Examining Drifter Velocity Measurements for Use in Constraining Climate Models

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I. Scientific Questions and Approach

- How good are surface circulations simulated in climate models?
- Can climate models be improved by incorporating surface drifter velocity measurements?
- Use surface circulation in latest state estimate from ECCO (Estimating the Circulation and Climate of the Ocean) as an example.
- Estimate data errors, including both instrumental errors and representation errors (signals in the data that cannot be represented by model physics and resolution)
- To weight the model-data misfits on timescales of daily, monthly and climatology.

II. Data

Global Drifter Program (GDP)

- Pseudo-Eulerian horizontal velocities at ~15 m derived from drifter locations
- Wind induced non-oceanic velocity and high frequency signals (e.g., tides and inertial motions) removed

Estimating the Circulation and Climate of the Ocean (ECCO)

- ECCO describes the ocean state by fitting a general circulation model (MITgcm) to observations in a weighted least square sense.

Ocean Surface Current Analysis Real-time (OSCAR)

- OSCAR represents altimetry-derived geostrophic and wind-stress-estimated Ekman components.

<table>
<thead>
<tr>
<th>product</th>
<th>depth</th>
<th>temporal scales</th>
<th>spatial scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>~15 m</td>
<td>6 h</td>
<td>a few km</td>
</tr>
<tr>
<td>ECCO</td>
<td>~15 m</td>
<td>1 day</td>
<td>~20 km to ~100 km</td>
</tr>
<tr>
<td>OSCAR</td>
<td>upper 30 m</td>
<td>5 day</td>
<td>1/3 degree</td>
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III. Surface Currents in ECCO and GDP

- Daily GDP and ECCO velocities: processed to same temporal and spatial coverage.

IV. GDP Instrumental and Representation Errors

Daily and Monthly Timescales:

Measured velocity $D$ and modeled velocity $M$ consists of true value $s$ and errors $\varepsilon_D$ and $\varepsilon_M$: $D = s + \varepsilon_D$ and $M = s + \varepsilon_M$. Data error variances $\text{var}(\varepsilon_D)$ can be derived as

$$\text{var}(\varepsilon_D) = \text{var}(D) - \text{cov}(D, M)$$

where $\text{var}$ and $\text{cov}$ are variances and covariances. Equation (1) holds if $\text{cov}(s, \varepsilon_D)$, $\text{cov}(s, \varepsilon_M)$ and $\text{cov}(\varepsilon_D, \varepsilon_M)$ can be neglected. To avoid unphysically large estimates of $\text{var}(\varepsilon_D)$ from (1), we arbitrarily cap $\text{var}(\varepsilon_D) \leq 90\% \text{var}(D - M)$.

Climatology 1992-2017:

Data errors are estimated to be the absolute value of difference between GDP and OSCAR climatologies.

V. Constraining ECCO Velocity Field

The model-data misfits against estimated data errors (i.e., cost) are used to examine whether constraining ECCO velocity using drifter data could be important. Cost is calculated as:

$$\text{cost} = \frac{\text{var}(D - M)}{\text{var}(\varepsilon_D)}$$

Regions with cost values $>1$ are where ECCO velocities deviate from the measurements by more than expected from considering instrumental and representation errors.

VI. Summary

- ECCO surface currents tend to be weaker and less variable than GDP measurements.
- Constraining ECCO solutions to GDP data may have an impact on mean surface velocity estimates, but not so much on daily and monthly values, except mostly in equatorial regions.