Sustained observation of the Southern Ocean: What is happening, and what else is needed?

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Oscar Schofield, Anna Wahlin, Steve Rintoul, Louise Newman, Eberhard Fahrbach, Eileen Hofmann, Matt Mazloff, Andrew Constable, Alberto Naveira Garabato etc etc
and all involved in planning and implementing SOOS

SOOS
SOUTHERN OCEAN OBSERVING SYSTEM

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Scientific Committee on Oceanic Research

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Thanks to the organisers for the invitation…

The brief they gave me was:-

"Talk about the state of Southern Ocean observations, and don't worry if it's controversial..."

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3 key points:-

- The Southern Ocean is globally important, and is changing
- Understanding these changes and their impacts is critically limited by lack of data
- We can, must, and will do better, and this requires strategic planning and prioritisation of observations

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Point 1: The Southern Ocean is globally important, and is changing

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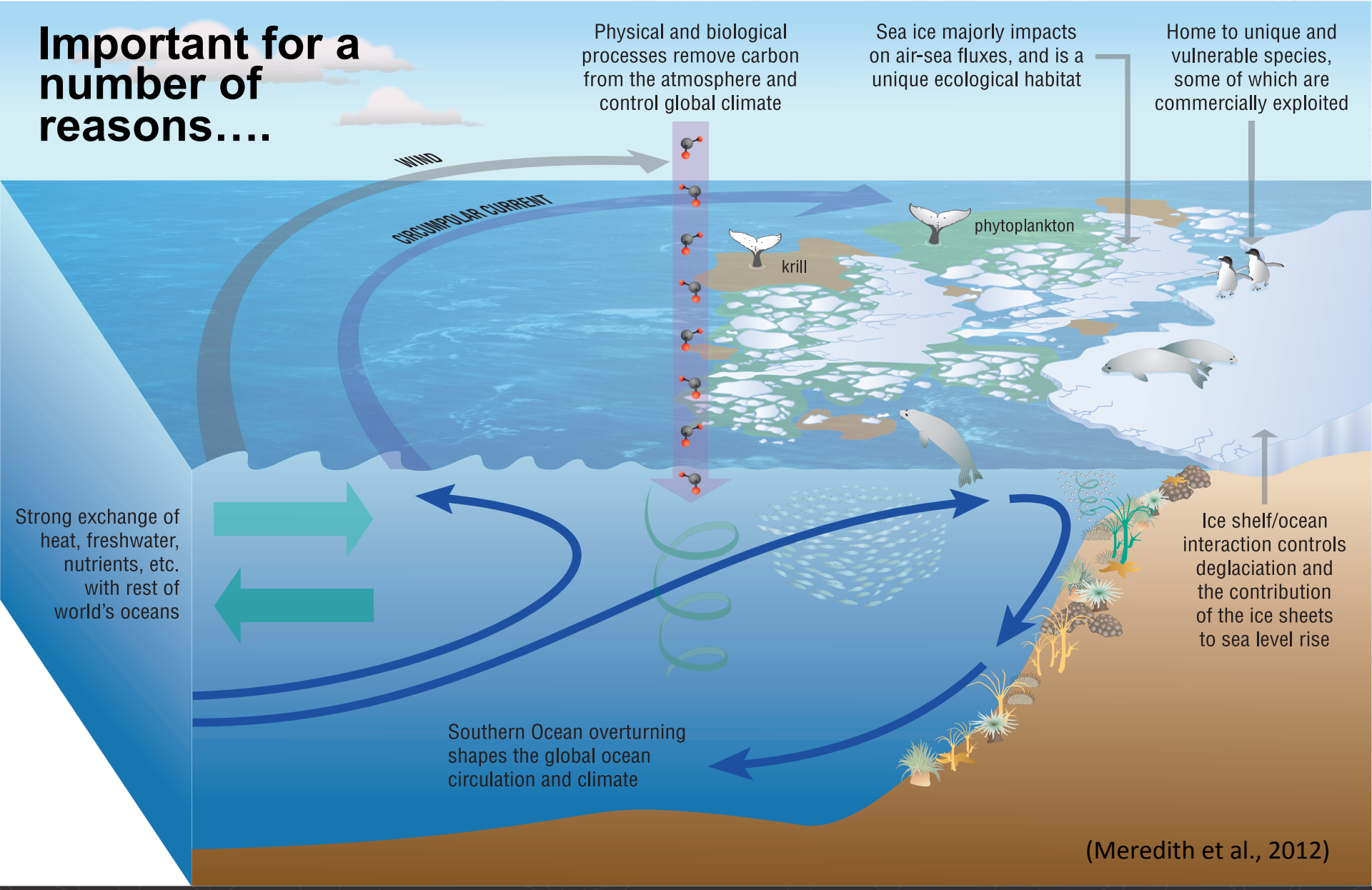
Important for a number of reasons….



(Meredith et al., 2012)

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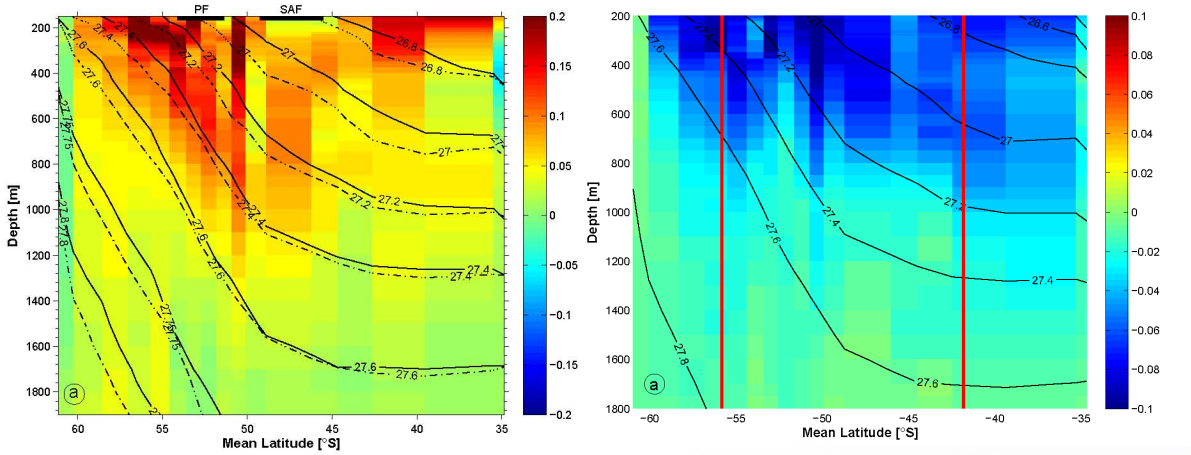
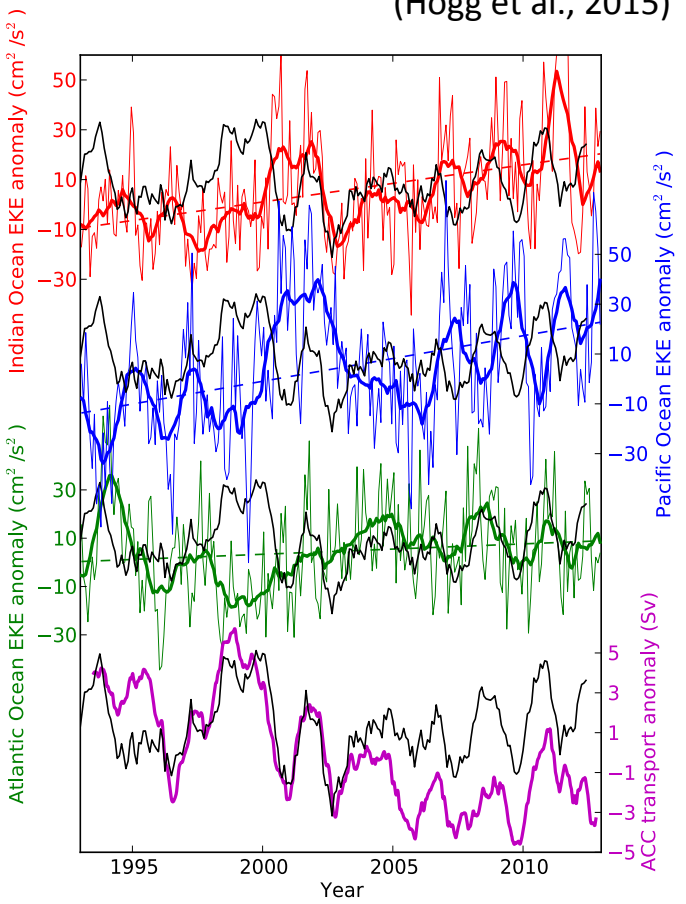
Some aspects are changing dramatically; others more subtle



