SURA / IOOS Testbed for the Evaluation of Wave, Storm Surge and Inundation Models

Rick Luettich

University of North Carolina at Chapel Hill
Institute of Marine Sciences
Center for the Study of Natural Hazards and Disasters

12th Waves Workshop & 3rd Coastal Hazard Symposium
November 3, 2011

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Objectives

Provide evaluation of models in or under consideration for “operational use”

- Behavior
  - Accuracy
  - Robustness
  - Execution speed
- Implementation requirements
  - Resolution
  - Parameterization
  - Computer capacity

Objectives

Develop testbed infrastructure to greatly facilitate future model evaluation

- Standards
- Interoperability
- Model evaluation tools (e.g., IMEDS skill assessment)
- Data/model archives and access

Example Questions

Should I use a grid having?

- 10,000 cells
- 100,000 cells
- 1,000,000 cells
- 10,000,000 cells

Under what circumstances?

For what expected benefit?

At what cost?

Example Questions

Am I better off using my computational resources to?

- Run a 3D model (vs a 2D model)
- Increase horizontal resolution
- Run a coupled wave model
- Run ensembles of low resolution models

Under what circumstances?

For what expected benefit?

At what cost?

Example Questions

From the user's perspective

- Are all models about the same in terms of accuracy, efficiency?
- Is there a preferred model out there?

From the model developer's perspective

- Why aren't you using my model?

A bridge between Research & Operations

Conclusions

Considerable time to develop common infrastructure (get on same page)

- Grids
- Forcing
- Data Formats
- Observational data sets
- Parameter sets & methodology

Seeing differences between 3 Unstructured Grid surge models (ADCIRC, FVCOM, SELFE)

Systematic differences btwn UG surge models & SLOSH

Not far enough along with wave models for conclusions

It’s hard to do a testbed well, requires much consensus!

Very positive community building activity

Testbed Geographical Locations

Extratropical Storms in the Gulf of Maine

- 2005 & 2007 Nor'Easters
- Focus on Scituate Harbor, MA
- Little observational data in Scituate Harbor

Tropical Storms in the Gulf of Mexico

- Hurricanes Rita (2005) and Ike (2008)
- Focus on northwestern Gulf of Mexico
- Extensive observational data sets (e.g., >700 water level hydrographs for Ike)

Extratropical - Gulf of Maine Team

ADCIRC + unstructured SWAN
- Joannes Westerink – U Notre Dame

FVCOM + SWAVE
- Bob Beardsley – Woods Hole Oceanographic Institute, co-Lead
- Changsheng Chen – U Mass Dartmouth

SELFE + WWM
- Harry Wang – Virginia Institute of Marine Sciences

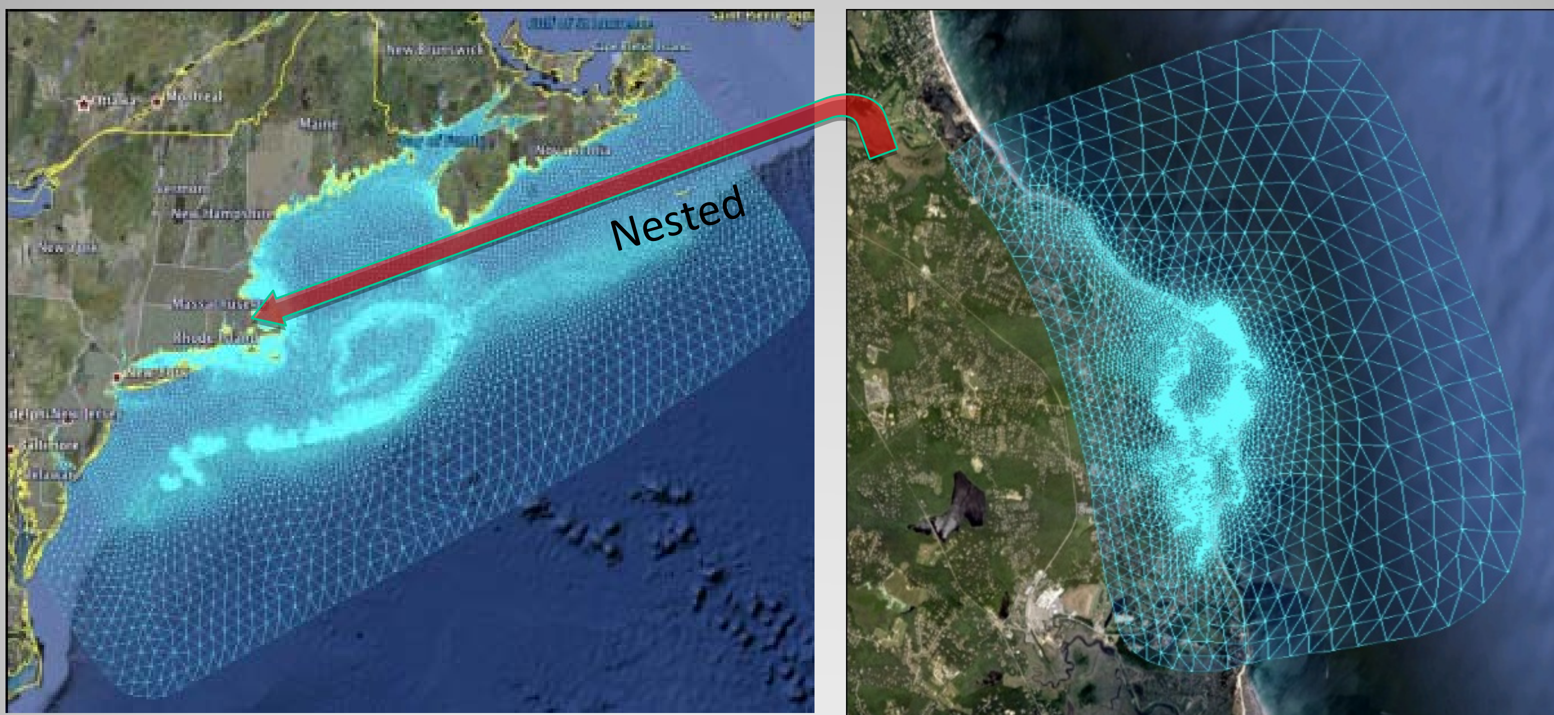
SLOSH + SWAN – PV2 hurricane basin, ECETSS
- Don Slinn – U Florida

WWIII & SWAN
- Will Perrie, Bash Toulaney – Bedford Institute of Oceanography

OTHERS
- Jeff Hanson – US Army Corps of Engineers FRF
- Jesse Feyen – NOAA CSDL
- Arthur Taylor, Anne Kramer, Amy Haase – NOAA MDL
- MANY OTHER WORKERS!

Extratropical - Domains

Gulf of Maine with high resolution nesting in Scituate, MA

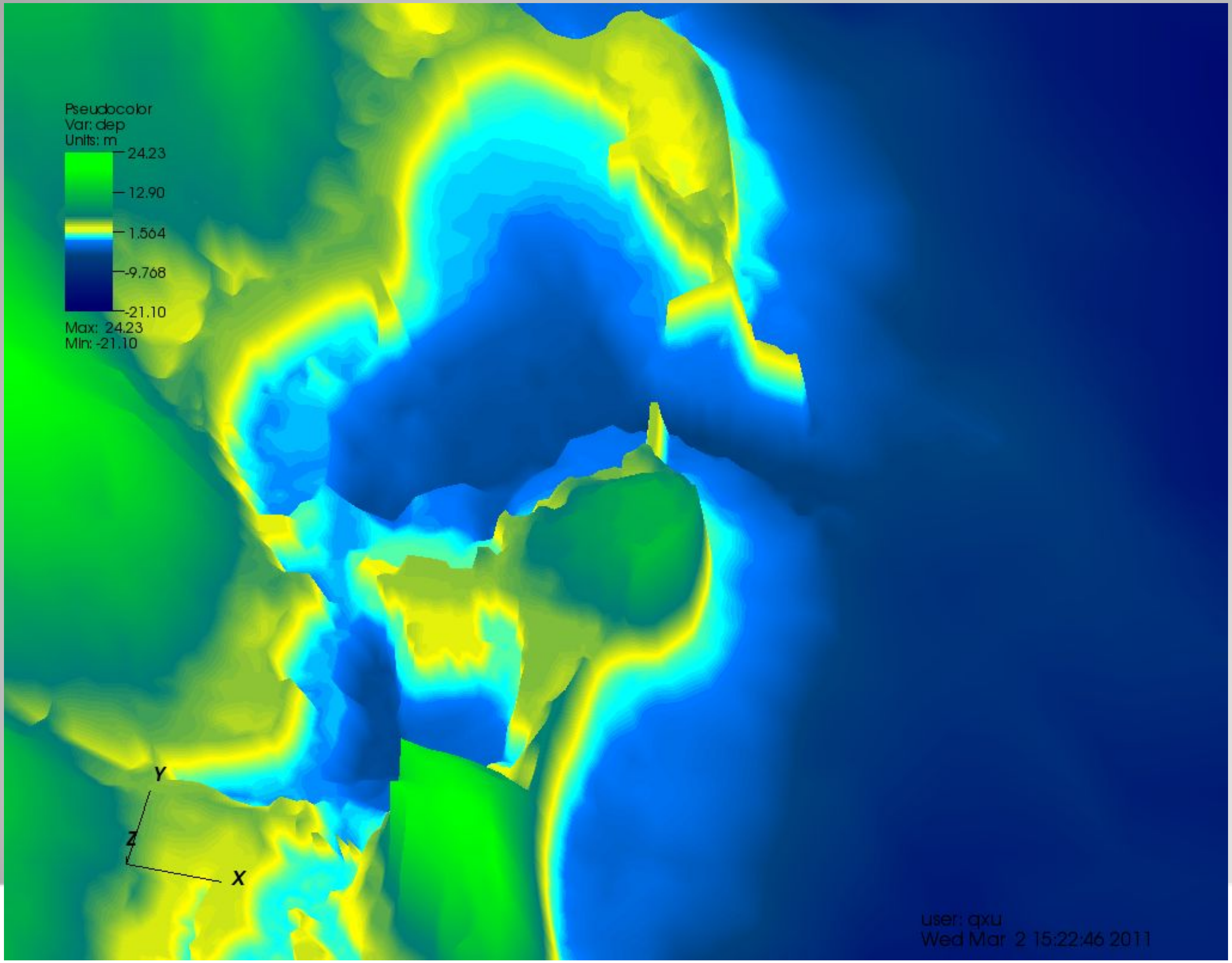


5620 nodes
10 m – 1 km horiz resolution

Scituate Harbor

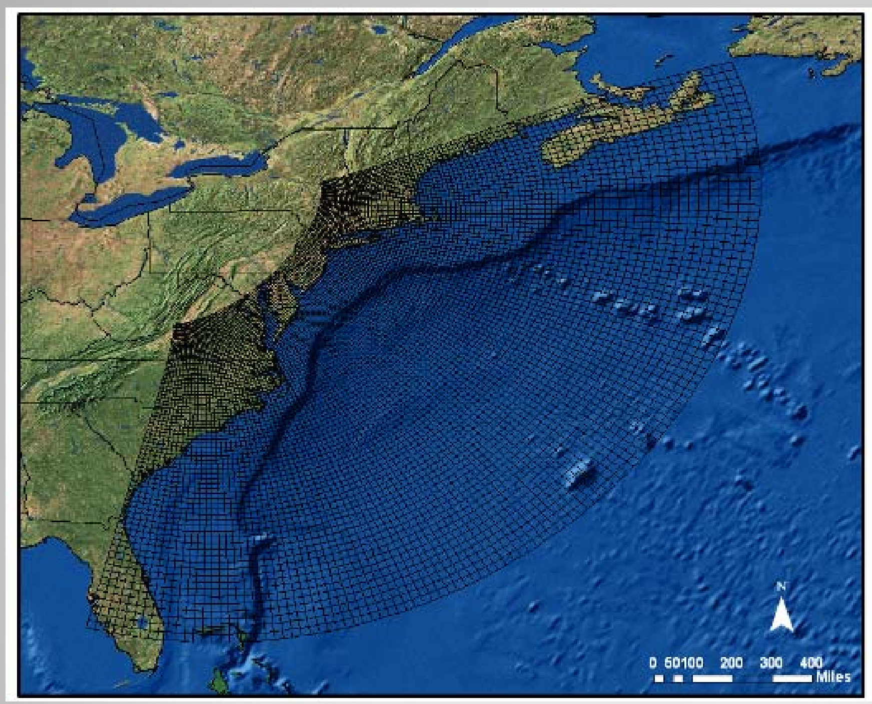
- <2km in size
- 2 particular areas of concern flood frequently during Nor'Easters

