The US Navy’s Coupled Atmosphere-Ocean-Wave-Sea Ice System

Tim Whitcomb
Marine Meteorology Division
Naval Research Laboratory
## Descriptions of Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Atmosphere</th>
<th>Ocean</th>
<th>Sea Ice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>NAVGEM</td>
<td>HYCOM</td>
<td>CICE</td>
</tr>
<tr>
<td>Agency</td>
<td>DoD</td>
<td>DoD</td>
<td>DOE</td>
</tr>
<tr>
<td>Current Resolution</td>
<td>T359L50 (~37 km 50 levels)</td>
<td>GLBb0.08 (~9 km 41 layers)</td>
<td>GLBb0.08 (~9 km 4 layers)</td>
</tr>
</tbody>
</table>

**Mediator/Coupler:** Earth System Modeling Framework (ESMF)/National Unified Operational Prediction Capability (NUOPC)
System Design
Interactions with Atmospheric DA

Mean analysis difference of 2m Temperature between NAVGEM w/CICE5 and NAVGEM control for May 2014.
Products & Skill Assessment
Sub-seasonal diagnostics for the ESPC system are under development

**Existing diagnostics:**

- RMMI MJO index
- AO/AAO indices
- Equatorial and regional precipitation diagnostics
- SST bias/error
- Mixed layer characteristics
- Surface currents
- Sea Ice percentage/volume

**Planned:**

- NAO
- Monsoons
- Tropical cyclogenesis/tropical depressions tracking
- Extreme events.
Considerable progress has been made in representing the Nov. 2011 DYNAMO period MJO events.

Propagation across the Maritime Continent remains a challenge.

Preparations for ensemble tests are underway.
Prediction of ENSO (El Nino – Southern Oscillation) events in the coupled system will require a realistic ocean response to westerly wind bursts associated with the MJO.

Simulated zonal current development associated with the westerly wind burst during the second MJO episode during DYNAMO (left). Diagnosed impact of currents on surface latent-heat flux (right).

Ocean Response to MJO  Feedbacks to Atmosphere Through Current effect on Surface Fluxes

Day
Nov 24
Nov 28
Dec 2

Zonal Current
Impact of Currents on Surface Latent Heat Flux

Westerly wind burst in ESPC coupled system hindcast – too strong and overly extensive.
Separation of predicted surface drifter trajectories are compared for the last 30 days of the hindcast.

While the sample size is small, the hindcast error is only slightly larger than a standalone ocean-only analysis.

Drifter trajectories are not assimilated in the analysis.
Wave Watch 3 has been implemented on the ESPC tri-pole grid.

Data models are used for the ocean and atmosphere, importing:
1) ocean sea level
2) 10 m wind speeds (vector)
3) surface currents (vector)
4) ice concentration

The currents are doing the following to the wave model:
1) shifting energy in frequency space
2) changing effective wind stress
3) refracting wave energy

The short animation shows the spinup of waves from strong storms in the North Atlantic and North Pacific (regions where curvature of the tri-pole grid occurs) and intensification of waves by the Gulf Stream.
Requirements for Future Development
• Weakly coupled DA
  – Scripting for Atmospheric DA is set up
  – Need scripting for Ocean/Ice DA
  – Need scripting to combined Atmospheric and Ocean/Ice DA

• Ensemble Hindcasting
  – Time Lagged currently possible, but not routinely used
  – Exploring Possible more complex Ensemble Options (e.g., perturbed obs.)

• Tighter Coupling Between NAVGEM and CICE

• Diagnostics!
Readiness For Research
Current Status

1) The NAVY ESPC System is being used for 30 – 50 day hindcasts in research mode in preparation for operational implementation in 2018.

2) Initial states currently come from component model analyses. A coupled system data assimilation capability is not yet in place.

3) Combined ONR/NRL funding, coupled system hindcasts and participation with an early version of NAVGEM in the joint MJO Task force/YOTC/GEWEX international model intercomparison project, “Vertical Structure and Diabatic Processes of the MJO”, have contributed to considerable progress towards improving the representation of the MJO in the system.

4) Arctic sea ice summer melt hindcasts for 2014 are within the range of dynamical models participating in the Sea Ice Prediction Network (SIPN).
EXTRA SLIDES
MJO Rainfall Prediction - 50-Day Integration from November 1, 2011

Propagation across the Maritime Continent Remains a Challenge