(Boning et al., 2008)

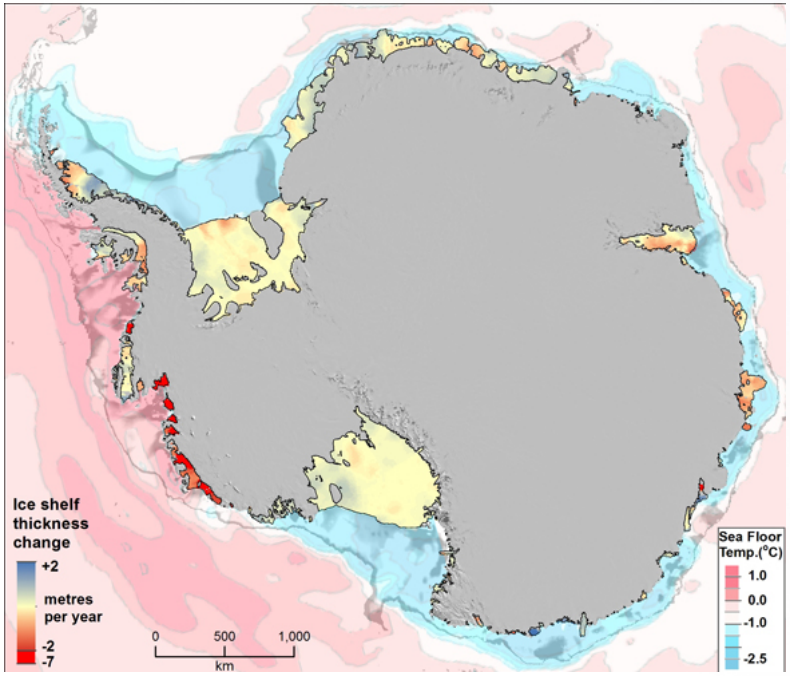
(Hogg et al., 2015)



Rate of warming exceeds that of the global ocean as a whole, for reasons not fully determined.

Freshening is consistent(ish) with an accelerating hydrological cycle.

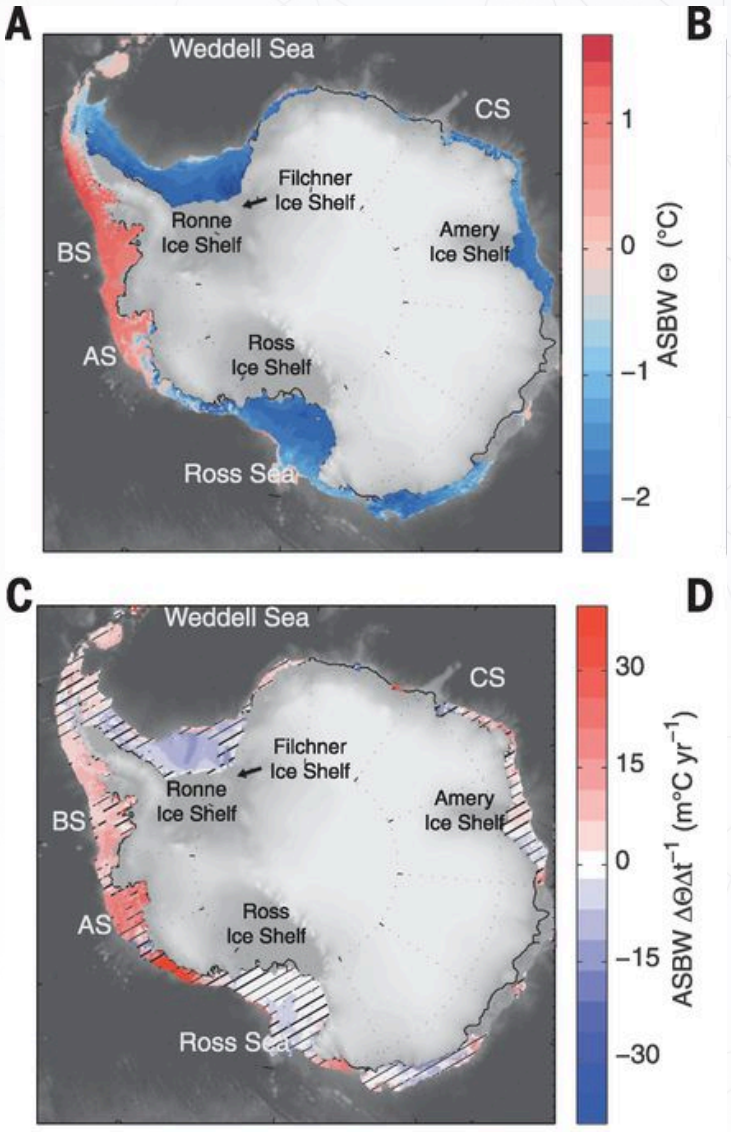
ACC transport changing rather little; eddy intensity changing more…



Pritchard et al. (2012)

Warmer ocean appears to be increasing melt in parts of the fringes of Antarctica.

Strong implications for ice sheet stability and hence sea level rise.



Schmidtko et al. (2014)

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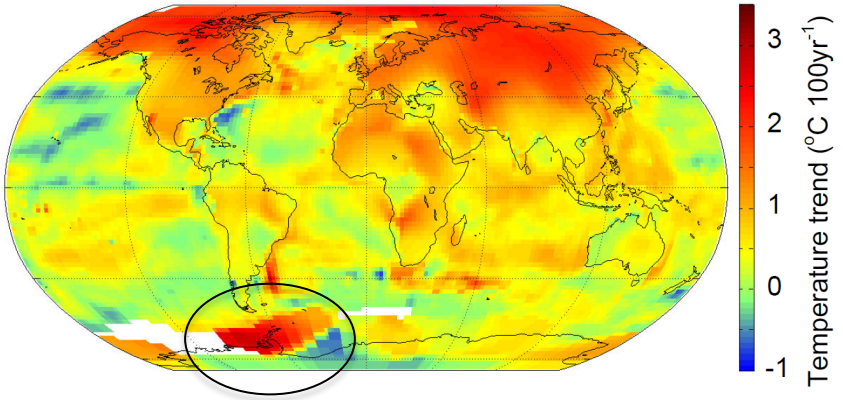
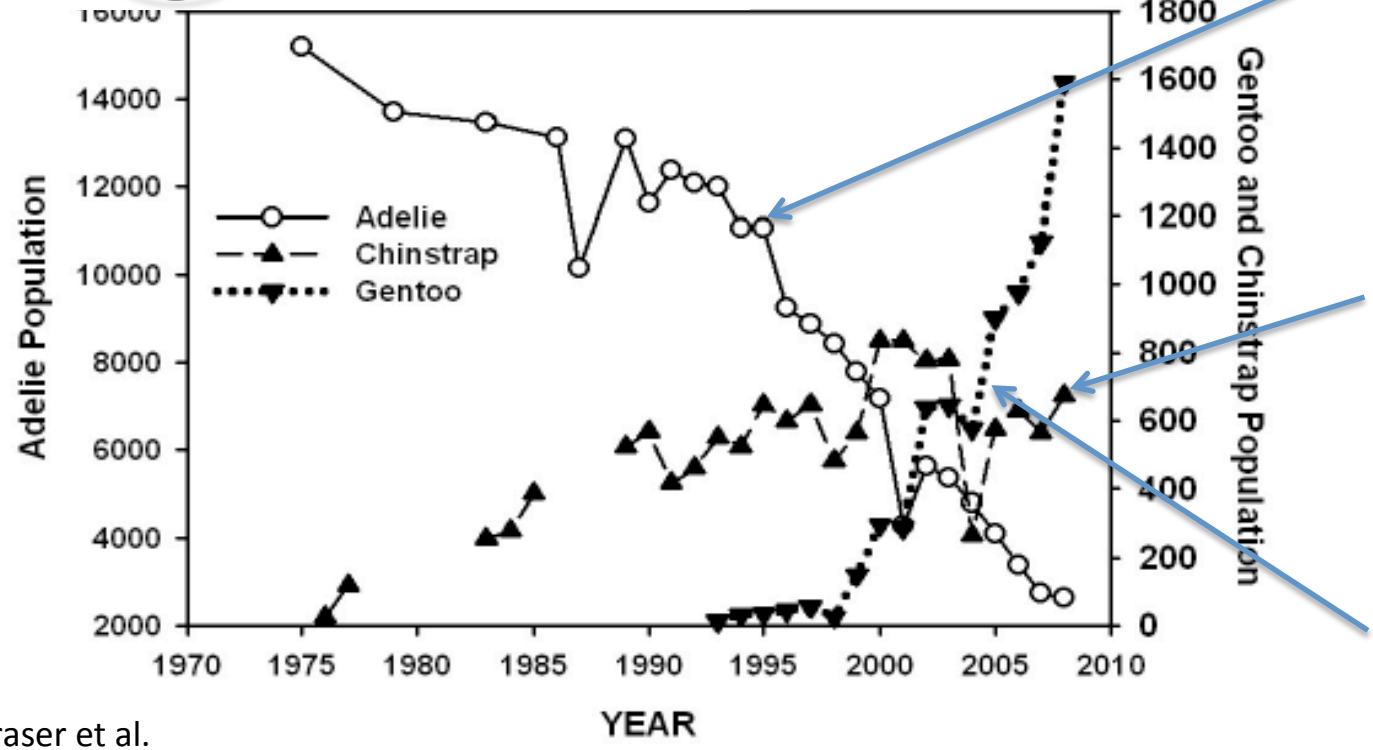
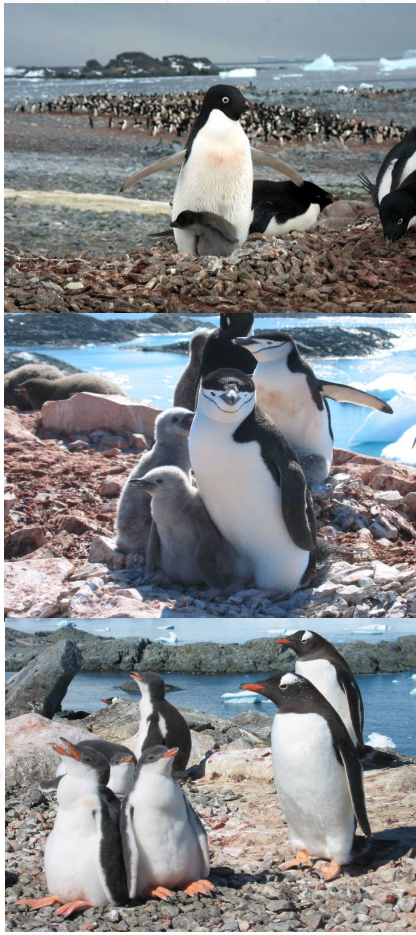
Dramatic shifts in regions of rapid change…