Scituate Harbor

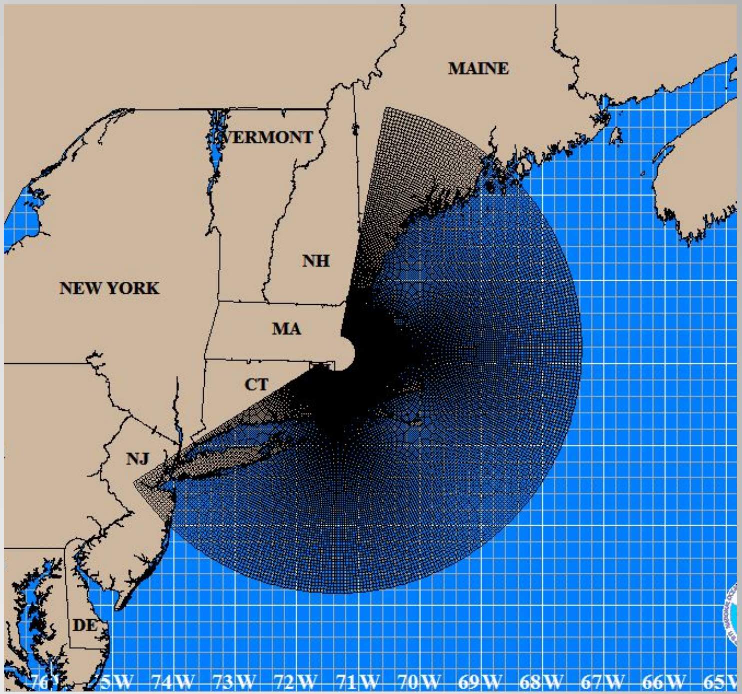


Gulf of Maine SLOSH Grids

East Coast Extratropical Storm Surge Grid



PV 2 Slosh Hurricane Basin



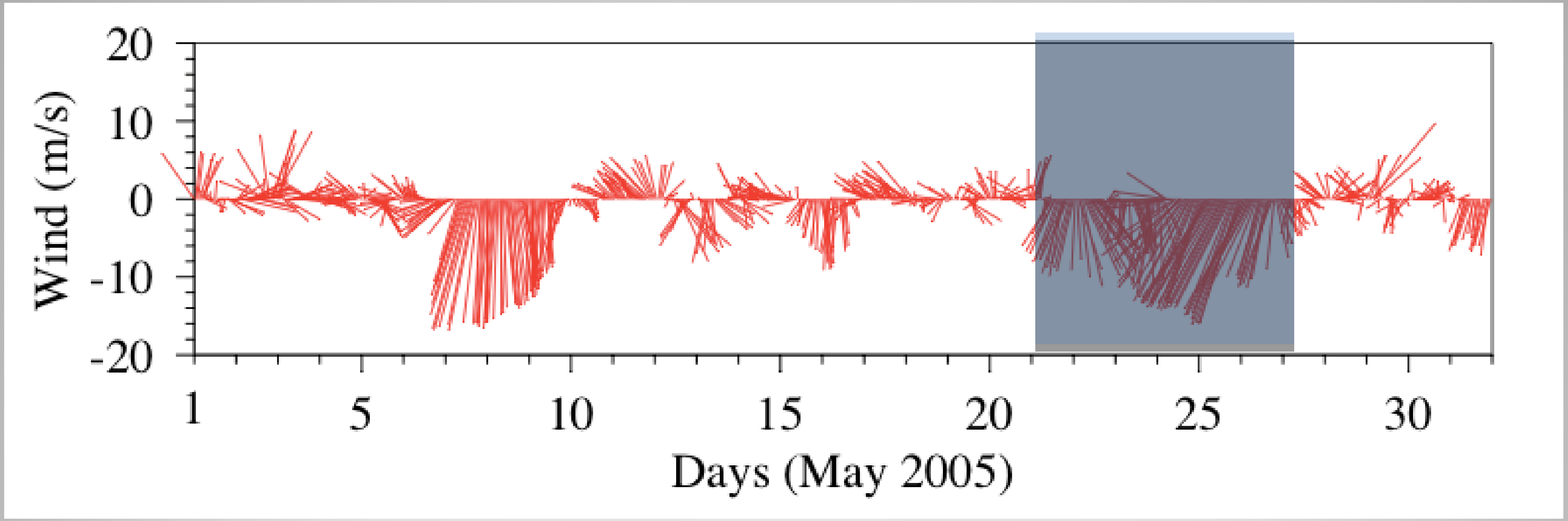
~2 km horiz resolution near Scituate

Gulf of Maine / Scituate Regular Wave Grids

WW III and SWAN

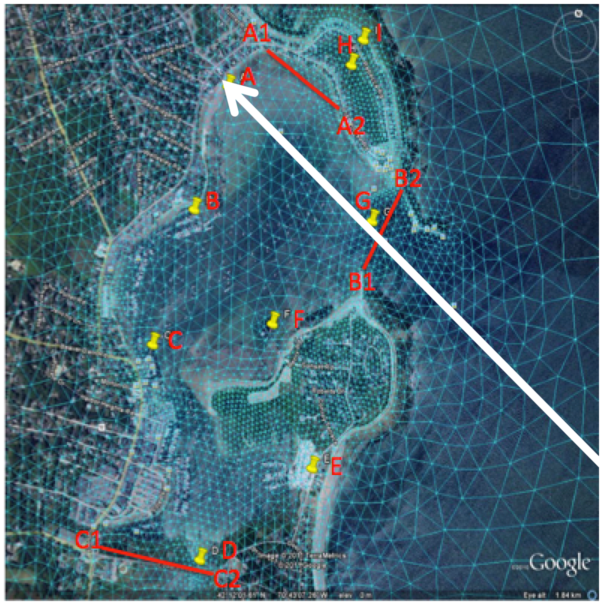
- Series of nested grids

2005 Nor'Easter

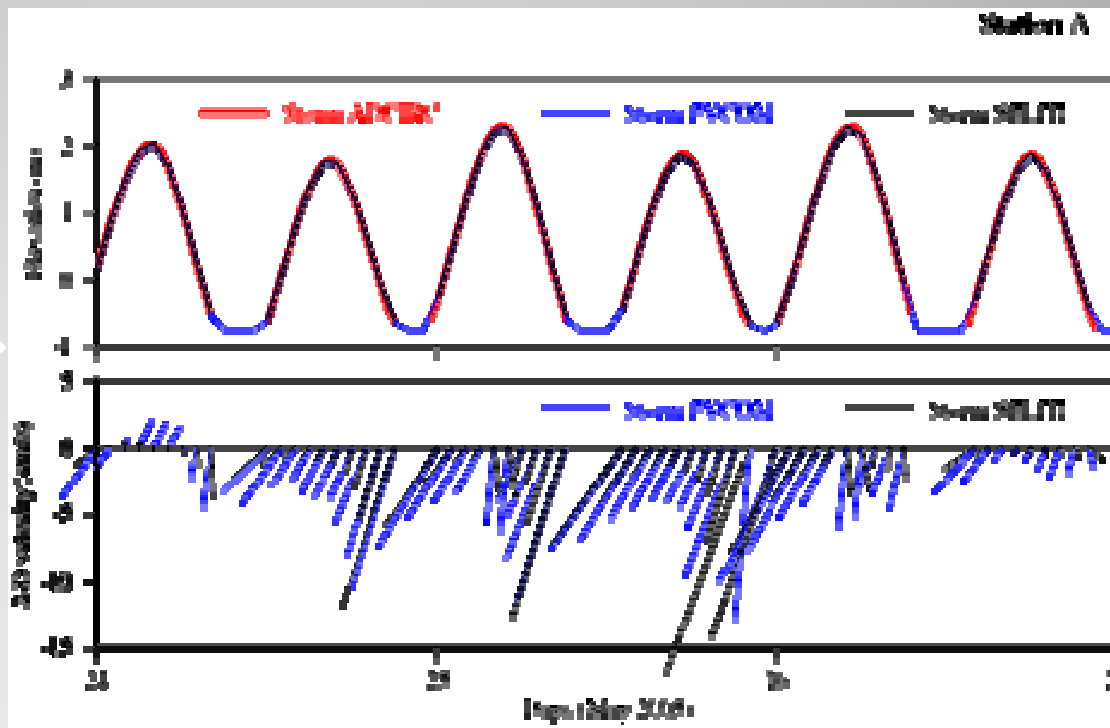


2005 Nor'Easter

Sites and sections in the model grid

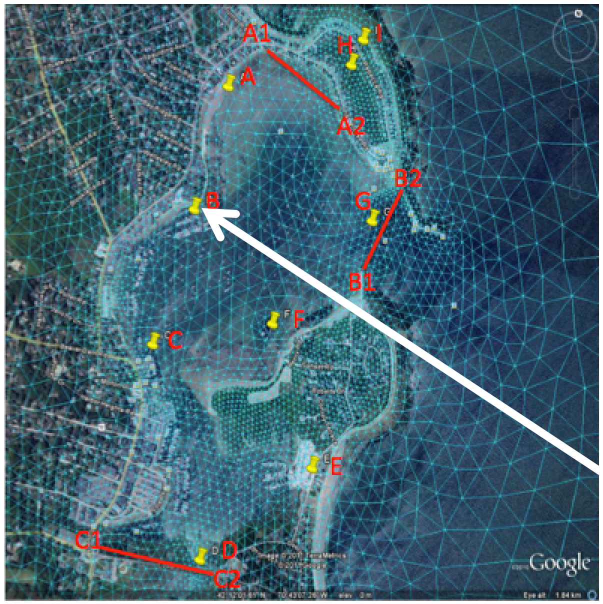


No Waves

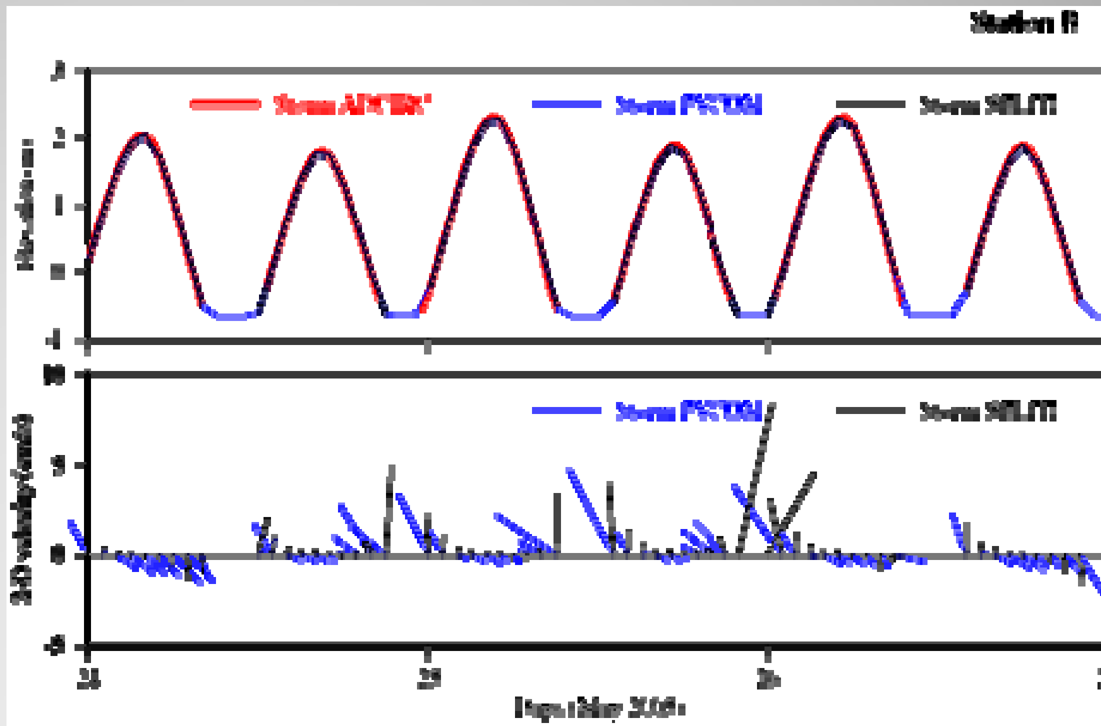


2005 Nor'Easter

Sites and sections in the model grid

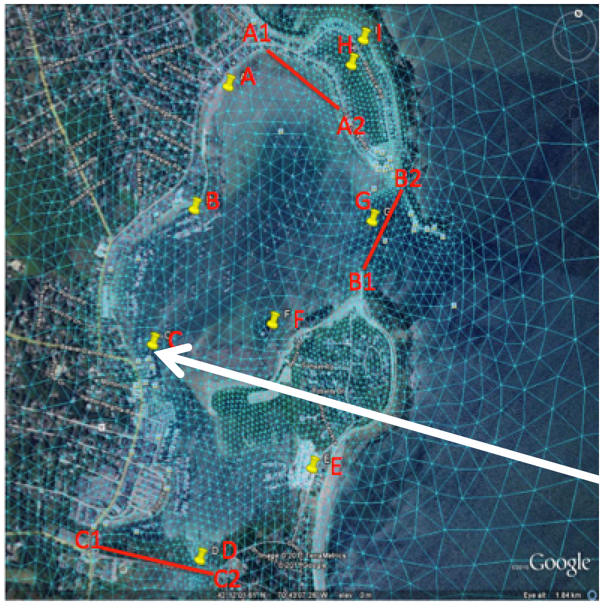


No Waves

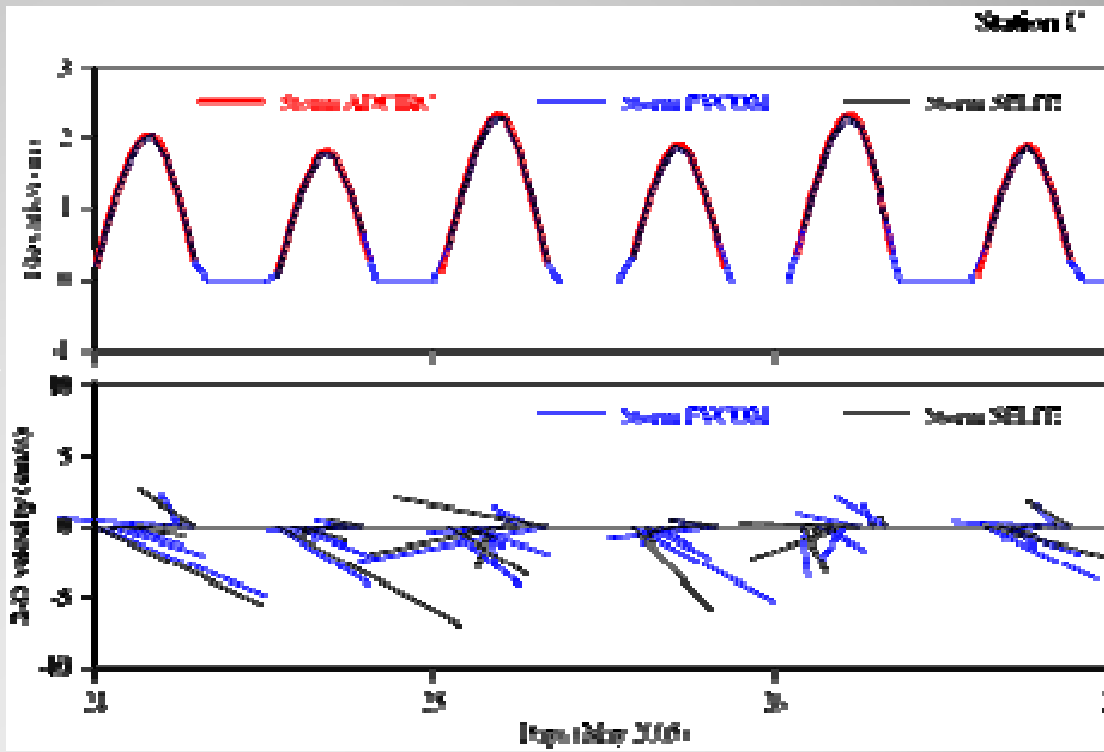


2005 Nor'Easter

Sites and sections in the model grid

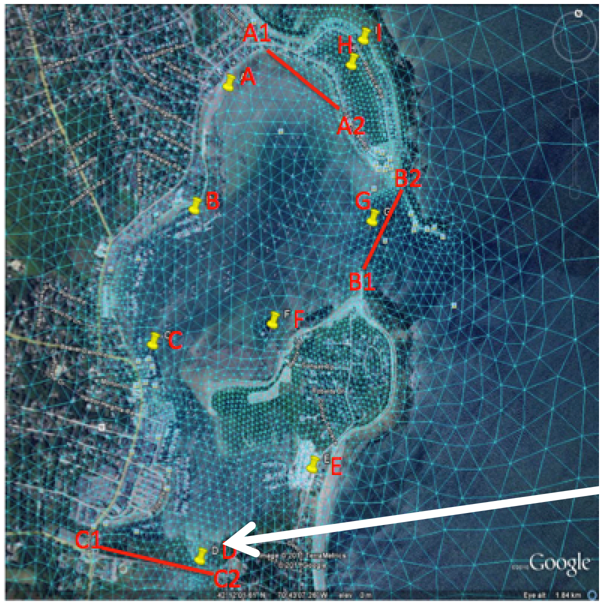


No Waves

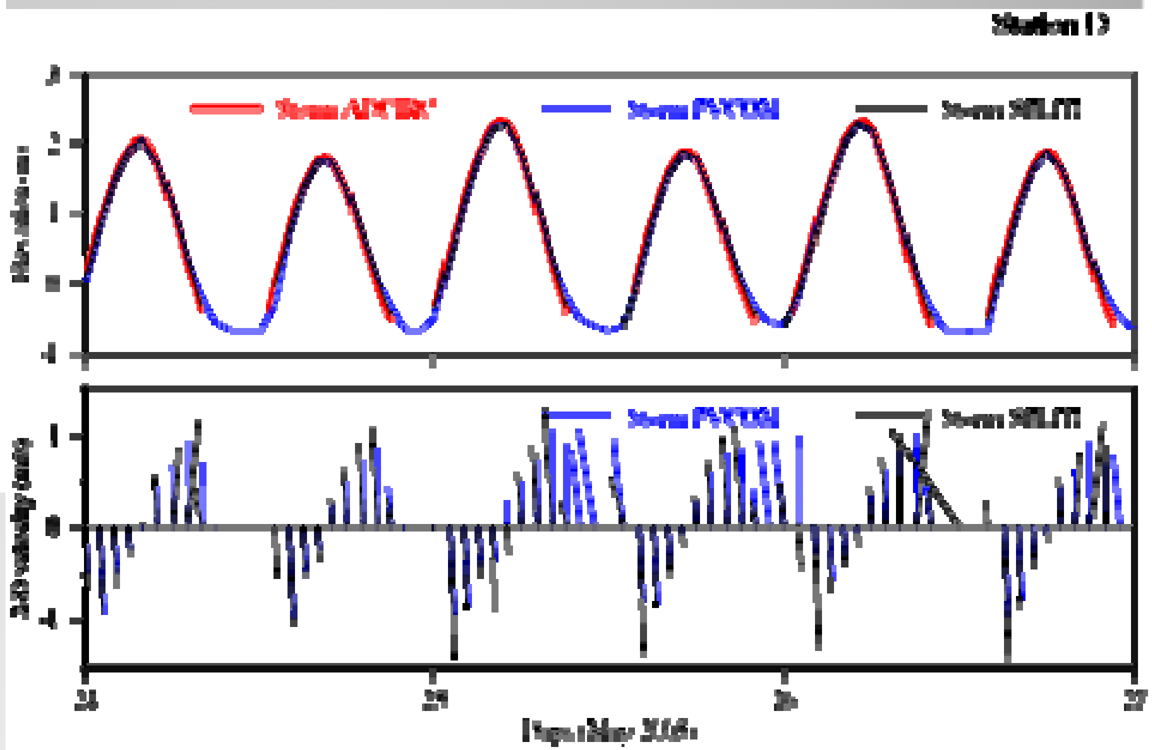


2005 Nor'Easter

Sites and sections in the model grid

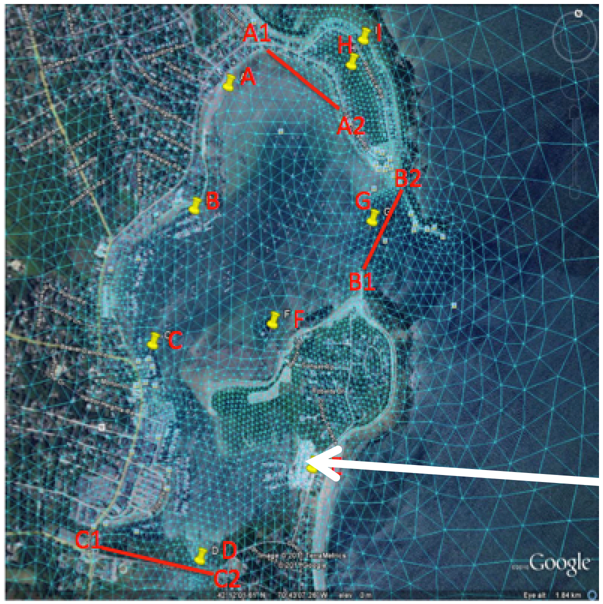


No Waves

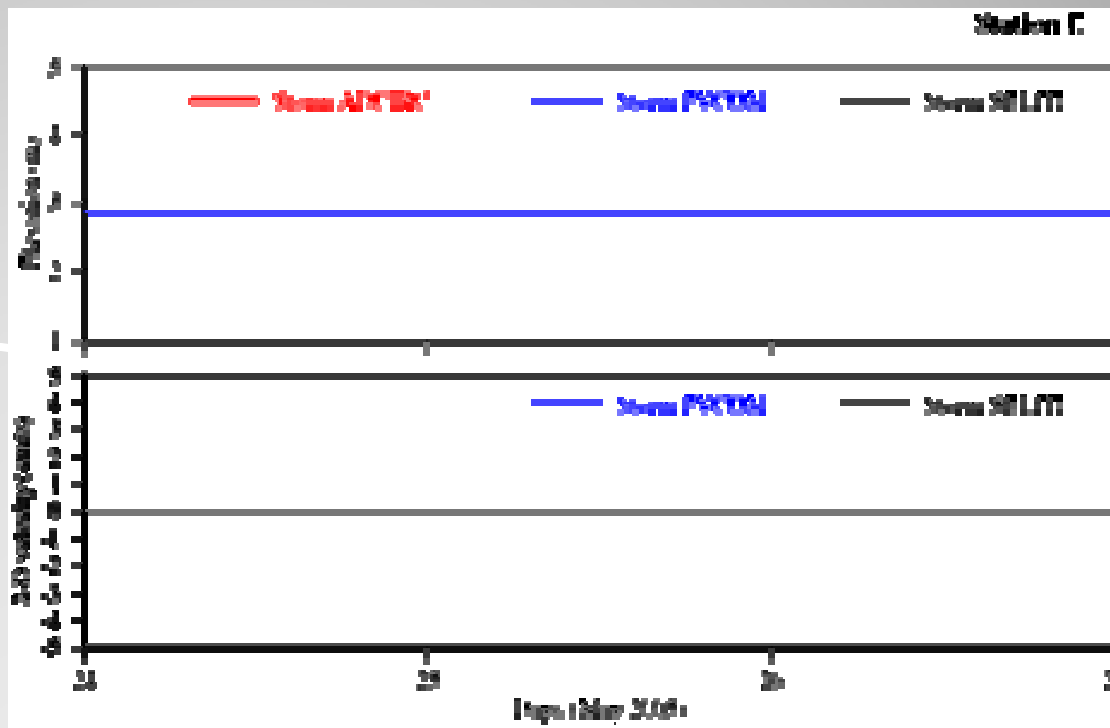


2005 Nor'Easter

Sites and sections in the model grid

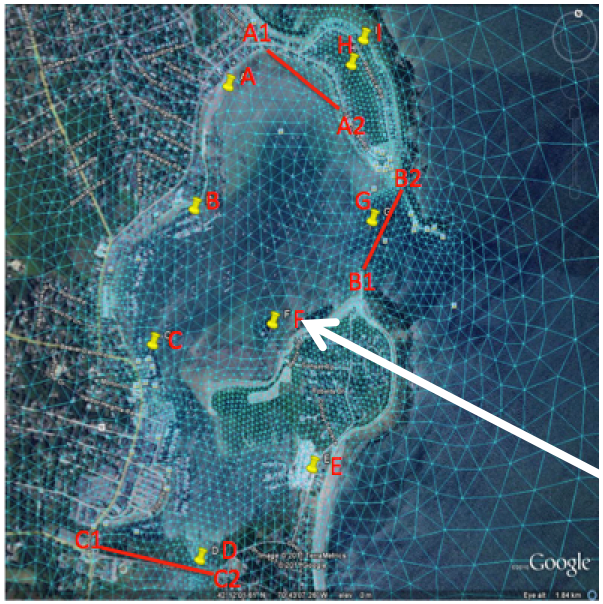


No Waves

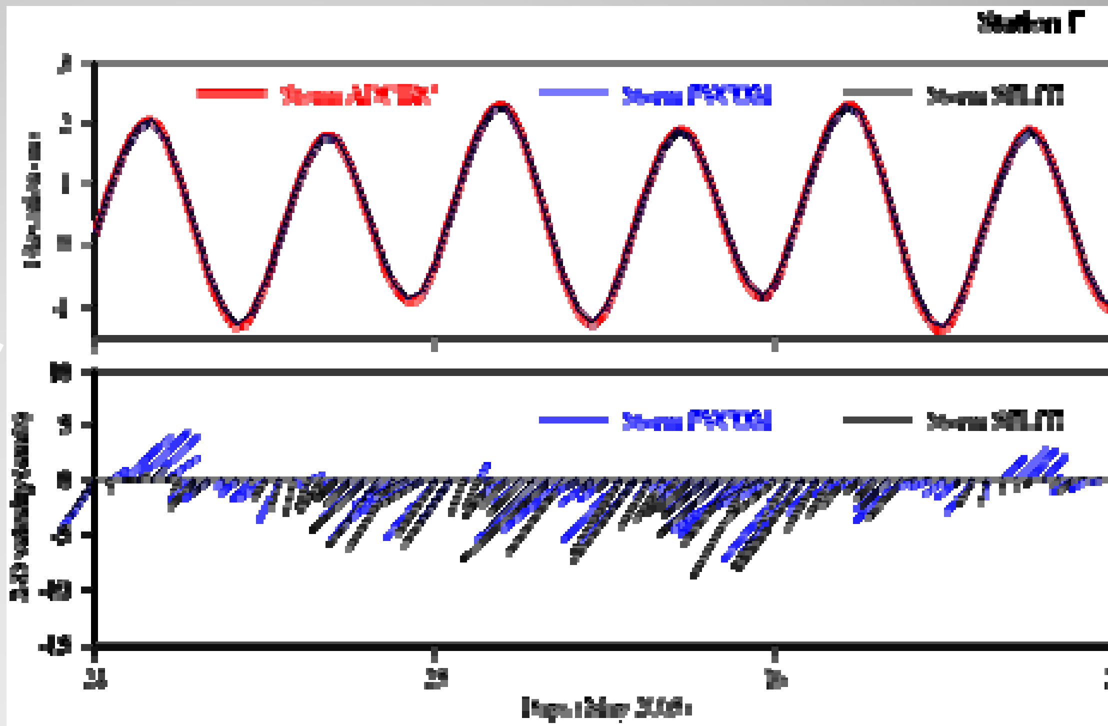


2005 Nor'Easter

Sites and sections in the model grid

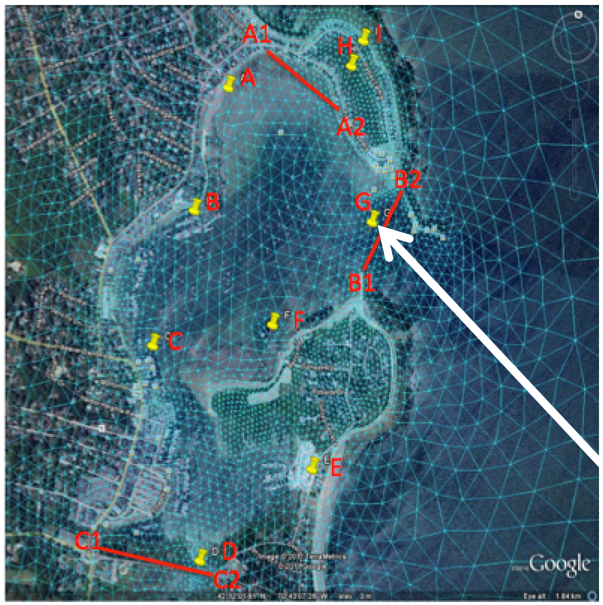


No Waves

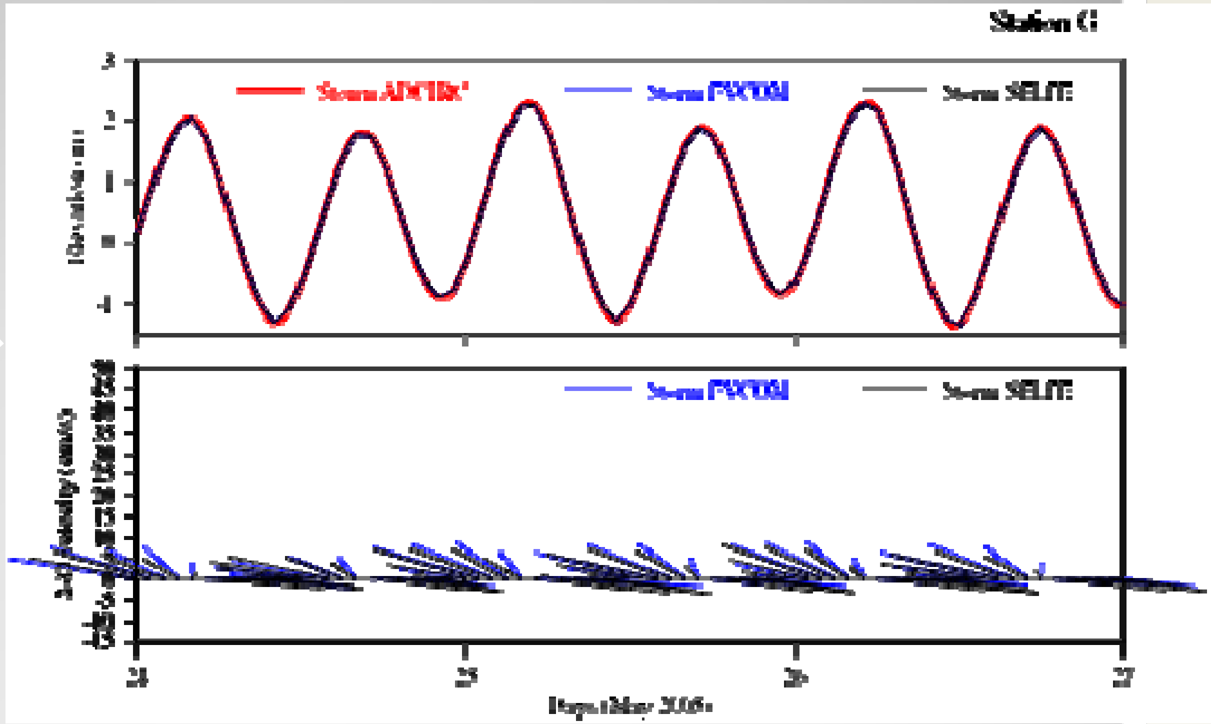


2005 Nor'Easter

Sites and sections in the model grid

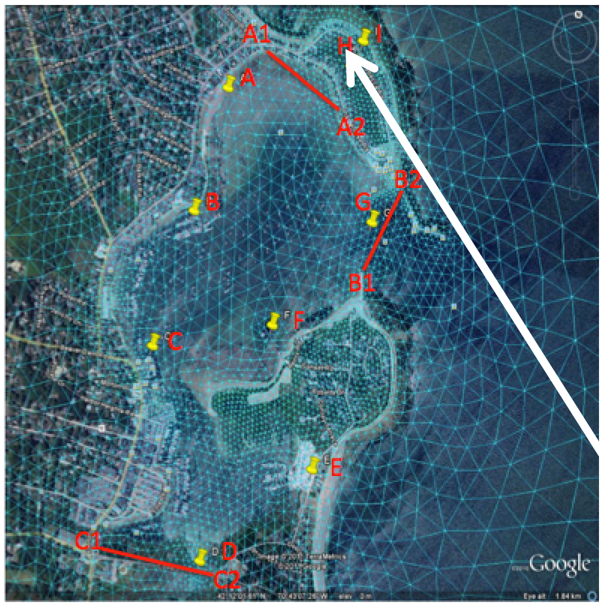


No Waves

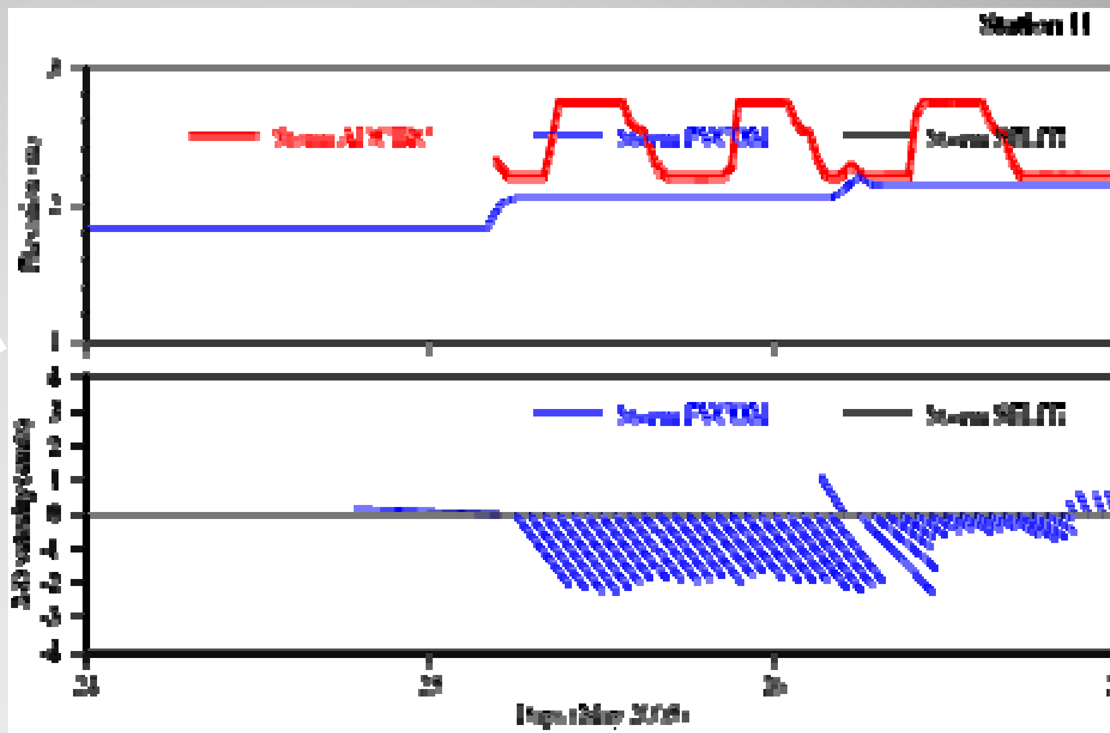


2005 Nor'Easter

Sites and sections in the model grid

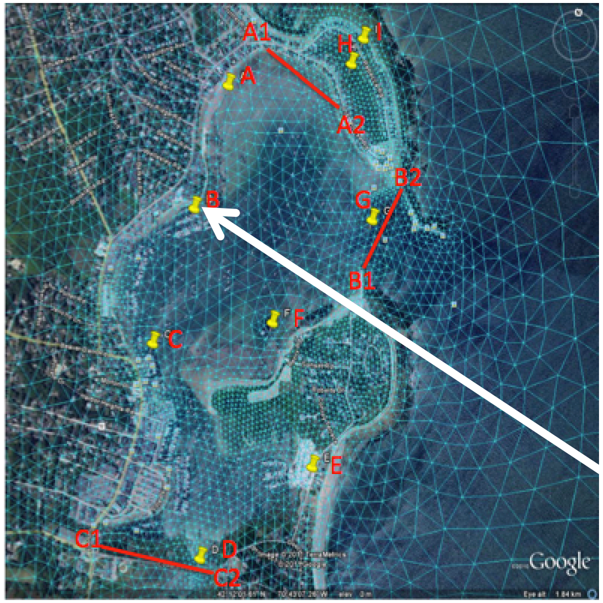


No Waves

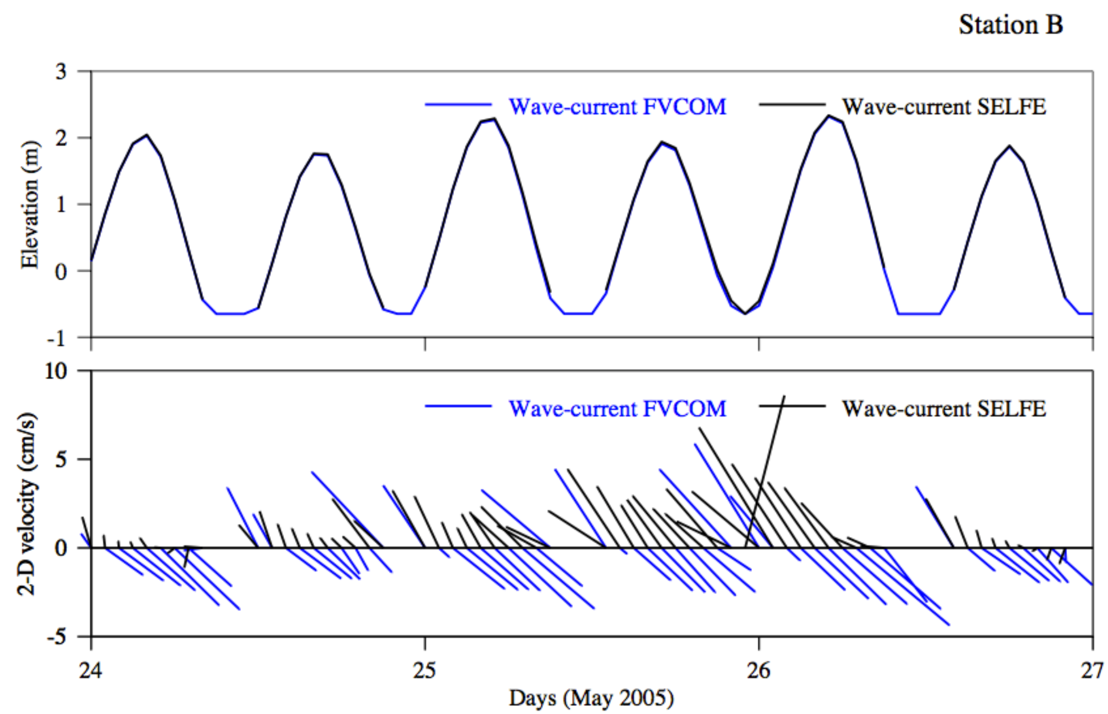


2005 Nor'Easter

