Atlantic Ocean Forecast System: Progress; atmospheric fluxes, river outflow and tides

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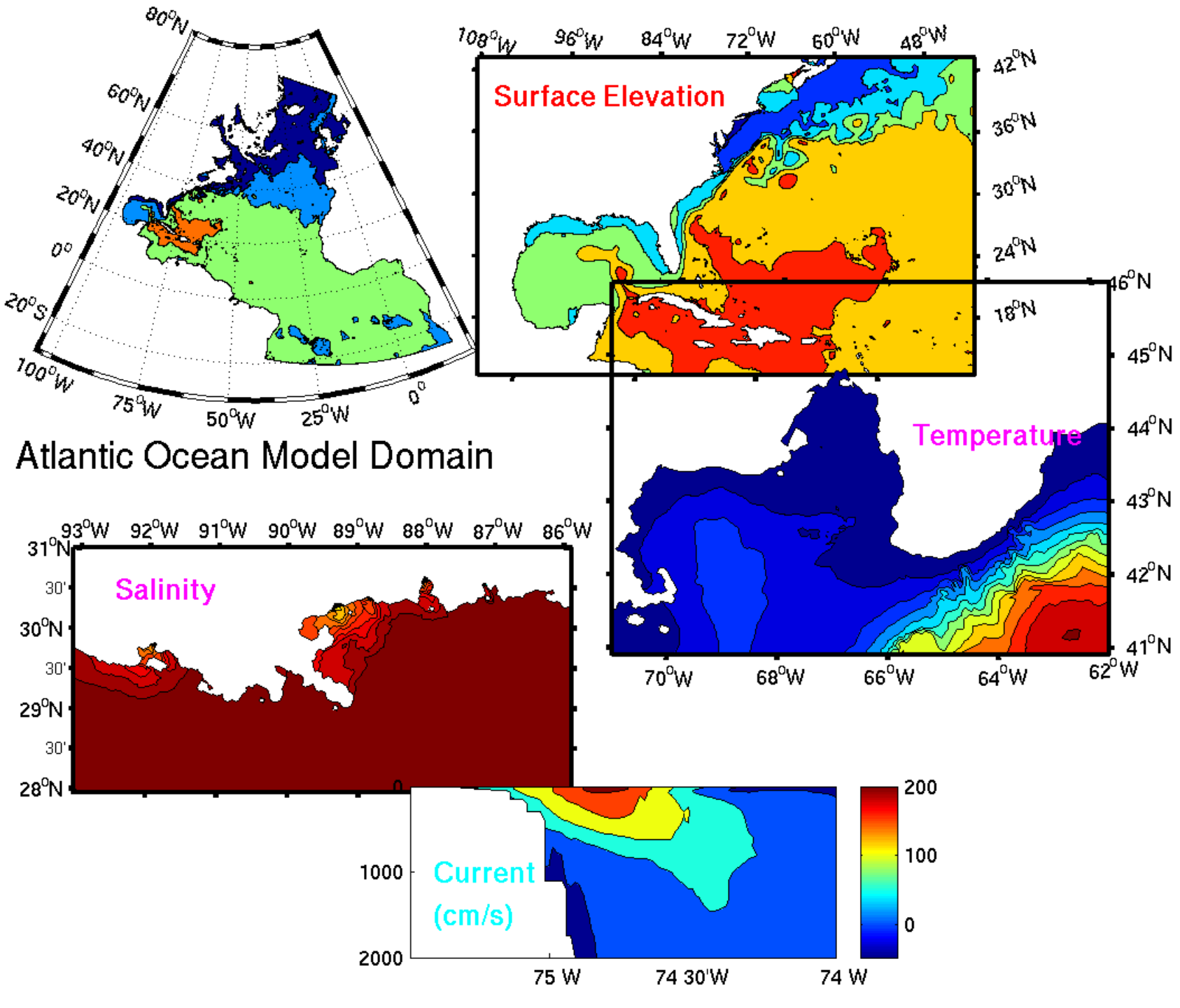
MMAB/NCEP/NOAA

HYCOM meeting December 6 2005

HYCOM dynamical model and forcing

- **Primitive equation with free surface.**
- **Sub-grid scale parameterizations. Vertical and horizontal eddy viscosity and mixing. Diapycnal mixing.**
- **Tides, river outflow.**
- **Atmospheric fluxes.**


80°N
60°N
40°N
20°N
0°
20°S
100°W
75°W
50°W
25°W
0°
Atlantic Ocean Model Domain
108°W
96°W
84°W
72°W
60°W
48°W
42°N
36°N
30°N
24°N
18°N
Surface Elevation
46°N
45°N
44°N
43°N
42°N
41°N
Temperature
70°W
68°W
66°W
64°W
62°W
93°W
92°W
91°W
90°W
89°W
88°W
87°W
86°W
31°N
30°N
29°N
28°N
Salinity
1000
2000
Current
(cm/s)
200
100
0
75 W
74 30'W
74 W

Atlantic Ocean Forecast System

Horizontal grid: **orthogonal, dx/dy~1**

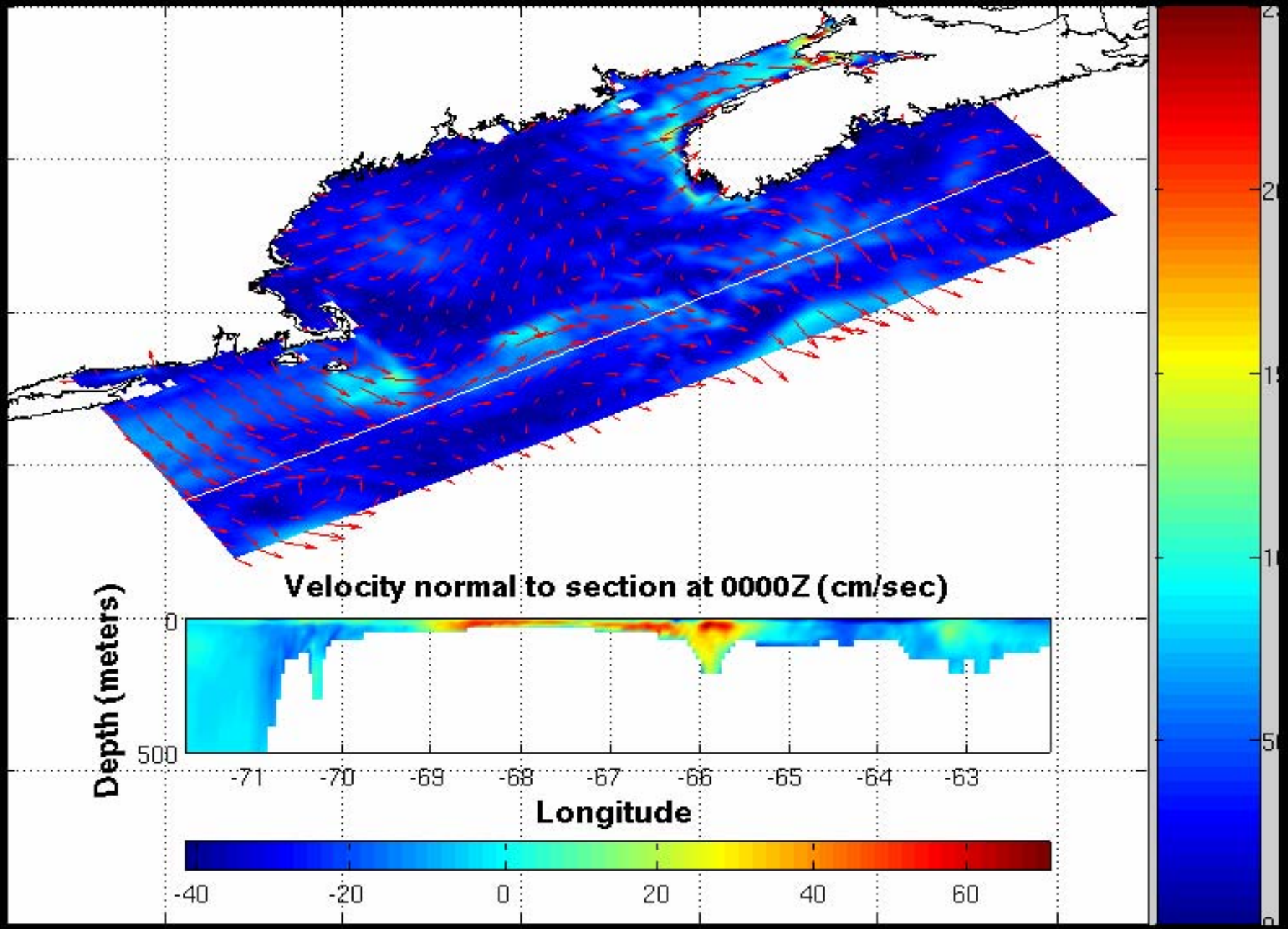
Bathymetry: **ETOPO2 (NGDC)**

Coastal boundary: **blend of bathymetry and coastline datasets (NGDC).**

Surface forcing: **GDAS/GFS (NCEP) 3hourly**

River outflow/runoff: **blend of observations (US rivers USGS) and climatology (RIVDIS)**

Open boundaries: **T,S from climatology, SSH and barotropic velocity from tidal model (TPX06) and climatology.**

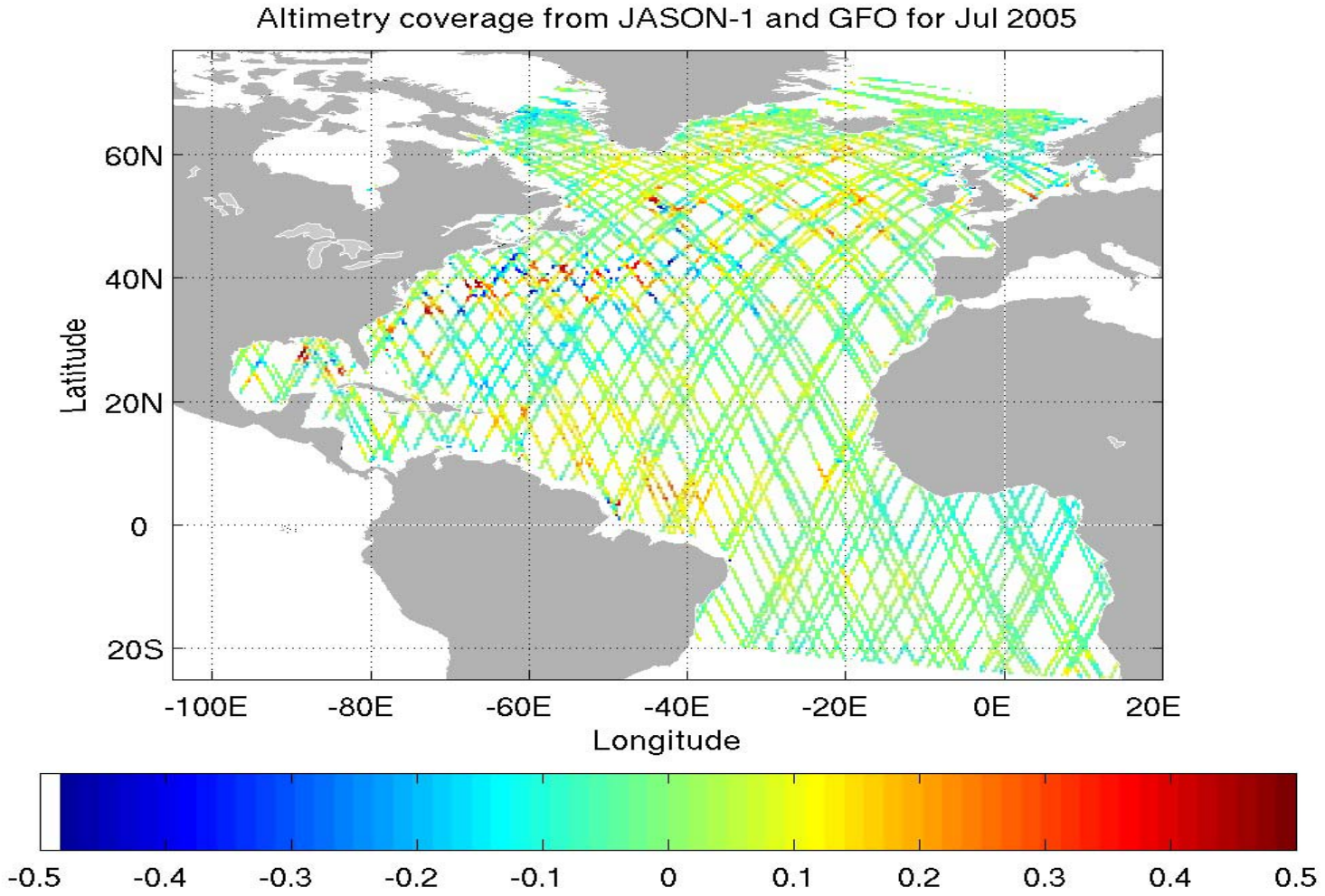

Velocity normal to section at 0000Z (cm/sec)
Depth (meters)
0
500
-71
-70
-69
-68
-67
-66
-65
-64
-63
Longitude
-40
-20
0
20
40
60

Atlantic Ocean Forecast System

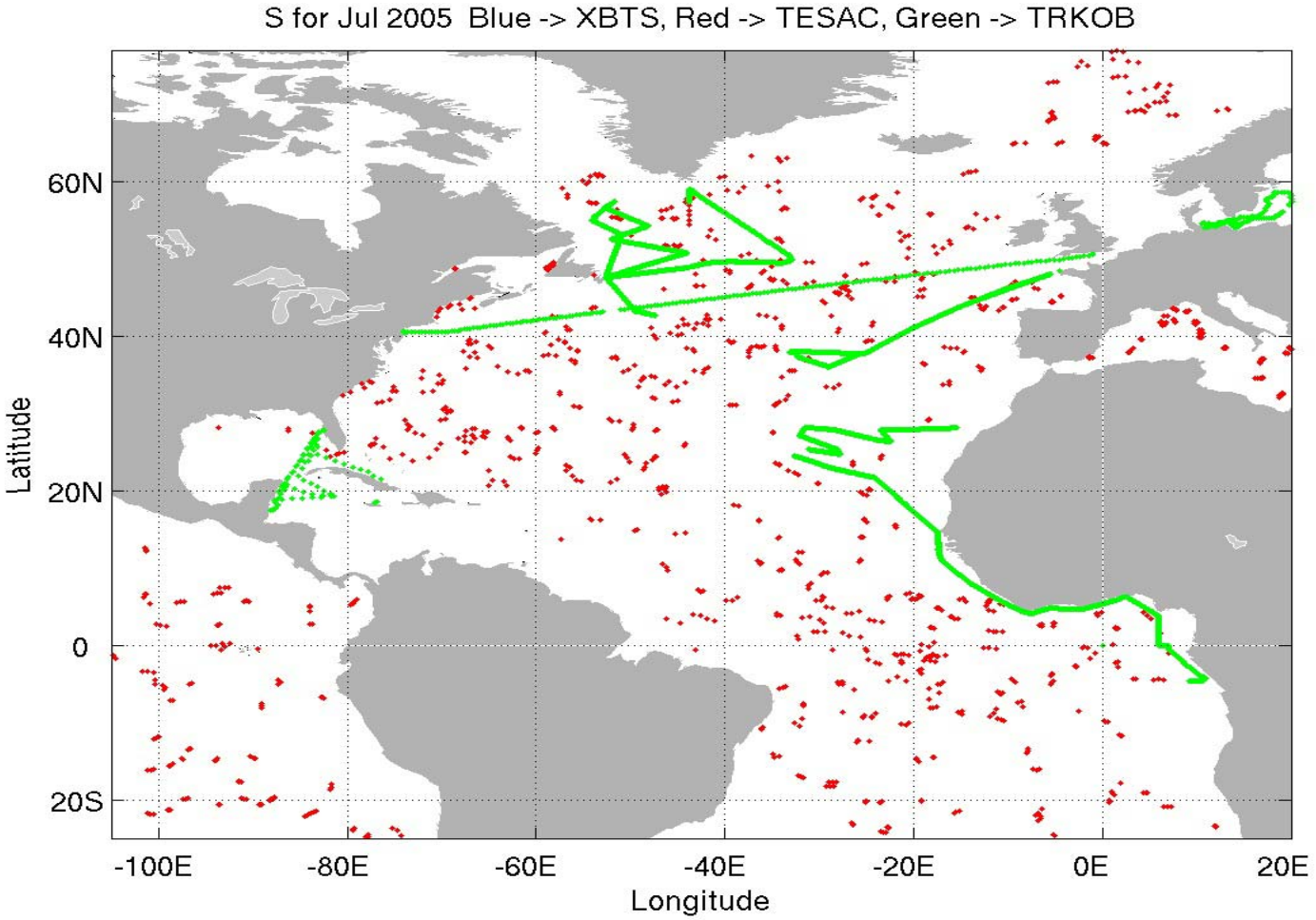
Data used: **SST (AVHRR, GOES),**
SSH (Jason, GFO, Envisat),
S,T (ARGO, CTD, XBT, buoys,..),
Currents (buoys,..),
Drifters (Buoys, ARGO),
Sea surface elevations (Tide gauges),
US rivers discharge (USGS).