Fraser et al.

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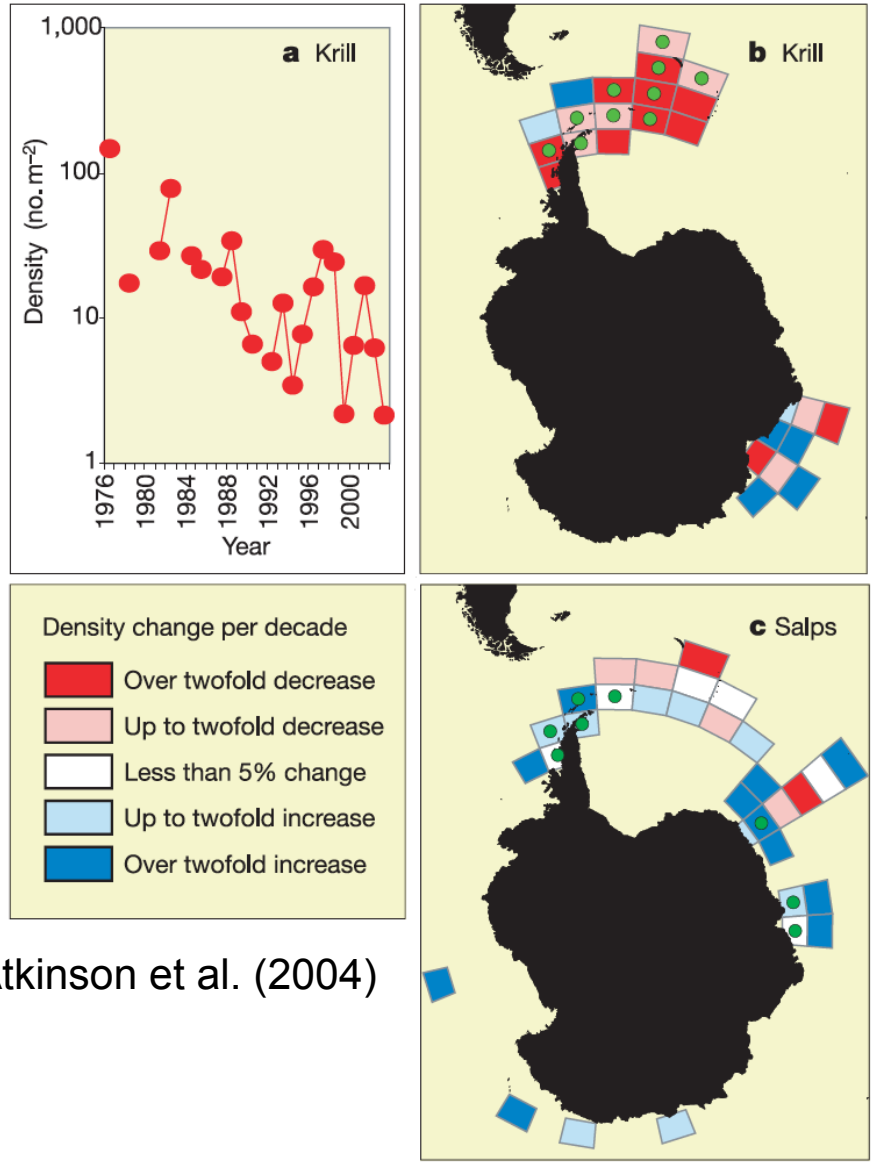
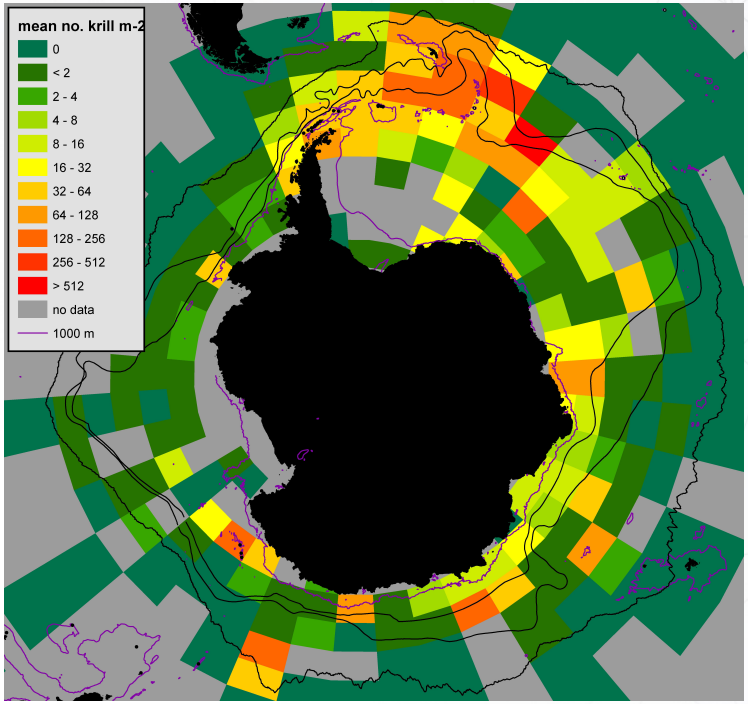


Atkinson et al. (2004)

Declines seen in krill and a concurrent increase in salps …




Point 2: The changes we have observed (or think we have observed) are only the tip of the iceberg…

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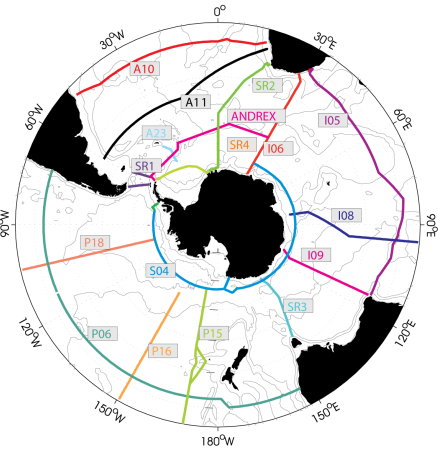
… reason being that the Southern Ocean has historically been (and continues to be) one of the world's biggest data deserts…

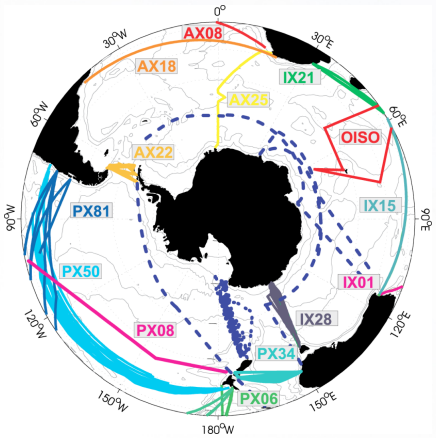
Each of the changes outlined has been identified using (in large part) data from one of a very small number of sources:-

