Seasonal effects of Indian Ocean freshwater forcing in a regional coupled model

-Barrier Layers and Indian Monsoon-

Hyodae Seo, Shang-Ping Xie
Raghu Murtugudde, Markus Jochum, Art Miller

IPRC Symposium
June 2, 2009
Outline

• **Background**
  
  River discharge ➔ Freshwater flux ➔ Barrier layers (BLs) ➔ Heat flux and SST ➔ Air-sea interactions ➔ Monsoon precipitation

• **Tool**

  Regional ocean-atmosphere coupled model
Introduction: BLs and temperature inversion

Summer weak heat flux

BLs *decouple* dynamics and thermodynamics of the ocean by acting as a barrier to sub-thermocline water to mixed layer.
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Seasonal cycle of BLT

- Permanent feature persisting throughout the year (>10 months)
- BLs form during summer monsoon due to river discharge and rainfall
- Maximum in boreal winter.
- Expect more impacts of BLs during the winter time!

Mignot et al. 2007
Regional coupled model
Model and Experiment:
Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model

- Higher model resolution in the ocean and atmosphere.
- Dynamical consistency with the NCEP Reanalysis forcing.
- More complete and flexible coupling strategy.
- Parallel architecture.
- State-of-the-art physics implemented in RSM and ROMS.
- **Greater portability**

Seo, Miller and Roads, 2007
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<table>
<thead>
<tr>
<th>EXPs</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>SR</strong></td>
<td>SSS is restored to WOA05</td>
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<tr>
<td><strong>NoSR</strong></td>
<td>No SSS restoring</td>
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- Resolution: 25 km ocean and atmosphere
- Integration: 1993-2004
- Coupling: Daily
Simulated Salinity Fields

- In WOA05, the freshest water is found in BoB in both seasons.
- Too high salinity in NoSR
- SSS restoring removes error.
- So, we are adding a strong perturbations (>4 psu) in salinity fields.
Seasonal cycle of BoB Salinity and Temperature

- Largest salinity signal found in July-October.
- Temperature only marginally increases in summer.
- In winter, surface layer cools but the subsurface warms ➜ temperature inversion
Surface heat fluxes

(a) Net Heat Flux

Surface heat flux cooling

Summer: Weak heat flux ➔ near-isothermal structure

Winter: Surface heat flux cooling ➔ temperature inversion
Model Validation
• **Summer**: Warm east/cold west. Weak upwelling in the Arabian Sea and cold bias in BoB.

• **Monsoon rainfall** is excessive in the western and northern IO.

• **Winter**: SST is lower over the whole basin, but the rainfall bias is less than in summer.
Seasonal sensitivity of ocean and atmosphere to freshwater forcing
Summer response: SR-NoSR

- BLT increases ➔ MLD decreases
- BoB SST increases by 0.1-0.2°C.
- Amplitudes are not large
  1) Isothermal structure,
  2) Weak heat flux
- Equatorial changes in SSS/SST cause increases in rainfall
  ➔ This is not directly related to river flux forcing
Winter response: SR-NoSR

- BLT thickens substantially ➔ MLD shoals more than 25m (MLD in SR is ~5-25m)
- The entire northern Indian Ocean cools with significant change of SST by 1°C.

1) Max. BL and Min. ML
2) Heat flux cooling

- Divergence atmospheric flows ➔ enhances precip. in the ITCZ.
Conclusion and Future Work

• A fully coupled high-resolution regional climate model is used to find that it is in the boreal winter that freshwater flux from river discharge is most influential to the atmosphere
  1) Max. BLT and Min. of MLD
  2) Wintertime heat flux cooling and the temperature inversion

• **Summer precipitation is not sensitive to river discharge in BoB**, (n.b.: But, it is sensitive to equatorial changes in SSS/SST)
  1) Isothermal structure of the ocean
  2) Weak total heat flux

• **Future work**
  1) Treat the river discharge as a local forcing
  2) Better tuning of model parameter to reduce mean model bias
  3) Survey of BLs from coupled GCMs to detect robust sensitivity of monsoon
Thanks!