Sources: **GTS and for SSH NAVOCEANO.**

SSHA available in realtime



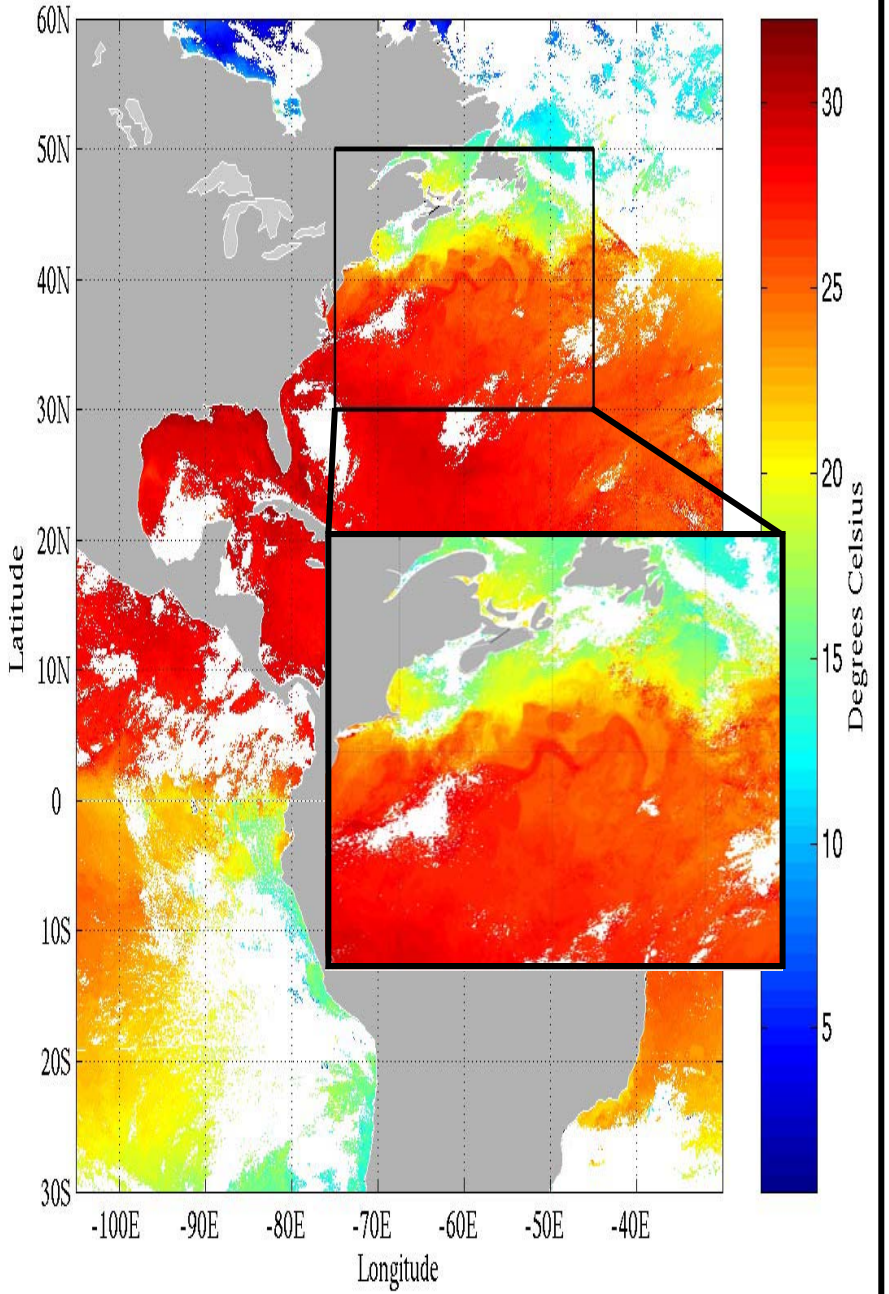
Salinity Observations available in realtime

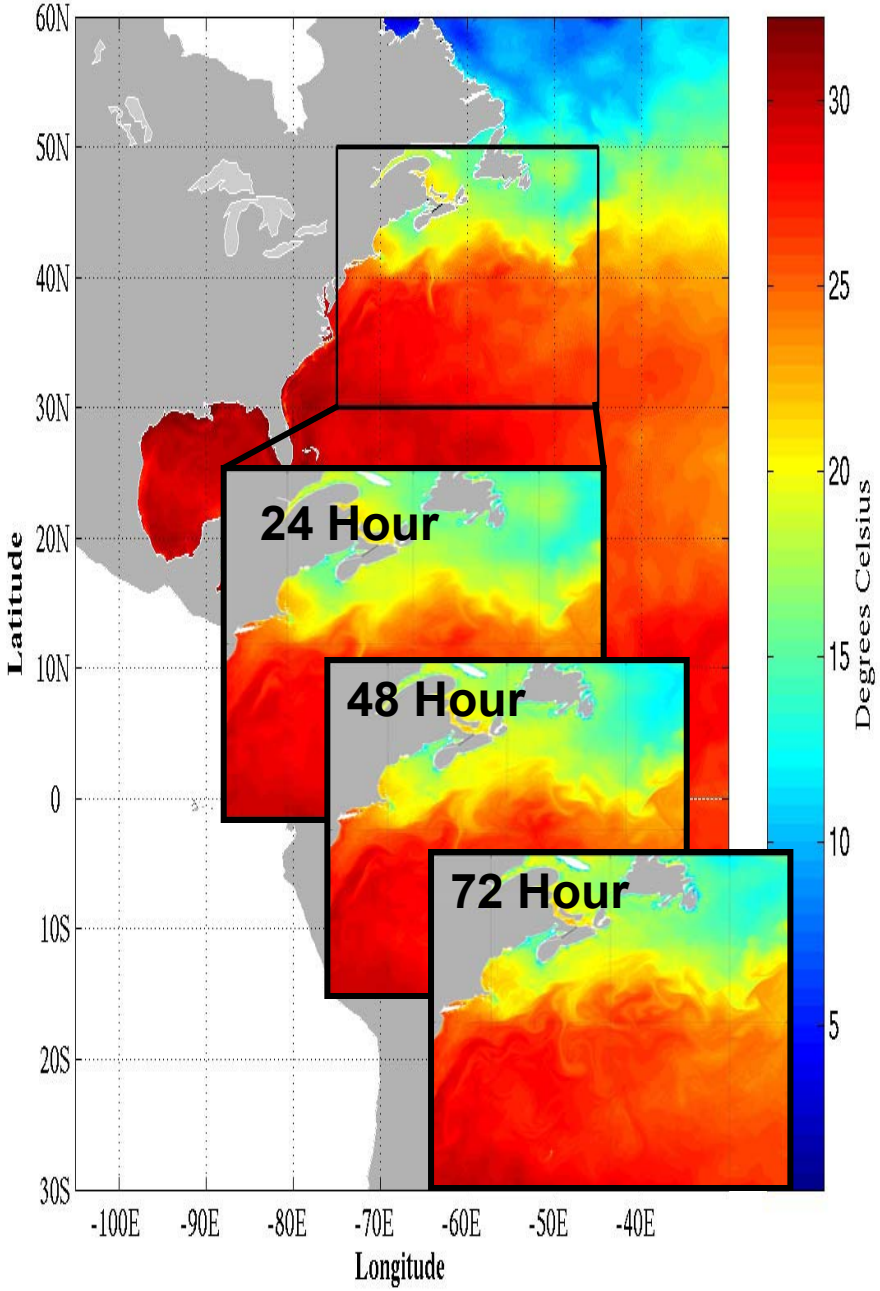


Data Assimilation

- Data: SST
  - AVHRR
  - GOES
  - In-situ

- Assimilation: Linear interpolated (2DVar) analysis values are nudged during nowcast in the mixed layer.

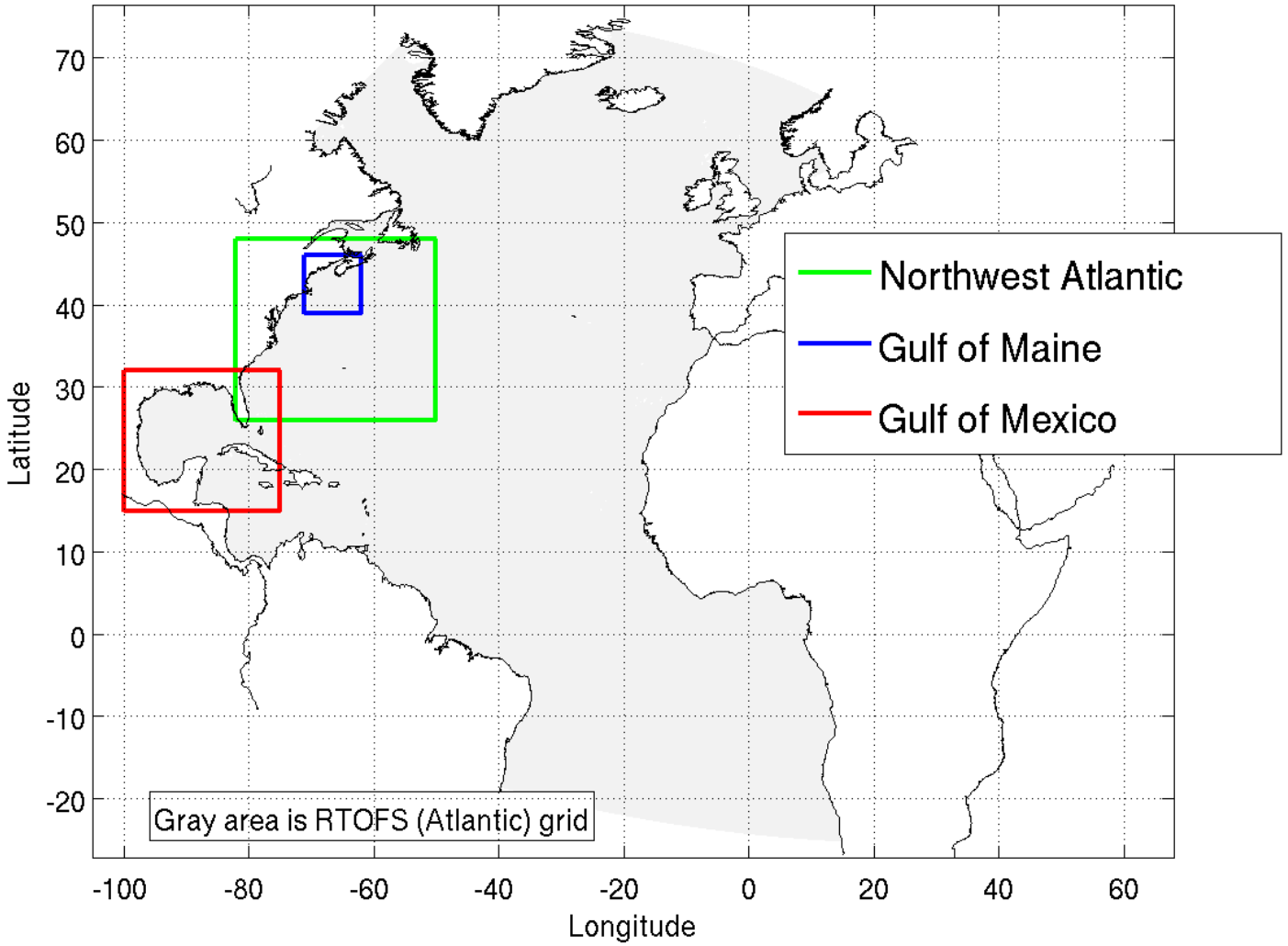

GOES SST Daily Composite July 23, 2005 (6 km resolution)
60N
50N
40N
30N
20N
10N
0
10S
20S
30S
Latitude
-100E
-90E
-80E
-70E
-60E
-50E
-40E
Longitude
30
25
20
15
10
5
Degrees Celsius


HYCOM SST 1/12 deg 24 hr Forecast Valid July 23, 2005 (~7 km resolution)
60N
50N
40N
30N
20N
10N
0
10S
20S
30S
Latitude
-100E
-90E
-80E
-70E
-60E
-50E
-40E
Longitude
30
25
20
15
10
5
Degrees Celsius
24 Hour
48 Hour
72 Hour

Daily Operations and Product Distribution

- Once daily (4Z)
  - Nowcast 1day
  - Forecast 5 days
- Grib files for nowcast and forecast
  - Hourly surface T,S,U,V, SSH, barotropic velocity, mixed layer depth
  - Daily T,S,U,V,W, SSH
- Product distribution
  - NCO servers (ftp) [December 14 2005]
  - NOMADS [sub-setting] (full data server functions)
  - MMAB Web server (ftp, graphics)

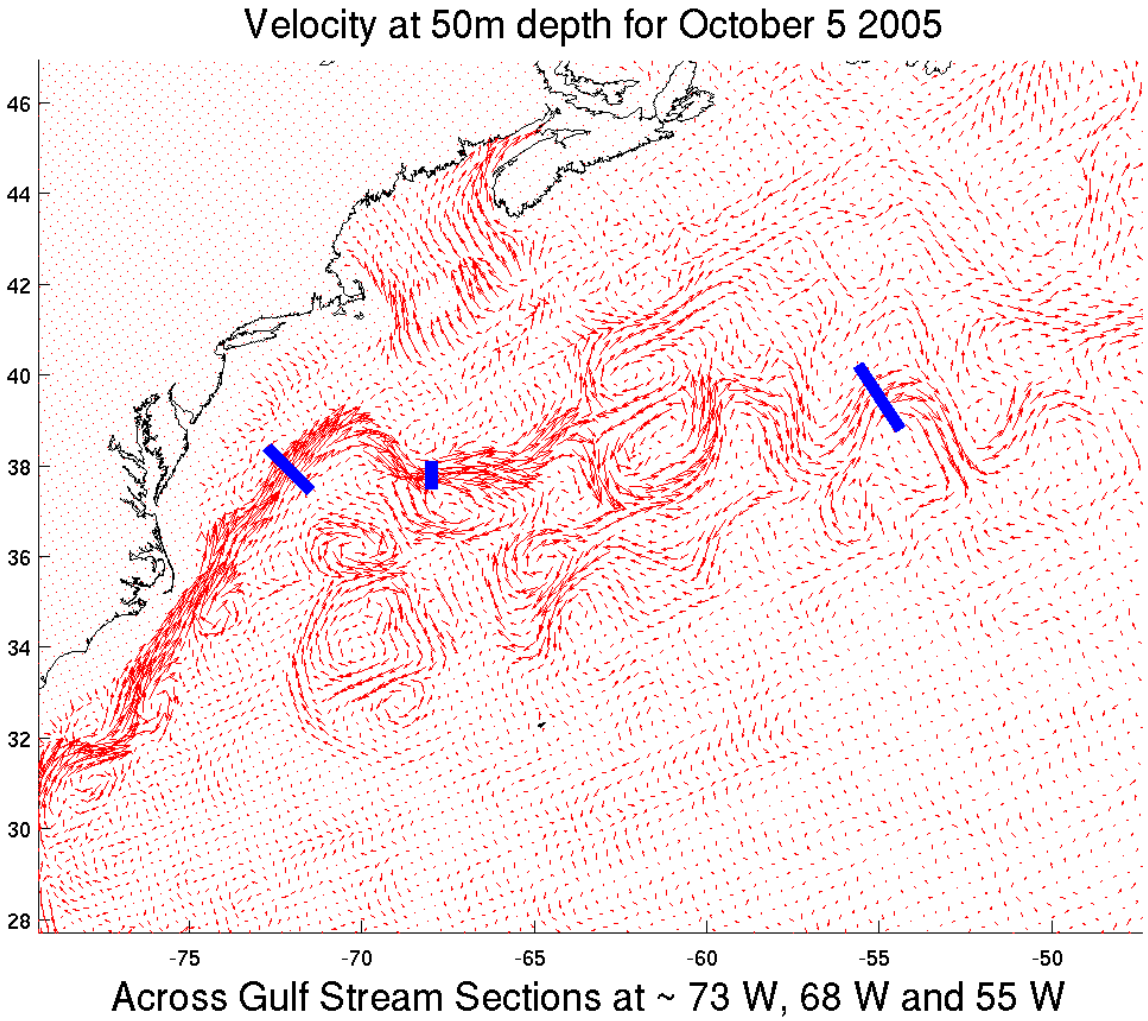
Evaluation of RT-OFS in selected regions



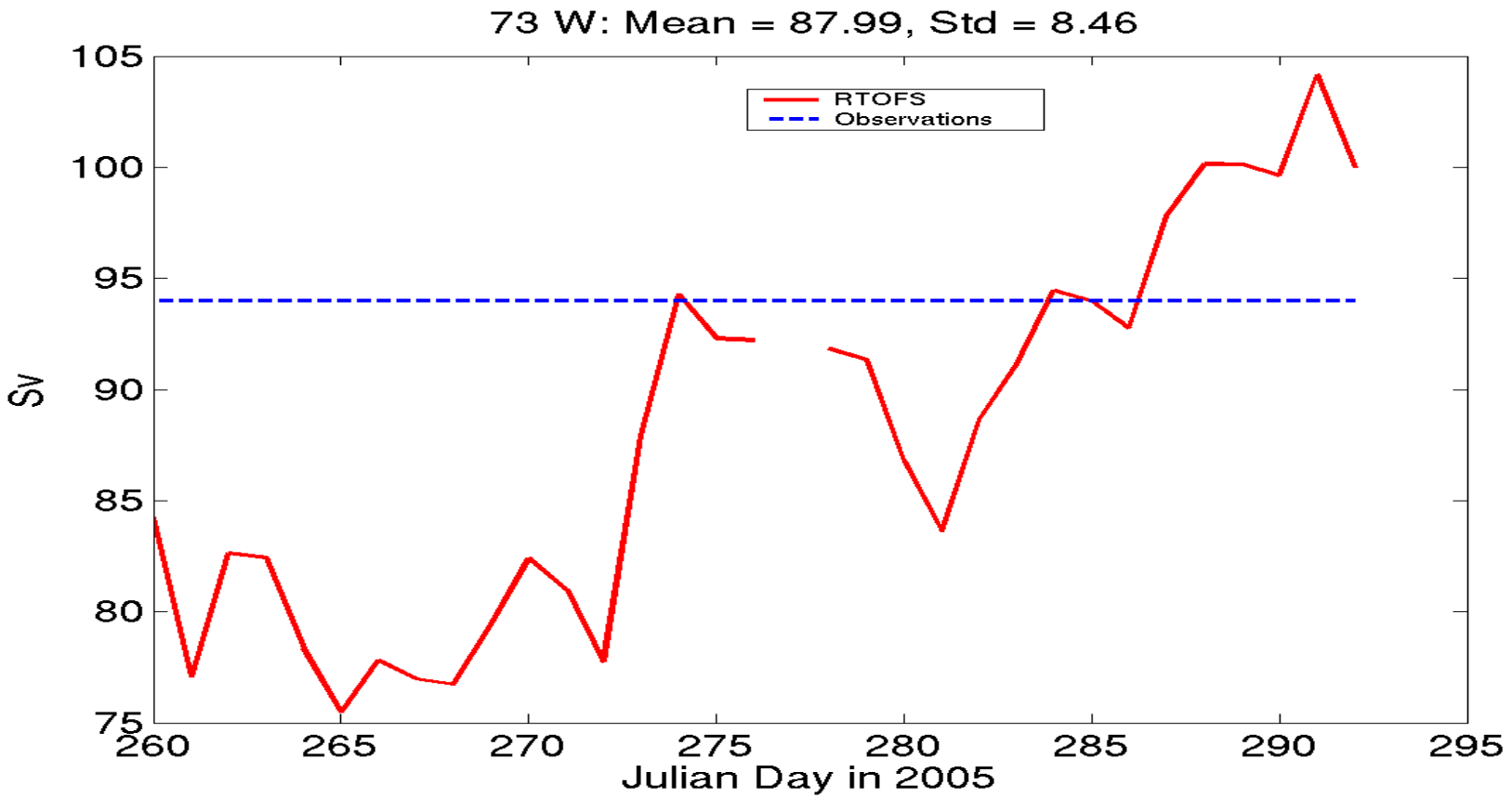
Comparisons of Nowcast and Forecasts with Data

- Data includes time-space collocated data, historical data and climatology
- How well does the model represent the state of the ocean in the nowcast?
- How well do the forecasts perform?
- To compare, we use:
  - Sea surface temperature: Satellite.
  - Subsurface temperature and salinity: CTD.
  - Water level: Tide gauges.

