73rd MORSS CD Cover Page

712CD

UNCLASSIFIED DISCLOSURE FORM CD Presentation

21-23 June 2005, at US Military Academy, West Point, NY

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15. SUBJECT TERMS

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a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**34**	
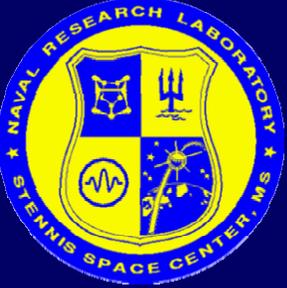
High Resolution Characterization of Riverine and Coastal Currents

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

Oceanography Division
Naval Research Laboratory
Stennis Space Center, MS

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**


Inter-tidal Zones

Bays
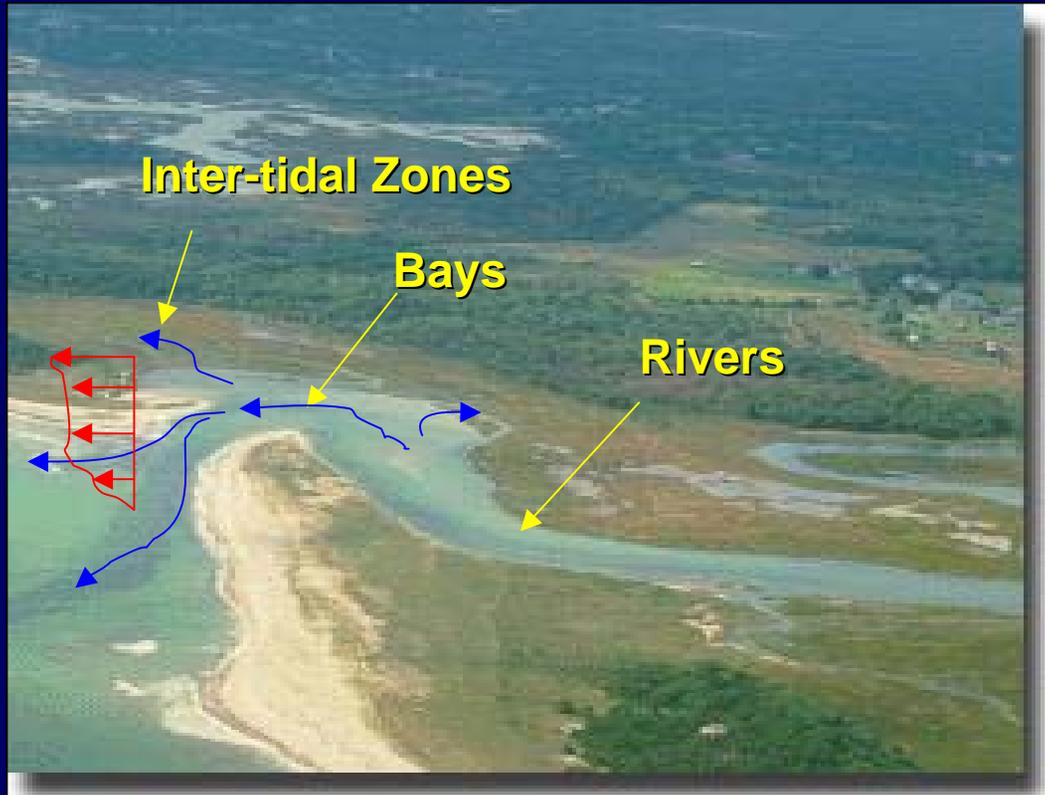
Rivers

ADCIRC Model

- **3D dynamics**

- **Forcing from tides, wind, waves, and rivers**

- **Shoreline inundation/recession**

- **Utilizes unstructured grids (based on finite elements)**

- **MPI parallelization**

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Advantage: Mesh Flexibility

Atch. River

Pearl River

Lake Ponchartrain

MS River

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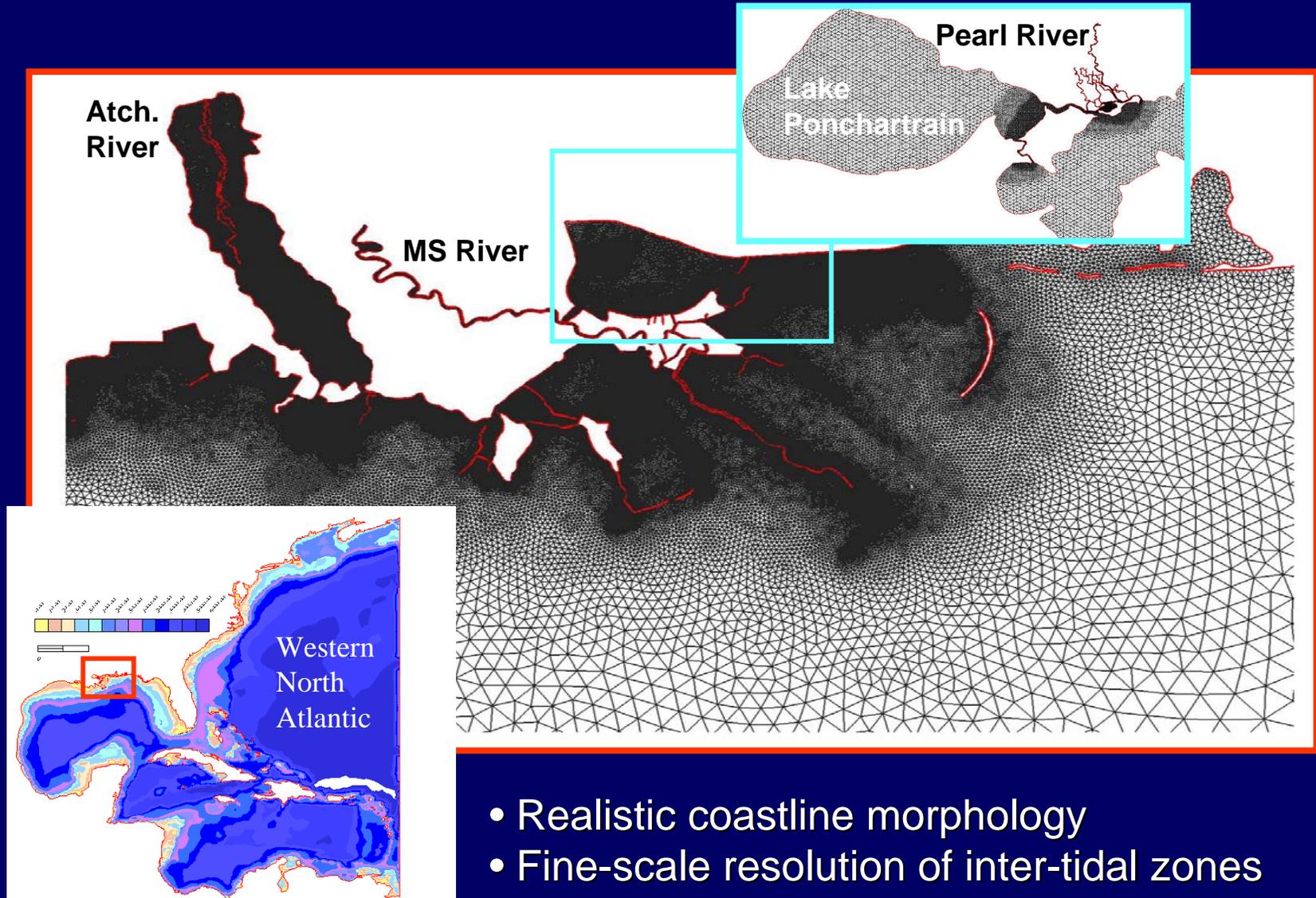
- Realistic coastline morphology
- Fine-scale resolution of inter-tidal zones
- Large domains with remote open boundaries

Contact: Dr. Cheryl Ann Blain, 228-688-5450
*blain@nrlssc.navy.mil*

ADCIRC: SE Louisiana Coastal Waters

Atchafalaya River

MS River

Region of Interest

Mesh Module elevation
120
106
92
78
64
50
36
22
8
-6
-20
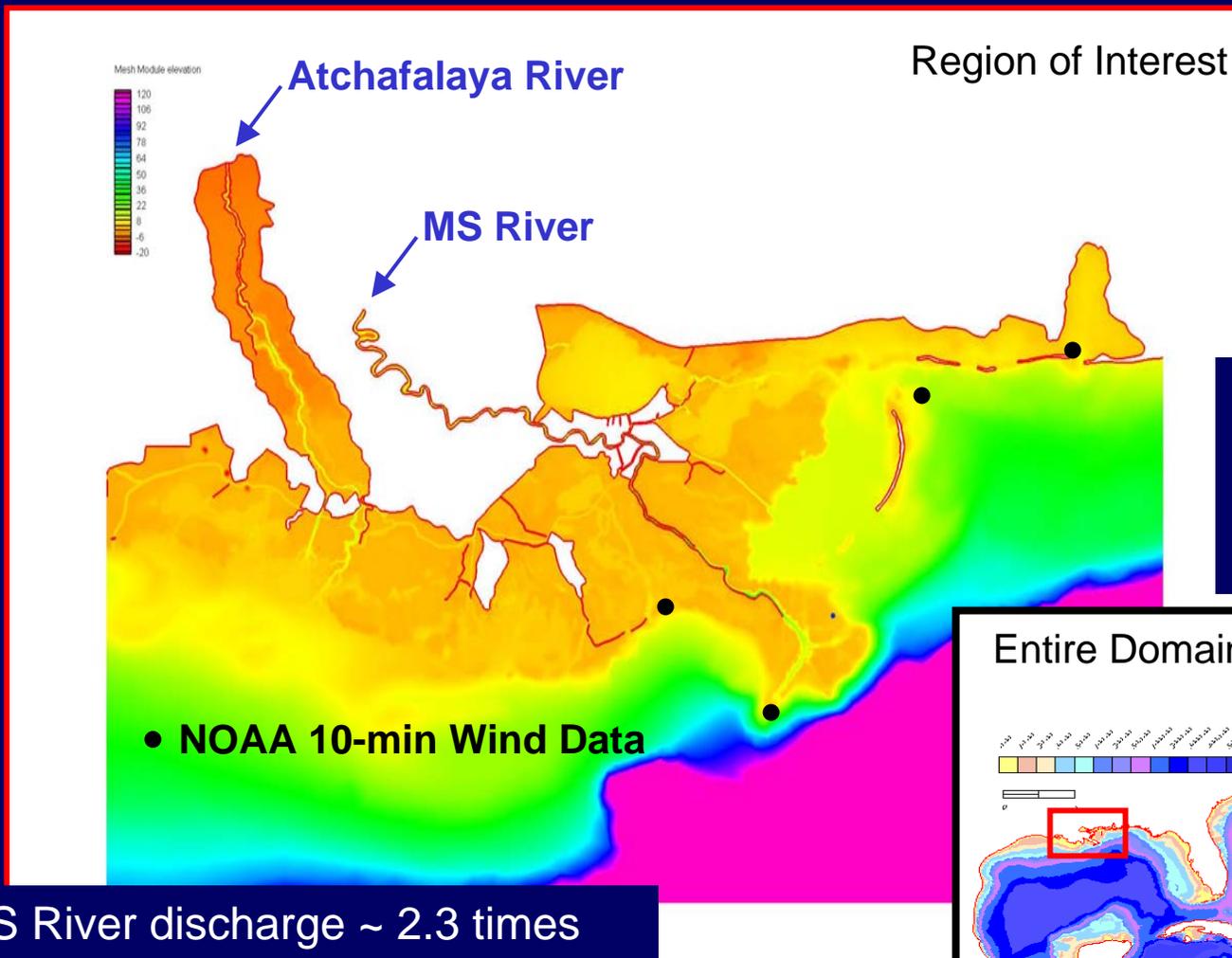
Tidal forcing along ocean boundary from global tide model

Entire Domain

● NOAA 10-min Wind Data
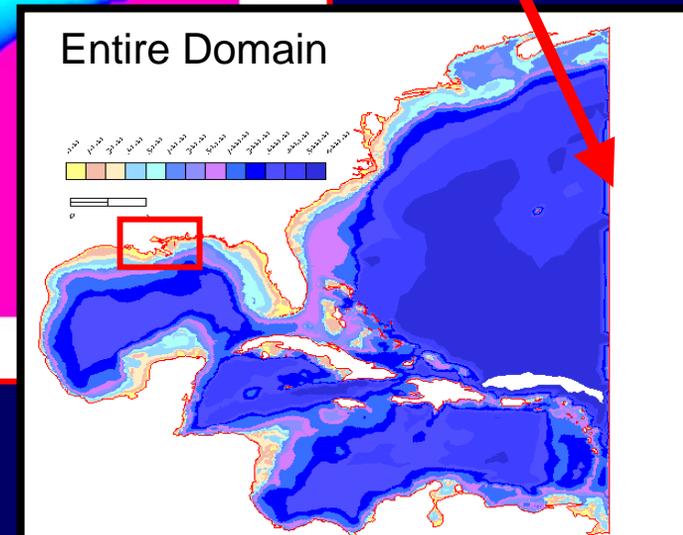
MS River discharge ~ 2.3 times Atchafalaya River discharge

ADCIRC: SE Louisiana Coastal Waters

Bathymetry

Atchafalaya River

Baton Rouge, LA

LAND   0-10 m   25-1200 m

-24.50 -10.00 -1.00 0.00 1.00 2.50 5.00 10.00 25.00 50.00 100.00 200.00 1200.00

L. Ponchartrain

MS River

L. Borgne

Chandeleur Sound

Atchafalaya Bay

Breton Sound

Barataria Bay

Terrebonne Bay

SW Pass

blain@nrlssc.navy.mil

ADCIRC: SE Louisiana Coastal Waters

Simmesport, MS

Tarbert Landing, LA

ADCIRC FE Mesh

No. elements = 455,203
No. nodes = 236,528
Depths = - 24m to 7858m

Resolution 100 m in rivers;
200-500 m in coastal waters

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Modeled Currents – March 17-24, 2004

