Nested Gulf of Mexico Modeling with HYCOM

Patrick J. Hogan
Alan J. Wallcraft

Naval Research Laboratory
Stennis Space Center, MS

HYCOM Meeting
December 6-8, 2005
University of Miami, Miami, FL

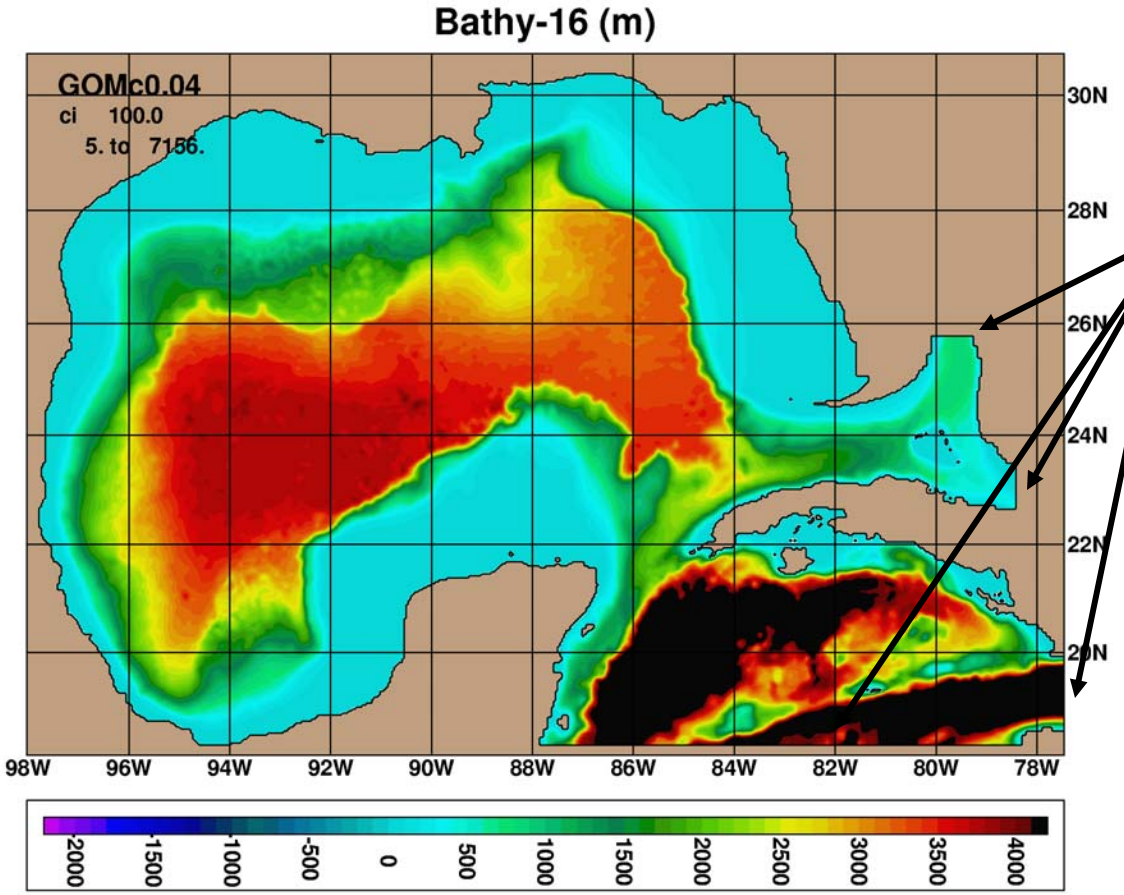
1/25° (~4 km) non-assimilative Nested Gulf of Mexico

- Initialized from January 1, 2000 1/12° Atlantic HYCOM
- Lateral boundary conditions from 1/12° Atlantic HYCOM
- Surface forcing is from 6-hourly/3-hourly NOGAPS (2000/2001)
- 20 layers in the vertical (bottom 5 from Atlantic discarded)
- 16 Rivers included as salinity flux
- GISS Mixed Layer submodel
- Bottom topography is from NRL-DBDB2
- Integrated over 2000-2001

Possible cross-shelf transport mechanisms

- Shelf break instabilities
- Shelf break flow reversals
- Eddy-eddy interactions
- Eddy-topography influence

1/25° Gulf of Mexico Model (~4 km)



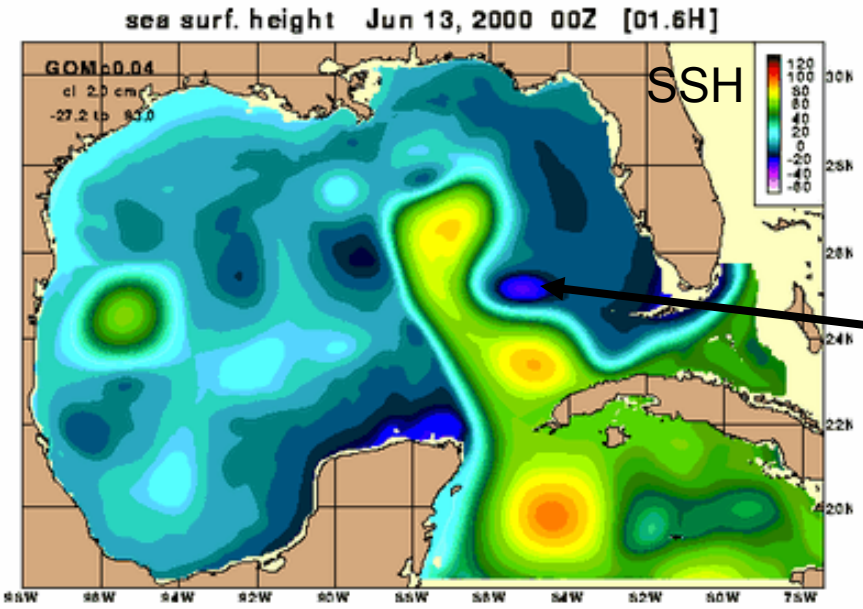
Open boundary locations

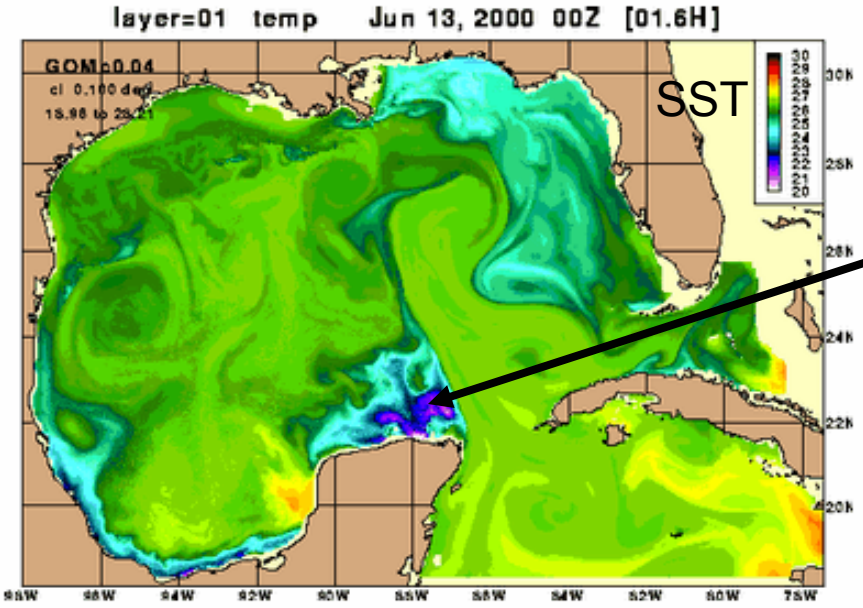
Method of Characteristics used To update the barotropic mode

20 gridpoint buffer zone for baroclinic mode with e-folding time 1 to 10 days

Atlantic boundary data provided daily

1/25° (~4 km) Nested Gulf of Mexico





Snapshot of SSH and SST on June, 13 2000

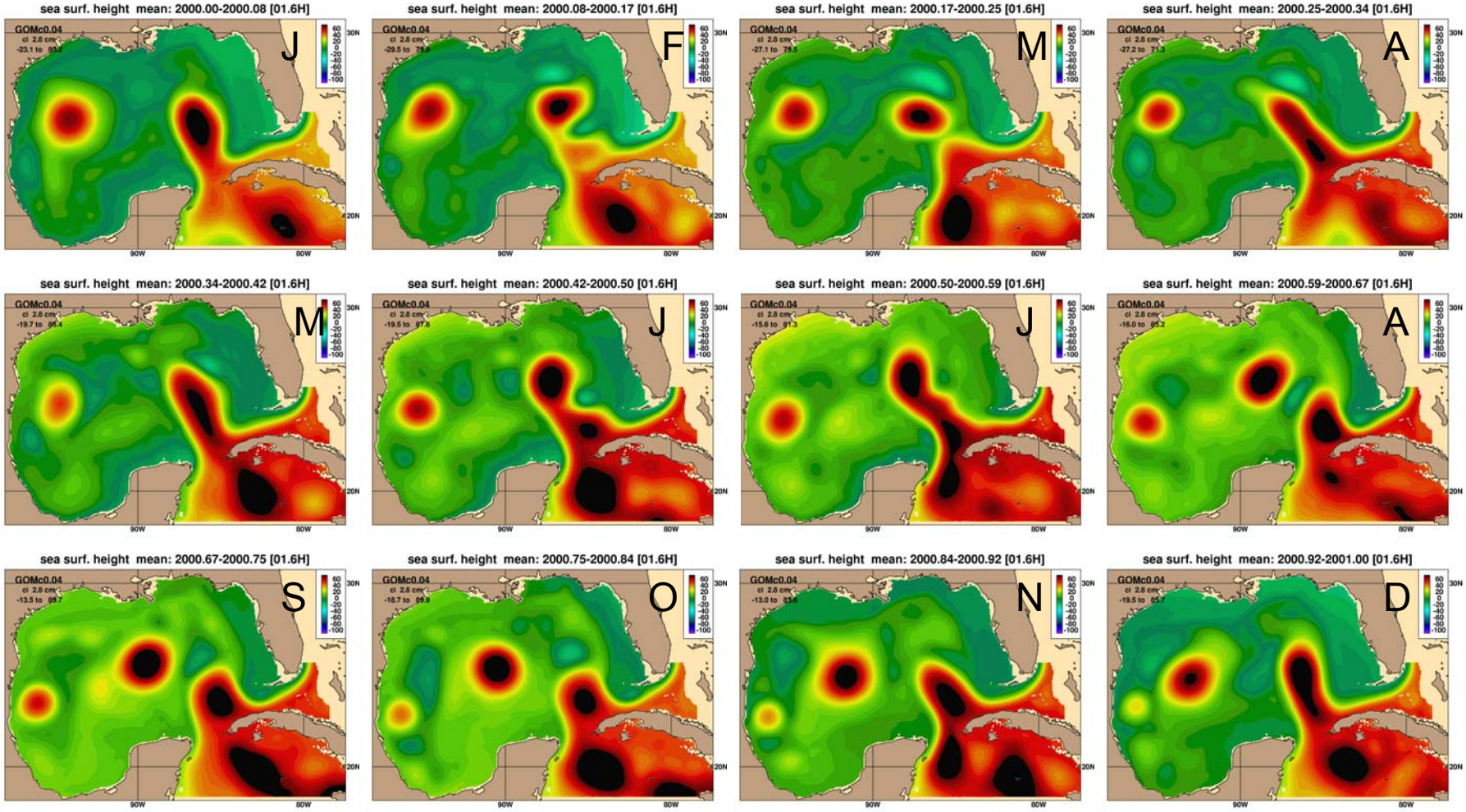
Lots of cyclonic cold core eddies (impact of 2x res.)

