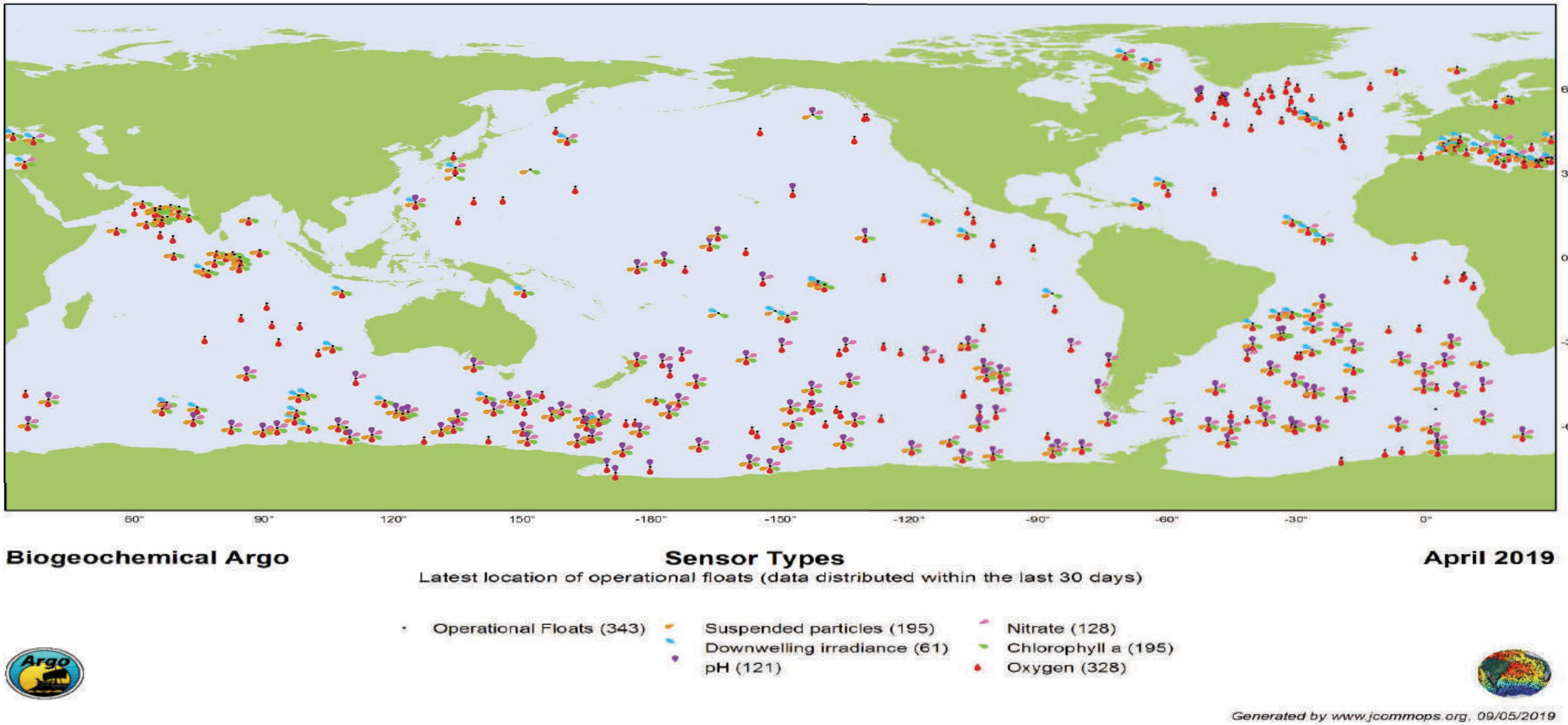
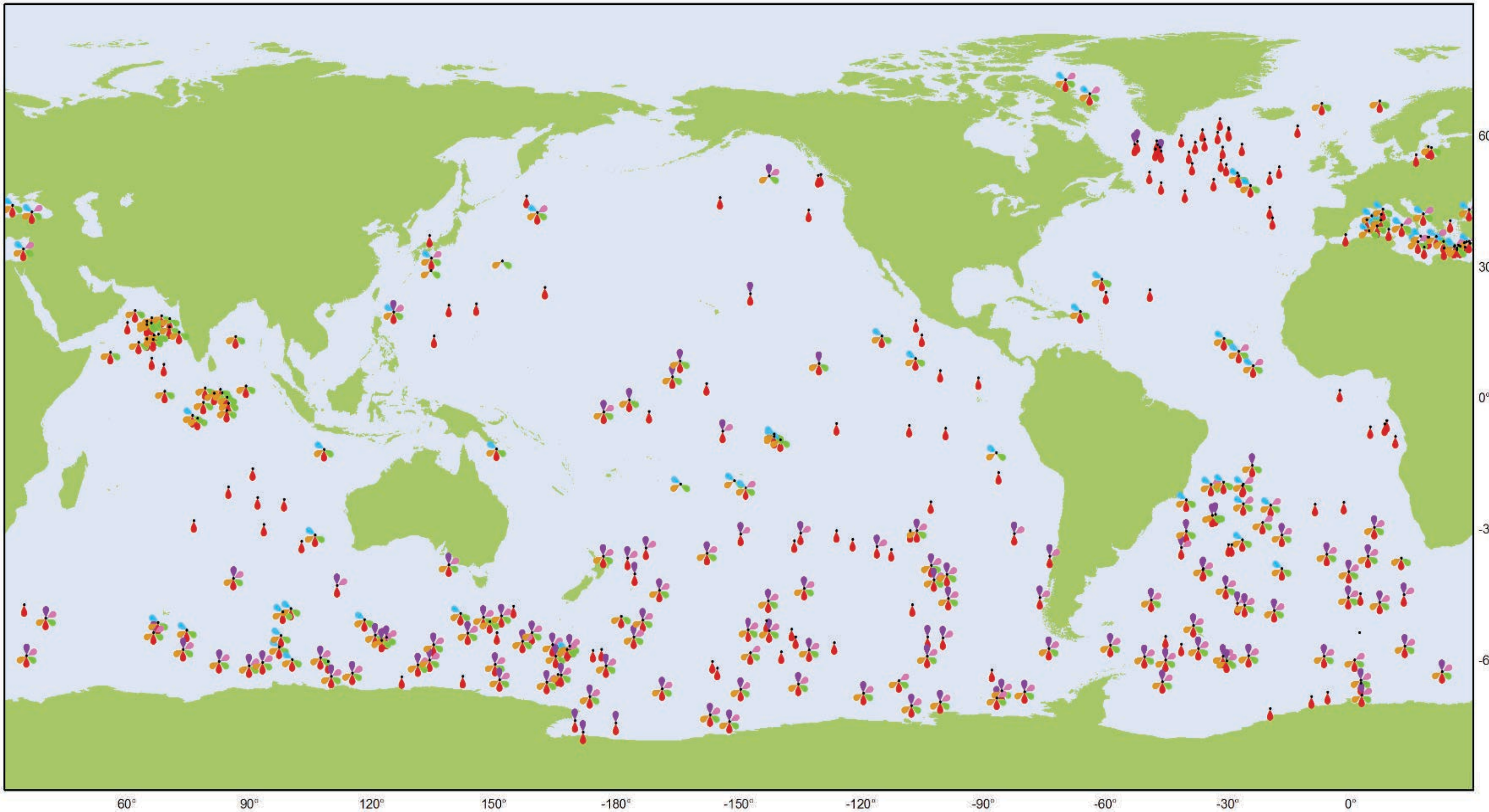
Community update: Biogeochemical-Argo

ECCO summer school, May 2019

Matt Mazloff (SIO), Ken Johnson (MBARI)





Biogeochemical Argo

Sensor Types

Latest location of operational floats (data distributed within the last 30 days)

April 2019

- Operational Floats (343)
- Suspended particles (195)
- Downwelling irradiance (61)
- pH (121)
- Nitrate (128)
- Chlorophyll a (195)
- Oxygen (328)

Generated by www.jcommops.org, 09/05/2019

What is a BGC-Argo float?

Mature sensor suite

- biooptical sensors: chlorophyll fluorescence, backscatter, light intensity.
- chemical species: dissolved oxygen, nitrate, and pH.

Protocols have been established based on peer-reviewed publications and international working groups.

Sensor	Oxygen	Nitrate	pH
Initial accuracy	2 µmol/kg	1 µmol/kg	0.01

New sensors must be accompanied by quality calibration and validation procedures until demonstrated that specifications are achieved with the "factory calibration". Must also be means available to assess the changing performance of sensor over time.

https://soccom.princeton.edu/content/float-specifications

For what is a SOCCOM float and sensor references

What is a BGC-Argo float?

Mature sensor suite

- biooptical sensors: chlorophyll fluorescence, backscatter, light intensity.
- chemical species: dissolved oxygen, nitrate, and pH.

Data management

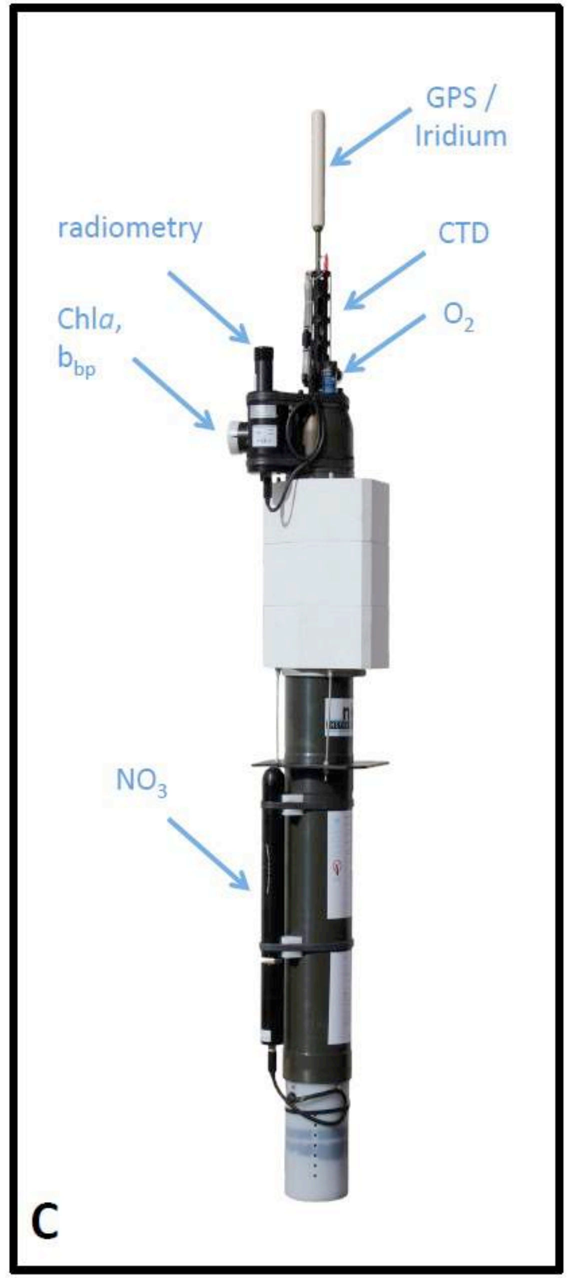
- real-time data delivery for operational purpose
- delayed-mode quality-controlled data delivery for science
- new products complying with end-user requirements

Critical Ocean Processes for climate variability, ecosystem health, management marine resources, carbon budgets

- ocean carbon uptake
- ocean deoxygenation, oxygen minimum zones and related cycles of denitrification
- ocean acidification
- the biological carbon pump
- phytoplankton communities.

