Ocean circulation generated magnetic signals and their application in data assimilation methods

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Motivation

- The ocean is a very complex system

- Dynamics on many temporal and spatial scales (periodic and non-periodic), e.g.:
  - Tides
  - Seasonal cycles
  - Global circulation
  - Tsunamis
  - Eddies

- Even a 'perfect' model does not necessarily produce realistic model results
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  - Tides
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- Even a 'perfect' model does not necessarily produce realistic model results
- Using **data assimilation methods** and real world data, the modelling of unknown model variables can be improved
- Modern satellites (e.g. SWARM) indirectly measure global ocean flow via **induced magnetic signals** with unprecedented precision
Motivation – Motional Induction

- Conducting sea water moves in the ambient geomagnetic field of the Earth
- Electrically charged ions in the salt water are deflected by the Lorentz’ force
- Spatial charge accumulations lead to induction of electric and magnetic fields ("motional induction")
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- Significant contribution to the magnetic field (several nano Teslas) that can be measured by satellites (e.g. CHAMP, SWARM)

- Oceanic contributions are mostly of unknown order, precision and origin

- Motionally induced magnetic field data as additional information for modelling global ocean dynamics
Expected results and perspectives

- Range of oceanic magnetic signals induced by global ocean circulation (strength, location and variability)

- Uncertainty of oceanic magnetic signals (forcing, conductivity distribution, covariances)

- Robust spatio-temporal patterns and correlations, i.e., features with small errors that are insensitive to uncertain assumptions
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Implemented the modelling of oceanic induction in the Ocean Model for Circulation and Tides (OMCT)
Motionally induced Magnetic Field

**Mean values** of the induced magnetic field due to global ocean circulation at **sea level** (2001)
Motionally induced Magnetic Field

Mean induced magnetic field, superimposed by mean ocean velocities (arrows) and ambient geomagnetic field (contour)
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Induction is strongest where ocean flow velocities are orthogonal to the isocontours of the ambient geomagnetic field
Motionally induced Magnetic Field

**Mean values** of the induced magnetic field due to global ocean circulation at **sea level** (2001)

**Mean values** of the induced magnetic field due to global ocean circulation at **450 km satellite altitude** (2001)

- Weaker signal strength at satellite altitude due to harmonic field continuation
- Small scale patterns and details are blurred
- Large scale patterns are preserved
Motionally induced Magnetic Field

**Variability** (standard deviation) of the induced magnetic field due to global ocean circulation at **sea level** (2001)
Motionally induced Magnetic Field

**Variability** (standard deviation) of the induced magnetic field due to global ocean circulation at **sea level** (2001)

<table>
<thead>
<tr>
<th>Sea level</th>
<th>Signal range</th>
<th>Standard Deviation</th>
<th>Peak to Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>-6 to 4 nT</td>
<td>≤ 0.6 nT</td>
<td>≤ 4 nT</td>
</tr>
<tr>
<td>Satellite altitude (450 km)</td>
<td>-2 to 2 nT</td>
<td>≤ 0.2 nT</td>
<td>≤ 1.5 nT</td>
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</tbody>
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Combine found ocean dominated patterns with derived error information

Identify separable ocean signals in observation data provided by satellite measurements

Long term goal: inversion/assimilation of observation to improve global ocean modelling and simulations
Thank you for your attention!