Local upwelling

1/25° Nested Gulf of Mexico HYCOM

Monthly Mean Sea Surface Height Year 2000

Evolution of Loop Current Eddy Shedding

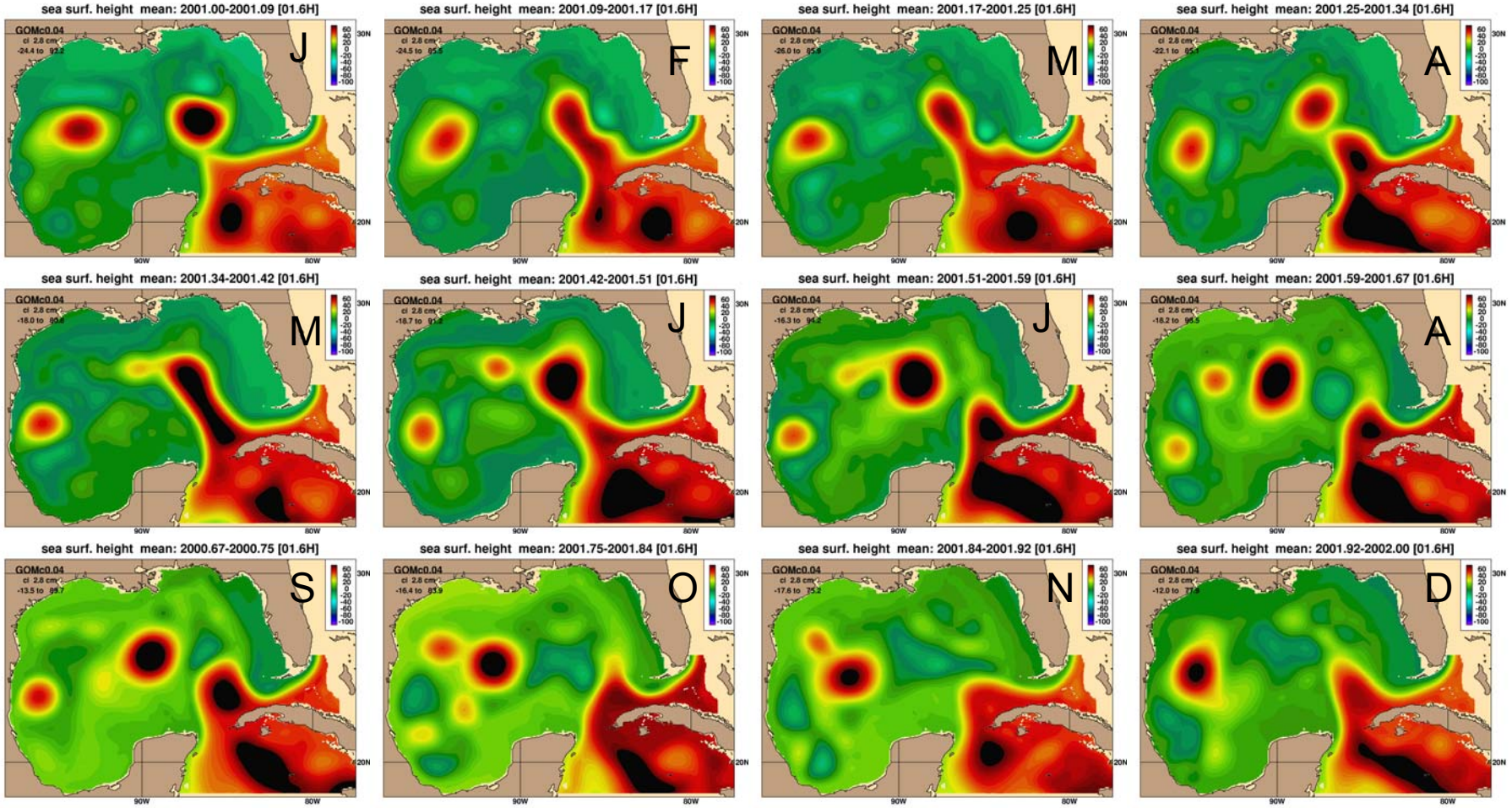


- Loop Current Eddy sheds in August 2000
- Role of cyclones in Loop Current Eddy shedding evident

1/25° Nested Gulf of Mexico HYCOM

Monthly Mean Sea Surface Height Year 2001

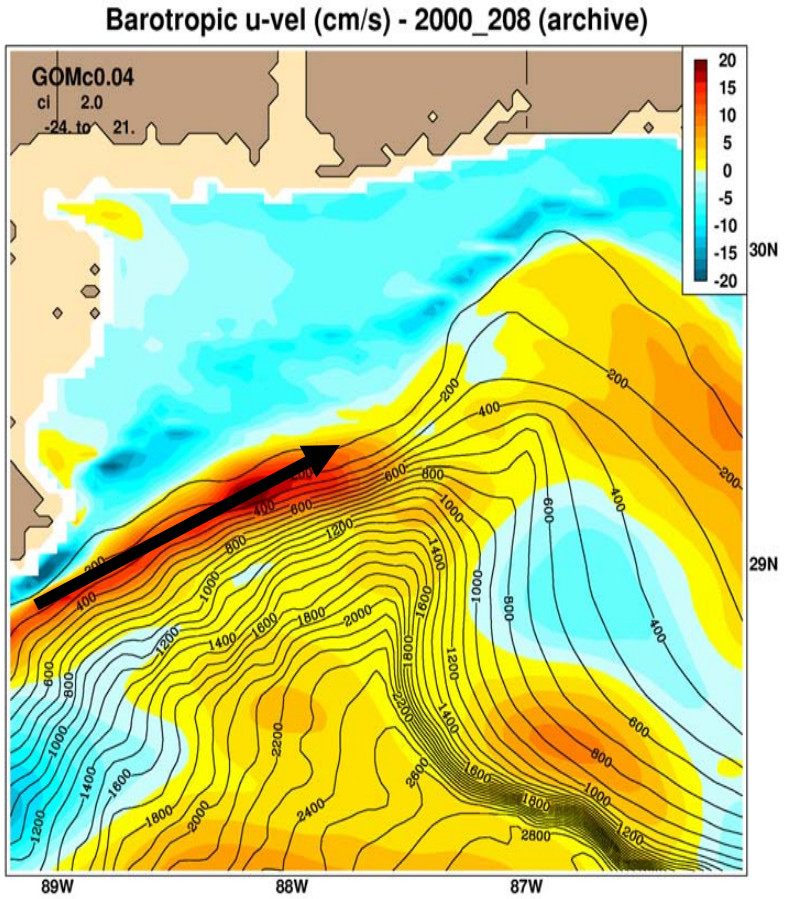
Evolution of Loop Current Eddy Shedding



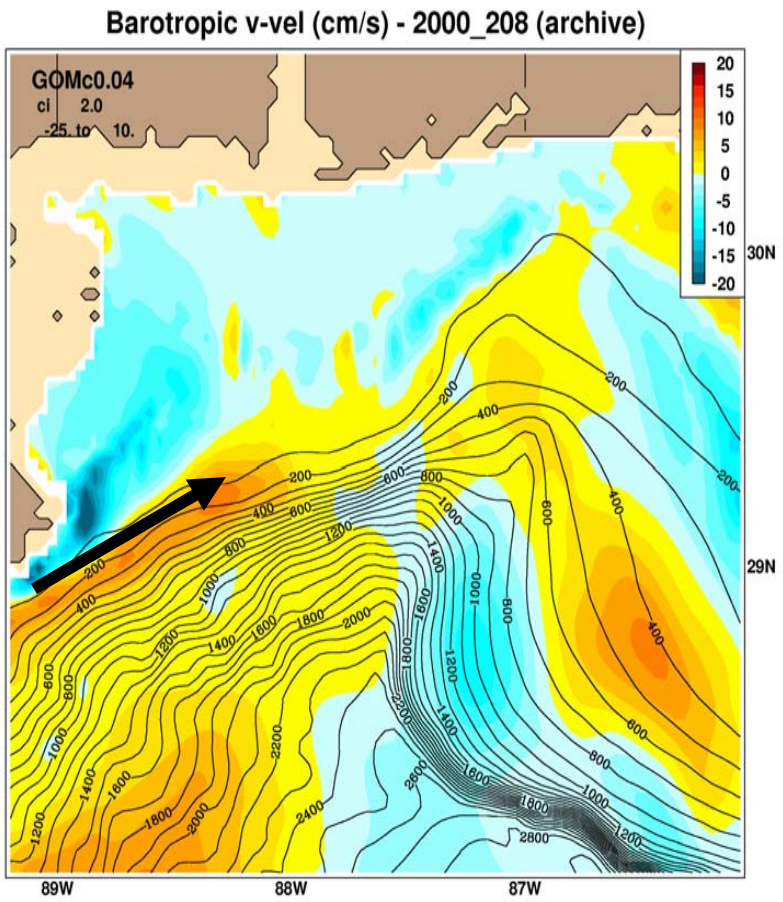
- Loop Current Eddy sheds 10 months later (July 2001)
- Detached eddy reattaches in several cases