Velocity Magnitudes on Day 13.00
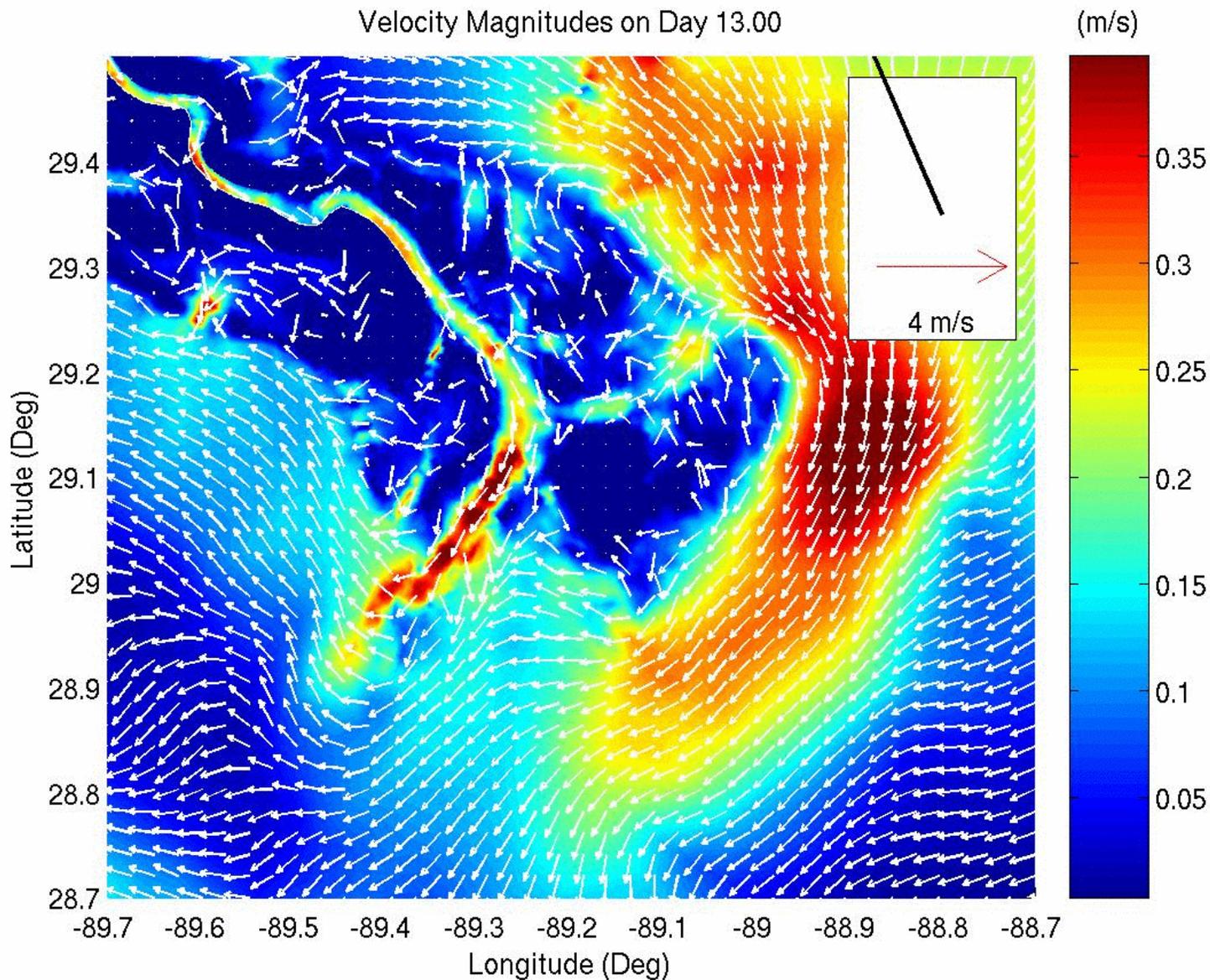
Development of Embayment and River Models

Pearl River Model

Bay St. Louis Model

Biloxi Bay Model

Mobile Bay Model
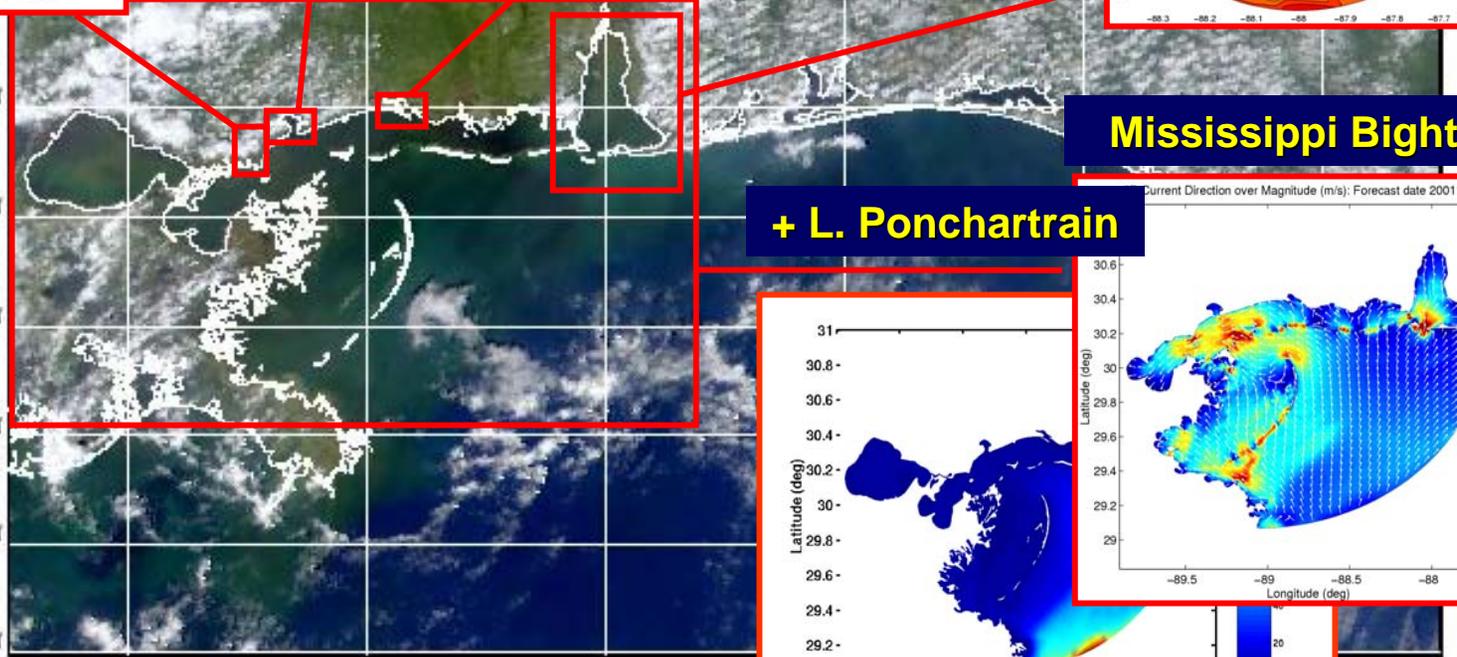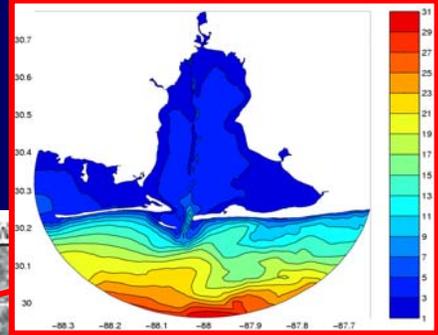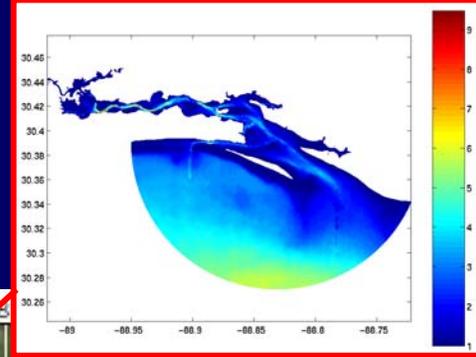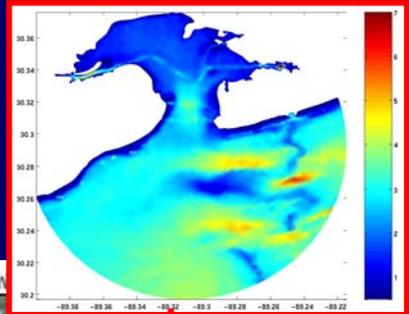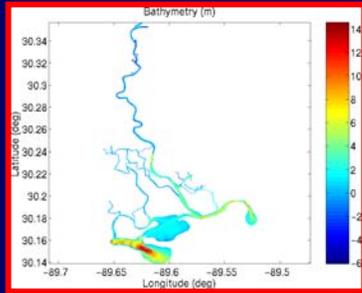
Mississippi Bight Model

+ L. Ponchartrain
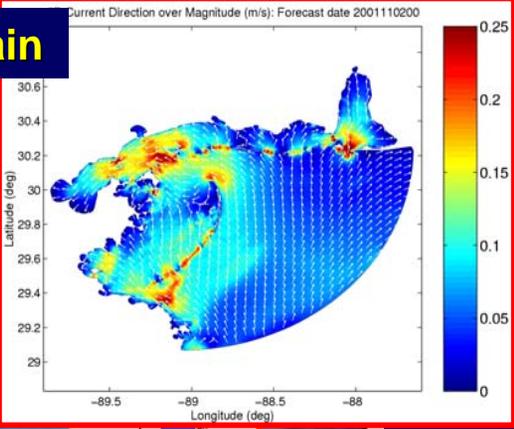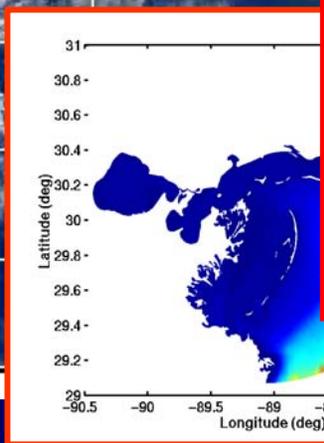
# Coupled Wave-Tide Circulation in Bay St. Louis

Pathways of Numerical Drifters over 23 Hours
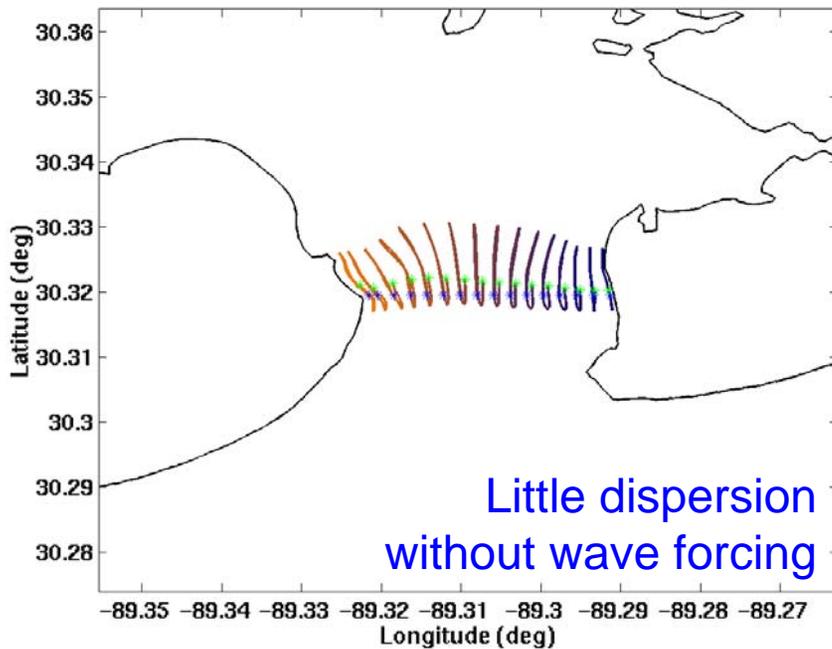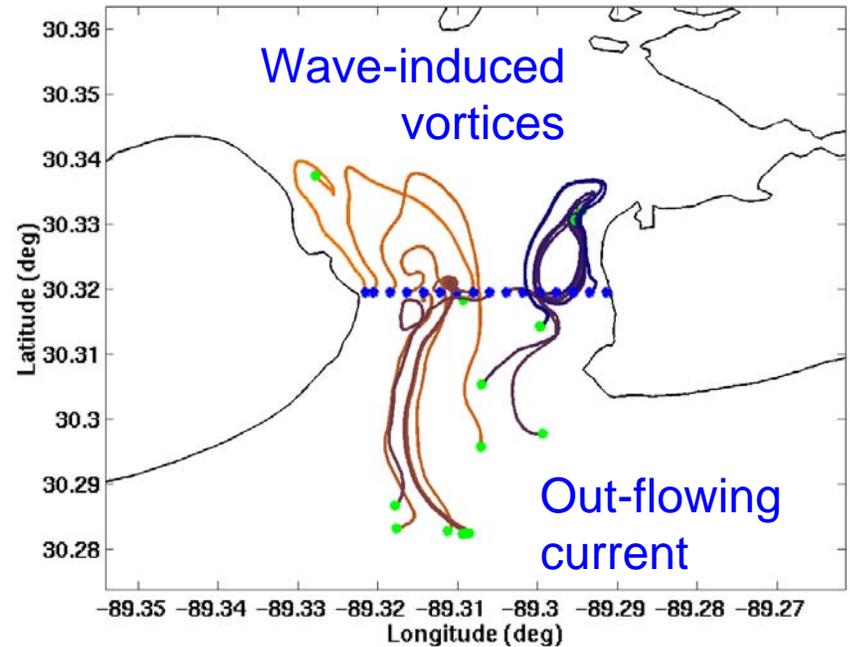
Tidal Forcing Only   **Wave-Tide Interaction**

