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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

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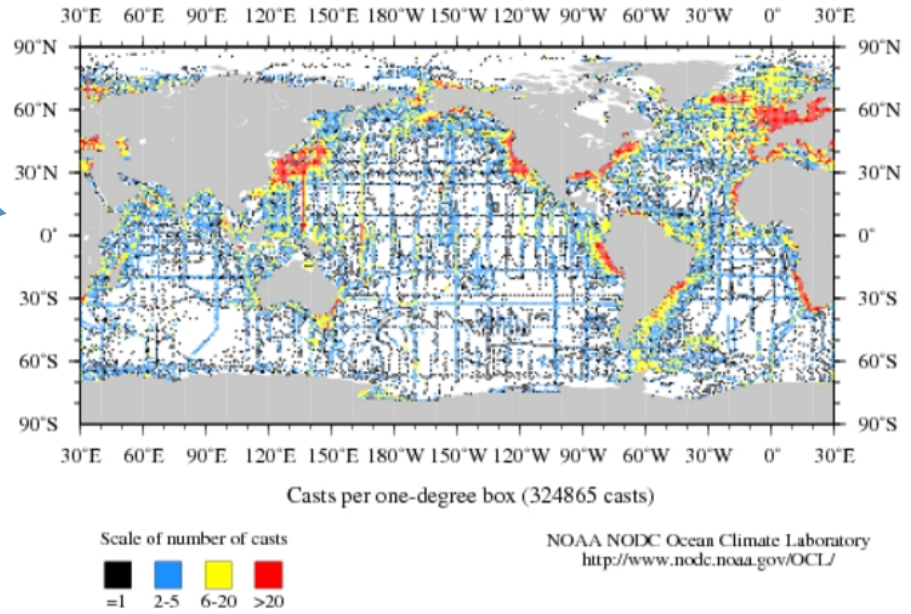
The grand challenge

- 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.

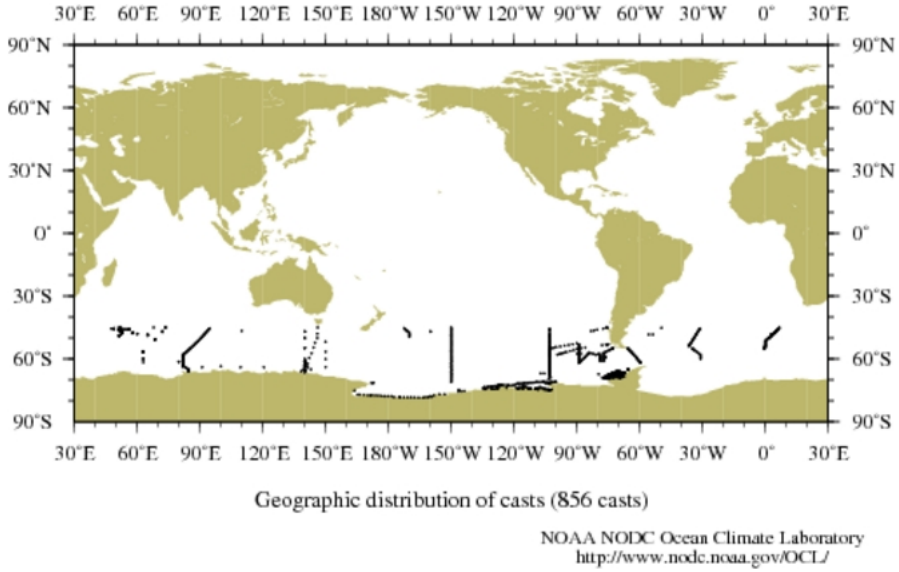
National Oceanographic Data Center ocean stations with NO_3^- data.