Sites and sections in the model grid



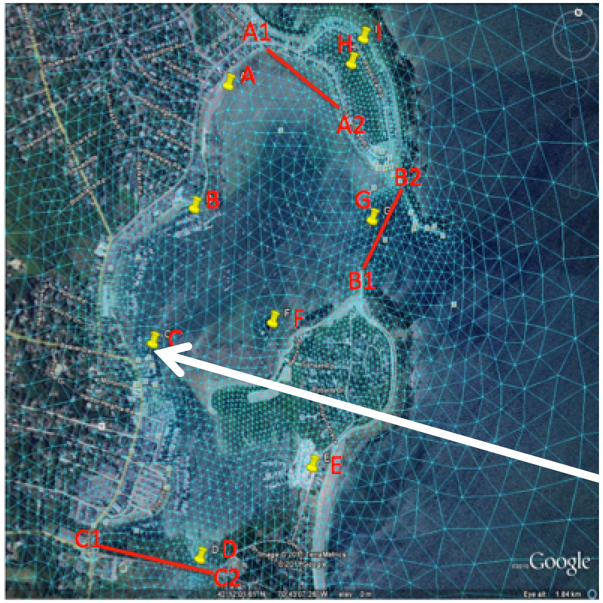
Including Waves

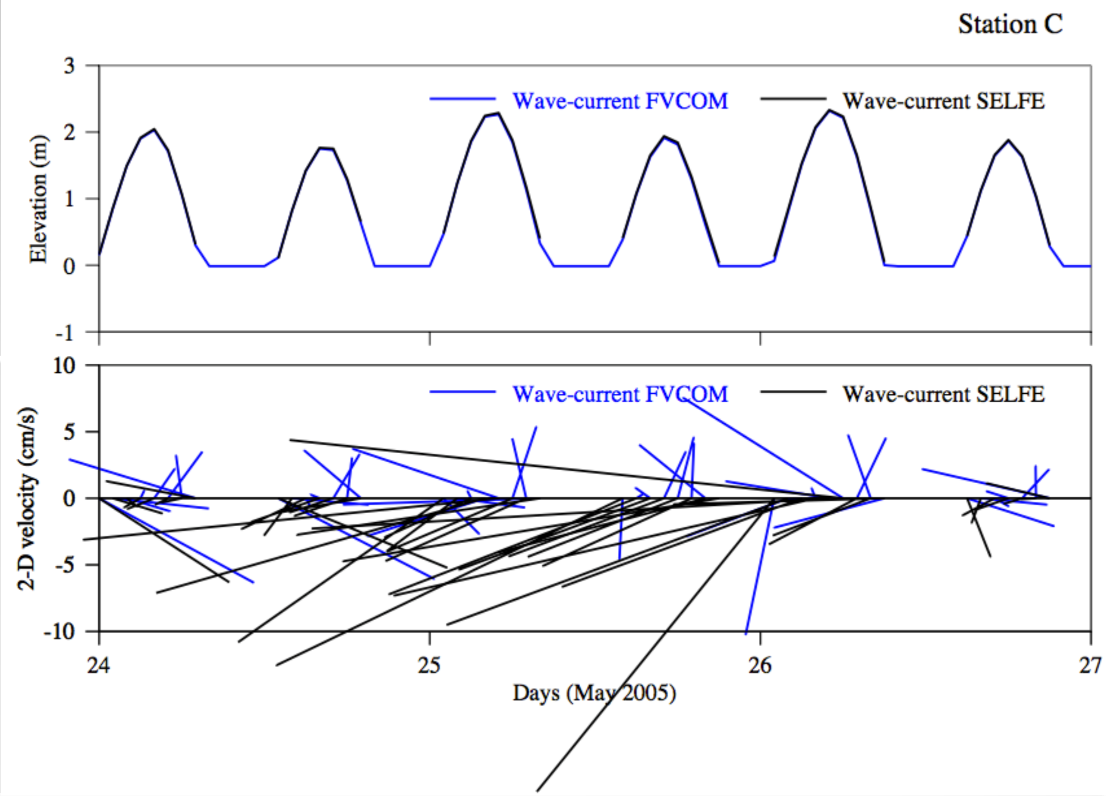


2005 Nor'Easter

Including Waves

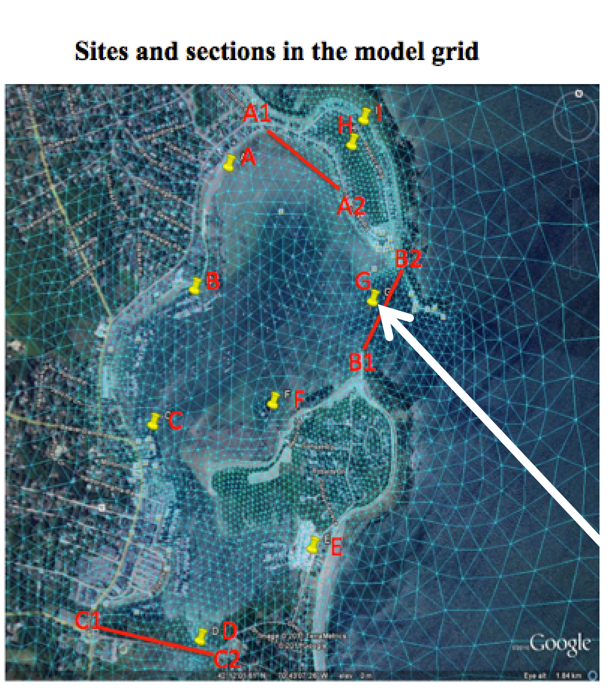
Sites and sections in the model grid

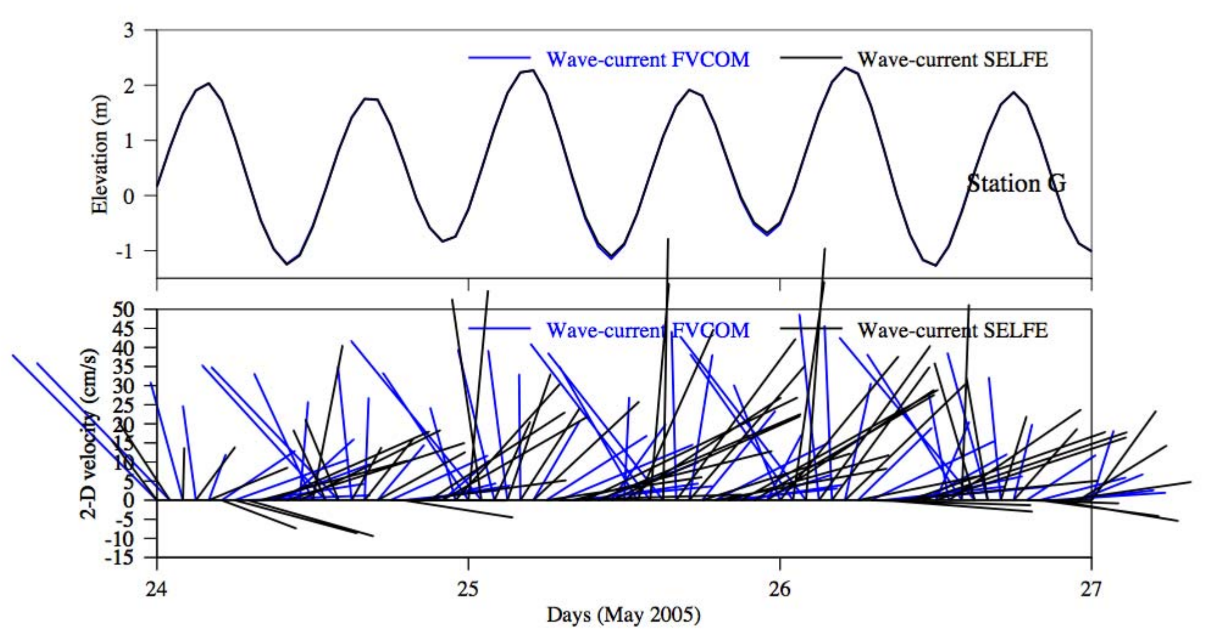




2005 Nor'Easter

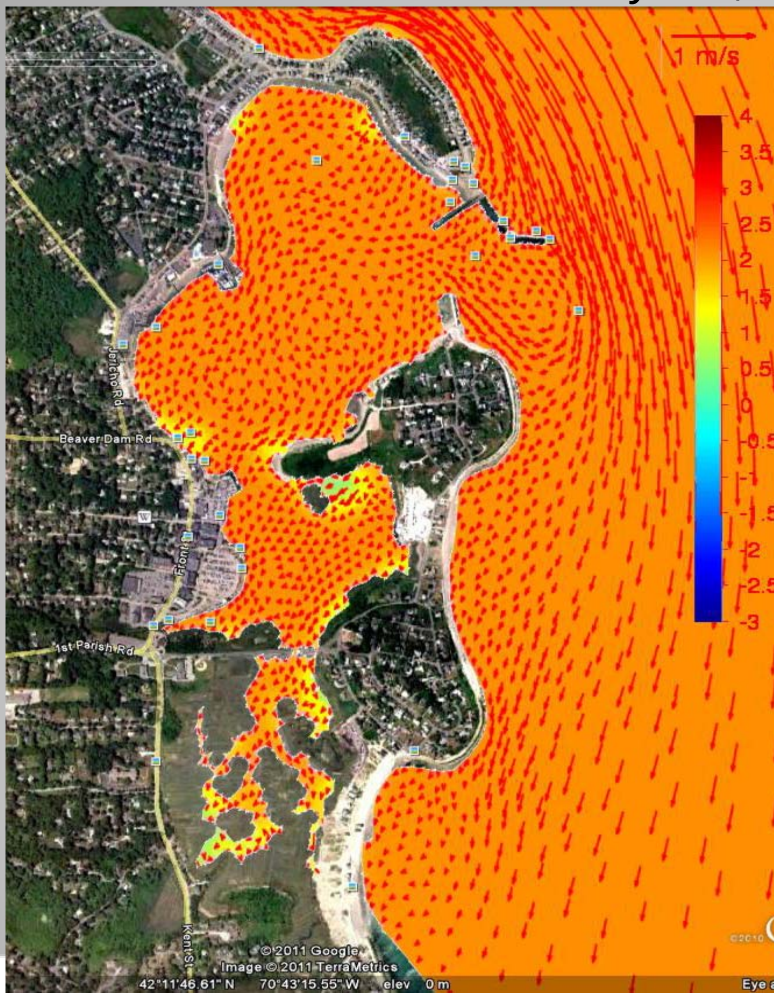
Including Waves

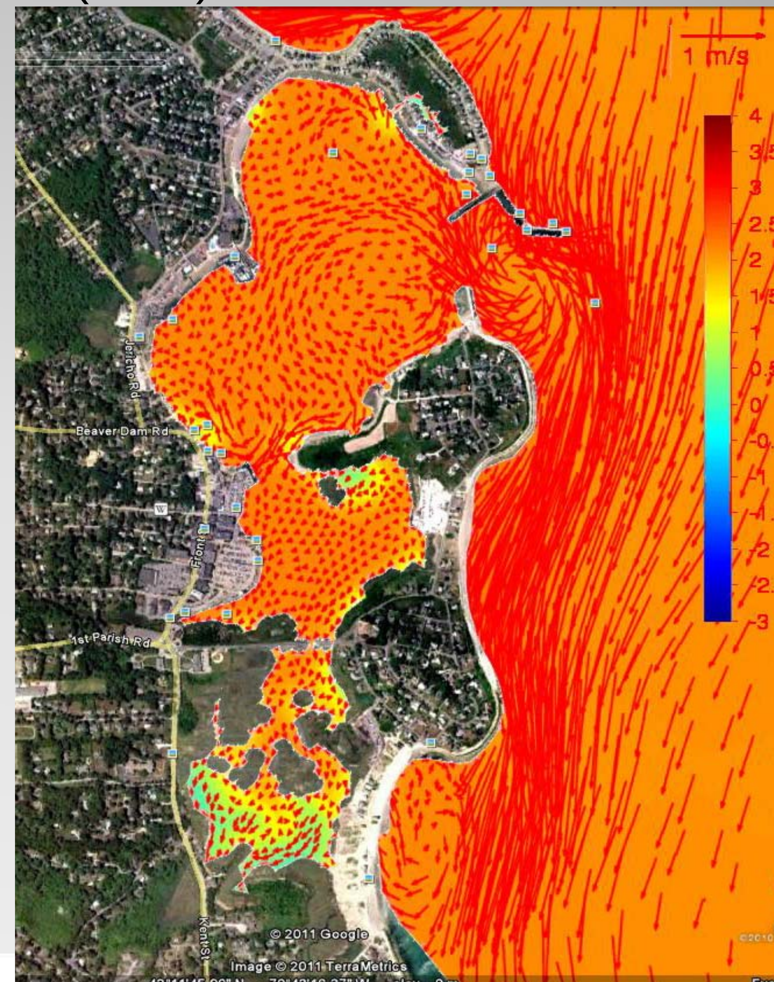




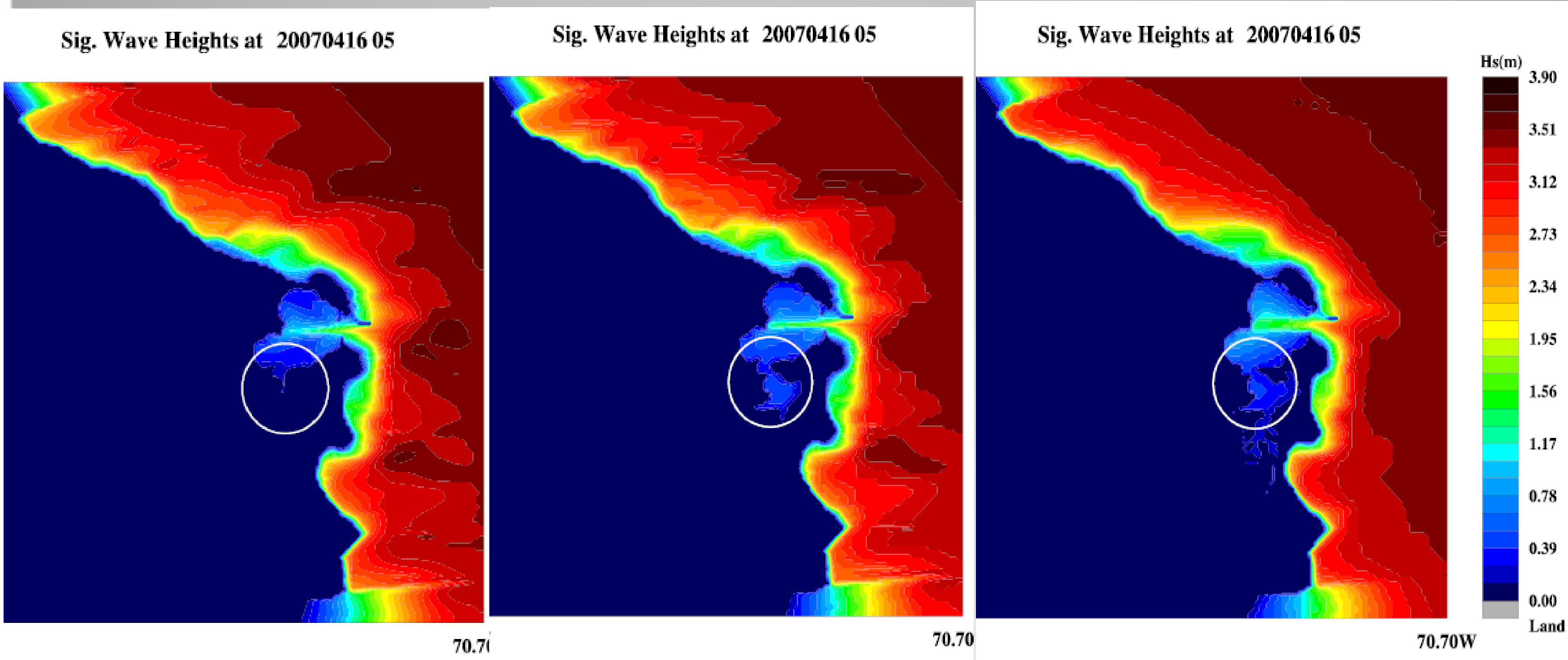
2005 Nor’Easter

Currents May 25 , 05 AM (GMT) **Currents-Waves**





Wave Model Resolution (2007)



25 frequencies
24 directions

30 frequencies
36 directions

35 frequencies
72 directions

Extratropical Findings

Scituate Harbor

- Water levels very close between ADCIRC, FVCOM, SELFE for tidal forcing and storm forcing – some differences in inundation behavior
- Velocity fields similar without waves, significantly different with waves coupling (via radiation stress gradient terms)
- Including wave coupling increases flux past and into mouth of Scituate Harbor, although perhaps not into interior
- Results are sensitive to wave model resolution?

Greater Gulf of Maine

- Wave model comparisons are ongoing

Tropical - Gulf of Mexico Team

ADCIRC + unstructured SWAN

- Joannes Westerink – U Notre Dame

FVCOM + SWAVE

- Bob Weisberg – U South Florida
- Chunyan Li – Louisiana State University

SELFE + WWM

- Harry Wang – Virginia Institute of Marine Sciences

SLOSH + SWAN

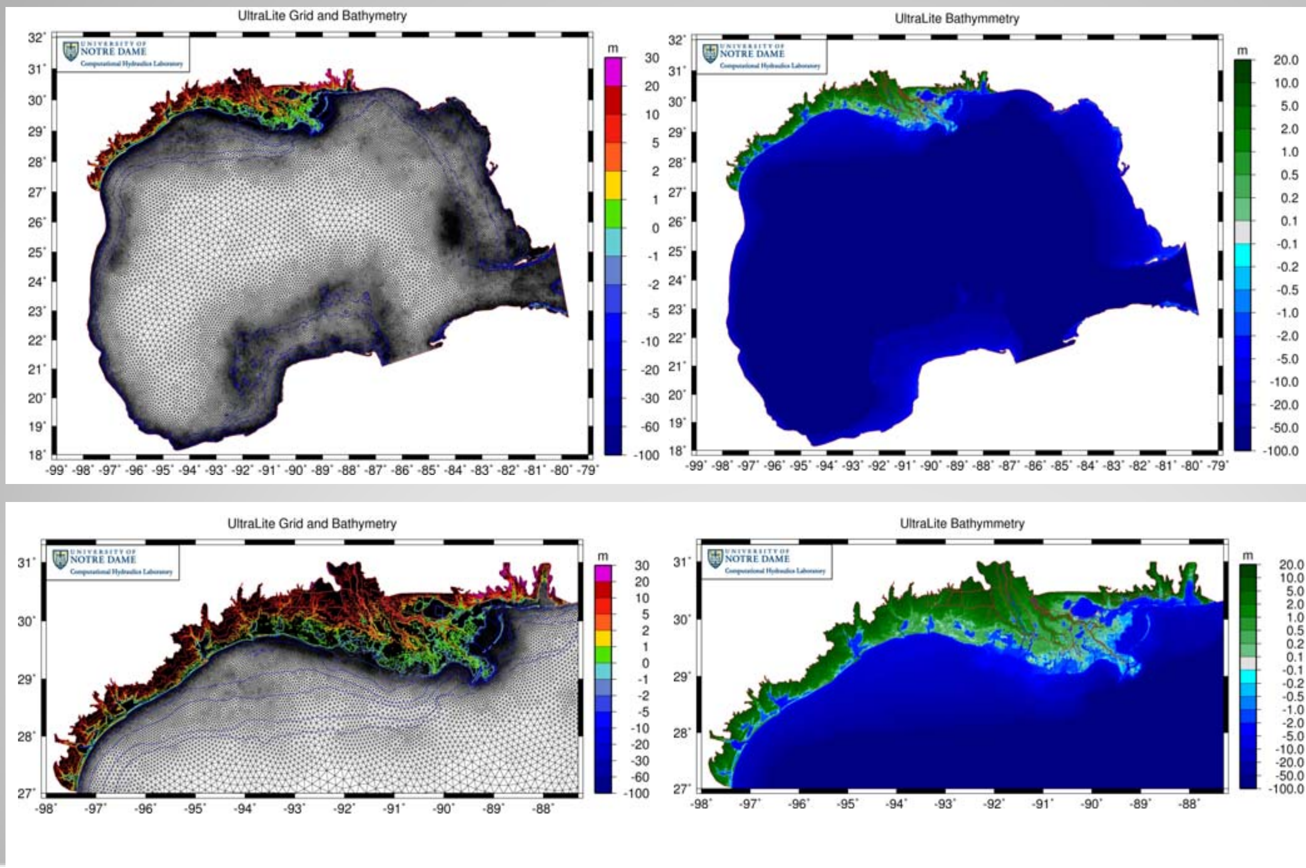
- Don Slinn – U Florida

OTHERS

- Jeff Hanson – US Army Corps of Engineers FRF
- Jesse Feyen – NOAA CSDL
- Jamie Rhome, Christina Forbes - NHC
- MANY OTHER WORKERS!