- Ship-based measurements (and very few ships ply the Southern Ocean, esp. in winter)
- Shore-based measurements (and Antarctica is the least-inhabited continent)
- Instruments deployed from ships, such as floats, moorings etc (invaluable, but sparse and easily lost in hostile conditions)
- Satellites (invaluable data, but can't do everything)

Existing observing system elements are priceless…



GO-SHIP



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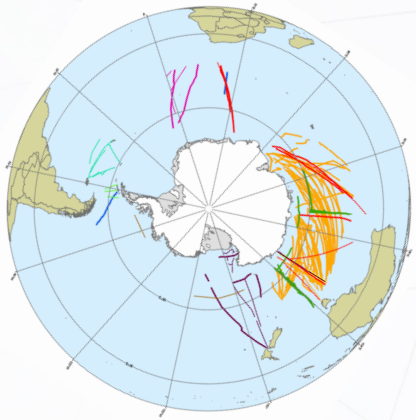
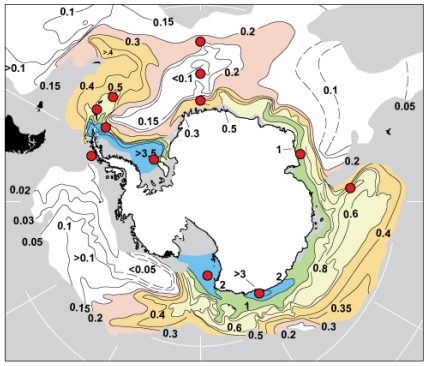
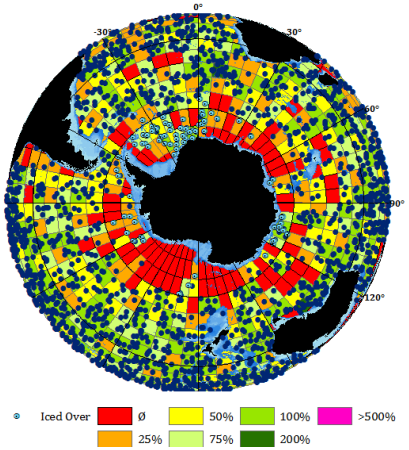


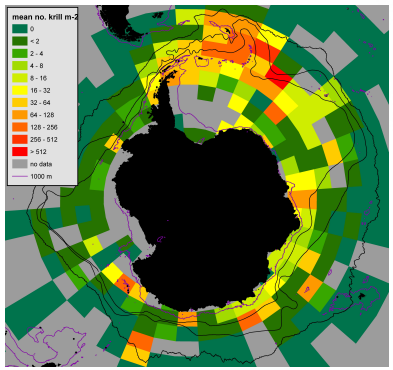
CPR



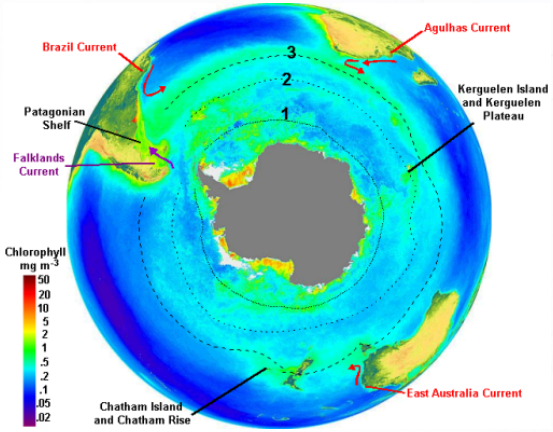
Moorings



Argo



Krillbase/SONA



Satellites

Etc

Etc

Etc…

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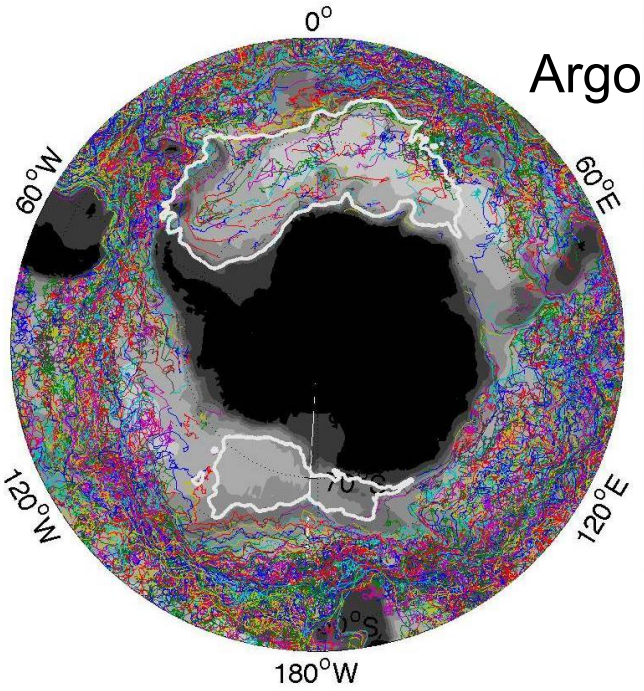
A sobering example: the annual BAMS “State of the Climate” report now includes a Southern Ocean section for the first time…

What could be assessed for 2014?

- Surface temperature, circulation, sea ice, etc (from satellites)
- Upper-ocean heat content, MLD, some water mass changes (from Argo)
- Bits about the shelf regions, though very regionally dependent
- Bits about carbon, from underway sampling primarily

What could not be assessed?

- Deep ocean water masses, aside from bits of repeat hydrography
- Biogeochemistry across very large areas
- Under the sea ice, aside from bits in the Weddell etc
- Under the ice shelves
- Biological variables, aside from some specific sites
- etc

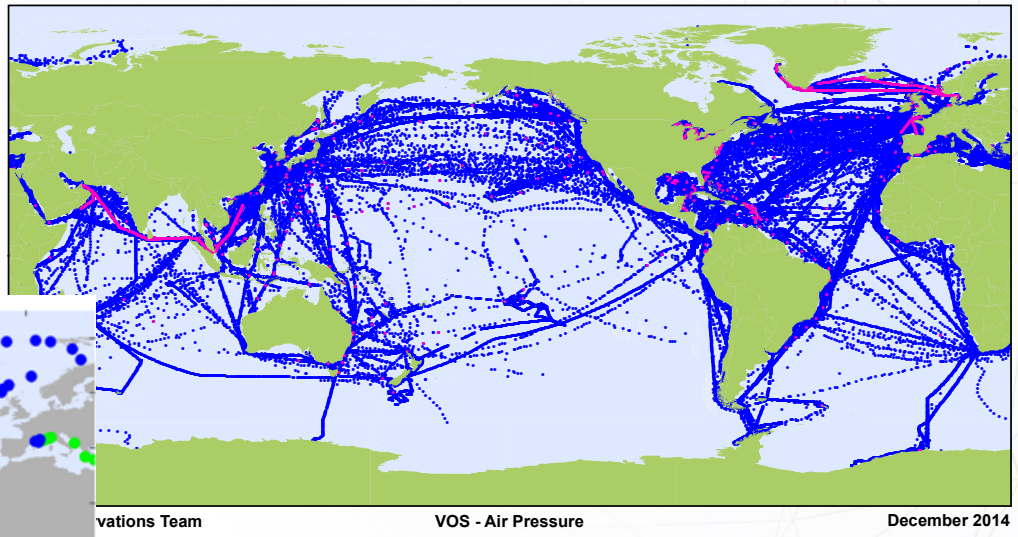


Argo

As indicators, coverage of profiling floats drops off dramatically when the sea ice zone is reached…

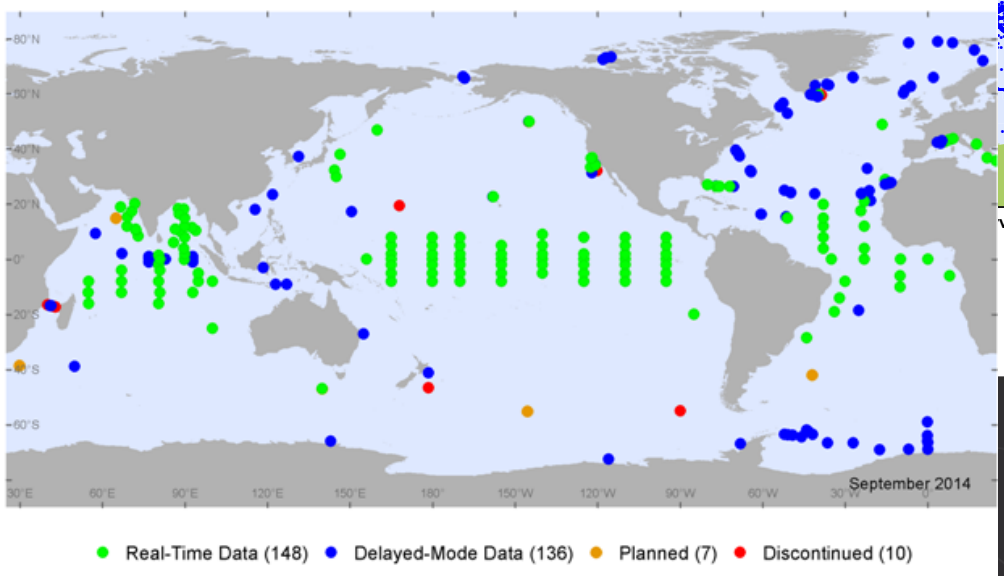
Sustained moorings coverage is poor (except Weddell Sea).

