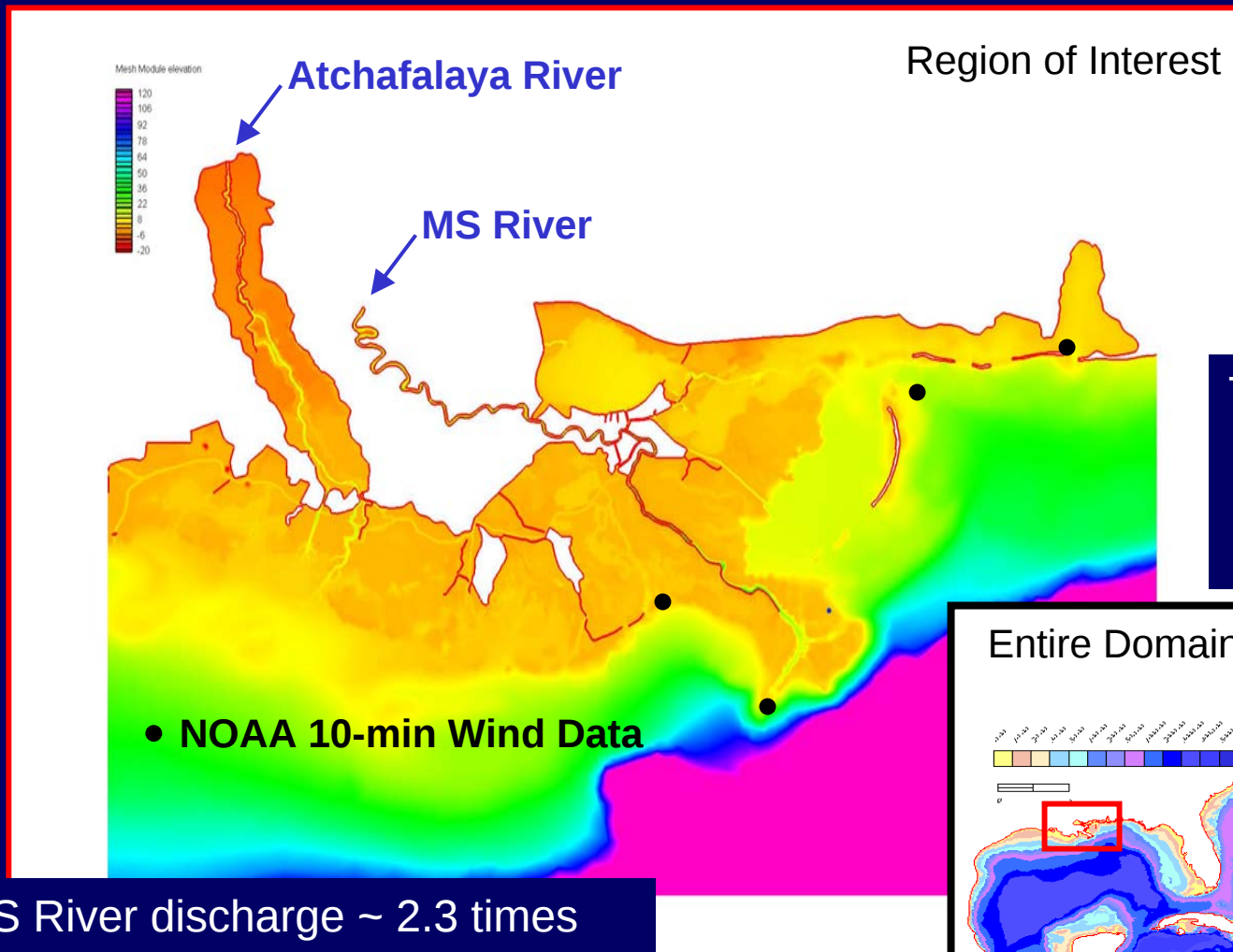
Advantage: Mesh Flexibility



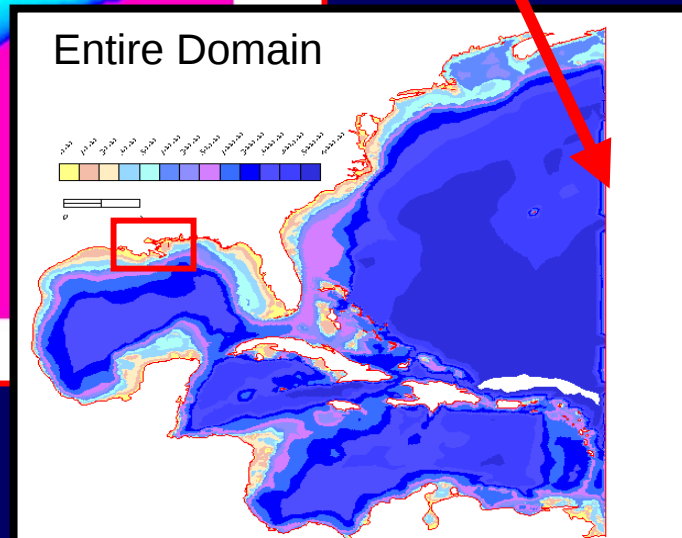
- Realistic coastline morphology
- Fine-scale resolution of inter-tidal zones
- Large domains with remote open boundaries



ADCIRC: SE Louisiana Coastal Waters



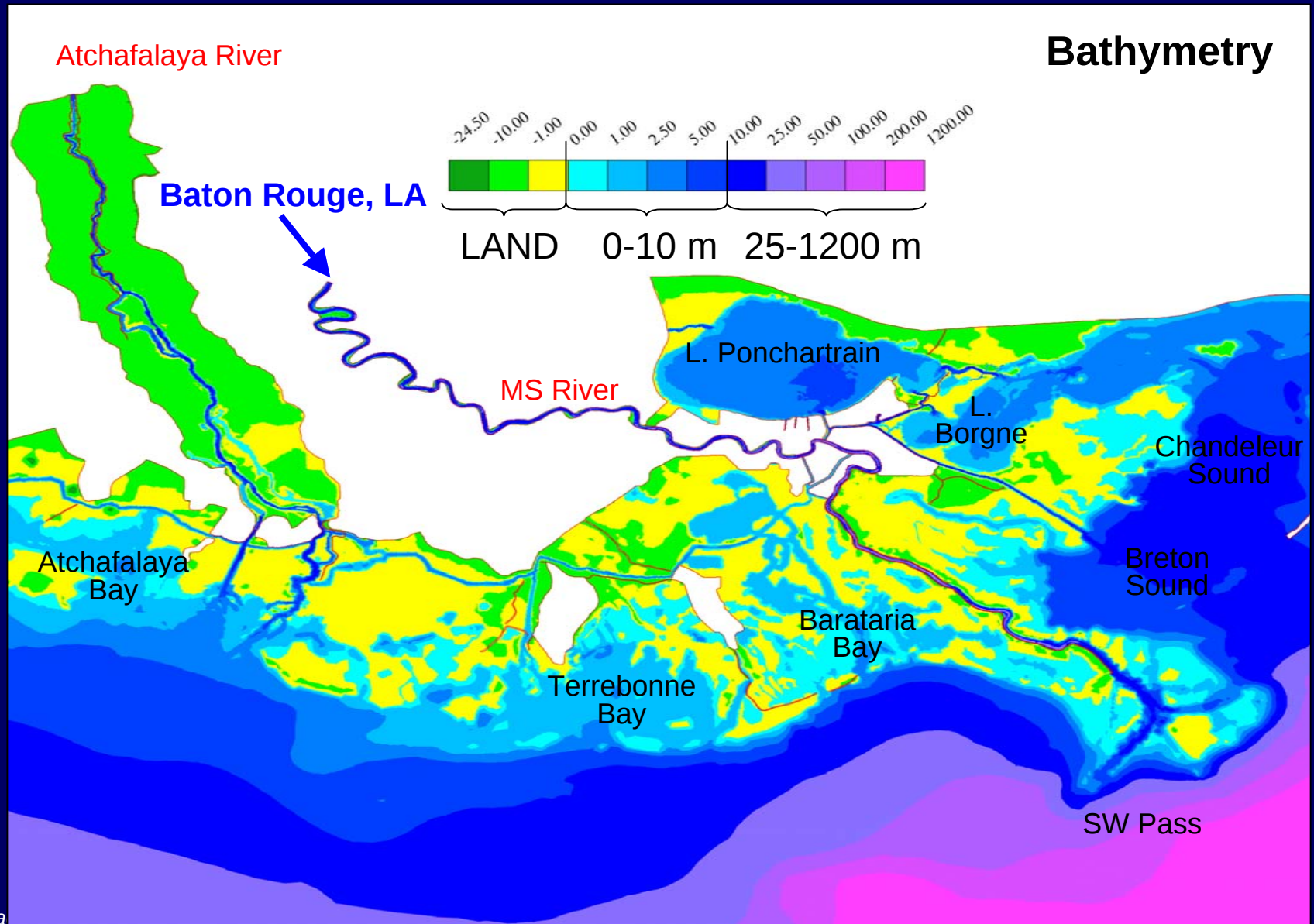
Tidal forcing along ocean boundary from global tide model



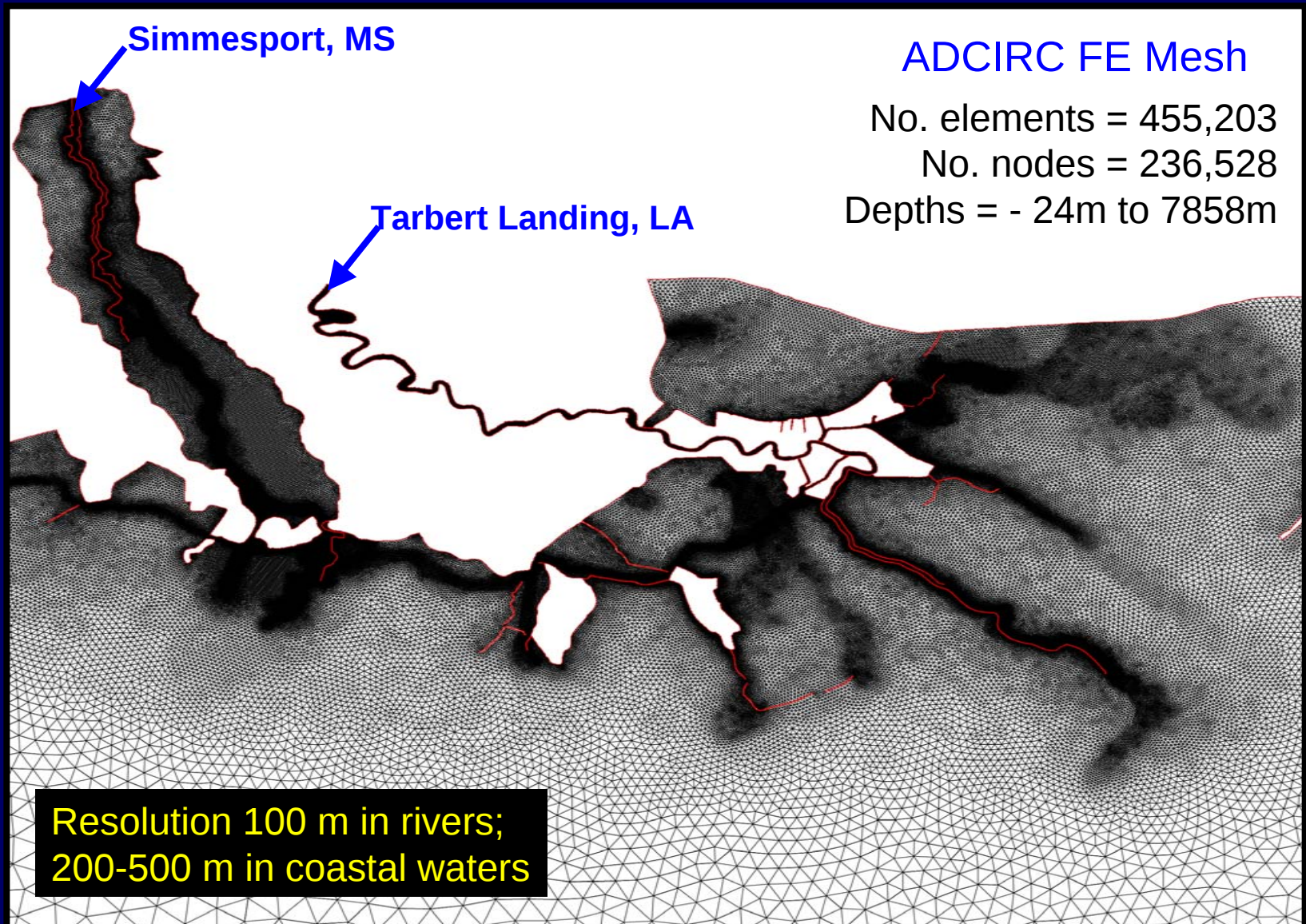
MS River discharge ~ 2.3 times
Atchafalaya River discharge