Navis

APEX



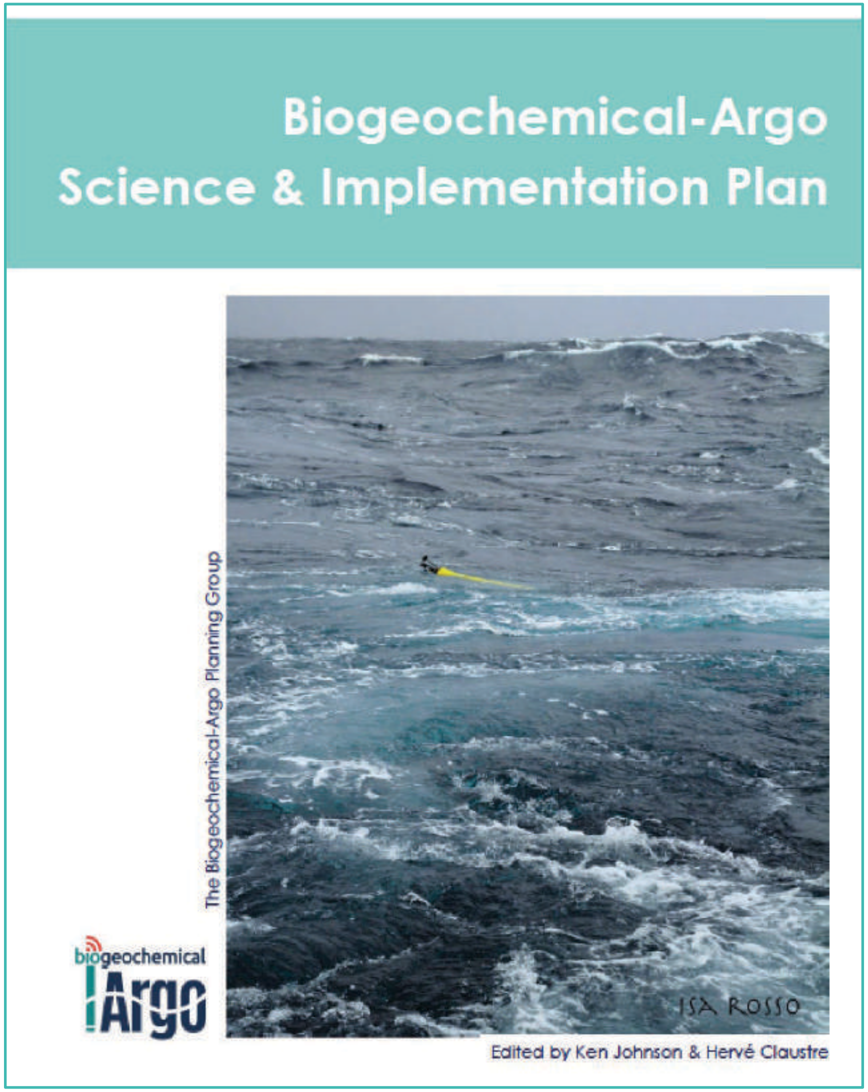
Provor

SOLO-II
SIO
In development

biogeochemical Argo

The Biogeochemical-Argo Implementation Plan

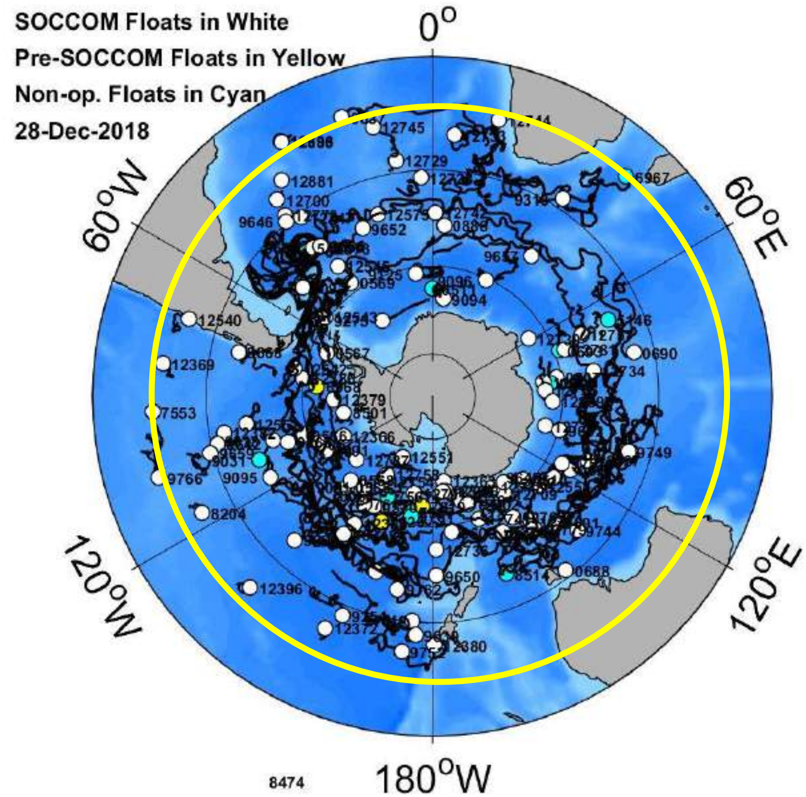
- An international plan
- 1000 profiling floats with O_2, pH, NO_3^-, bio-optics
- Observe seasonal and interannual change in carbon cycling, OMZ's, nutrient flux, acidification, biological carbon pump, phytoplankton phenology
- Ocean management of living marine resources & carbon budget verification
- Sustaining 1000 floats requires ~250 floats/year
- ~$25,000,000/year (~$12,500,000/year for US share?).



http://biogeochemical-argo.org

Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM): A basin scale program.

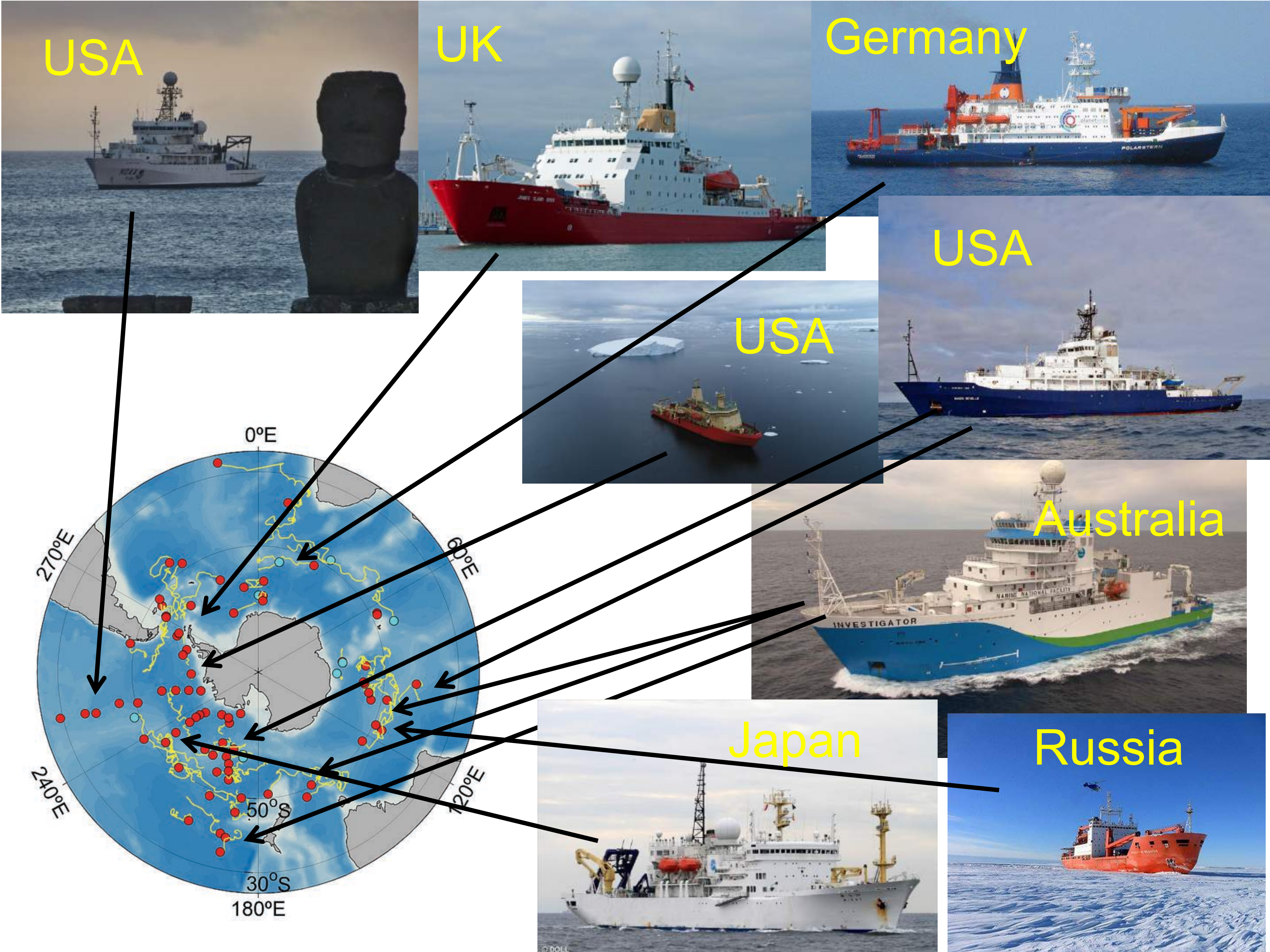
136 active floats (May 2019)



The goal is ~200 floats with O_2, NO_3^-, pH, bio-optics in So. Ocn.

Funded by NSF Polar Programs with NASA, NOAA add-ons.

