Using Dynamic Ocean Topography To Probe Southern Ocean Circulation
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Introduction

- **Motivation:** Mean Dynamic Ocean Topography (DOT) is the difference between the time-averaged sea surface and the geoid. Estimation of DOT is challenging since the time invariant sea surface height signal is overwhelmed by changes in sea surface height due to geoid. Accurate knowledge of the DOT is difficult in the Southern Ocean, because in situ observations are sparse. Nonetheless eddy-mean flow interactions and other key ocean circulation questions depend on the DOT.

- **Goals:** Quantify the differences between the suite of available geoids and corresponding DOT fields, produce a best-estimate DOT, and with uncertainty estimates.

- **Approaches:** (1) Statistical intercomparison of available DOT fields, (2) use assimilating model SOSE to assess which of the available DOT fields is most consistent with all other available Southern Ocean observations.

Mean Dynamic Ocean Topography Products

<table>
<thead>
<tr>
<th>DOT</th>
<th>time period</th>
<th>resolution</th>
<th>reference</th>
<th>type in short</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGM08</td>
<td>1993-2004</td>
<td>1/60 X 1/60</td>
<td>Pavlis et al. 2008</td>
<td>geoid + altimetry</td>
</tr>
<tr>
<td>MAXI</td>
<td>1992-2002</td>
<td>1/2 X 1/2</td>
<td>Maximenko, Niler 2005</td>
<td>hybrid</td>
</tr>
<tr>
<td>ATLAS</td>
<td>1993-2009</td>
<td>1/2 X 1/2</td>
<td>Gouretski, Jancke 1998</td>
<td>hydrography</td>
</tr>
<tr>
<td>SOSE</td>
<td>2005-2007</td>
<td>1/6 X 1/6</td>
<td>Mazloff et al. 2009</td>
<td>assimilating model</td>
</tr>
</tbody>
</table>

Hybrid approaches combine altimetry and geoid with other oceanic in situ measurements including hydrography and surface drifter data. The model challenge using surface drifter data is the wind slip bias. Hydrographic data provide dynamic height only with respect to a reference level.

Correction for Time Period

DOT products each represent a slightly different time period. Formally they should be corrected to a common date range. The sea level anomalies (panel A shows the differences between the 1993-1999 mean and the 2005-2007 mean) are up to 30 cm. However, the RMS differences in the products are not improved by the correction. (Panel B shows variance preserving zonal wavenumber spectra for a circumpolar latitude band between 55°S and 65°S. The Sea Level Anomalies (magenta) capture eddy scales, whereas the DOT are much smoother.

Differences

To compare the different fields, a constant offset equal to the average of each product between 64°S and 35°S is subtracted. The differences reflect both large-scale differences in ACC strength and more localized differences along the path of the ACC. Both ATLAS and MAXI predict weaker surface geostrophic flow as compared to the altimeter products. ATLAS could be biased to have low gradients due to neglected bottom flow.

The largest RMS differences are with the ATLAS product (panel B). The smallest RMS difference is between the two altimeter products Grace and EGM08 (not shown). The two hybrid products AVISO and MAXI show substantial differences (panel D).

Mean and Standard Deviation AVISO, MAXI, EGM08, GRACE

The standard deviation of the AVISO, MAXI, EGM08 and GRACE products (panel B) is ≤ 2 cm in 90% of the Southern Ocean. It reaches > 20 cm in localized areas where DOT gradients (panel D) are high and the surface flow is restricted by topography, such as Kerguelen Plateau, South of New Zealand, and in the Agulhas Retroflection. The standard deviation (panel B) is not high everywhere that eddy kinetic energy, as given by the time variability of DOT (panel C), is enhanced.

Assessing DOTS with the Southern Ocean State Estimate (SOSE)

SOSE optimizes model-data misfit for the region south of 25°S during the time period from 2005-2007. A cost function is used to compare the SOSE solution to in situ observations (Argo profiling floats, conductivity-temperature-depth, Southern Elephant Seals as Ocean Samplers, expendable bathythermographs, altimetric anomaly observations (Envisat, GOFO, TOPEX/Poseidon), and others. Reduction of the model-observation misfit is achieved by systematically estimating the control variables including prescribed atmospheric state and initial conditions in an iterative procedure. The present SOSE simulation is largely consistent with this wealth of data.

The model/data misfits are up to 50 cm. Most striking differences occur in the Southern Indian Ocean and Brazil Basin. Large-scale shift across the ACC implies different ACC strengths.

Summary

- DOT products all differ, in some locations by more than their nominal error bars.
- DOT products smooth over eddy scales and cannot trivially be corrected for time period.
- The differences have implications for mean transport of the ACC.
- SOSE shows dramatic misfits in a few key locations.

Outlook

- Interpreting misfits
- Perform more detailed scale analysis
- Analyse frontal positions and ACC transports
- Determine an uncertainty estimate for DOT products
- Conduct sensitivity experiments

References