1/25° Nested Gulf of Mexico HYCOM

red=east blue=west **July 27, 2000** red=north blue=south



Barotropic u-velocity

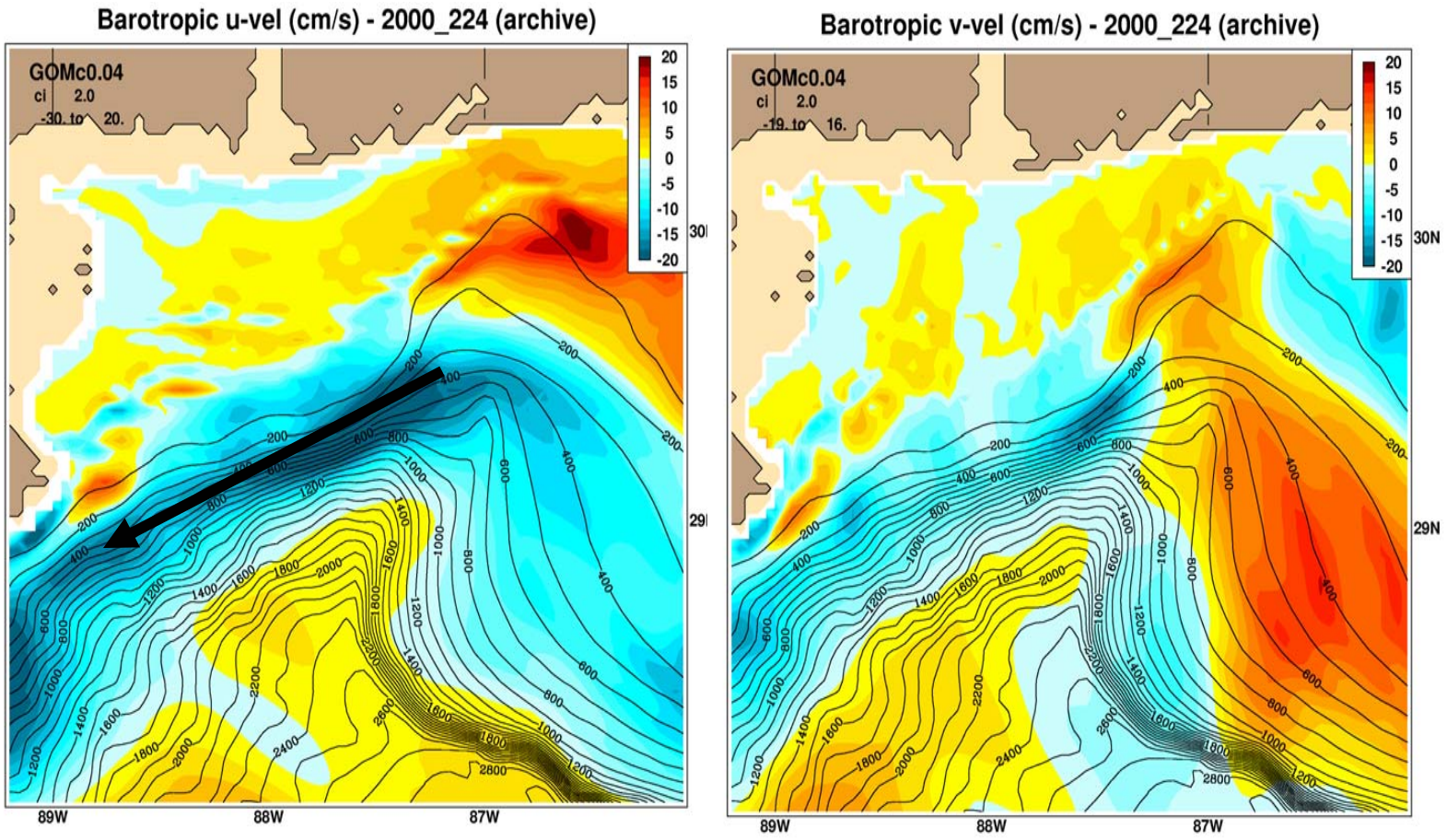


Barotropic v-velocity

Initial eastward along-shelf break current in geostrophic balance

1/25° Nested Gulf of Mexico HYCOM

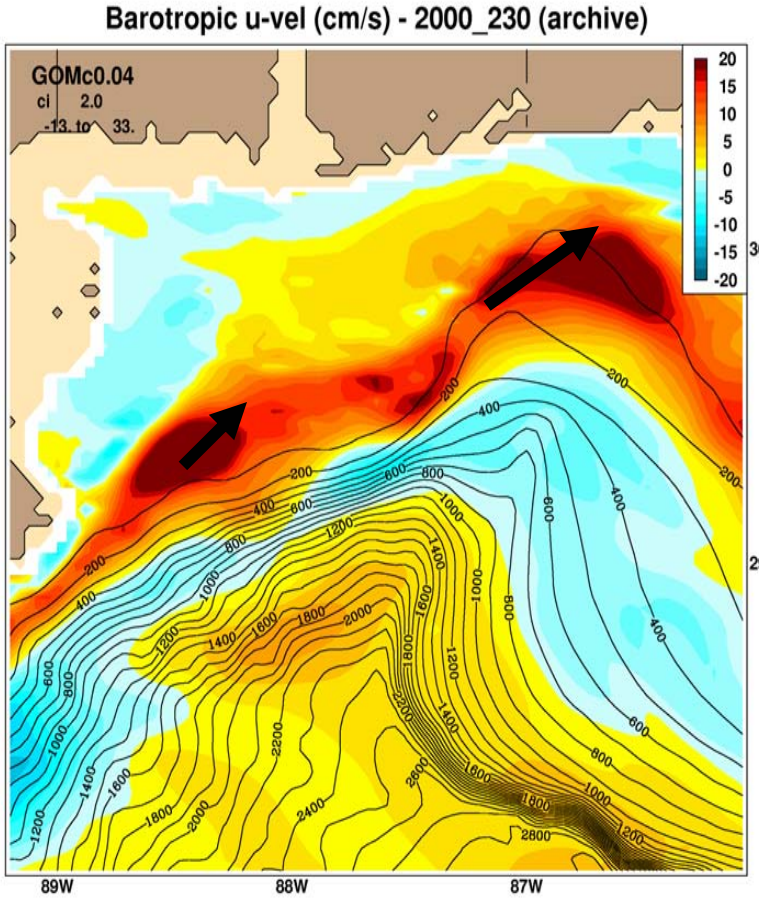
red=east blue=west **August 12, 2000 (+ ~2 weeks)** red=north blue=south

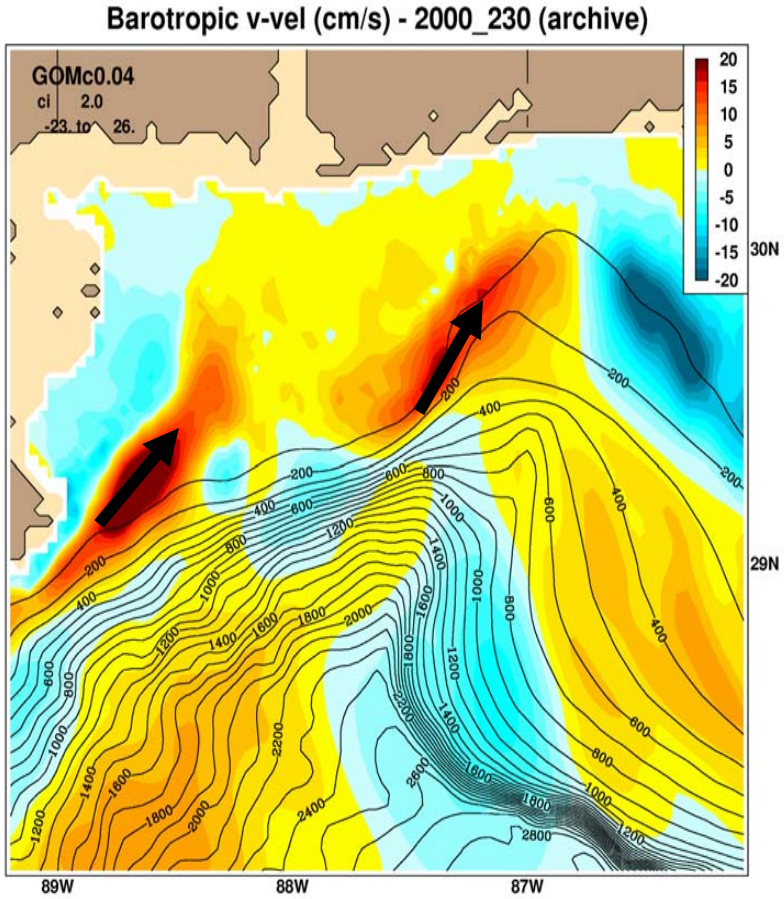


A reversal in the barotropic currents triggers a transition of the along-shelf break currents to flow onto the shelf

1/25° Nested Gulf of Mexico HYCOM

August 18, 2004 (+ ~1 week)