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

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Sensitivity of Bay-Shelf Exchange to Forcing and Model Dimensionality

3-D CIRCULATION

After 15 days

Drogues leave the bay only under max river flow conditions

Most drogues leave the bay regardless of forcing

2-D CIRCULATION

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil
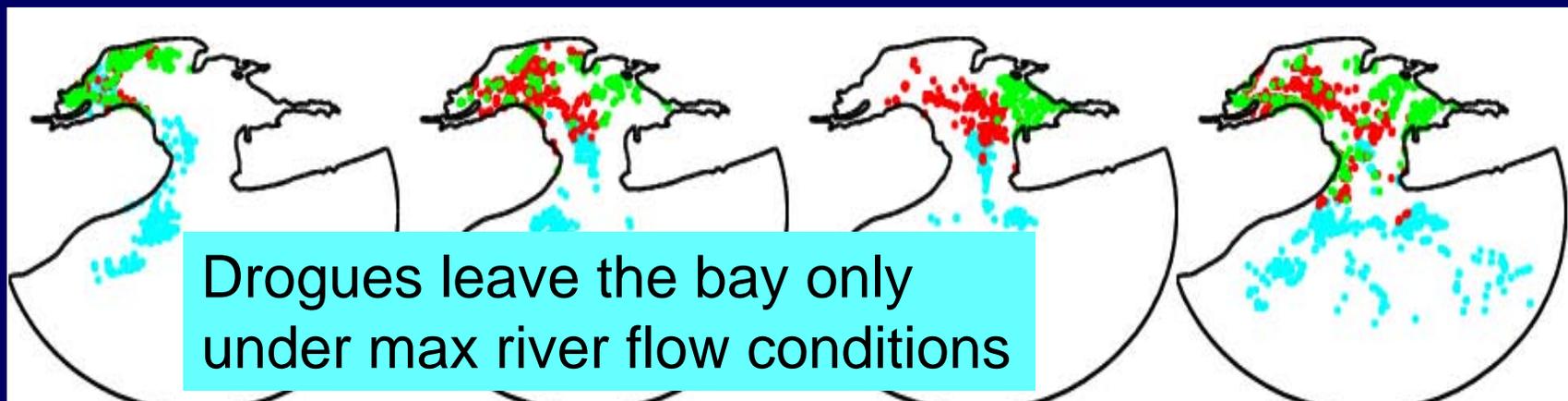
Real-Time Forecast Capability

MET. FORCING
COAMPS

TIDAL FORCING
GRENOBLE

Automated Script Infrastructure

OBSERVATIONS

DATA ASSIMILATION
ADJOINT/Kalman Filters

ADCIRC
FE Coastal Circulation Model

COUPLING

OPEN OCEAN FORCING
ADCIRC, NCOM, HYCOM

Computing Resources
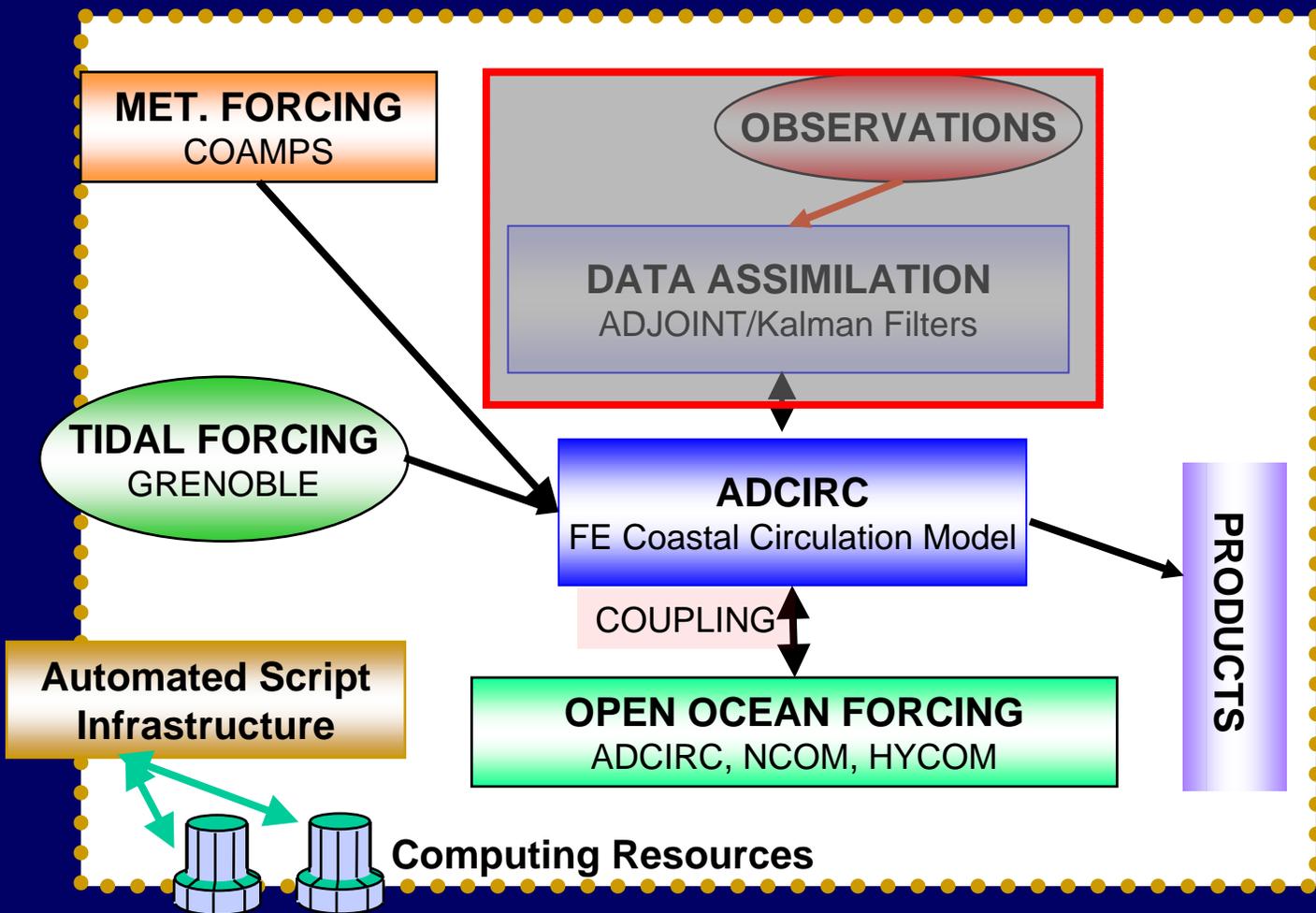
PRODUCTS

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

Contact: Dr. Cheryl Ann Blain, 228-688-5450
        blain@nrlssc.navy.mil
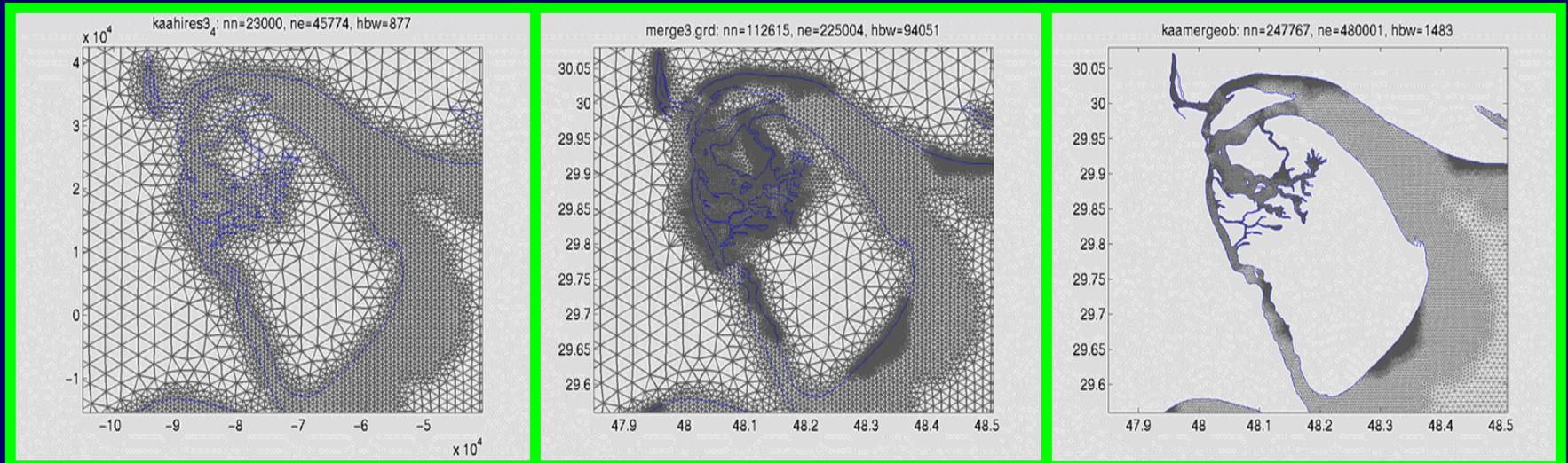
A Tidal Model in the N. Persian Gulf
Operation Iraqi Freedom, March-April 2003

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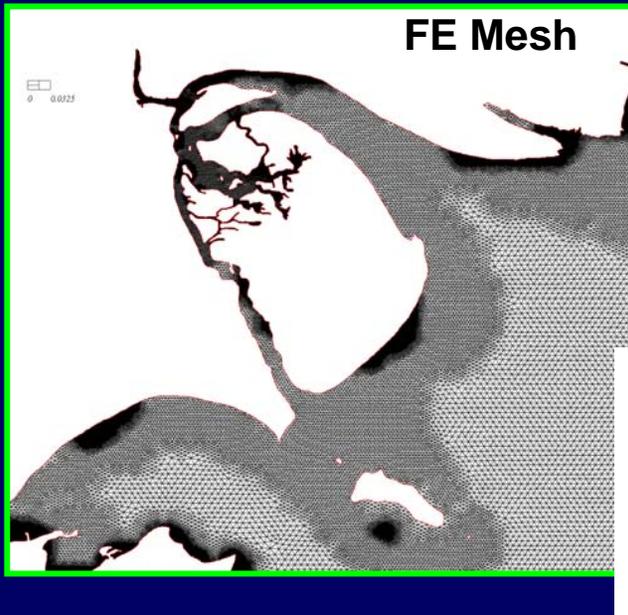
No. nodes	247,767
No. elements	480,001
Resolution	2 m – 1 km

Resolution (m)

KAA Region

1/8 deg

Bathymetry (m)

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil
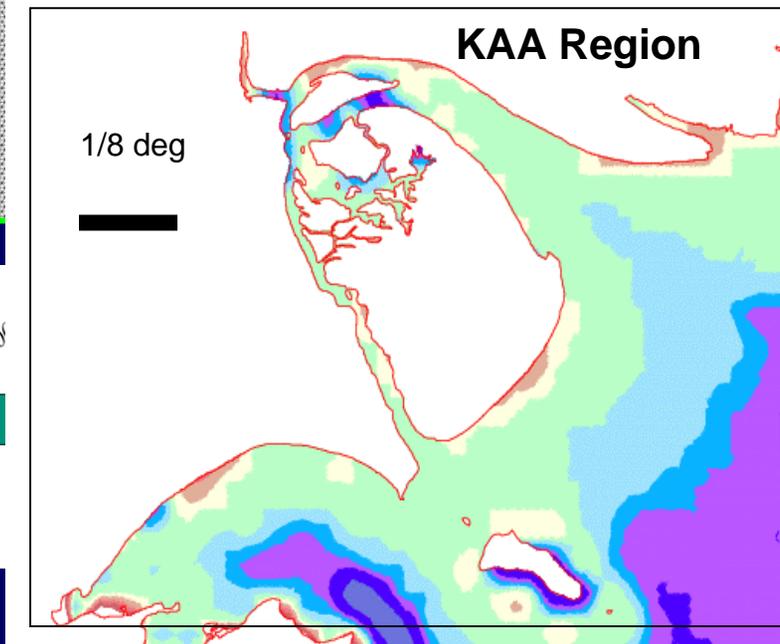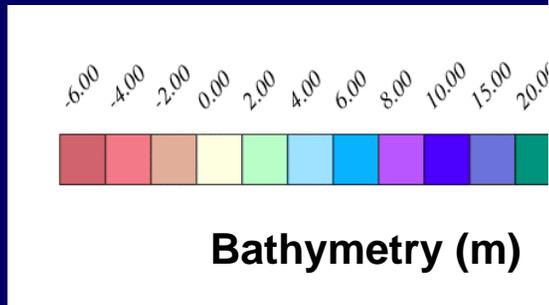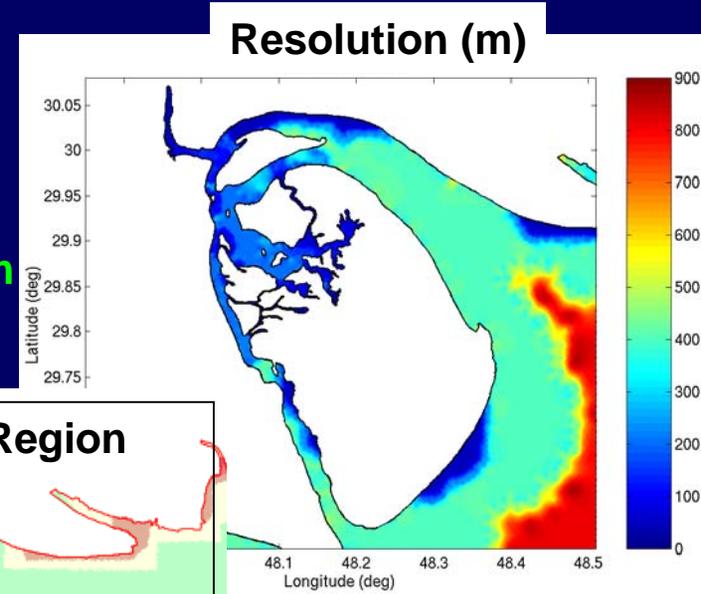
Validation of the Forecast Elevations