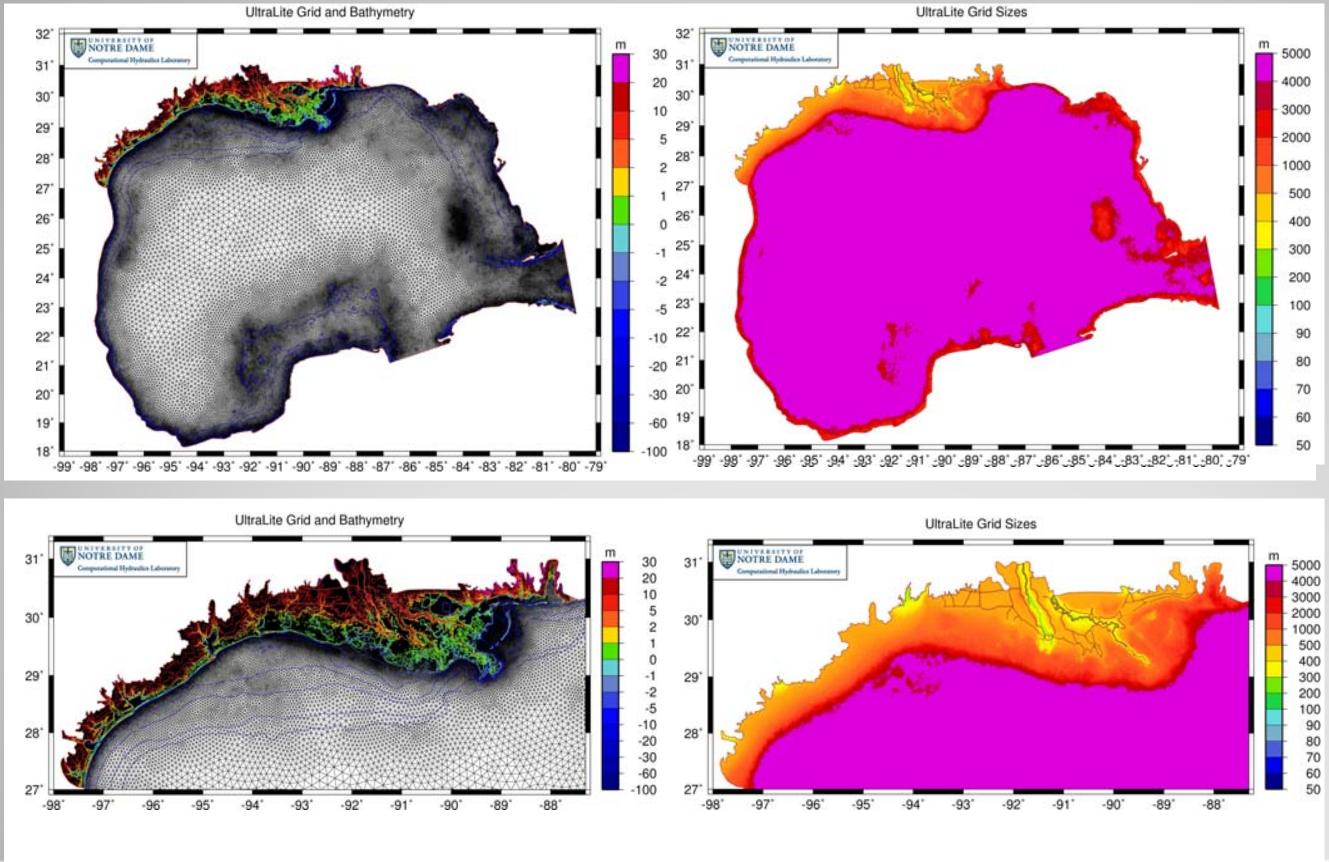
Tropical - Domains

Gulf of Mexico with enhanced resolution along the western Louisiana and Northern Texas coasts where Rita and Ike landed



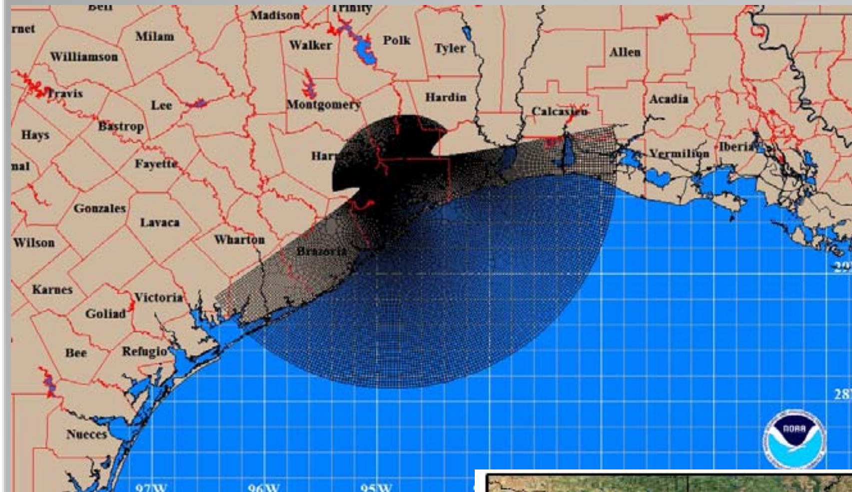
Tropical - Domains

Gulf of Mexico with enhanced resolution along the western Louisiana and Northern Texas coasts

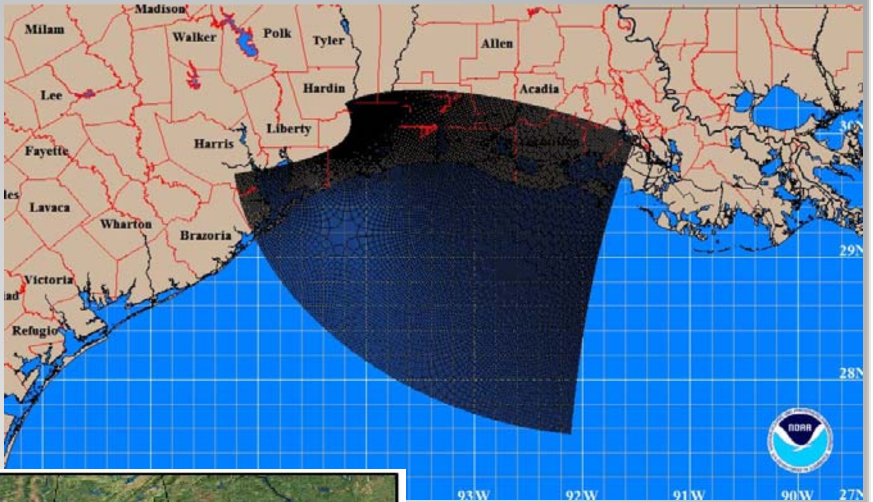


~425,000 nodes

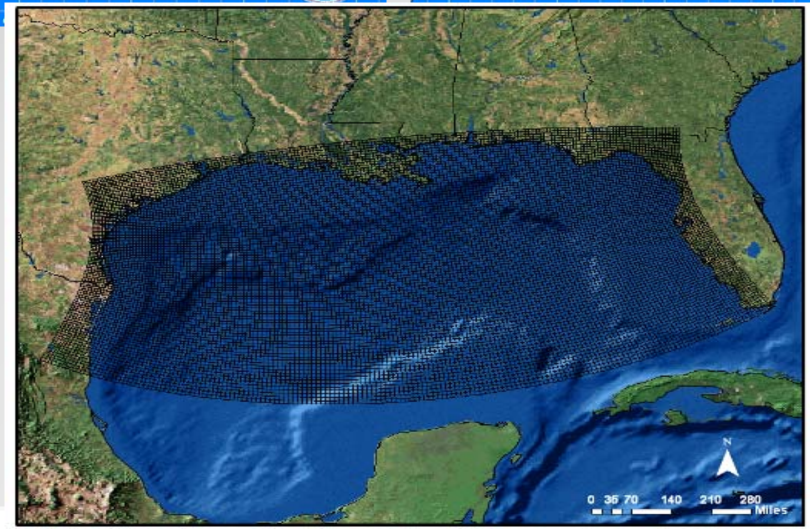
Gulf of Mexico SLOSH Grids



Galveston 3
Slosh Basin

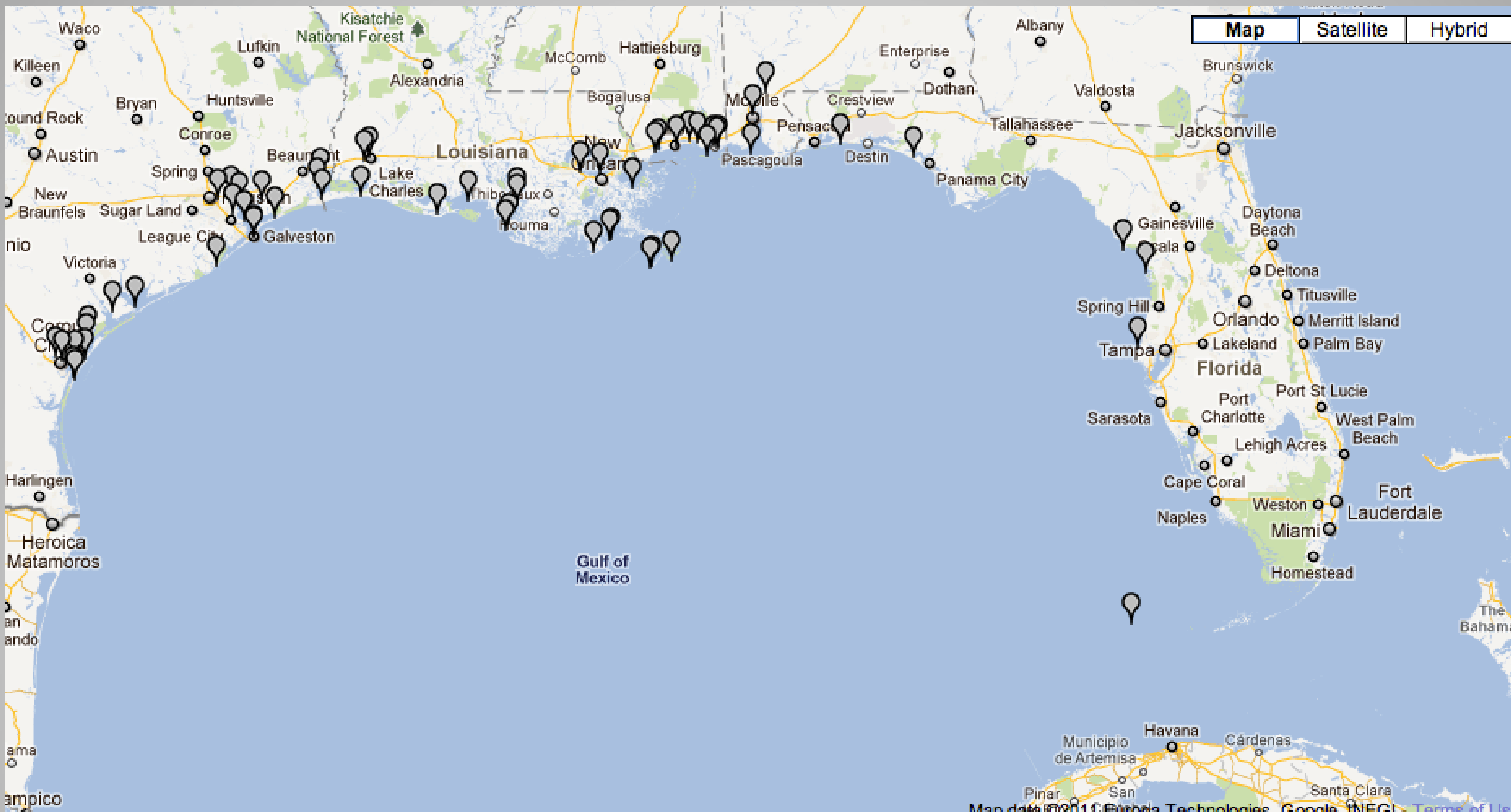


Sabin Pass
Slosh Basin

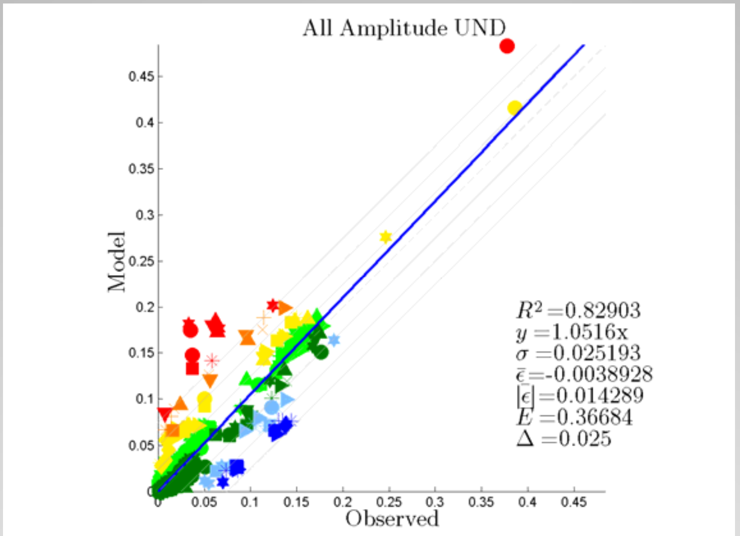


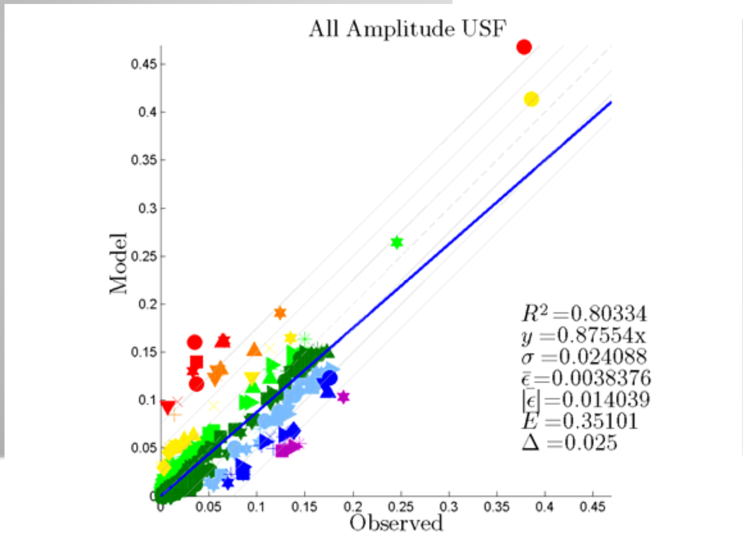
GoMx Extratropical
Storm Surge Grid

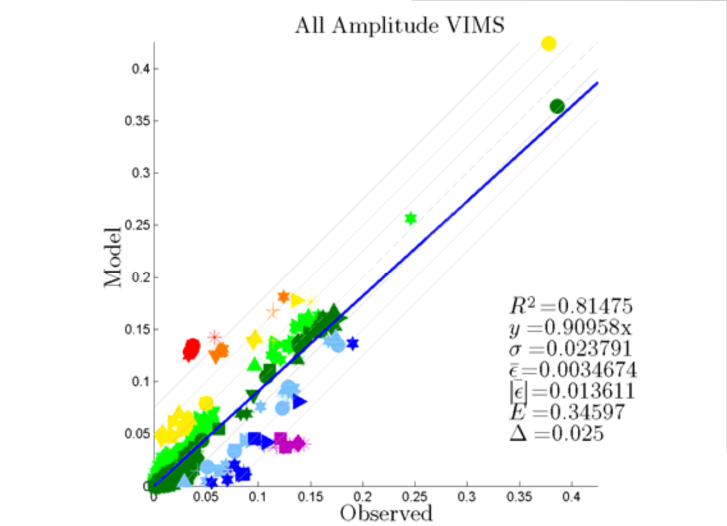
Tidal Observation Stations



10 Constituent Tidal Amplitudes

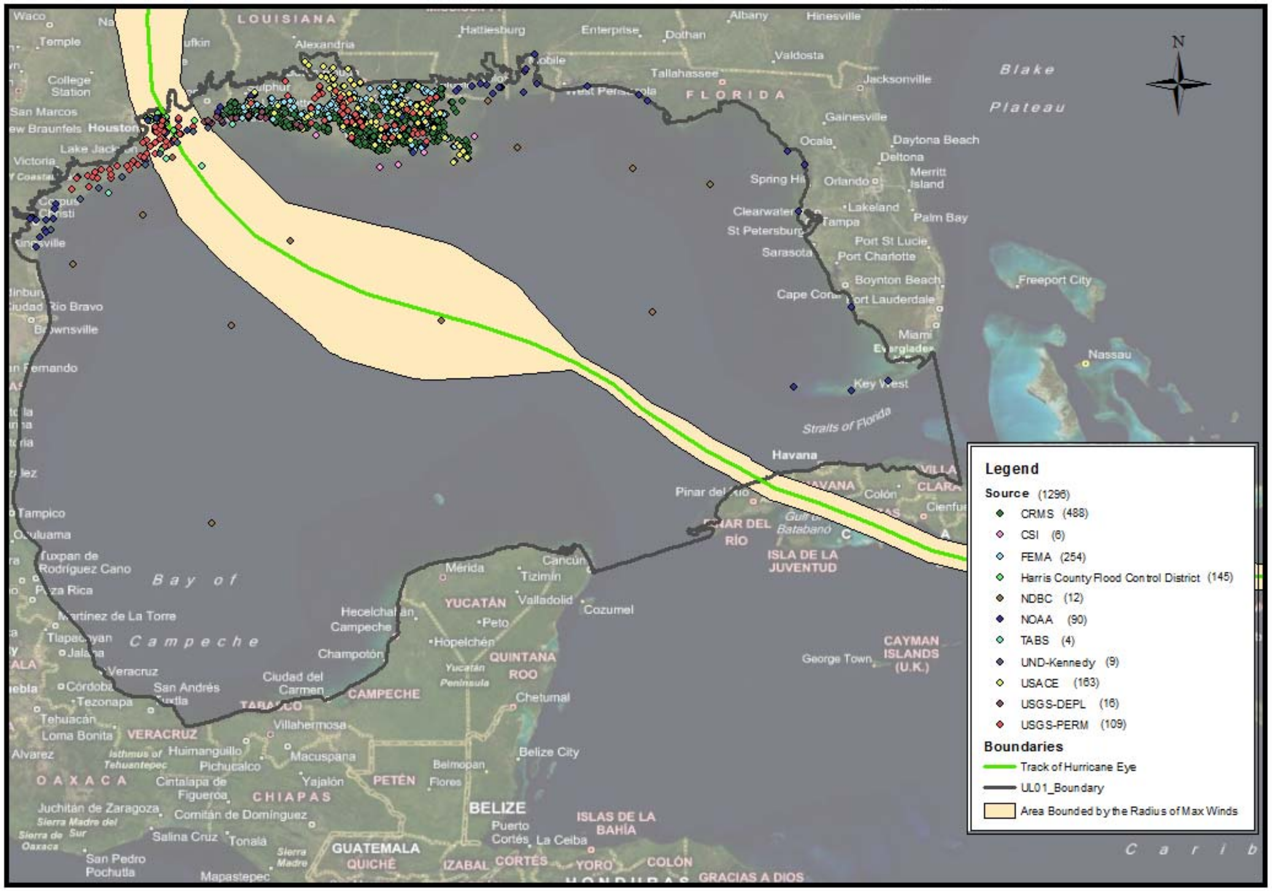




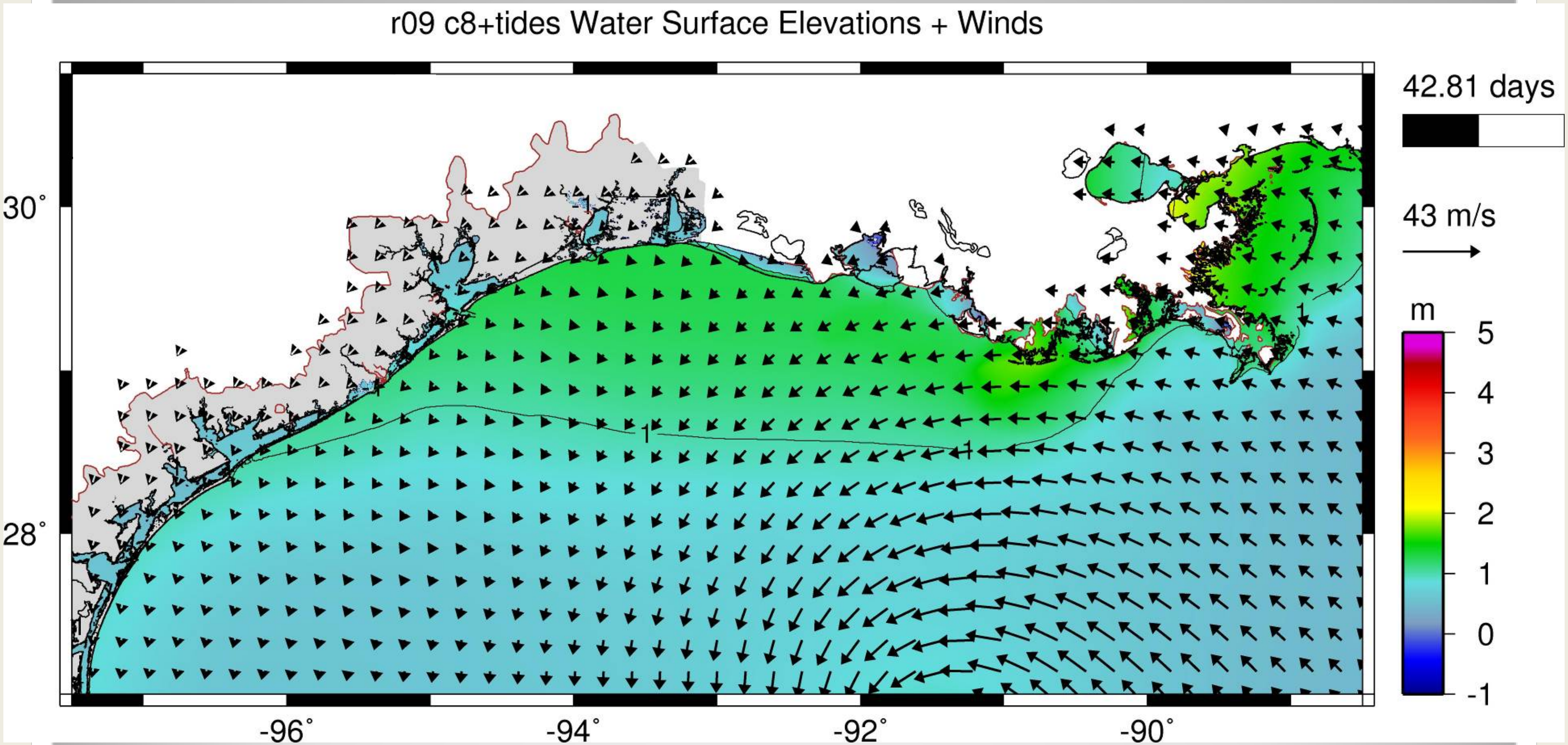


Hurricane Ike (2008)