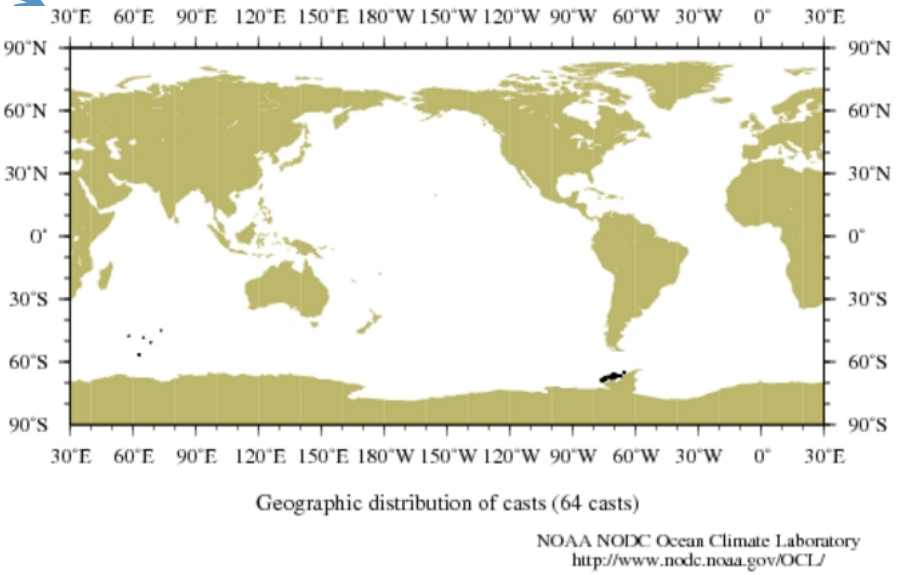
All NO_3^- stations from 1900-2012.



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.





