HYCOM Caspian Sea Modeling.

Part I: An Overview of the Model and Coastal Upwelling

By

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MOTIVATION

- Caspian Sea model set up
  - Resolution, vertical layers, atmospheric forcing, etc

- Upwelling along the eastern coast
  - Ability of HYCOM in producing upwelling

- Hybrid versus sigma–z simulations
  - Do they successfully generate the upwelling?
The Caspian Sea is **NOT** included in majority of OGCMs

<table>
<thead>
<tr>
<th>Resolution</th>
<th>OGCMs excluding the Caspian Sea</th>
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<tbody>
<tr>
<td>1/32°</td>
<td>NLOM (Wallcraft et al., 2003)</td>
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<td>NRL Layered Ocean Model</td>
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<tr>
<td>1/16°</td>
<td>MFSTEP (Pinardi et al., 2003)</td>
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<td>Mediterranean Forecasting System</td>
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<tr>
<td>1/12°</td>
<td>HYCOM (Chassignet et al., 2006)</td>
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<td></td>
<td>HYbrid Coordinate Ocean Model</td>
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<tr>
<td>1/12°</td>
<td>DMI (Buch and She, 2005)</td>
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<td>Danish Meteorological Institute</td>
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<tr>
<td>1/8°</td>
<td>NCOM (Barron et al., 2006)</td>
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<tr>
<td></td>
<td>Navy Coastal Ocean Model</td>
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<tr>
<td>1/3°</td>
<td>MERCATOR (Ferry et al., 2005)</td>
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<td></td>
<td>Mercator Ocean</td>
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</tbody>
</table>
| **Grid resolution:** | \([1/25^\circ \cos(\text{lat}) \times 1/25^\circ]\)  
\[ \approx 3.2 \text{ km} \] |
|----------------------|--------------------------------------------------|
| **Vertical layers:** | Two configurations  
25 layer hybrid and 30 level sigma–z |
| **Initialization:**  | Russian data–based T/S climatology |
| **Mixed layer:**     | K–Profile Parameterization (KPP) |
| **Bathymetry:**      | Modified DBDB–2 with the Russian data |
| **Bottom layer:**    | Active bottom boundary layer |
| **Atm. forcing:**    | ERA–40 climatology (1979–2002) |
| **River forcing:**   | Three major rivers as runoff |
| **Turbidity:**       | SeaWiFS ocean color data |
| **Bulk formulas:**   | Sensible and latent heat fluxes |
| **Relaxation:**      | Sea surface salinity only |
| **Assimilation:**    | None |
- DBDB–2 in the Caspian Sea is not correct.
- The Russian data set was used to modify it.
  - HYCOM uses land–sea isobath of 2 m.
  - Maximum depth is $\approx 1015$ m.
• Basin–averaged T/S from the Russian data
• Temperature gradually drops with depth.
• Salinity is constant \( \approx 11.8 \) psu below 50 m.
• Temperature has more effect on density.
- HYCOM reads in monthly mean river discharges.
- Runoff addition to the surface precipitation field.
HYCOM SIMULATIONS

- Use KPP mixed layer model
- Perform climatologically–forced simulations
- Run 5 years until statistical equilibrium
- Run another 4 years and form monthly means

As mentioned before, there is
  - no data assimilation, and
  - no relaxation except for sea surface salinity.
What is the importance of heat and salinity fluxes in simulating upper ocean quantities in the Caspian Sea?

Note: Net buoyancy flux is the sum of
  - buoyancy due to heat flux and
  - buoyancy due to salinity (i.e., E–P) flux.

- Four sensitivity simulations:
  - expt 1: standard simulation (30 level sigma–z)
  - expt 2: twin of expt 1 but **no** salinity relaxation
  - expt 3: twin of expt 1 but **no** E–P
  - expt 4: twin of expt 1 but **no** rivers
  - expt 5: twin of expt 1 but **no** E–P and **no** rivers
• Meridional averages of variables from 40.5°N to 45.0°N
UPWELLING NEAR THE EASTERN COAST

- Summer SST from AVHRR (16 June 2001)

AVHRR: Advanced Very–High Resolution Radiometer
• Snapshots of daily HYCOM SST from
  o 25 layer hybrid
  o 30 level sigma–z
• Existence of upwelling near the eastern coast

• We typically use daily MODAS SST as truth
  o because it is a satellite–based re–analysis product.
• However, it is not included in the movies
  o because MODAS has no SST in the Caspian Sea.
• Bias (°C) with respect to 4 km Pathfinder SST climatology

(a) 25 LAYER HYBRID
(b) 35 LEVEL SIGMA–Z

• Basin–averaged SST bias:
  \( \approx 0^\circ C \) for both simulations

• Large SST error near the eastern coast: Upwelling issues!!
RMS SST OVER THE SEASONAL CYCLE

- RMS (°C) with respect to 4 km Pathfinder SST climatology

(a) 25 LAYER HYBRID

(b) 35 LEVEL SIGMA–Z

- Basin–averaged RMS SST difference:
  - 1.4°C (1.2°C) for HYBRID (SIGMA–Z) simulation
SUMMARY and CONCLUSIONS

- **A fine resolution (∼ 3.2 km) HYCOM Caspian Sea model:**
  - model set up for hybrid and sigma–z coordinates
  - climatologically–forced simulations (no assimilation)
  - used coarse resolution (1.125°) ERA–40 forcing

- **Initial evaluations for upper ocean quantities:**
  - evidence of upwelling consistent with observations
  - net heat flux generally dominates E–P flux
  - SST is well simulated, even with no assimilation

- **Ongoing studies and future plans:**
  - processes controlling upwelling near the eastern coast
  - finer resolution (0.25°) European ECMWF forcing
  - inter–annual model simulations (1990 through 2006)