Topographic Control of the Gulf Stream

Ocean Model Working Group Meeting

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Current Model Biases

(C°) (g/kg)

C.1 Project Description – Type I: Topographic Control of the Gulf Stream

The ocean is an integral component of the global climate system, and credible climate projections on the annual to decadal time scale must include a coupled ocean module. All modern ocean general circulation models (OGCMs) exhibit a number of biases, i.e. persistent deviations of model ocean structure from observed ocean structure, having deleterious impacts of various magnitudes on the quality of any climate prediction. Amongst the most notable and troubling of these involve the separation and subsequent pathway of the Gulf Stream/North Atlantic Current. The impacts of this are several, including large errors in model hydrography in the subtropical and subpolar North Atlantic (see Fig. 1). Biases as major as these erode the reliability of model climate projections, particularly on the decadal time scale.

Fig. 1. Community Climate System Model (CCSM) biases in sea surface temperature and salinity. The top row shows model climatological SST and SSS and the bottom row the difference between the model and observations. The biases in excess of 6°C and 3PSU in the North Atlantic are associated with errors in the Gulf Stream separation and trajectory.

The defining structural aspect of this particular bias is the strong interaction of the Gulf Stream

NCAR Role

Examine CCSM-POP 1° model through a systematic study of model bathymetry, parameterization, and parameter choices with a particular view toward the Gulf Stream and the separated North Atlantic Current

Included considerations:

- Bottom topographic features
- Degree of topographic smoothing
- Horizontal viscosity formulation
- Strength of deep western boundary current

UCLA and FSU

Using embedded high resolution models to investigate influence of the boundary on flow and potential parameterizations

Goals

- Improve understanding of controls on Gulf Stream path and strength
- Propose a parameterization to improve upon Gulf Stream representation in POP2

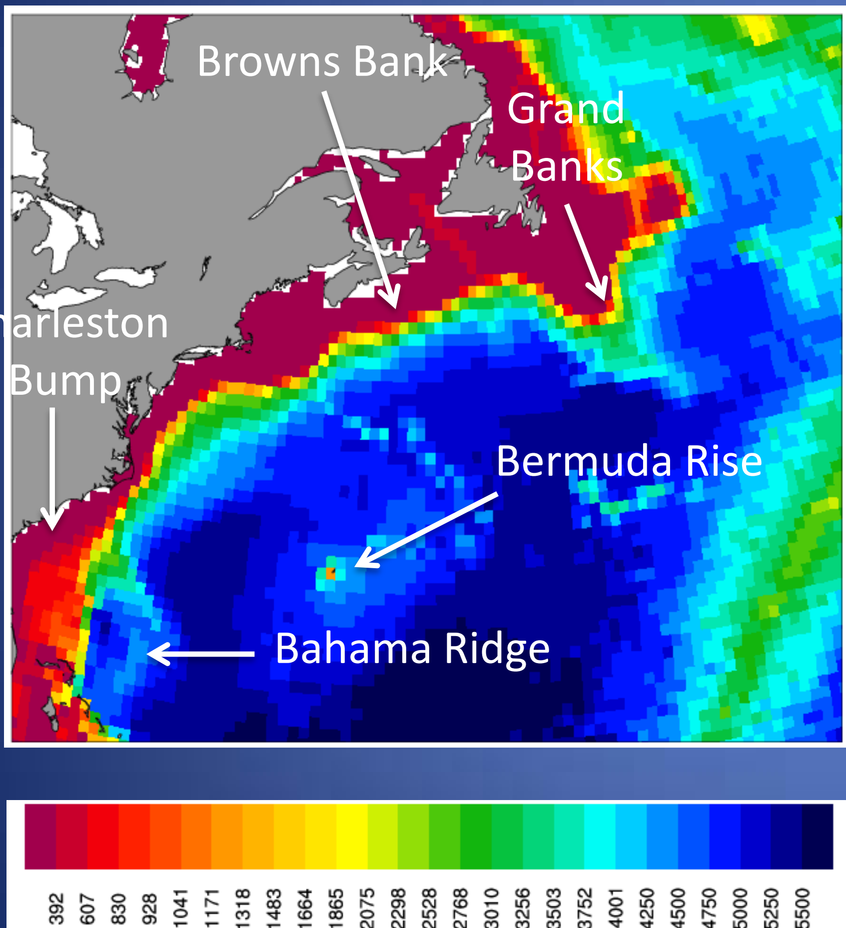
Bottom Topography in CCSM4

Data source: ETOPO2 (2’x2’) topography

1. Averages ETOPO2/ETOPO1 over nominal 1° model grid boxes
2. Adds standard deviation of depth (if requested)
3. Minimum depth of 5 meters
4. Smoothes depth field as requested (9pt smoother)
5. Maps the depth field to the model discrete levels (kmt, 60 levels)
6. Removes isolated points
7. Minimum kmt of 3
8. Handedits for overflows, passage ways, land/ocean mask, topographic features, etc. (subjective)
9. Use ETOPO2 everywhere except in North Atlantic where the modified ETOPO1 data is used.