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

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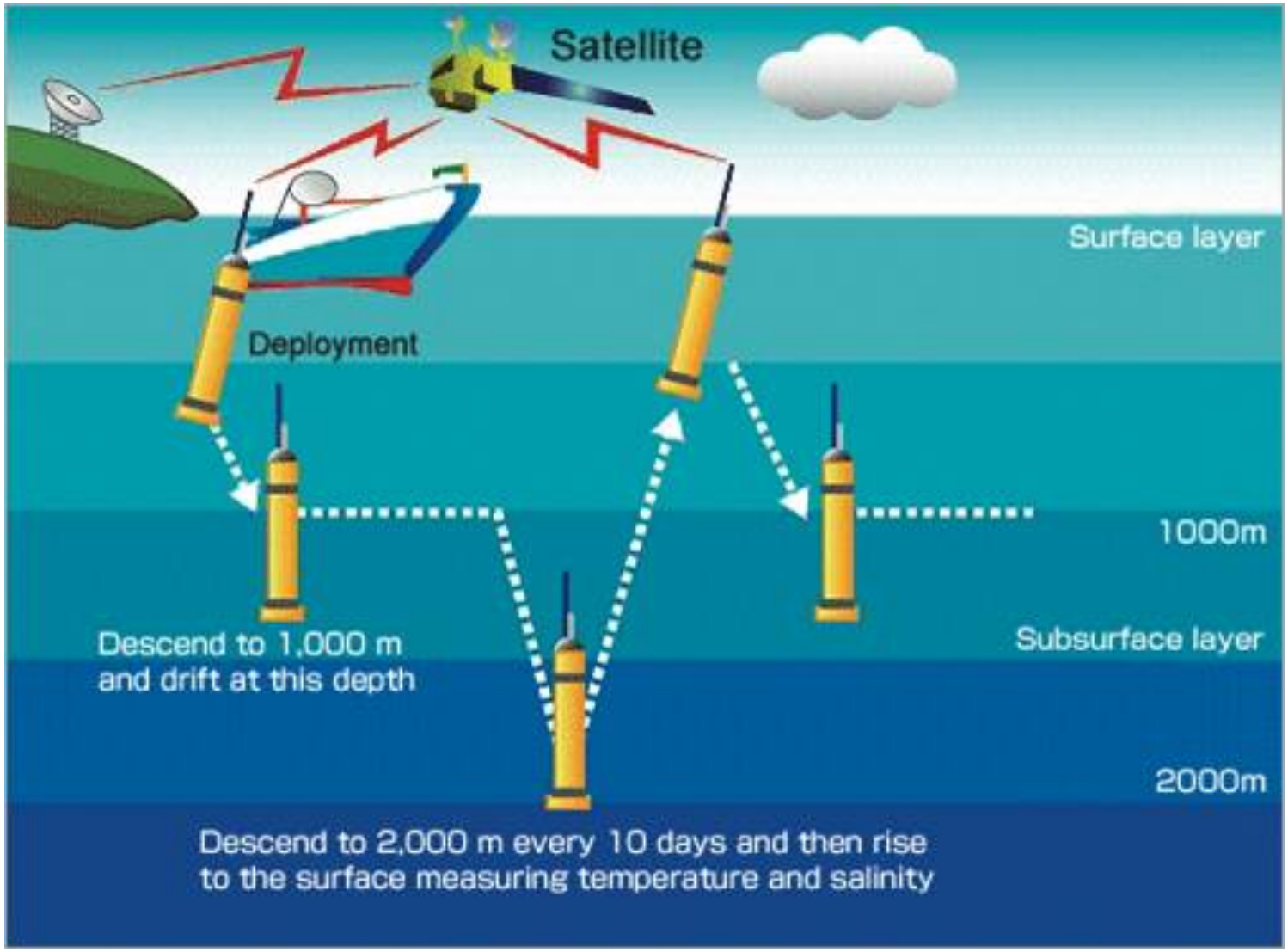
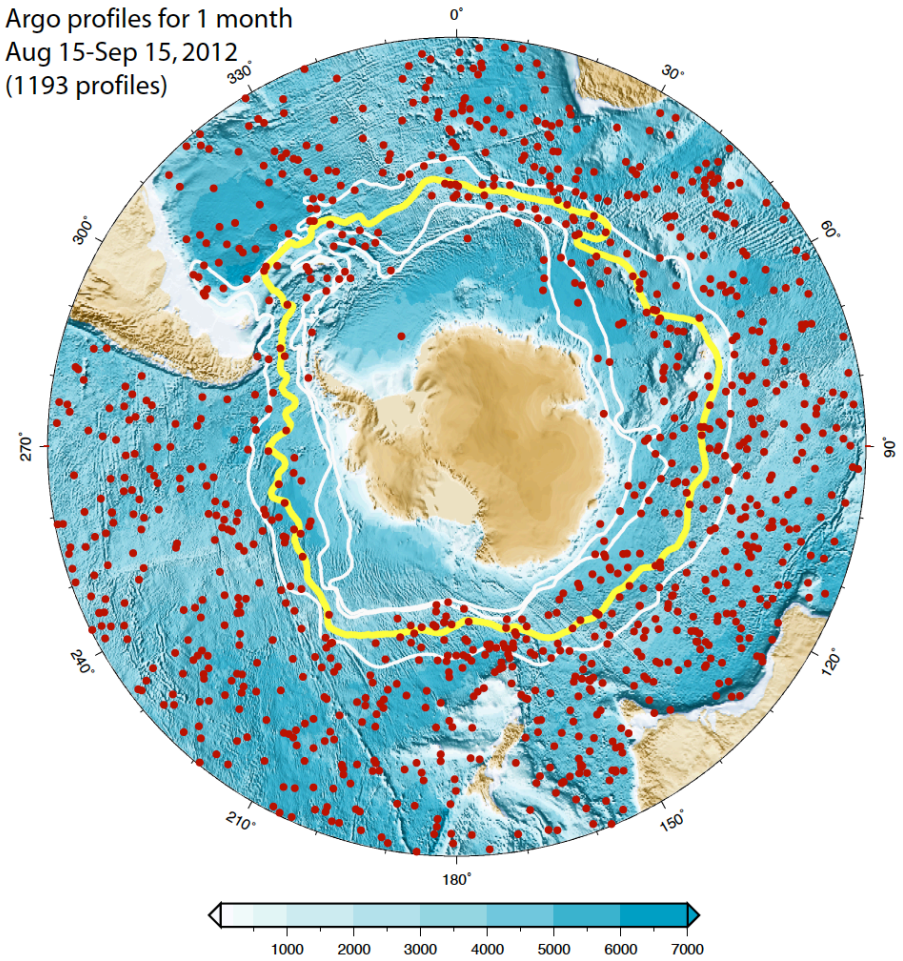
A typical Argo mission (200-250 profiles, over ~5.4 years)