Map of Observation Stations by Type for Hurricane Ike

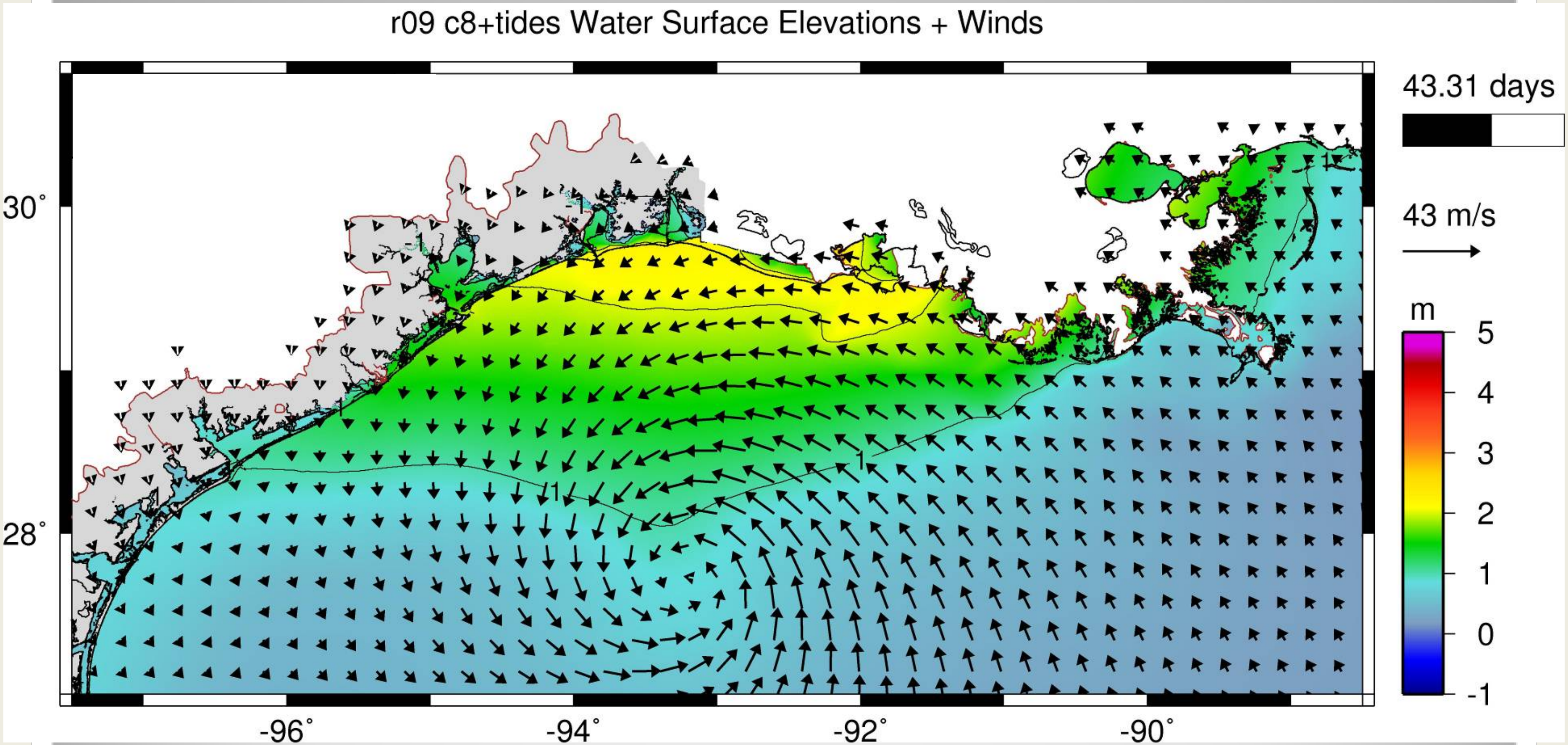


Ike surge contours (m) and wind vectors (m/s)



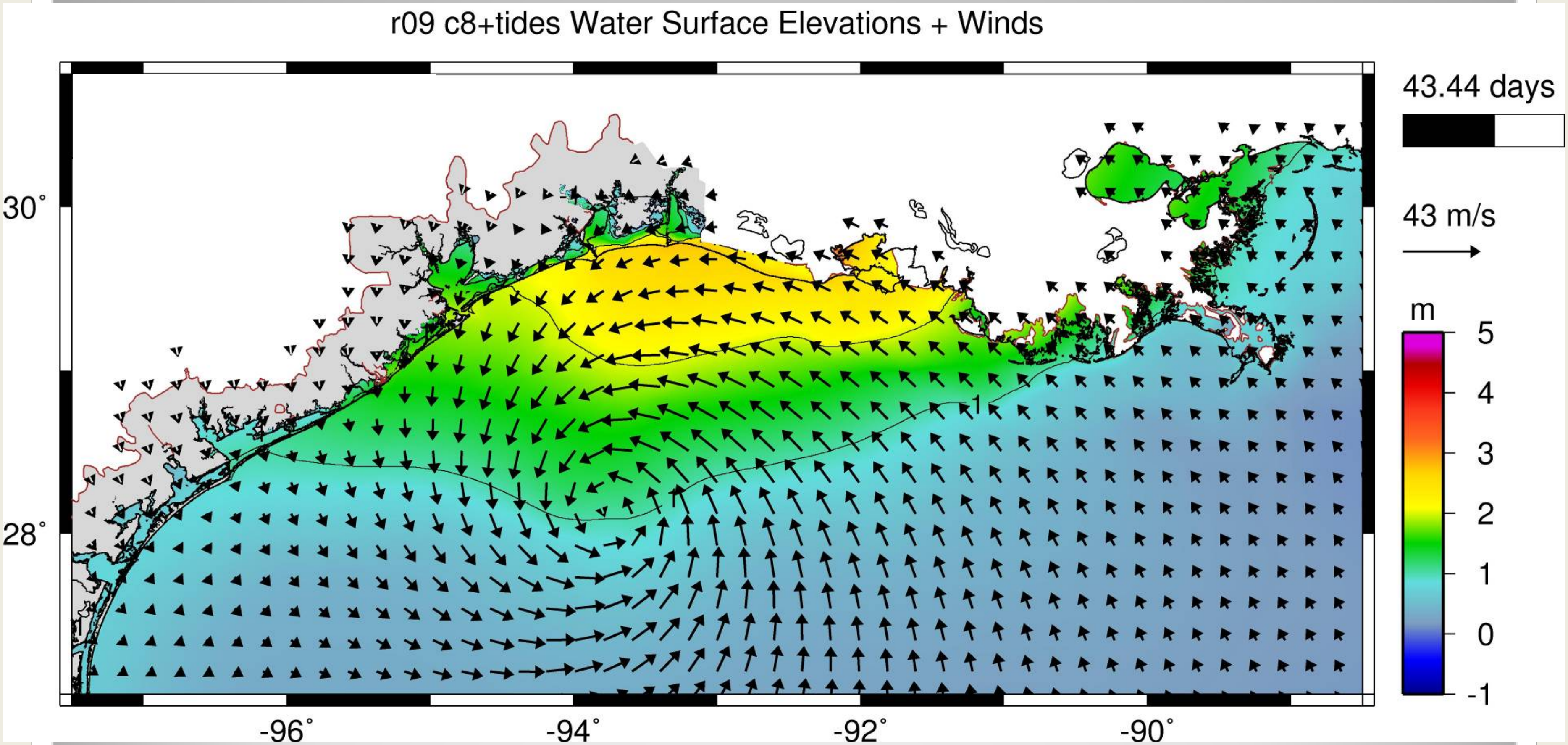
- 24 hrs

Ike surge contours (m) and wind vectors (m/s)



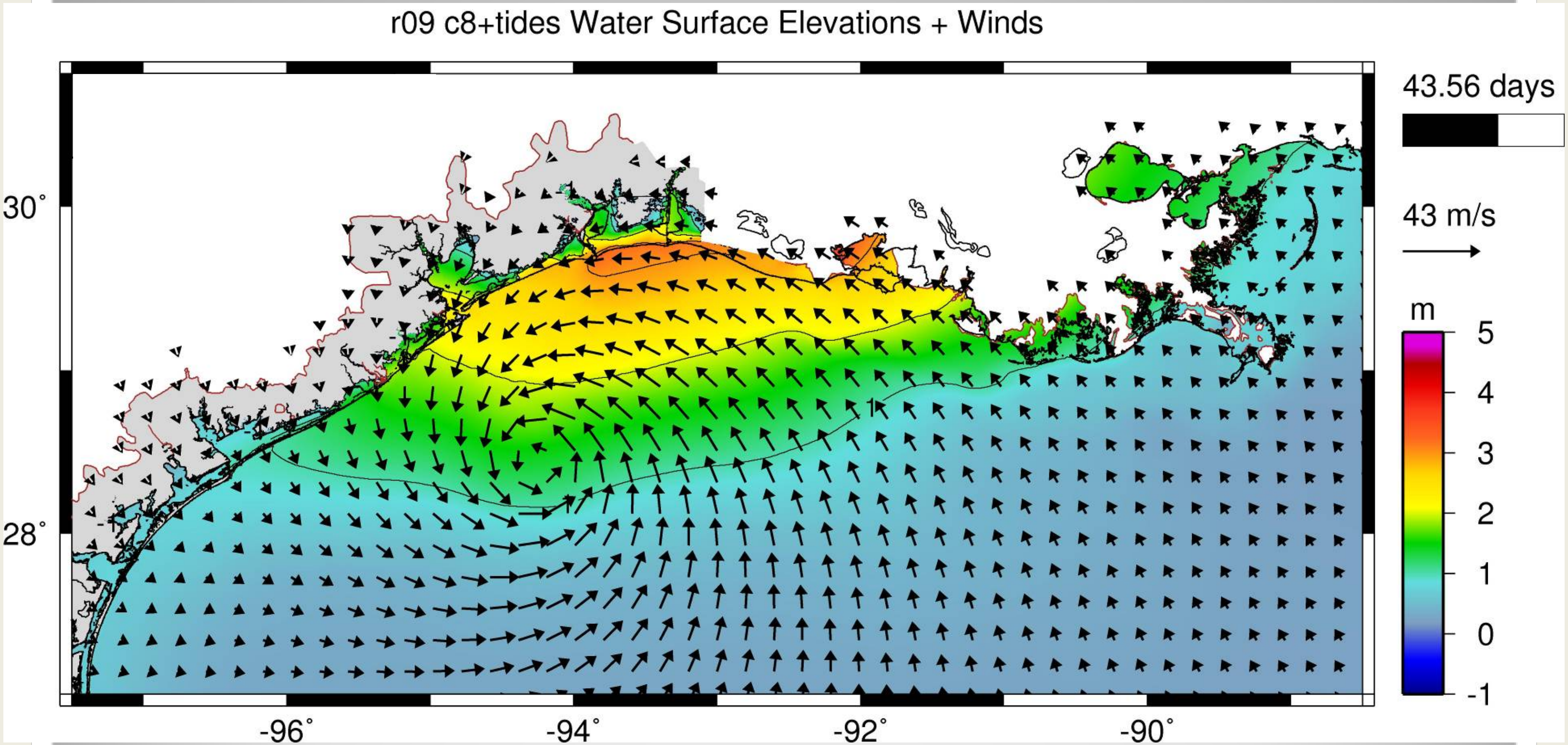
- 12 hrs

Ike surge contours (m) and wind vectors (m/s)



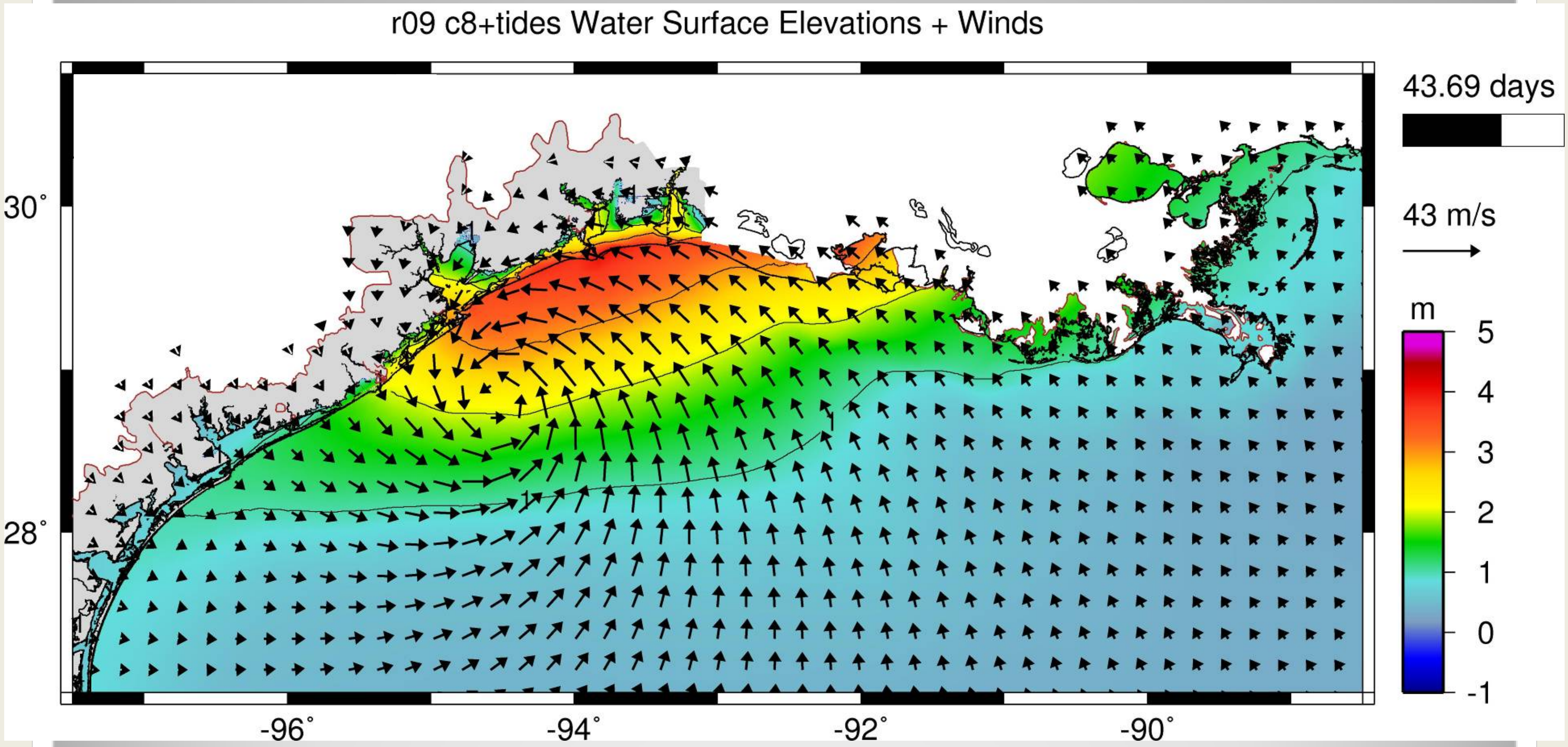
- 9 hrs

Ike surge contours (m) and wind vectors (m/s)



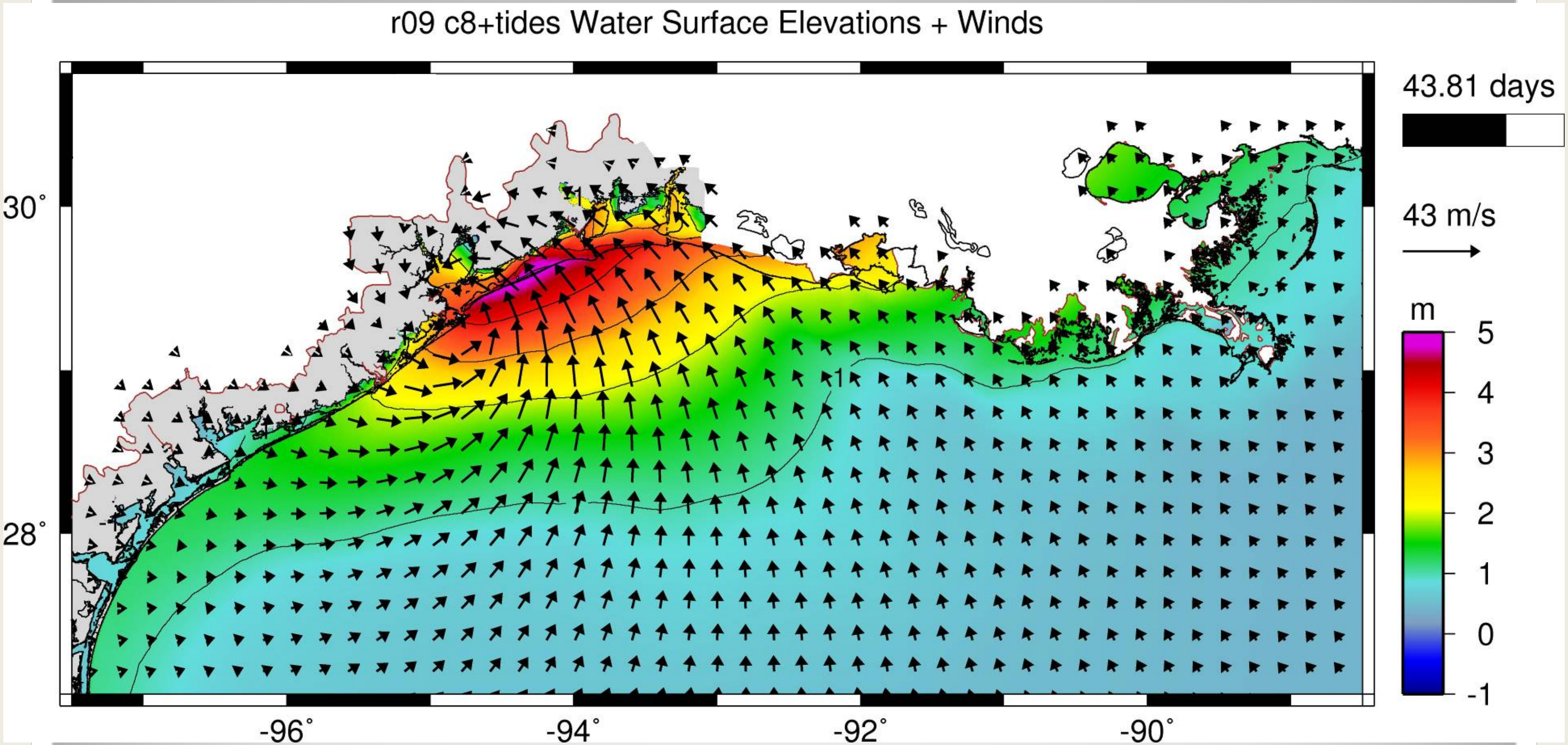
- 6 hrs

Ike surge contours (m) and wind vectors (m/s)

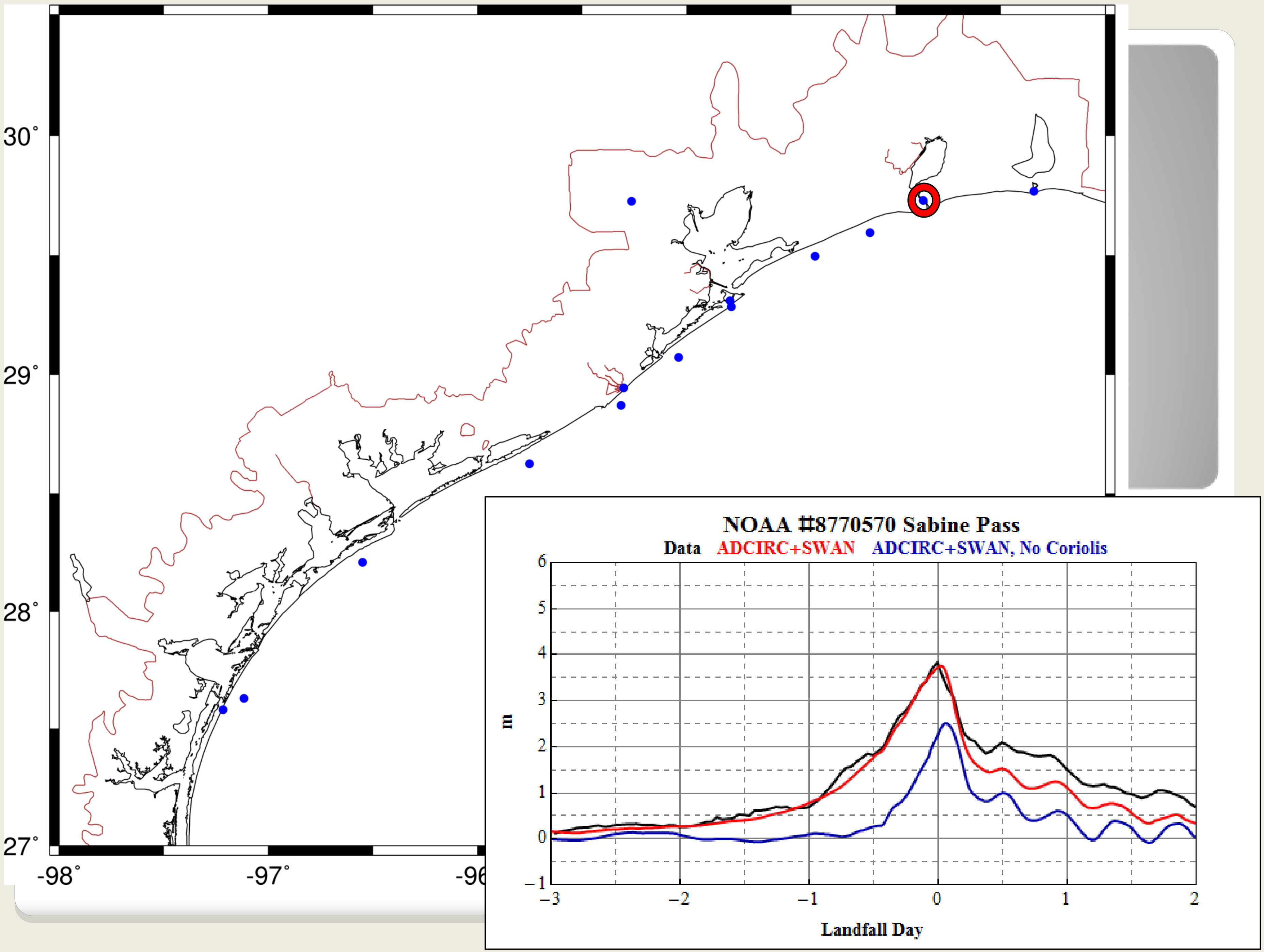


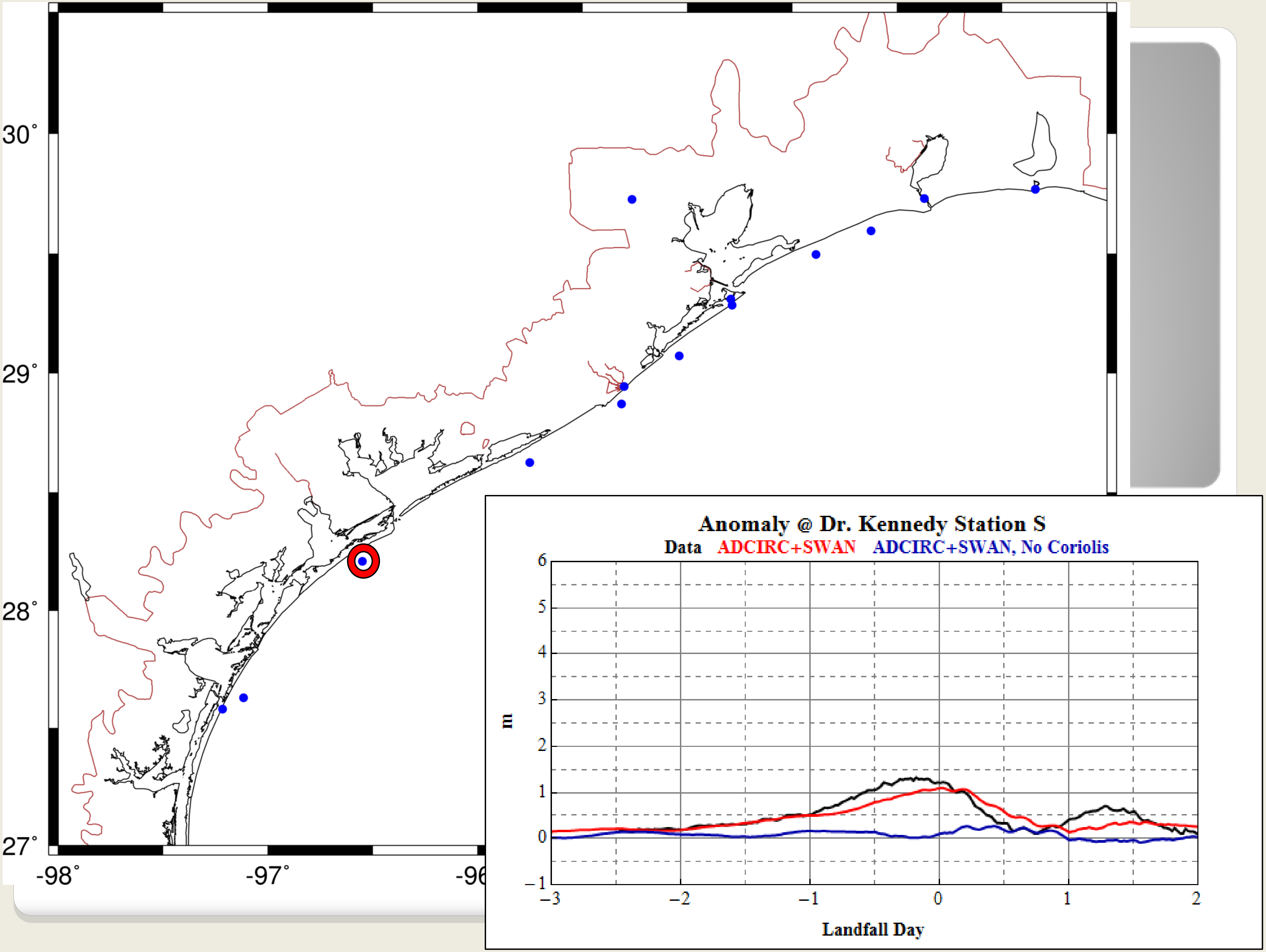
- 3 hrs

Ike surge contours (m) and wind vectors (m/s)