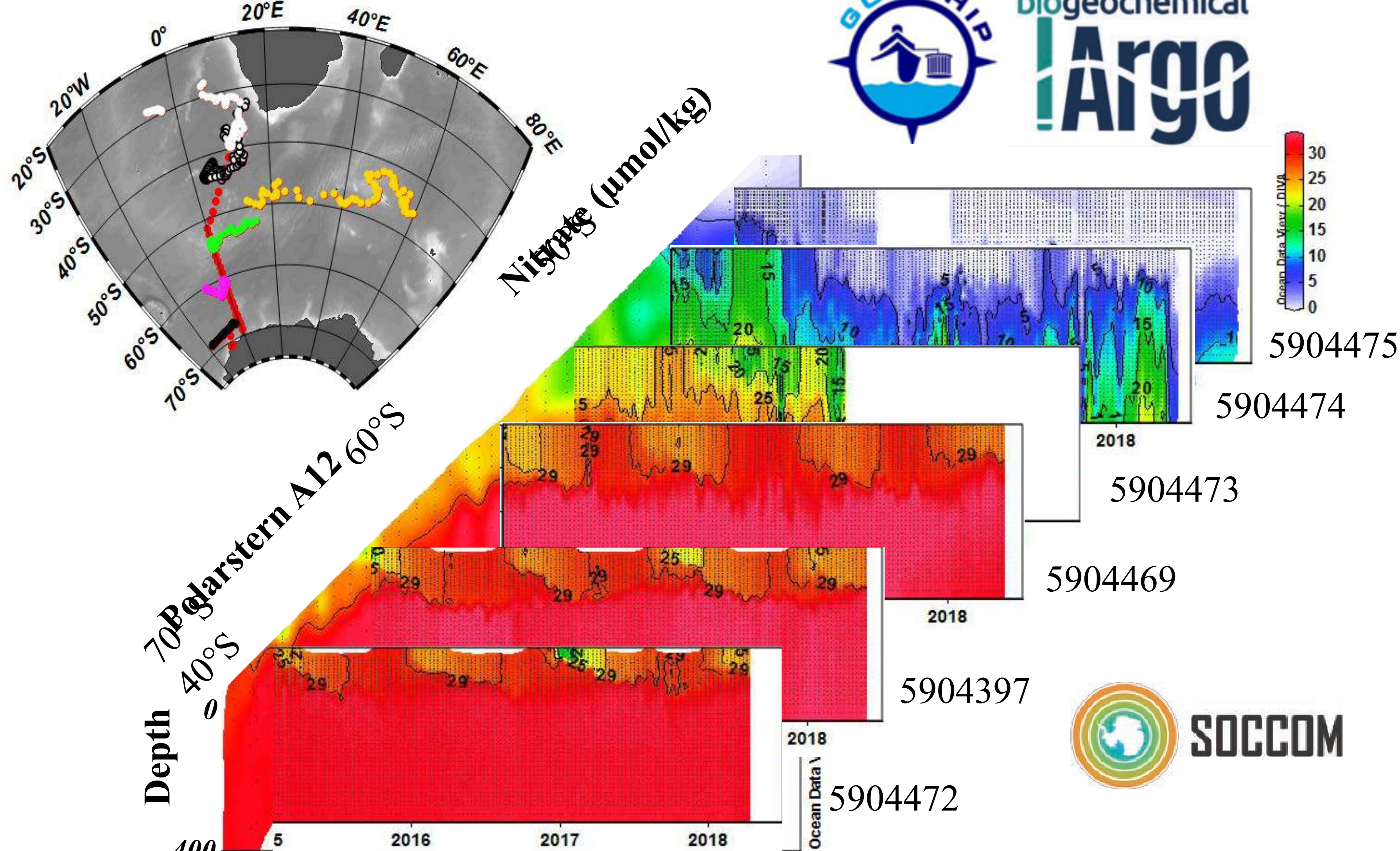
All data publically available, in real-time at http://soccom.princeton.edu and through the Argo Global Data Assembly Centers.


USA
UK
Germany
USA
USA
Australia
INVESTIGATOR
Japan
Russia
0ºE
60ºE
120ºE
180ºE
240ºE
270ºE
50ºS
30ºS

2018 BGC Plans

Canada	2	Italy	7
China	12	Japan	5
EU	2	Mexico	1
Finland	3	Norway	5
France	19	Poland	1
Germany	3	UK	6
Greece	1	USA	37
India	20		
		Total	**124**

But note that the sensor load is quite variable. Some have O_2 only. Some have O_2, NO_3, pH, Chloro, Backscatter, Irradiance. And everything in between!



Johnson et al., JGR, 2017

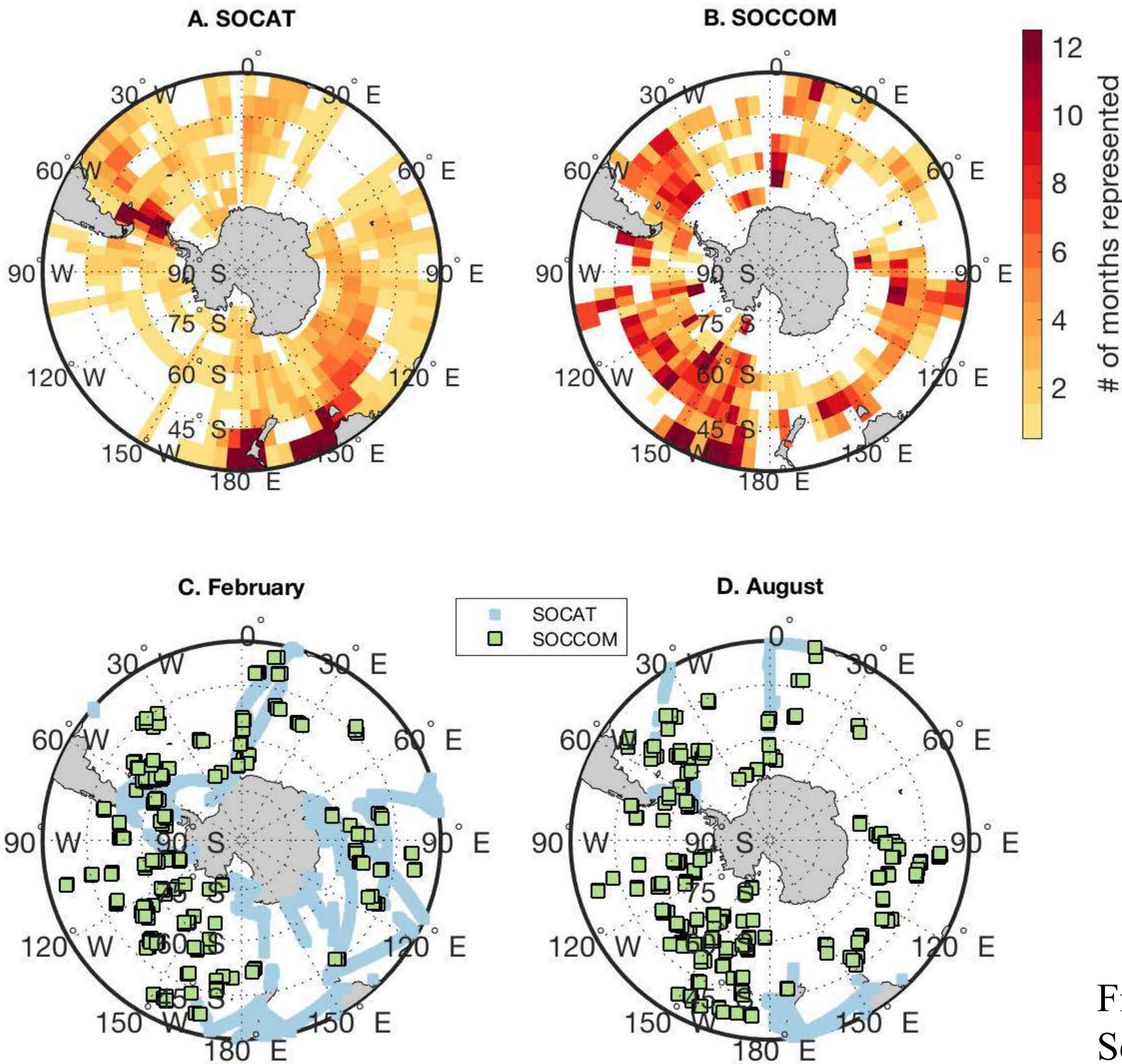


Figure from Seth Bushinsky

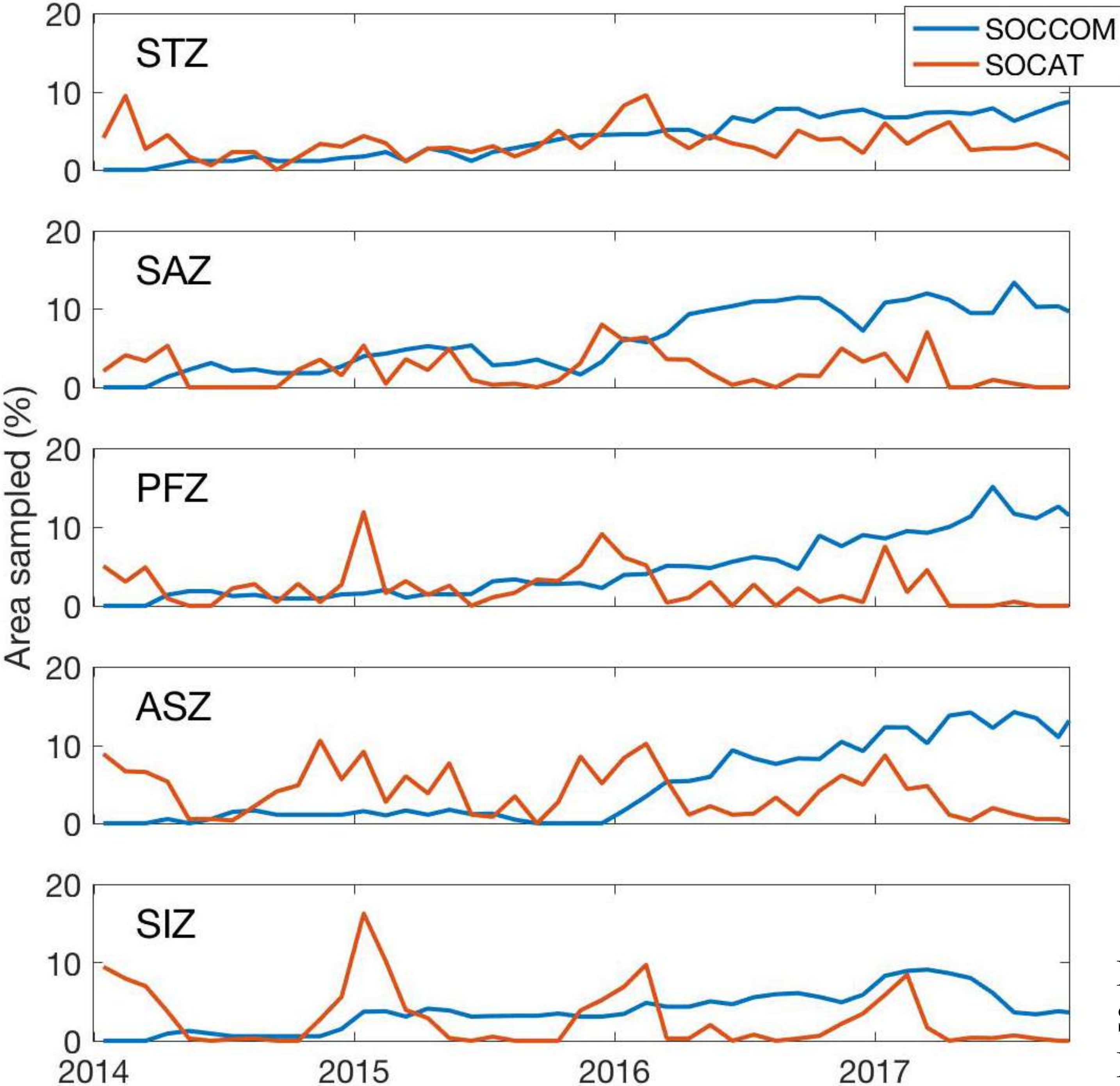
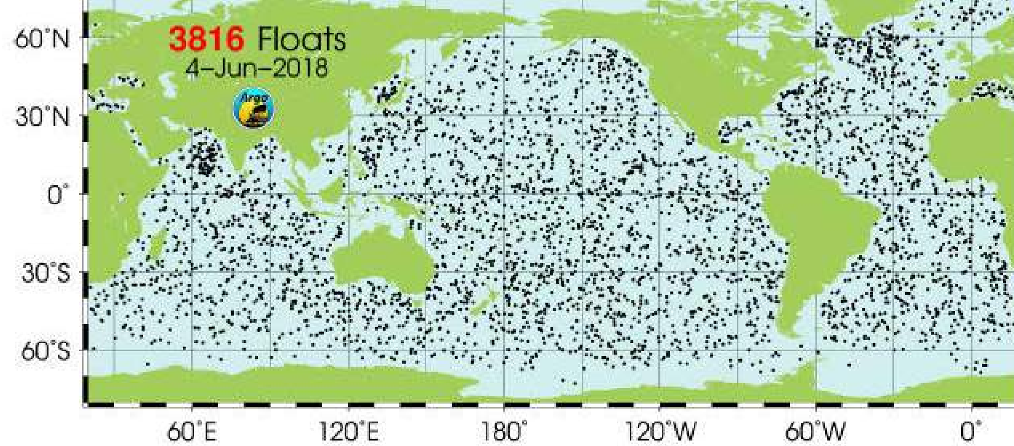
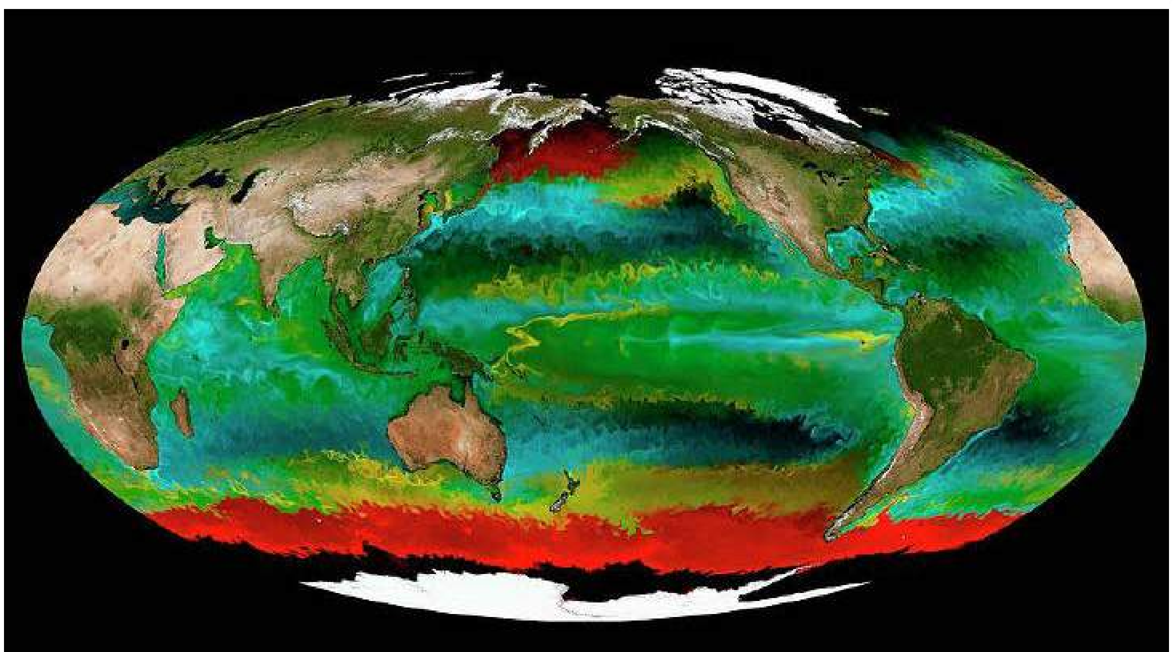