Courtesy of S. Riser

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)

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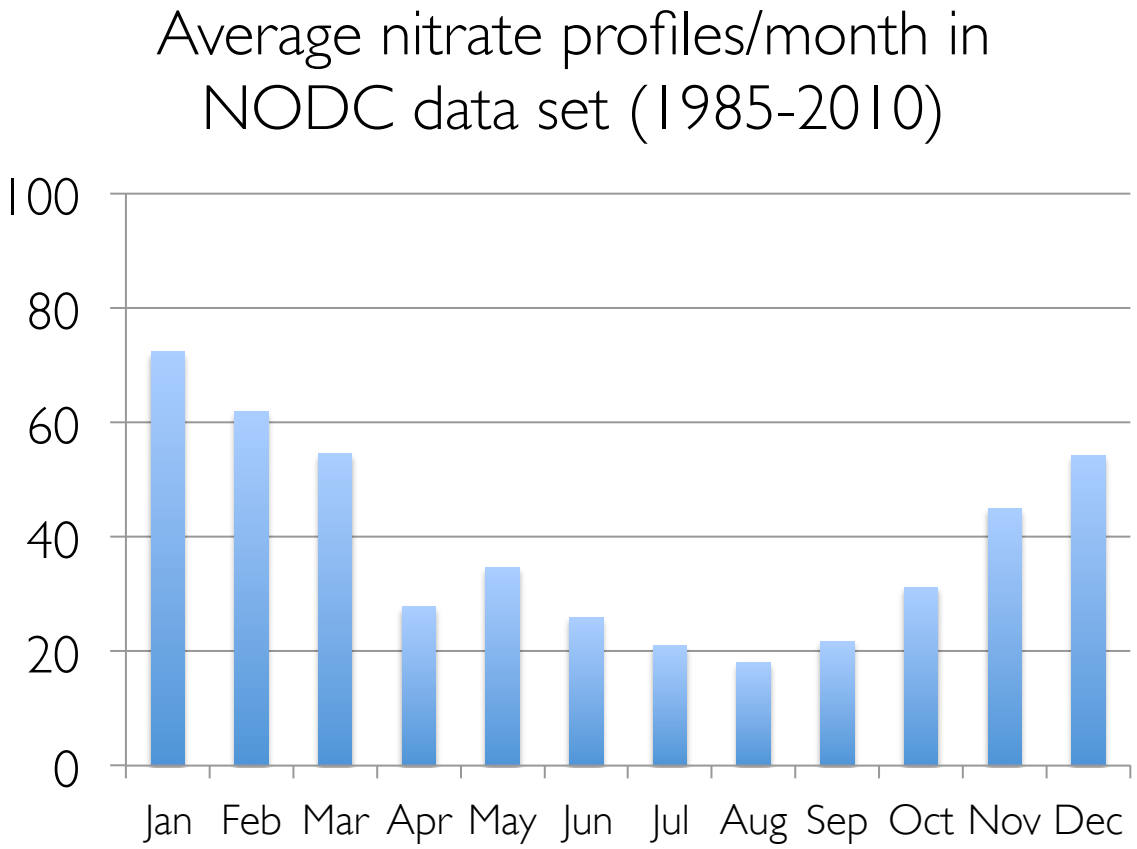
Southern Ocean: a paradigm shift
Transformative biogeochemical sensors

- Field developing rapidly:
  - Körtzinger, et al. (2005) – Optode O_2
  - Tengberg et al. (2006) – Optode O_2
  - Riser and Johnson (2008) – Optode O_2
  - Johnson et al. (2010) – ISUS nitrate
  - Johnson and Coletti (2002) – 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