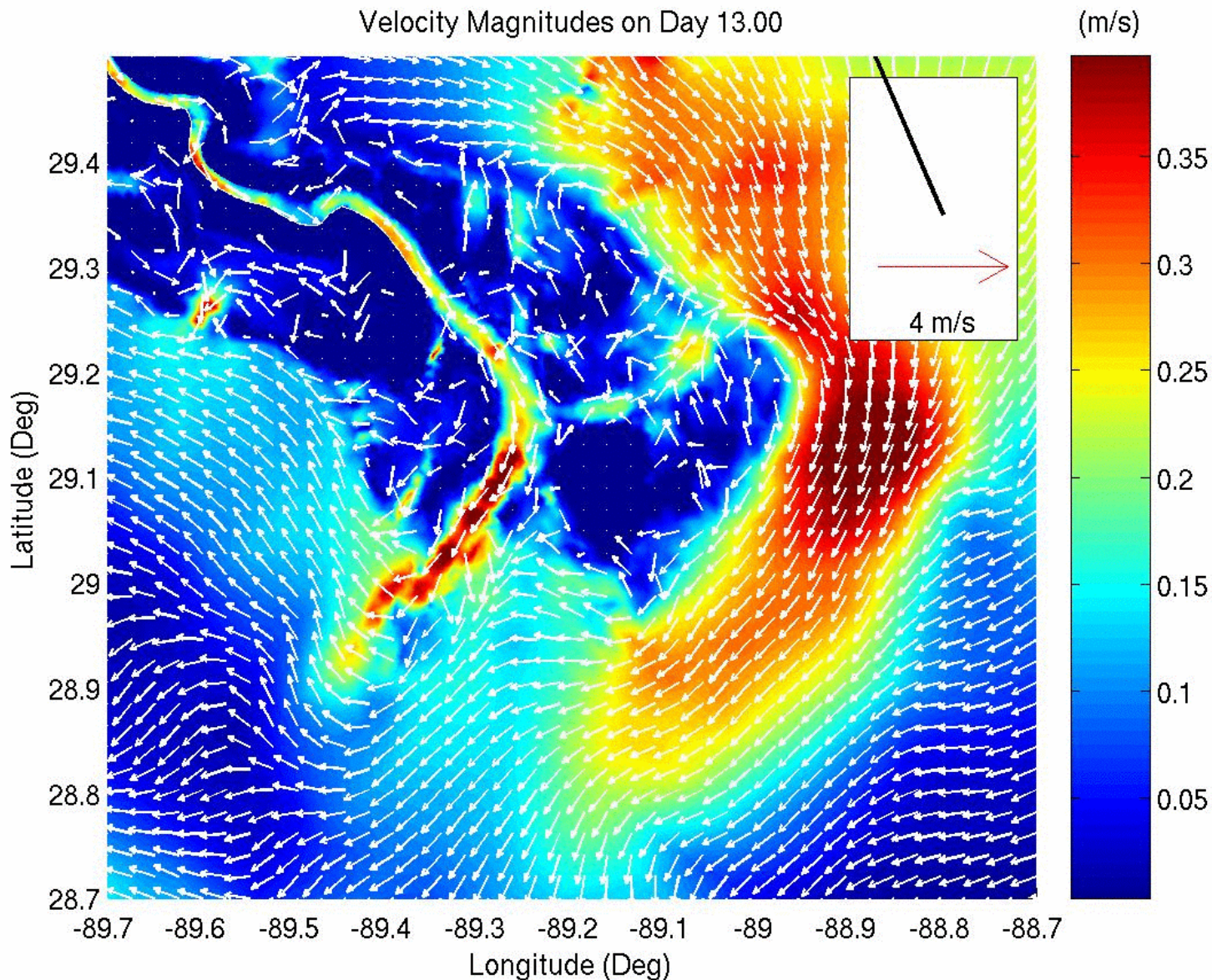
ADCIRC: SE Louisiana Coastal Waters



ADCIRC: SE Louisiana Coastal Waters

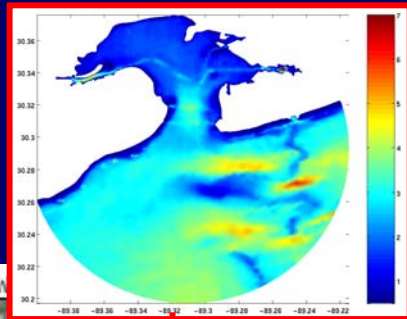


Modeled Currents – March 17-24, 2004

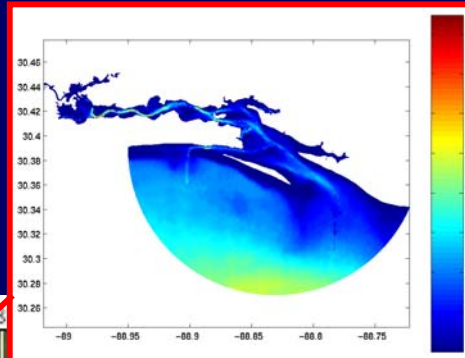


Development of Embayment and River Models

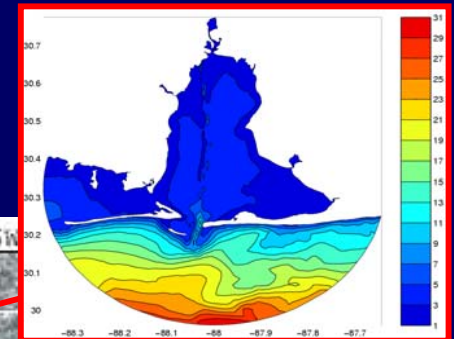
Bay St. Louis Model



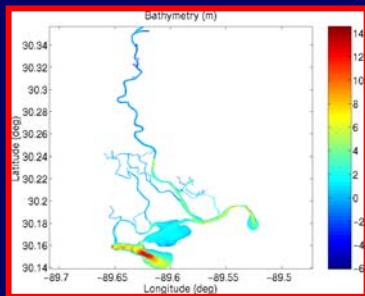
Biloxi Bay Model



Mobile Bay Model

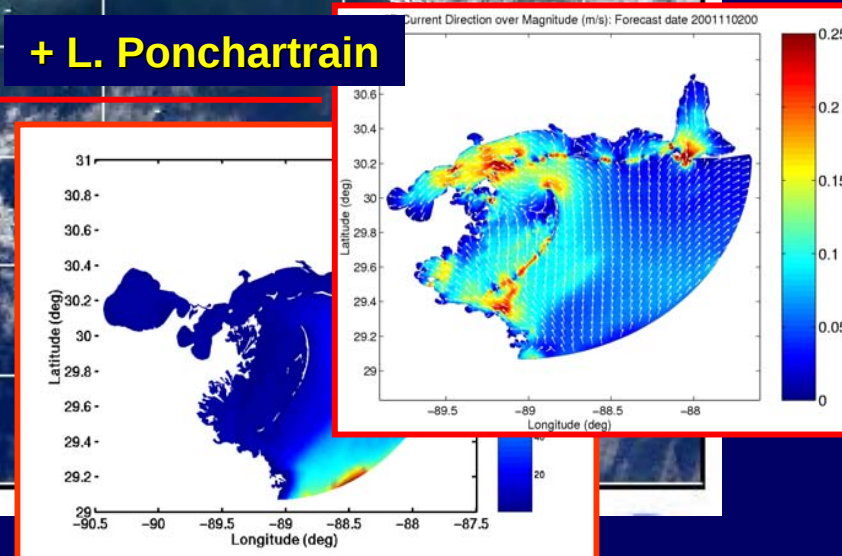


Pearl River Model



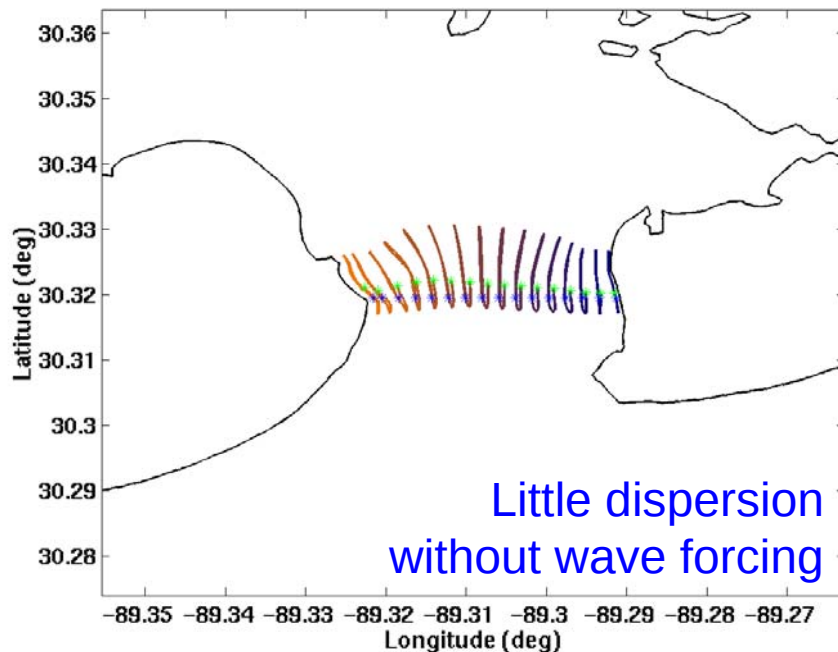
Mississippi Bight Model

+ L. Ponchartrain

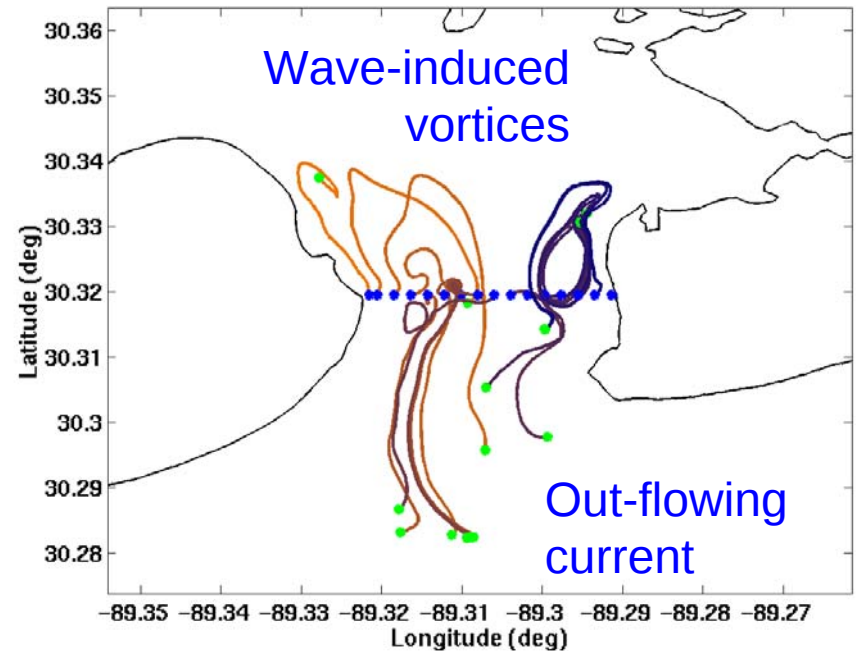


Coupled Wave-Tide Circulation in Bay St. Louis

Pathways of Numerical Drifters over 23 Hours



Tidal Forcing Only



Wave-Tide Interaction

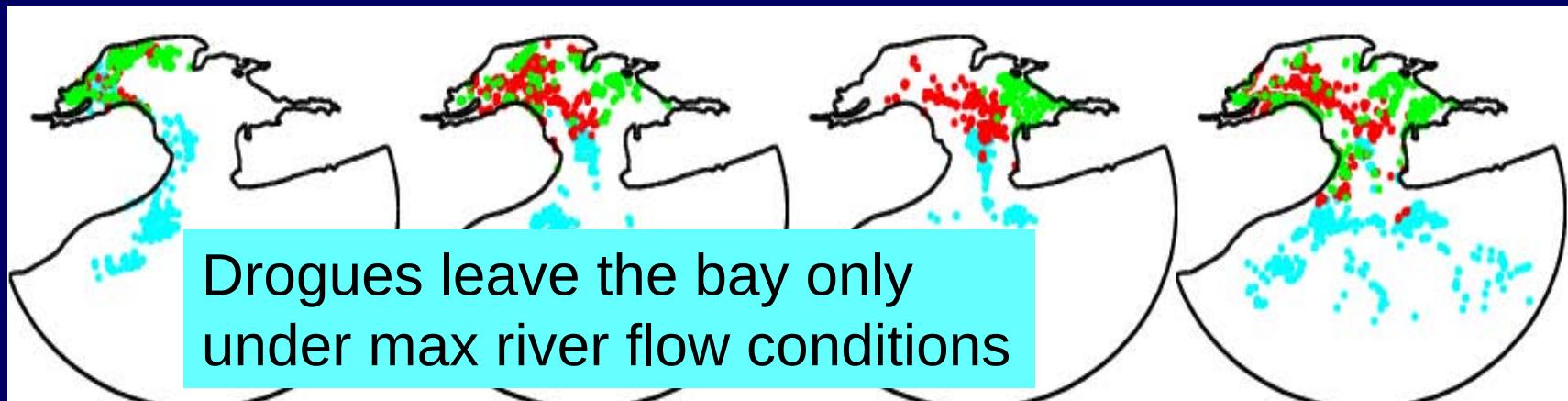
Cobb and Blain, MTS, 2002
Blain and Cobb, NRL Report,
Cobb and Blain, NRL Report,



