Ideas for a Multi-year Southern Ocean Experiment with Floats and Gliders

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with contributions from Tom Trull, U Tasmania

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Long-term goals of autonomous biogeochemical observations in the Southern ocean

Southern Ocean currently accounts for ~40% of oceanic uptake of anthropogenic CO_2. How might this change in the future?

→ Will SO carbon uptake to "saturate" as climate warms and Westerlies increase? LeQuere et al. 2007 and responses

Antarctic Intermediate Water and Mode Waters play a major role in ventilating the ocean interior

→ How will ventilation via AAIW and SAMW change in the future?

Profiling floats equipped with biogeochemical sensors (O_2 and NO_3) are an ideal tool for addressing these questions

Ideas for near-term, multi-year experiments

1. Quantify coastal Antarctic CO_2 sink
2. Origin of Polar Frontal Zone deep chlorophyll maximum
3. Origin of ice-edge phytoplankton distributions
4. Carbonate saturation horizons and their relation to shelf circulation
5. Biogeochemical impact of natural iron fertilization

Coastal CO_2 sink
rationale/science questions

- CO_2 fluxes in coastal Antarctic waters poorly resolved
- Model results suggest annual atmospheric CO_2 flux in Ross Sea equal to 27% of CO_2 sink for entire SO

Questions:

- Do observations agree with models?
- Are equally large fluxes observed in other coastal regions?
- What is the interannual variability (and its drivers) in the coastal CO_2 sink?

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Arrigo, K.R., van Dijken, G. and Long, M., 2008. Coastal Southern Ocean: A strong anthropogenic CO2 sink. Geophysical Research Letters, 35(21): 6.

Coastal CO_2 sink
rough outline

- Where? Have models and experience in the Ross Sea, but should we go somewhere new? Antarctic peninsula (LTER site), polynas south of Australia?
- How? Floats could hang out under the ice, surface as it retreats to record full annual cycle- seasonal 'edges' often where the action is. Gliders for spatial coverage. Moorings? Drifters? For CO_2…
- What? CO_2 flux (pCO_2, wind speed), net community production (nitrate, O_2), export (carbon flux at depth), photosynthetic competency (FRR- WOS example)

Natural iron fertilization
rationale/science questions

- Evaluate the carbon-impact of future and past changes in iron supply to the oceans including geo-engineering proposals
- What is the efficiency of fertilization? ie carbon exported/Fe added?
- Is the export ratio (primary production/export) different in Fe-fertilized blooms?
- Mixing (see Trull target #4)

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Blain, S., et al. 2007. Effect of natural iron fertilization on carbon sequestration in the Southern Ocean. Nature, 446(7139): 1070-1074.

Pollard, R.T., et al. 2009. Southern Ocean deep-water carbon export enhanced by natural iron fertilization. Nature, 457(7229): 577-U81.

Natural iron fertilization
rough outline

- Where? Kerguelen plateau, or Crozet islands have already been studied. Proposed repeat of KEOPS in 2012

- How? Compare dynamics of Fe-stimulated bloom with a control area for the duration of the bloom. Maintaining floats within the bloom for months might not be feasible. Gliders instead?

- What? Net community production (nitrate, O_2), export (carbon flux at depth), photosynthetic competency (FRR), bio-optics

Tom Trull

Upcoming Australian Field Programs
Research Targets for Gliders/Floats

Take home message – work with us!

Tom Trull, Univ. of Tasmania, CSIRO Marine Research

Potential Research Targets

1. Origin of Polar Frontal Zone Deep Chlorophyll Maximum

Sub-pycnocline persistent DCM forms throughout PFZ south of Australia. Not simply a Chla/C feature. May result from Fe limitation, or diatom sinking, or other causes. Estimated to contribute 30-50% of primary production. (Parslow et al., 2001 JGR SAZ Project special section.)

Improved definition of structure, seasonal progression will illuminate origins.

Potential target for FLNTU/O2 glider mission.