March 26-27, 2003

IHO Stations

Shat-Al-Arab
- Obs - Shat-Al-Arab
- ADCIRC - Shat-Al-Arab

Mina-Al_Ahmadi
- Obs - Mina-Al-Ahamdi
- ADCIRC - Mina-Al-Ahmadi
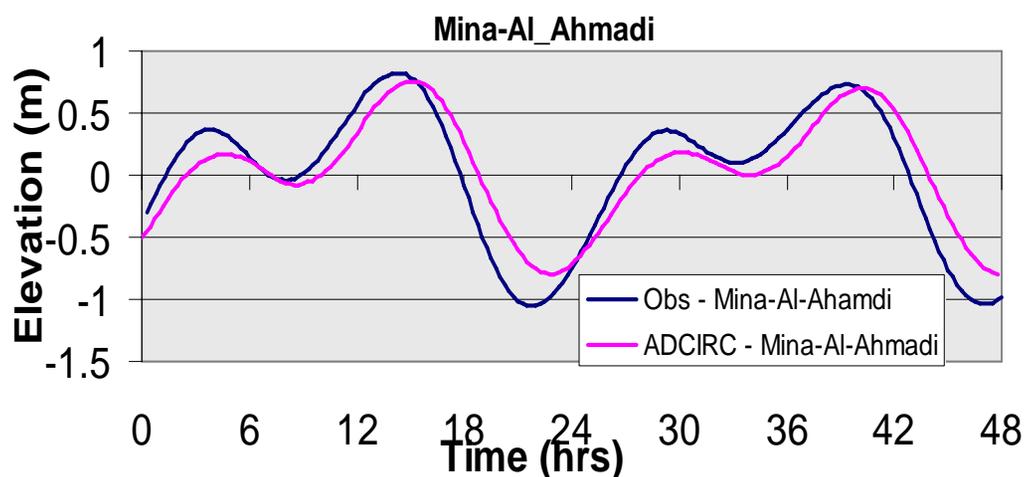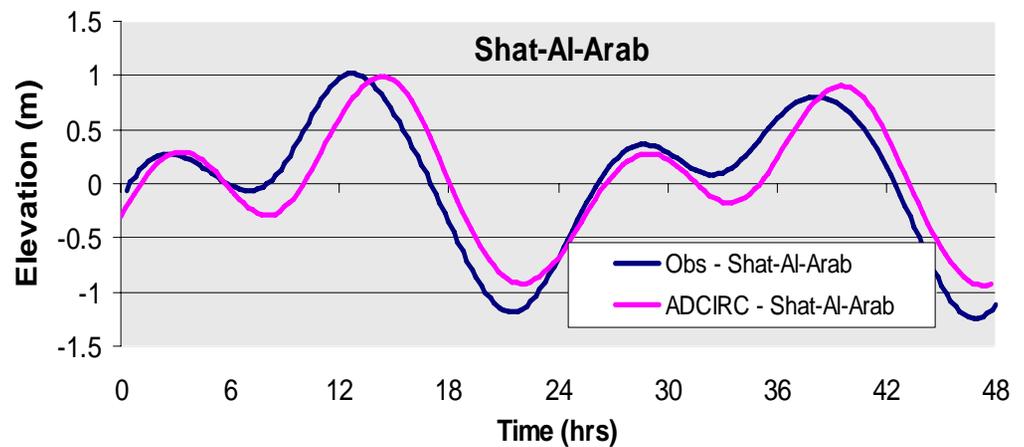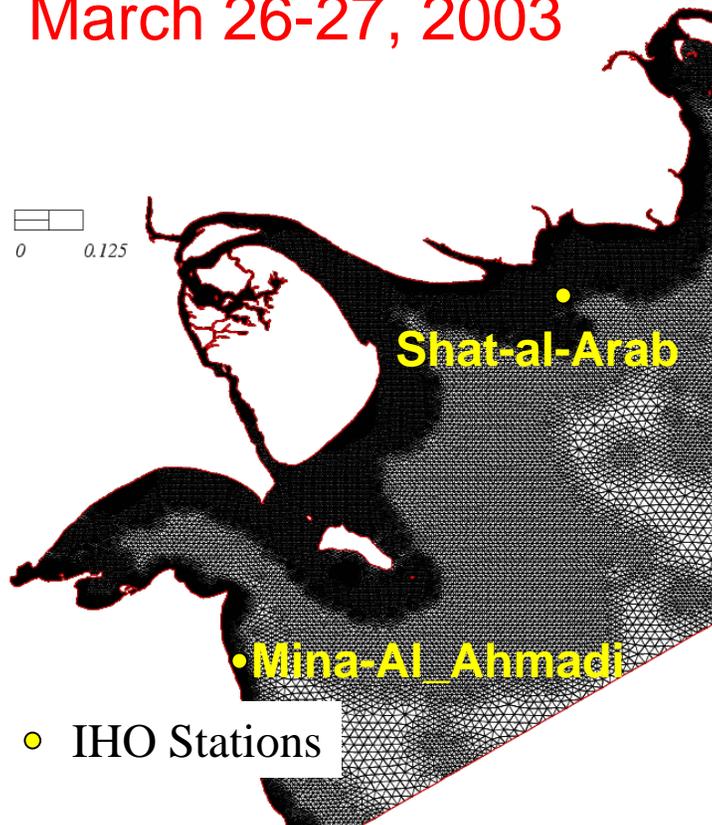
RMS Error	25 cm
Mean Absolute Error	20 cm
Phase Lag	15-30 min

Time series correlation   0.98

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

ADCIRC Model Support for OIF, 2003

Resolution
2 m – 400 m
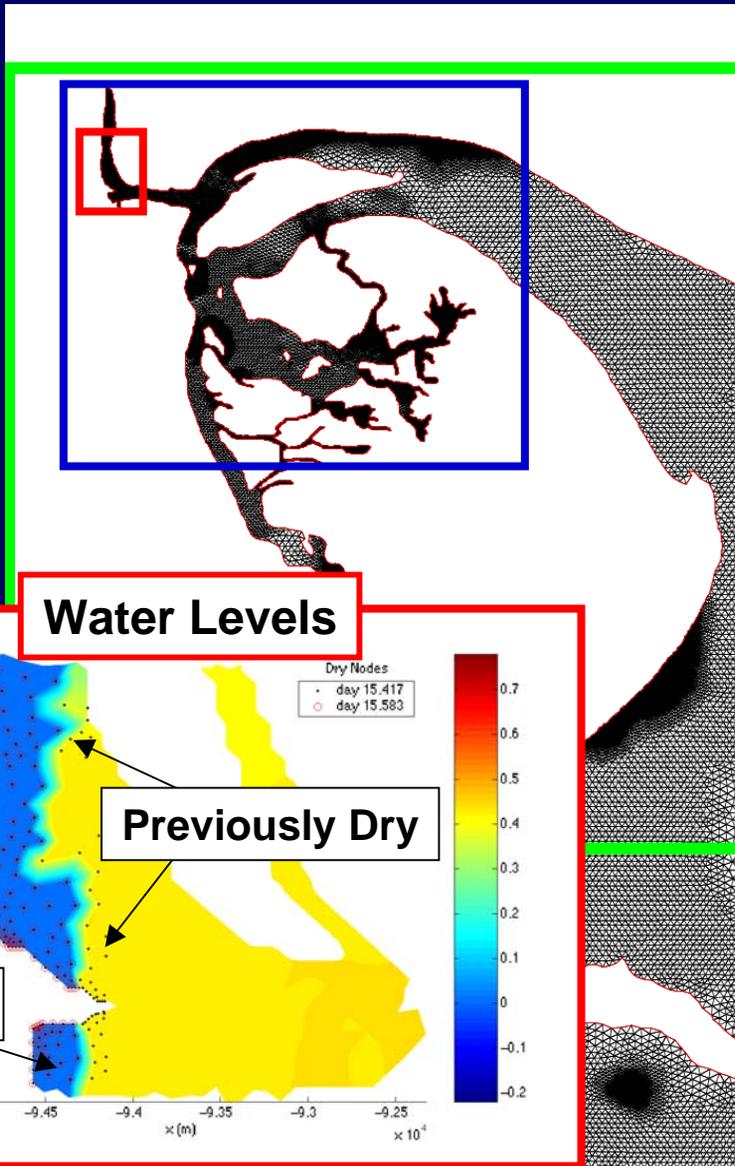
Max 12-hr Current Thresholds

Water Levels

Previously Dry

Dry Regions

2D Currents (Mag/Dir)

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil
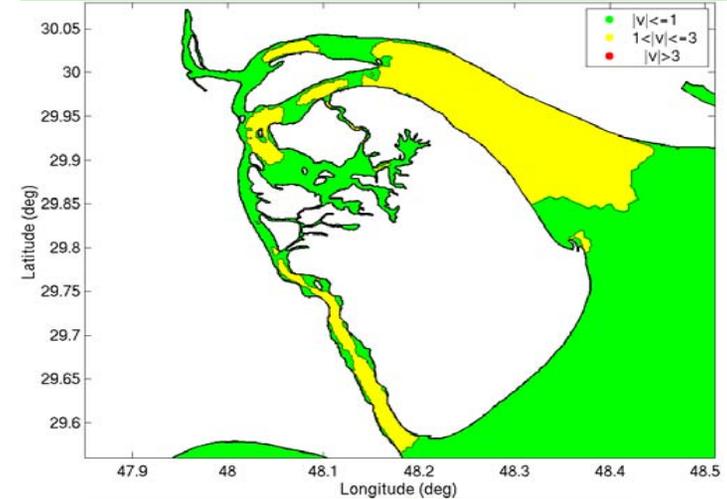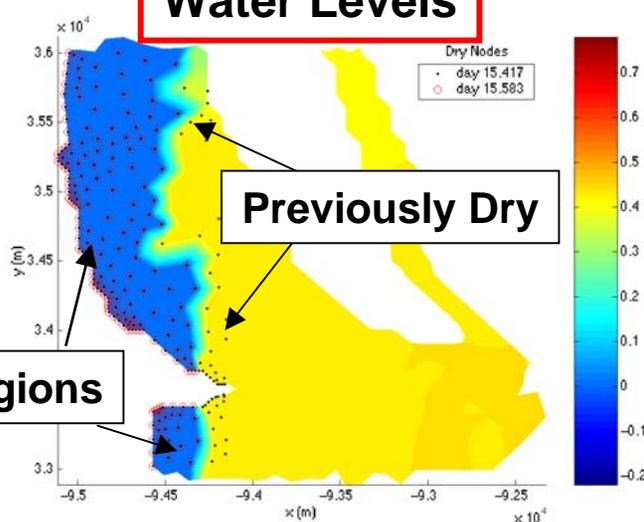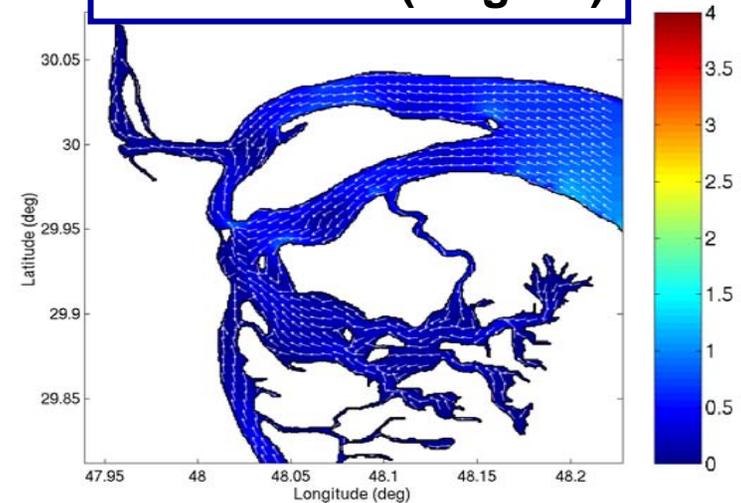
Fine-Scale Circulation Features

Depth-averaged tidal currents north of Um Qsar
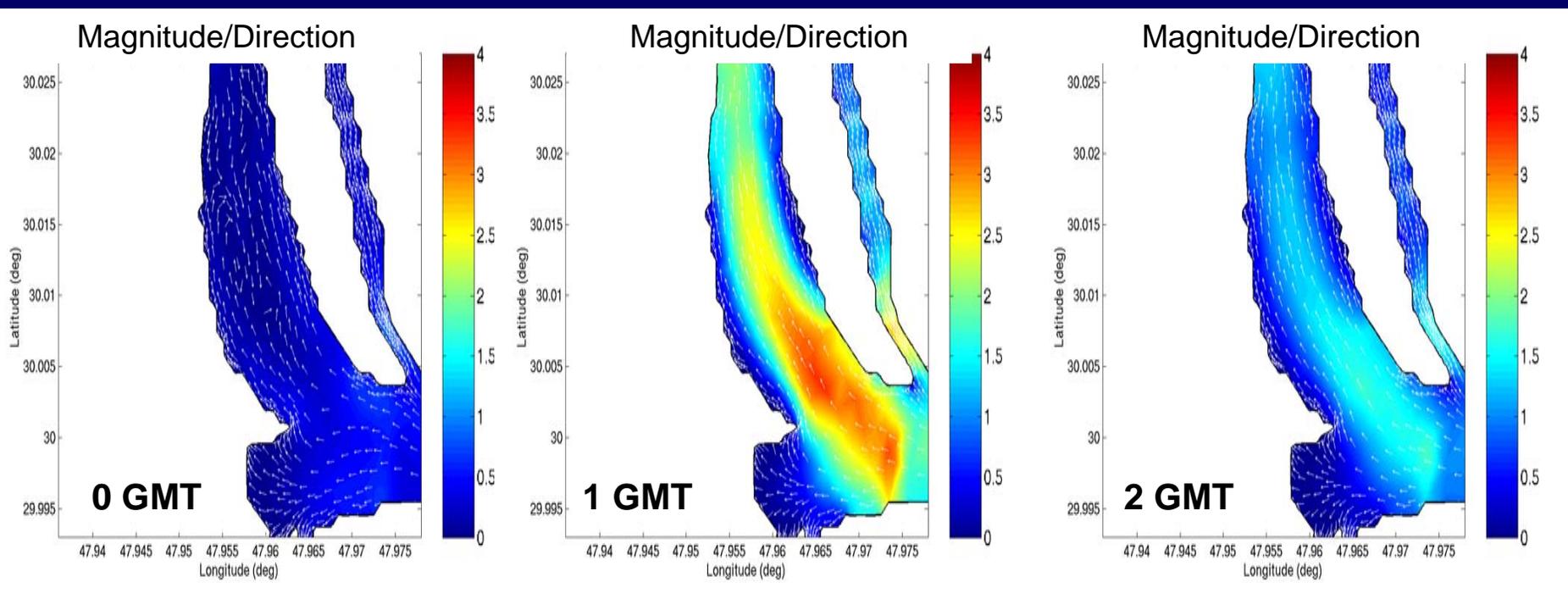
Variability on the scale of hours