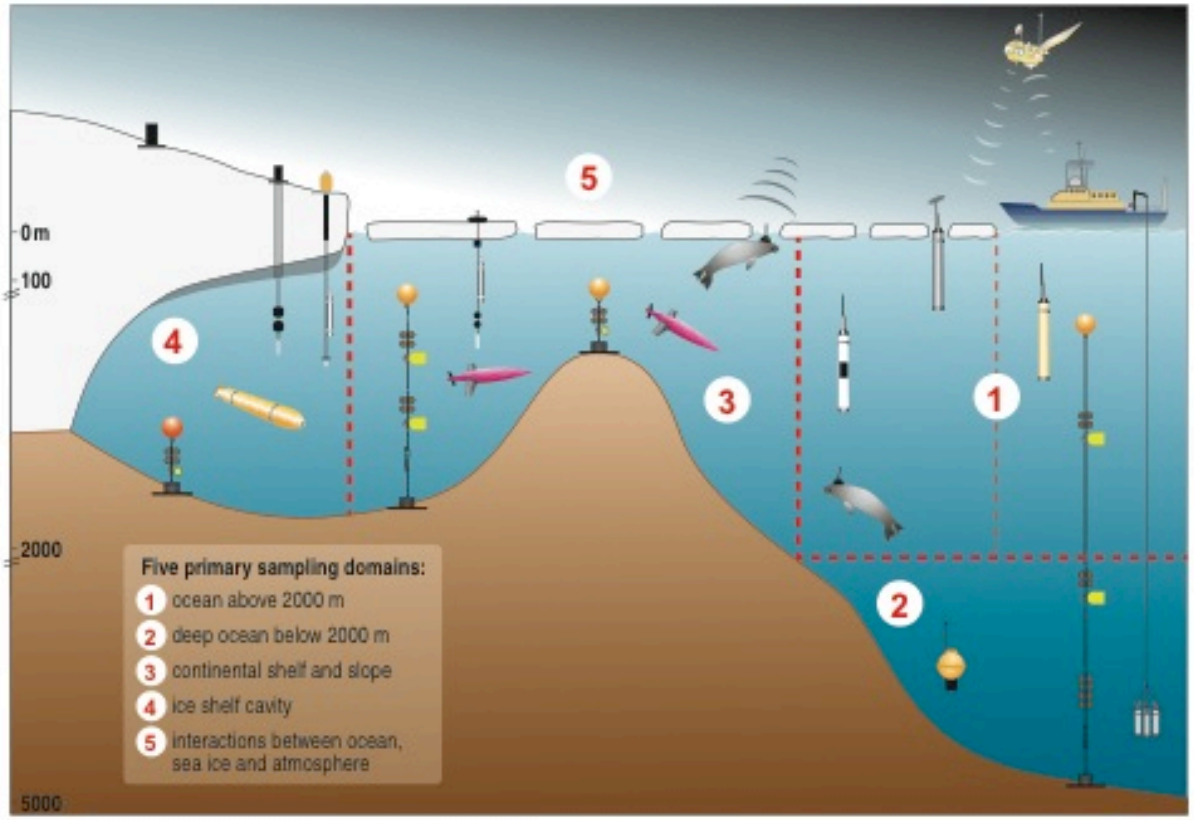
VOS lines are very sparse.



VOS

OceanSITES





If we divide Southern Ocean into five sampling domains, only half of domain 1 is anywhere near sufficiently sampled, and even there only for physics at present.

The Southern Ocean in winter is virtually unsampled, aside from Argo and satellites.

More sustained observations are needed, BUT they need to be planned and coordinated strategically, so that the right data are collected in the right place at the right time, in order to tackle the really pressing scientific and societal problems.

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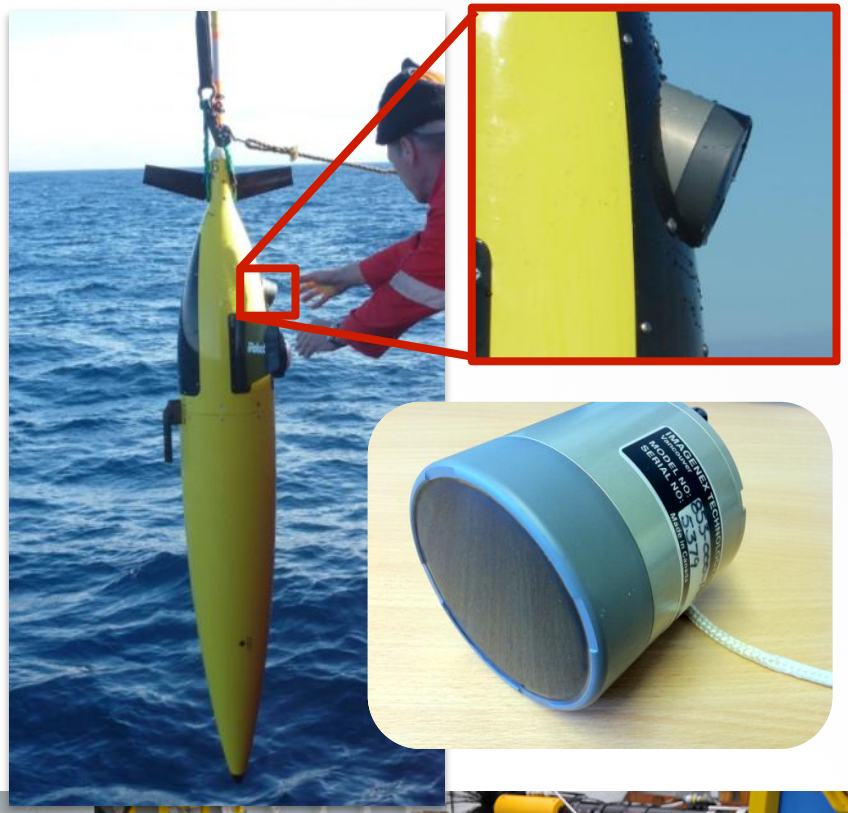
Point 3: How do we do better, and what does “better” look like?

A key point….

The number of these is not likely to increase significantly in the foreseeable future, if ever.