Comparison of cross Gulf Stream section transports at 73 W, 68 W and 55 W with historical data

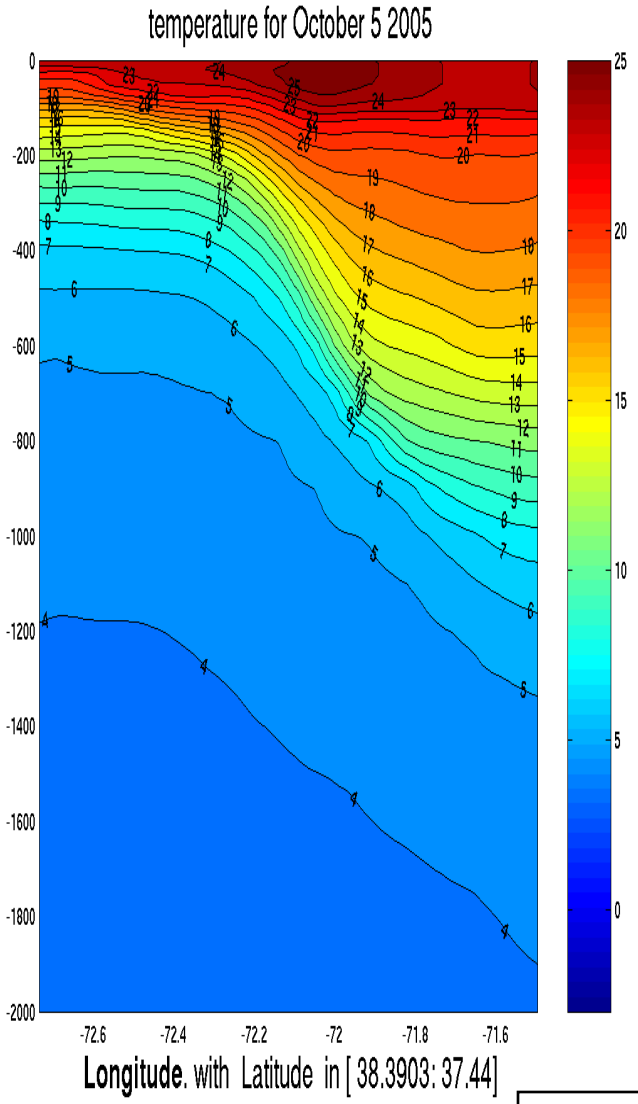


Gulf Stream Transport at 73 W in "cross-stream" coordinates



Observed Mean ~ 94 Sv (Leaman et al., JPO, 1989)

Transect at 73 W



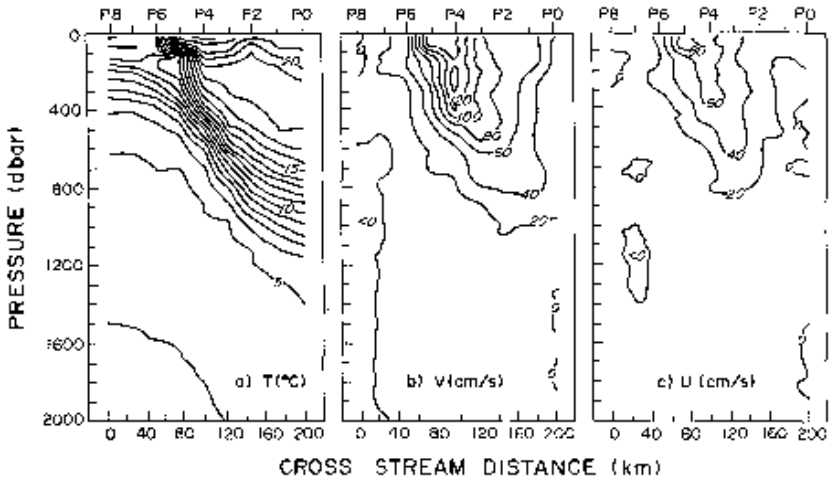
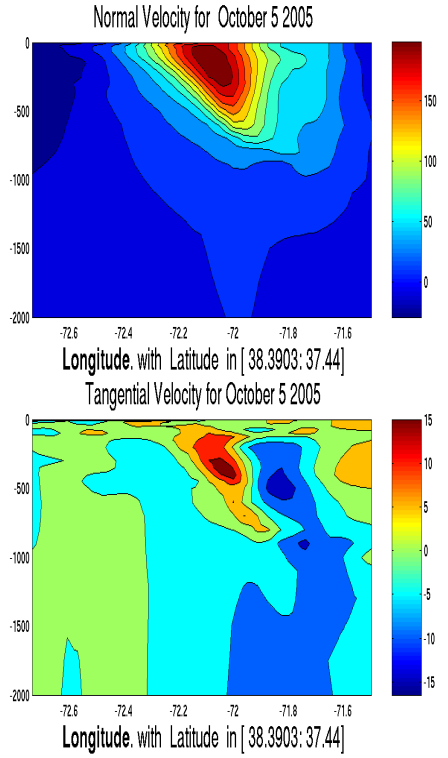


FIG. 4. Sections of temperature and velocity in the transect coordinate system for March 1982: (a) temperature; (b) the component of velocity perpendicular to the transect; (c) the component parallel to the transect (positive values indicate flow in the direction 141°T).

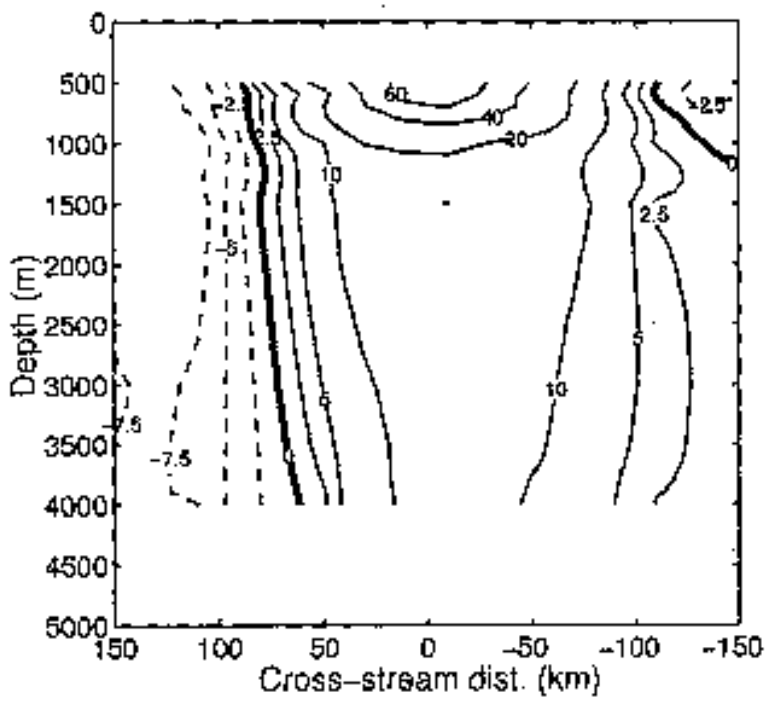
Halkin and Rossby, JPO 1987

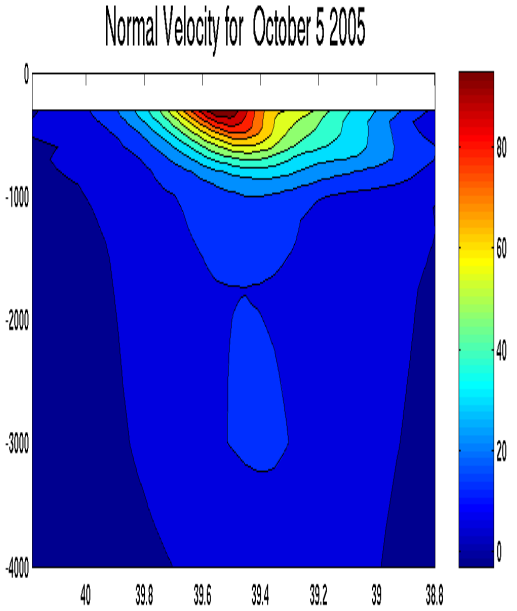


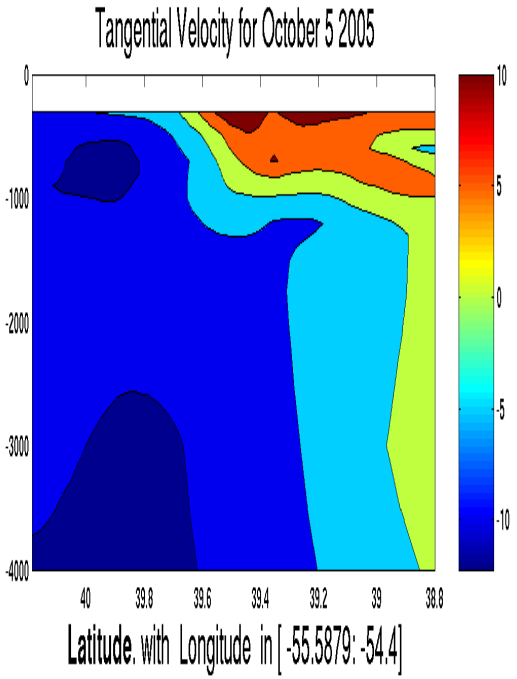
RT-OFS (Atlantic)