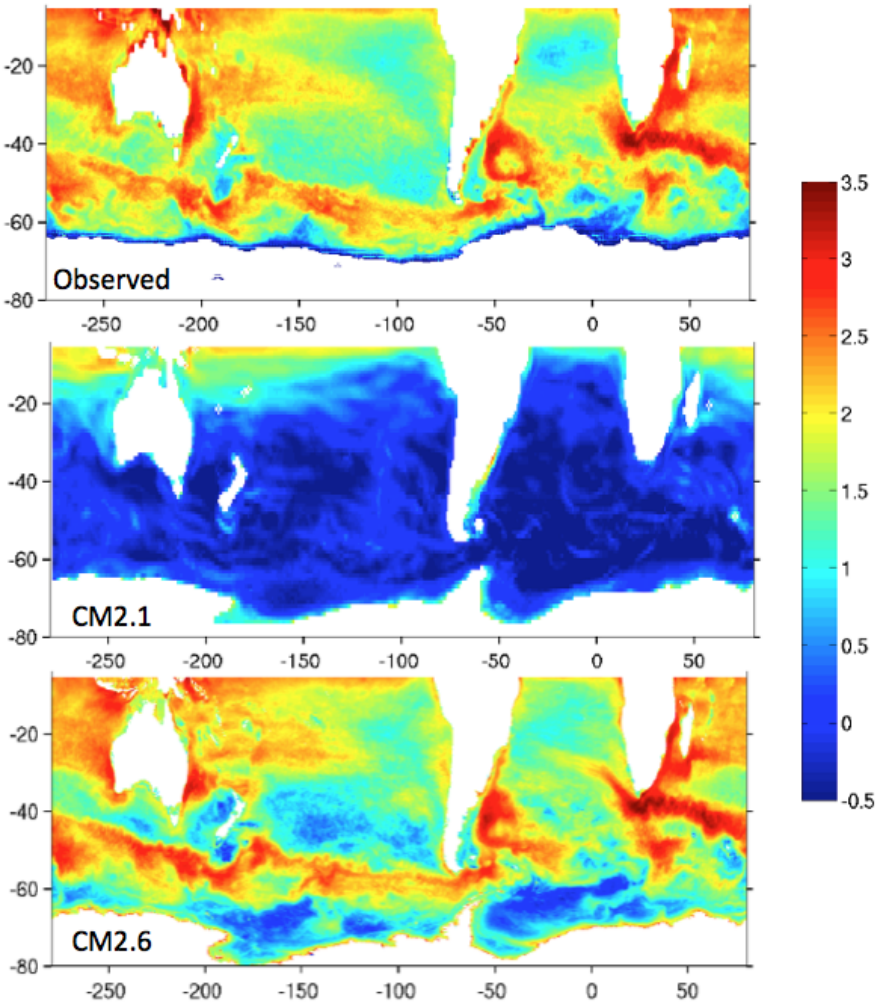
With 200 floats, we would measure 740 profiles per month every month of the year

Eddy kinetic energy in the Southern Ocean ($cm^2\ s^{-2}$)

Observed

CM2.1 has 1° resolution

CM2.6 has 0.1° resolution



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Delworth et al. (2012)

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A proposal for a Southern Ocean biogeochemical observations and modeling program (SOBOM)

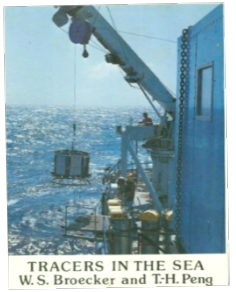
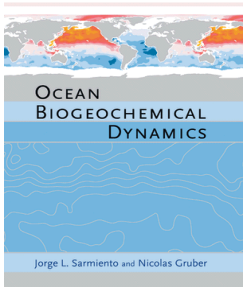
Goals

- 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

Vision is compelling, ambitious, and complex

Decade	Program		
1970s	GEOSECS	2-D	
1990s	JGOFS and WOCE	3-D	
2010s	Biogeochem-Argo	4-D	?

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

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