Sensitivity of Bay-Shelf Exchange to Forcing and Model Dimensionality

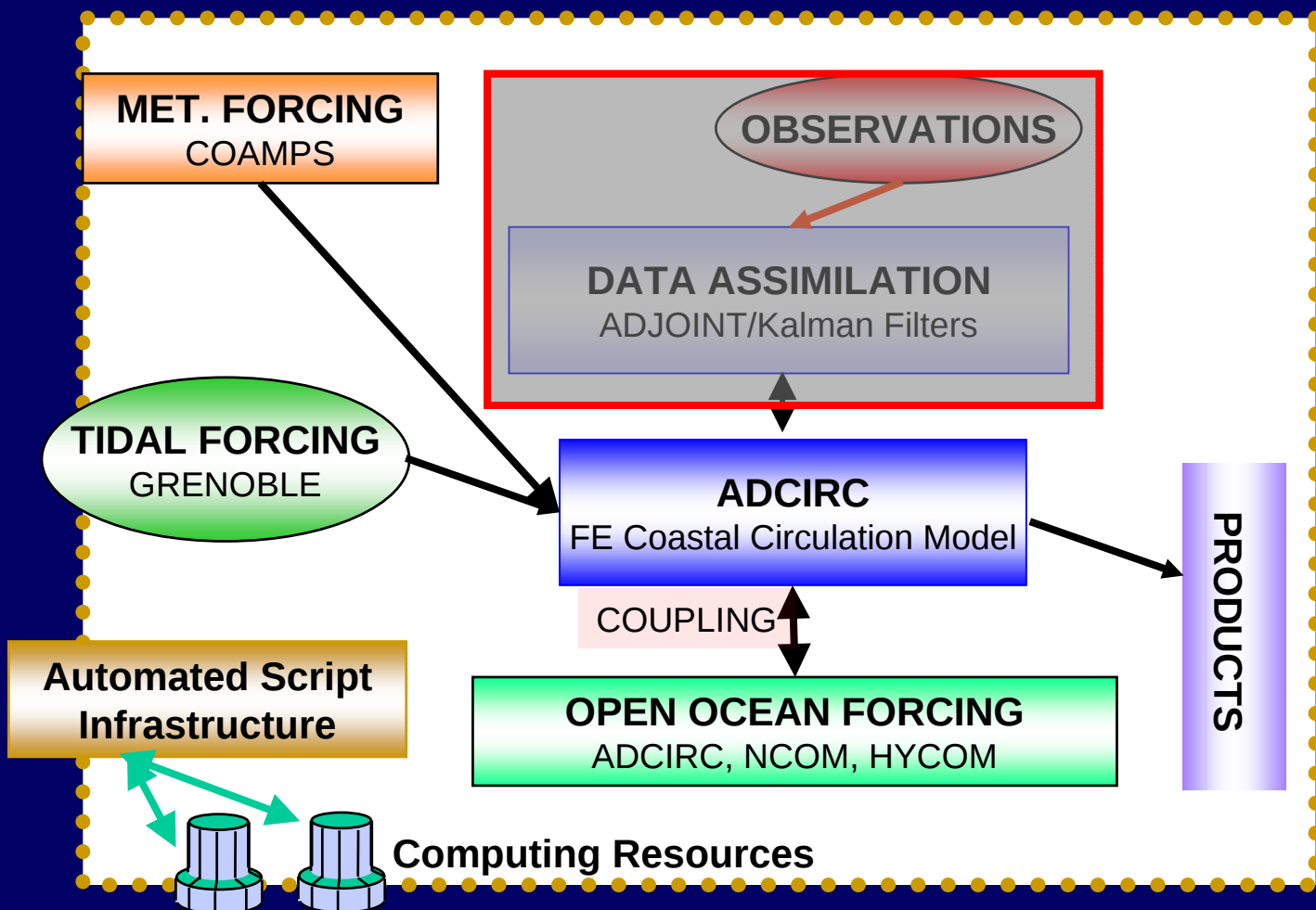
3-D CIRCULATION

After 15 days



2-D CIRCULATION

Real-Time Forecast Capability



Under
Development

Goals

- Rapid Re-Location
- Timely forecasts
- Relevant products

Applications

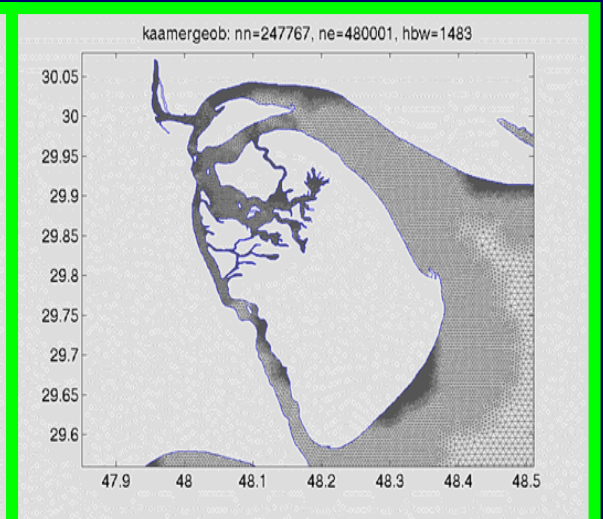
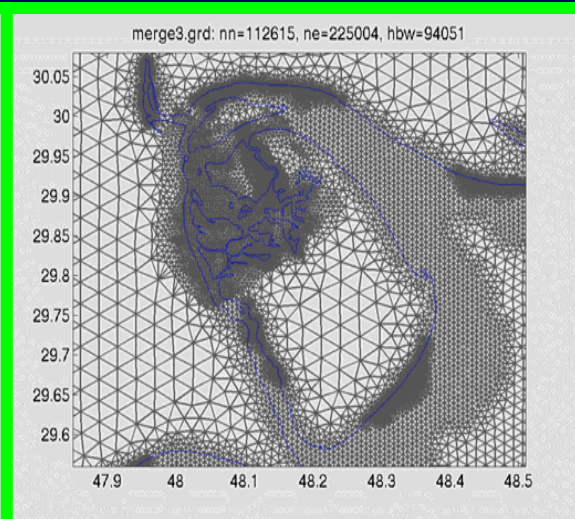
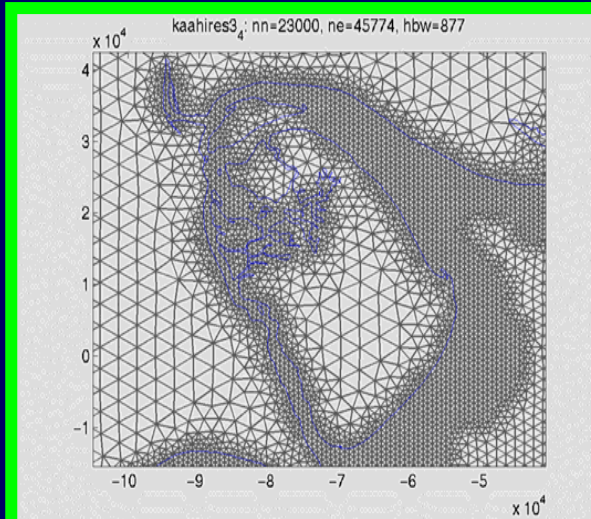
- AUVFEST
Oct-Nov, 2001
Mississippi Sound

- *Prestige* Oil Spill
Nov-Dec, 2002
Spanish coast

- *Operation Iraqi Freedom*
Mar-Apr, 2003
KAA Persian Gulf

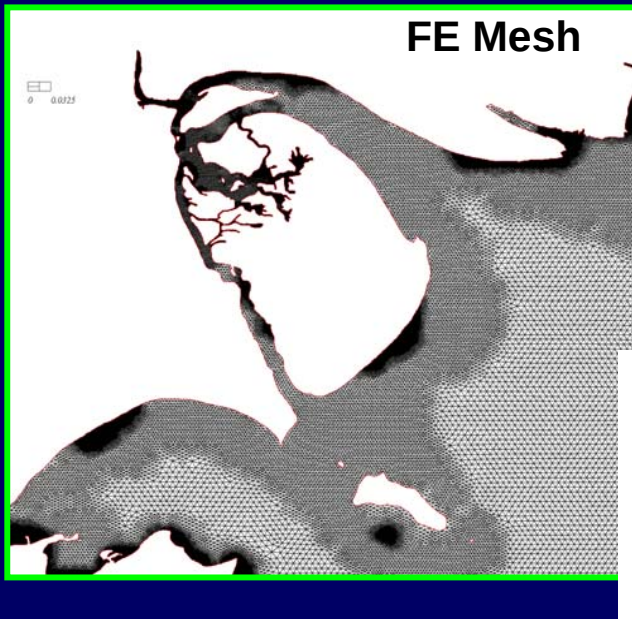
Criteria for Success

- Accurate and flexible dynamical model
- Ability to meet operational time constraints
- Automated, rapid relocation
- Generation of meaningful operational products
- Quantification of forecast skill

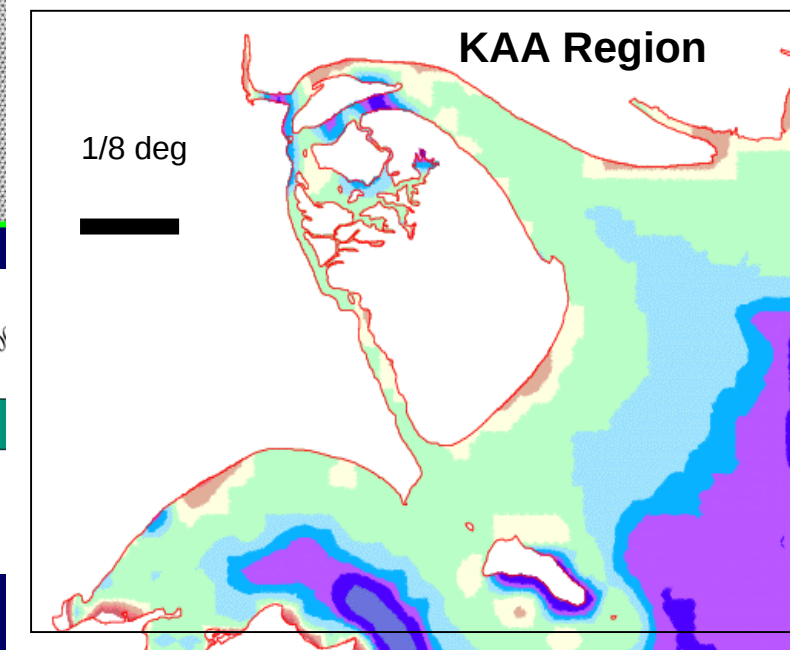
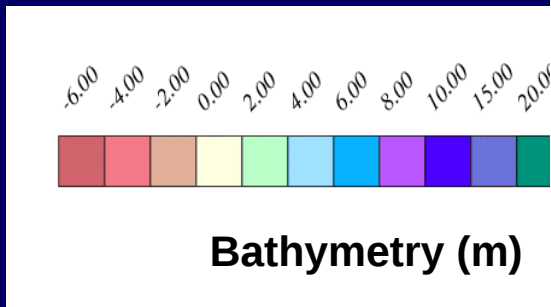
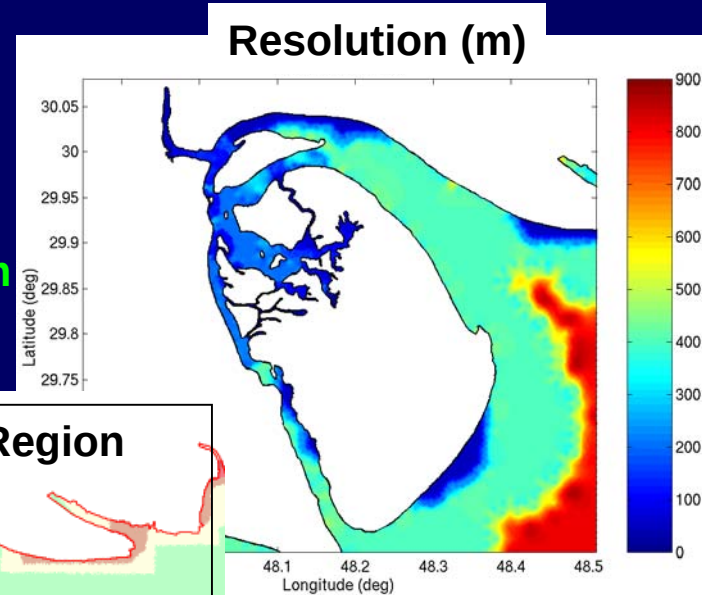


A Tidal Model in the N. Persian Gulf

Operation Iraqi Freedom, March-April 2003



No. nodes 247,767
No. elements 480,001
Resolution 2 m – 1 km



Validation of the Forecast Elevations

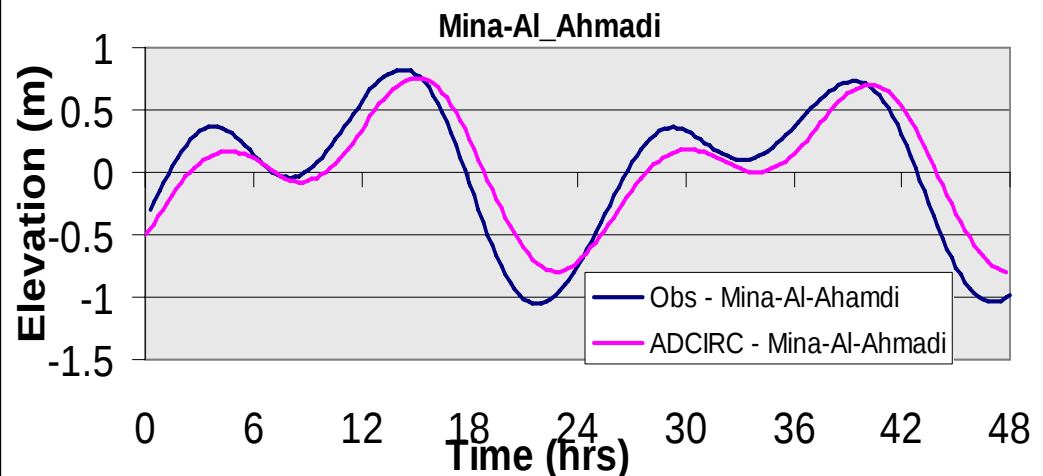
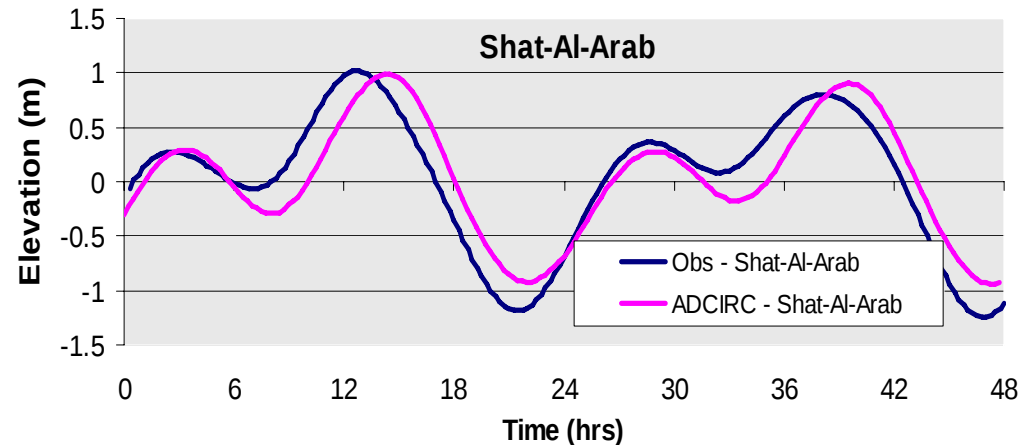
March 26-27, 2003