Transect at 55 W

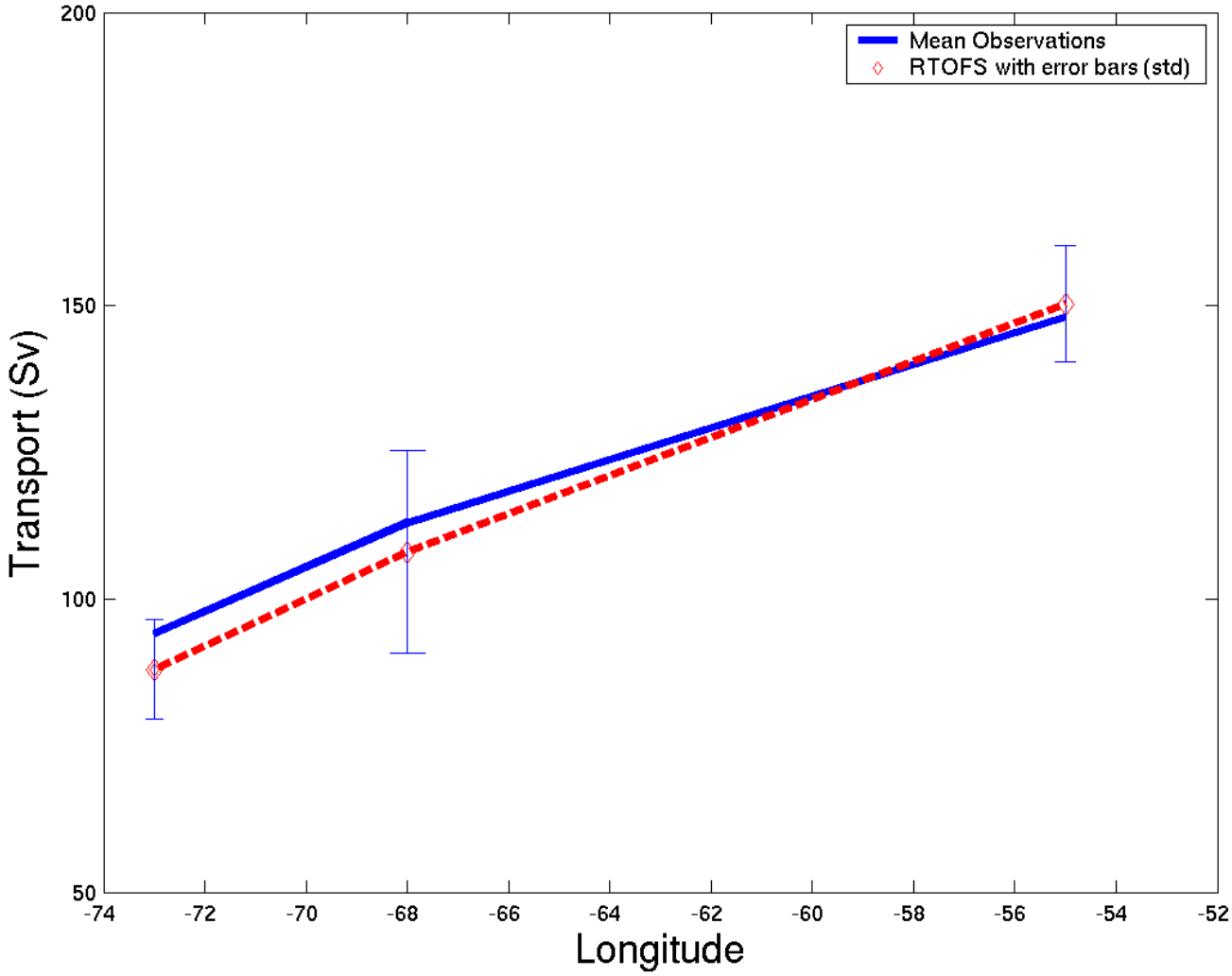
Bower and Hogg, JPO 1996







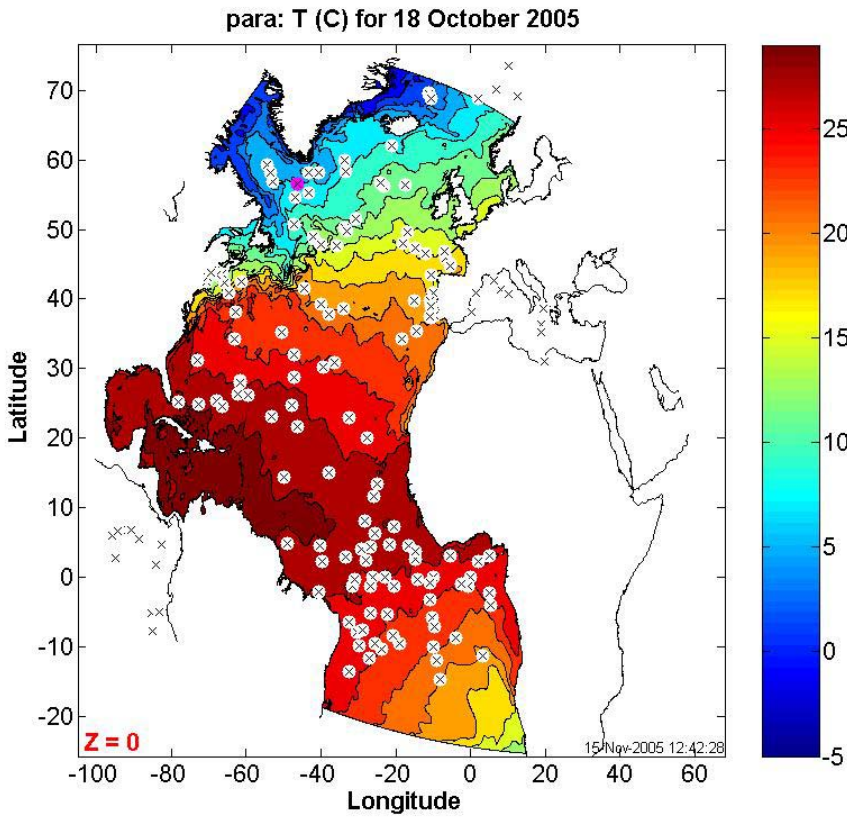
Gulf Stream Transport

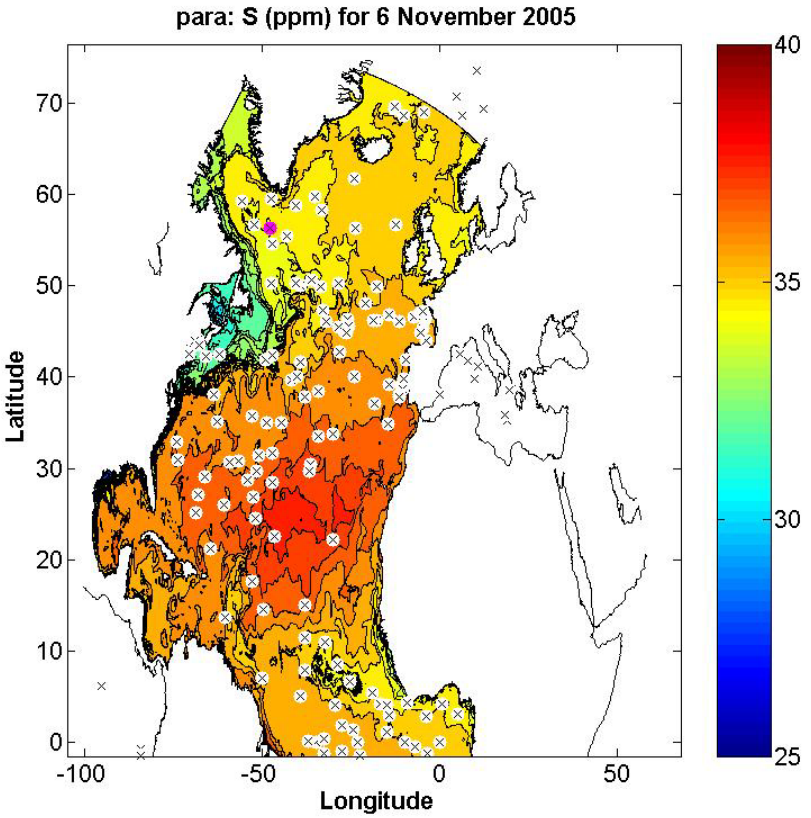


Subsurface Temperature and Salinity

Model vs. in-situ locations

- Observations are within a 3 day window of

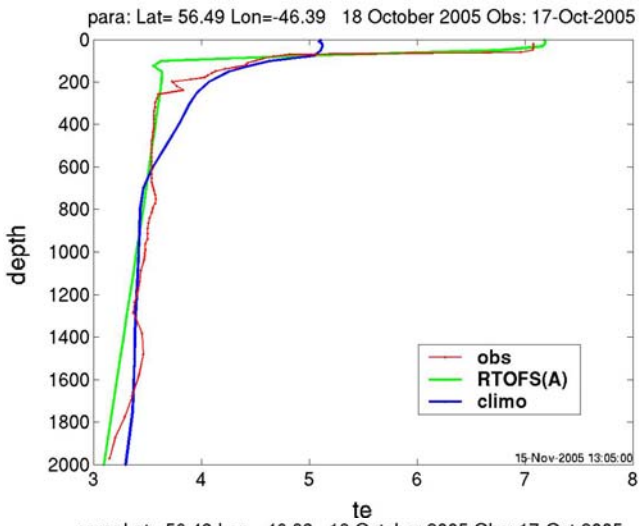


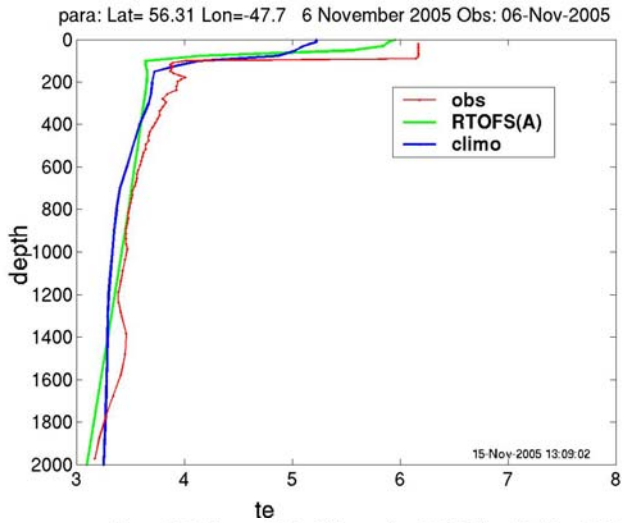


NW Atlantic : model, climate, observation

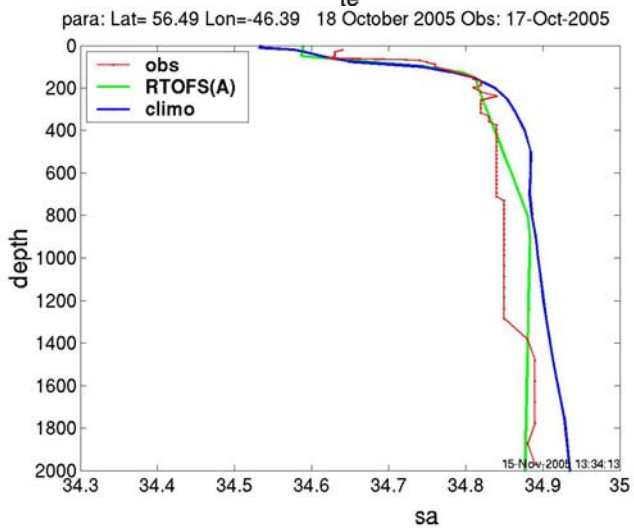
Oct.18, 2005 | **Nov. 6, 2005**

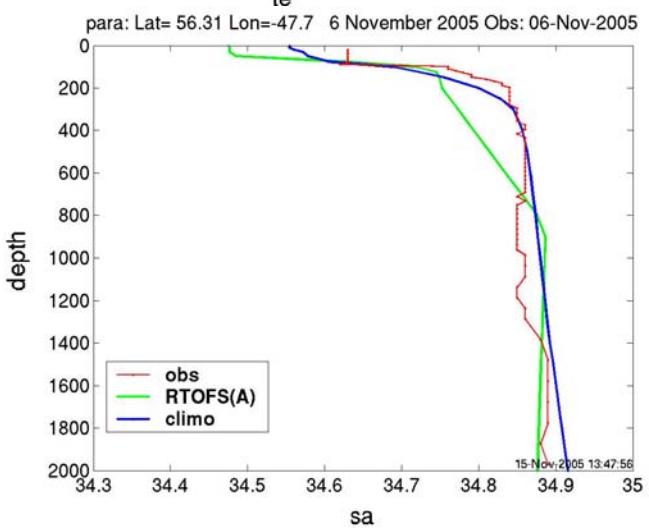
Temperature



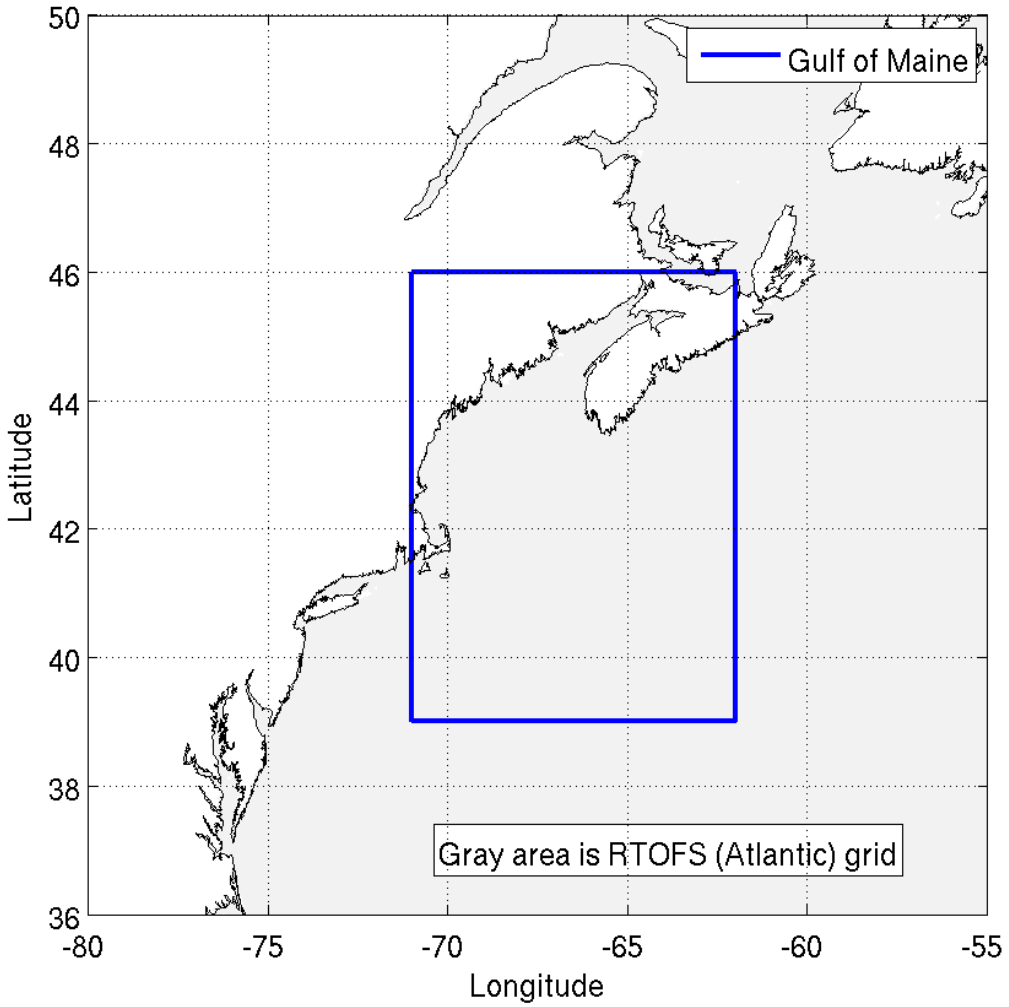


Salinity



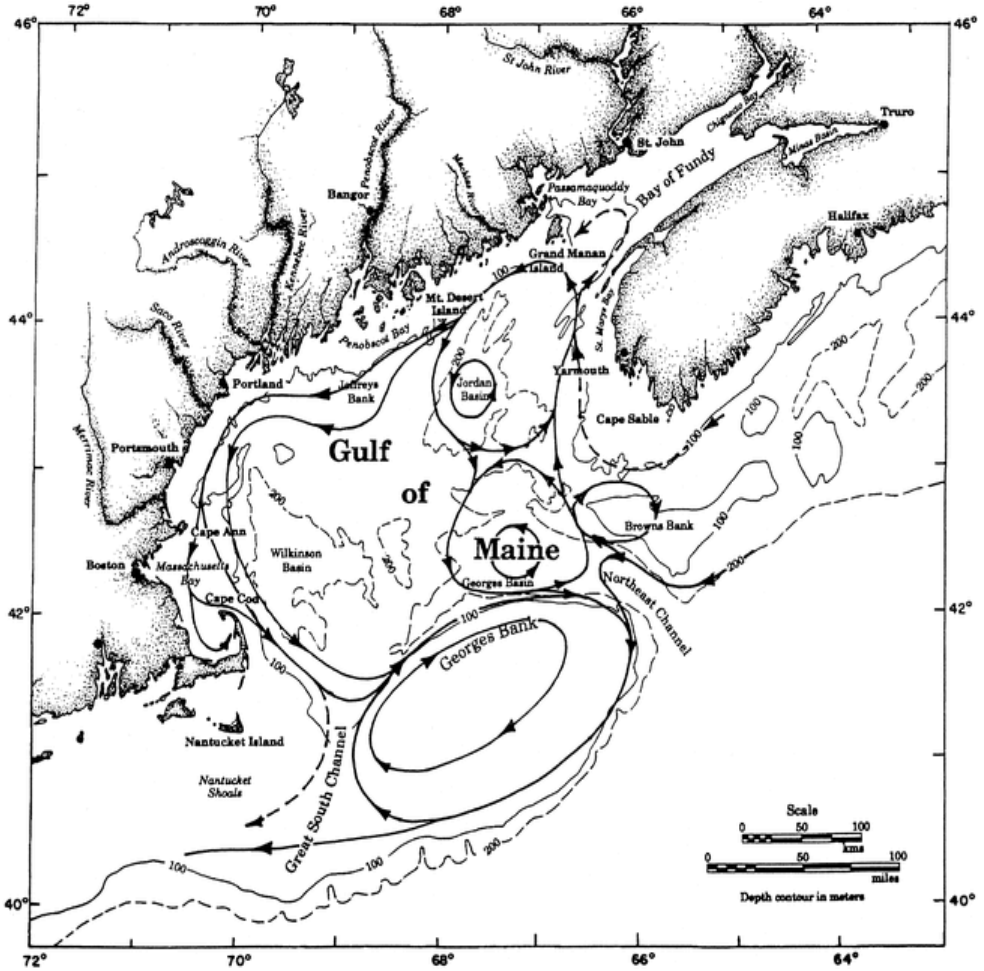


Gulf of Maine



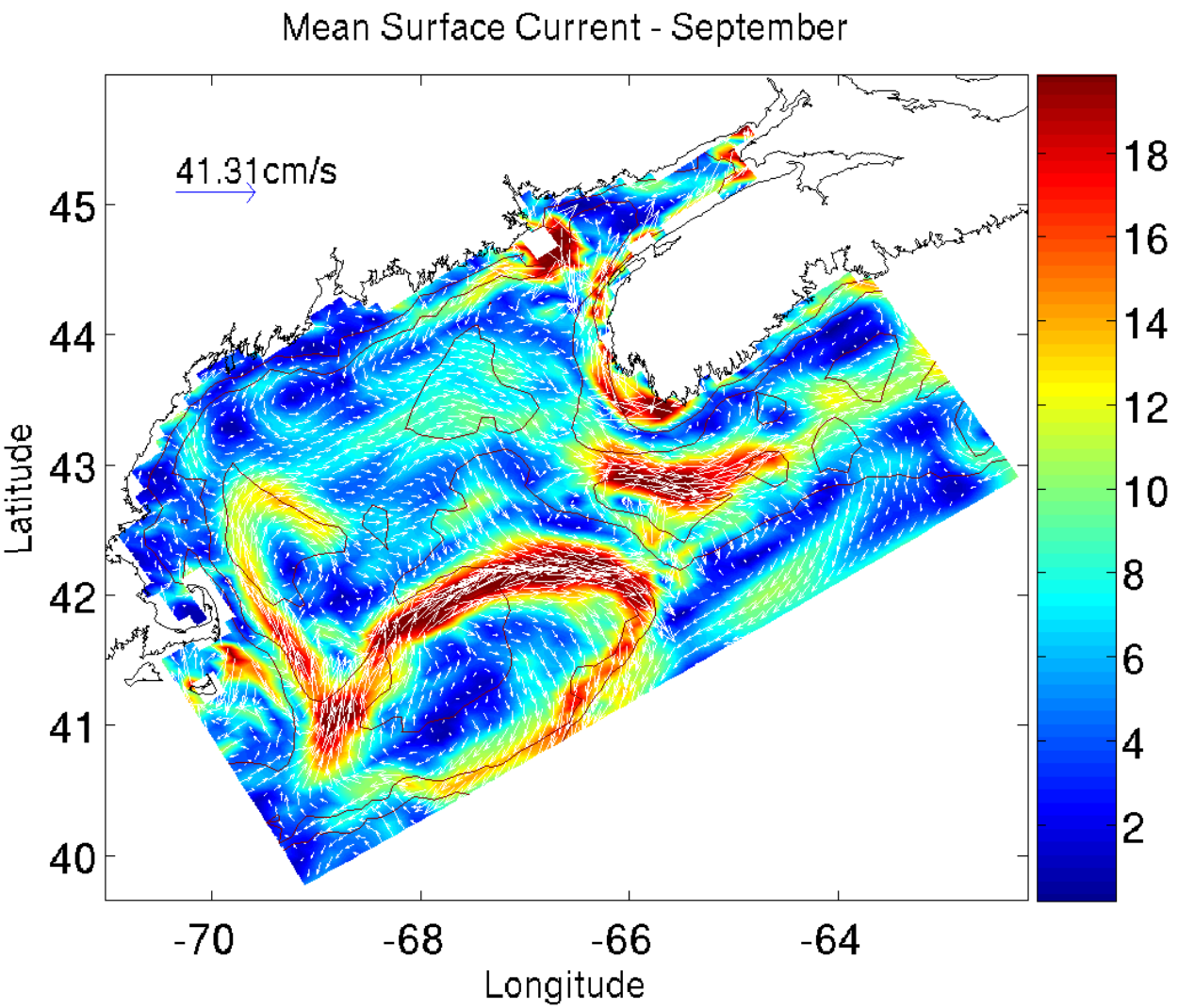
- Subsurface temperature and salinity.
- Surface salinity.
- Surface currents.
- Freshwater transport.
- Water levels.

Gulf of Maine Surface Circulation



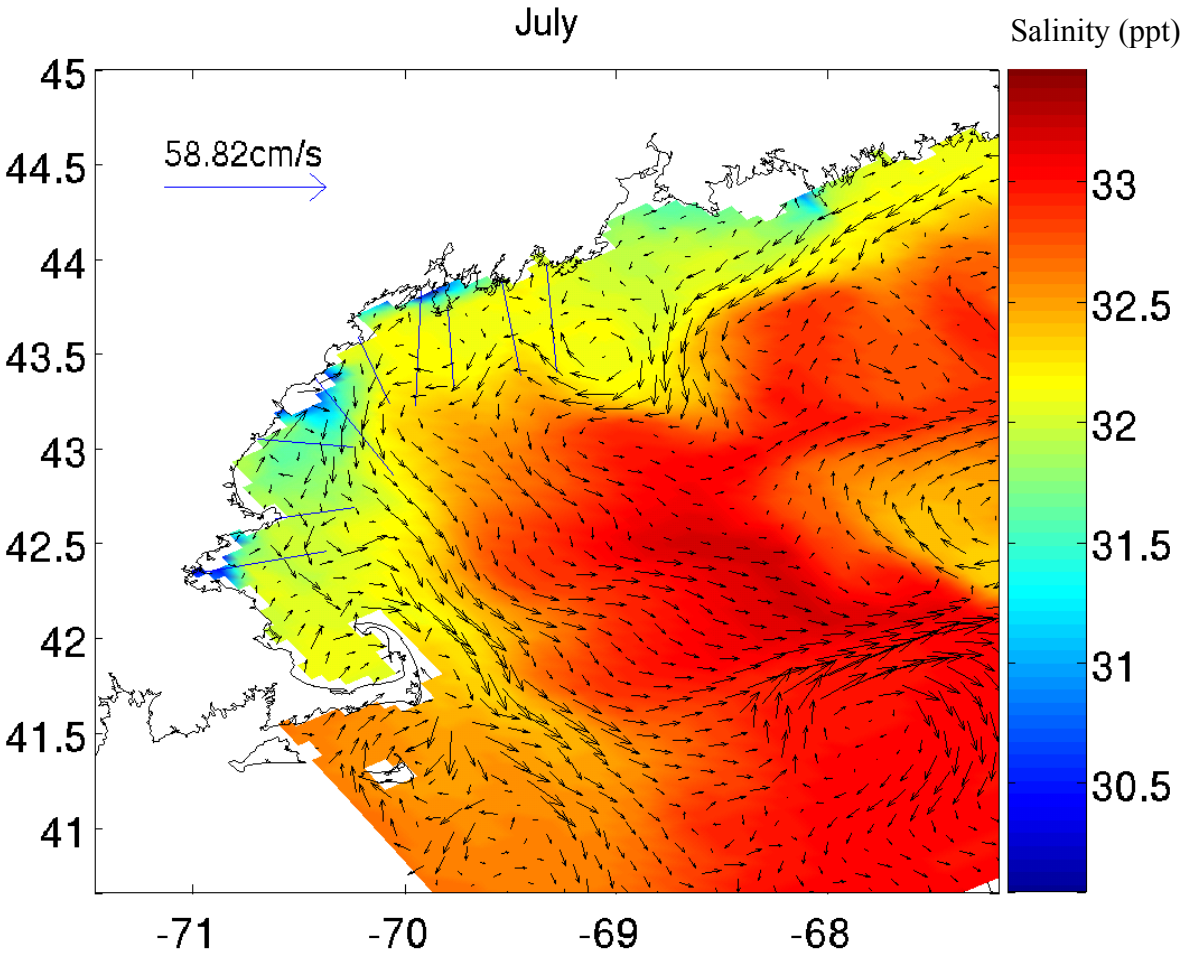
Xue, H., F. Chai, and N.R. Pettigrew (JPO 2000)