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Fine-Scale Circulation Features

2D Current Magnitude/Direction

0 GMT

500 m eddy

Um Qsar

High current shear on ebb/flood transitions
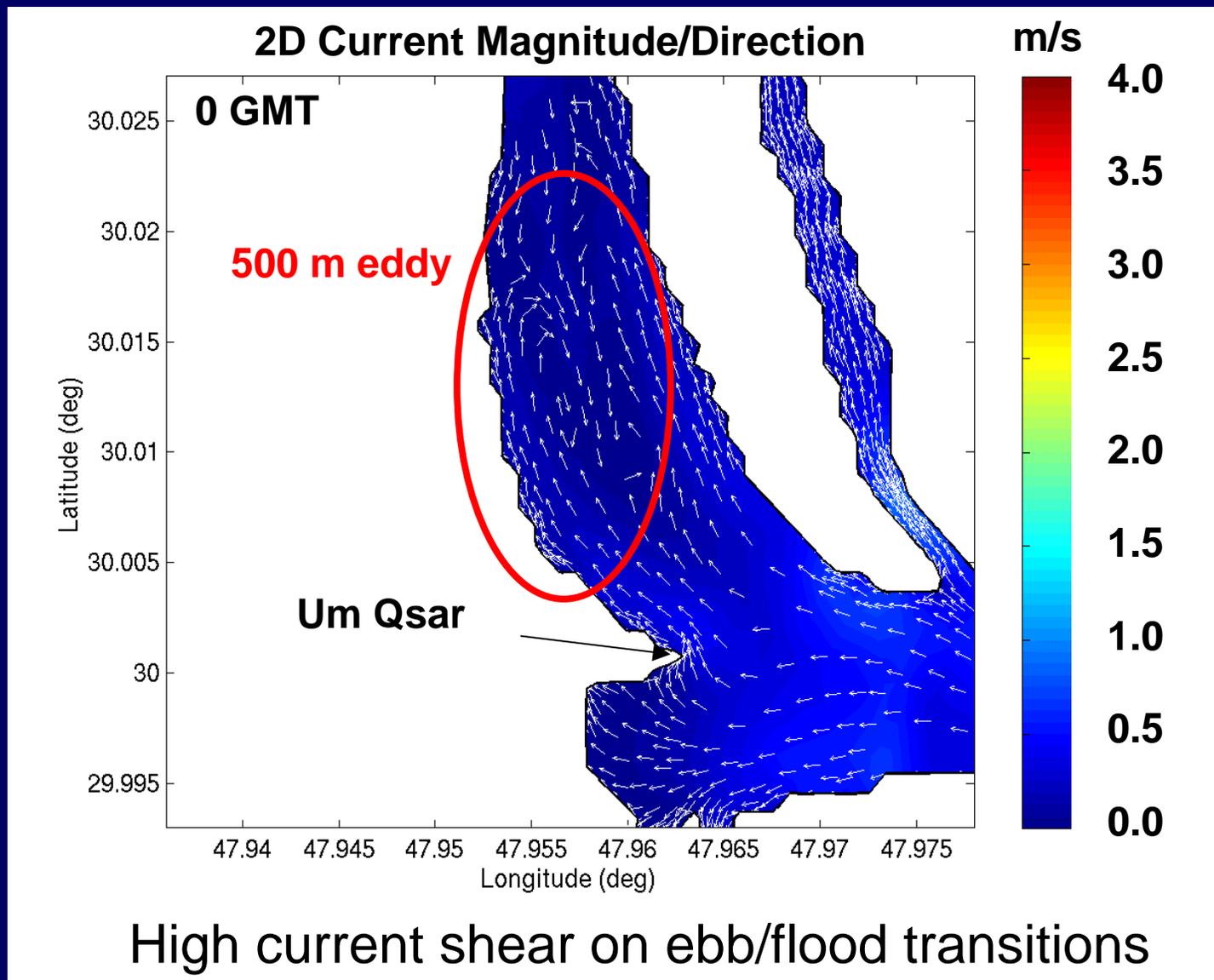
Importance of Including Inundation

2D Currents — No Shoreline Inundation/Drying: Higher flow

2D Currents — With inundation: No flow, Higher flow, Reduced flow
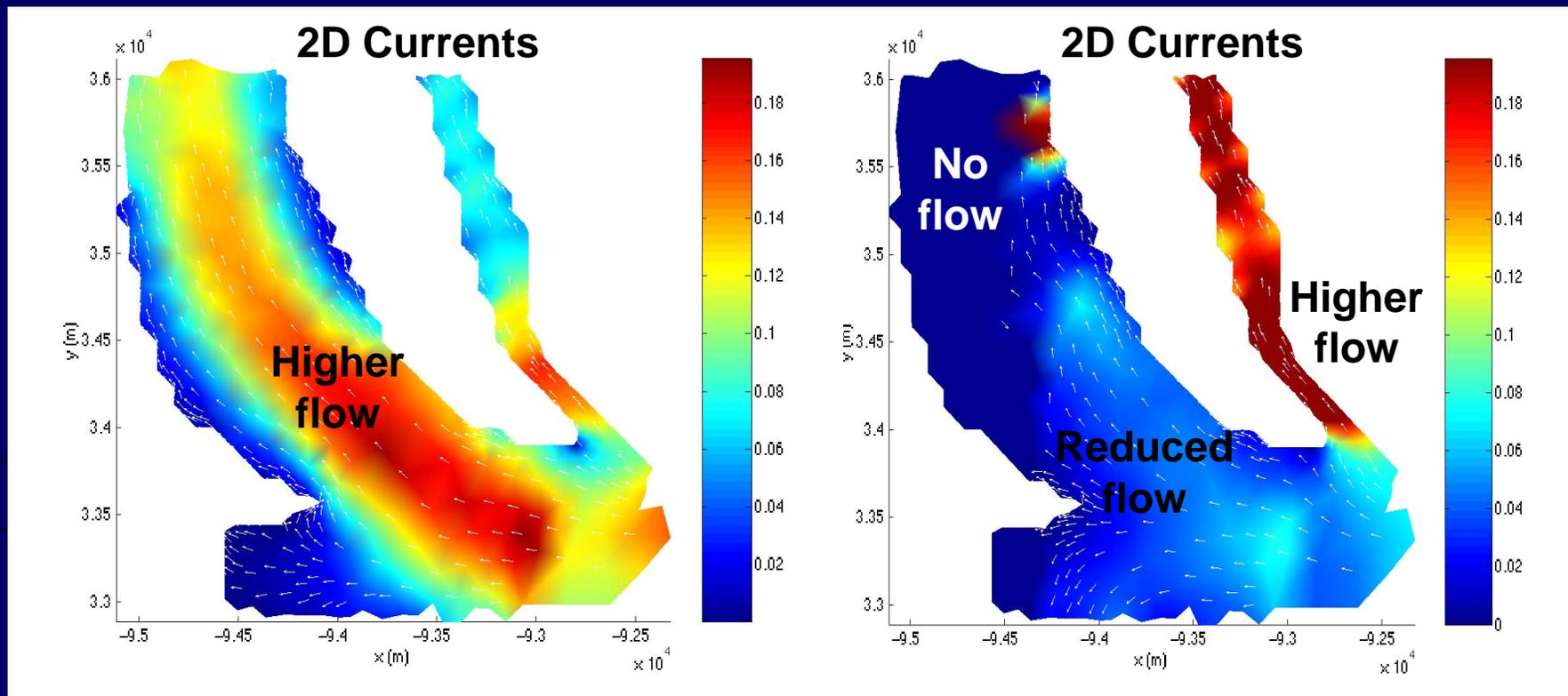
No Shoreline Inundation/Drying

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

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Why Merge Models and Ocean Color Data?

Modeled Coastal Dynamics

Remotely-Sensed Ocean Color Data
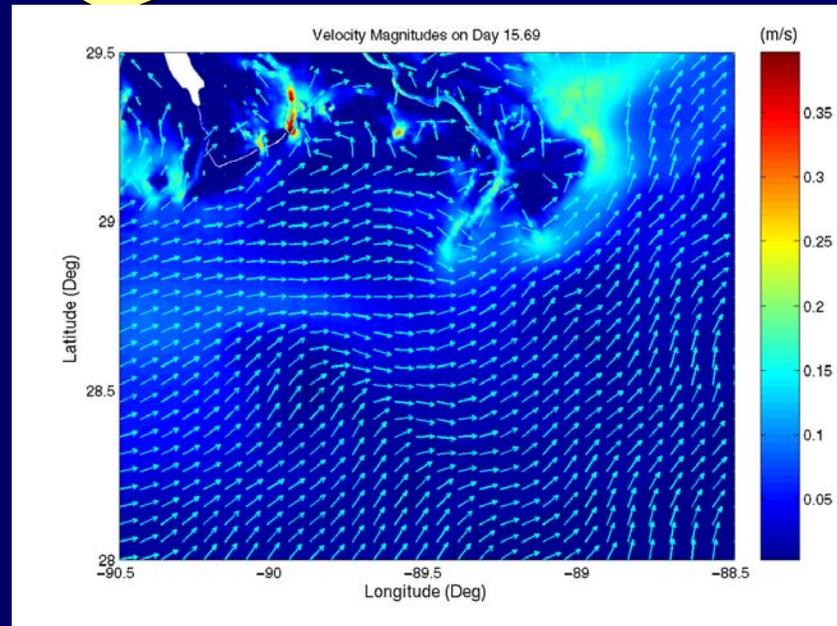
Relate Optical and Physical Properties of the Coastal Ocean

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Complementary Aspects of Merging Models and Ocean Color Data

	Imagery	**Coastal Models**
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

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

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

MODAMQKM2003064072500.L3_NOAA_KWT   Horizontal Visibility at 645 nm   Wed Mar 5 07:25:00 2003

Al Basrah

03/05/03 0725 UTC

Umm Qasr

Kuwait City

Daily Changes responding to tidal cycles

0.32   0.76   1.8   meters   4.4   10.5   25
1.04   82
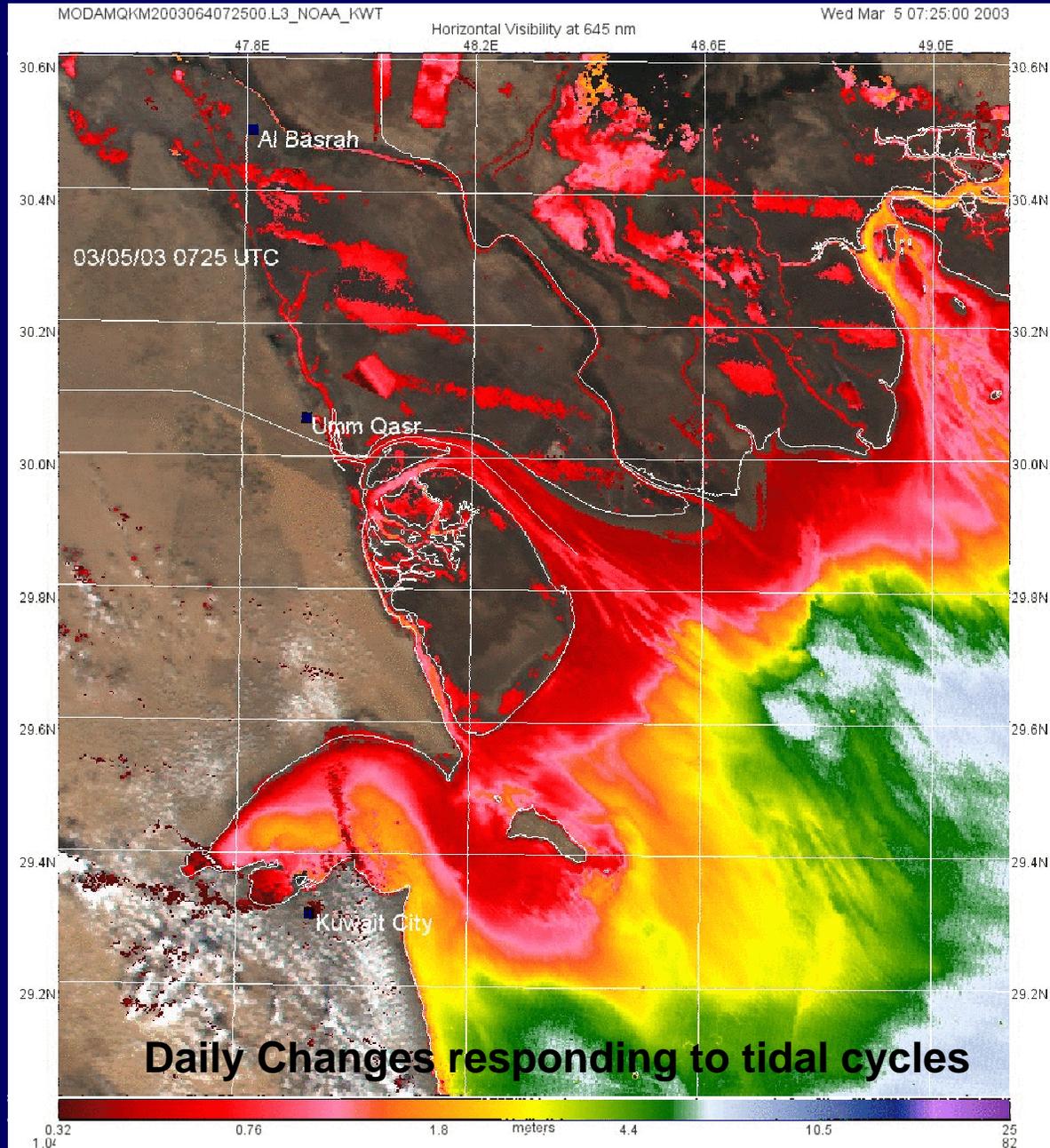
March 5 – May 3, 2003