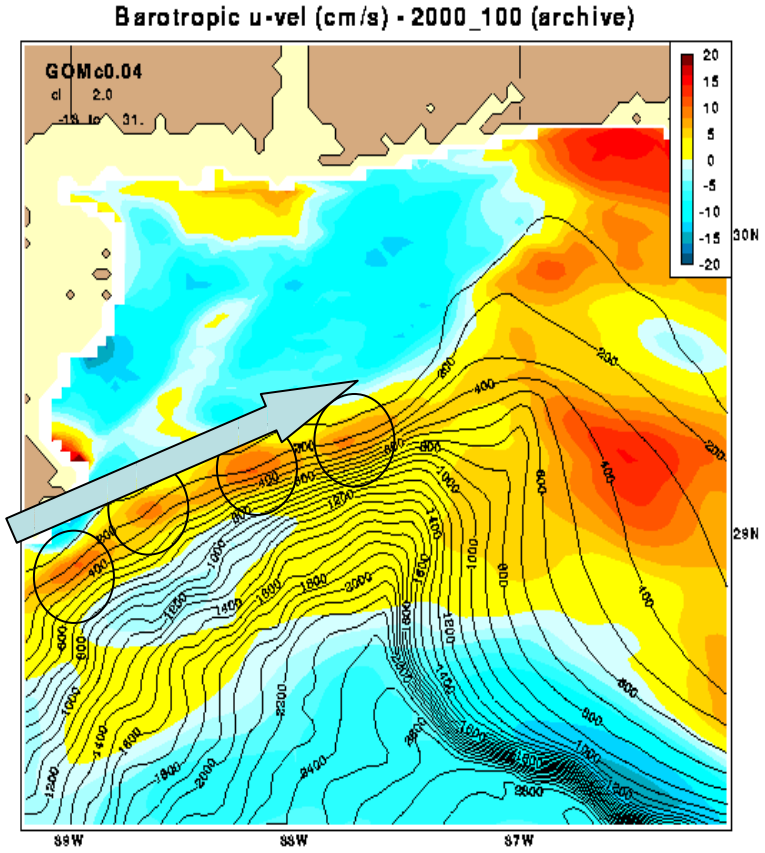


red=east **blue**=west

red=north **blue**=south

Significant cross-shelf flow exists after the reversal

1/25° Nested HYCOM forced by NOGAPS



April 10, 2000

red=east blue=west

Jet flowing eastward along isobaths

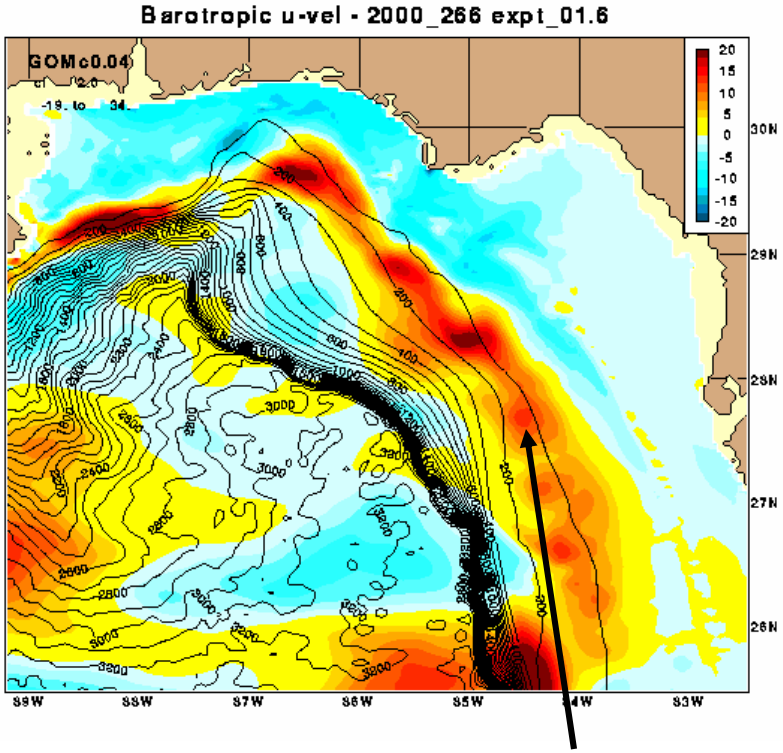
The depth changes in isopycnals across the current serve as a potential energy source for baroclinic eddies

Shelf break eddies associated with baroclinic instability of the along shelf-break current

1/25° Nested Gulf of Mexico HYCOM

Barotropic u-velocity

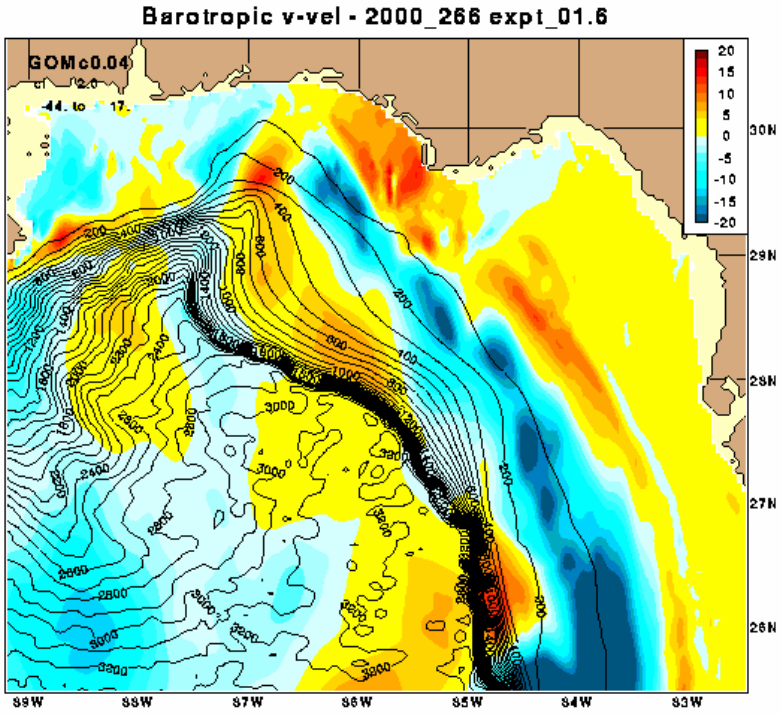
red=east blue=west



Meandering of the along-shelf jet

Barotropic v-velocity

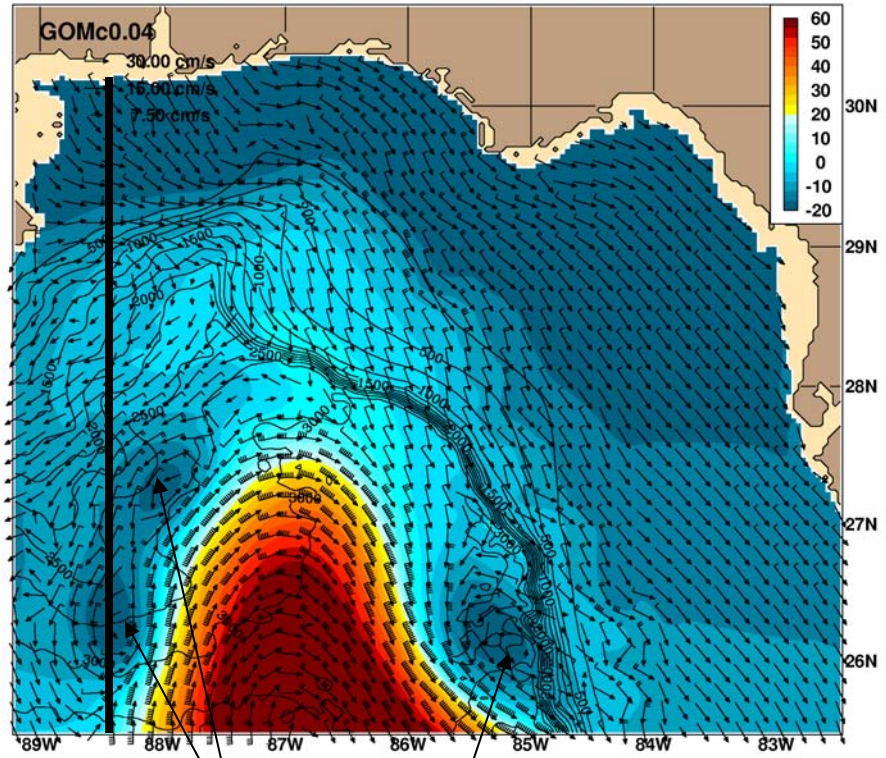
red=north blue=south



Clockwise along-shelf break flow common in eastern Gulf

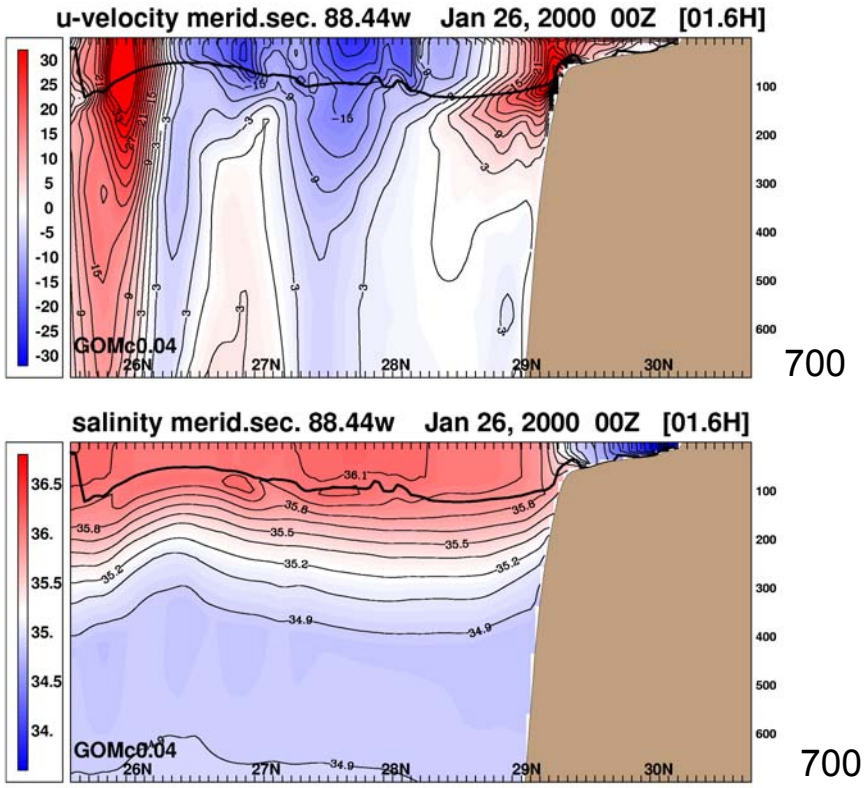
1/25° Nested Gulf of Mexico HYCOM

Jan 26 2001 SSH and Surface Currents



cyclones

Cross-section along 88.4°W



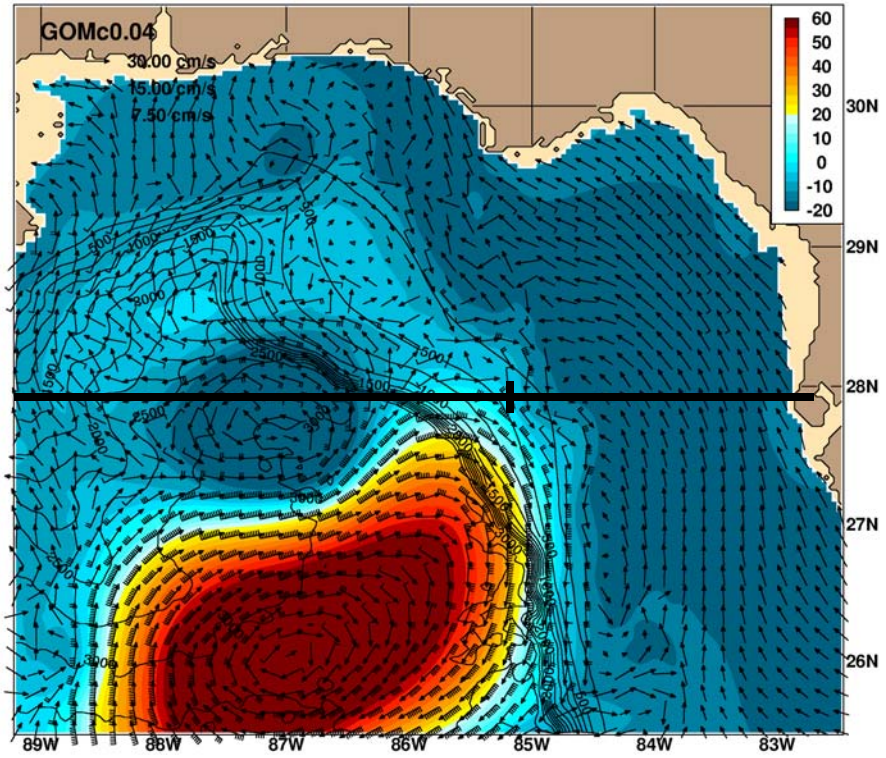
- Cyclone cores are ~700m deep
- Robust shelf-break current associated with strong salinity gradient
- Loop Current penetration to ~28°N