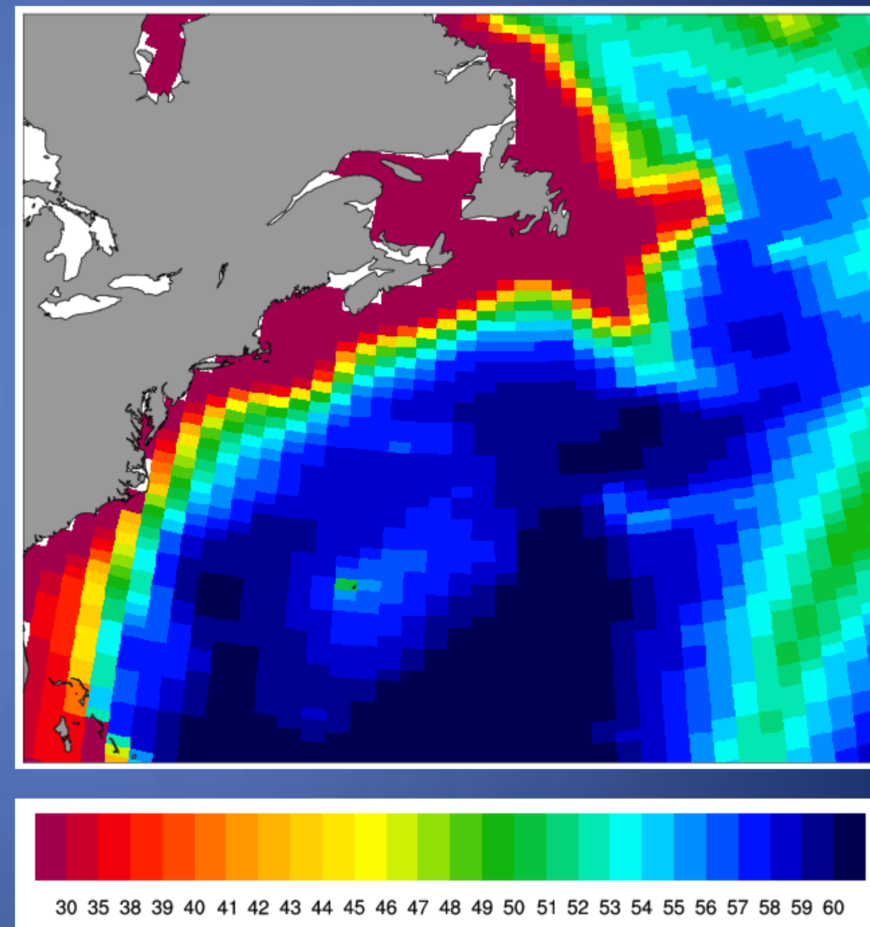
ETOPO2 to model grid

ETOPO2 30’ average



Depth in meters

ETOPO2 converted to model levels



KMT level

Experiment Description

Details

- Constant 1850 conditions
- 30–year integrations – bias develops immediately
- Initialized with Levitus temperature and salinity
- Only modify topography in North Atlantic
- Average the last 20 years for analysis
- SST/SSS current metrics

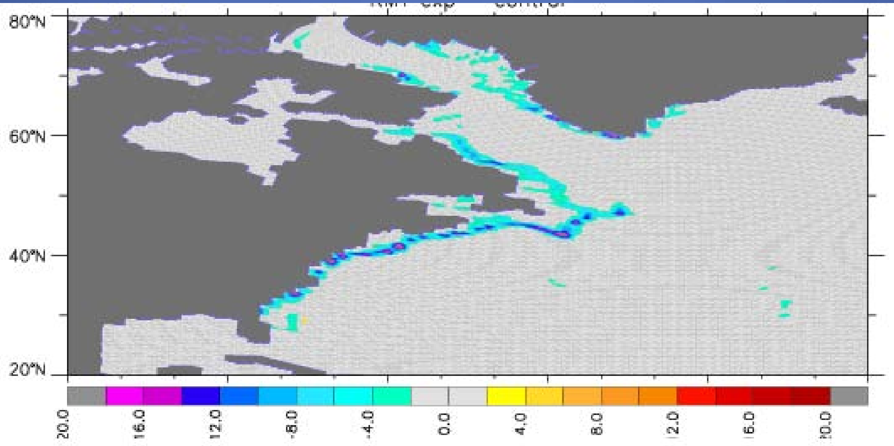
Categories

- Topography Resolution – ETOPO1/2
- Smoothing
- Standard Deviation of depth
- Topographic Features
- Lateral Viscosity
- Enhance Deep Western Boundary Current