Figure from Seth Bushinsky

BGC-Argo Network
1000 profiling floats with
T & S, oxygen, nitrate, CDOM &
chl fluorescence, backscatter,
irradiance and pH



Operational Centres
Global and regional models
assimilate RT data for forcasting
and DL-mode data for reanalyses



Improved model products
for applications ranging from
climate predictions, carbon
accouncting, assessment of
ocean acidification and
deoxygenation, and primary
production estimates to
managment of living marine
resources.

B-SOSE

Biogeochemical Southern Ocean State Estimate

Data assimilation of carbon and other biogeochemical constraints

Ariane Verdy, Matt Mazloff

SCRIPPS INSTITUTION OF OCEANOGRAPHY

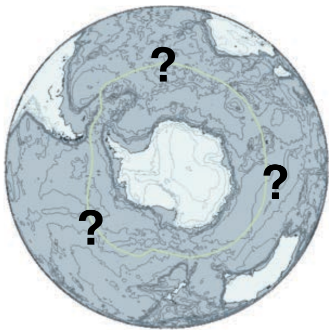
UC San Diego

Lynne Talley, Sharon Escher, Bruce Cornuelle, Isa Rosso, Natalie Freeman, Joellen Russell, Jorge Sarmiento, Ken Johnson, Emmanuel Boss, Matt Long, John Dunne, Eric Galbraith

State estimation

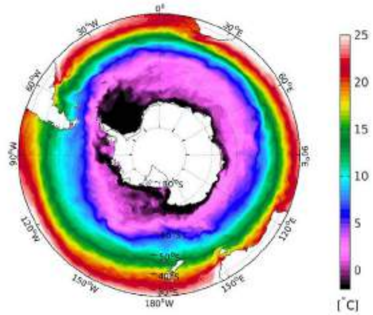
4D-Var, "adjoint" method

models are used to hindcast the ocean state (T, S, V, SSH)



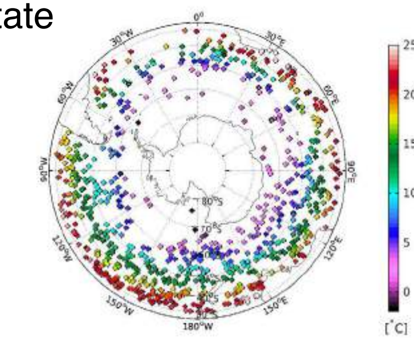
e.g. Southern Ocean 2013-2017

using inputs: initial conditions & atmospheric forcing



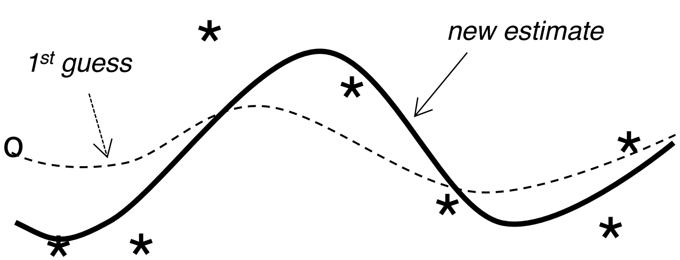
e.g. T & S from Argo maps, winds & air temp, etc. from ECMWF

adjust those inputs to bring the model closer to observations of the actual ocean state



e.g. from Argo profiles, satellites, …

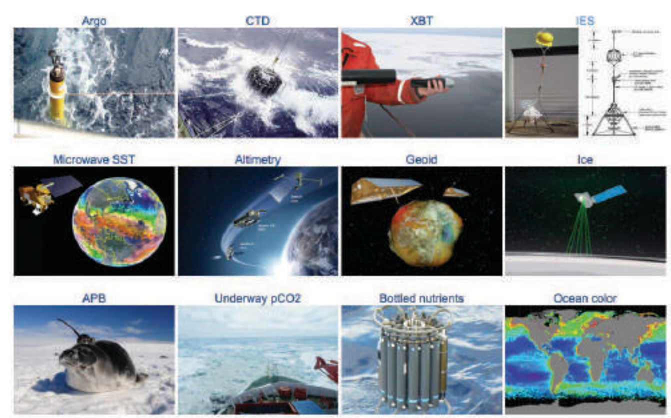
minimize the "cost function" :