Low Visibility

Oct. 10 7:05 GMT

FLOOD TIDE

Oct. 10 6:00 GMT
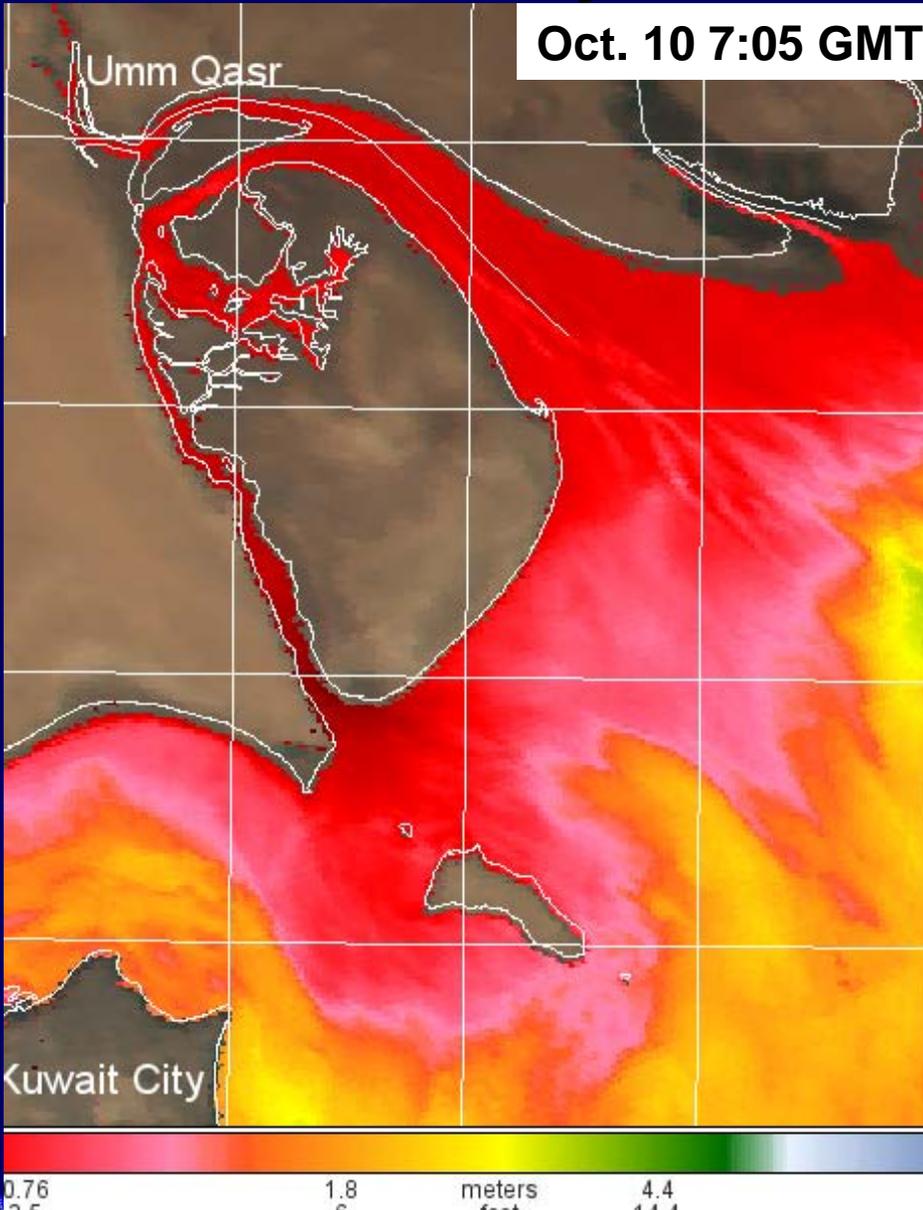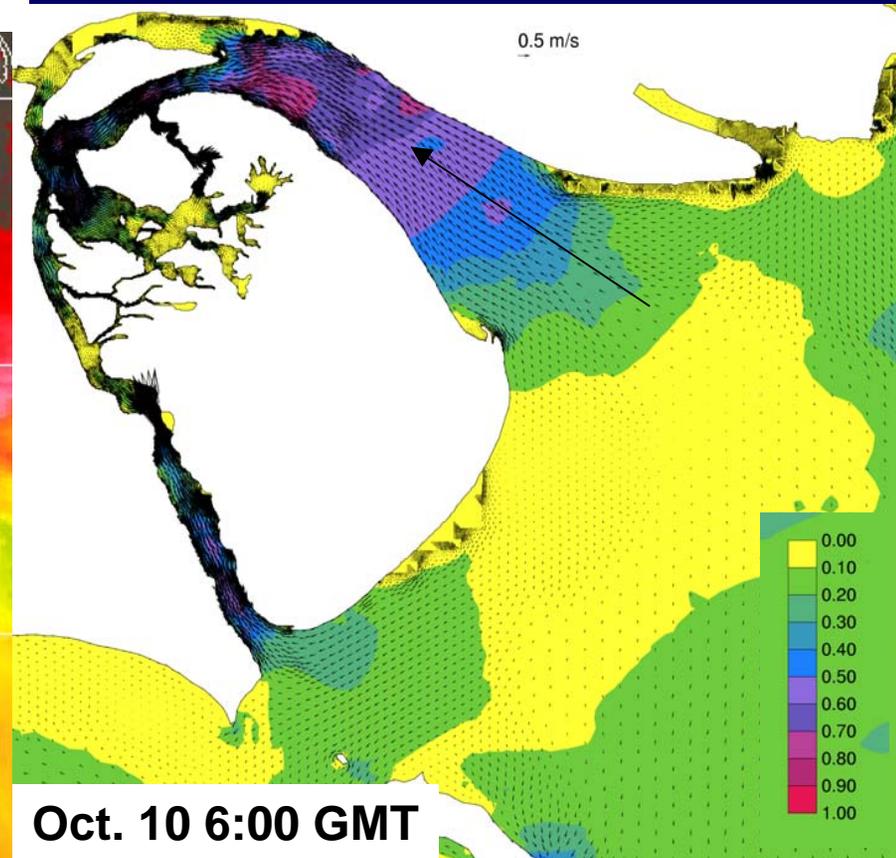
Higher velocities result in more mixing and thus increased turbidity

blain@nrlssc.navy.mil

Increased Visibility

SLACK TIDE

Oct. 10 22:15 GMT

Umm Qasr

Kuwait City

0.76   1.8   meters   4.4

blain@nrlssc.navy.mil

0.5 m/s

0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

Oct. 10 21:00 GMT
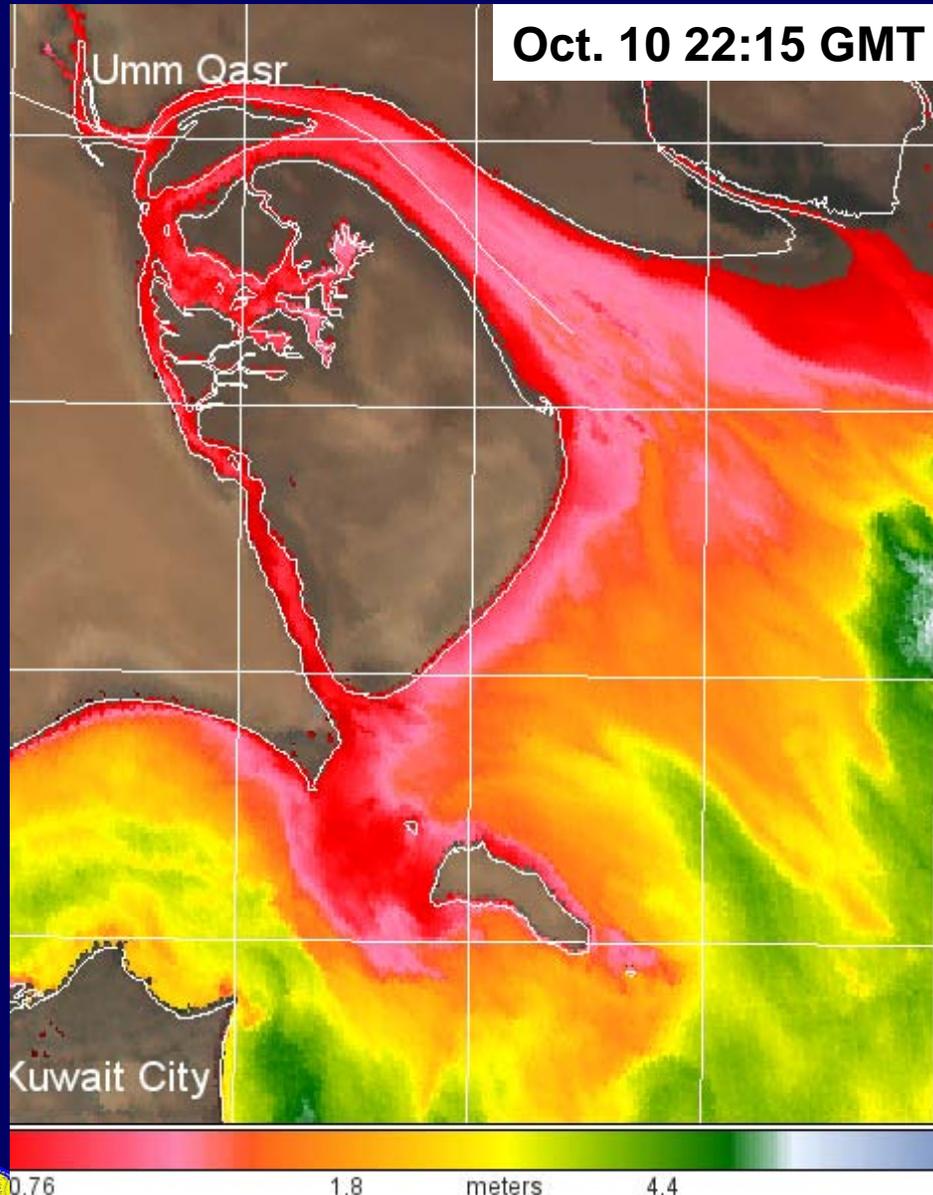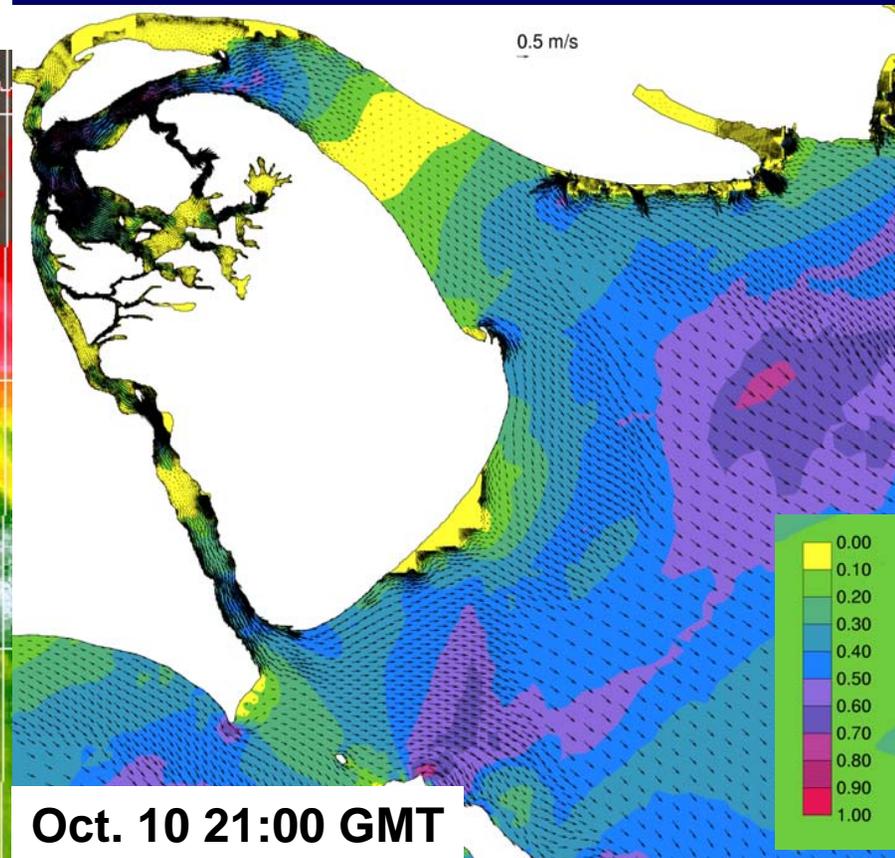
Low velocities allow particle settling and reduce turbidity