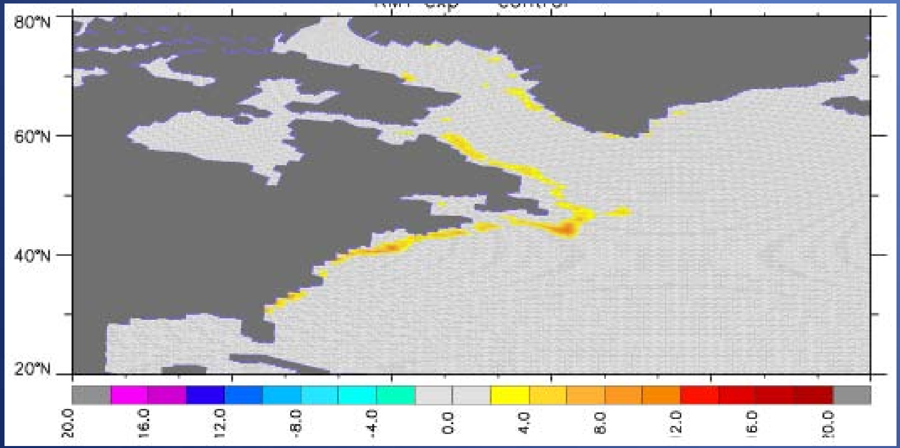
Smoothing Experiments: KMT Difference

Control Simulation = ETOPO1, depth smoothed once, removed isolated points

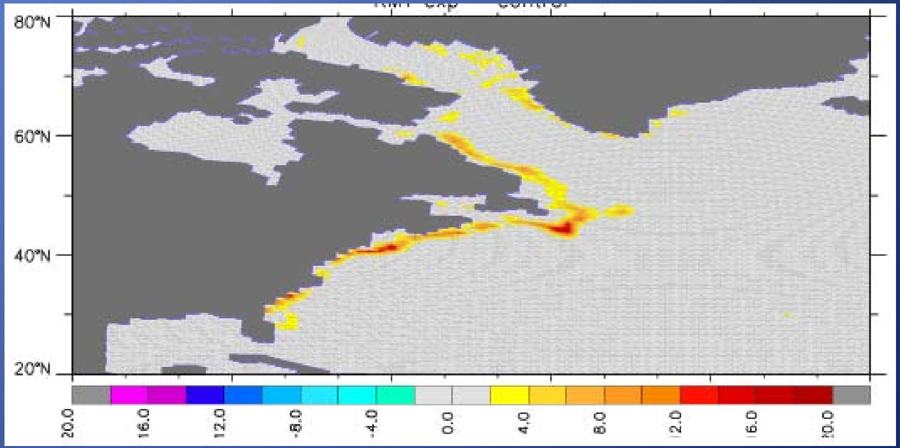
No smoothing - control



Smoothed twice - control



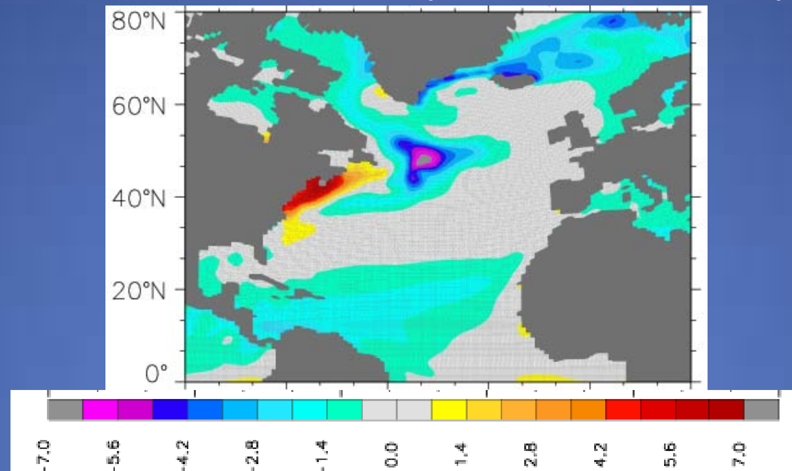
Smoothed 3 times - control



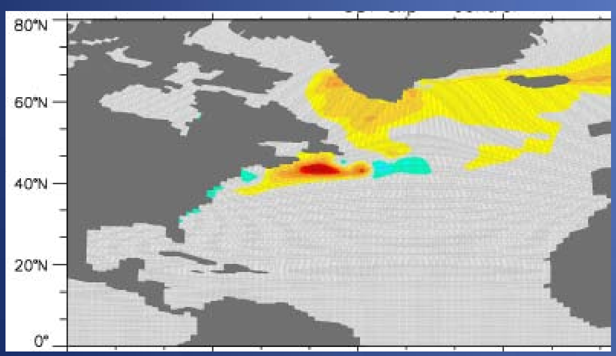
Smoothing increases depth along the continental shelf/slope.

Smoothing Experiments: SST (°C)

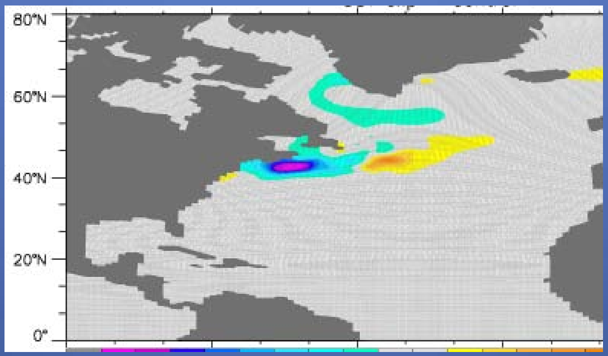
Control Model Bias (smoothed once)