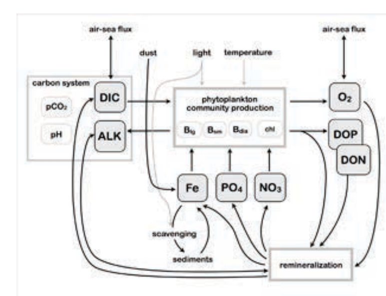


Σ (weighted model-observations misfit)² +
Σ (weighted adjustment to inputs)²

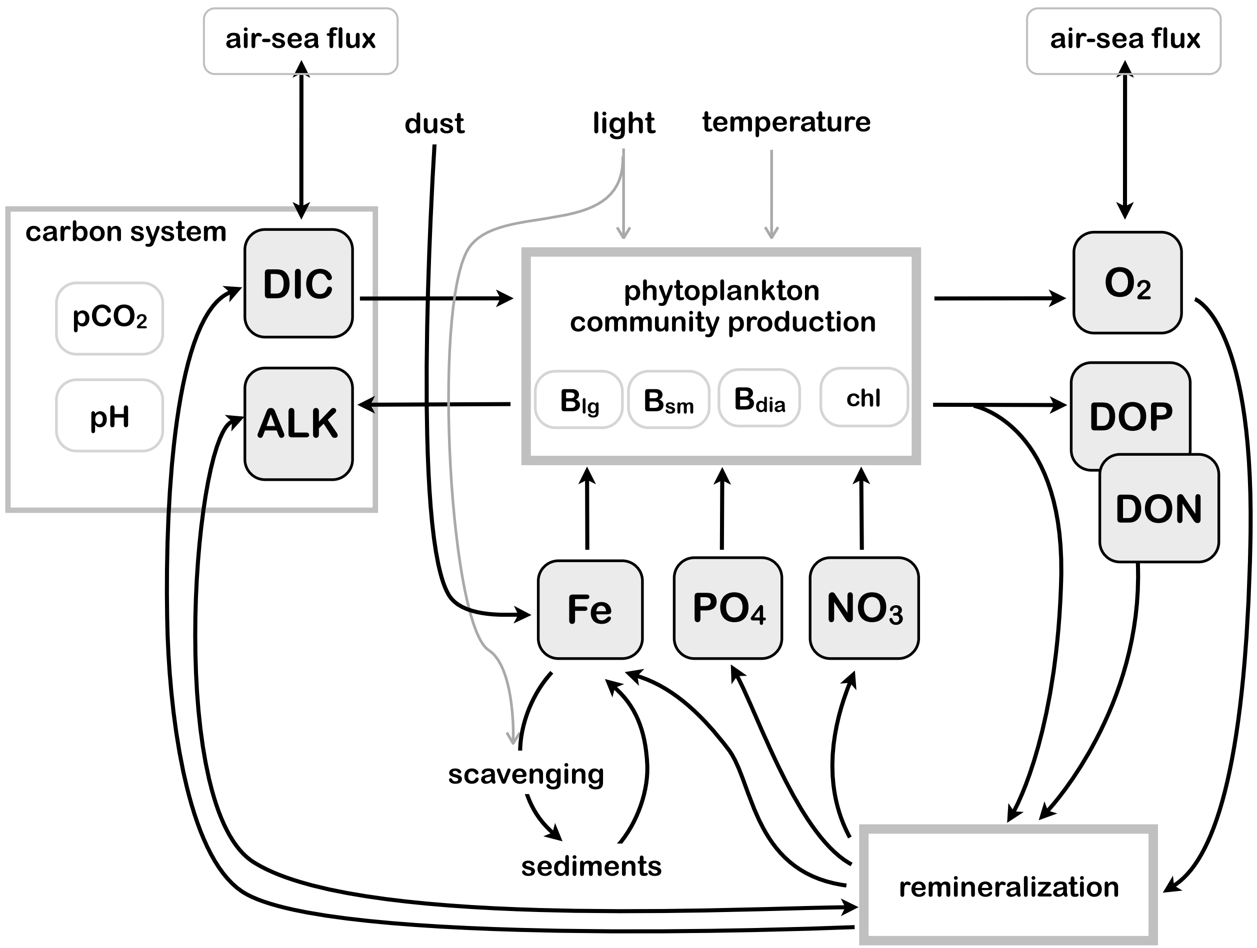
ecco.jpl.nasa.gov

B-SOSE: biogeochemical + physical state optimized together





Biogeochemical model



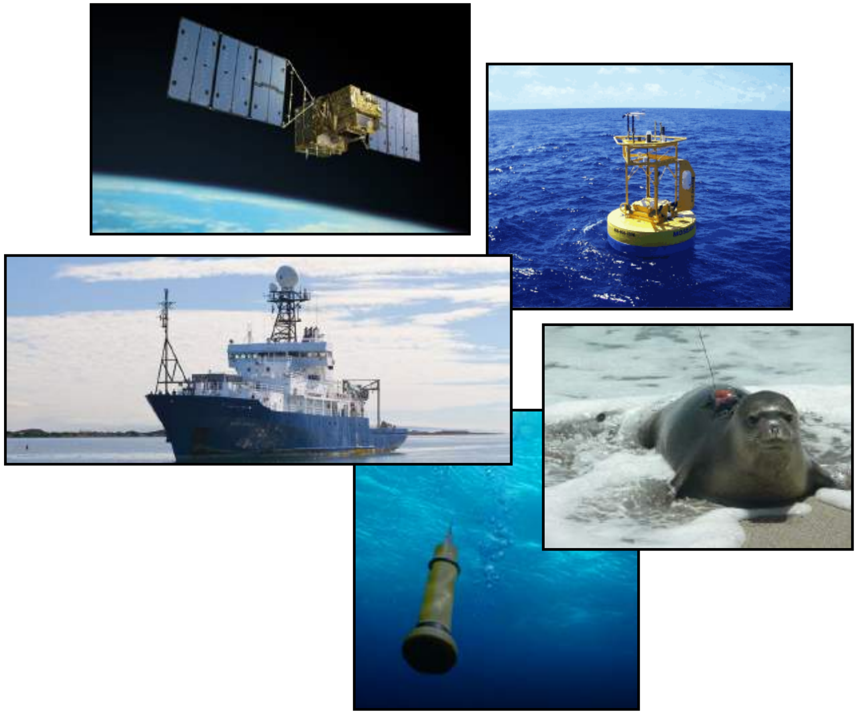
“N-bling”

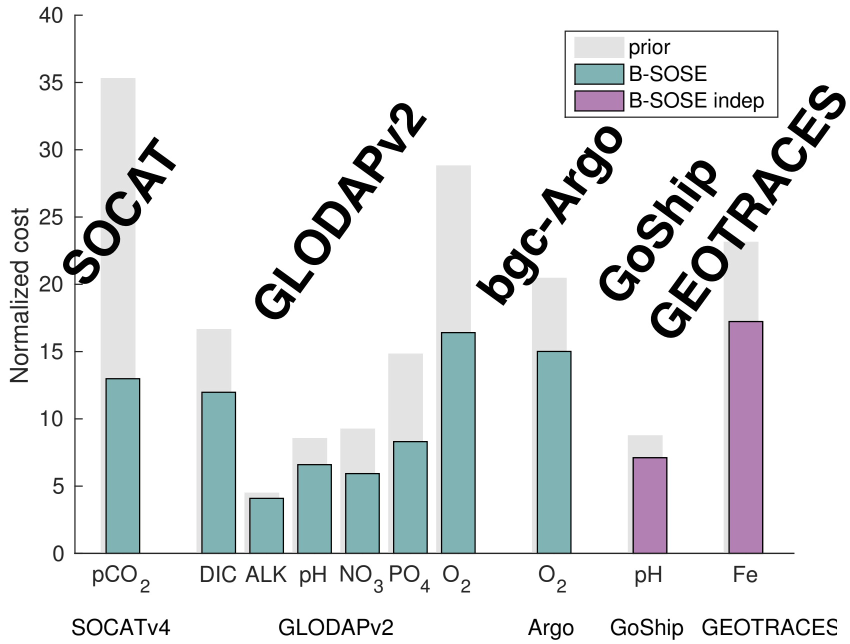
all prognostic and diagnostic variables are estimated; can be compared / constrained to observations

B-SOSE product

2008-2012, 1/3 degree

Verdy and Mazloff (2017), A data assimilating model for estimating Southern Ocean biogeochemistry, JGR-Oceans

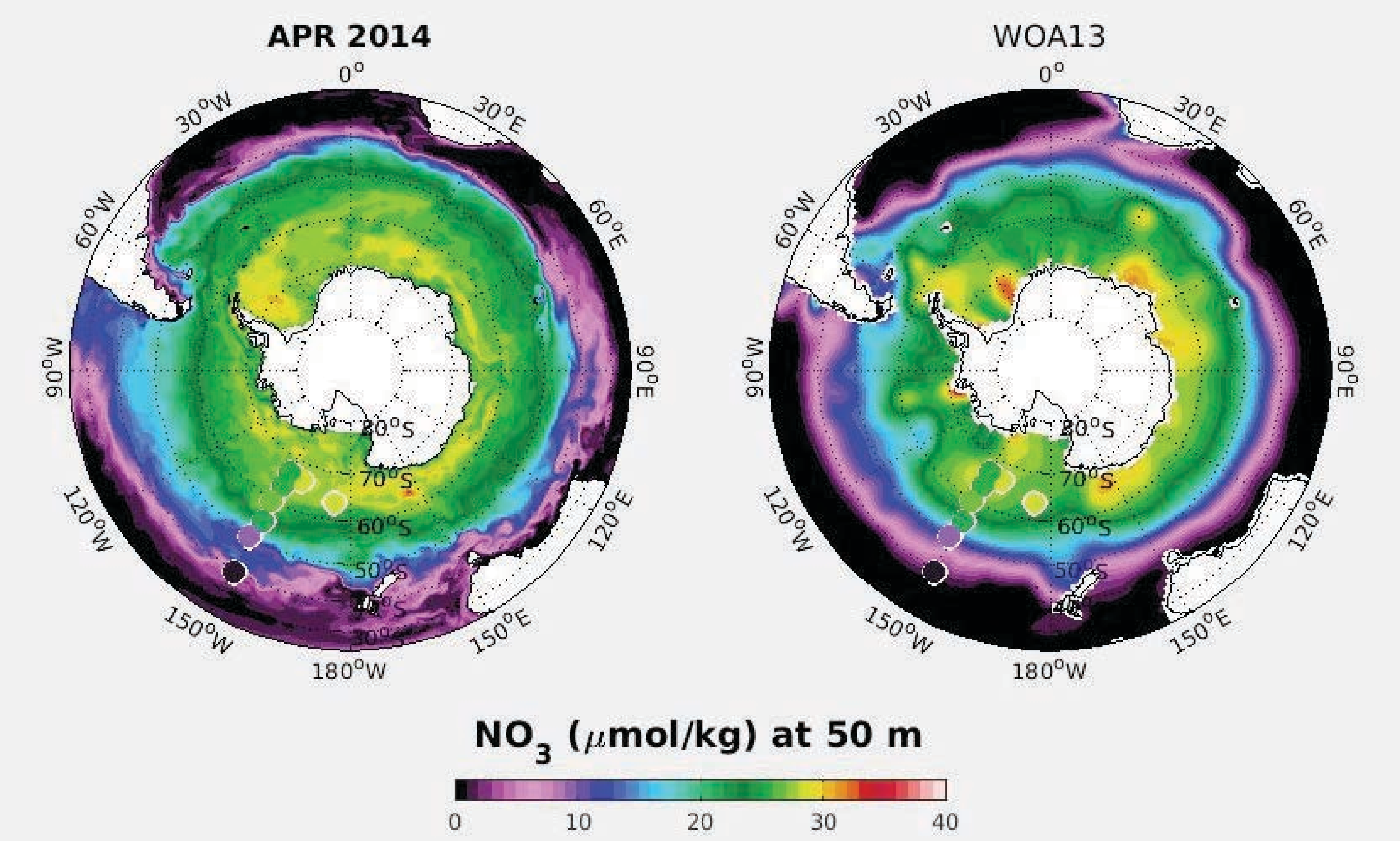




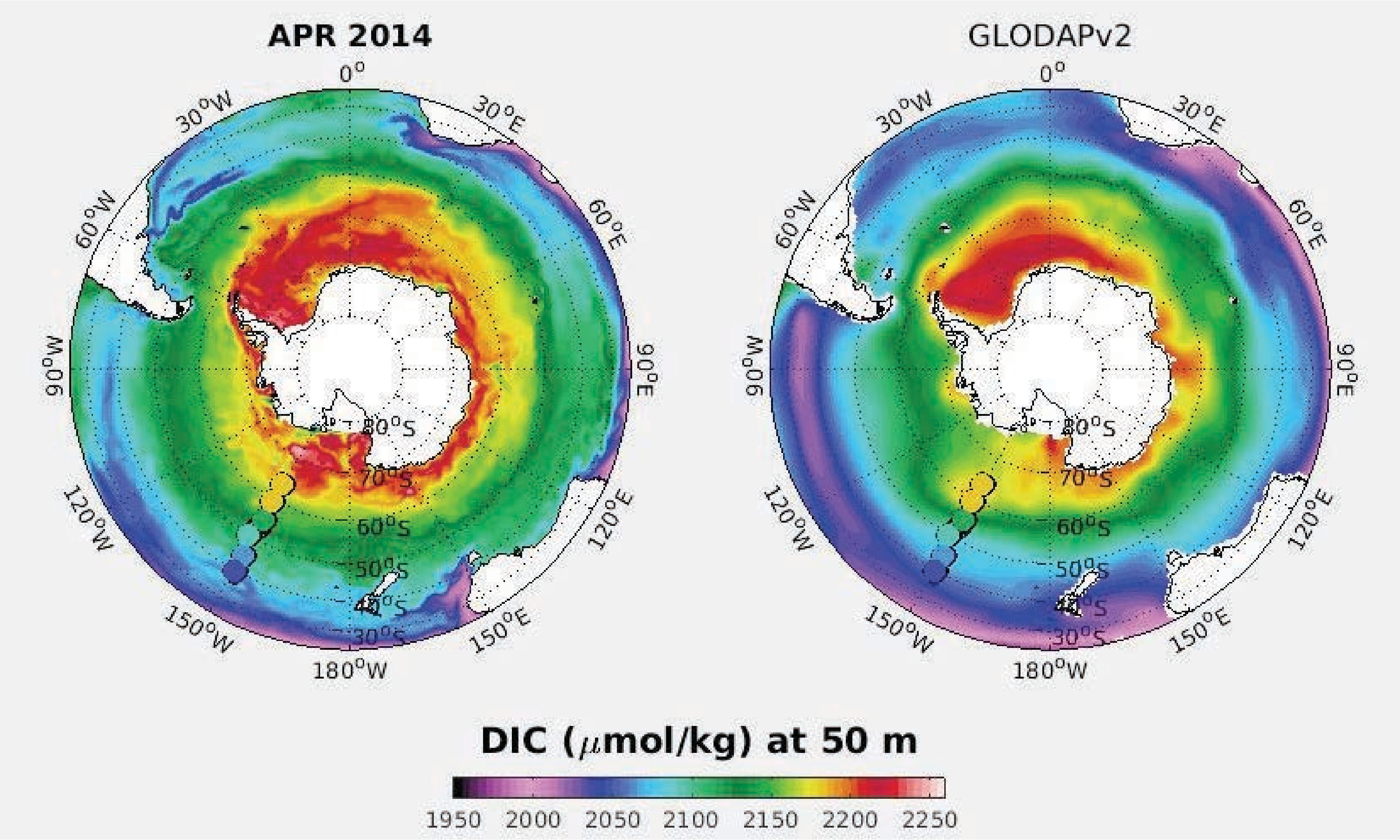
2013-2018 in production (with SOCCOM floats constraints)