0 0.125

Shat-al-Arab

Mina-Al_Ahmadi

IHO Stations



RMS Error

25 cm

Mean Absolute Error

20 cm

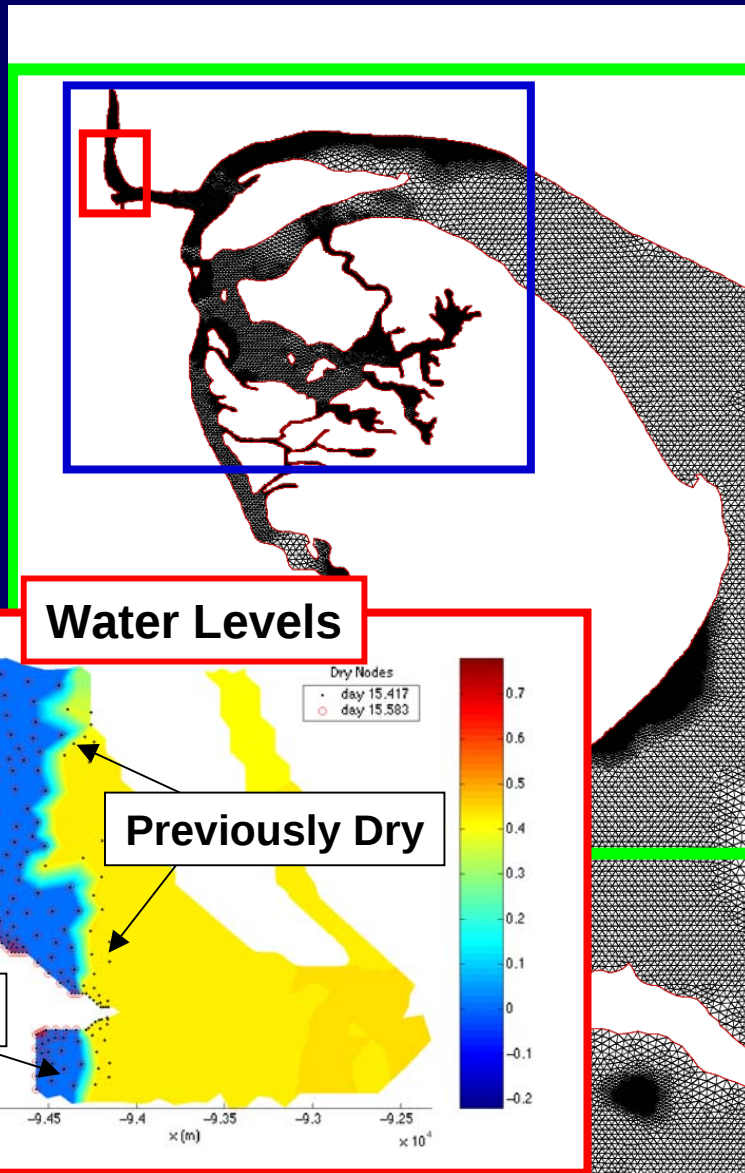
Phase Lag

15-30 min

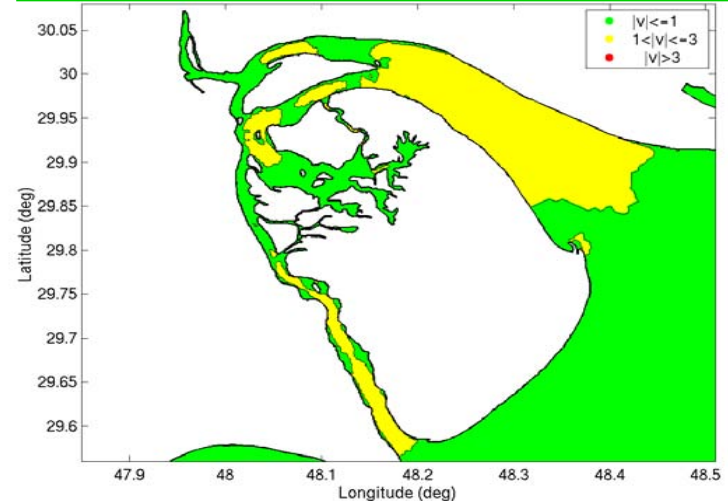
Time series correlation 0.98

ADCIRC Model Support for OIF, 2003

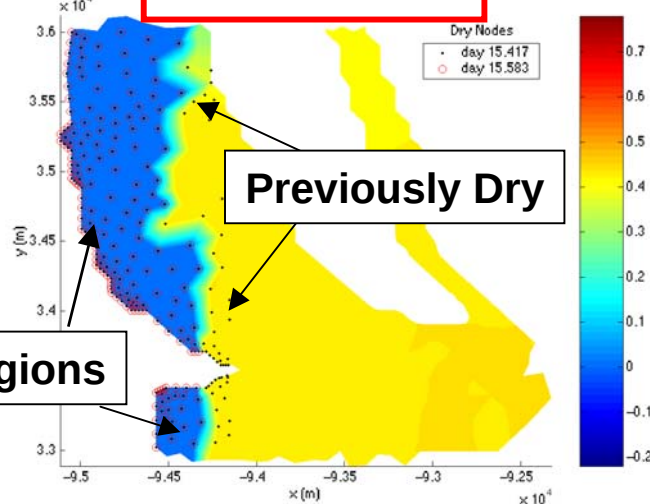
Resolution
2 m – 400 m



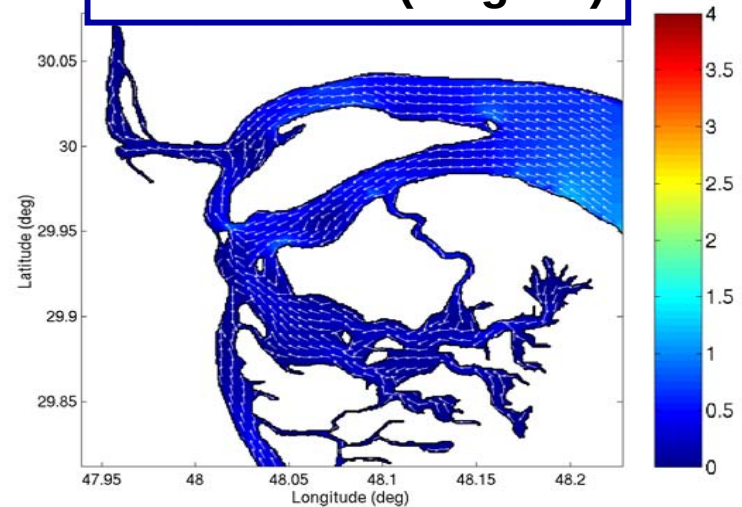
Max 12-hr Current Thresholds



Water Levels

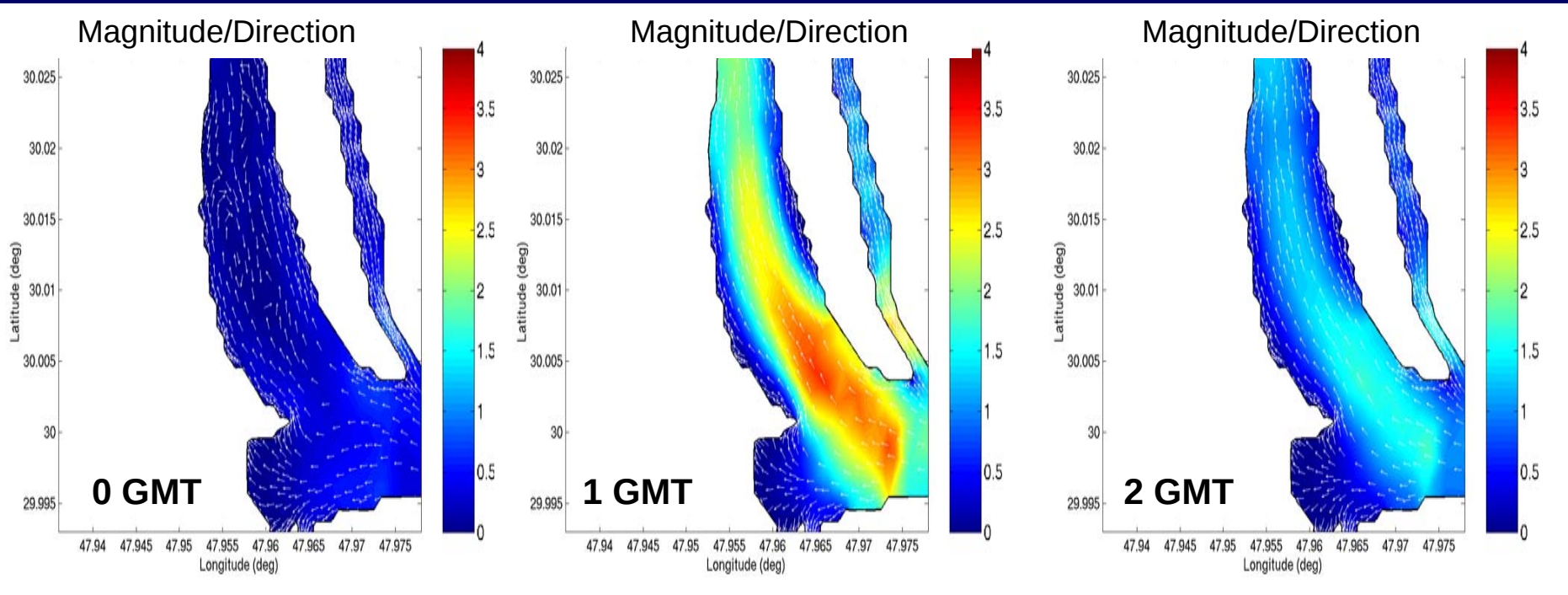


2D Currents (Mag/Dir)



Fine-Scale Circulation Features

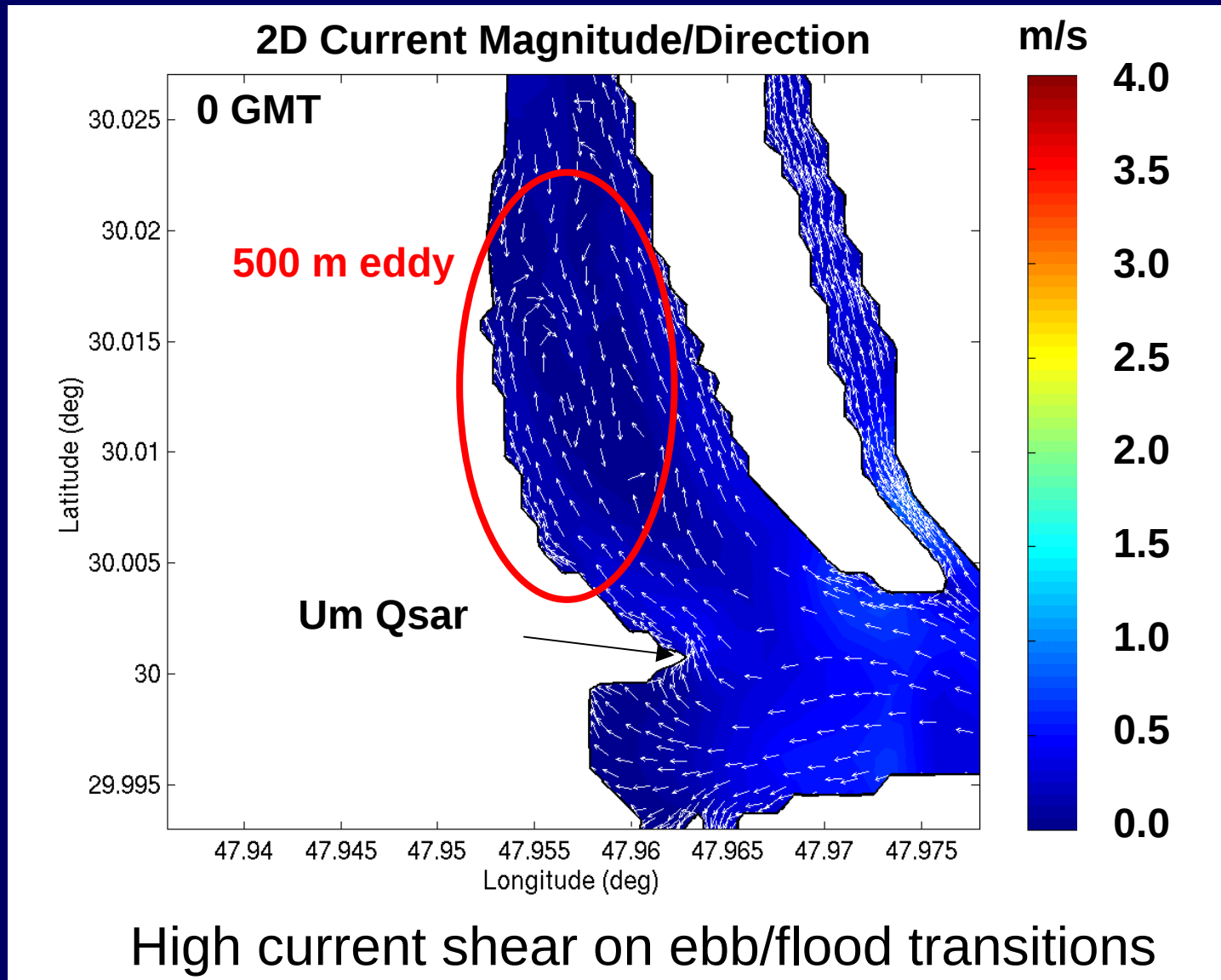
Depth-averaged tidal currents north of Um Qsar