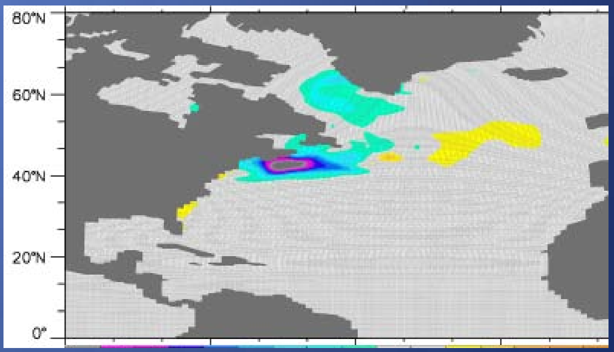
No smoothing - control

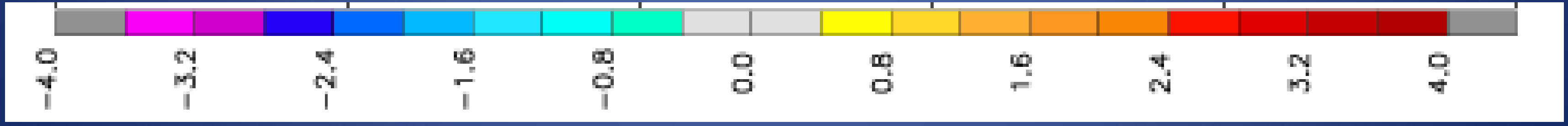


Smoothed twice- control



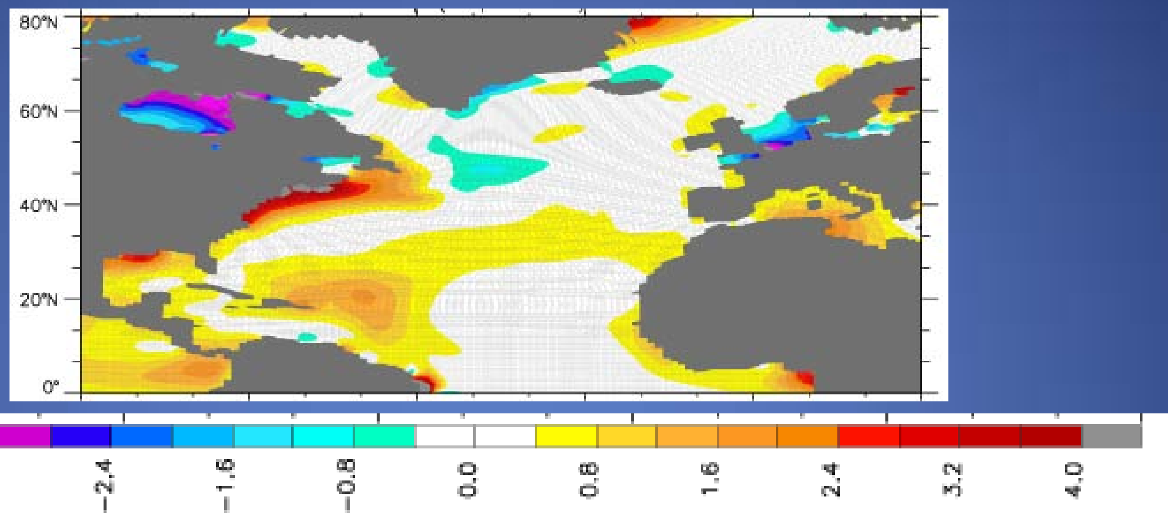
Smoothed 3 times - control



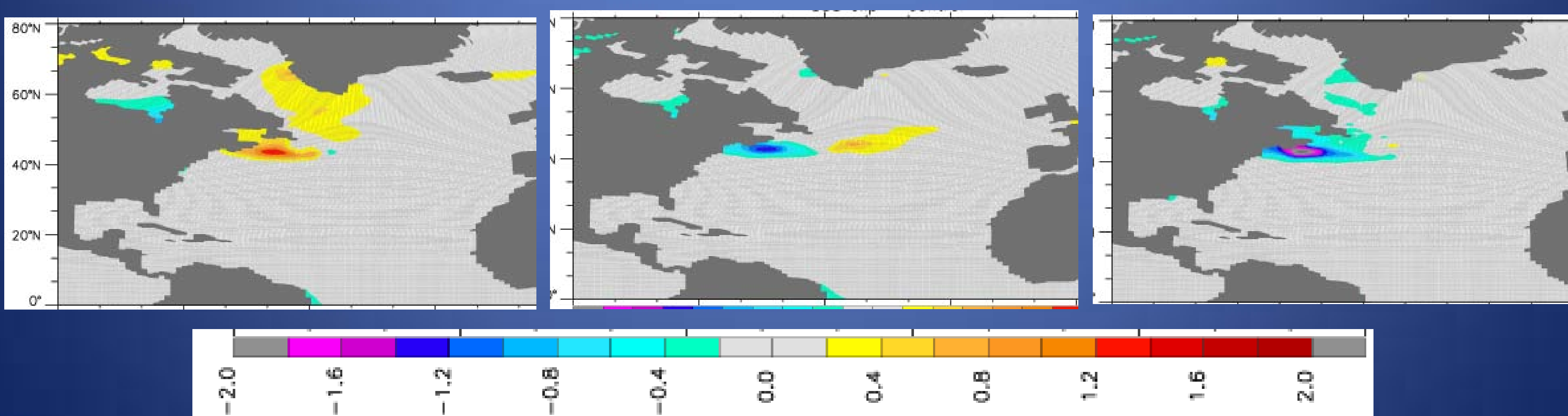


Smoothing Experiments: SSS (g/kg)