LANDFALL 0 hrs

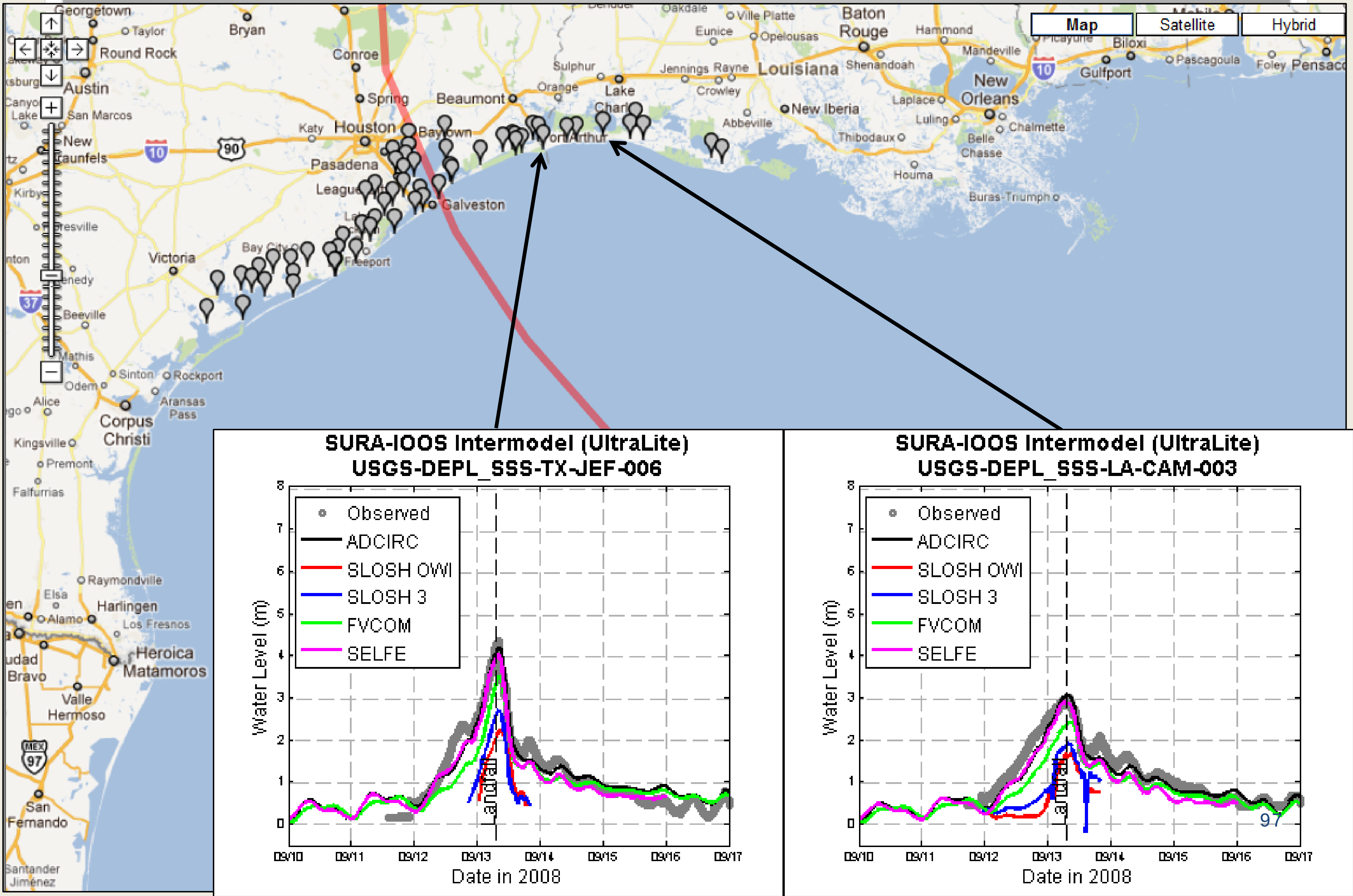

30°
29°
28°
27°
-98°
-97°
-96
NOAA #8770570 Sabine Pass
Data ADCIRC+SWAN ADCIRC+SWAN, No Coriolis
m
Landfall Day


30°
29°
28°
27°
-98°
-97°
-96
Anomaly @ Dr. Kennedy Station S
Data ADCIRC+SWAN ADCIRC+SWAN, No Coriolis
m
Landfall Day
6
5
4
3
2
1
0
−1
−3
−2
−1
0
1
2

Intermodel Comparison

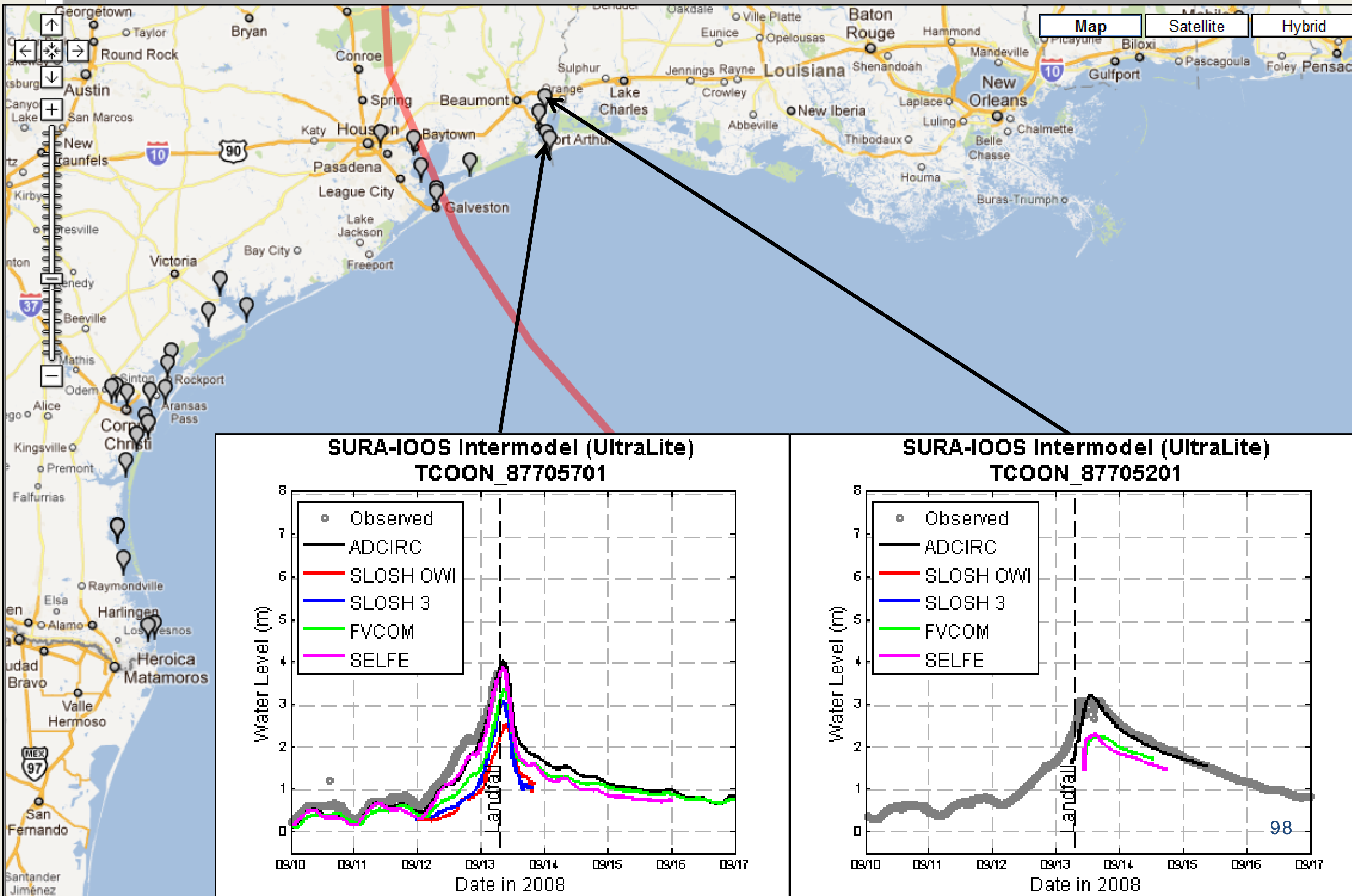
Without Waves

USGS-Deployable

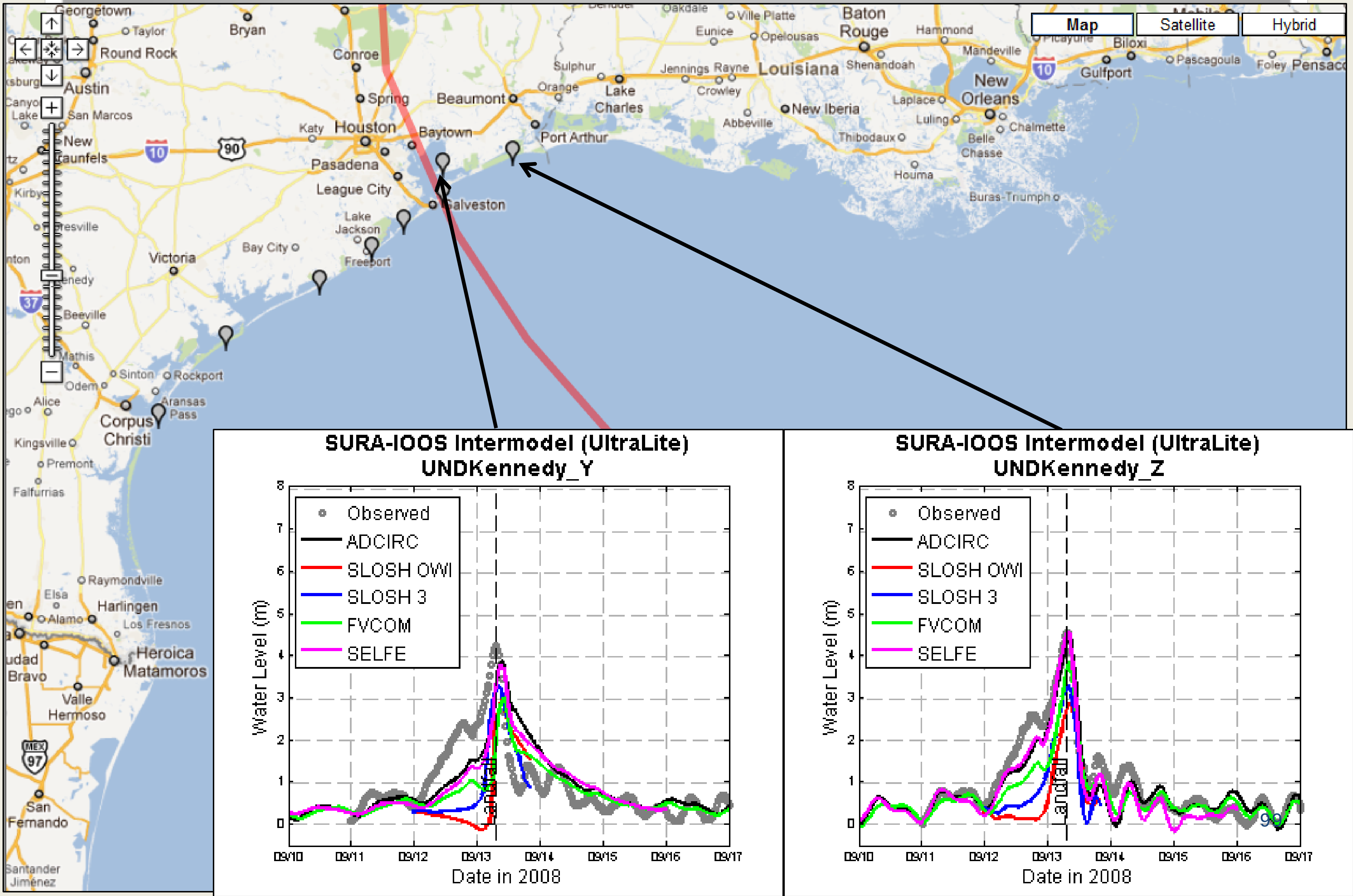


97

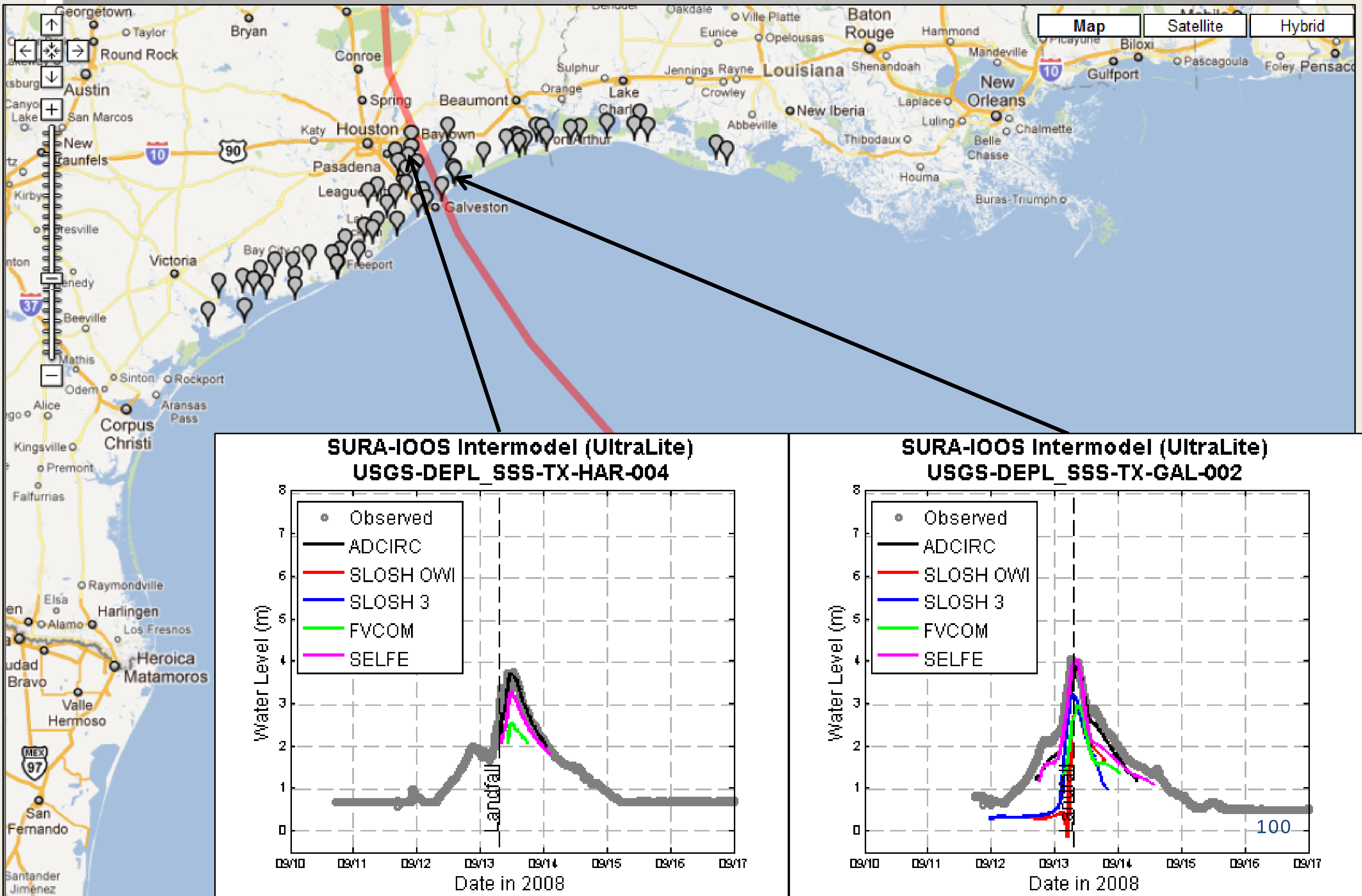
TCOON


Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
San Marcos
New Braunfels
Spring
Beaumont
Orange
Houston
Katy
Baytown
Port Arthur
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Alice
Aransas Pass
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Harlingen
Alamo
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
Sulphur
Lake Charles
Jennings
Rayne
Crowley
Eunice
Opelousas
Ville Platte
Oakdale
Abbeville
New Iberia
Louisiana
Baton Rouge
Shenandoah
Hammond
Mandeville
Laplace
New Orleans
Luling
Chalmette
Thibodaux
Belle Chasse
Houma
Buras-Triumph
Biloxi
Gulfport
Pascagoula
Foley
SURA-IOOS Intermodel (UltraLite)
TCOON_87705701
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Landfall
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17
SURA-IOOS Intermodel (UltraLite)
TCOON_87705201
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Landfall
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17

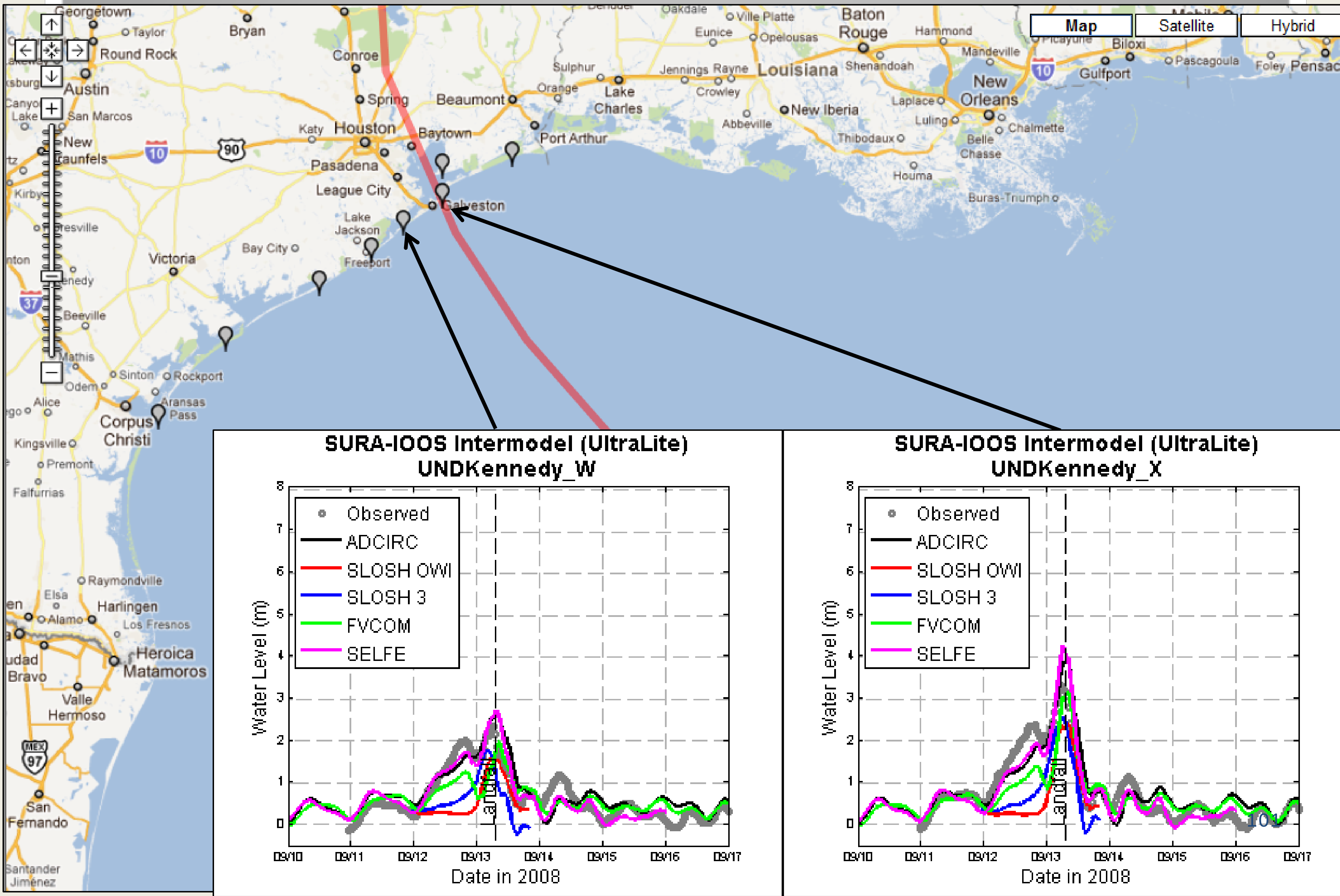
UND Kennedy


Map
Satellite
Hybrid
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_Y
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Landfall
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_Z
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Landfall
Date in 2008