Red=east
Blue=west

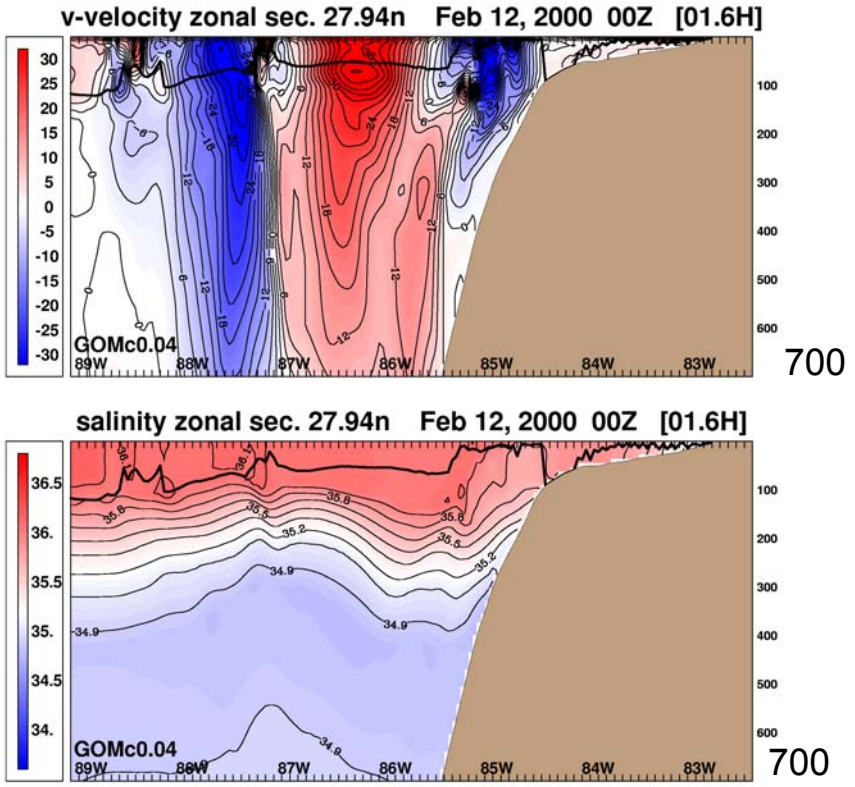
1/25° Nested Gulf of Mexico HYCOM

Red=north
Blue=south

Feb 12, 2001 SSH and Surface Currents



Cross-section along 27.9°N



Loop Current has migrated to NE and is impinging on shelfbreak

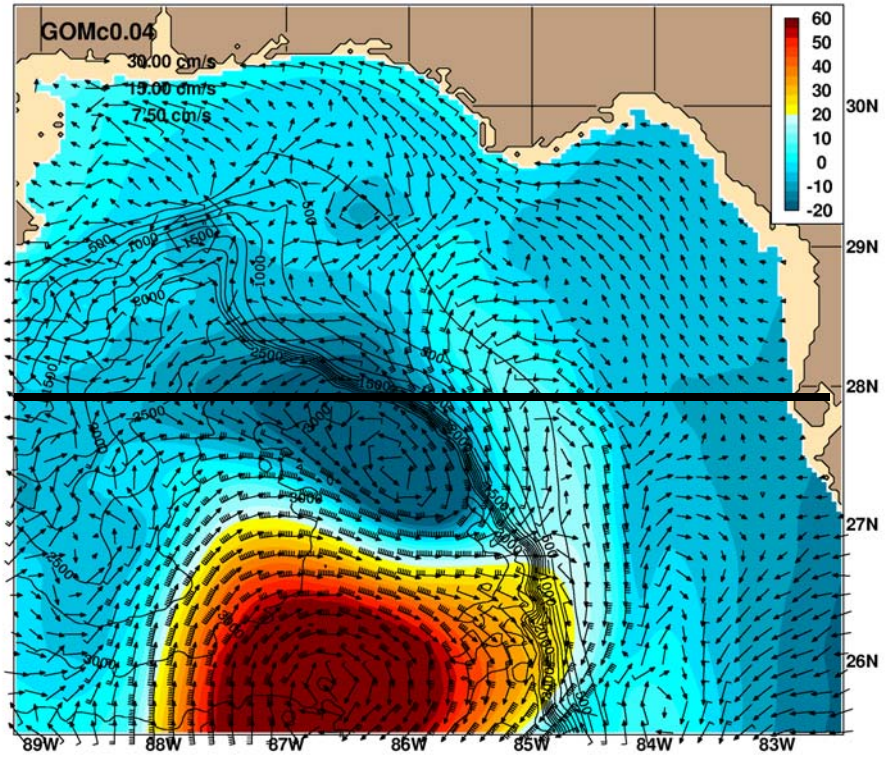
Cyclone also impinging on shelfbreak

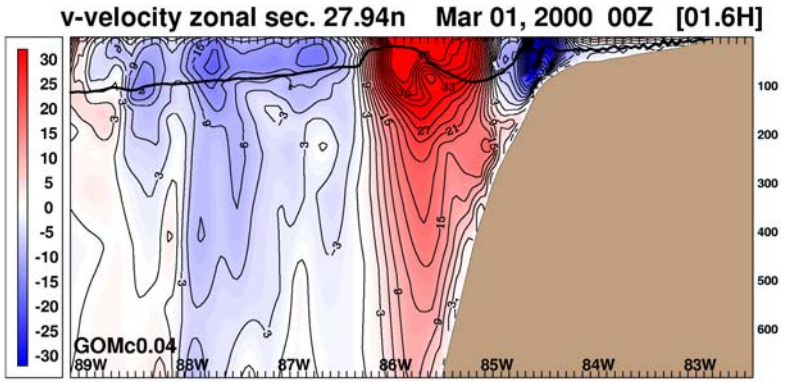
- Doming of isohalines associated with cyclone
- Sharp shelfbreak front
- Intense northward subsurface jet

1/25° Nested Gulf of Mexico HYCOM

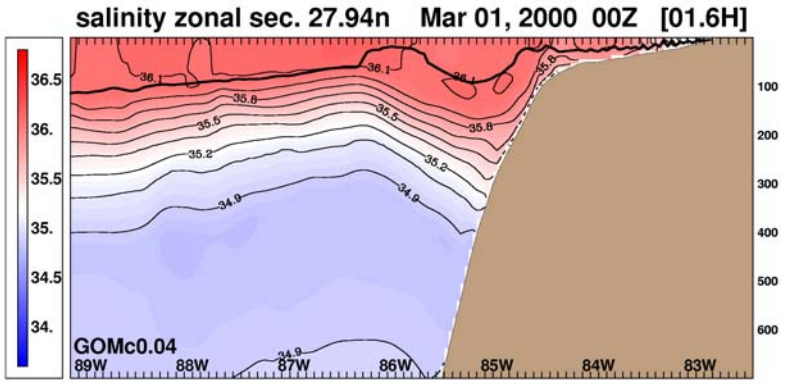
Red=north
Blue=south

March 01, 2001 SSH and Surface Currents





700



700

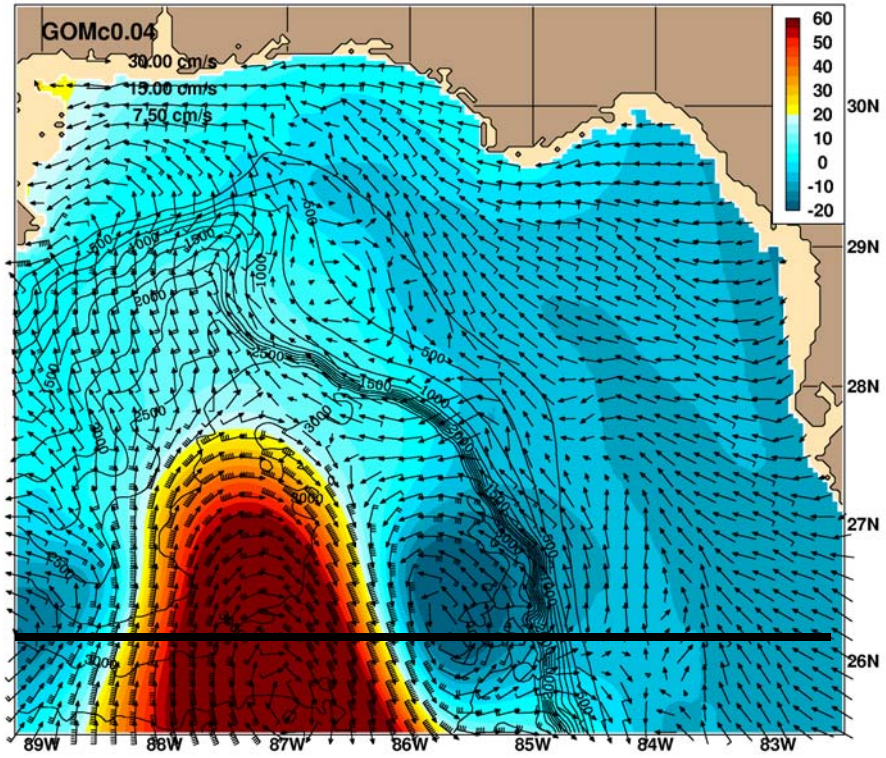
- Cyclone orbiting Loop Current Eddy,
- Loop Current Eddy breaching shelf break
- Southward flow enhanced by vortex compression?