Potential Research Targets

2. Origin of ice-edge phytoplankton distributions

Phytoplankton distributions along most (1000's of km) of E.Antarctic sea-ice edge show a fascinating feature of high biomass beneath the ice and offshore at depth, but with a gap near the ice edge . The origins of this distribution are unclear. They may relate to small scale circulation, links between melting and production, or intensification of grazing near the ice edge. Observations to date have been insufficient to define small scale structure or seasonal evolution. (Wright et al., DSRII in press)

Potential target for FLNTU/ADCP glider missions.

Sea-ice process voyage in 2011-12 offers opportunity

Potential Research Targets

3. Carbonate saturation horizons and their relation to shelf circulation

High conservation value coldwater coral distributions appear to be constrained by (decreasing) carbonate saturation state along the deep E.Antarctic shelf – 600 to 1200m (Riddle,Tilbrook, in prep).

The relation between saturation surfaces, T,S, and shelf flows, including CDW upwelling and polynya outflows, is not understood.

Potential target for pH/O2 glider/float missions.

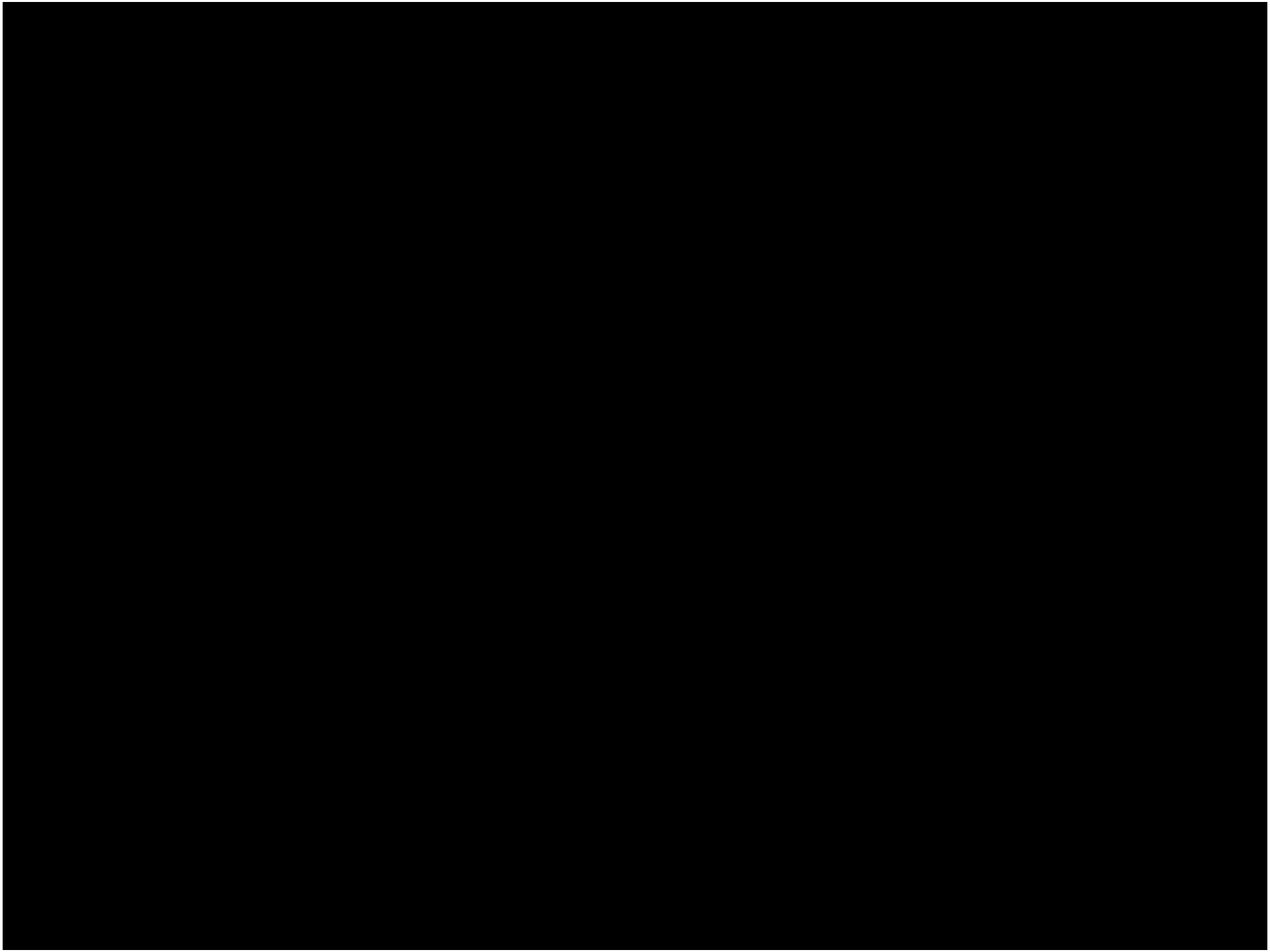
Potential Research Targets

4. The role of mixing in controlling biomass generation in high production plumes

The Kerguelen plateau generates a downstream bloom ~1000km in the ACC, which is well simulated as driven by winter-time iron advection with a removal constant of ~2% per day (Mongin et al., JMR in press). Summer-time cloud-free satellite images are too infrequent to permit assesssment of biomass decay as blooms are advected off the plateau and mixed into the downstream unfertilised waters.

Float missions with FLNTU/O2 profiling on diel cycles may enable production and thus eventually iron retention timescales to be extracted. An array of floats may allow horizontal dispersion to also be assessed.