USGS-Deployable

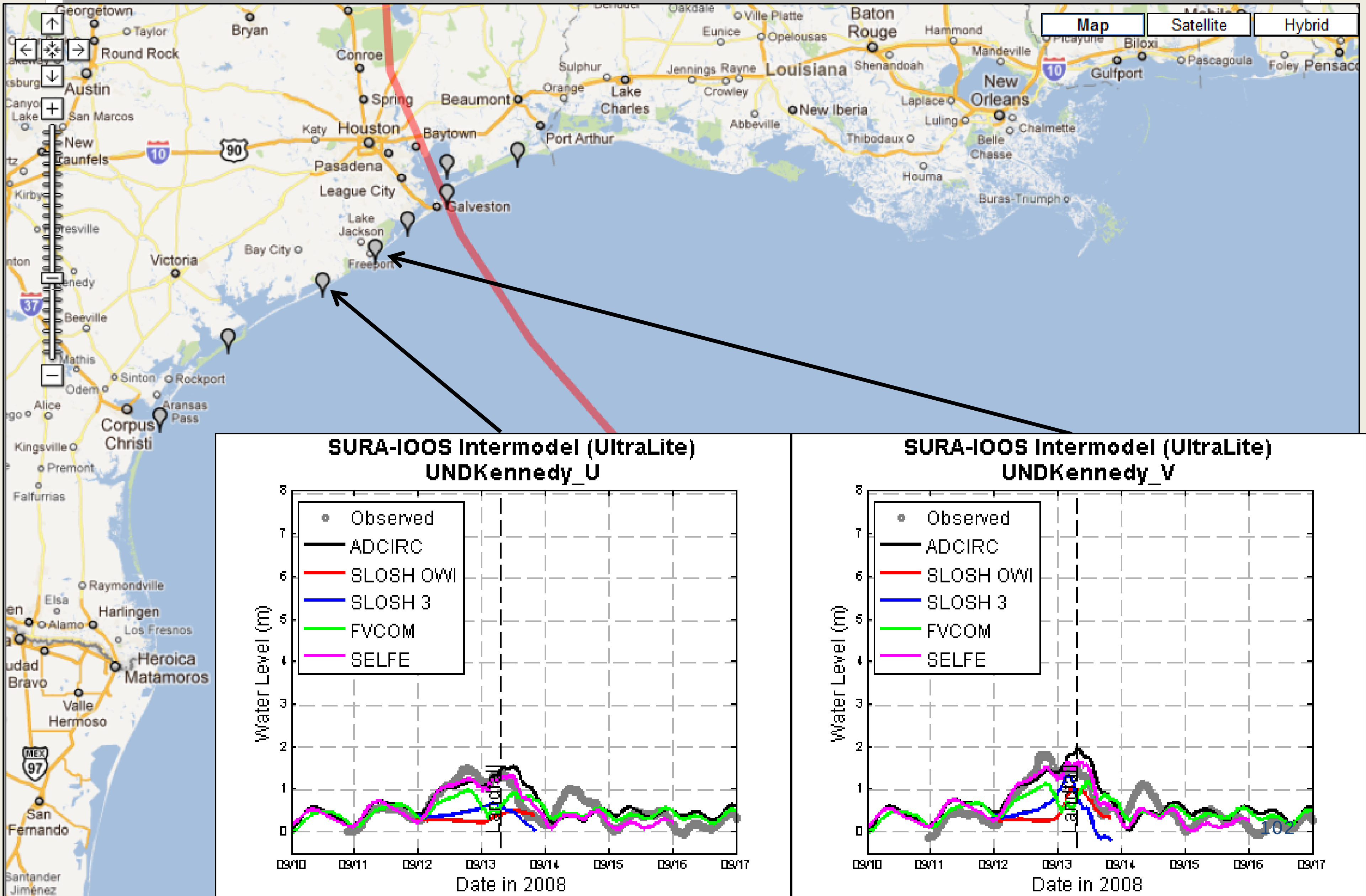


UND Kennedy



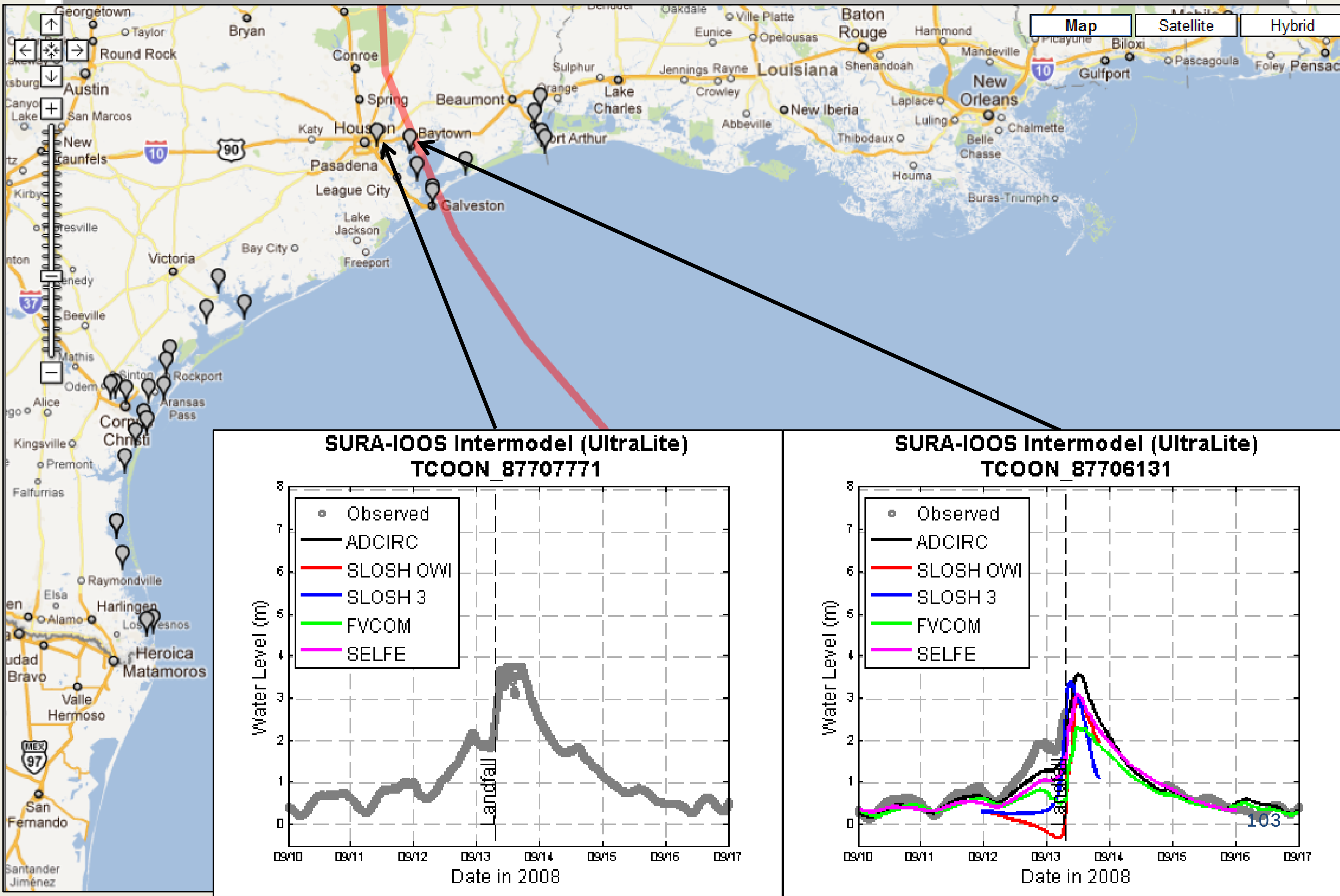
Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
Spring
Beaumont
Orange
Lake Charles
Sulphur
Jennings
Rayne
Crowley
Louisiana
Baton Rouge
Shenandoah
Eunice
Opelousas
Ville Platte
Hammond
Mandeville
New Orleans
Laplace
Luling
Chalmette
Belle Chasse
Thibodaux
Houma
Buras-Triumph
Abbeville
New Iberia
Biloxi
Gulfport
Pascagoula
Foley
San Marcos
New Braunfels
Katy
Houston
Baytown
Port Arthur
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Alice
Aransas Pass
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Alamo
Harlingen
Los Fresnos
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_W
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
landfall
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17
Date in 2008
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_X
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
landfall
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17
Date in 2008

UND Kennedy



Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
San Marcos
New Braunfels
Spring
Beaumont
Orange
Lake Charles
Sulphur
Jennings
Rayne
Crowley
Eunice
Opelousas
Ville Platte
Oakdale
Baton Rouge
Louisiana
Hammond
Mandeville
Shenandoah
New Orleans
New Iberia
Abbeville
Laplace
Luling
Chalmette
Belle Chasse
Thibodaux
Houma
Buras-Triumph
Picayune
Biloxi
Gulfport
Pascagoula
Foley
Katy
Houston
Baytown
Port Arthur
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Alice
Aransas Pass
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Harlingen
Alamo
Los Fresnos
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
10
90
37
97
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_U
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17
SURA-IOOS Intermodel (UltraLite)
UNDKennedy_V
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
09/17

TCOON

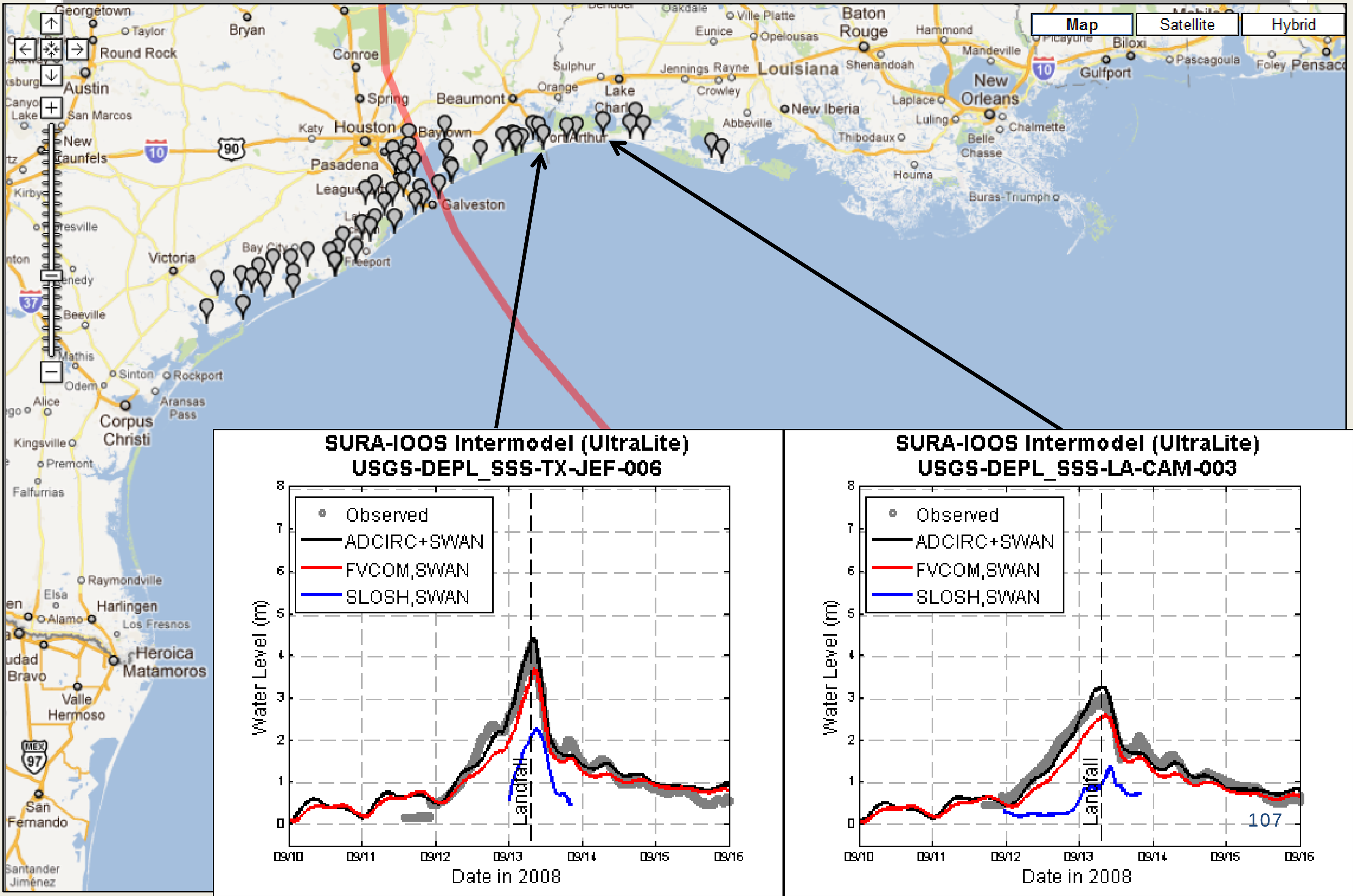


Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
San Marcos
New Braunfels
Spring
Beaumont
Houston
Katy
Baytown
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Aransas Pass
Alice
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Harlingen
Alamo
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
Sulphur
Orange
Lake Charles
Port Arthur
Jennings
Rayne
Crowley
Abbeville
Oakdale
Ville Platte
Eunice
Opelousas
Baton Rouge
Louisiana
Shenandoah
New Iberia
Hammond
Mandeville
New Orleans
Laplace
Luling
Chalmette
Thibodaux
Belle Chasse
Houma
Buras-Triumph
Picayune
Biloxi
Gulfport
Pascagoula
Foley
SURA-IOOS Intermodel (UltraLite)
TCOON_87707771
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Landfall
Water Level (m)
Date in 2008
SURA-IOOS Intermodel (UltraLite)
TCOON_87706131
Observed
ADCIRC
SLOSH OWI
SLOSH 3
FVCOM
SELFE
Water Level (m)
Date in 2008

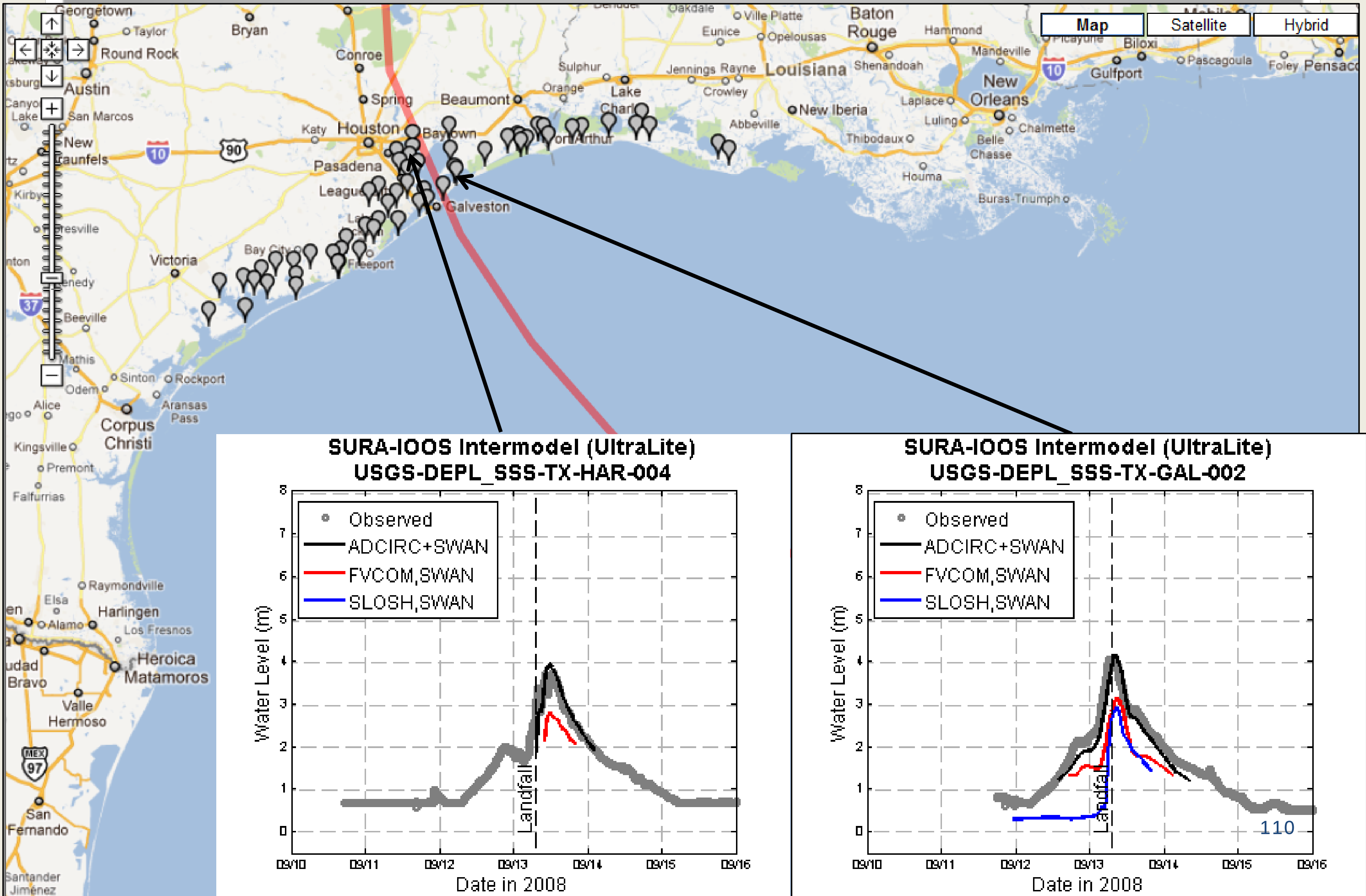
Intermodel Comparison

With Waves

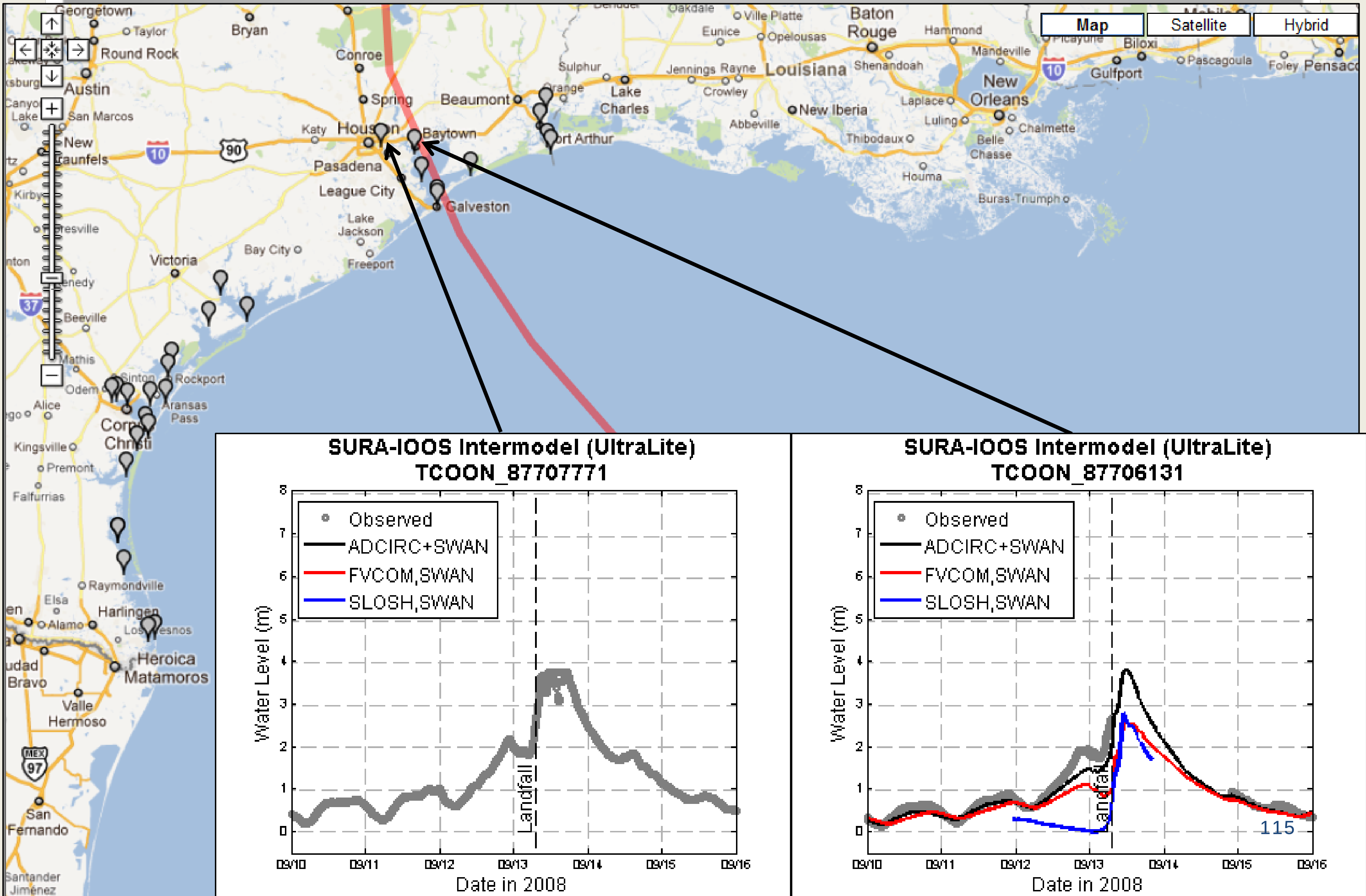
USGS-Deployable



USGS-Deployable



TCOON



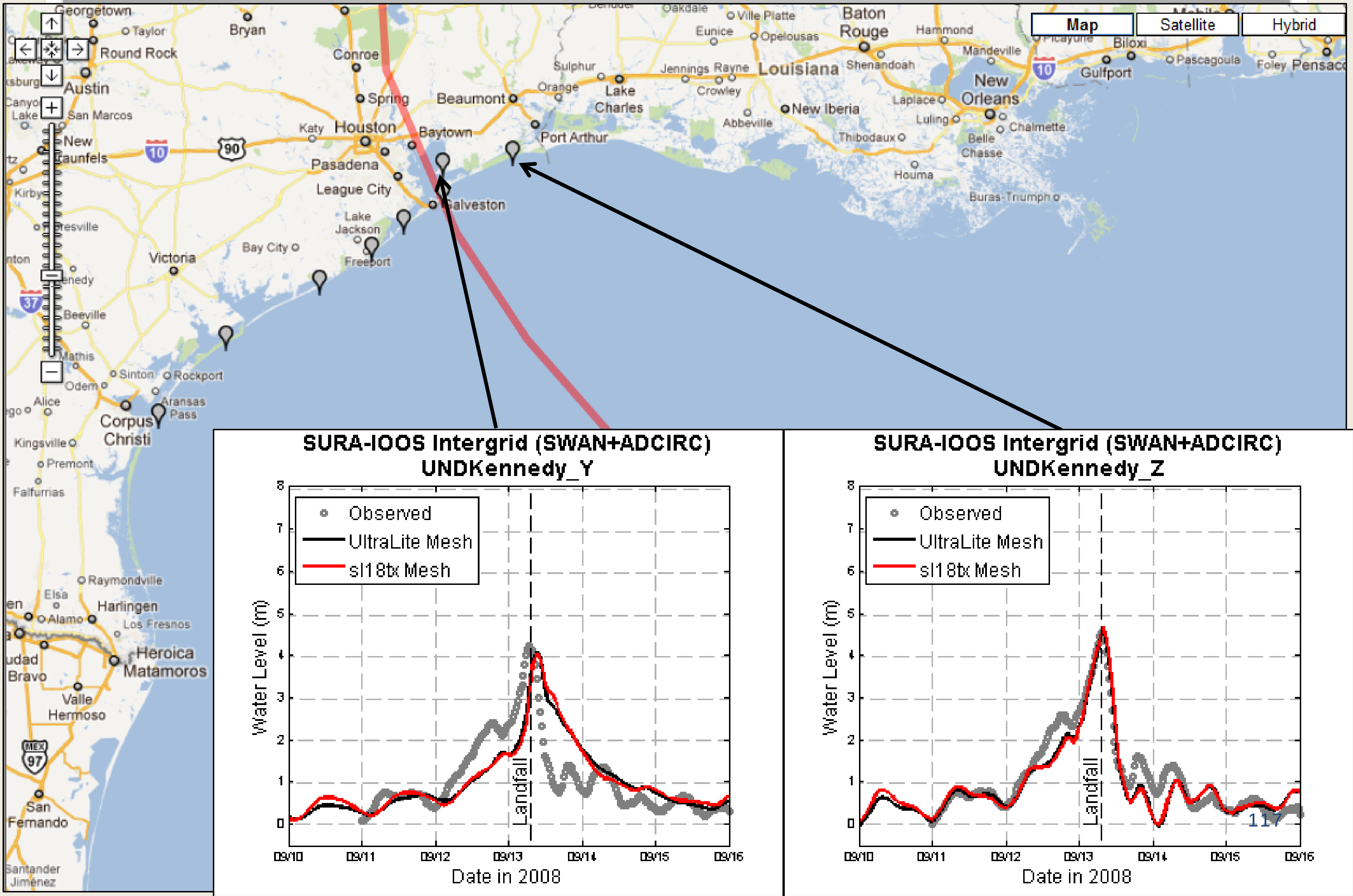
Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
San Marcos
New Braunfels
Spring
Beaumont
Houston
Katy
Baytown
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Aransas Pass
Alice
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Harlingen
Alamo
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
Orange
Port Arthur
Sulphur
Lake Charles
Jennings
Rayne
Crowley
Louisiana
Abbeville
New Iberia
Eunice
Ville Platte
Opelousas
Baton Rouge
Hammond
Shenandoah
Mandeville
Laplace
New Orleans
Luling
Chalmette
Thibodaux
Belle Chasse
Houma
Buras-Triumph
Picayune
Biloxi
Gulfport
Pascagoula
Foley
SURA-IOOS Intermodel (UltraLite)
TCOON_87707771
Observed
ADCIRC+SWAN
FVCOM,SWAN
SLOSH,SWAN
Landfall
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
SURA-IOOS Intermodel (UltraLite)
TCOON_87706131
Observed
ADCIRC+SWAN
FVCOM,SWAN
SLOSH,SWAN
Water Level (m)
Date in 2008