The number of these is rising rapidly, and is set to continue…

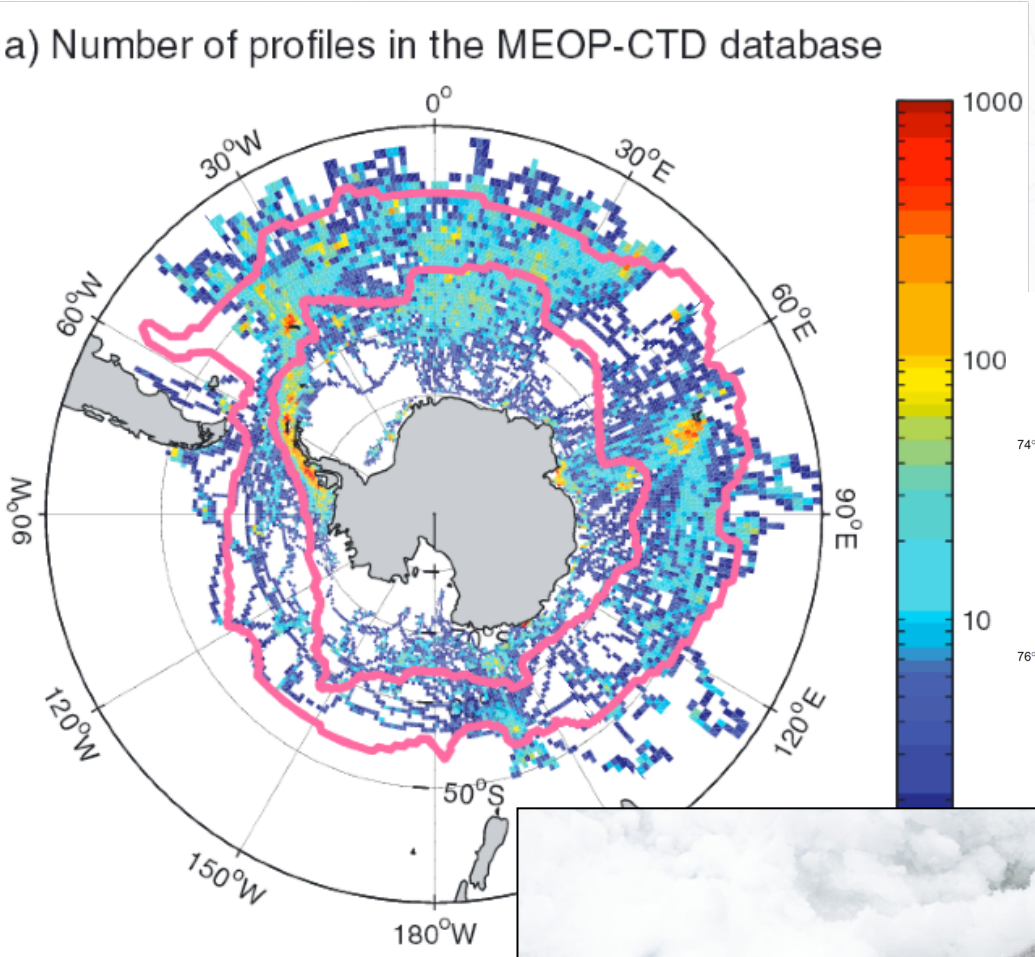


Swarms of autonomous vehicles needed, to give greater spatial coverage than ships will ever allow, plus control concerning where the data is collected.

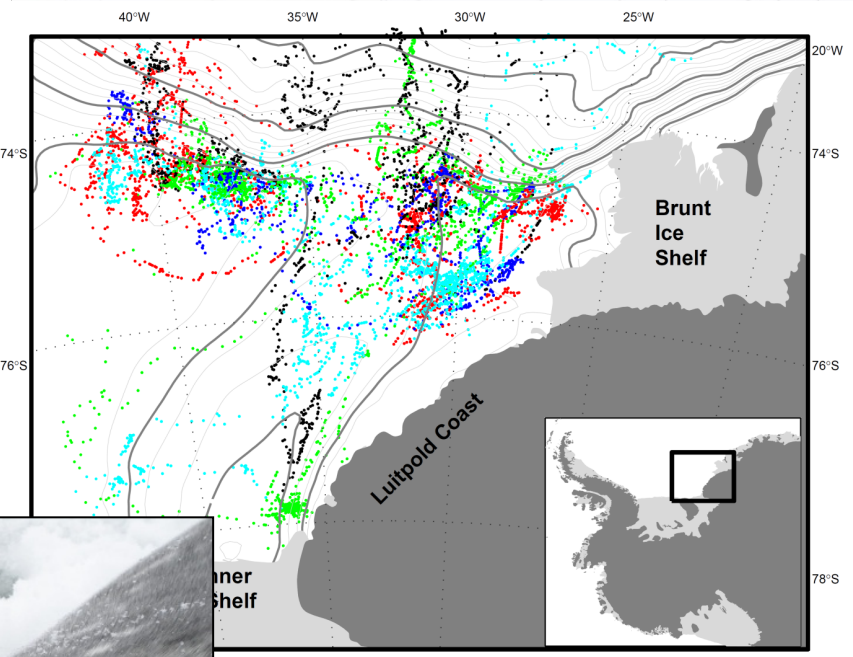
Can use same acoustic technology as Argo-under-ice, for winter measurements …

Can carry any number of exotic sensors.

Fleets of surface vehicles needed for e.g. flux measurements



Needs to be sustained systematically (c.f. UK example!)



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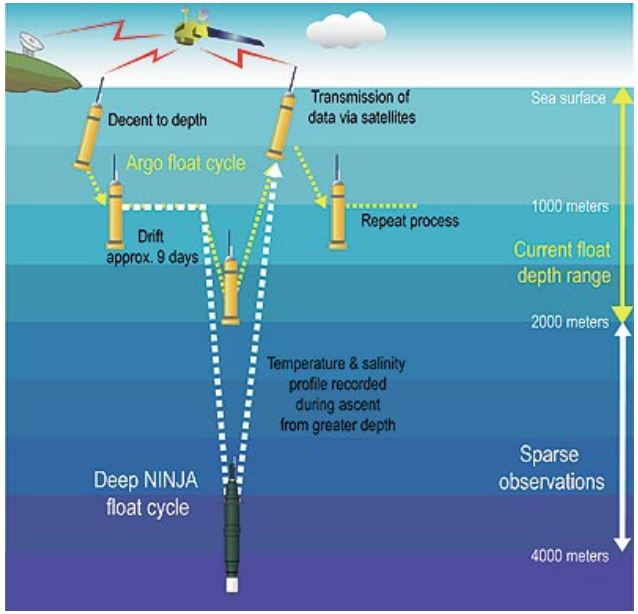
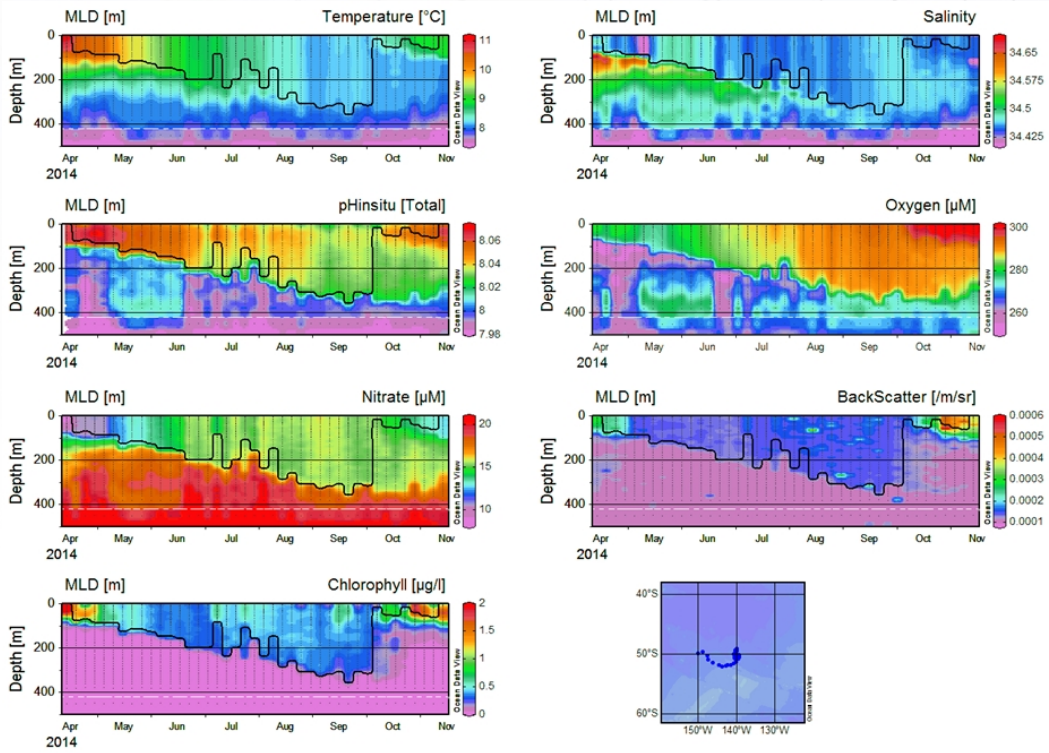
Enhancements to “conventional” Argo …



e.g. deep Argo …



e.g. biogeochemical sensors on large float arrays (courtesy Ken Johnson)