Mean Surface Current for September



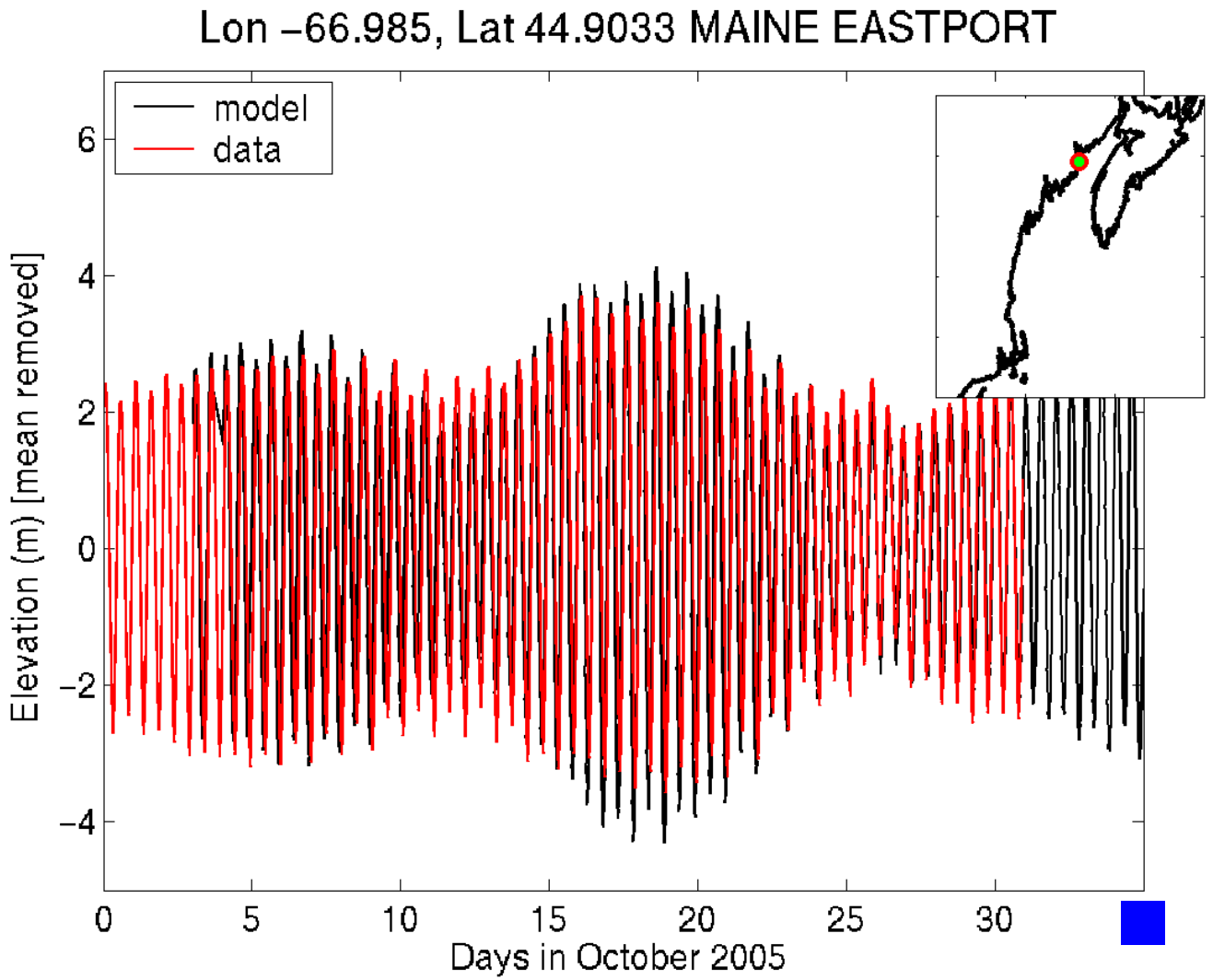
Freshwater Transport for July

Freshwater mean:
Data: 1338.9 m^3/s
RTOFS: 1149.1 m^3/s

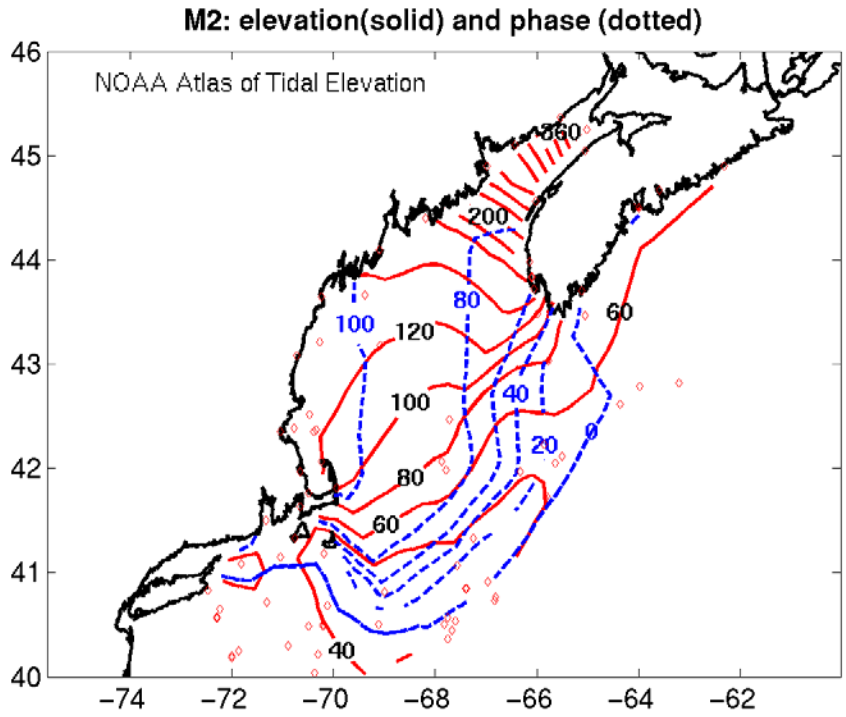


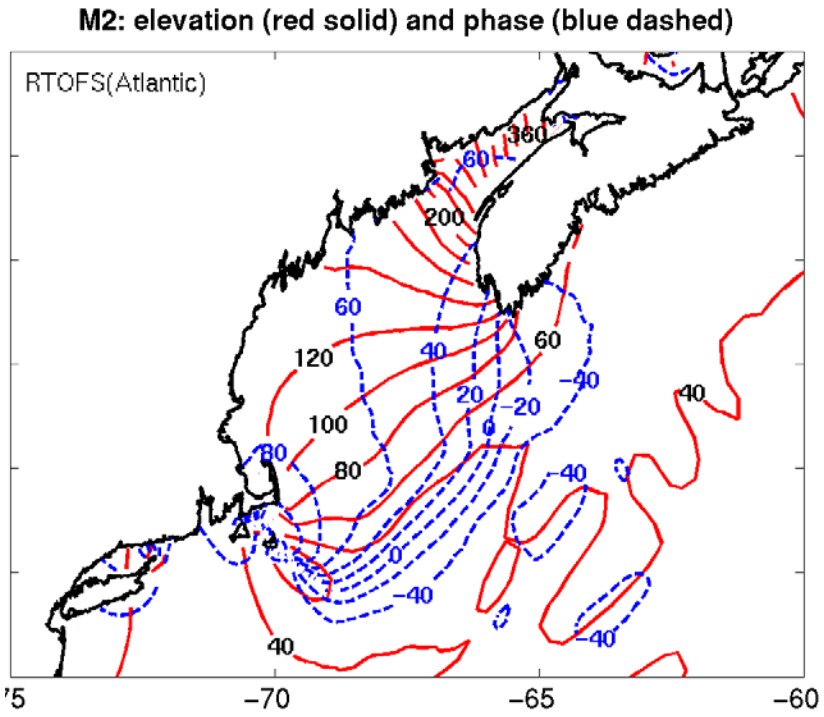
Data from Geyer et al., *Continental Shelf Research*, 2004.

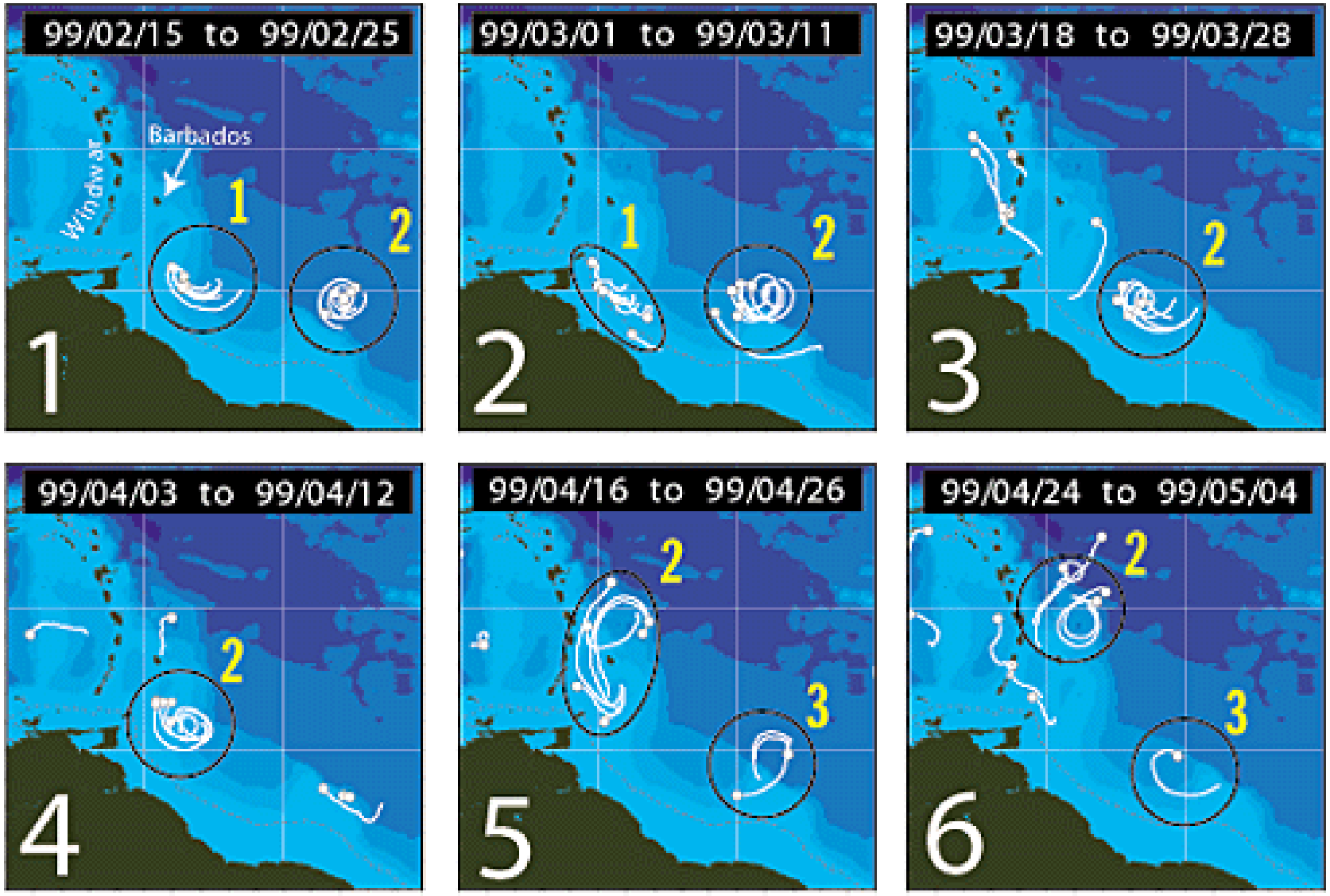
Water Levels in the Gulf of Maine

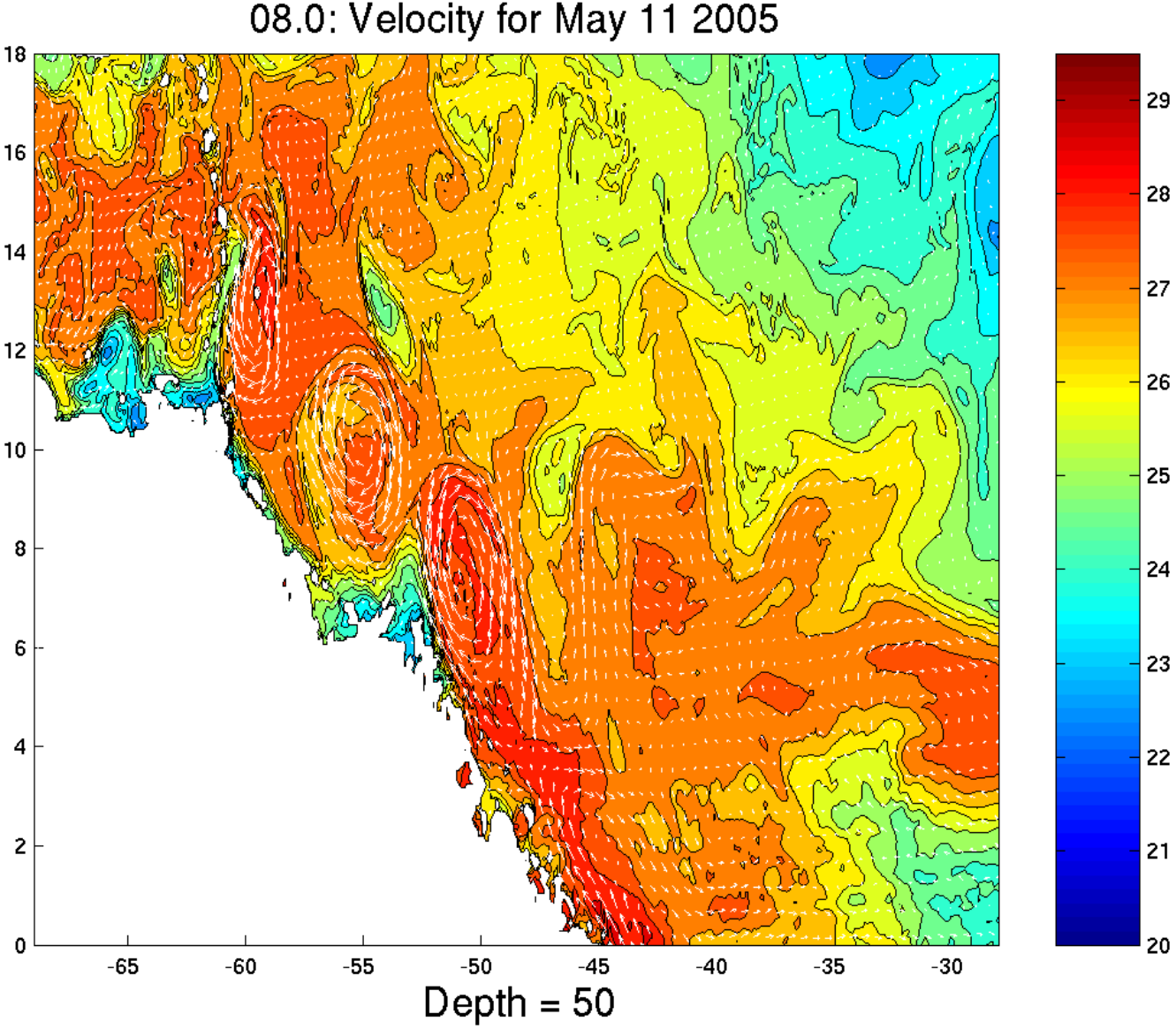


M2 Tidal Component in the Gulf of Maine



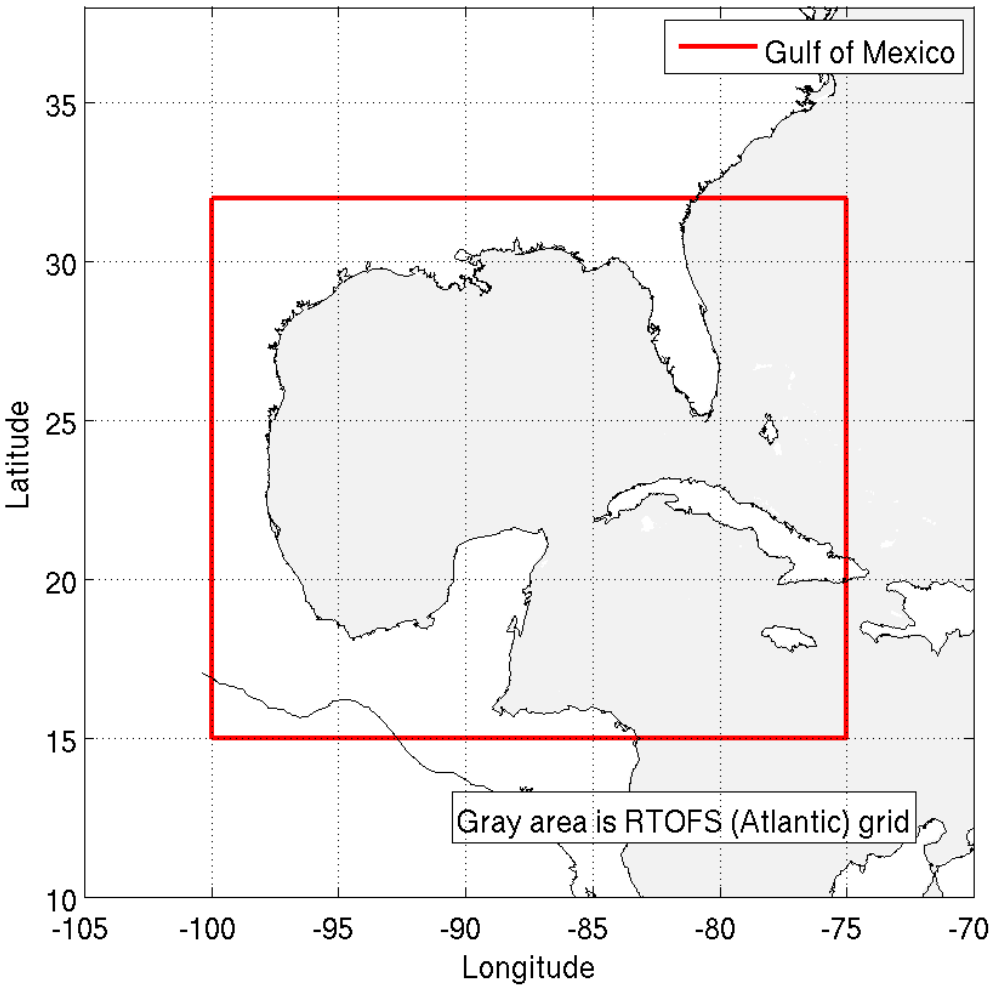



99/02/15 to 99/02/25
Barbados
Windward
1
2
1
99/03/01 to 99/03/11
1
2
2
99/03/18 to 99/03/28
2
3
99/04/03 to 99/04/12
2
4
99/04/16 to 99/04/26
2
3
5
99/04/24 to 99/05/04
2
3
6



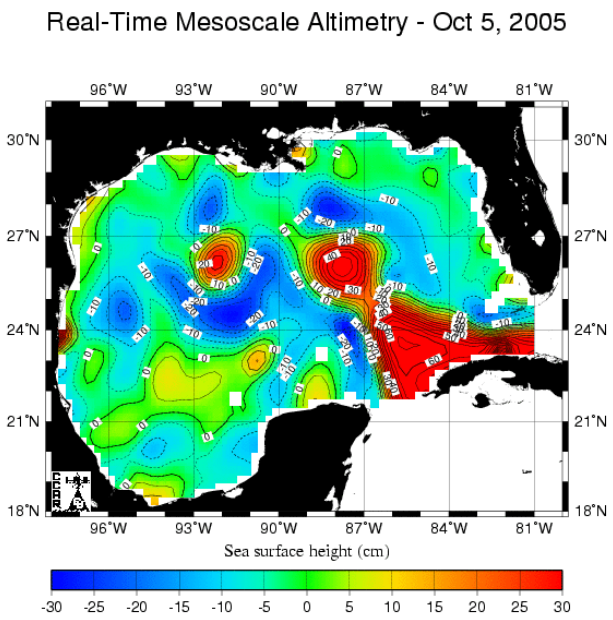
Nowcast Velocity field at 50 m depth superposed on the Temperature field from May 11 – June 13

Gulf of Mexico

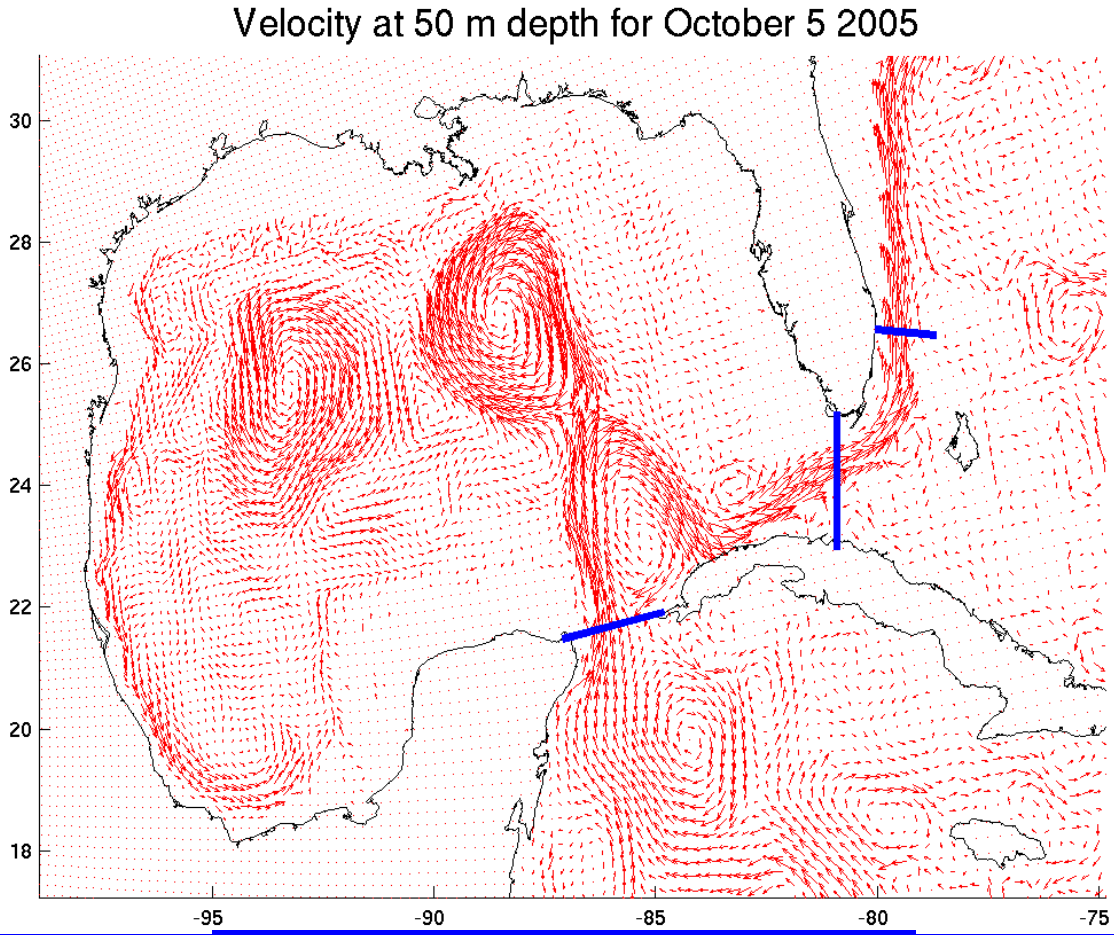


- Transports:
  - Yucatan Channel.
  - Florida Current.
- Water levels.
- Hurricane events:
  - Surface currents.
  - Sea surface temperature.
  - Sea surface height.
  - Mixed-layer depth.
  - Tide surge.