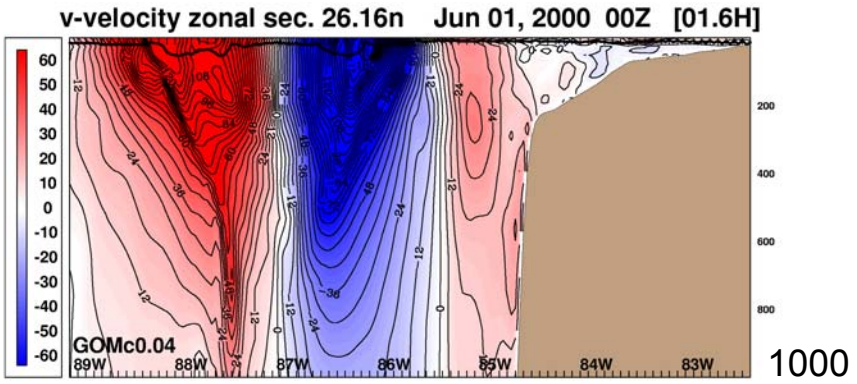
Southward subsurface velocity maximum

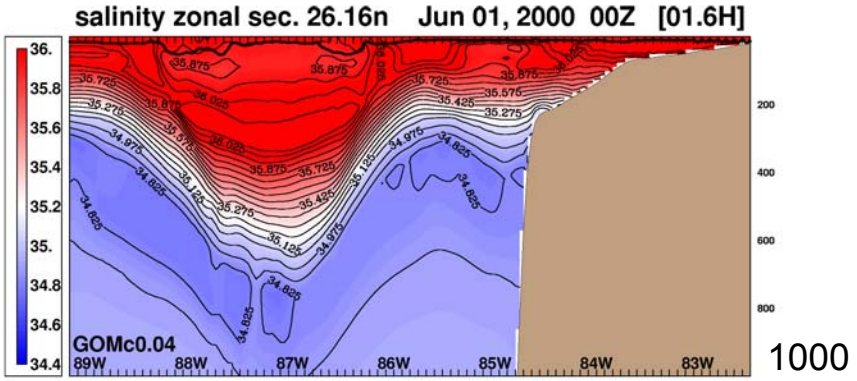
1/25° Nested Gulf of Mexico HYCOM

Red=north
Blue=south

June 02, 2001 SSH and Surface Currents



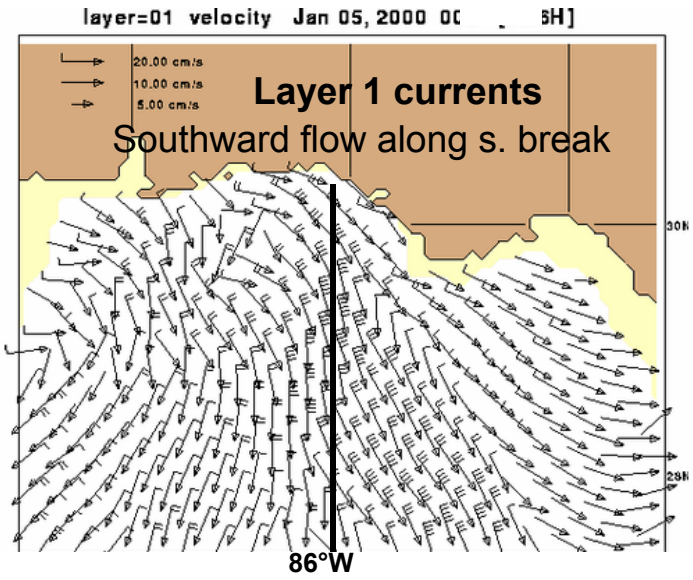




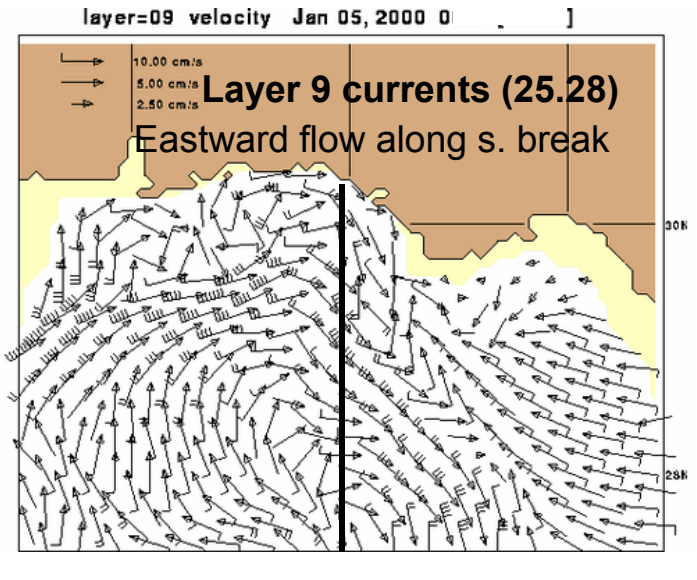
3 months later cyclone hasn't migrated very far but is being steered by the shelf break

- Strange symmetry of LCE especially on western side
- Subsurface salinity max beneath LCE

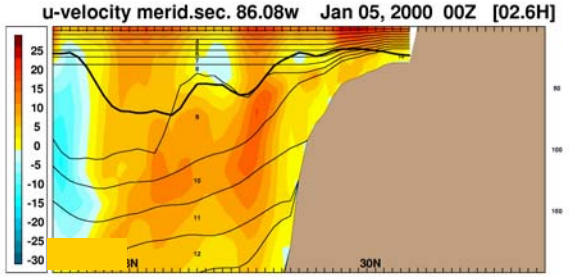
January 05, 2002 Upwelling in the northern Gulf of Mexico

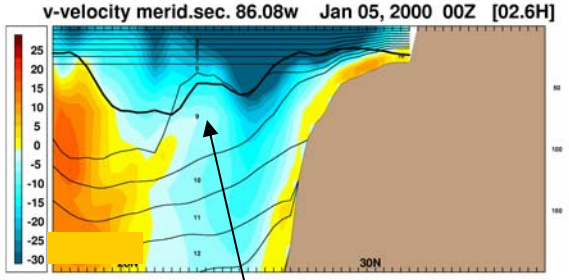


Layer 1 currents
Southward flow along s. break

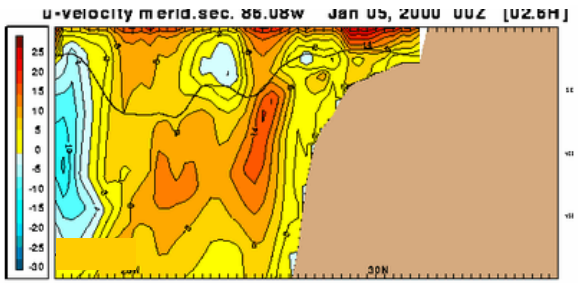


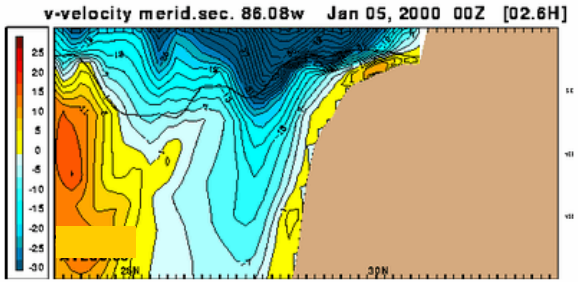
Layer 9 currents (25.28)
Eastward flow along s. break



