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

This 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 model. All present 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 on the quality of any climate prediction. Amongst the most notable and troubling of these involve the separation and subsequent pathways of the Gulf Stream/North Atlantic Current. The impacts of this are several, including large errors in model hydrography in the sub-tropical and sub-polar North Atlantic (see Fig. 11). Biases as major as these arise due to the inability of model climate projections, particularly on the decadal time scale.

Fig. 2: Community Climate System Model (CCSM) biases in sea surface temperature and salinity. The top map shows model climatology for SSF and SSF and the bottom map the differences between the model and observations. The response in terms of TSF and SPRT in the North Atlantic are associated with errors in the Gulf Stream separation and recirculation. 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.
ETOP02 to model grid

- ETOPO2 30’ average
- ETOPO2 converted to model levels

Locations:
- Browns Bank
- Grand Banks
- Bermuda Rise
- Bahama Ridge
- Charleston Bump

Depth in meters

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
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 cm²/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

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