Comparison of Loop Current and Florida Current transports with historical data

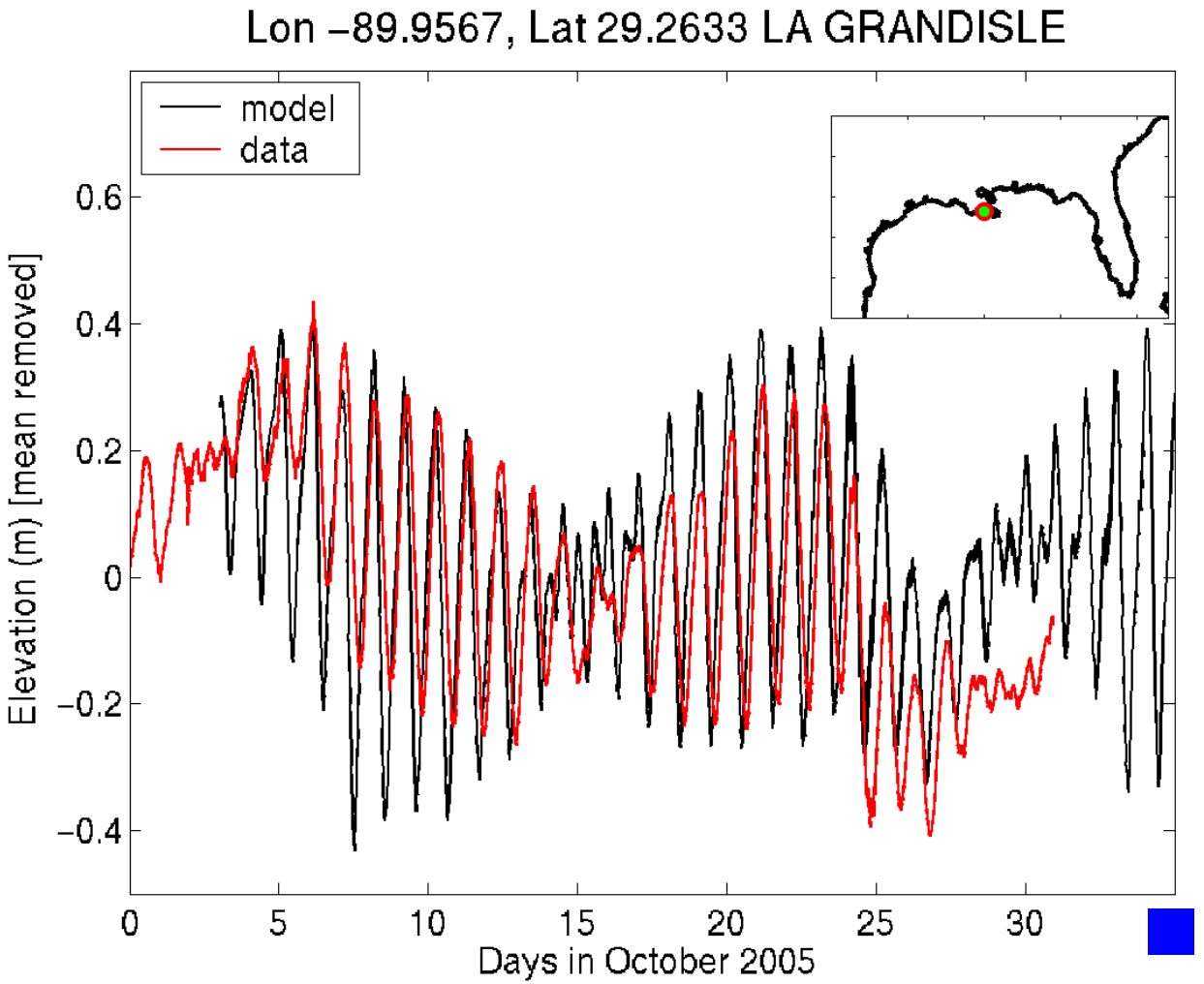


http://argo.colorado.edu



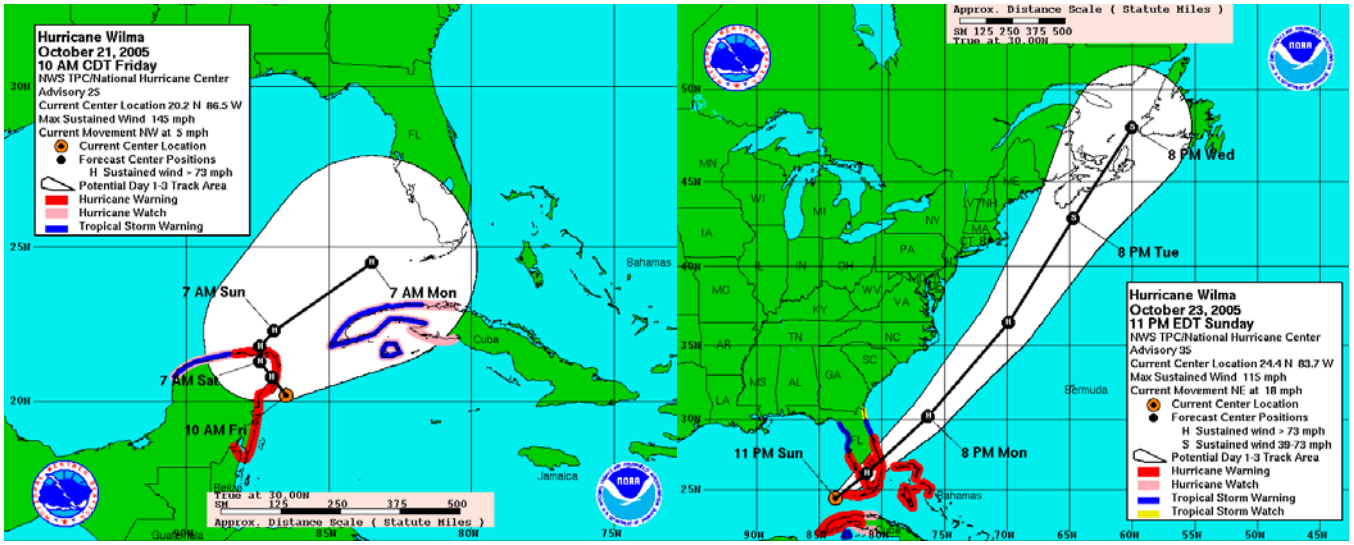
Location of Loop Current and Florida Current Sections