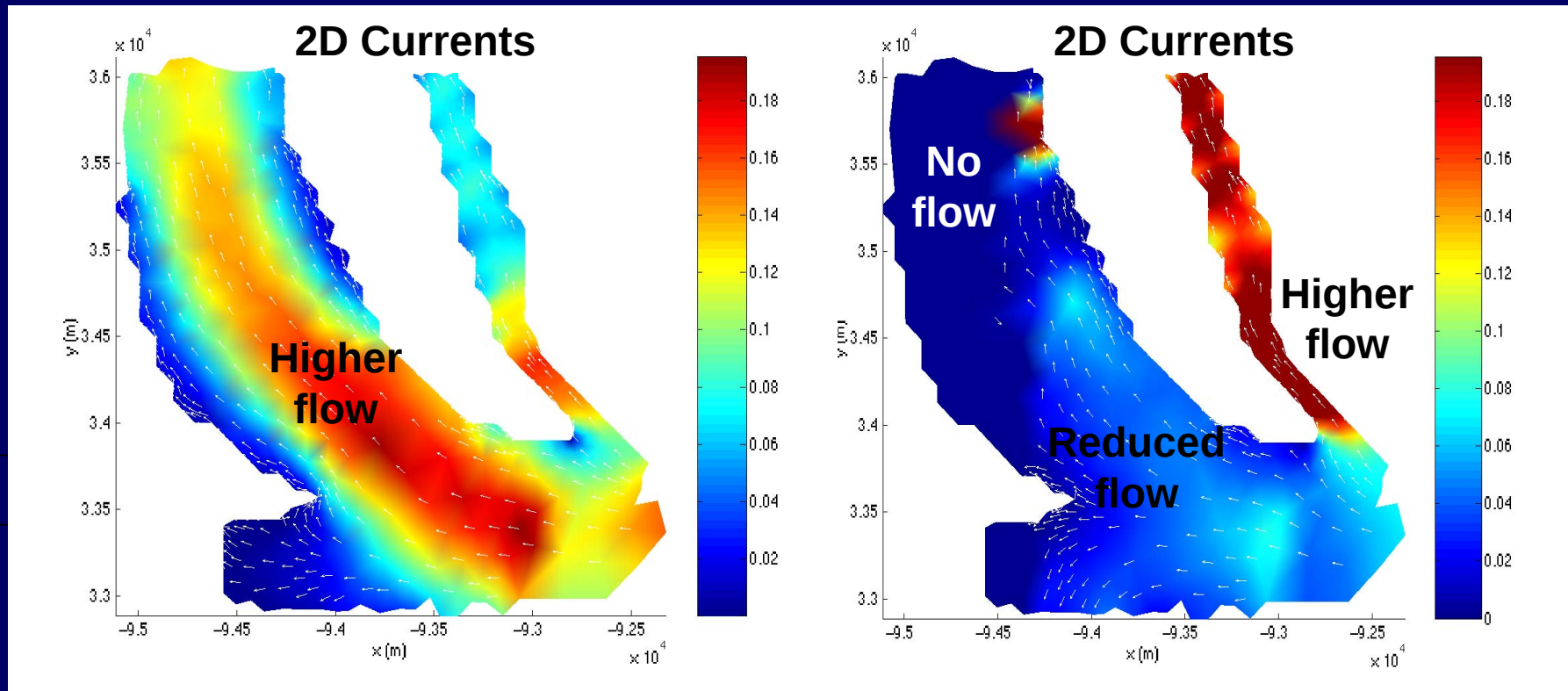
Variability on the scale of hours



Fine-Scale Circulation Features



Importance of Including Inundation

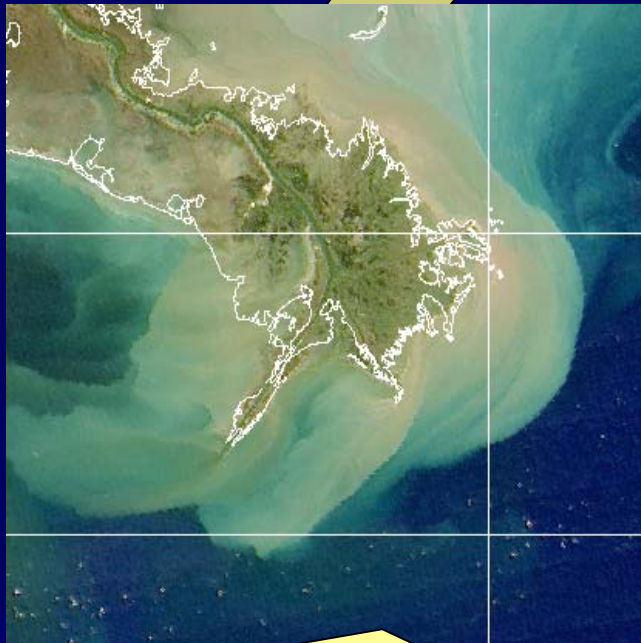


**No Shoreline
Inundation/Drying**

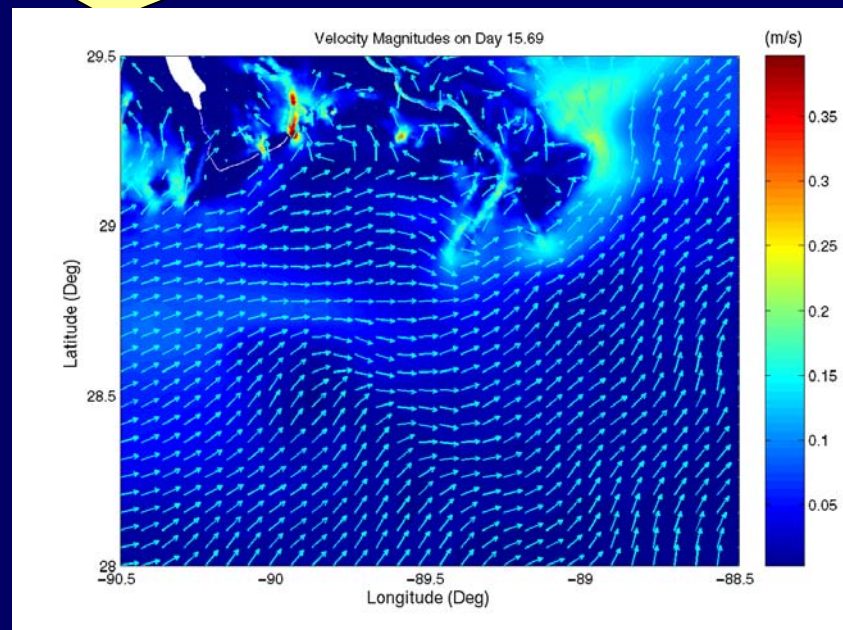
Spatial and temporal resolution sufficient to capture shoreline inundation/drying but circulation highly sensitive to bathymetric data.



Why Merge Models and Ocean Color Data?



Modeled Coastal
Dynamics



Remotely-Sensed
Ocean Color Data

Relate Optical and Physical
Properties of the Coastal Ocean



Complementary Aspects of Merging Models and Ocean Color Data

	<u>Imagery</u>	<u>Coastal Models</u>
Temporal Resolution	1-2 times daily	hourly or less
Spatial Resolution	250 m – 1 km	10 m -100 m
Dimensionality	surface information only	3D representation

Models can fill spatial and temporal gaps in ocean color data
Ocean color data provide observations of the real ocean

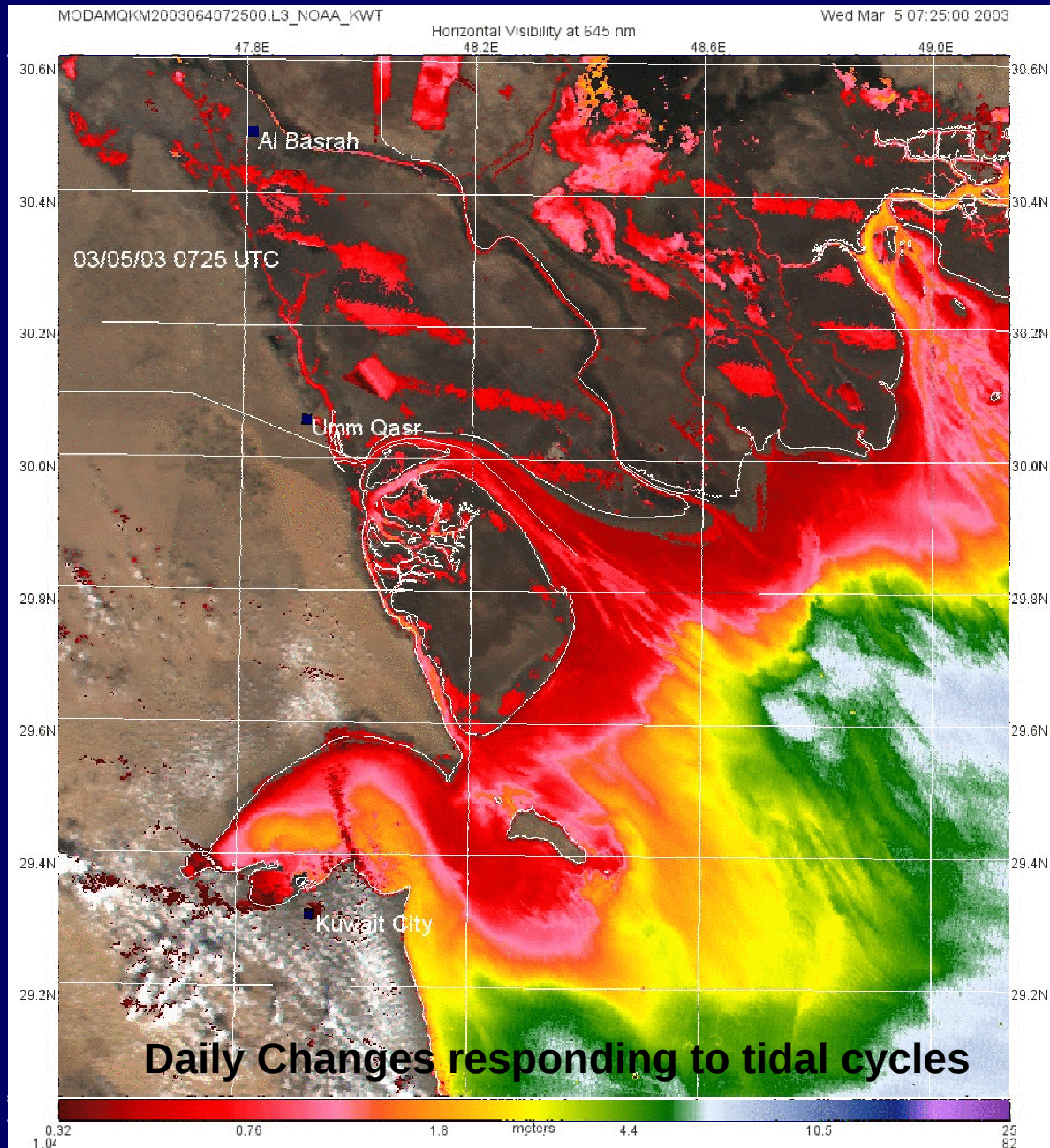
Together they can unravel the role of various bio-geo-physical processes in the coastal ocean