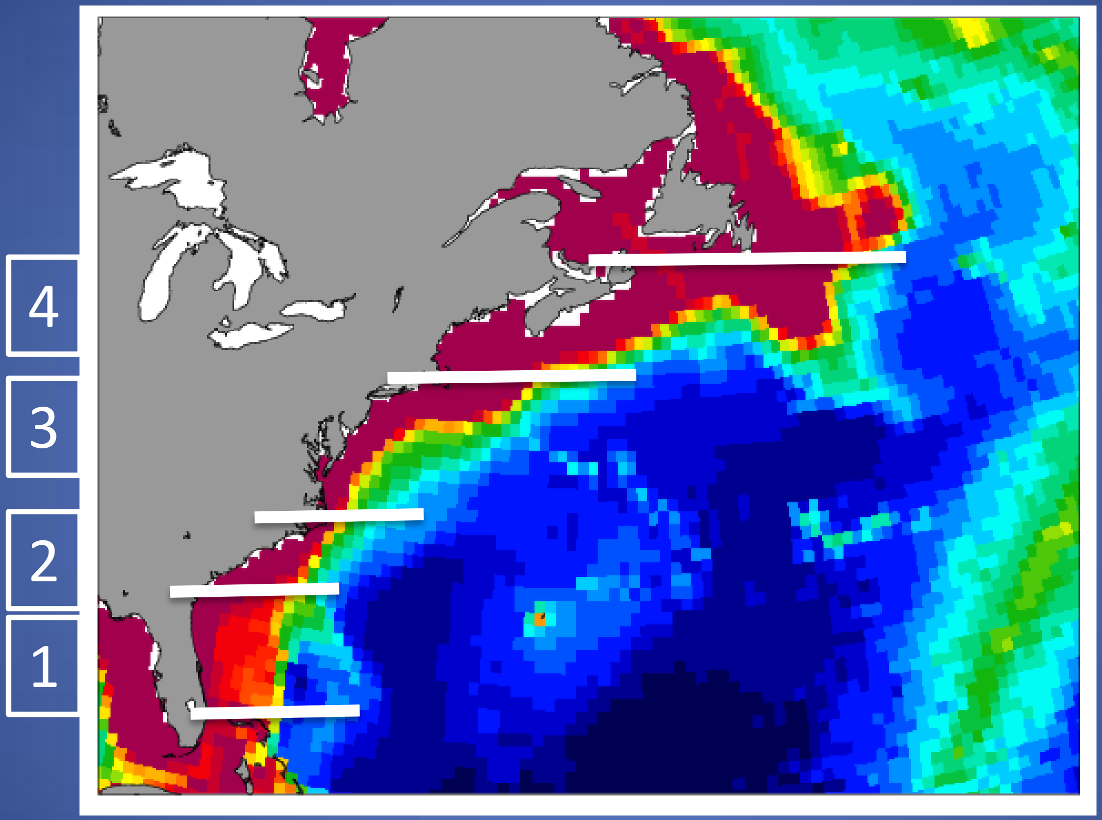
Control Model Bias (smoothed once)