Tides in the Gulf of Mexico

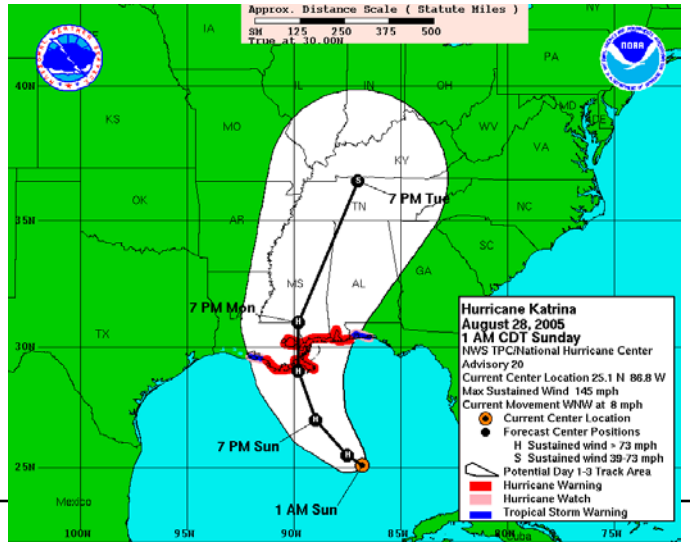


Hurricanes in the Gulf of Mexico

Hurricane Wilma
October 21 - 24

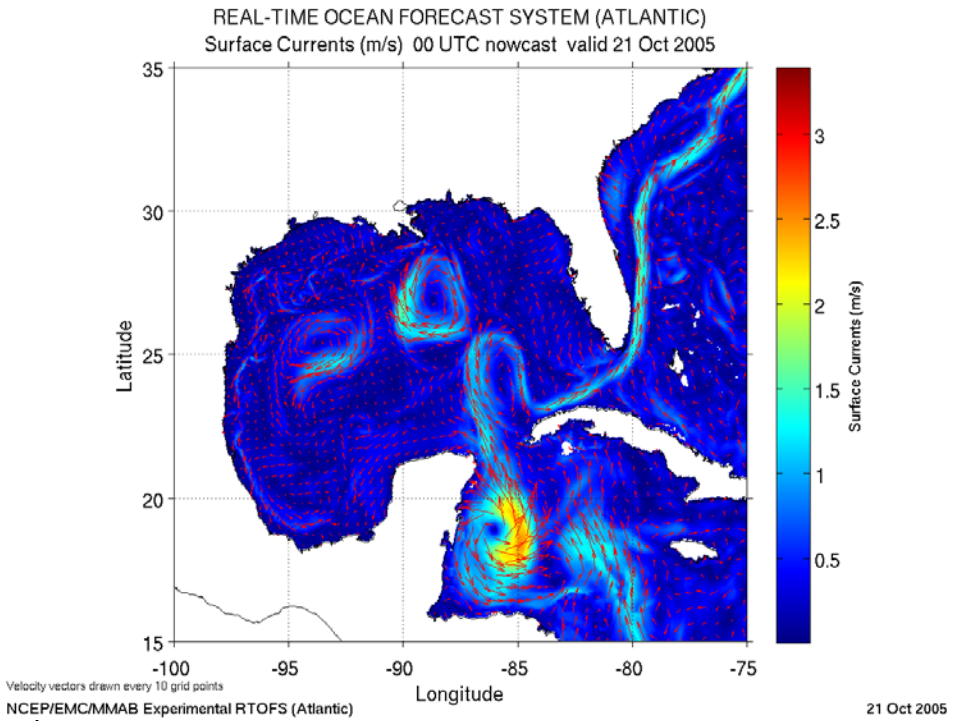


Hurricane Katrina
August 28 - 29

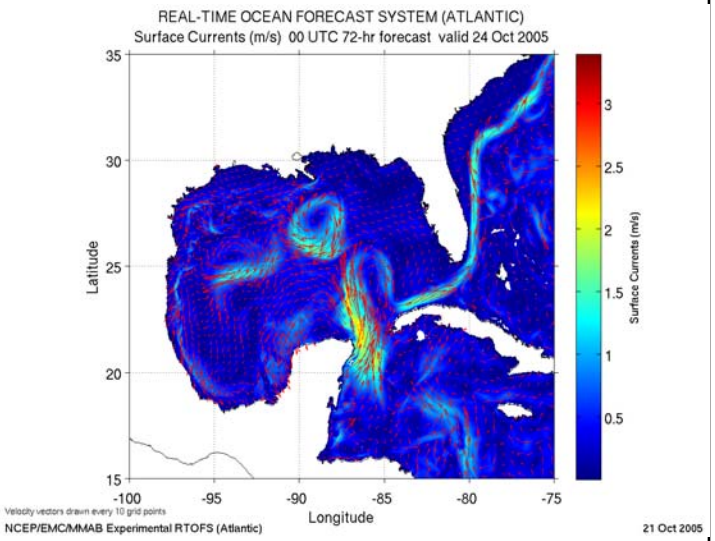


Surface Currents During Hurricane Wilma

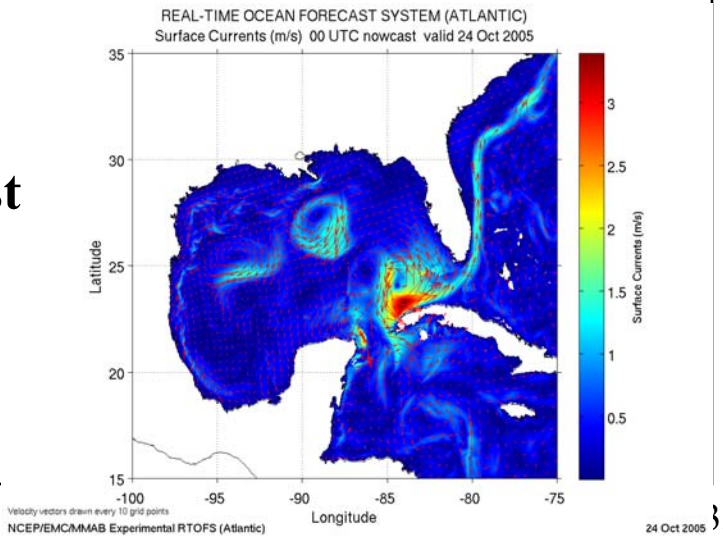
Nowcast valid Oct 21



72-hr forecast valid Oct 24

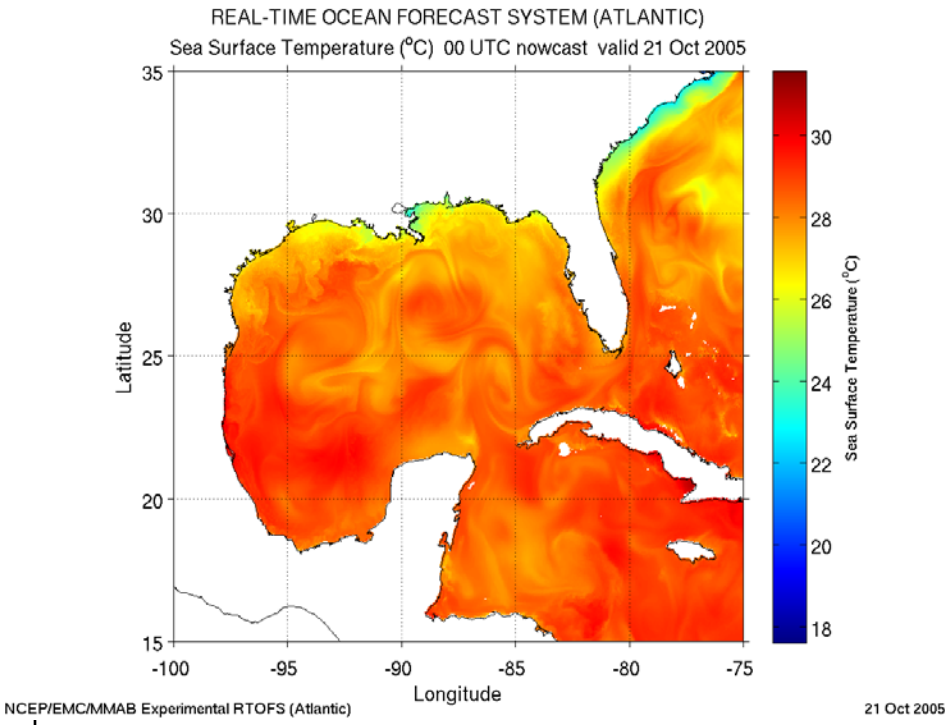


Nowcast valid Oct 24

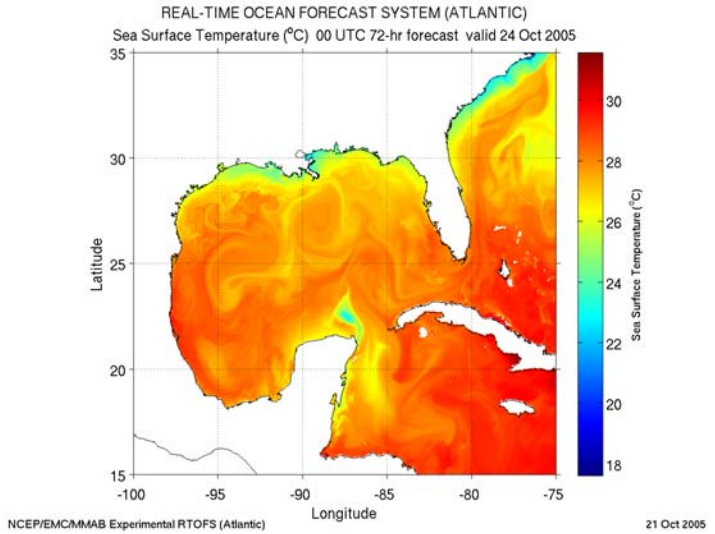


SST During Hurricane Wilma

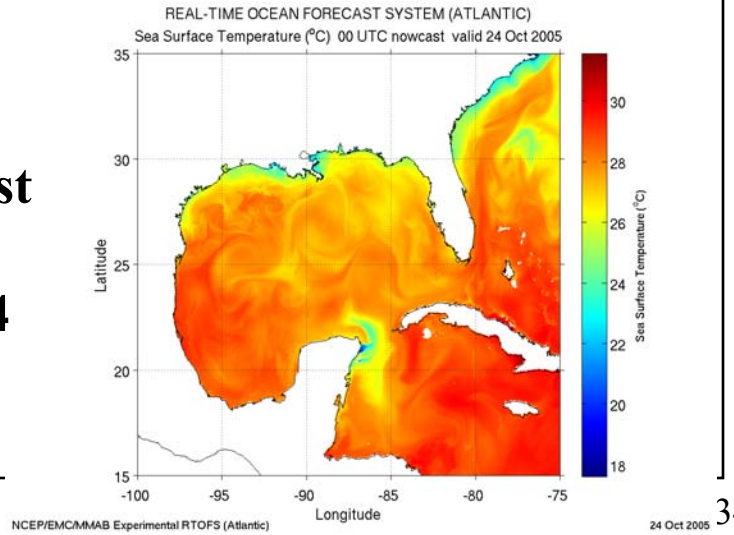
Nowcast valid Oct 21



72-hr forecast valid Oct 24

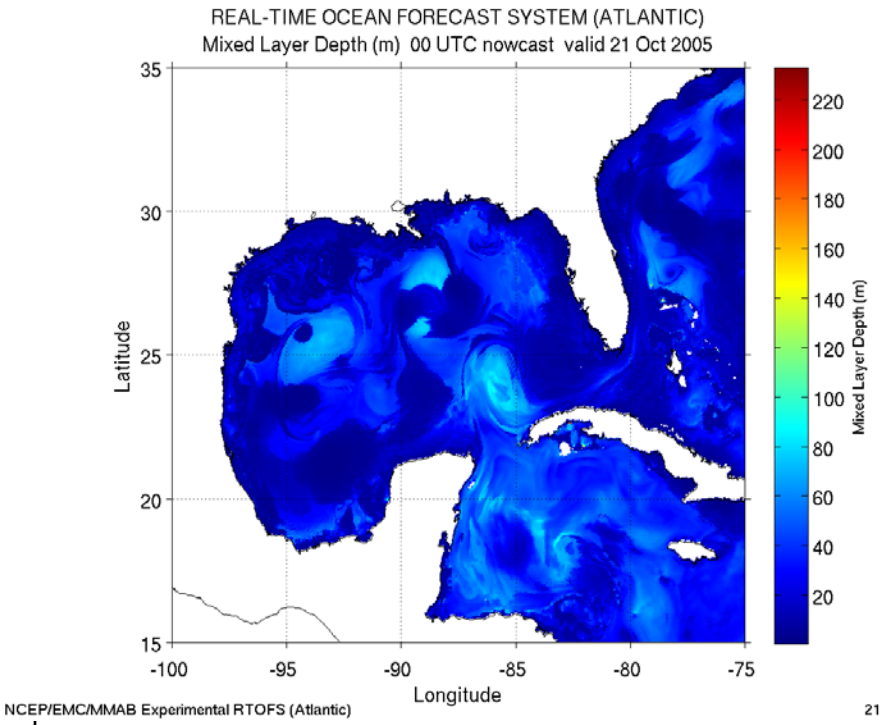


Nowcast valid Oct 24

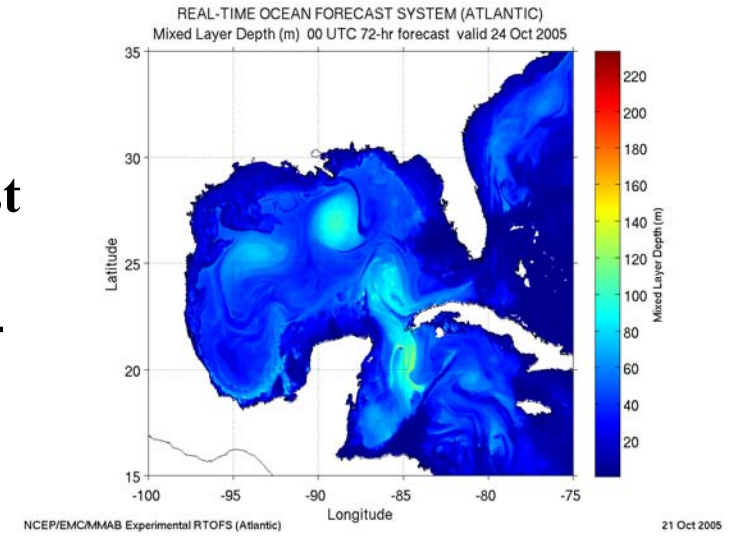


Mixed-Layer Depth During Hurricane Wilma

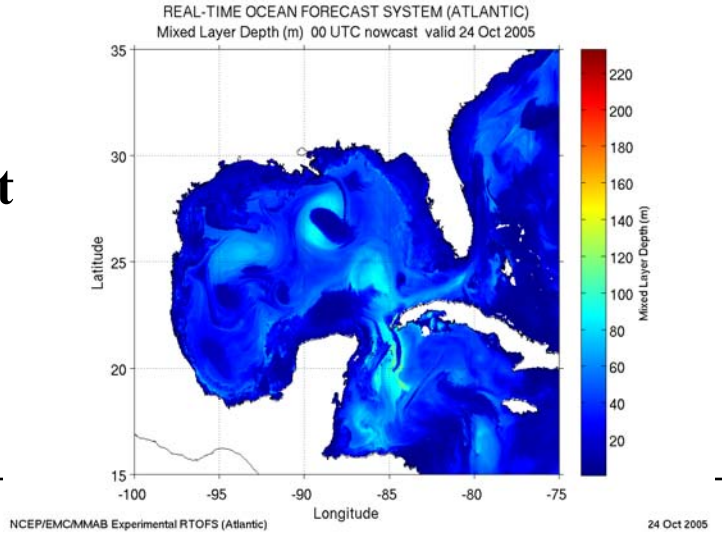
Nowcast valid Oct 21



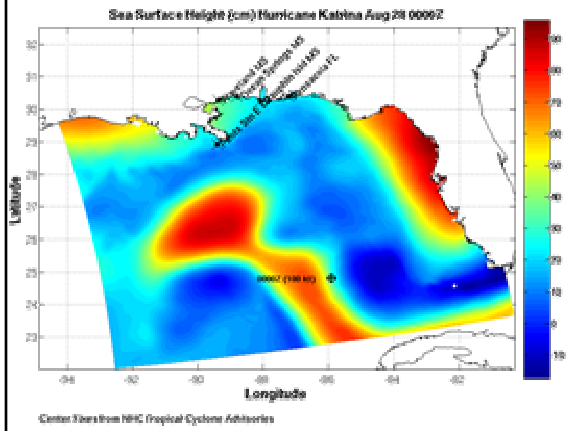
72-hr forecast valid Oct 24

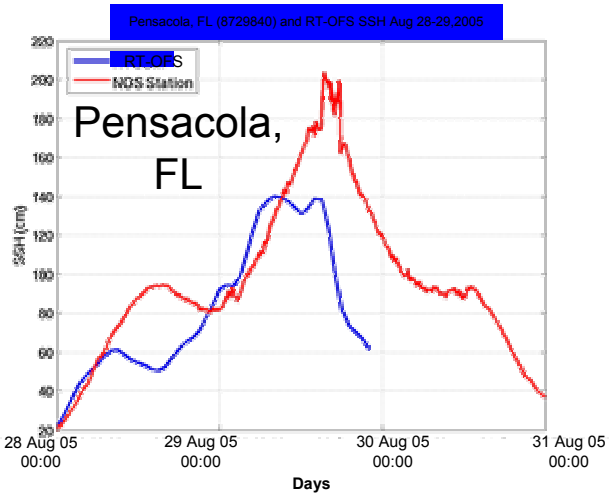


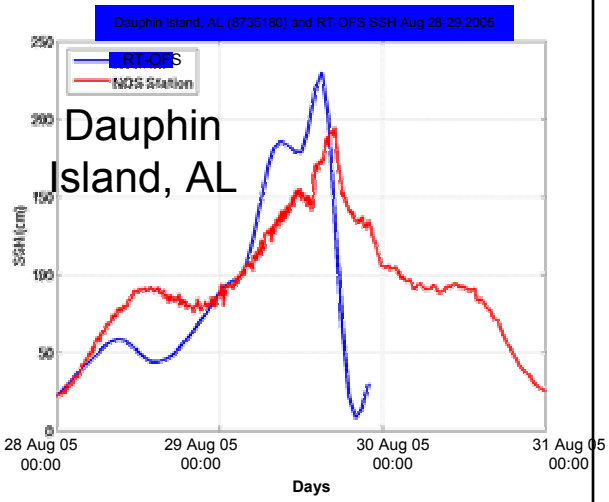
Nowcast valid Oct 24

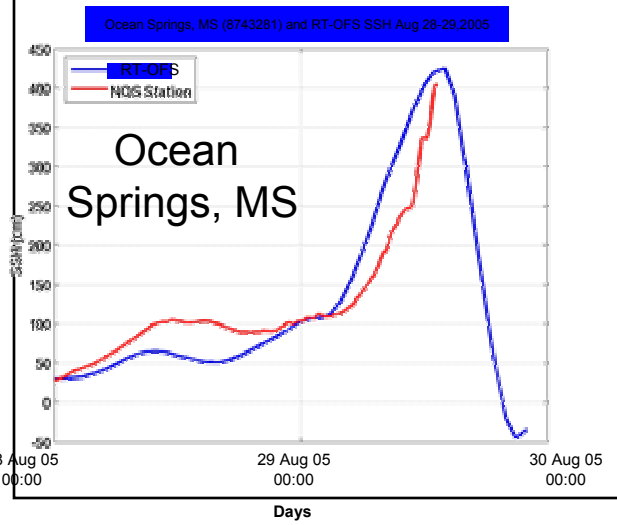


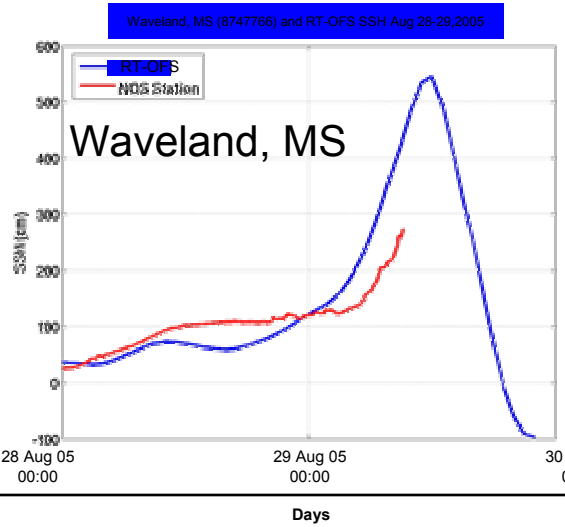
Tide Gauge Comparisons for Hurricane Katrina

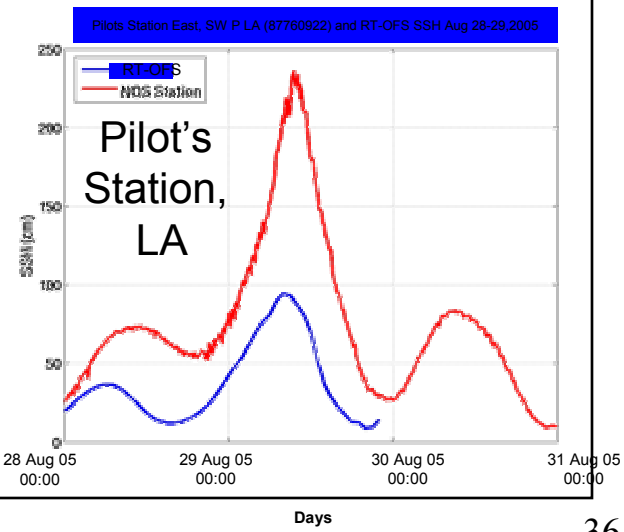




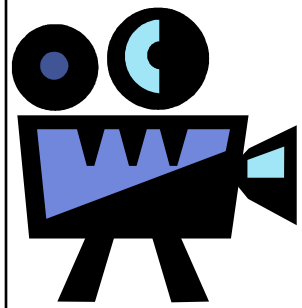


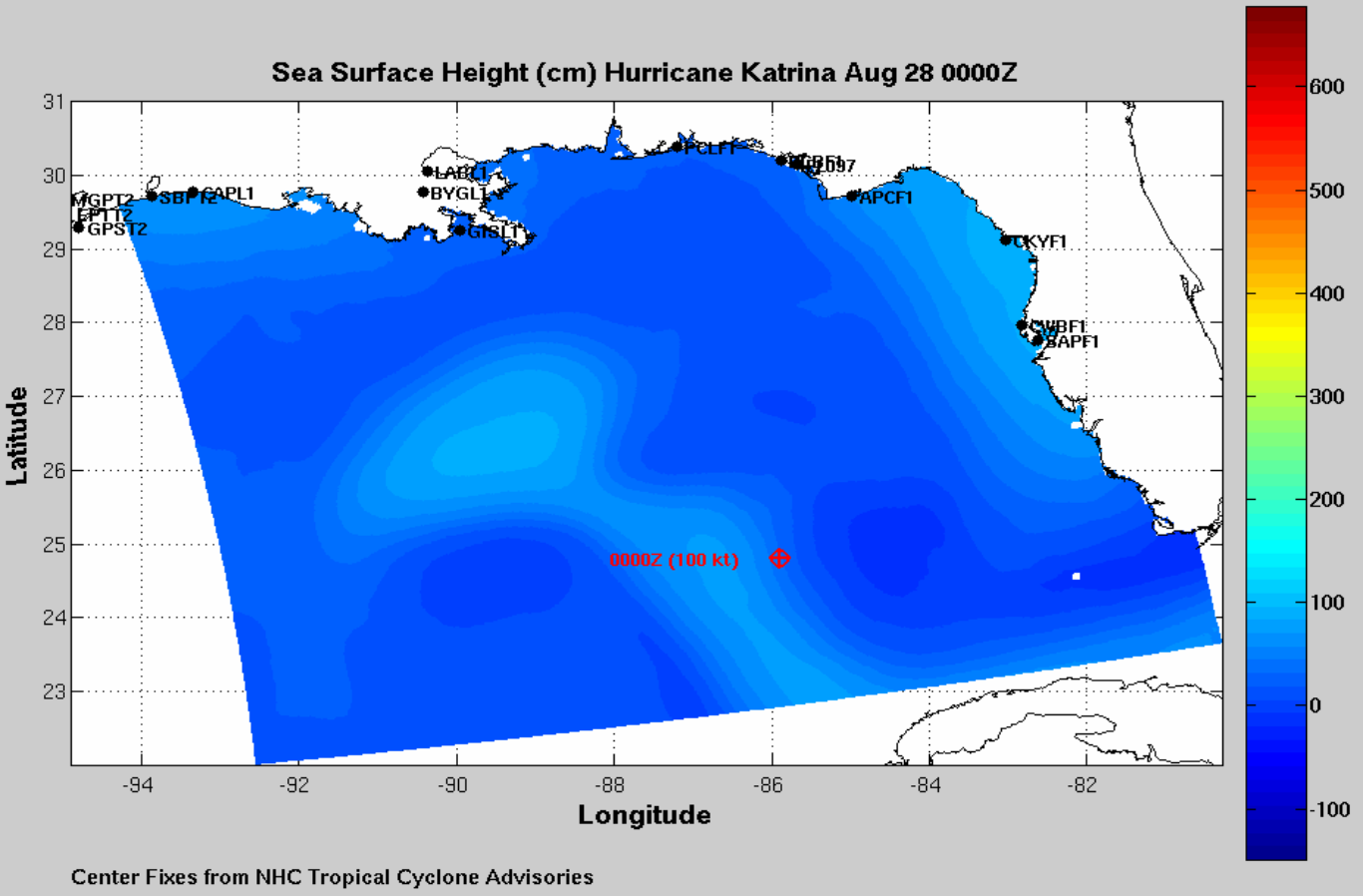






Tide Surge During Katrina





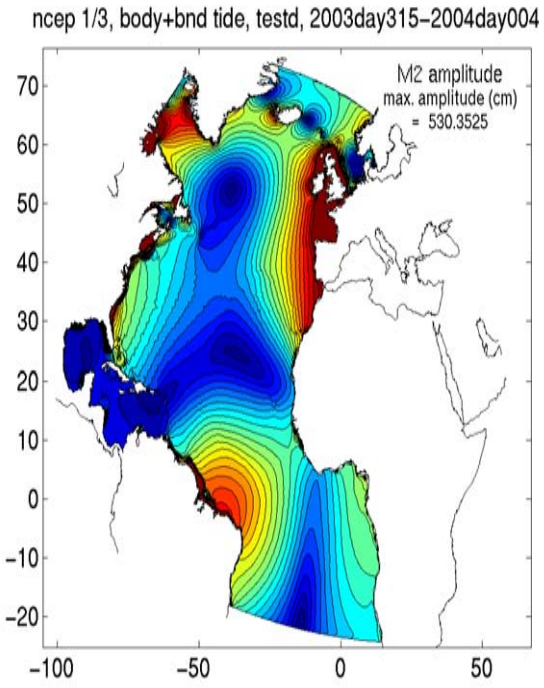
TIDES and OPEN BOUNDARIES in HYCOM

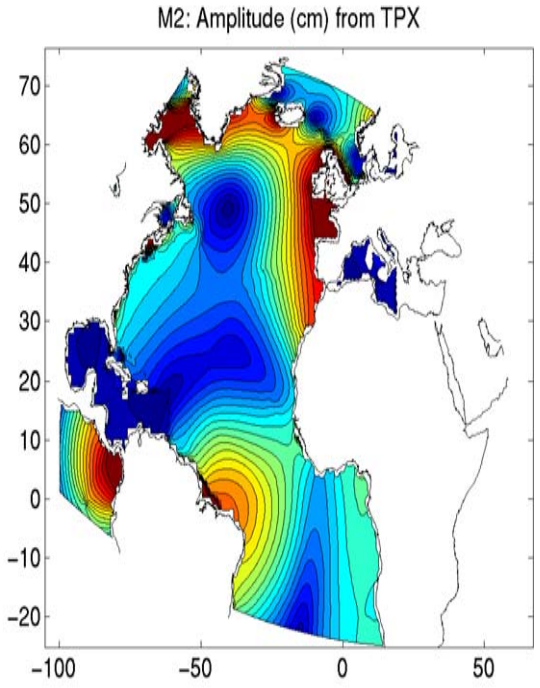
Boundary and body tides are needed:

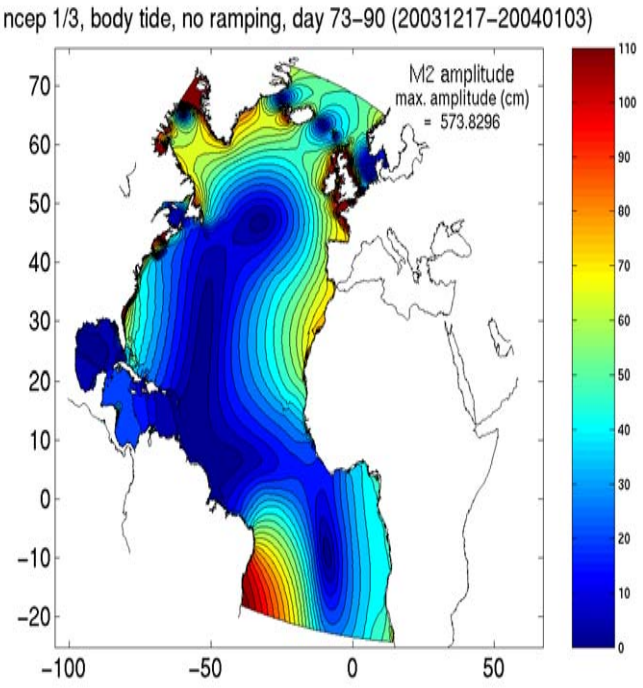
Boundary-tide: 1 invariant, AND body tide

TPX

Only body tide





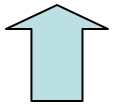


TIDES and OPEN BOUNDARIES in HYCOM

Constituents included (so far):

- Semi-diurnals: K2, M2, N2, S2
- Diurnals: K1, O1, P1, Q1

- Body-tide: the equilibrium tide potential $g\eta_{eqpot}$
- Boundary tide: the tidal response, from TPX 0.6 (Egbert)

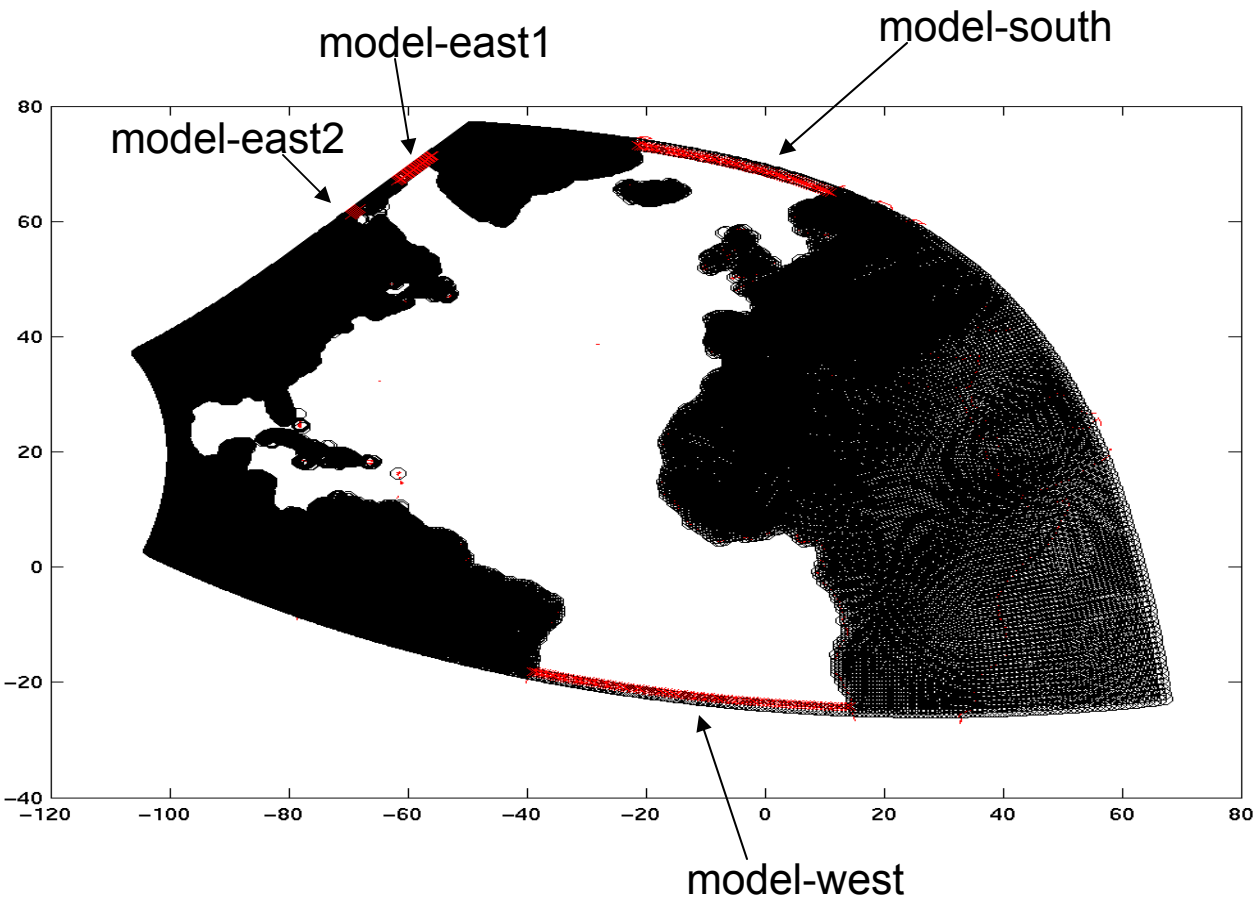


Requires opening of the boundaries

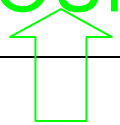
TIDES and OPEN BOUNDARIES in HYCOM

Opening of the boundaries

For external mode



TIDES and OPEN BOUNDARIES in HYCOM



Control on the open boundaries of:

- the barotropic (low frequency) u and η
- the barotropic (high frequency) u and η

Requirements of the boundary algorithms:

- Stability — depends on grid and discretization techniques

- Tracking — depends on choice of algorithms

TIDES and OPEN BOUNDARIES in HYCOM

Example of tested algorithms in Hycom:

Flux only	
$u_1 = u_{obs}$	$\eta_1 = \eta_1$
1 invariant	
$u_1 = u_{obs} + c(\eta_{obs} - \eta_1)$	$\eta_1 = \eta_1$
	$\eta_1 = \frac{1}{2}(\eta_{obs} + \eta_1)$
2 invariants	
$u_1 = u_{obs} + u_{\text{int}} - u_1 + \ldots$ $\ldots + c(\eta_{obs} - \eta_{\text{int}})$	$\eta_1 = \frac{1}{2}\frac{1}{c}(u_{obs} - u_{\text{int}}) + \ldots$ $\ldots + \frac{1}{2}(\eta_{obs} + \eta_1)$

Best results from this test

Show results from these!