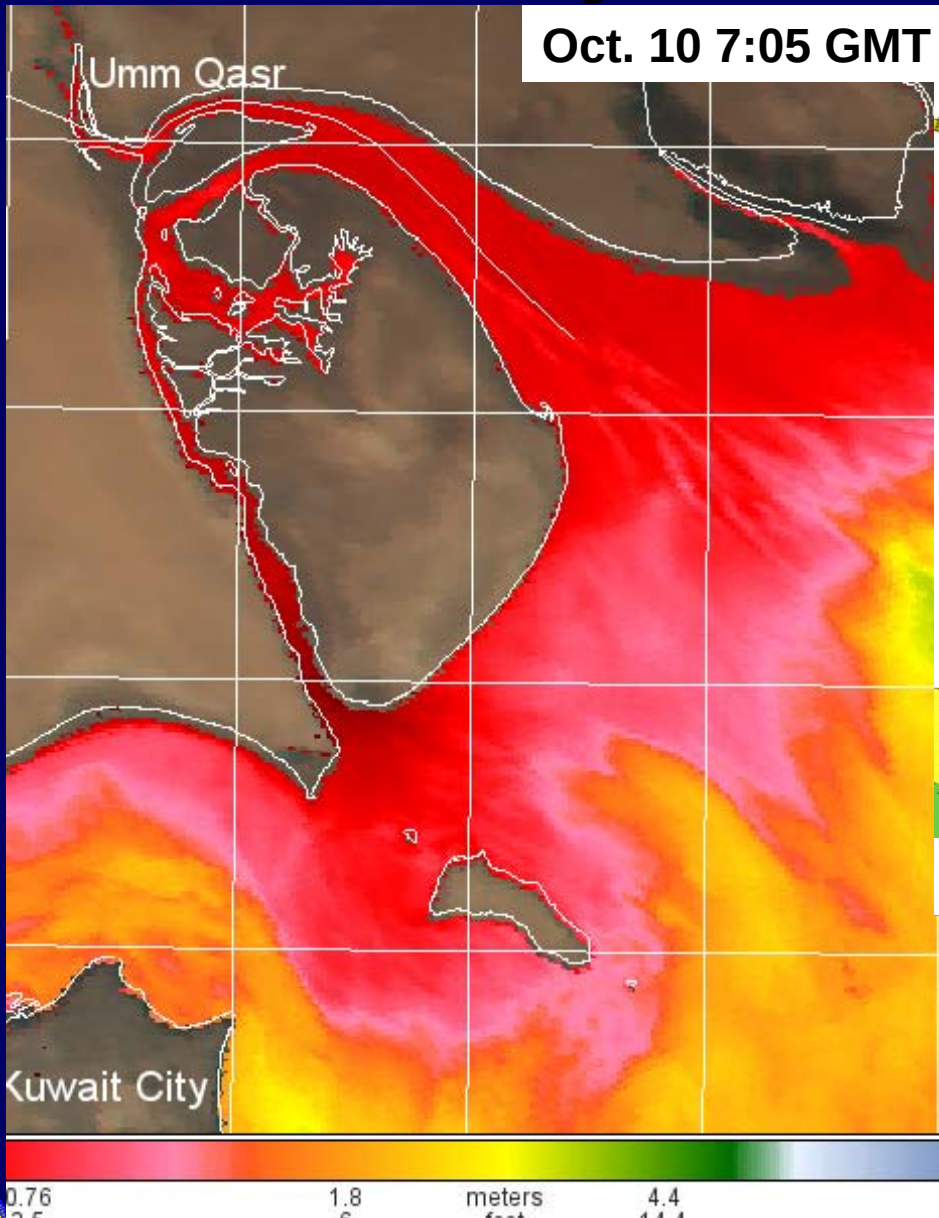
Diver Visibility

Derived using
beam attenuation
coefficient from
the MODIS
satellite

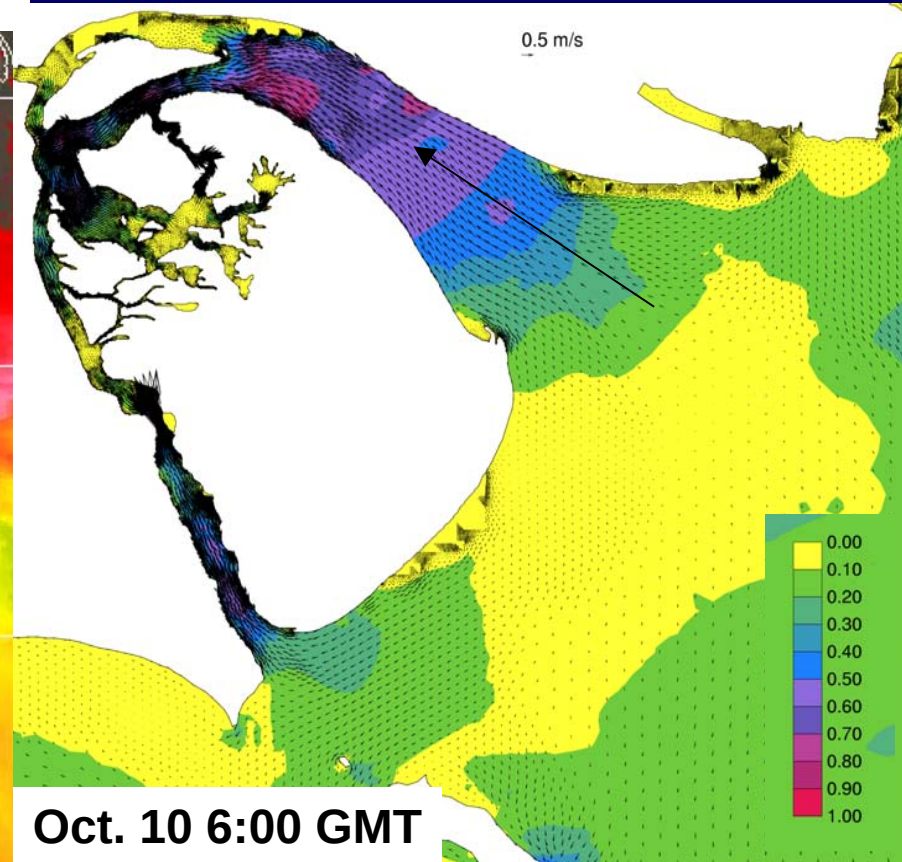
- AQUA and Terra
250 m channels
- AM: 7- 9 GMT
- PM: 22-24 GMT



Low Visibility



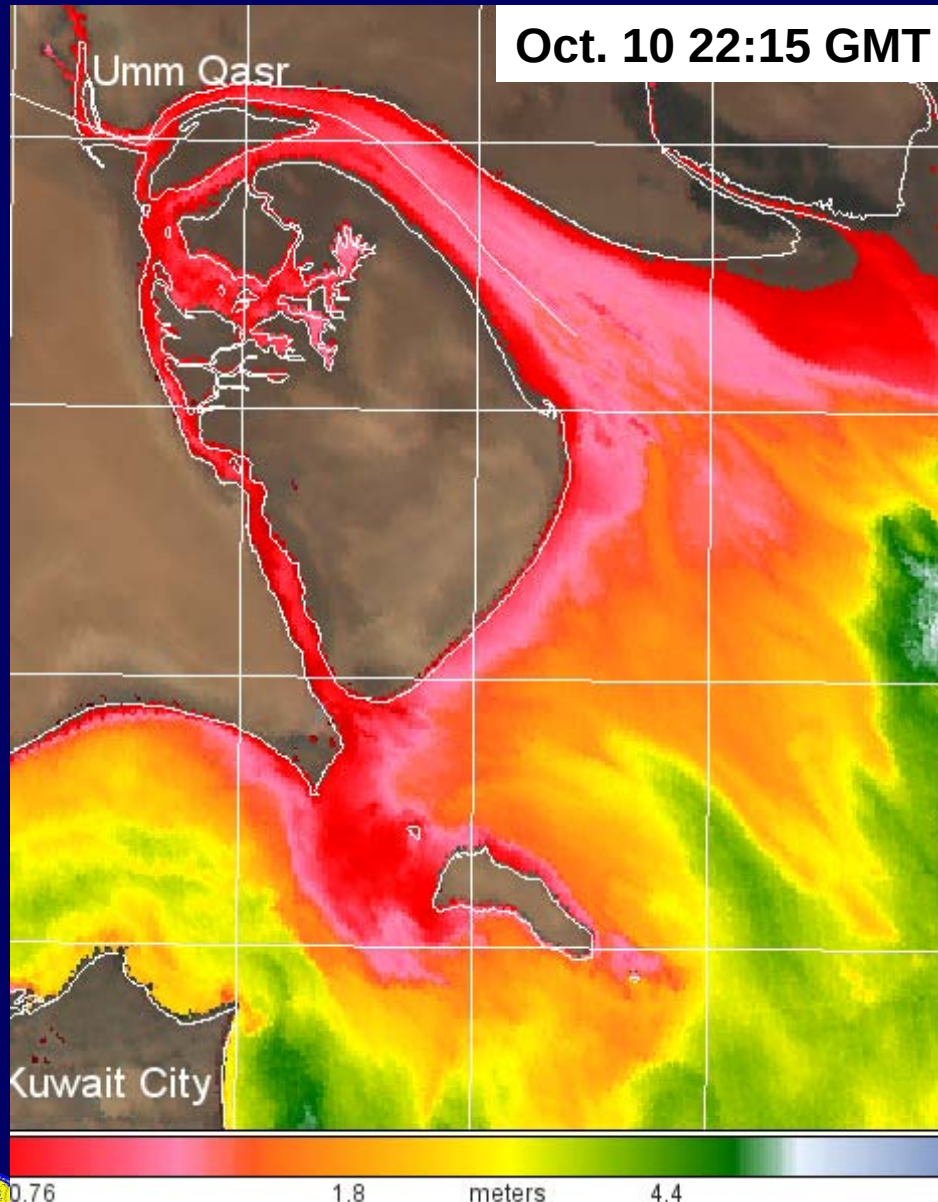
FLOOD TIDE



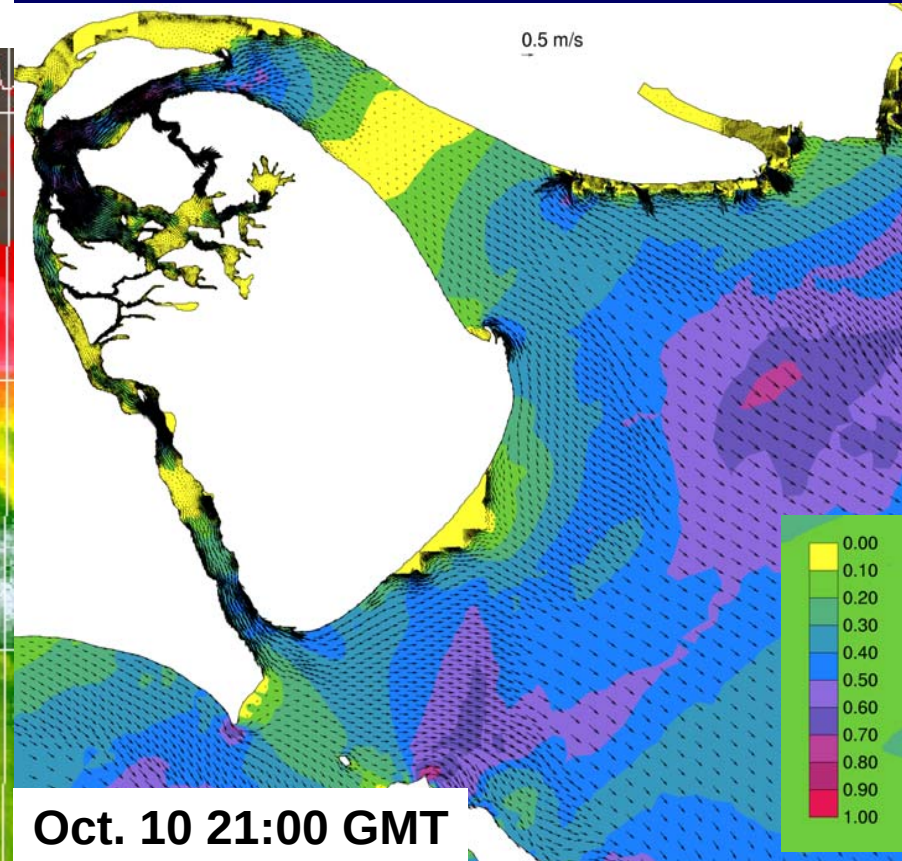
Higher velocities result in more mixing and thus increased turbidity