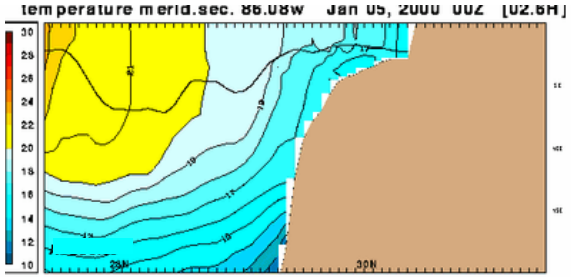


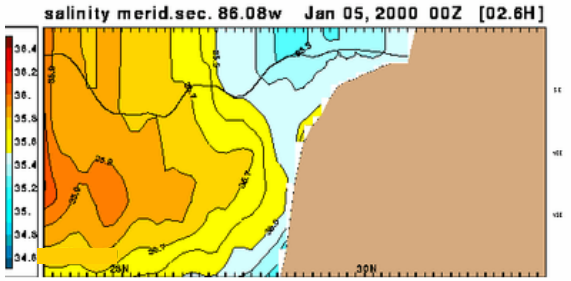
Layer 9





Northward velocity along shelf

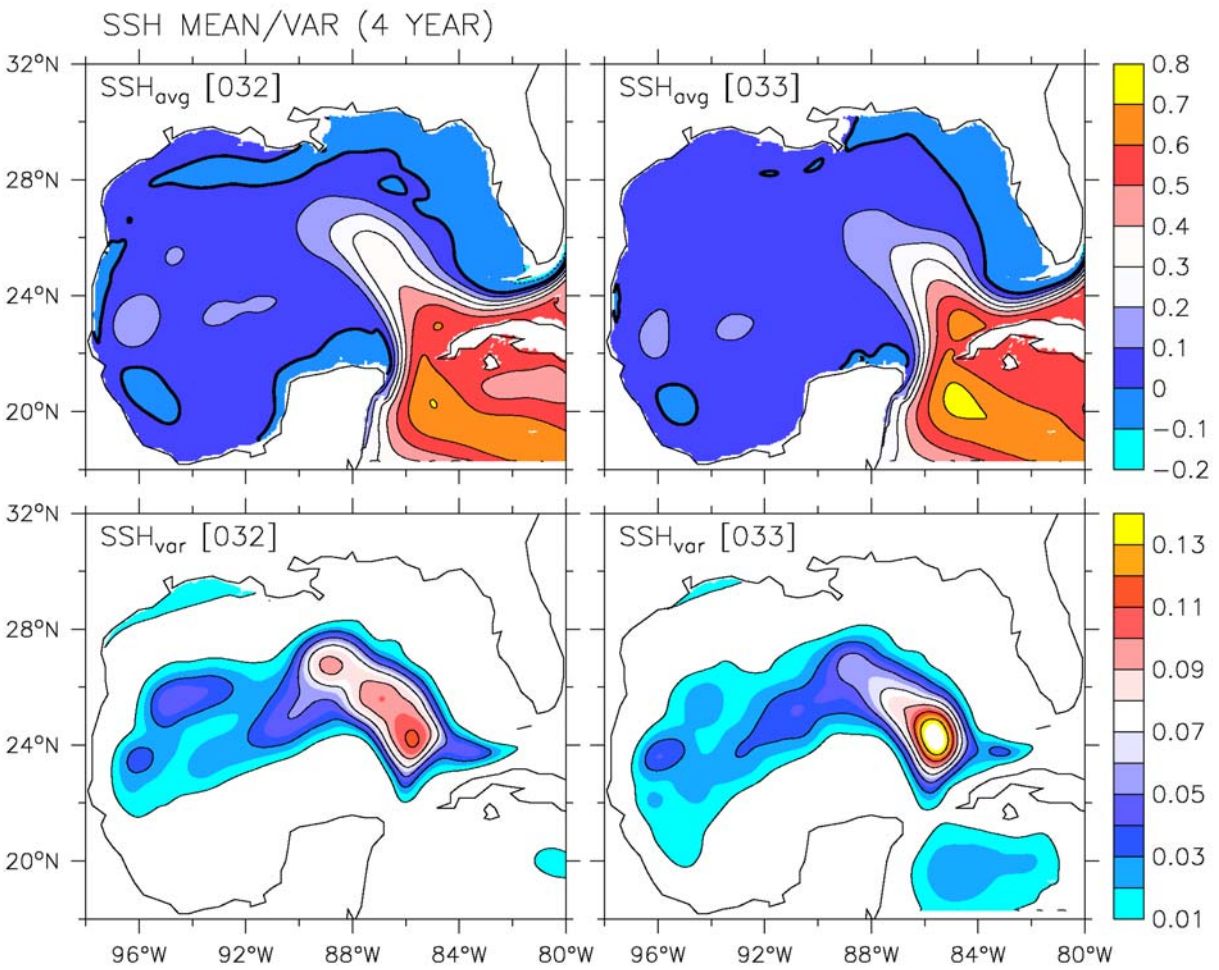




Upwelling of cold water

Sensitivity of boundary forcing updating

Allows for long-term integrations over any timeframe



1-day forcing

Climatological forcing

Monthly climatology formed from 1-day archives

Conclusions

Value of 2x resolution clear (cyclones, filaments, etc)

3 primary mechanisms of cross-shelf exchange:

- Along-shelf flow instabilities
- Along-shelf flow reversals
- Eddy-eddy interactions
- Influence of topography

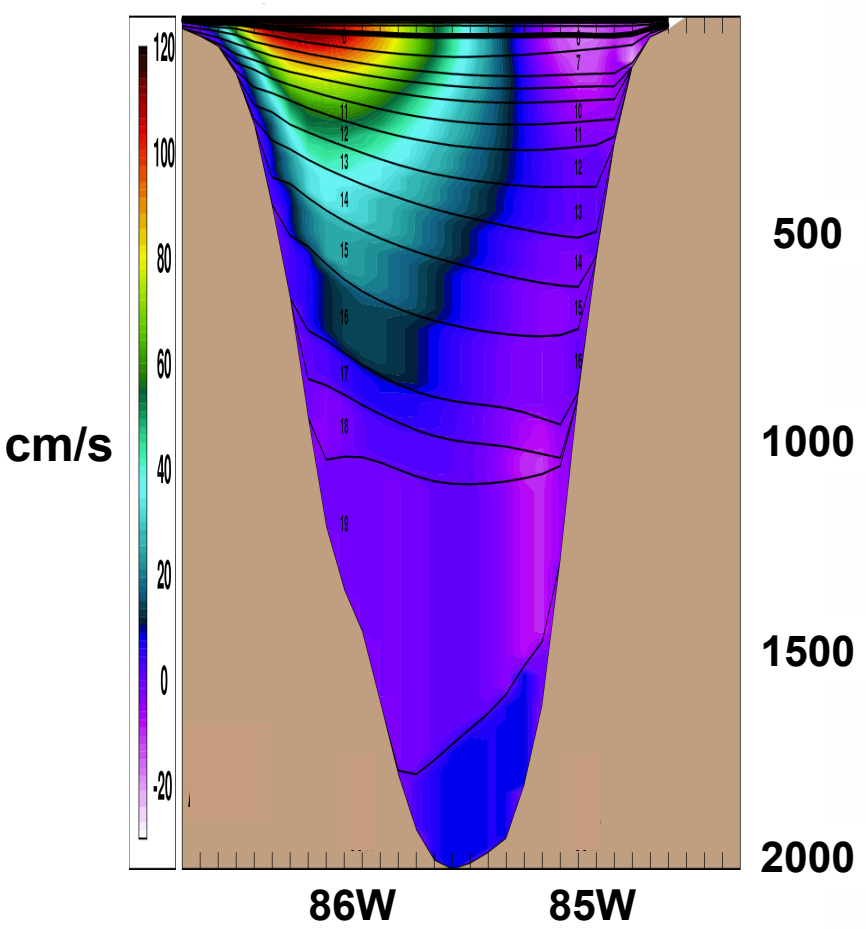
Upwelling well represented (Yucatan, northern Gulf)

Climatological boundary forcing doesn't appear to
Degrade the solution

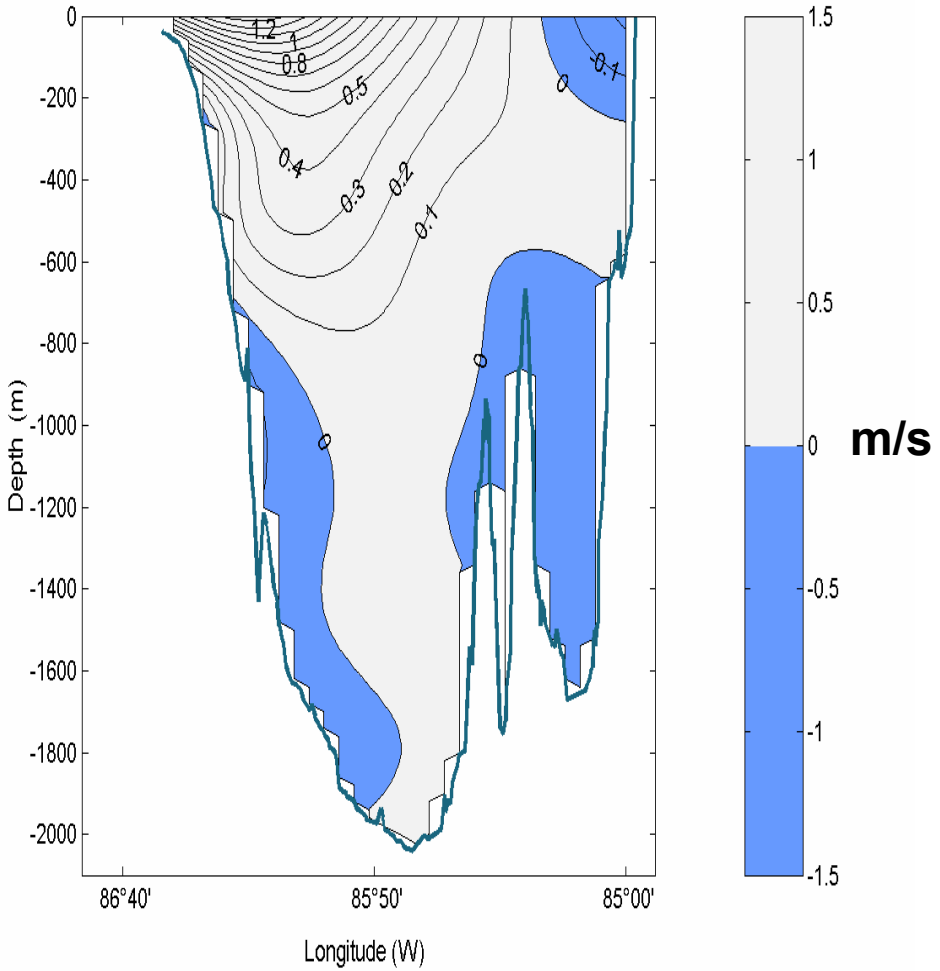
SUPPLEMENTAL SLIDES FOLLOW

Yucatan Channel Normal Velocity

0.08° ATL HYCOM 1-Year Mean



Observed Mean 8/1999-6/2000 (Abascal, et. al, 2001)



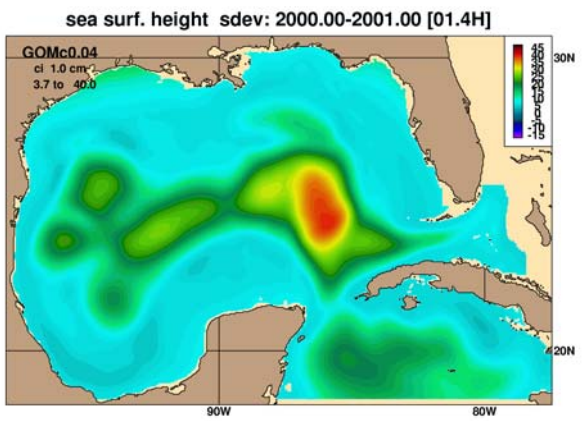
Note: section and sample period not identical