B-SOSE vs climatology

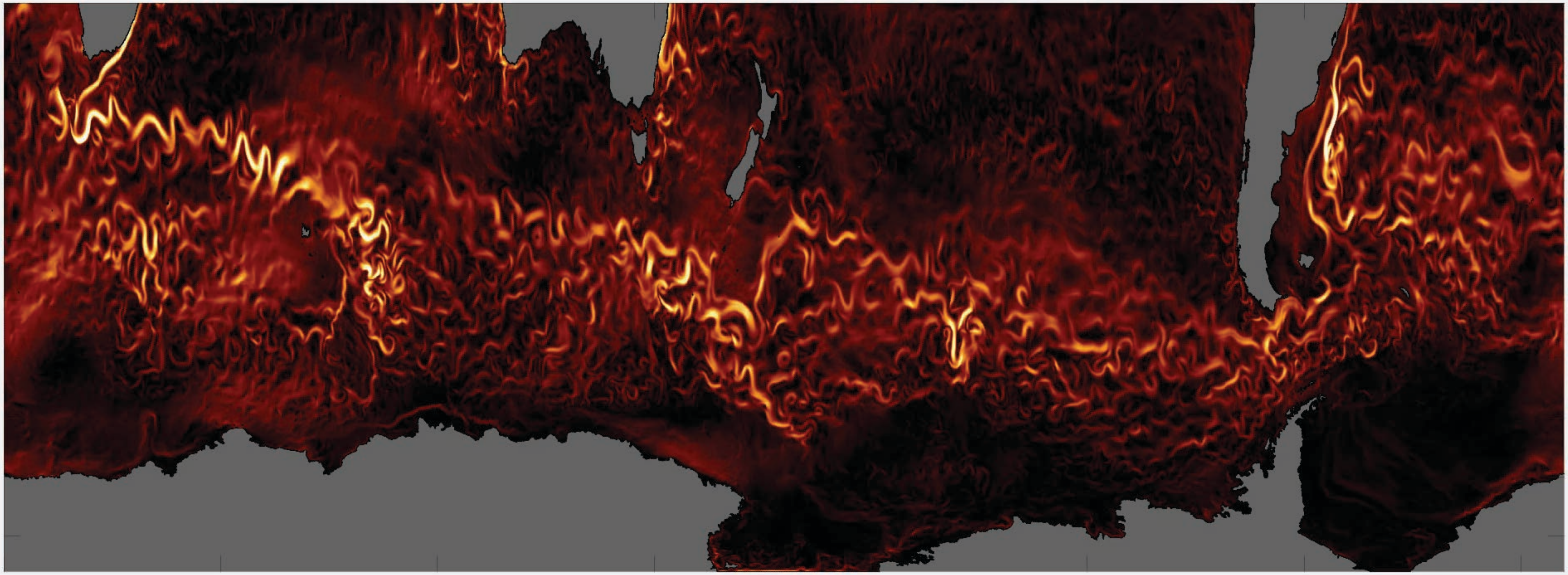
with SOCCOM float observations



B-SOSE vs climatology
with SOCCOM float observations



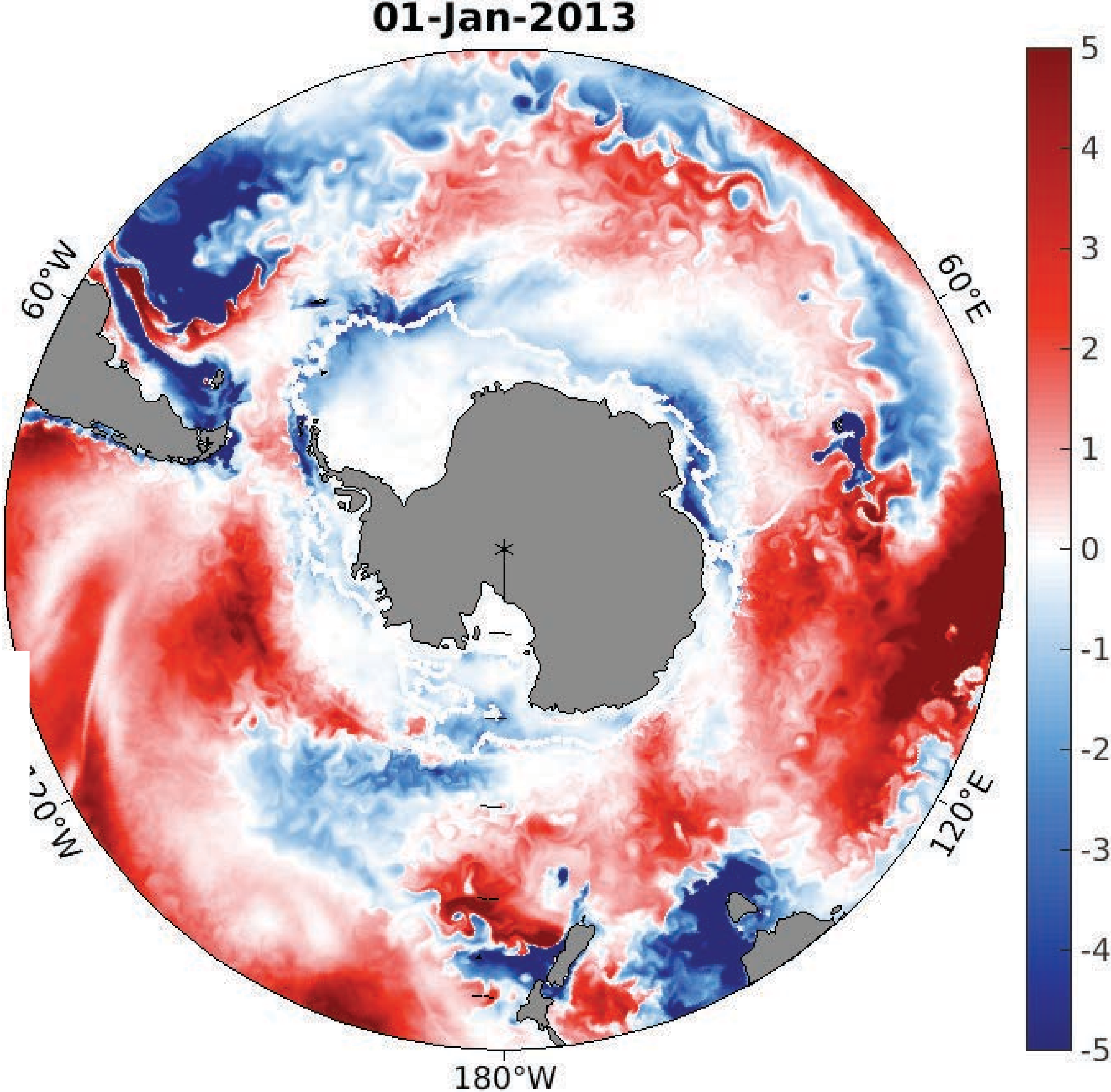
B-SOSE surface speed



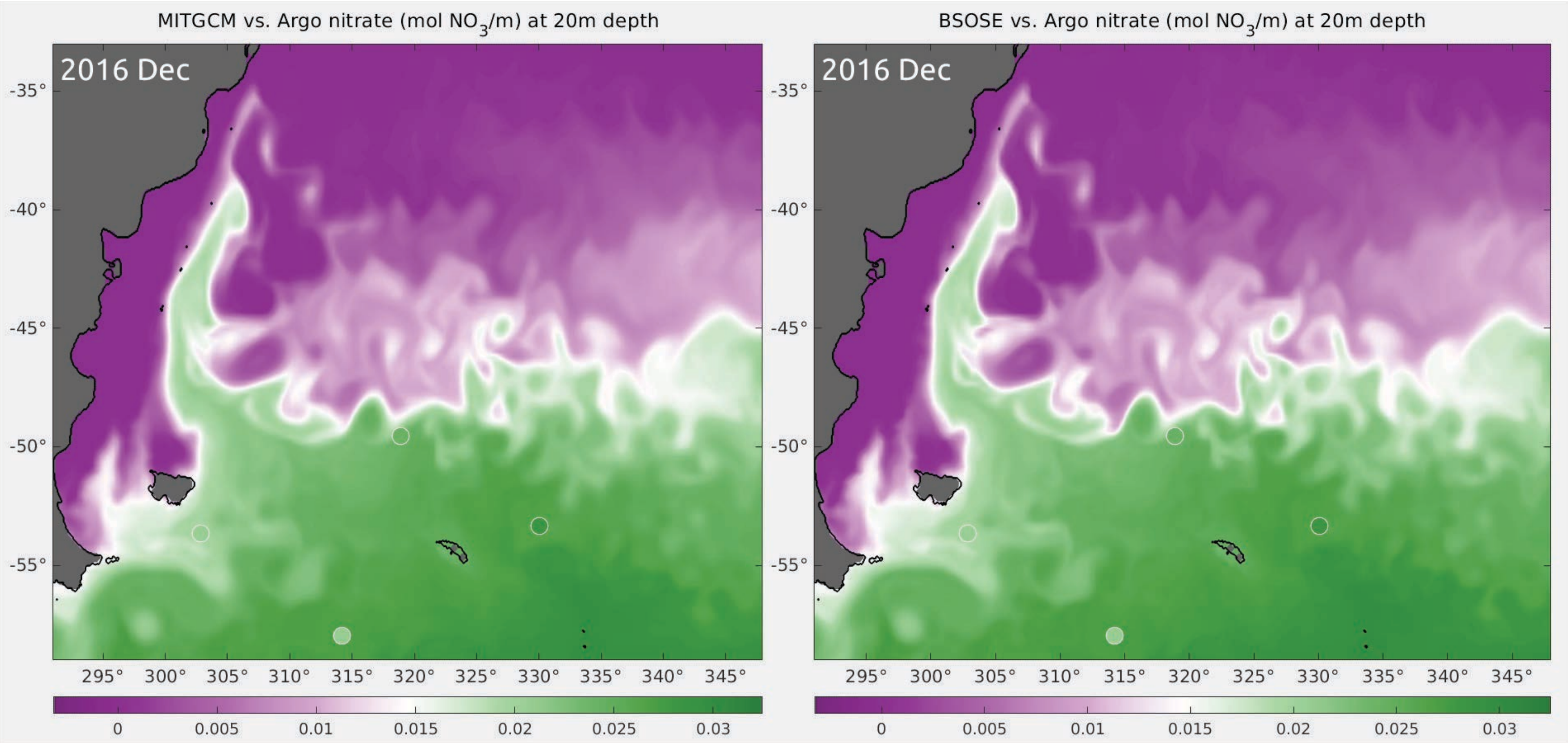
SOCCOM

Movie from Stan Swierczek

ARIZONA



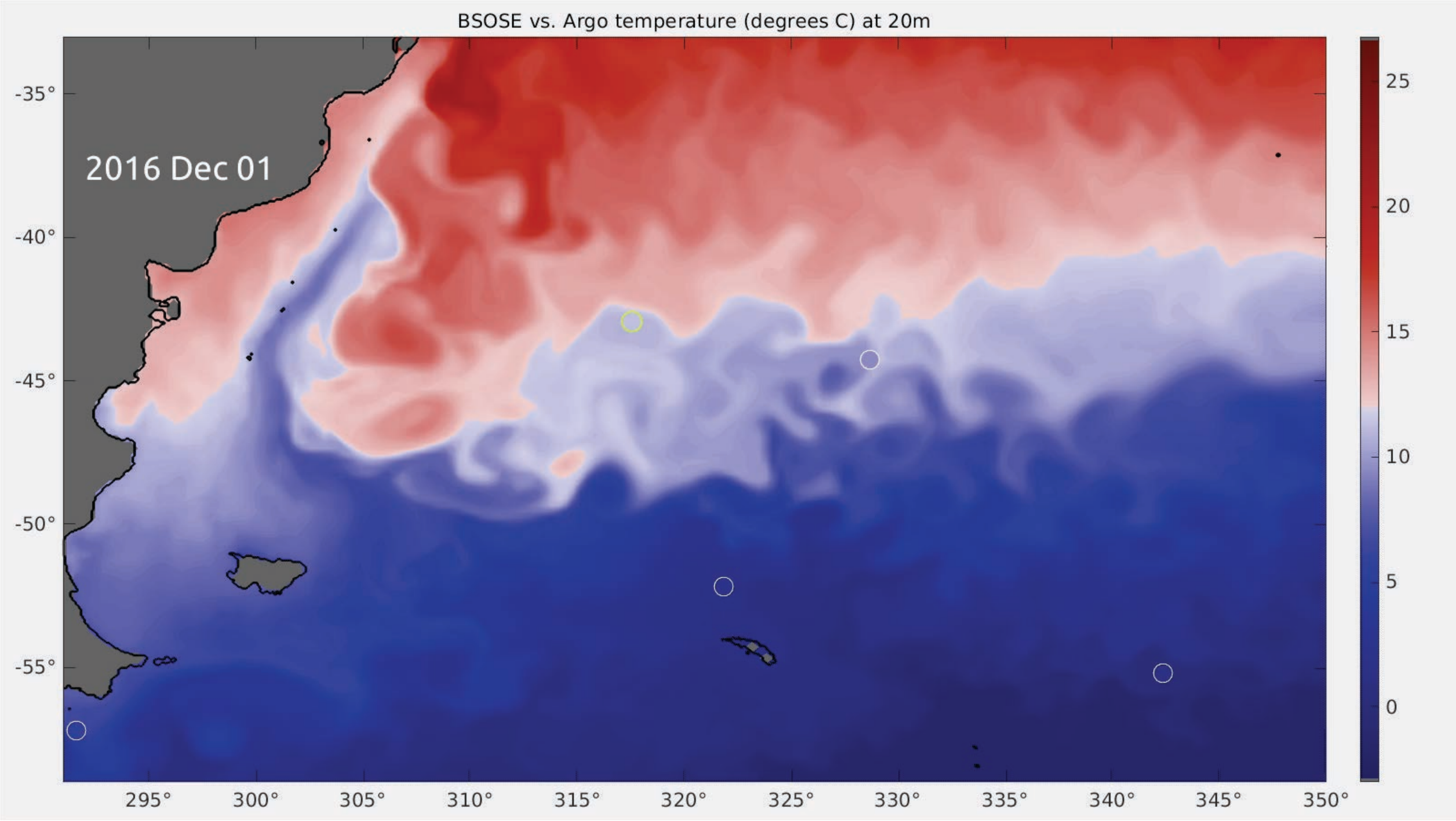
Air-sea CO_2 flux
[mol m^{-2} yr^{-1}]
from B-SOSE
2013 - 2017
solution



NO3 at 20m run at 1/3^o initialize from BSOSE

NO3 at 20m in 1/6^o BSOSE

Movie from Stan Swierczek



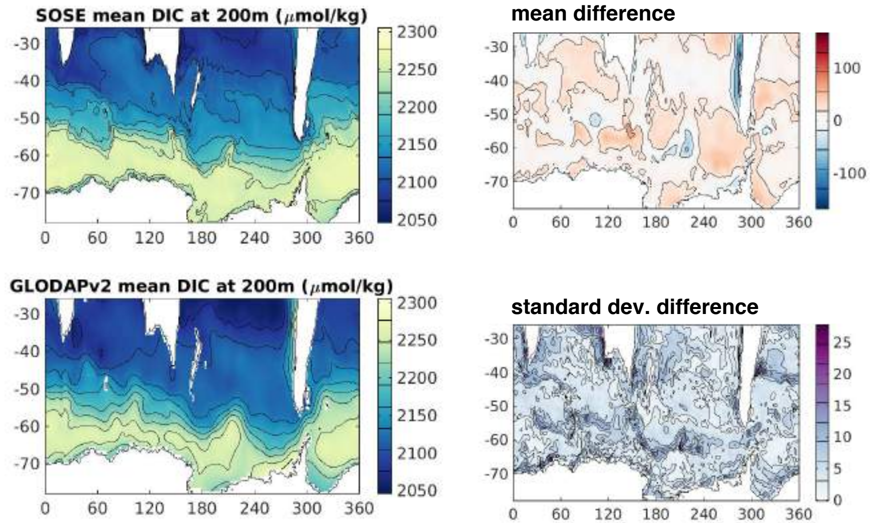
Potential temperature at 20m in