Intergrid Comparison

sl18tx
(18061765 Elements, 9,108,128 Nodes)

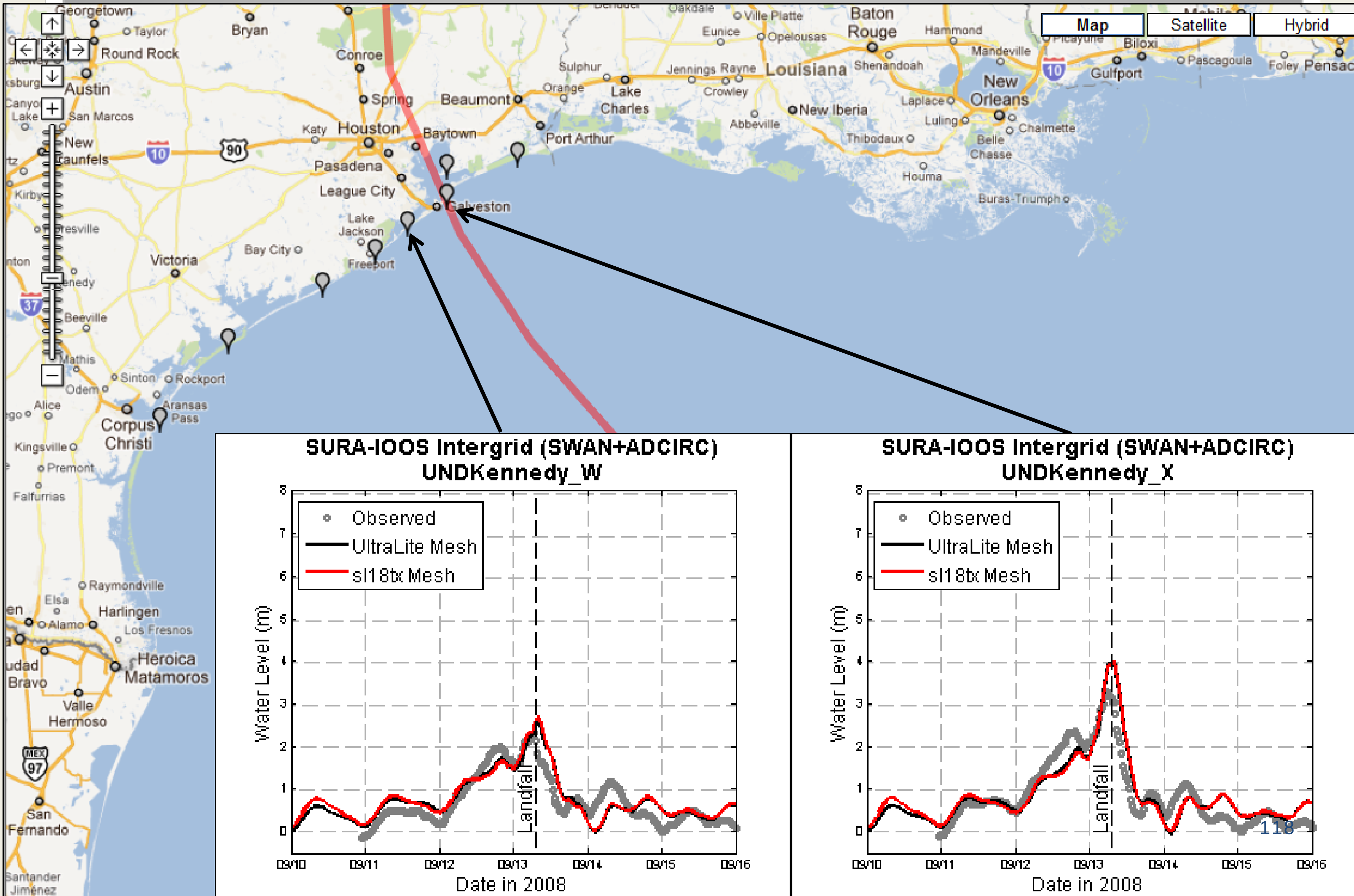
Standard
(825284 Elements, 424485 Nodes)

UND Kennedy

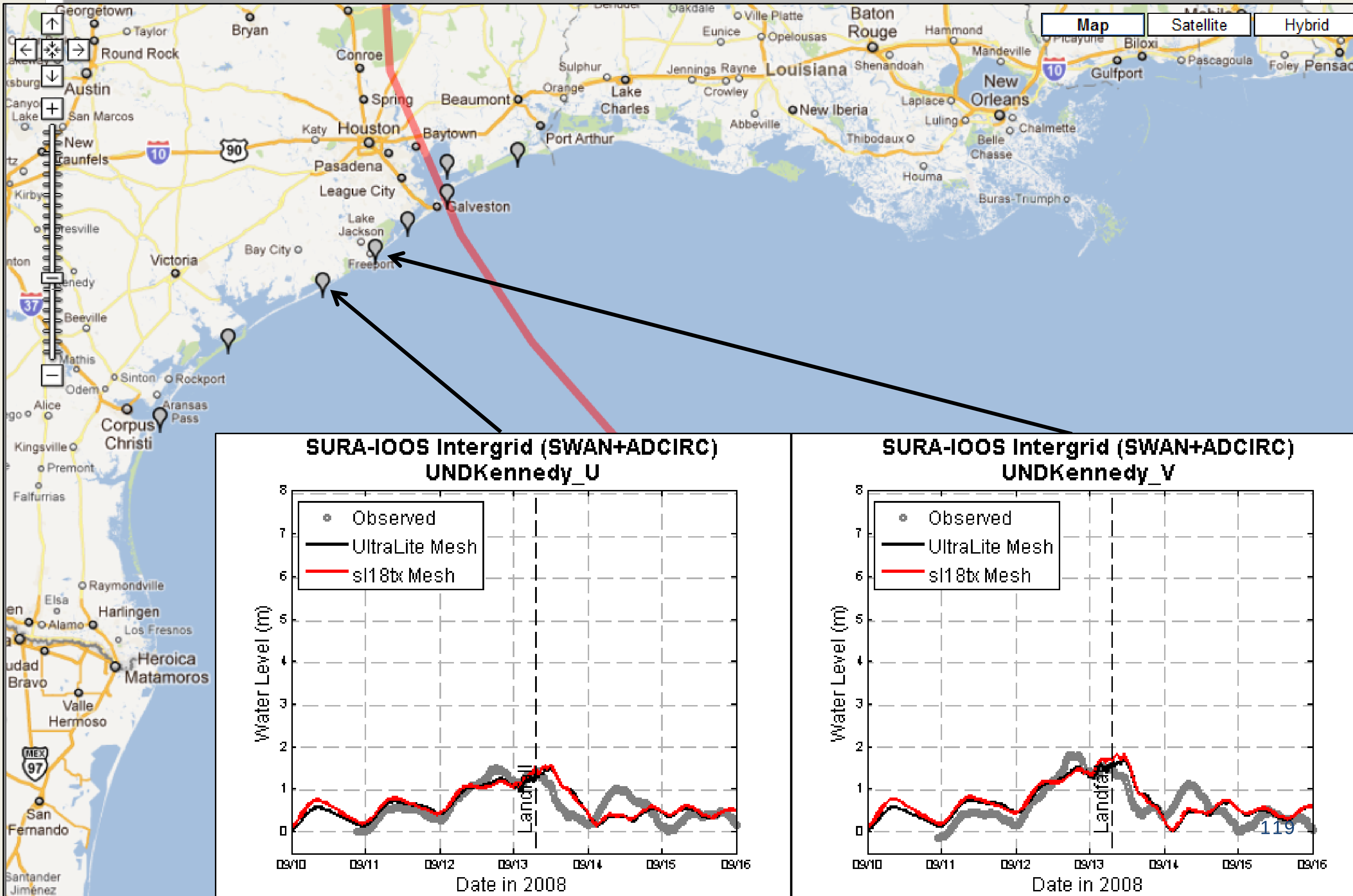


Map
Satellite
Hybrid
Georgetown
Bryan
Conroe
Round Rock
Austin
San Marcos
New Braunfels
Spring
Houston
Katy
Beaumont
Orange
Lake Charles
Sulphur
Jennings
Rayne
Crowley
Louisiana
Baton Rouge
Shenandoah
New Orleans
Gulfport
Biloxi
Pascagoula
Port Arthur
Baytown
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Aransas Pass
Corpus Christi
Alice
Kingsville
Premont
Falfurrias
Raymondville
Harlingen
Los Fresnos
Heroica Matamoros
Valle Hermoso
San Fernando
New Iberia
Abbeville
Thibodaux
Houma
Buras-Triumph
Chalmette
Laplace
Luling
Mandeville
Hammond
Eunice
Opelousas
Ville Platte
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_Y
Observed
UltraLite Mesh
sl18tx Mesh
Landfall
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_Z
Observed
UltraLite Mesh
sl18tx Mesh
Landfall
Water Level (m)
Date in 2008

UND Kennedy

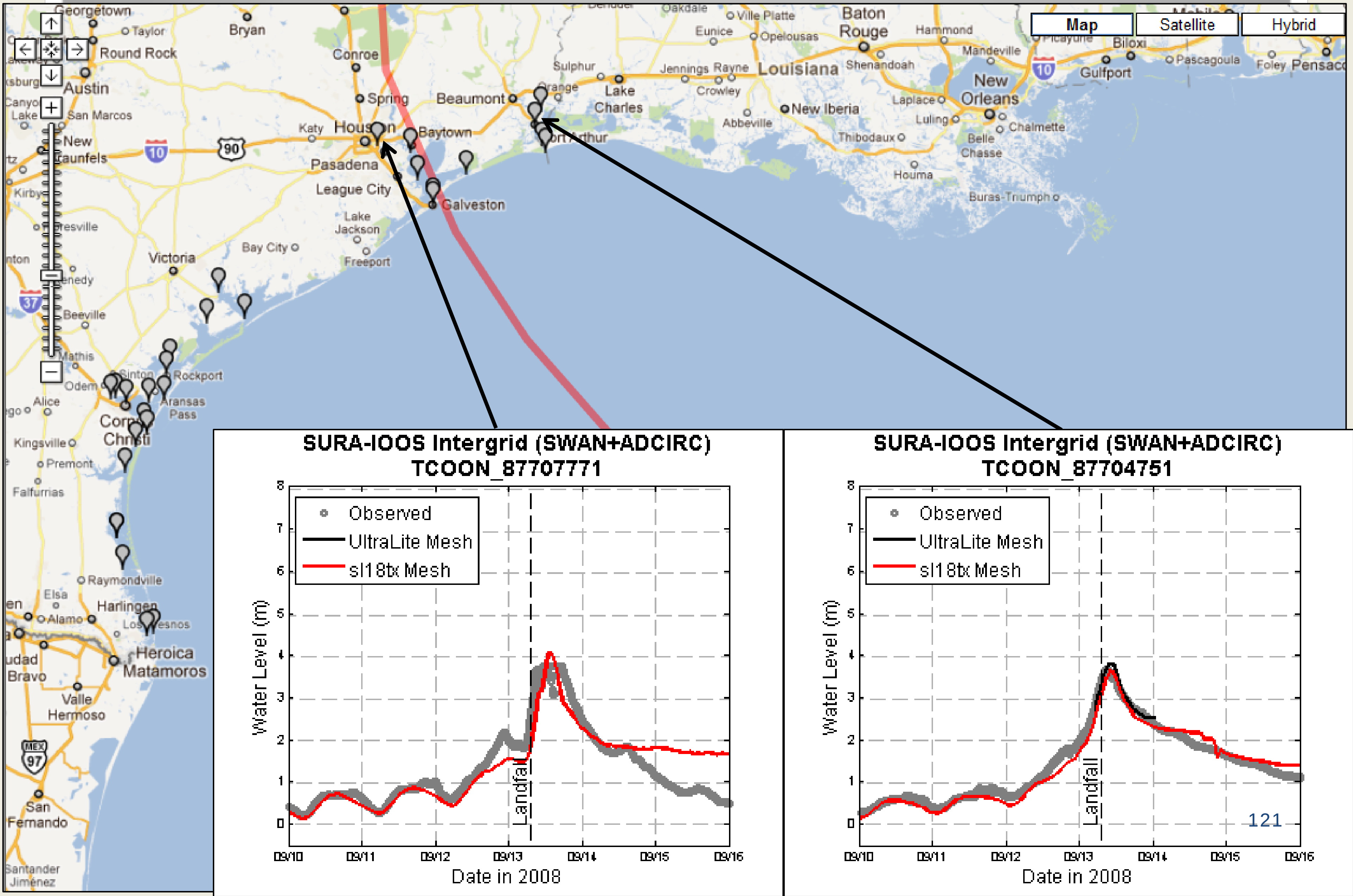

Map
Satellite
Hybrid
Houston
Galveston
Beaumont
Port Arthur
Lake Charles
Louisiana
Baton Rouge
New Orleans
Gulfport
Biloxi
Austin
Corpus Christi
Victoria
Freeport
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_W
Observed
UltraLite Mesh
sl18tx Mesh
Landfall
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_X
Observed
UltraLite Mesh
sl18tx Mesh
Landfall
Water Level (m)
Date in 2008

UND Kennedy

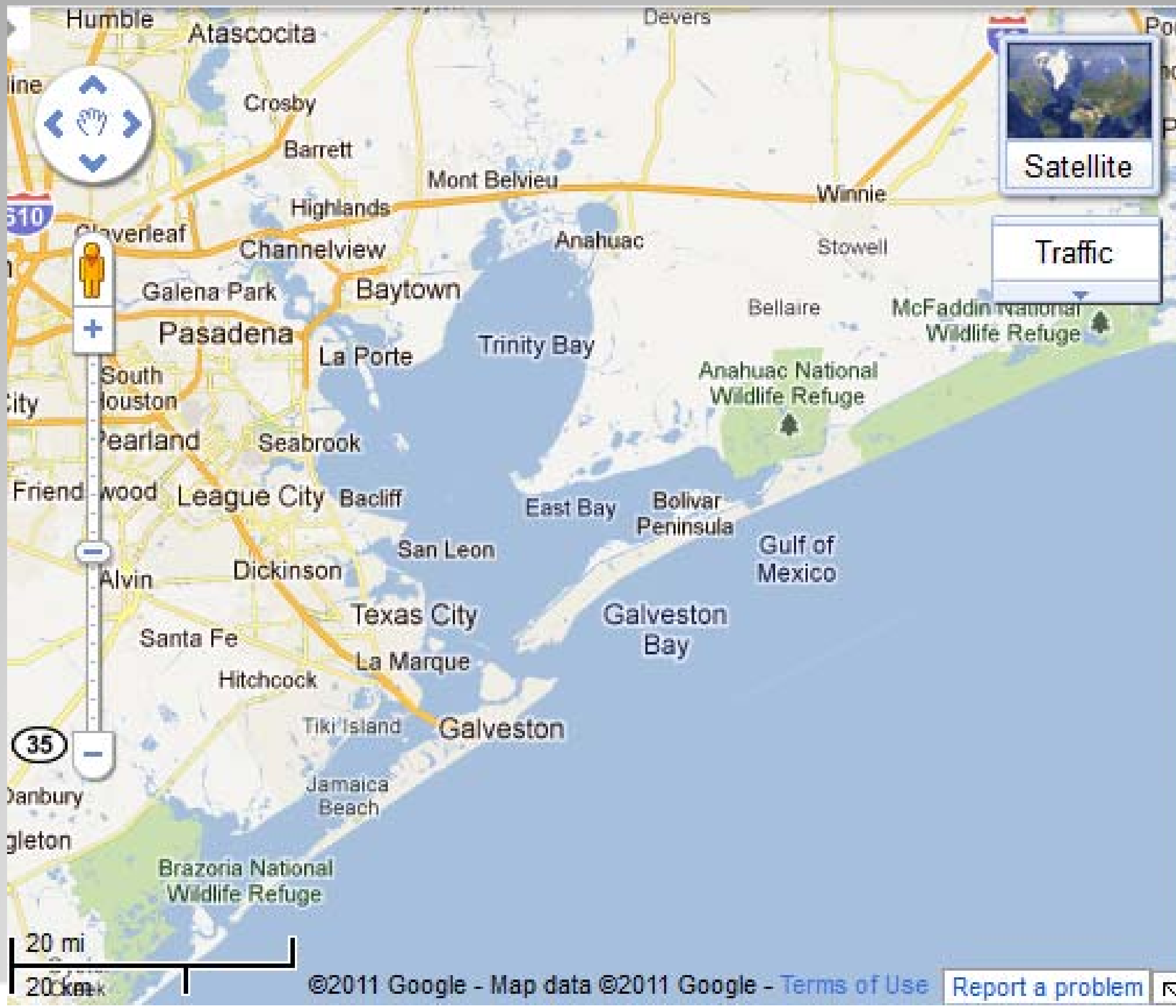


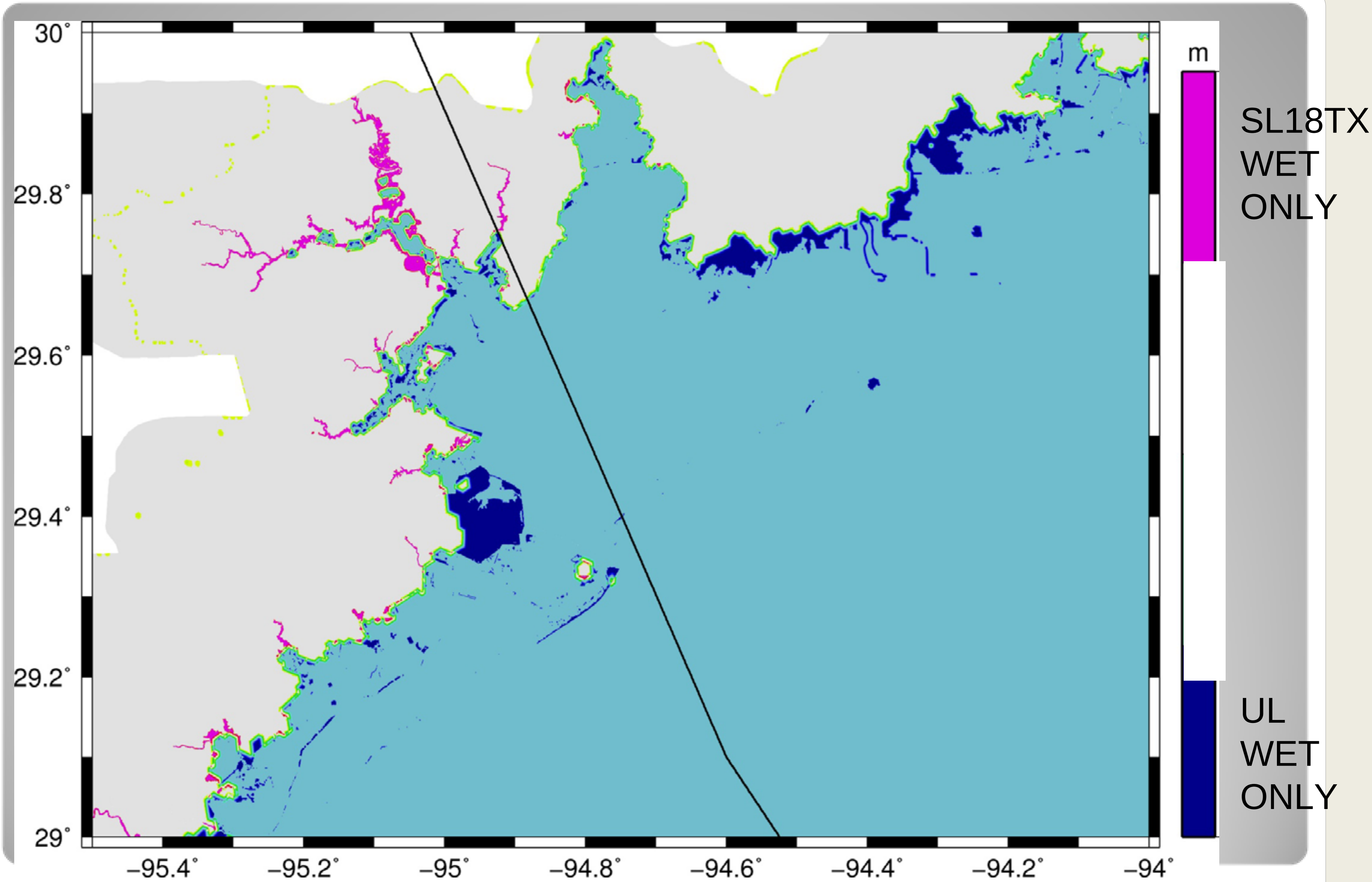
Map
Satellite
Hybrid
Georgetown
Taylor
Bryan
Round Rock
Conroe
Austin
San Marcos
Spring
Beaumont
Orange
Sulphur
Lake Charles
Jennings
Rayne
Crowley
Eunice
Ville Platte
Opelousas
Baton Rouge
Louisiana
Shenandoah
Hammond
Mandeville
Picayune
Biloxi
Gulfport
Pascagoula
Foley
New Orleans
Laplace
Luling
Chalmette
Belle Chasse
Thibodaux
Houma
Buras-Triumph
New Iberia
Abbeville
Katy
Houston
Baytown
Port Arthur
Pasadena
League City
Galveston
Lake Jackson
Freeport
Bay City
Victoria
Beeville
Mathis
Sinton
Rockport
Odem
Alice
Aransas Pass
Corpus Christi
Kingsville
Premont
Falfurrias
Raymondville
Elsa
Harlingen
Alamo
Los Fresnos
Heroica Matamoros
Valle Hermoso
San Fernando
Santander Jiménez
10
90
37
97
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_U
Observed
UltraLite Mesh
sl18tx Mesh
Water Level (m)
Date in 2008
Landfall
09/10
09/11
09/12
09/13
09/14
09/15
09/16
SURA-IOOS Intergrid (SWAN+ADCIRC)
UNDKennedy_V
Observed
UltraLite Mesh
sl18tx Mesh
Water Level (m)
Date in 2008
Landfall

TCOON



Map
Satellite
Hybrid
Houston
Baytown
Pasadena
League City
Galveston
Beaumont
Port Arthur
Lake Charles
Louisiana
Baton Rouge
New Orleans
Austin
Victoria
Corpus Christi
SURA-IOOS Intergrid (SWAN+ADCIRC)
TCOON_87707771
Observed
UltraLite Mesh
sl18tx Mesh
Landfall
Water Level (m)
Date in 2008
09/10
09/11
09/12
09/13
09/14
09/15
09/16
SURA-IOOS Intergrid (SWAN+ADCIRC)
TCOON_87704751


Humble
Atascocita
Devers
Crosby
Barrett
Mont Belvieu
Winnie
Highlands
Anahuac
Stowell
Channelview
Baytown
Galena Park
Bellaire
McFaddin
Wildlife Refuge
Pasadena
La Porte
Trinity Bay
South
Anahuac National
Wildlife Refuge
Seabrook
League City
Bacliff
East Bay
Bolivar
Peninsula
San Leon
Gulf of
Mexico
Alvin
Dickinson
Texas City
Galveston
Bay
Santa Fe
La Marque
Hitchcock
Tiki Island
Galveston
35
Jamaica
Beach
Brazoria National
Wildlife Refuge
Satellite
Traffic
20 mi
20 km
©2011 Google - Map data ©2011 Google - Terms of Use
Report a problem


30˚
29.8˚
29.6˚
29.4˚
29.2˚
29˚
−95.4˚
−95.2˚
−95˚
−94.8˚
−94.6˚
−94.4˚
−94.2˚
−94˚
m
SL18TX WET ONLY
UL WET ONLY

Tropical Findings

- FVCOM, SELFE, tides slightly more damped than ADCIRC
- ADCIRC, FVCOM, SELFE capture both parts to hurricane Ike surge – although FVCOM is consistently lower than the other two
- SLOSH misses the geostrophic setup ahead of storm and is consistently below other models
- Enhanced grid resolution does make a difference in local areas, albeit at high cost
- Wave model comparisons ongoing.