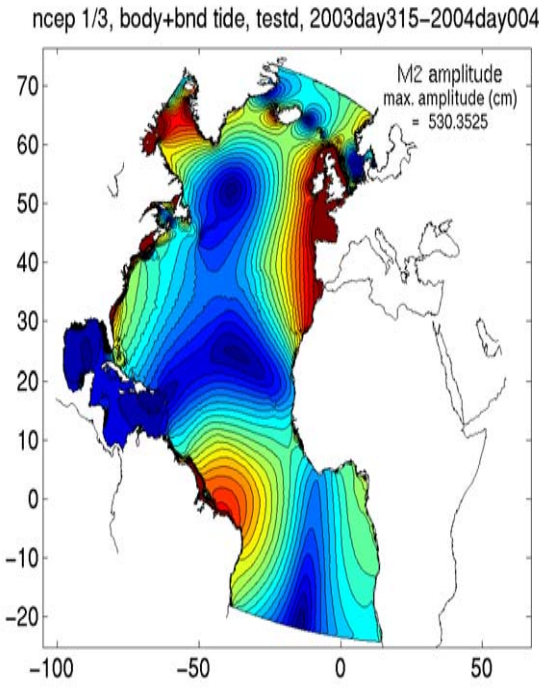
TIDES and OPEN BOUNDARIES in HYCOM

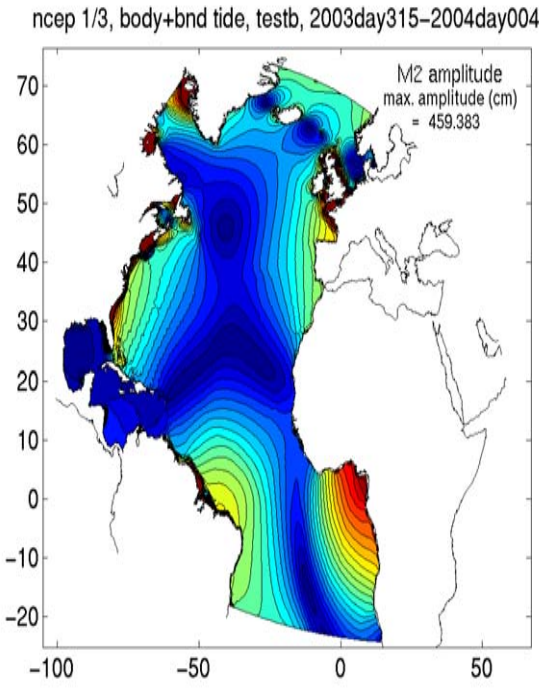
Tidal analysis from run-day 18 to 72 (=for 54 days)

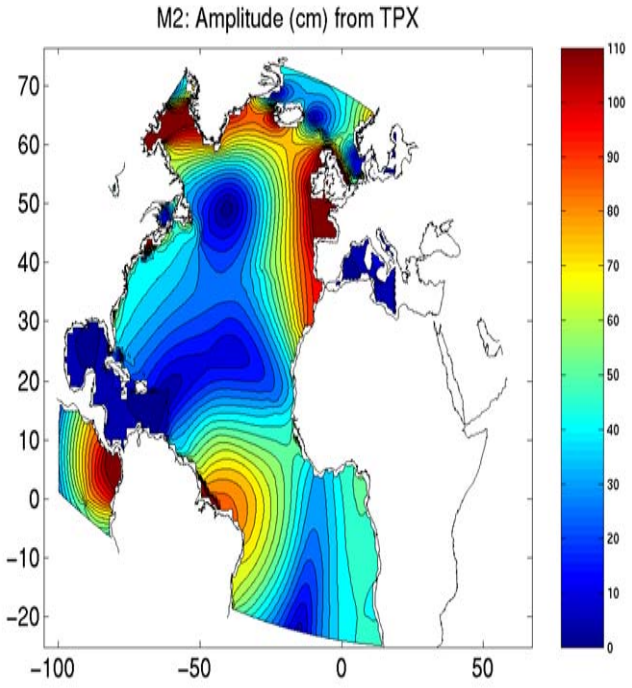
1 invariant

2 invariants

TPX







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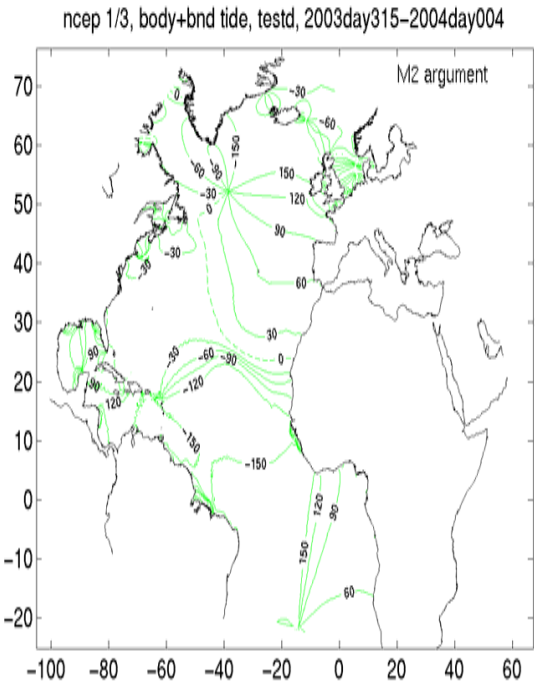

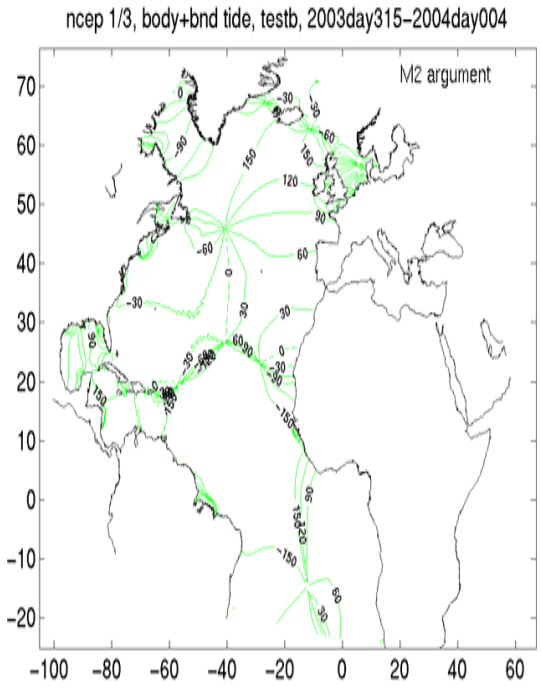

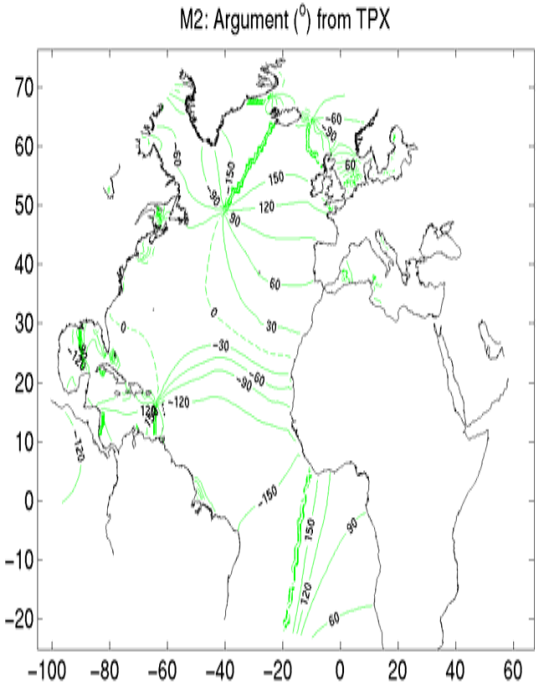

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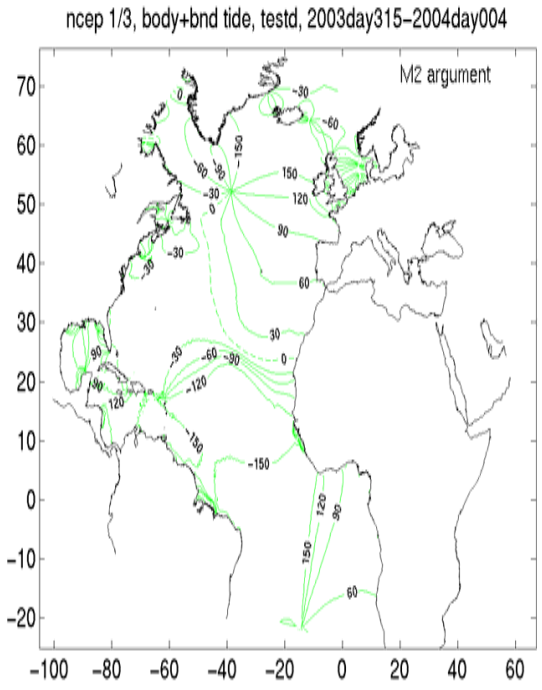
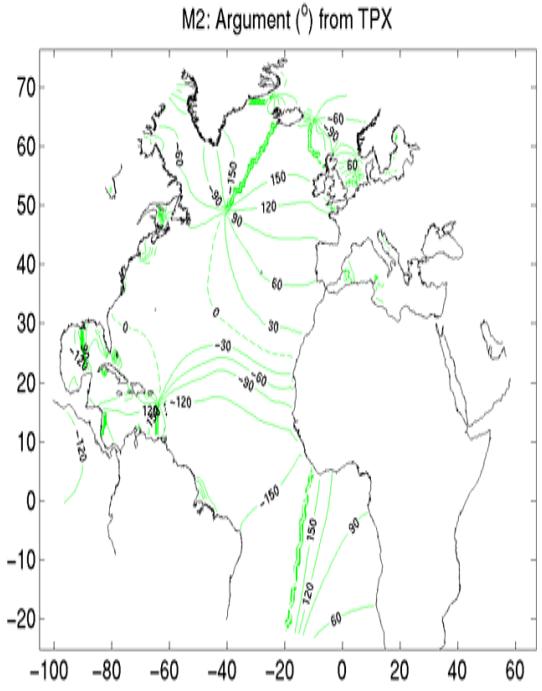
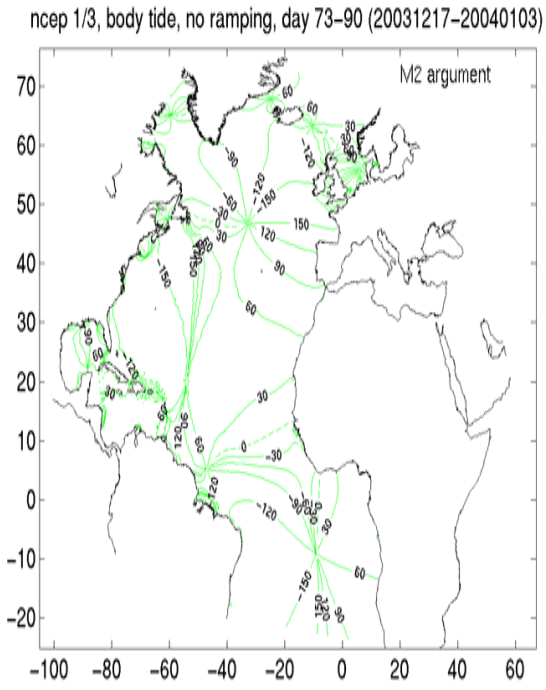
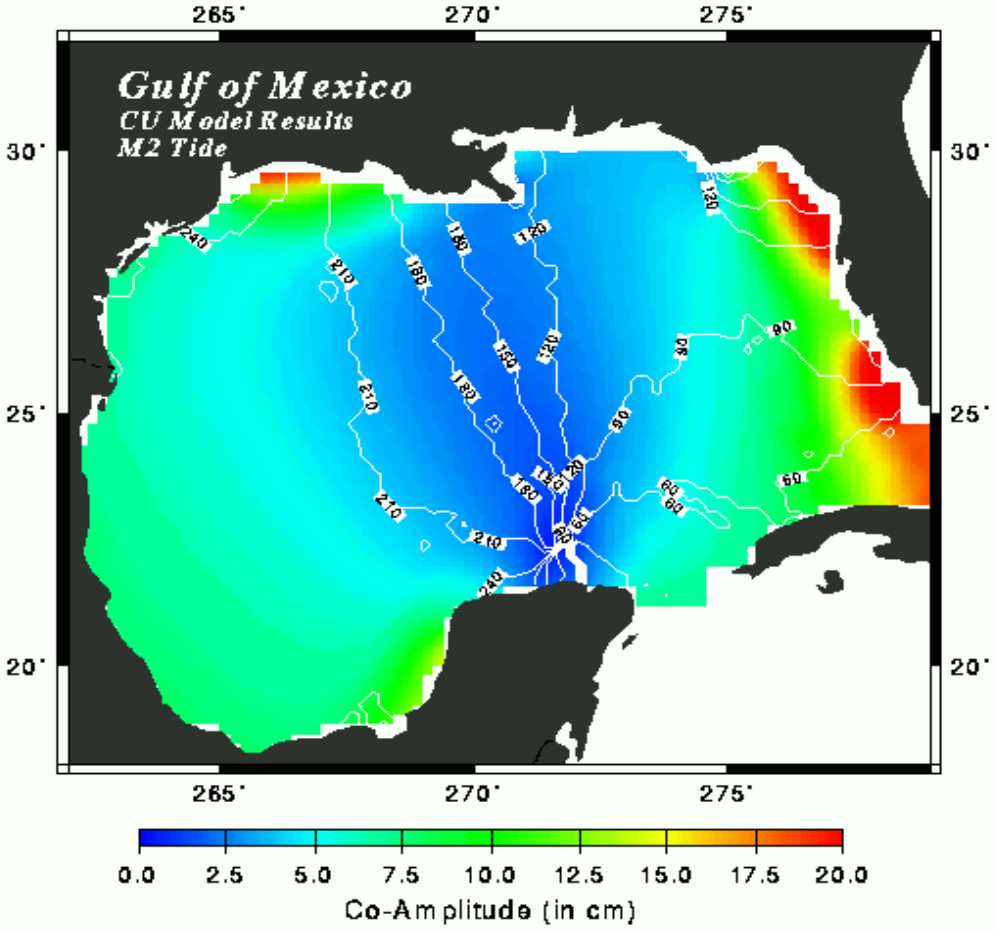


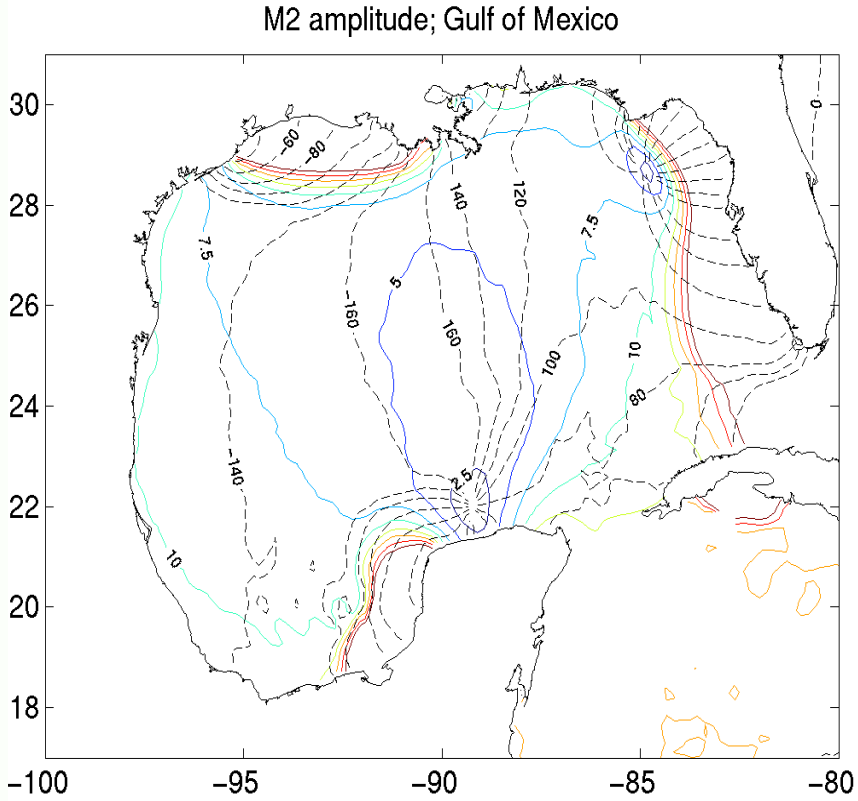




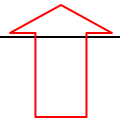
TIDES and OPEN BOUNDARIES in HYCOM

close-up (M2 amplitude and phase), Gulf of Mexico:





TIDES and OPEN BOUNDARIES in HYCOM



On going work:

- Calibration and validation

  Calibration parameters:
  - Topography (etopo2, dbdb2 and regional topographies)
  - Coastline
  - Open ports
  - Dynamical model parameters, e.g. bottom bnd layer