Low Visibility

EBB TIDE

Oct. 18 7:55 GMT

Umm Qasr

Kuwait City

0.76   1.8   meters   4.4

0.5 m/s

Oct. 18 6:00 GMT

0.00	
0.10	
0.20	
0.30	
0.40	
0.50	
0.60	
0.70	
0.80	
0.90	
1.00	
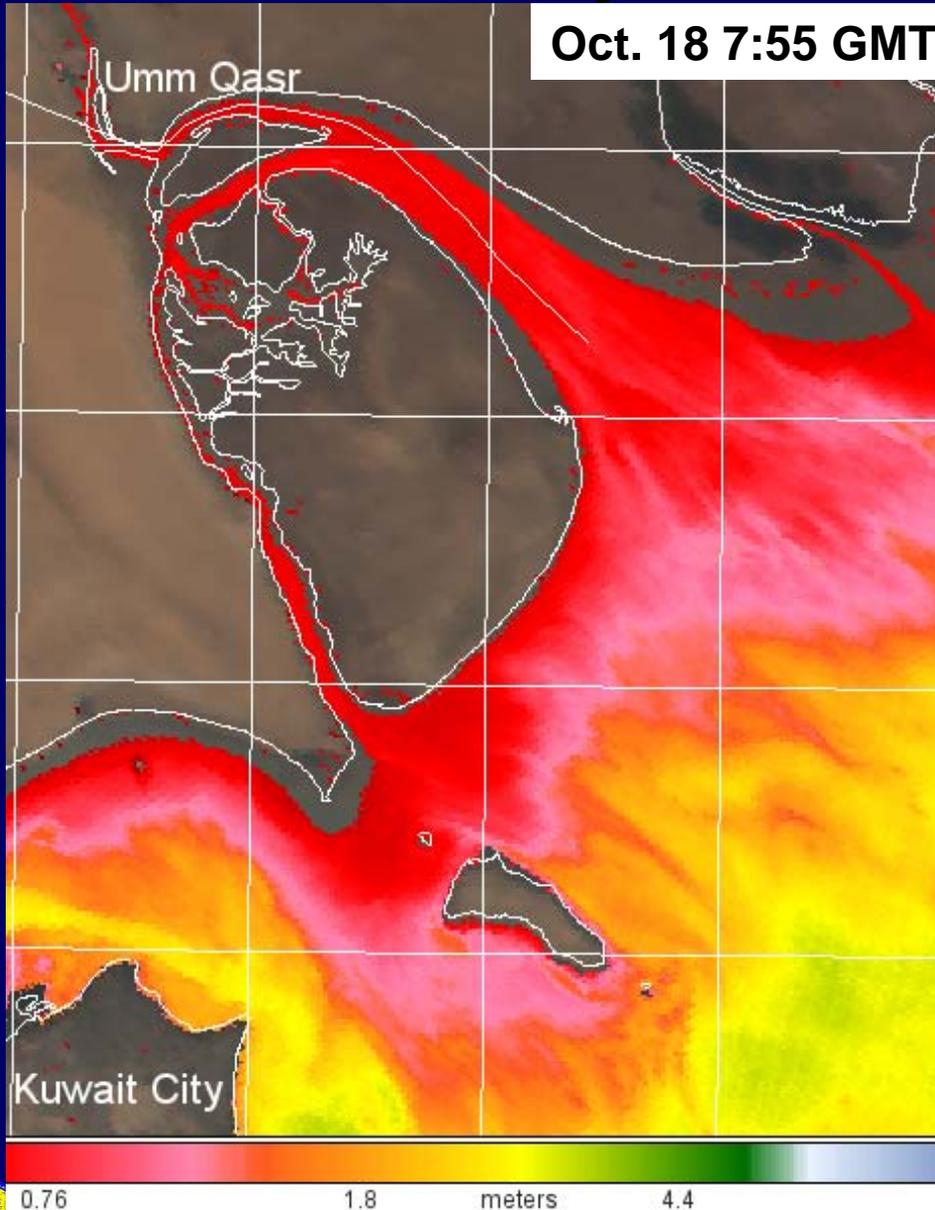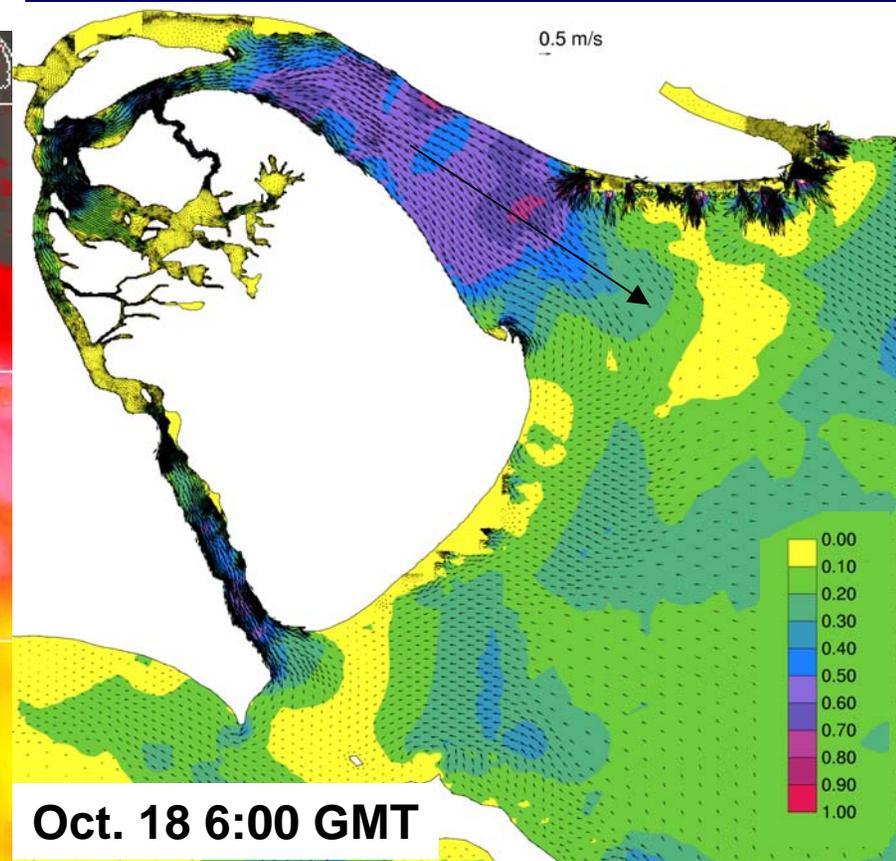
The magnitudes of the ebb tide are not as strong as for flood tide

blain@nrlssc.navy.mil

Beam Attenuation vs. Currents

Velocity Magnitudes on March 17, 2004

MODIS 250

Wind

19 20 21 22 23

(m/s)

Longitude (Deg)

blain@nrlssc.navy.mil

Transport Pathways
Passive Numerical Drogues

MAR 17

MAR 19

MAR 21

m/s

	0.50
	0.45
	0.40
	0.35
	0.30
	0.25
	0.20
	0.15
	0.10
	0.05
	0.00

90:00W   89:30W   89:00W

March 17, 2003 - 00:00:00

Current Magnitude
(Tides+ Winds + River Forcing)
1 particle every hour

Contact: Dr. Chery
blain@nrlssc.navy.mil
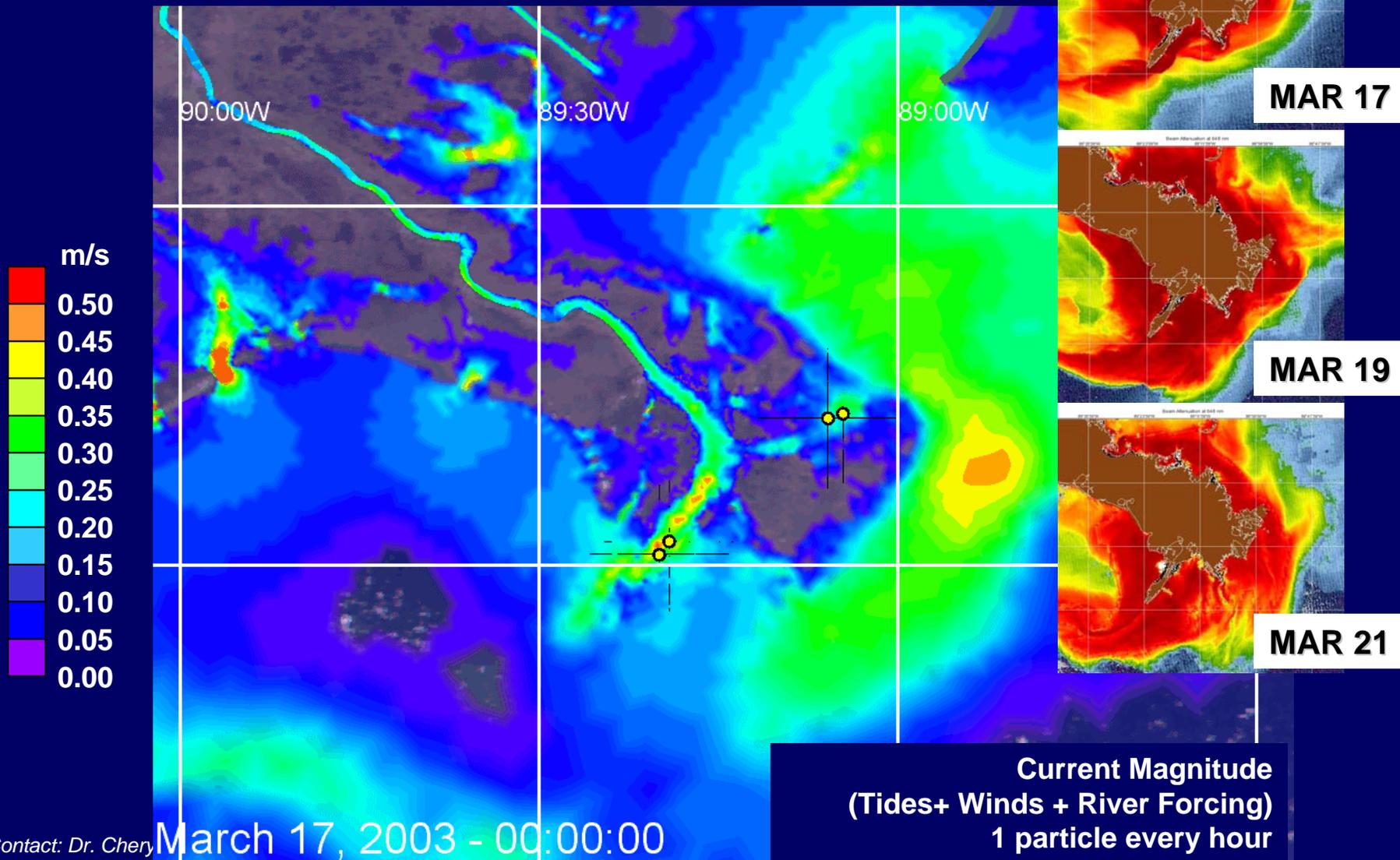
Where are we headed?

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**

Inter-tidal Zones

Bays
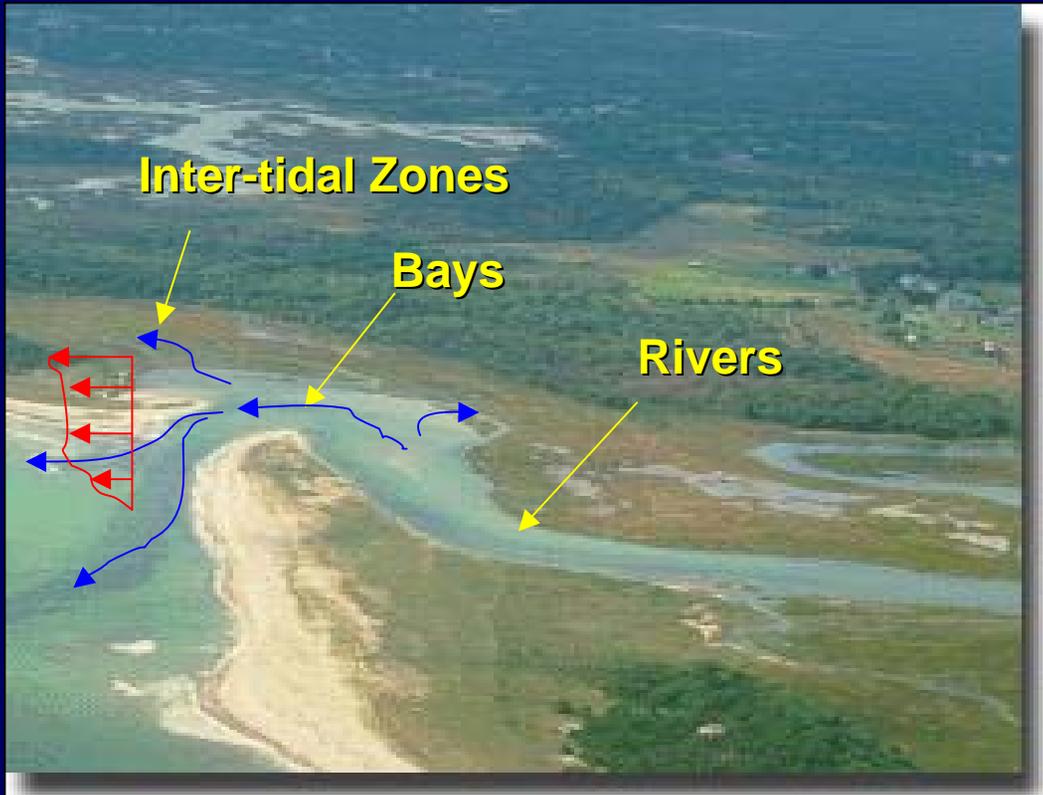
Rivers

Near-Term Developments

- **Transport (T, S, tracers)**

- **Nesting to regional models**

- **Connection to bio-optical properties**

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Finite Element Model Development