No smoothing - control | Smoothed twice- control | Smoothed 3 times - control

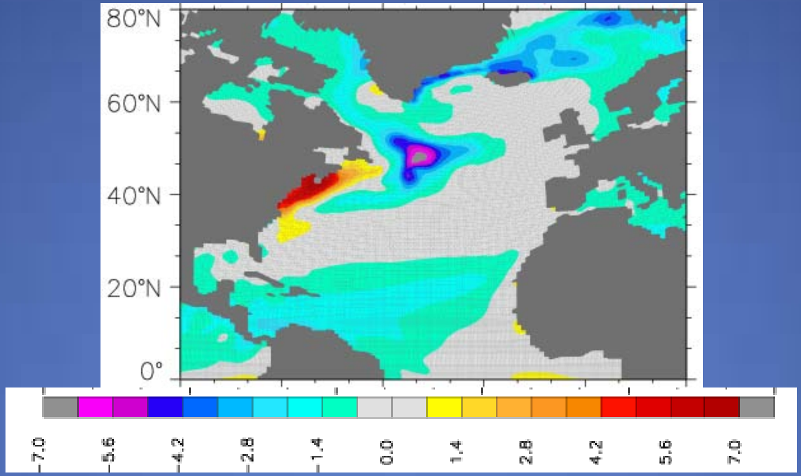


Segmented Coastline Experiments
Smoothed 3 times

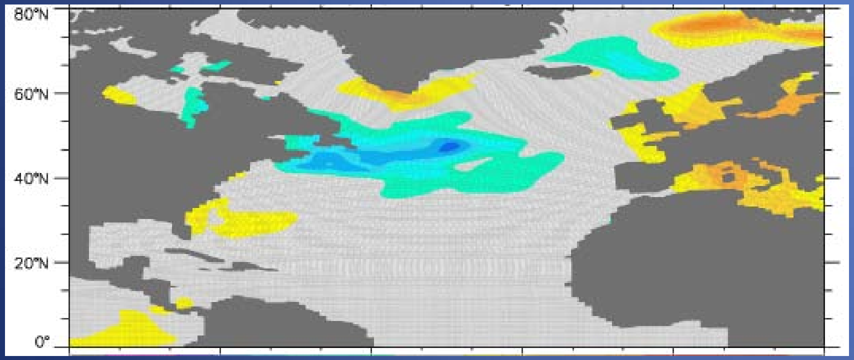


Segment Experiments: SST (°C)

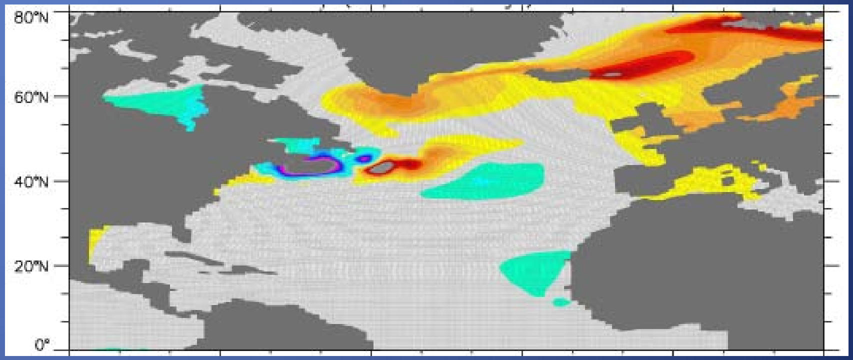
Control Model Bias (smoothed once)



