Evaluation and Improvement of Ocean Model Parameterizations for NCEP Operations

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• **Short-term goal:**
  – Improve ocean model performance in response to tropical cyclone (TC) forcing

• **Overarching goal:**
  – Improve performance of the ocean component of coupled hurricane forecast models
    • May reduce intensity forecast errors

• **Procedure:**
  – Evaluate ocean model simulations against satellite observations and against high-quality operational and targeted ocean observations
Ocean Model Evaluation (1)

- Ocean models still have significant errors and biases
  - Numerical algorithms
  - Sub-grid-scale parameterizations (e.g. vert. mixing)
  - Parameterizations of air-sea fluxes
- Comprehensive studies are required to understand how these factors combine to degrade ocean model performance
Ocean Model Evaluation (2)

- HYCOM is chosen as the ocean model
  - Future component of HWRF
  - Contains multiple choices of important numerical algorithms and sub-grid-scale parameterizations
- First comprehensive evaluation effort has been conducted for hurricane Ivan
- Results and recommendations for improving HYCOM performance have been communicated to NOAA/NCEP/EMC
HYCOM Ivan Experiments

• Run in Gulf of Mexico domain
• Forced by atmospheric model (27-km COAMPS model) blended with the NOAA/AOML/HRD H*WIND analysis to represent wind stress and wind speed within the storm
• Experiments
  – Control using default parameterizations based on prior model experience (but not with TC forcing)
  – Alternate experiments that varied horizontal resolution, vertical resolution, or a single parameterization
Hurricane Ivan Experiments (subset)

<table>
<thead>
<tr>
<th>Model Attribute</th>
<th>Control Experiment E1</th>
<th>Alternate Experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal resolution</td>
<td>0.04° Mercator</td>
<td>E2: 0.08° Mercator</td>
</tr>
<tr>
<td>Vertical resolution</td>
<td>26 layers, 4-8m in OML</td>
<td>E3: 21 layers, 8-15m in OML</td>
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<tr>
<td></td>
<td></td>
<td>E4: 31 layers, 3-5m in OML</td>
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<tr>
<td>Vertical mixing</td>
<td>KPP</td>
<td>E5: MY</td>
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<tr>
<td></td>
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<td>E6: GISS</td>
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<tr>
<td>$C_D$</td>
<td>Donelan</td>
<td>E7: Powell</td>
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<tr>
<td></td>
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<td>E8: Large and Pond</td>
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<td></td>
<td></td>
<td>E9: Large and Pond (cap)</td>
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<tr>
<td>Initialization</td>
<td>Data-assimilative ocean hindcast</td>
<td>E10: Shay and Jacob</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E11: Non-assimilative ocean simulation</td>
</tr>
</tbody>
</table>

Evaluated against Reynolds SST analyses and upper-ocean velocity profiles measured at ADCP moorings
Difference in SST cooling
Initialization Problems

- So far, have only used fields from the U. S. Navy HYCOM-based nowcast-forecast system
  - Correctly locates major ocean features
  - Large cold bias prior to many storms
    - This causes ocean to overcool during TC simulations
  - Cold bias relatively small prior to Ivan

- Will soon evaluate the NOAA/NCEP/EMC HYCOM-based Atlantic Ocean system (RTOFS)
<table>
<thead>
<tr>
<th>Model Attribute</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>Horizontal resolution</td>
<td>Up to 10 km is adequate (resolves scales of the eye and the eyewall)</td>
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<tr>
<td>Vertical resolution</td>
<td>Up to 10 m resolution in the ocean mixed layer is adequate</td>
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<tr>
<td>Wind stress drag coeff.</td>
<td>Donelan, Large &amp; Pond (capped at high wind speed) are reasonable choices (2.3-2.5 x 10^{-3} at wind speeds &gt; 30 m s^{-2})</td>
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<tr>
<td>Vertical mixing</td>
<td>KPP is optimum choice based on quality of momentum response at SEED moorings</td>
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<tr>
<td>Initialization</td>
<td>If the ocean initialization is poor, nothing else matters. This is true for both the location of ocean features and the accuracy of temperature, salinity, and density profiles in the upper ocean (e.g. the cold bias in the Navy product).</td>
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</table>
Future Plans

• Extend results to other storms
  – Other ocean regions
  – Storms with high quality, three-dimensional targeted observations before, during, and after passage

• Evaluate HYCOM in coupled TC forecasts
  – Work with NOAA/AOML/HRD modelers to include HYCOM in their HWRF-X model and evaluate ocean model performance