Salinity Fronts in MS River Delta

Baroclinic Dynamics

ADCIRC

Non-Hydrostatic Dynamics

Ω_e
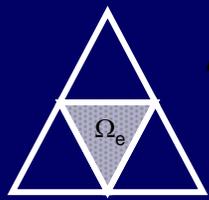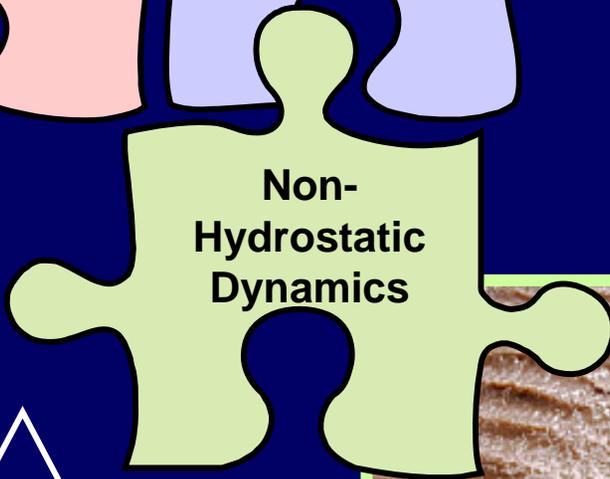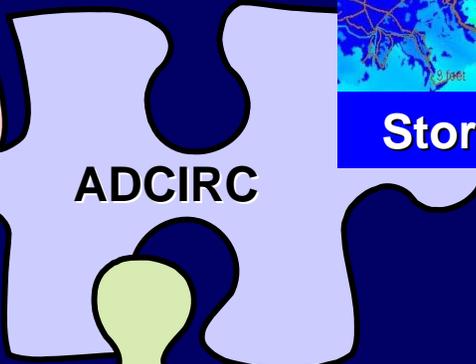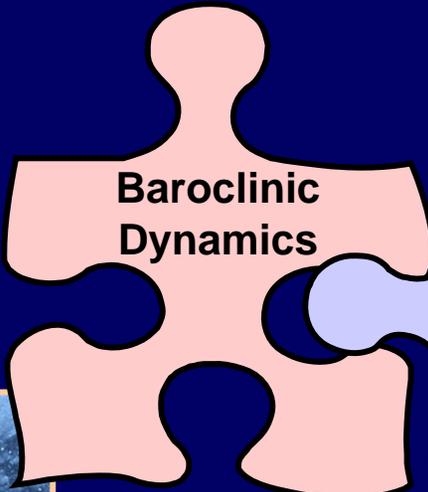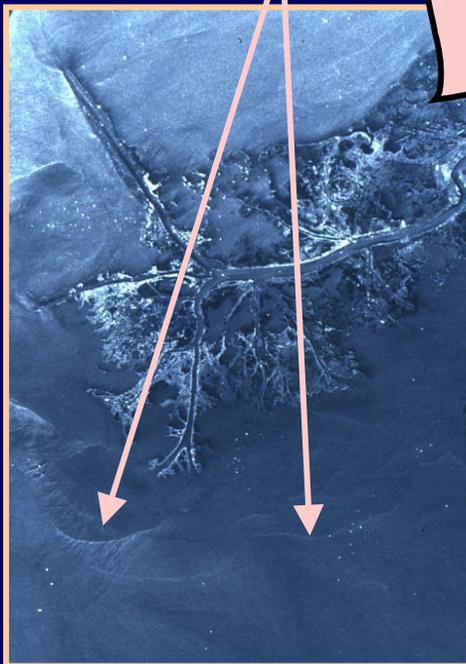
Discontinuous Galerkin Methods
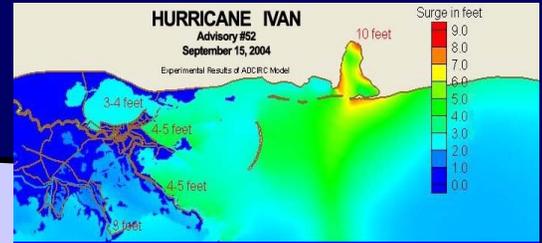
Storm Surge, Tides

Tidal Bore

Contact: Dr. Cheryl Ann Blain, 228-688-5450
blain@nrlssc.navy.mil

Future: Adaptive Mesh Refinement

**A Slotted Cylinder**
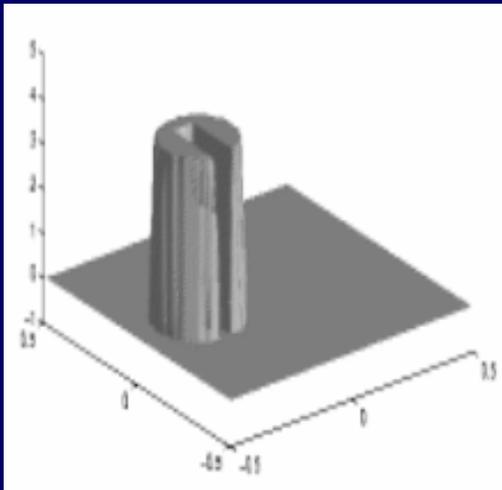
Error estimates guide the refinement process.

Uniform Mesh
1089 Nodes

PLOT: tracer variable + grid   (c) Joern Behrens, 1998
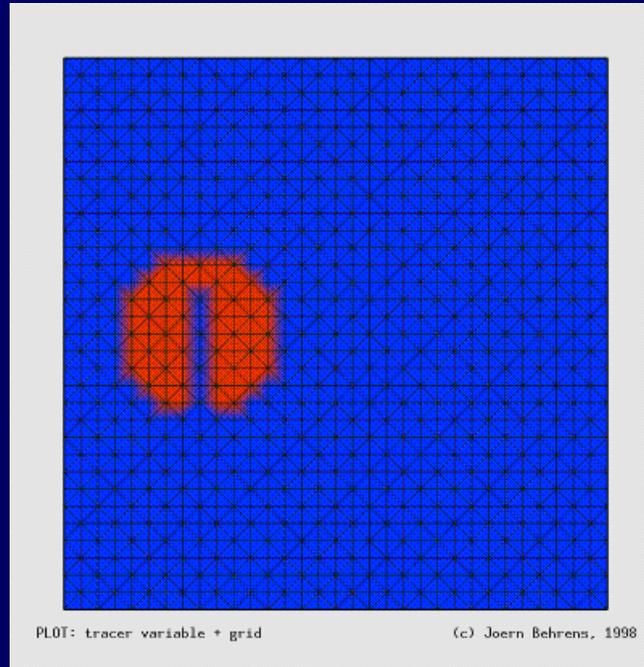
Adaptive Mesh
~800 to 1200 Nodes

PLOT: tracer variable + grid   (c) Joern Behrens, 1998
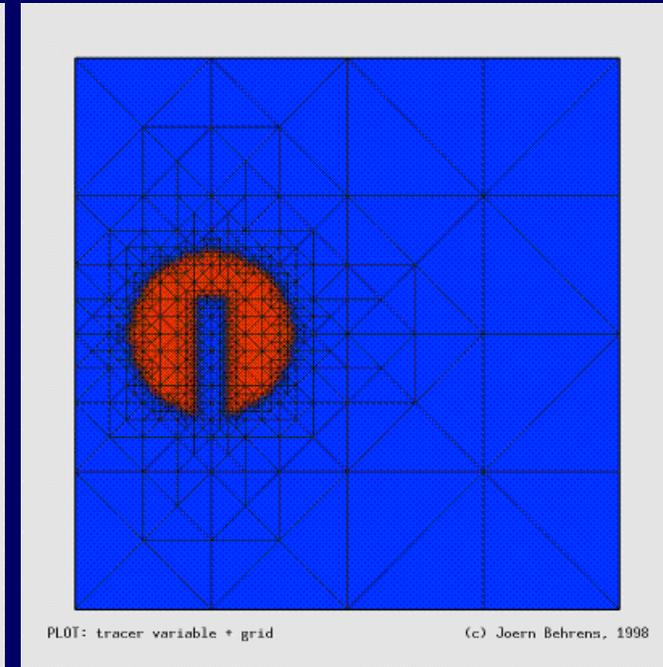
To achieve the same resolution as the adaptive mesh, a uniform mesh would require ~16,000 nodes.

Contact: Dr. Cheryl Ann Blain, 228-688-5450
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Images from AWI website.

http://www.awi-bremerhaven.de/InfoCenter/IT/WorkingGroups/SciComp/AdapFEM.html

Future: Connecting the Watershed, River and Coastal Ocean

Overlap between the watershed model and a coastal circulation model

Watershed	Circulation
Overland flow	River Discharge Sediment Load
Water in marshes	Inundation/Drying
Vegetation	Inundation/Drying Sediment Load

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Future: Limited Domain Applications

Coupling global/regional scale and coastal models

Baton Rouge, LA

**ADCIRC Elevations
Mississippi River Outflow, SE Louisiana**

HYCOM 0.08°

May 4
SST
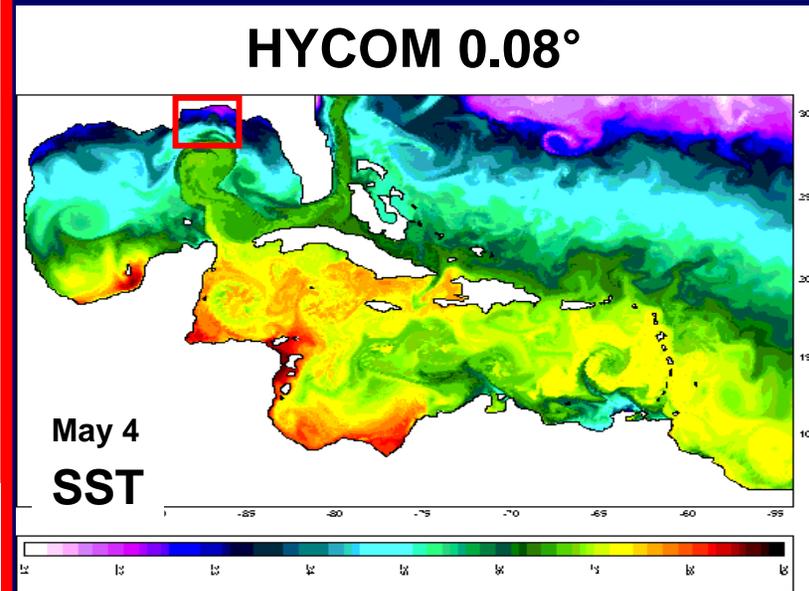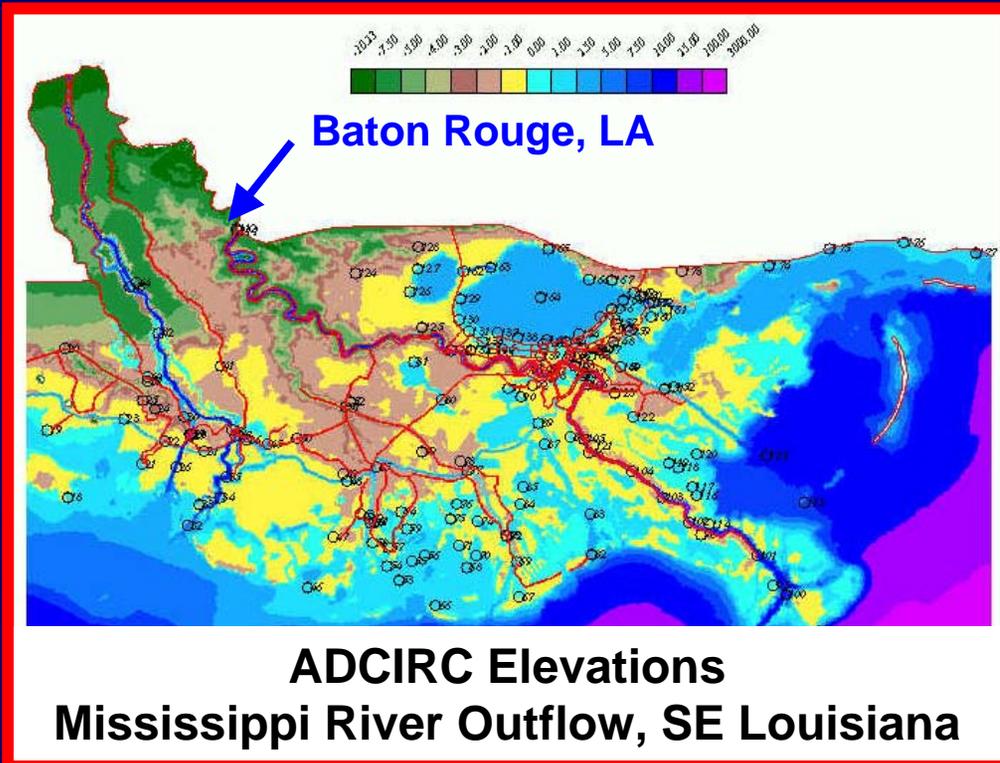
• Coastal application in northern Gulf of Mexico; determine how to best extract boundary forcing data from regional/global models

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Future: Predicting Bio-Optical Properties

Riverine Applications

IMAGERY

MODEL

Grid Resolution (m)

UAV

Pearl River, MS

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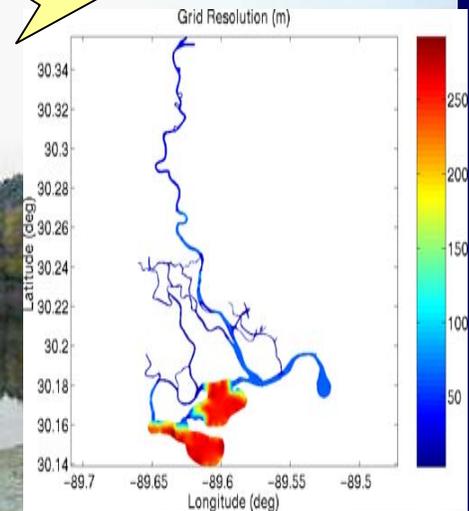
Future: Autonomous Chemical (Mine) Hunting

Ocean Circulation

Initial Likelihood

Subsequent Likelihood

Initial Detection

Subsequent Detection

Components

Realistic Environment

Advanced Ocean Model Capabilities

Transport, turbulent mixing

Chemistry Source/Sink

FEEDBACK

Network of UUVs

UUV
UUV
UUV
UUV
UUV

UUV observations

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