Southern Ocean processes
Introductory remarks

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Reasons the Southern Ocean (>30°S) is so important to understand

It accounts for

- Half of the current anthropogenic carbon dioxide uptake
- About 60% ± 20% of excess heat uptake
- Nutrients supporting three-quarters of biological production north of 30°S
- Closure of the meridional overturning circulation

Studies suggest

- Aragonite will undersaturate in 17 years (2030)
- Major changes in Southern Ocean circulation and mixing will occur
The grand challenge

• Despite its critical importance, the Southern Ocean is the least understood region of the world ocean.
  – The meridional overturning circulation is highly uncertain
  – Eddy fluxes are significant contributors to the meridional exchange, yet are poorly quantified.
  – Current climate models are unable to resolve the eddies that likely play a major role in how the Southern Ocean responds to changes in climate forcing
• And yet
  – It is also the least observed region of the world ocean
  – We are lacking in scientists who are experts in the role of the Southern Ocean in climate and have the cross-disciplinary training to use the new observational technology as well as ultra-high resolution model simulation tools
  – The public is largely unaware of the importance of this region to climate and biological productivity.
National Oceanographic Data Center ocean stations with NO$_3^-$ data.

All NO$_3^-$ stations from 1900-2012.

All NO$_3^-$ stations from 2000-2010 and south of 45°S.

All NO$_3^-$ stations from 2000-2010 during Austral winter (June/September) and south of 45°S.

National Oceanographic Data Center ocean stations with NO$_3^-$ data.
The opportunity

• A transformative observing system
  – Argo floats
  – Biogeochemical sensors
• A transformative data analysis method
  – State estimation in eddy resolving models
  – Now adding biogeochemistry
• A transformative modeling capability: the ability to carry out ultra high resolution climate model simulations
A typical Argo mission
(200-250 profiles, over ~5.4 years)

Descend to 1,000 m and drift at this depth

Descend to 2,000 m every 10 days and then rise to the surface measuring temperature and salinity

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Southern Ocean: a paradigm shift – Transformative observing system

• Argo float profiling for temperature/salinity has completely transformed ocean observing over the past 10 years.
• We propose to do the same for the carbon system, nitrate and oxygen, and net community production (including sea ice regions) by measuring biogeochemical parameters (pH, nitrate, oxygen, optics)
Southern Ocean: a paradigm shift
Transformative biogeochemical sensors

• Field developing rapidly:
  – Körtzinger, et al. (2005) – Optode O₂
  – Tengberg et al. (2006) – Optode O₂
  – Riser and Johnson (2008) – Optode O₂
  – Johnson et al. (2010) – ISUS nitrate
  – Martz et al. (2010) – Durafet pH
  – As well as ongoing work
  – E. Boss et al. (2008) – FLBB optics
  – Whitmire et al. (2009) – FLBB optics
  – Boss and Behrenfeld (2010) – FLBB optics
Nitrate profiles south of 30°S

Average nitrate profiles/month in NODC data set (1985-2010)

With 200 floats, we would measure 740 profiles per month every month of the year.
Eddy kinetic energy in the Southern Ocean
(cm² s⁻²)

Delworth et al. (2012)
A proposal for a Southern Ocean biogeochemical observations and modeling program (SOBOM)
Goals

• To quantify and understand the role of all regions of the Southern Ocean in carbon cycling, acidification, nutrient cycling, and heat uptake, on seasonal, interannual, and longer time scales.
• To develop the scientific basis for projecting the contribution of the Southern Ocean to the future trajectory of carbon, acidification, nutrient cycling, and heat uptake.
Why SOBOM?

• Vision is
  – Compelling
  – Ambitious
  – Complex

• Legacies would be significant
  – People
  – Ideas
  – New instrumentation and technologies
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<tr>
<th>Decade</th>
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<td>2010s</td>
<td>Biogeochem-Argo</td>
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A brief history of SOBOM

• Science and Technology Center ($5M/year for up to 10 years)
  – 1 of 40 out of 267 pre-proposals selected for a full proposal
  – 1 of 11 out of 40 proposals selected for a site visit
  – 1 of 5 proposals selected for support by a “blue ribbon” panel
  – Ultimately not funded due to sequester
• Plans being made to carry SOBOM forward.
• We hope OCB will play a role