1/6^{o} BSOSE

Movie from Stan Swierczek

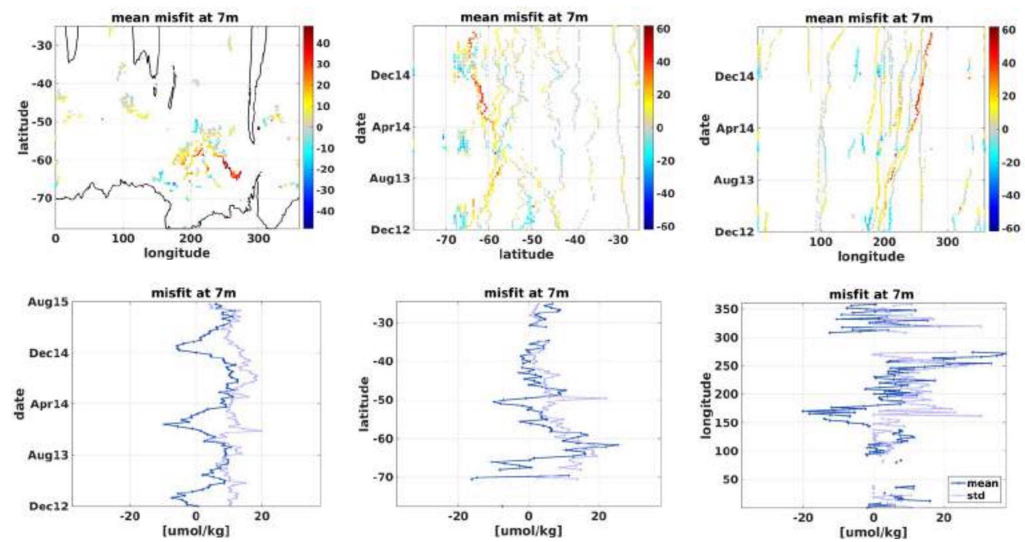
Validation http://sose.ucsd.edu/bsose_valid.html

* = assimilated

Comparisons with gridded products
* ocean color (chl, POC)
* altimetry
* microwave SST
* sea ice
Argo monthly mapped product
GLODAPv2, WOA13, SOCAT climatologies
Landschützer monthly mapped product

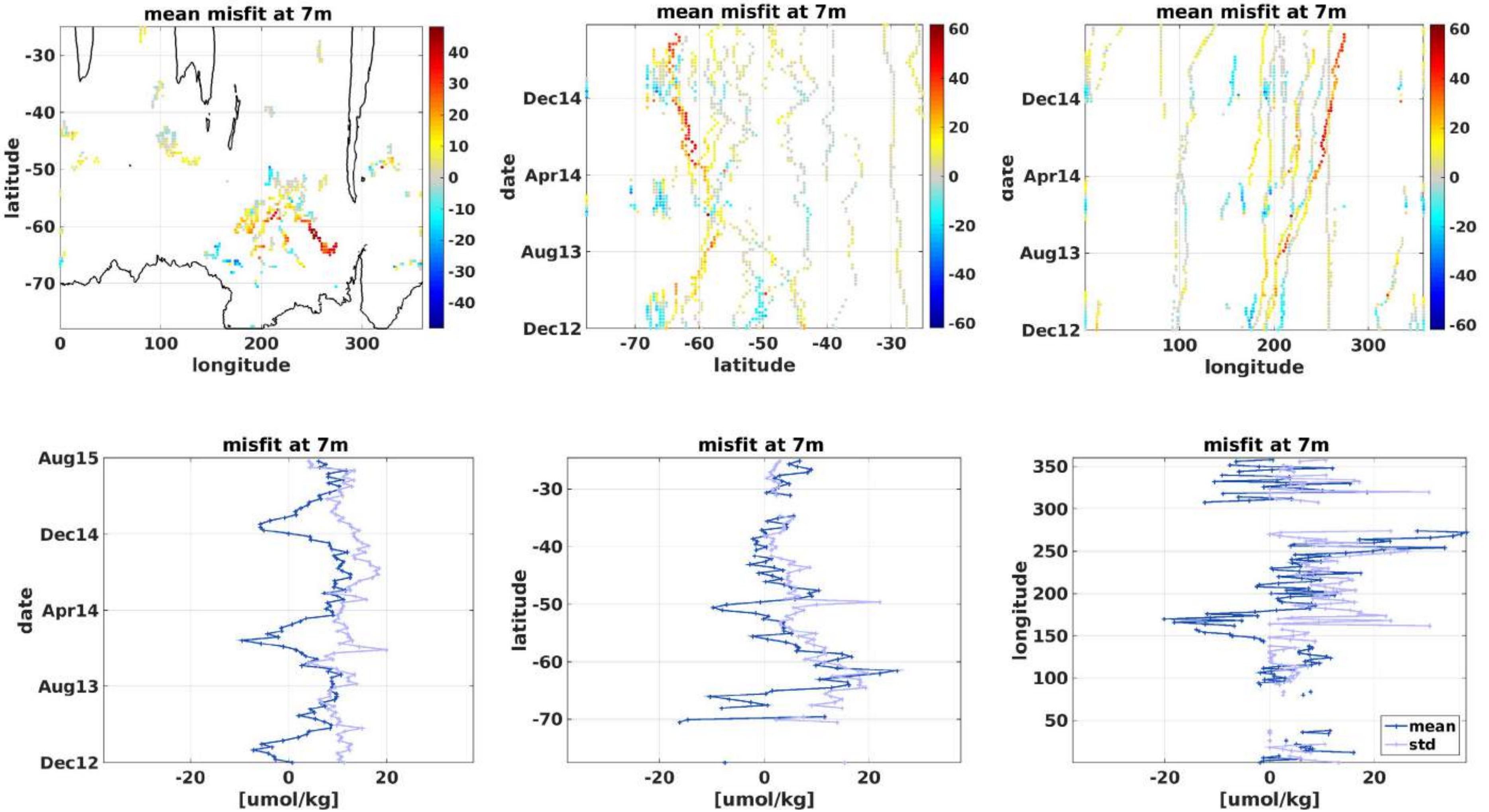


Comparisons with in situ observations
* Argo profiles (T,S)
* calibrated bgc-Argo (O_2)
* SOCCOM floats
* SOCAT (pCO_2)
* GLODAPv2 (carbon, nutrients)
* CTD (T, S, O_2, chl)
* XBT, MEOP, PIES
GEOTRACES