There is a proposal for a second KEOPS mission in 2012 (France and Australia) which would provide context and launch opportunities.



Australian S.Ocean Observations

1. Repeat WOCE/CLIVAR hydrographic sections from Australia to Antarctica

SR3 – 7 times already, most recent in 2008, next one ~2015 ?

I9 – 2 times already, most recent in 2007, next one in 2013 will include GEOTRACES

PIs Steve Rintoul, Nathan Bindoff, Bronte Tilbrook (carbon), Andy Bowie (GEOTRACES)

Australian S.Ocean Observations

2. Repeat surface water observations onboard French resupply vessel from Hobart to D'umont D'Urville – 3x2-way transits between Oct. and Mar. annually:

high density XBT(Rintoul and Morrow)

T,S, pCO_2, O_2/Ar, nutrients, FRRF (Tilbrook)

CO_2/TALK (Poisson/Goyet, France)

pigments and species counts (Wright)

In 2010:

Continuous plankton recorder (Richardson)

PIC/POC/BSi (Trull)

Australian S.Ocean Observations

3. Southern Ocean Time Series Moorings (www.imos.org.au)

SAZ near 47S, 140 E, 4500m depth

- Deep sediment traps
- Pulse surface mixed layer T,S,O2, PAR, FLNTU, water samples (MclaneRAS500) for nutrients/DIC/ALK, phyto i.d., (Fe?)
- ASIMET meteorological tower (WHOI) with pCO_2 (Sabine/NOAA), FLNTU, mld

4. PIs Tom Trull, Eric Shulz, Bronte Tilbrook

Australian S.Ocean Observations

4. AABW Moorings

Mertz polynya shelf-sill outflow

near 140 E

2008 to about 2012

T,S,ADCP

PI Steve Rintoul

Australian S.Ocean Observations

5. BGC profiling floats

- ~10 per year for next 3 years with O2-optodes in SAZ, PFZ, and AZ.
- ~ 8 over next 2 years with O2, FLNTU, Iridium hot-swapping depth table for near-surface (0-300) diurnal cycles at weekly intervals in SAZ
- PIs Bronte Tilbrook, Tom Trull

Australian S.Ocean Observations

6. Sea-ice processes study

- 2011-12 Aurora Australis
- Phys-chem-bio components
- Builds on SIPEX sea-ice process voyage in 2007.
- PIs Tony Worby, Rob Massom, Klaus Meiners, Andy Bowie