Increased Visibility



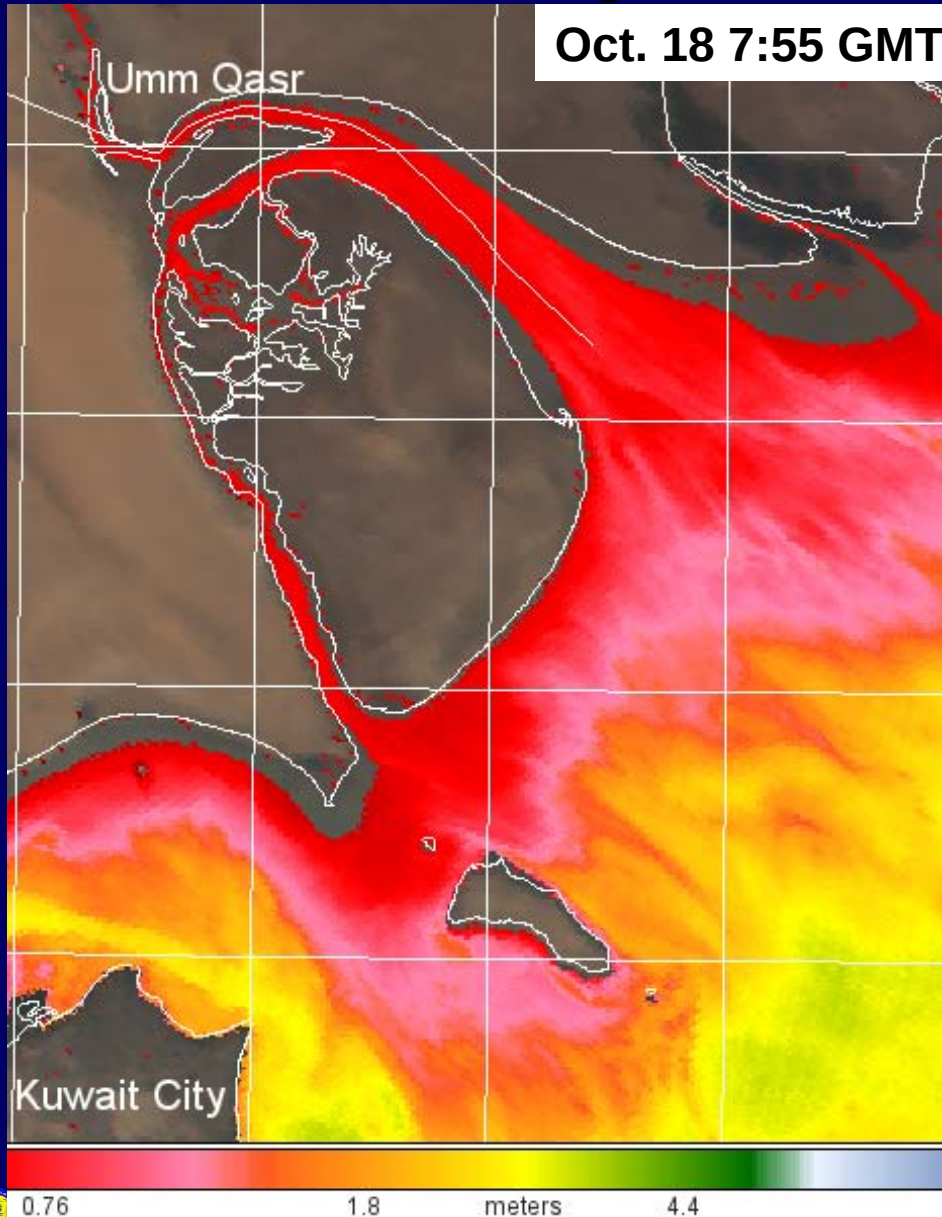
SLACK TIDE



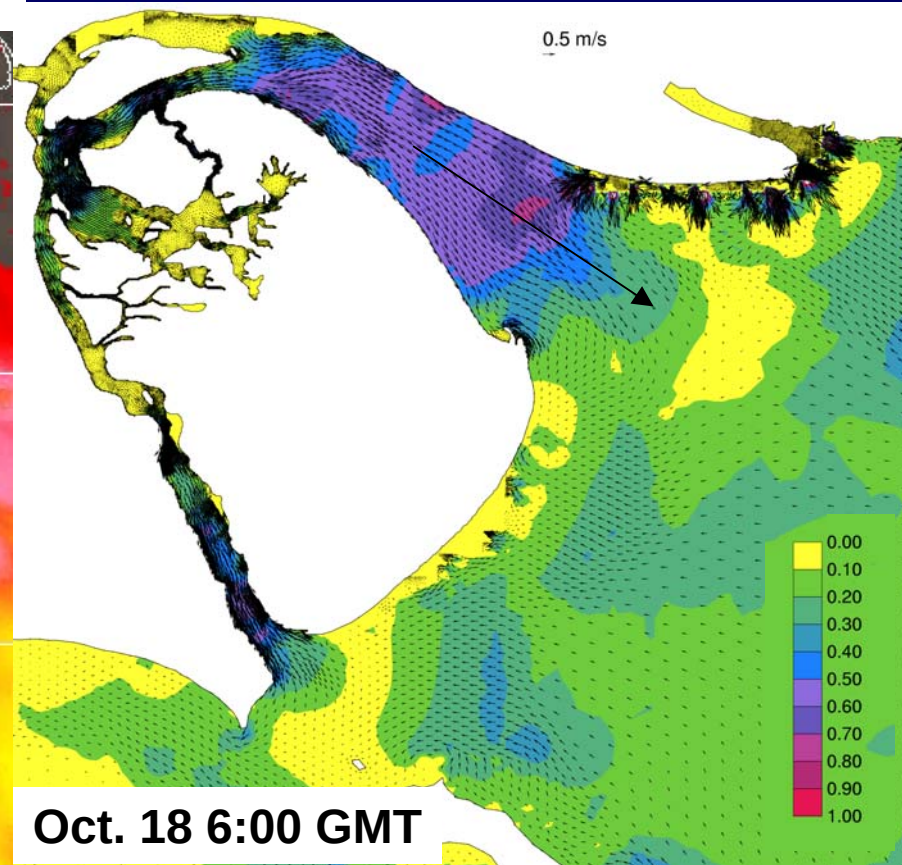
Low velocities allow particle settling and reduce turbidity



Low Visibility



EBB TIDE

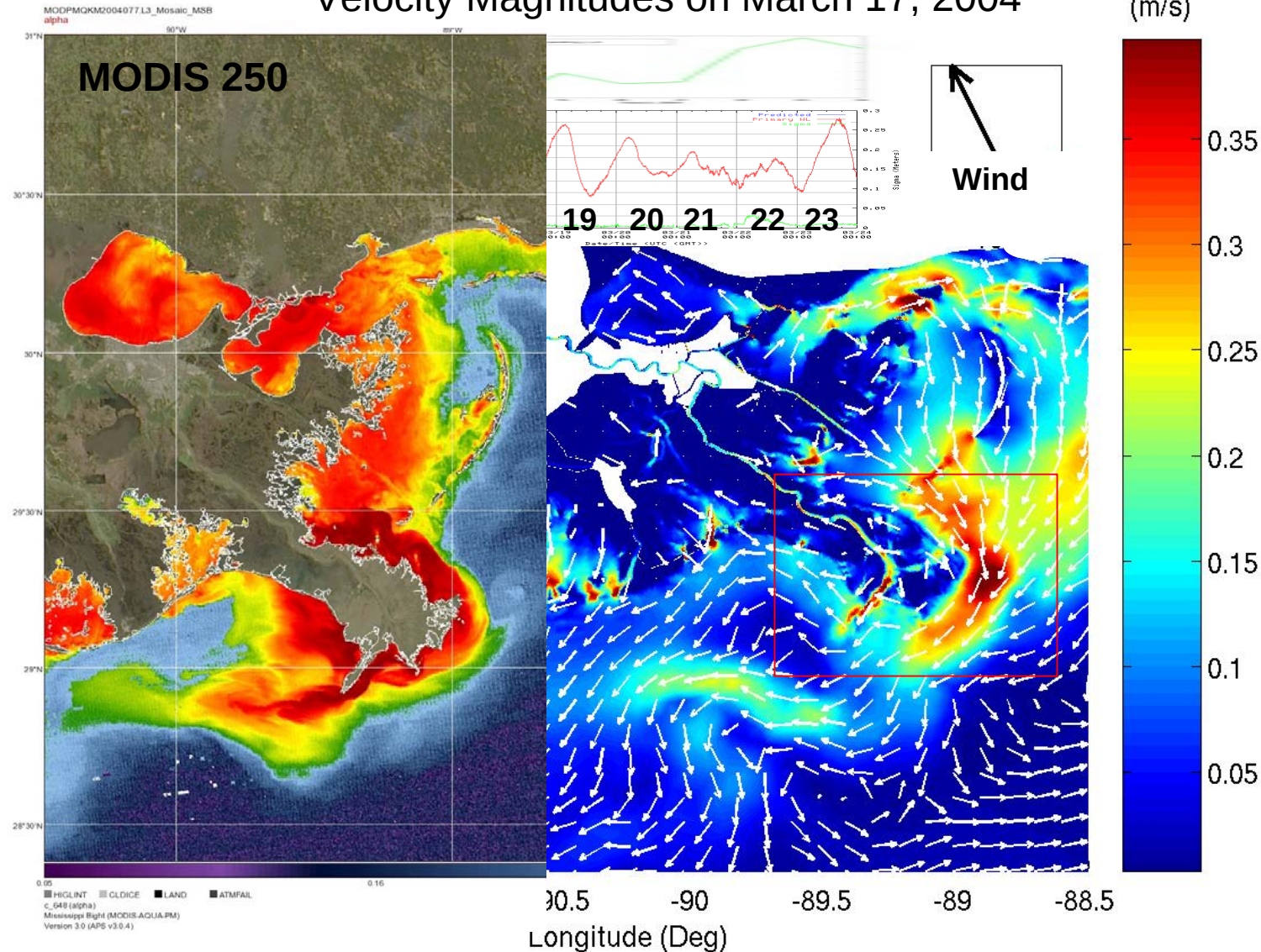


The magnitudes of the ebb tide are not as strong as for flood tide



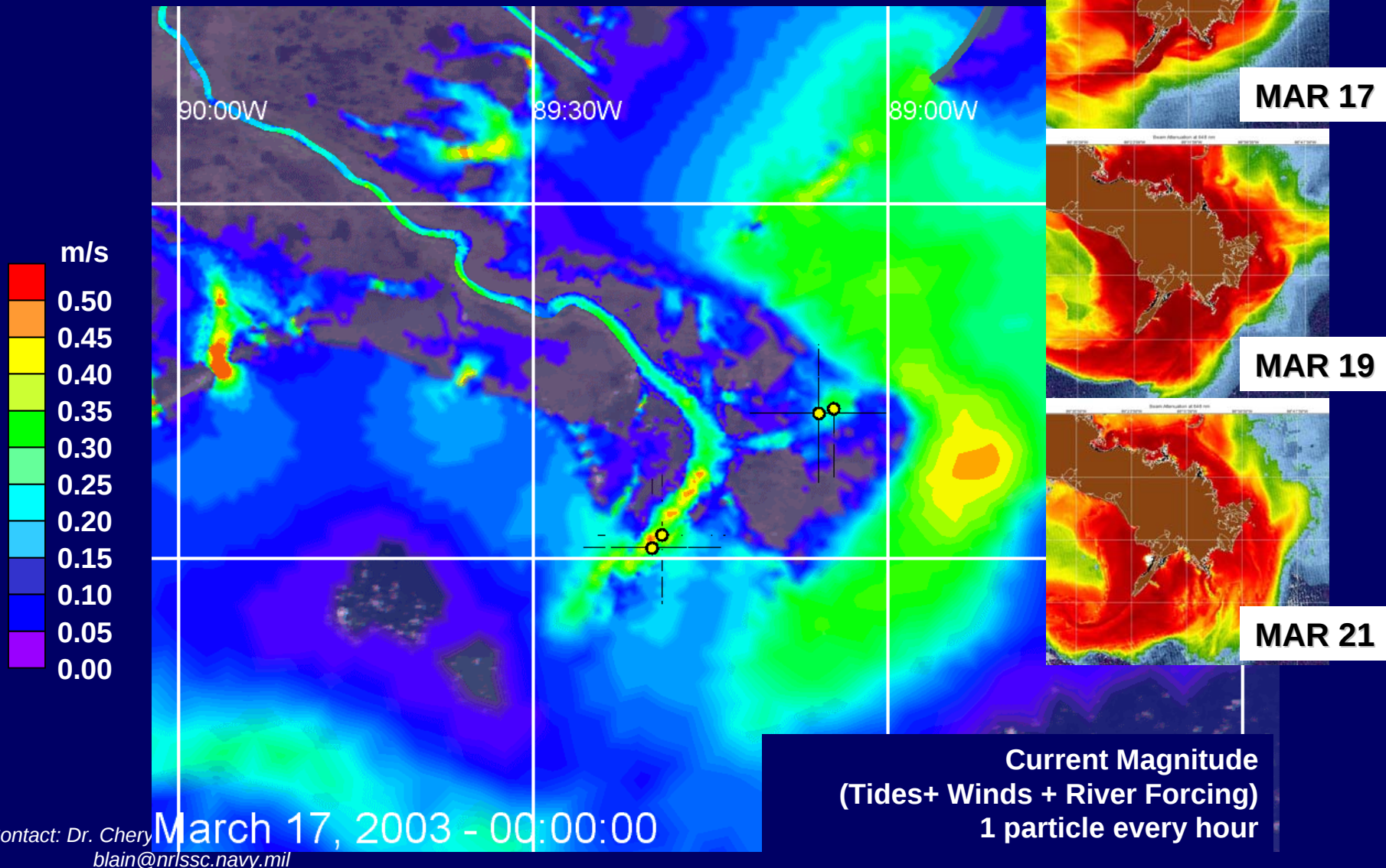
Beam Attenuation vs. Currents

Velocity Magnitudes on March 17, 2004



Transport Pathways

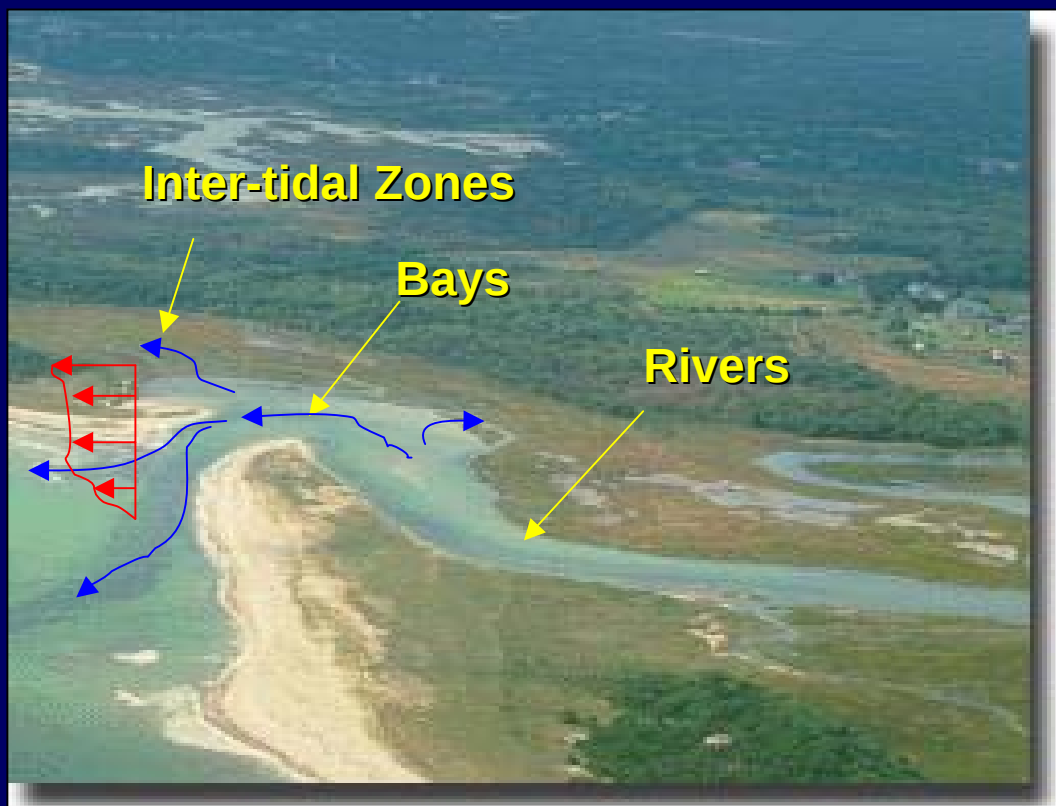
Passive Numerical Drogues



Where are we headed?