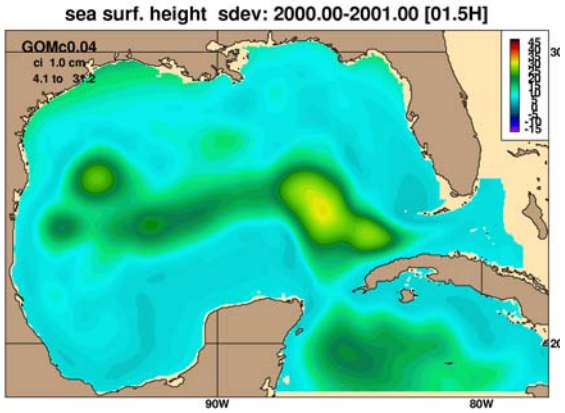
1/25° Free-Running Gulf of Mexico HYCOM

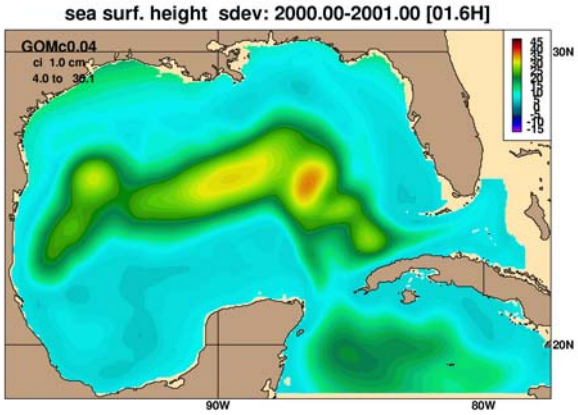
RMS SSH Variability

KPP | MY-2.5 | GISS

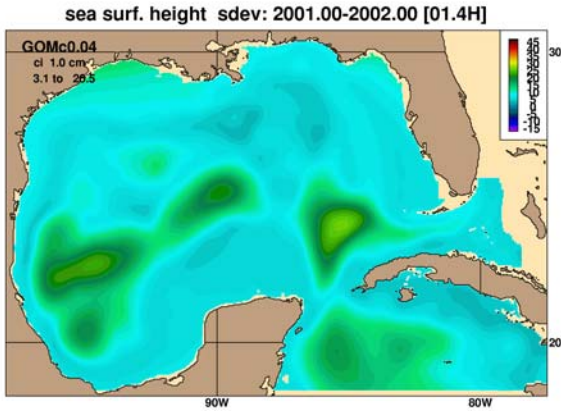
2000

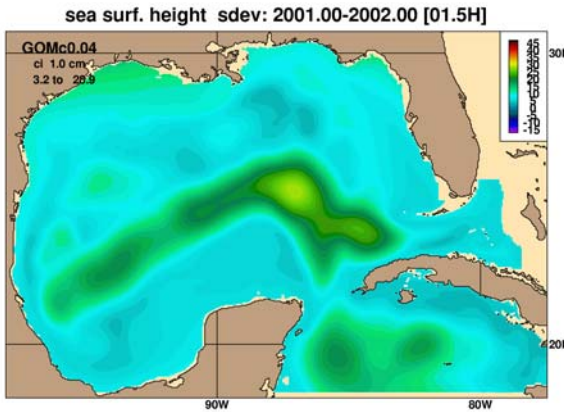


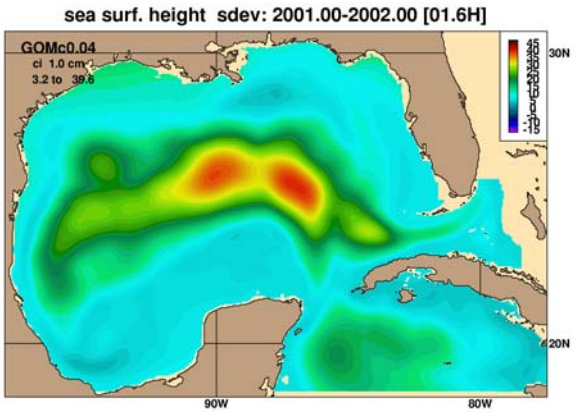




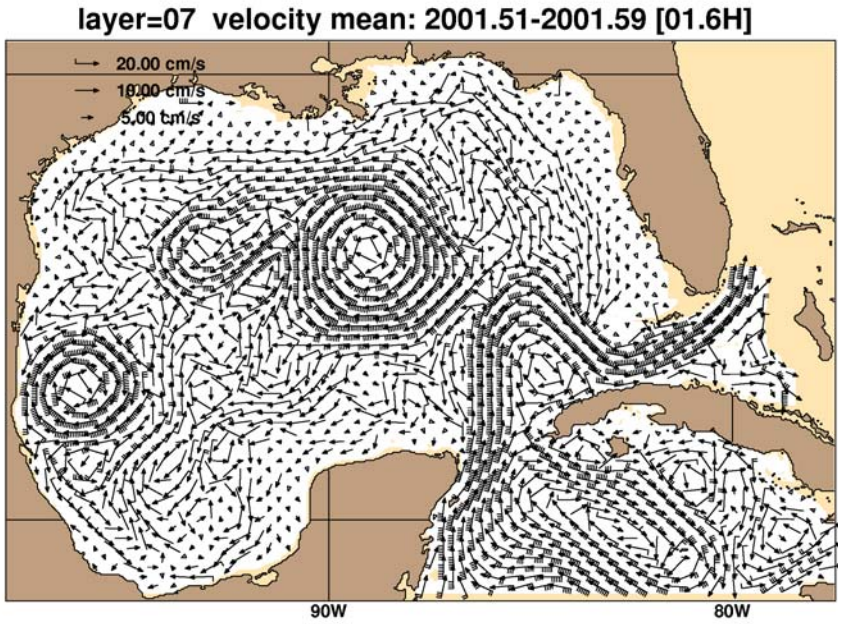
2001

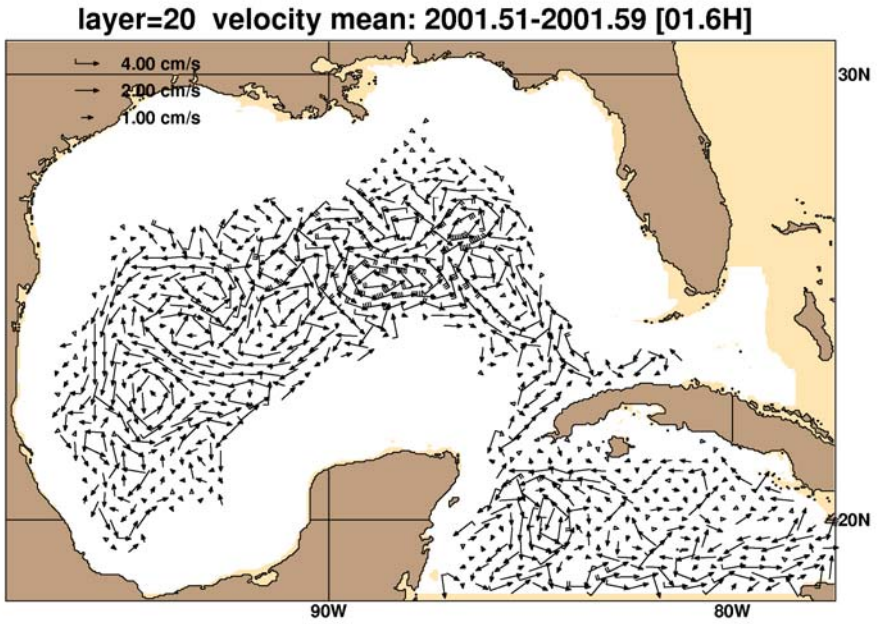


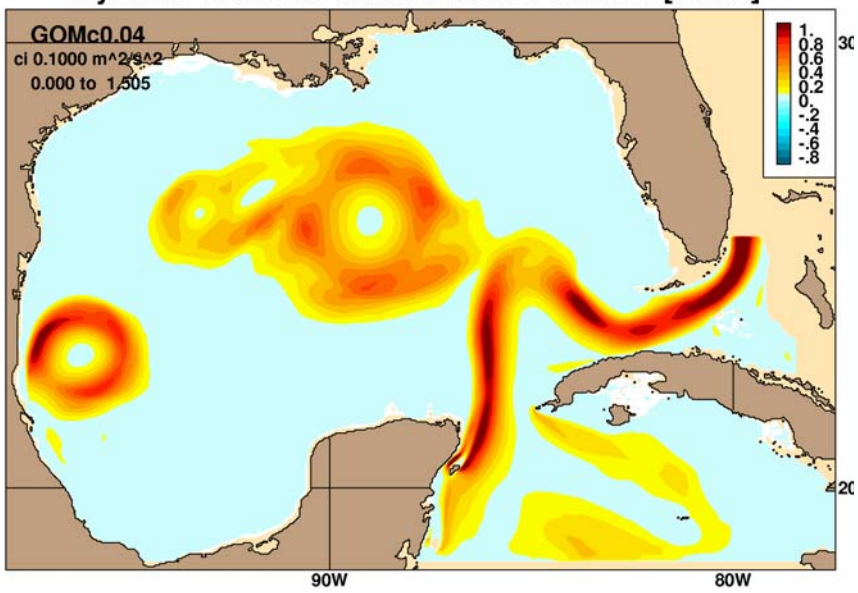


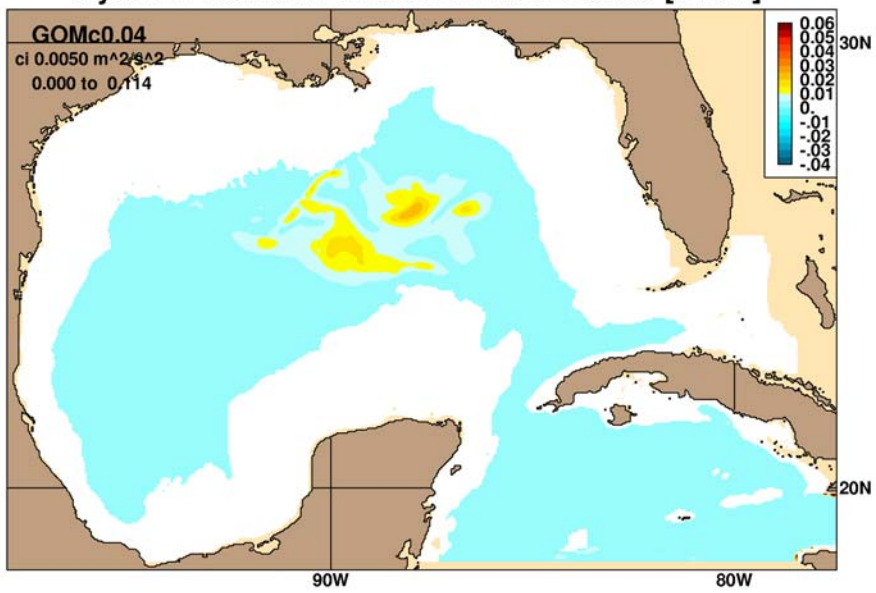


KPP variability low in 2001
MY-2.5 variability low in 2000 and 2001
Need longer time series for meaningful statistics


layer=07 velocity mean: 2001.51-2001.59 [01.6H]
20.00 cm/s
10.00 cm/s
5.00 cm/s
90W
80W


layer=20 velocity mean: 2001.51-2001.59 [01.6H]
4.00 cm/s
2.00 cm/s
1.00 cm/s
30N
20N
90W
80W


layer=07 ke/mass mean: 2001.51-2001.59 [01.6H]
GOMc0.04
ci 0.1000 m^2/s^2
0.000 to 1.505
1.
0.8
0.6
0.4
0.2
0.
-.2
-.4
-.6
-.8
90W
80W


layer=20 ke/mass mean: 2001.51-2001.59 [01.6H]
GOMc0.04
ci 0.0050 m^2/s^2
0.000 to 0.114
0.06
0.05
0.04
0.03
0.02
0.01
0.
-.01
-.02
-.03
-.04
30N
20N
90W
80W