Segment 1 - control

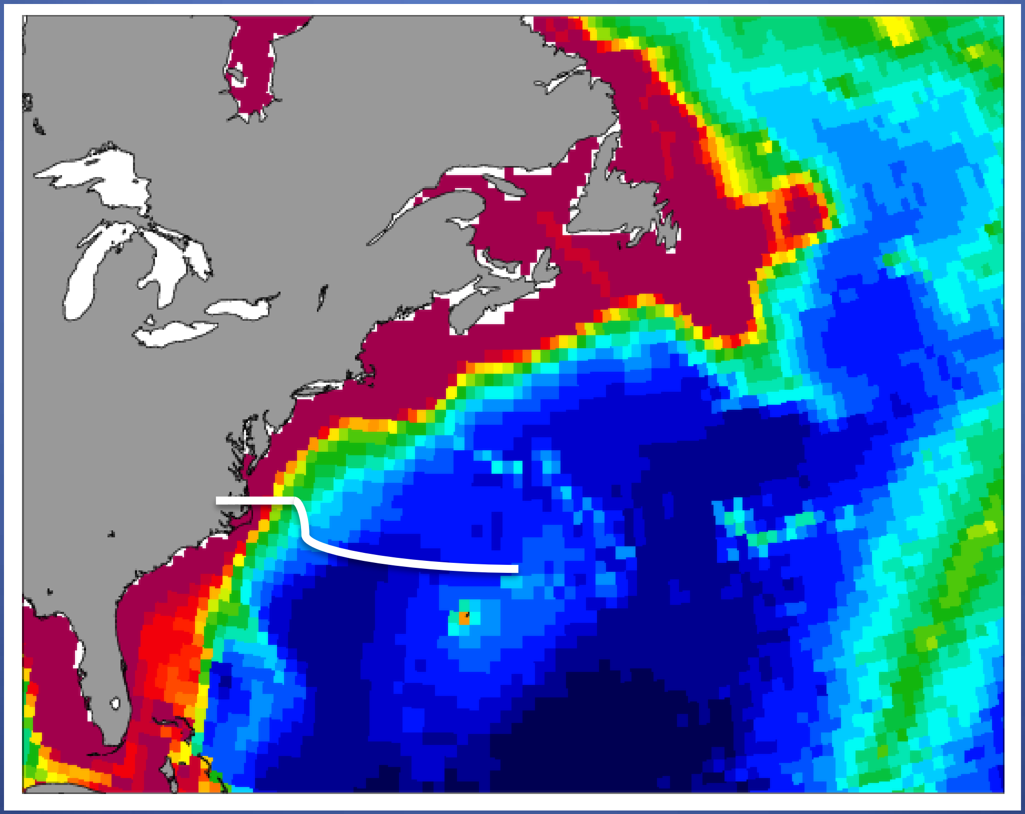


Segment 4 - control



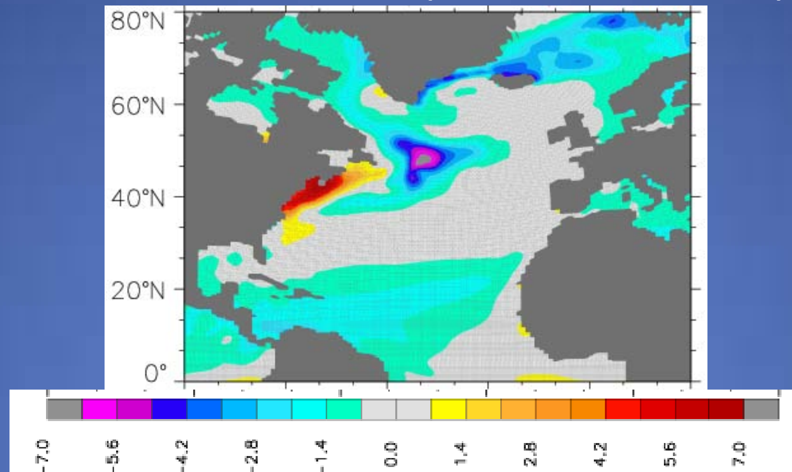
Lateral Viscosity Experiments

Control Simulation = ETOPO1, smoothed once, removed isolated pts
Experiments = increase / decrease lateral viscosity (0.6 e7 cm^2/s), widened viscosity “shelf, and decreased and narrowed “shelf”

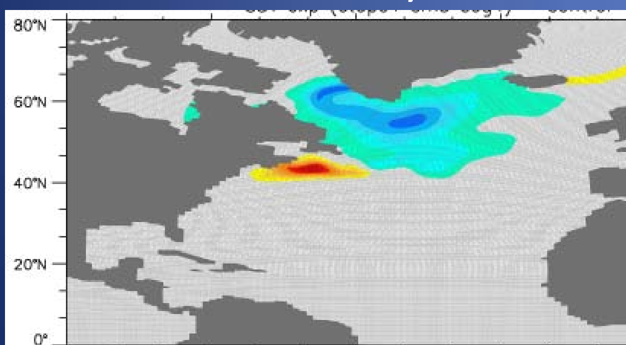


Viscosity Experiments: SST (°C)

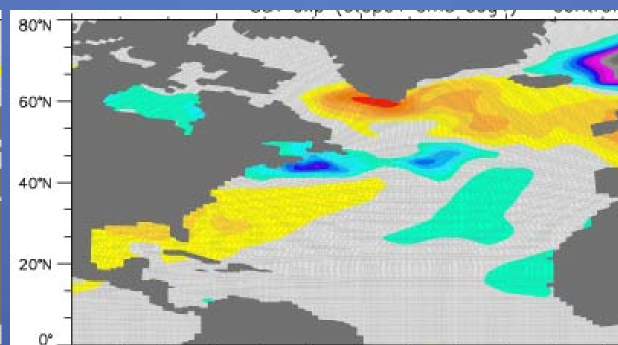
Control Model Bias (smoothed once)