Improvements to the Predictive Capability for Coastal Circulation and Transport

- High resolution (meters) currents and water levels in littoral environments that include bays, inter-tidal marshes and rivers



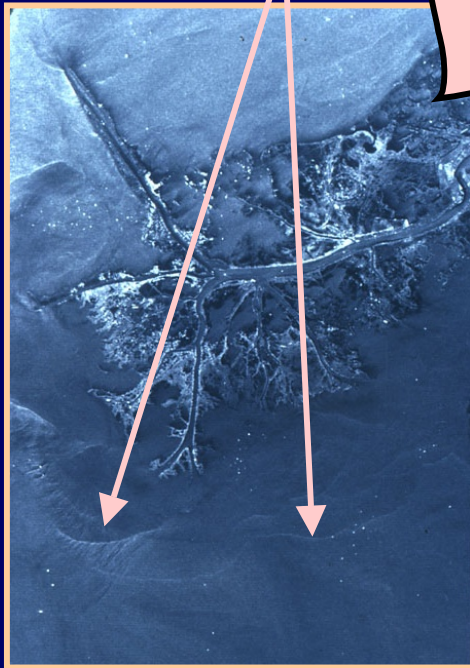
Near-Term Developments

- Transport (T, S, tracers)
- Nesting to regional models
- Connection to bio-optical properties



Finite Element Model Development

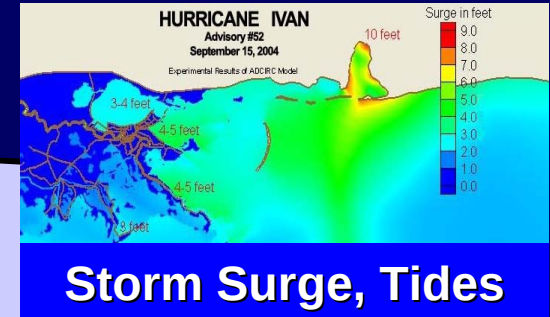
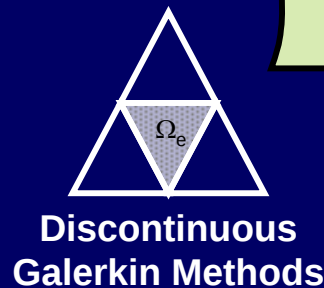
Salinity Fronts in
MS River Delta



Baroclinic
Dynamics

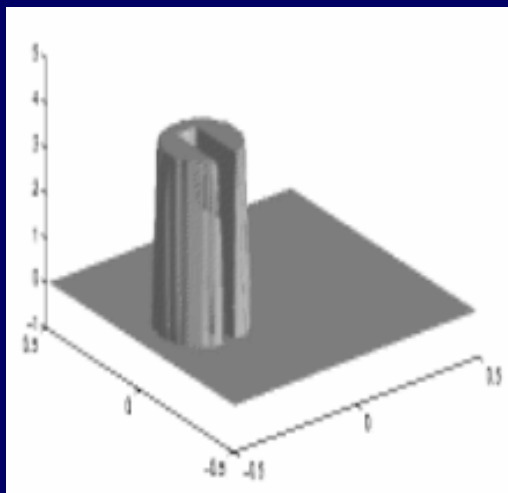
ADCIRC

Non-
Hydrostatic
Dynamics



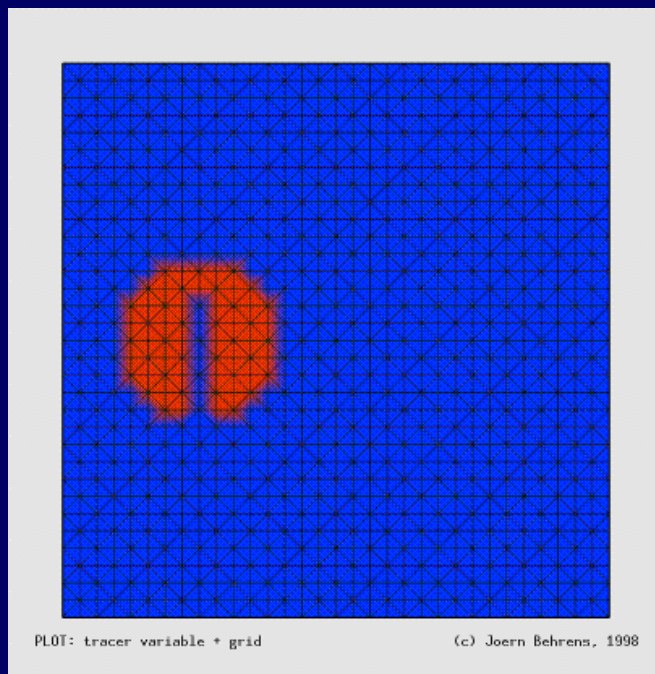
Future: Adaptive Mesh Refinement

A Slotted Cylinder

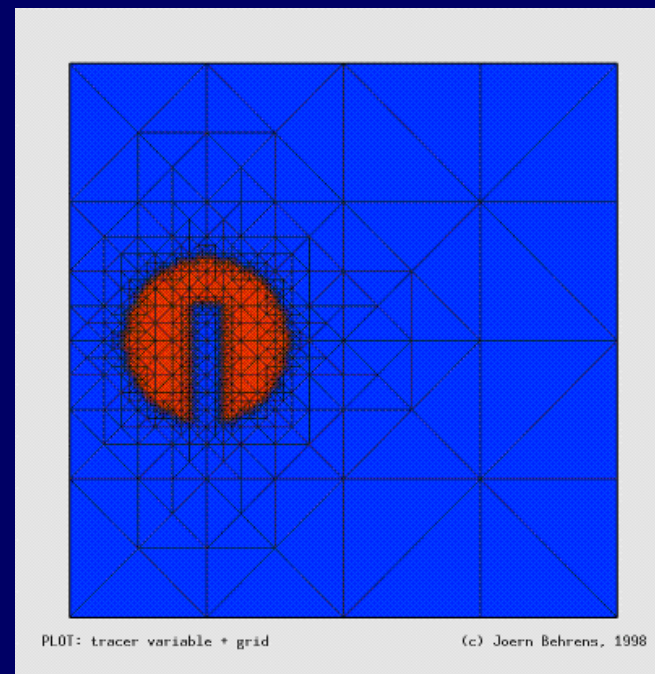


**Error estimates
guide the
refinement
process.**

Uniform Mesh
1089 Nodes



Adaptive Mesh
~800 to 1200 Nodes



To achieve the same resolution as the adaptive mesh, a uniform mesh would require ~16,000 nodes.

Future: Connecting the Watershed, River and Coastal Ocean



Overlap between the watershed model and a coastal circulation model

Watershed

Overland flow

Water in marshes

Vegetation

Circulation

River Discharge
Sediment Load

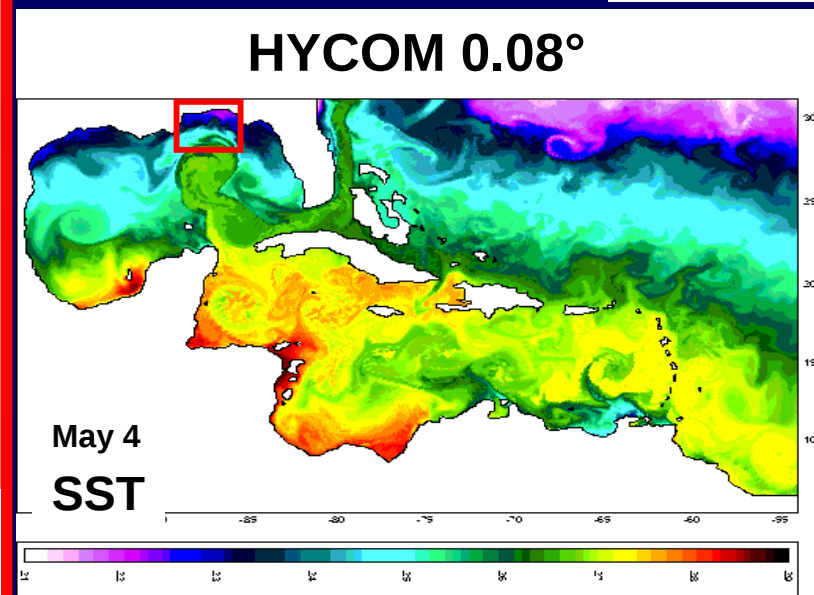
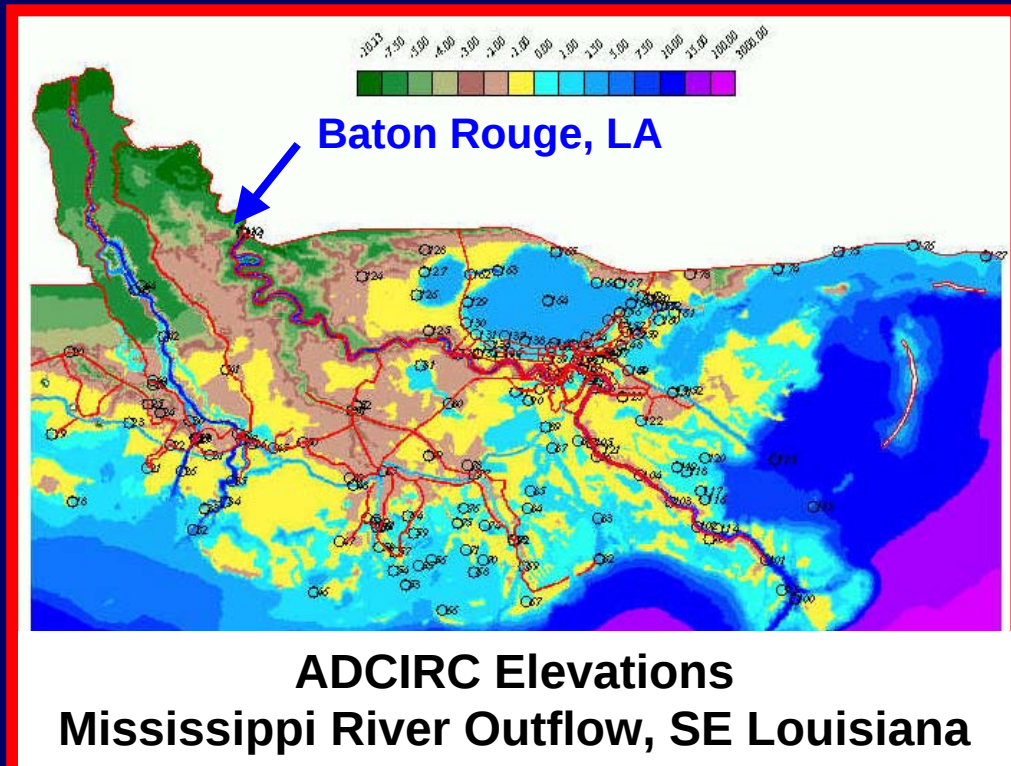
Inundation/Drying

Inundation/Drying
Sediment Load



Future: Limited Domain Applications

Coupling global/regional scale and coastal models

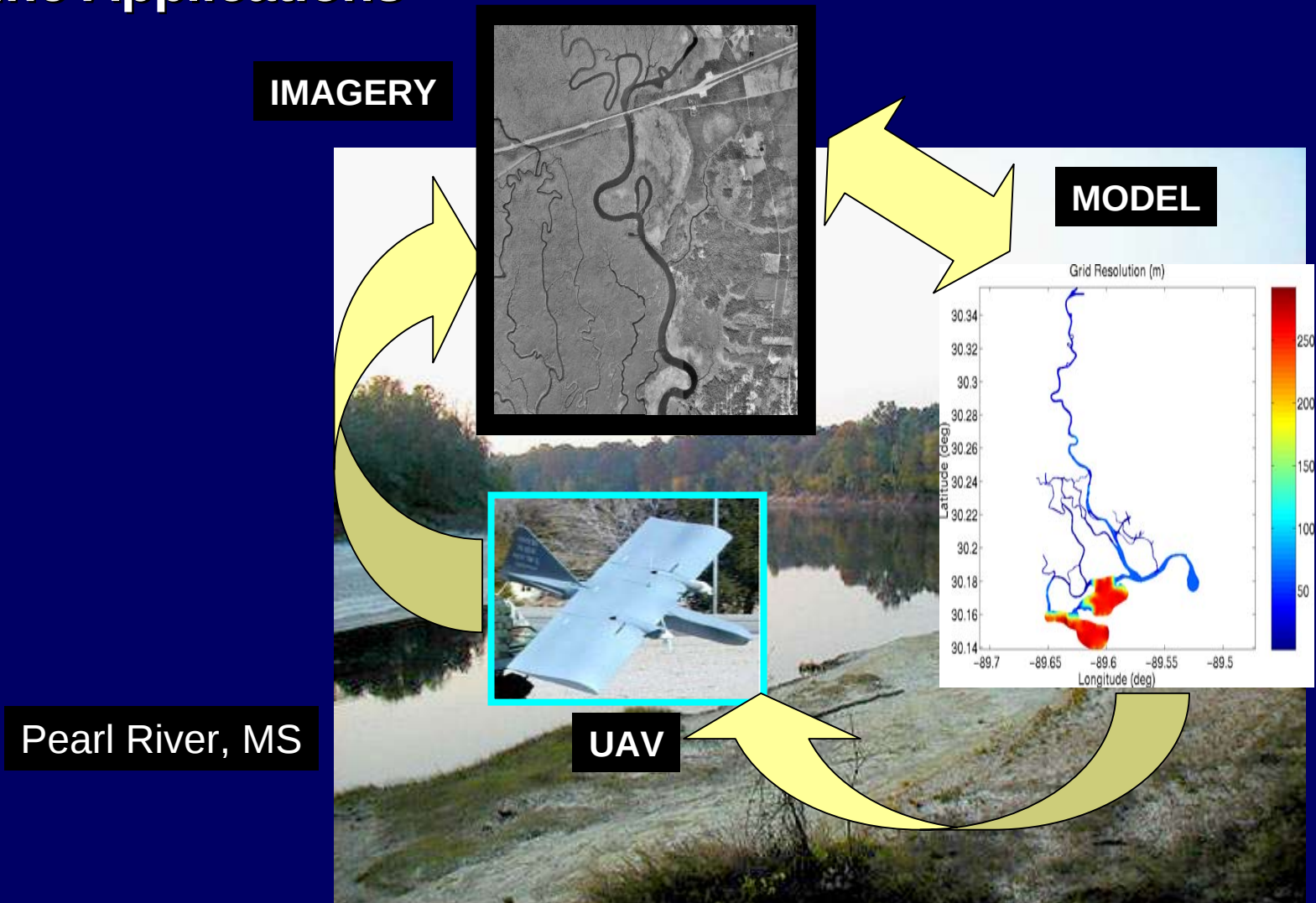


- Coastal application in northern Gulf of Mexico; determine how to best extract boundary forcing data from regional/global models



Future: Predicting Bio-Optical Properties

Riverine Applications



Future: Autonomous Chemical (Mine) Hunting