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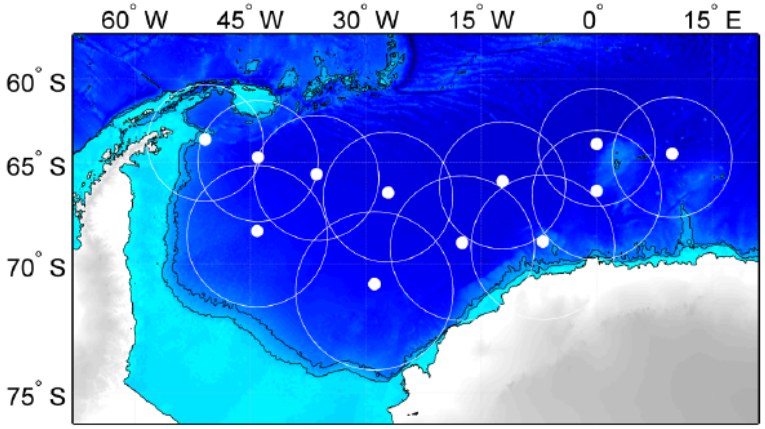
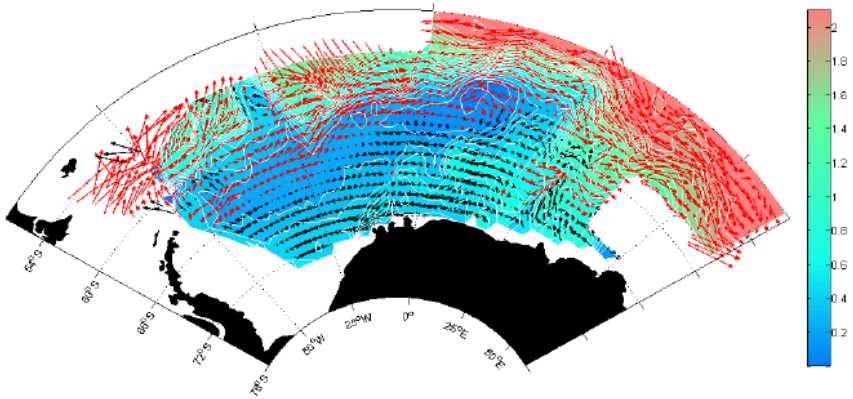
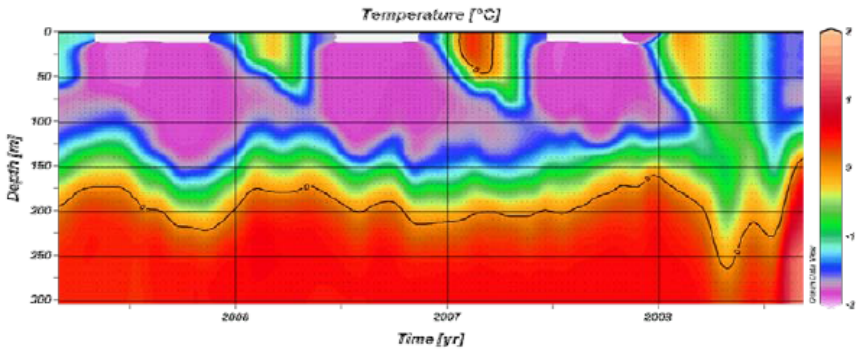




Sound source arrays for tracking of floats beneath sea ice …

Technology is proven (Alfred-Wegener-Institute array in Weddell Sea), but needs to be sustained, and needs rolling out in other ice-covered regions …

Need to expand network capability to include under-ice gliders



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Need sustained through-ice-shelf reference sites

- Moored instruments beneath ice shelves, reporting data autonomously
- Turbulence-resolving measurements beneath ice shelves
- Augment with autonomous phase-sensitive radar, for ice melt determination
- Add long-duration AUV missions, with real-time telemetry …

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So technology developments offer the potential for the data required… what are the immediate priorities?

Theme	Priority Observations
1 and 2 Circulation / climate	Deep ocean T, S and O_2 measurements
	Freshwater Tracer (18O, noble gases) measurements
	Shelf/slope and under ice measurements, focussing on key regions of shelf-ocean exchange and polynyas
3 Ice shelves	Bathymetry under and near ice shelves
	Year-round, sustained measurements of T, S and O2 under and near ice shelves
4 Carbon and biogeochemistry	Filling temporal/spatial gaps (using autonomous platforms)
	Ensure all ships are taking validated measurements of essential variables
	Develop time series measurements near coastal Antarctic stations
5 Sea ice	Sea-ice thickness from ships and coastal stations
	Sea-ice drift (meteorology, buoy arrays etc)
	Sea-ice extent and concentration observations
6 Biodiversity and ecosystems	Standardised biological sampling
	Sampling offshore from land-based activities (e.g., integration across land to marine observations)
	Improved capability on ships (e.g., CPR, acoustics, predator tracking/diet)

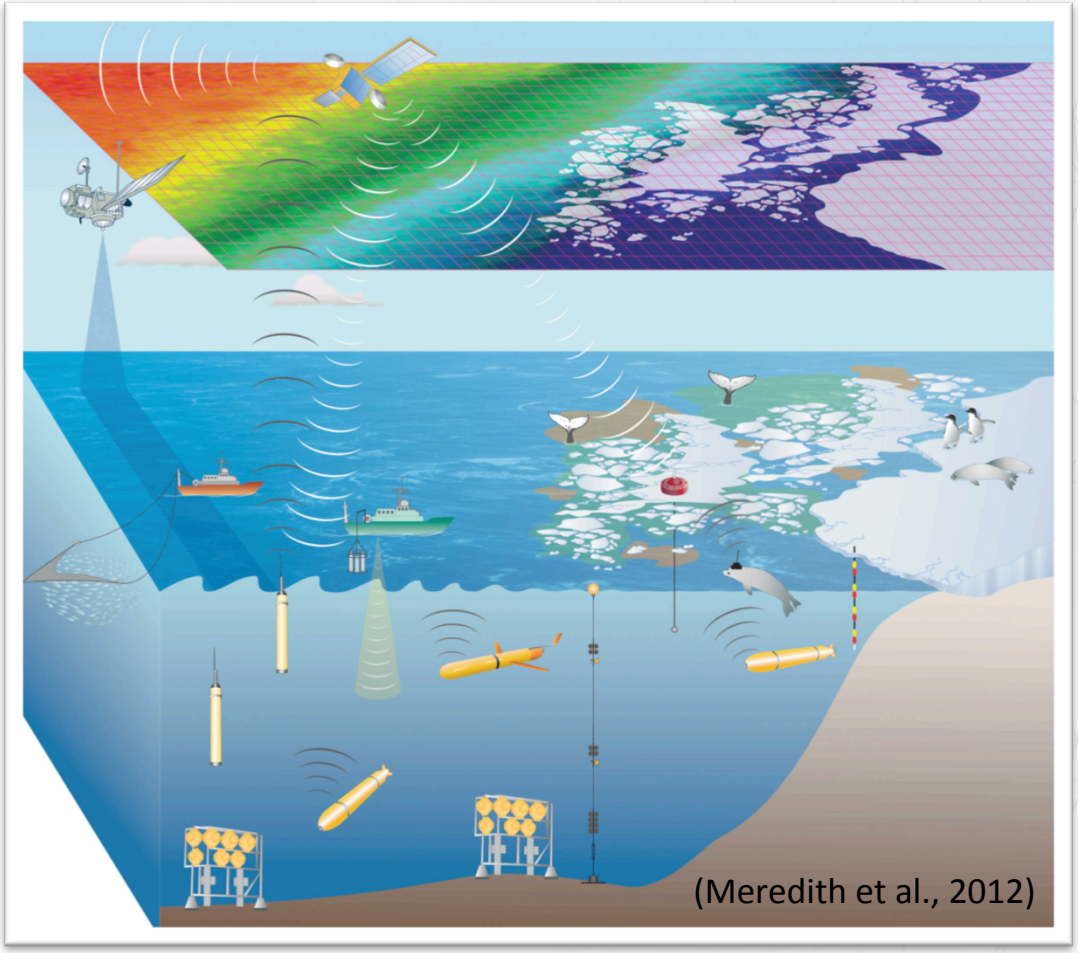
These relate to filling important geographical gaps, developing year-round data coverage, expanding range of parameters being measured (especially carbon etc), and determining the standardised biological parameters that a sustained system requires.

Longer-term vision is to develop a cyberinfrastructure-based system, linking standard platforms, autonomous vehicles, and assimilating models.

The concept is to develop a cyberinfrastructure-based system, whereby a backbone of autonomous vehicles relay multi-disciplinary data via satellite for real-time assimilation into models.

These models can then re-task the platforms to change their missions, by moving to different areas, prioritising other measurements, changing sampling rates, depths etc., depending on the state of the ocean and how well it is captured by the model.