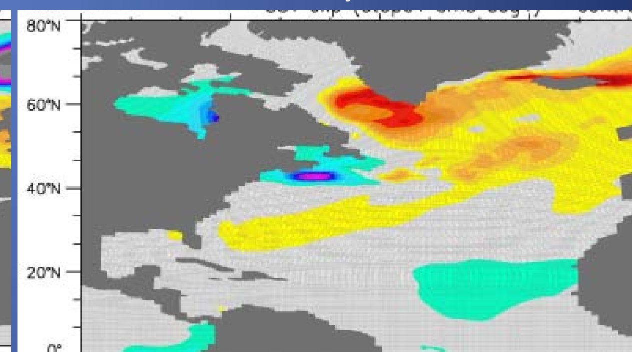
Increased viscosity - control

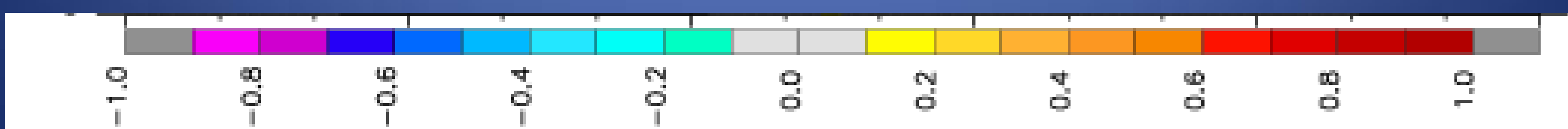


Widened “shelf” - control



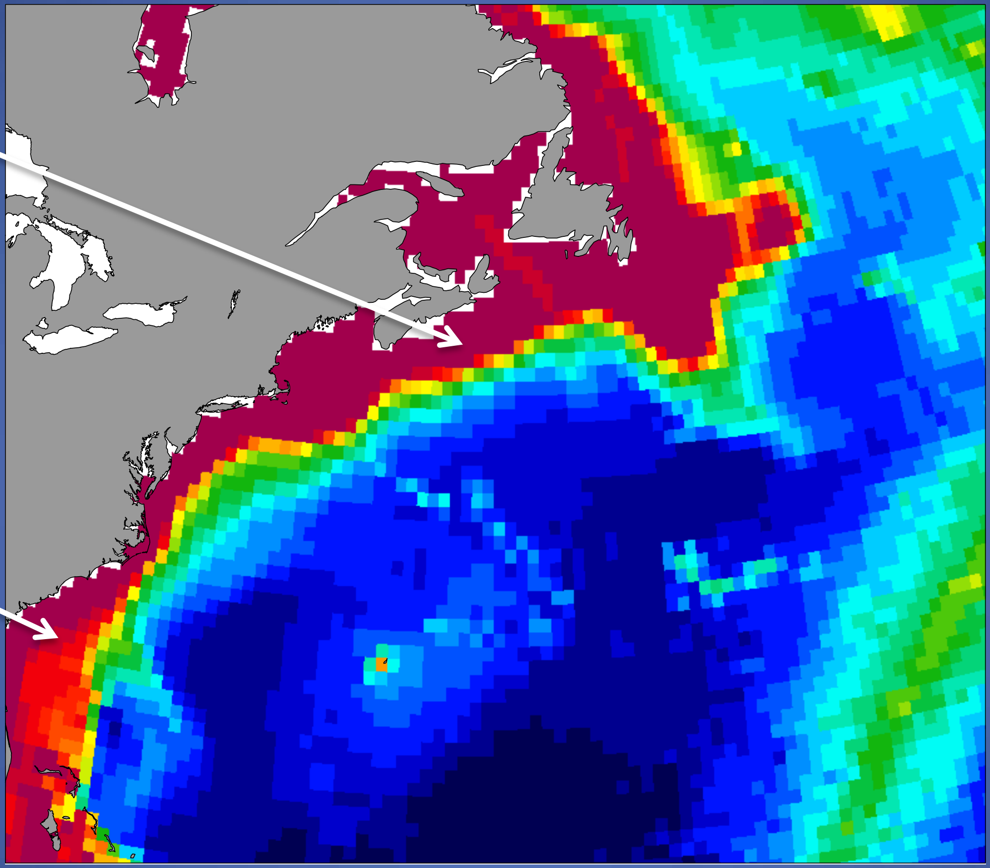
Decreased/narrowed viscosity- control





Topographic Feature Experiments

Based on ETOPO 2' data (30' average)

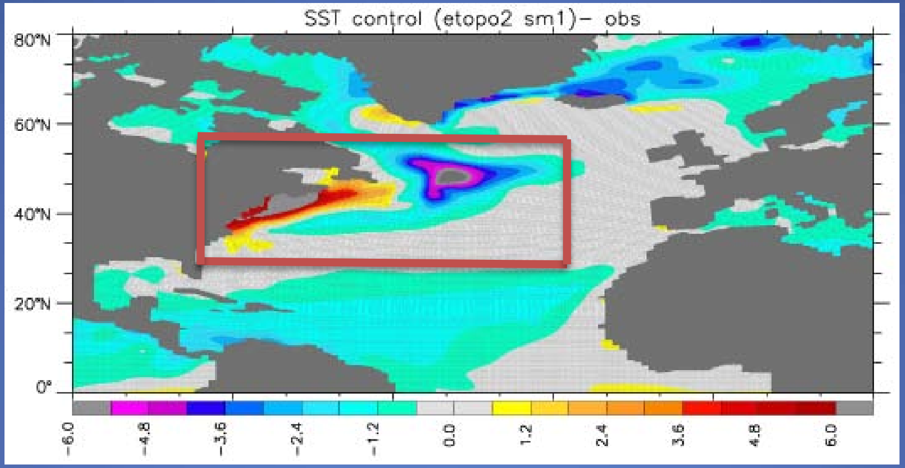


Browns Bank

Charleston Bump

Depth in meters

RMS in Bias Region



RMS in Bias Region

Experiment	SSS RMS	SST RMS
ETOPO2 Control	1.00	2.01
ETOPO1 Control	1.03	2.09
No smoothing	1.08	2.11
Smoothed twice	0.89	1.84
Smoothed 3 times	0.84	1.88
No smoothing, plus 1 std	1.13	2.36
No smoothing, minus 1 std	1.32	2.16
Deepen Browns Bank (sm1)	1.00	2.07
Shallow Browns Bank (sm1)	0.98	1.96
Smoothed 3 times, segment 1	0.98	2.08
Smoothed 3 times, segment 2	1.04	2.23
Smoothed 3 times, segment 3	0.98	2.05
Smoothed 3 times, segment 4	0.94	1.89
Decrease lateral viscosity	0.99	1.94
Increase lateral viscosity	1.09	2.38
Widen lateral viscosity shelf	0.98	2.00
Decrease, narrow viscosity shelf	0.97	1.91

Summary

- Deepening the shelf break in general seems to help
  - Except deepening by standard deviation addition gives local benefits and degradations elsewhere
- Nothing made the solution much worse, but nothing made it much better either
- Less/more smoothing had opposite effects. This is not true for +/- one standard deviation.
- Local effects of topography are probably important
  - But probably not Browns Bank
  - Potentially Charleston Bump
- Segment 4 had the most impact, but perhaps because the largest smoothing occurred here
- Changes in lateral viscosity formulation have impacts, but is it due to DWBC changes?