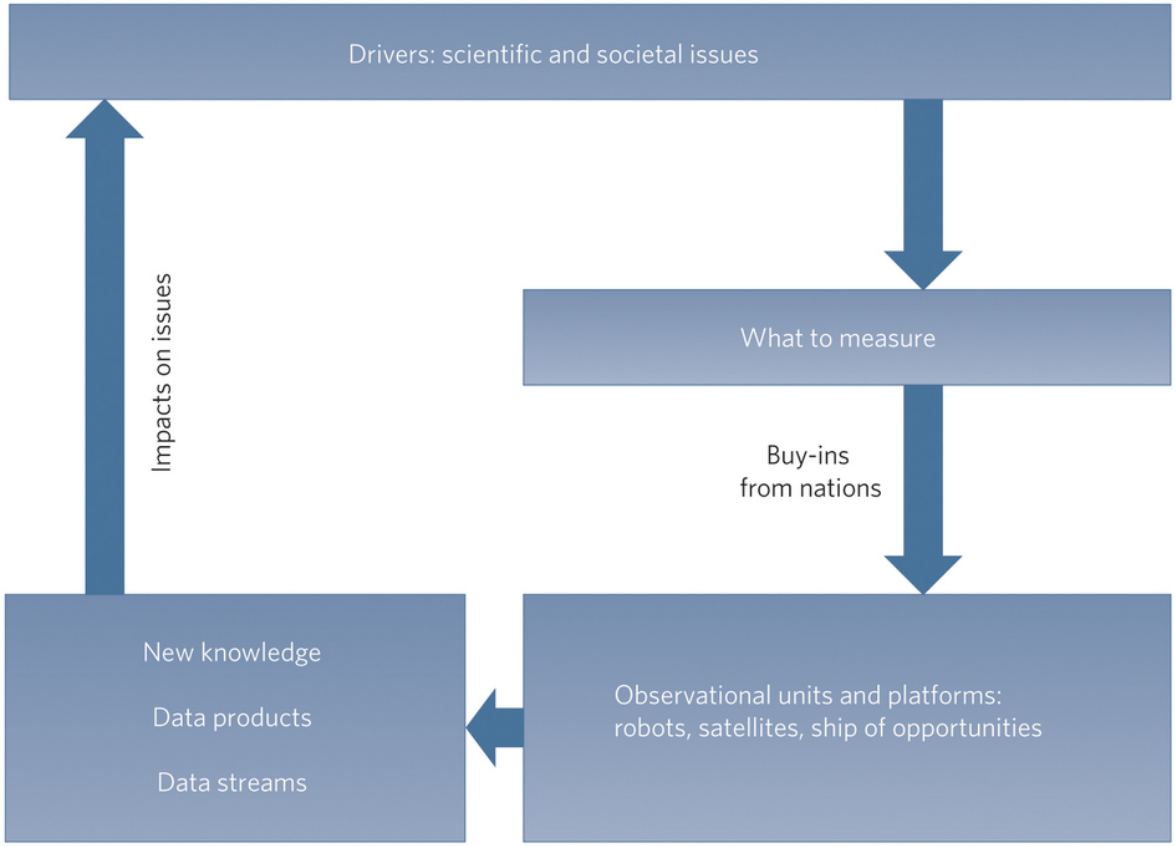
20-year timescale? Needs a regional pilot study…



To be sustainable, needs an end-user “pull”…

- Researchers, of course
- Resource managers (eg CCAMLR)
- Policy makers
- IPCC
- Local planners (sea-level rise)
- Antarctic tourism operators
- Shipping operators
- Weather and climate forecasters
- Educators
- Operational/conservation agencies
- Industry
- Etc

(Who of these has most money?)



"Scientific and societal issues determine variables to measure, attracting investment from nations through their research institutions. The outcome of the observations, that is, data, products and new knowledge, inform both existing and new issues, and a feedback loop that keeps the observation system 'fit for purpose'."

- Cai et al., *Nature Climate Change*, 2015

- True, but reflects the scientists' perspective …
- "Owners" of the issues have a near-reverse feedback loop
- Difference between "useful", "useable", and "used"

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Work in progress…
…but it's always going to be…

End goal is a sustained, coherent, multidisciplinary observing system, that is fit for purpose in any given year but which can be expanded/adapted as new scientific and societal drivers are realised.

Needs to be able to both adopt and drive new technology developments

Requires far greater international coordination/cooperation – but this can be achieved (e.g. translate Argo model to glider swarms etc)

Requires working across traditional disciplinary boundaries - need to maximise use of any asset, autonomous or otherwise.

Status and activity …

Embryonic but growing. Some of the elements are ~mature; others still being developed (e.g. sustained under-ice obs).

Some of the complex biological elements still require full specification, in terms of what is needed, plus standardised protocols.

Assessments are being conducted to define temporal/spatial sampling requirements, and identify gaps.

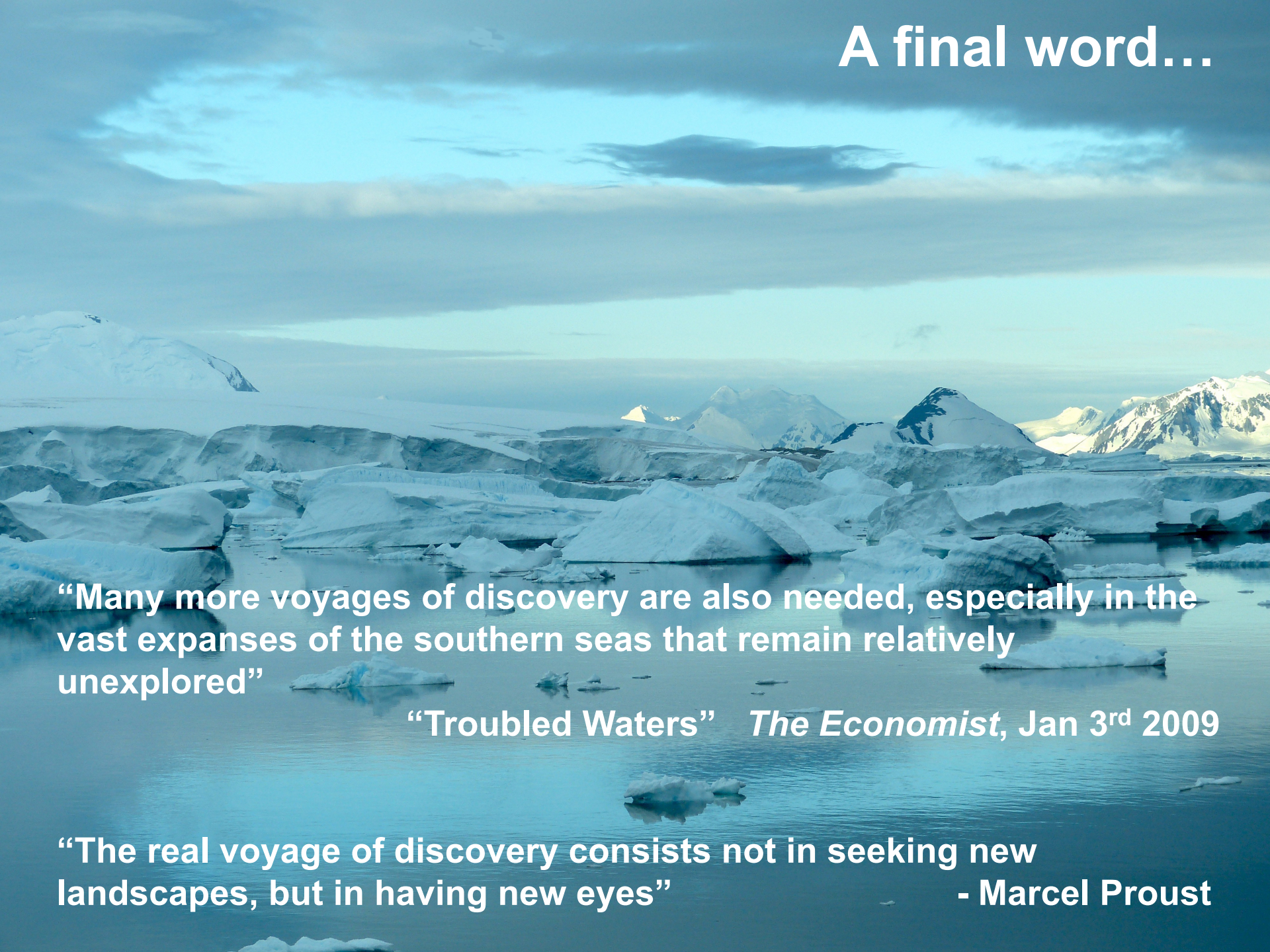
Regional groups being formed to conduct gap analyses and drive implementation (some things easier to fund regionally).

Data and data product system being built.

Development of cyberinfrastructure; pilot(s). To progressed ….

(Full details available from Louise Newman; newman@soos.aq)

A final word…



"Many more voyages of discovery are also needed, especially in the vast expanses of the southern seas that remain relatively unexplored"

"Troubled Waters" *The Economist*, Jan 3rd 2009

"The real voyage of discovery consists not in seeking new landscapes, but in having new eyes" - Marcel Proust


Thanks for your interest…!