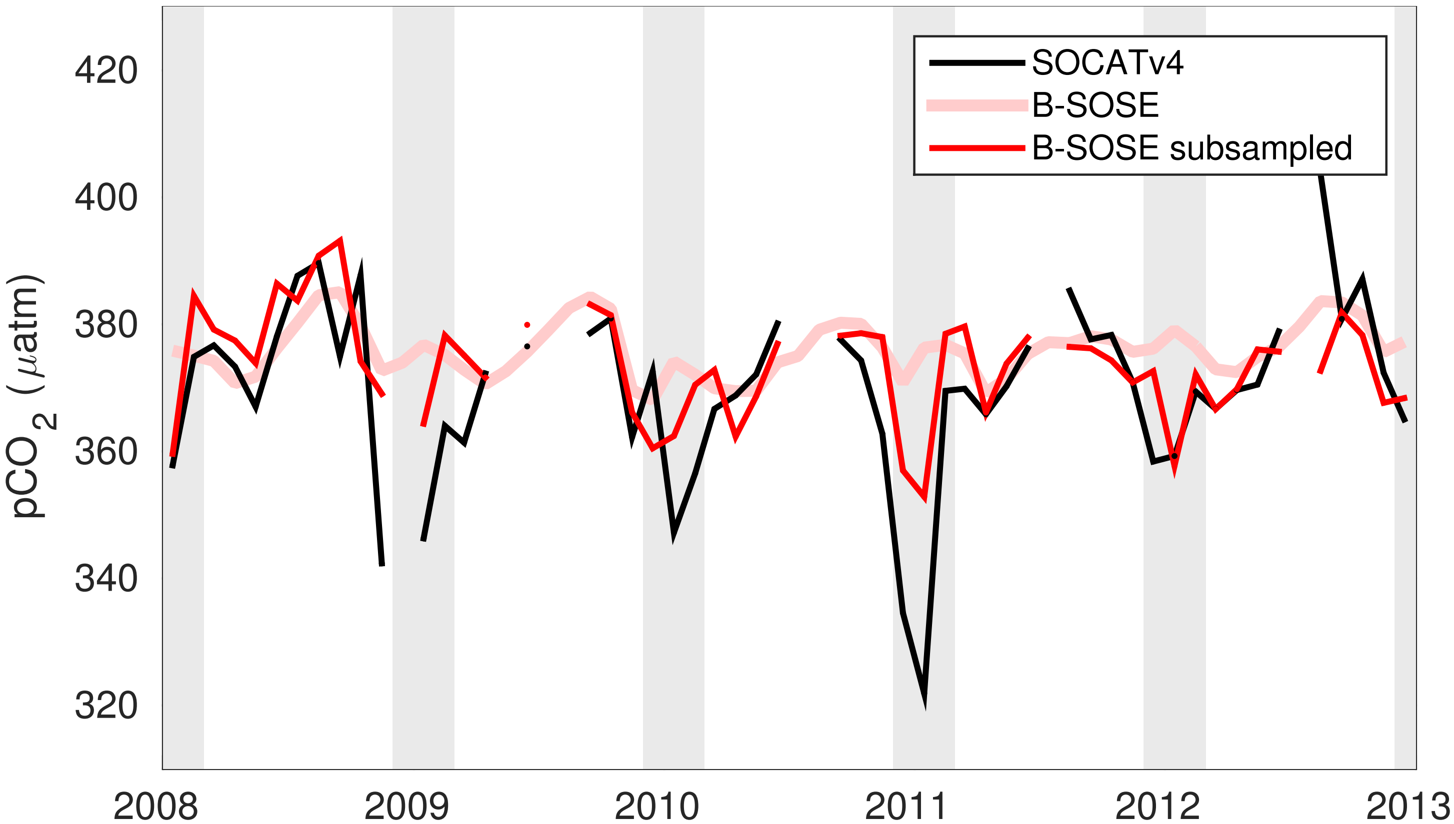


Comparisons with in situ observations

7 m O_2 in B-SOSE 2013-2017 is compared to bgc-Argo



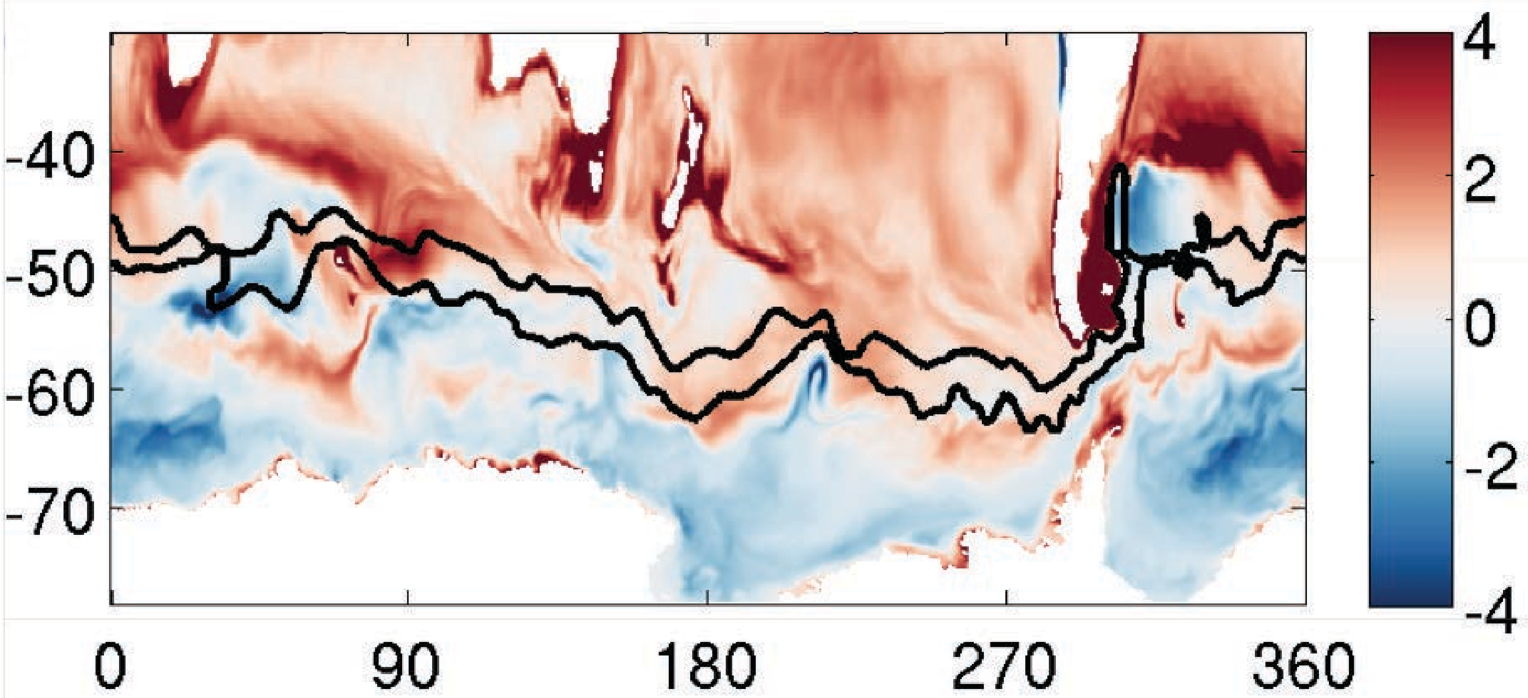
pCO_2 in Drake Passage



Monthly-averaged pCO_2 in Drake Passage (75°W to 55°W, south of 50°S) from SOCATv4 observations (black) [Bakker et al., 2016; Munro et al., 2015a, 2015b], and from B-SOSE (area average in pink; subsampled at the location of observations in red). Summer months are shaded gray.

We have the adjoint tool. Use it to address question:

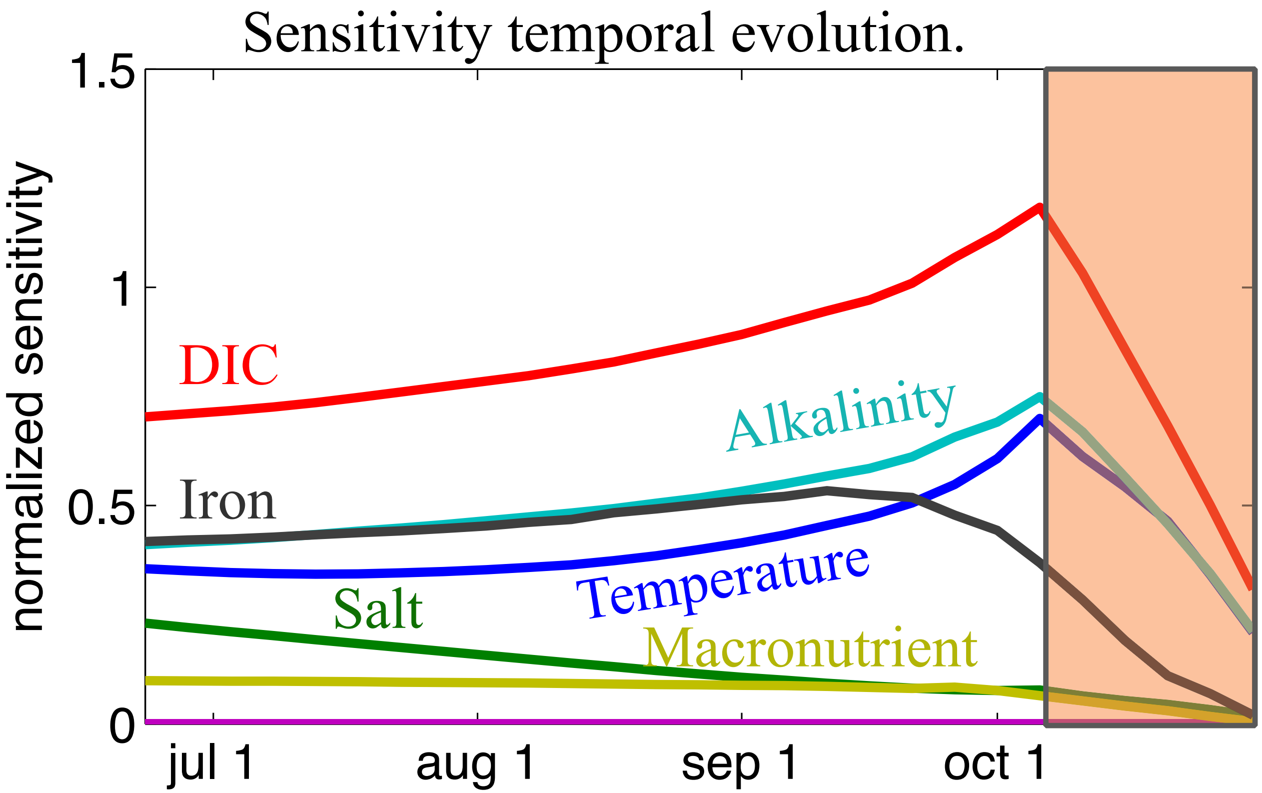
What is the sensitivity of October air-sea carbon



October mean CO_2 flux in model [mol m^{-2} yr^{-1}].

Warm colors are CO_2 uptake by ocean. Cool colors are CO_2 outgassing.

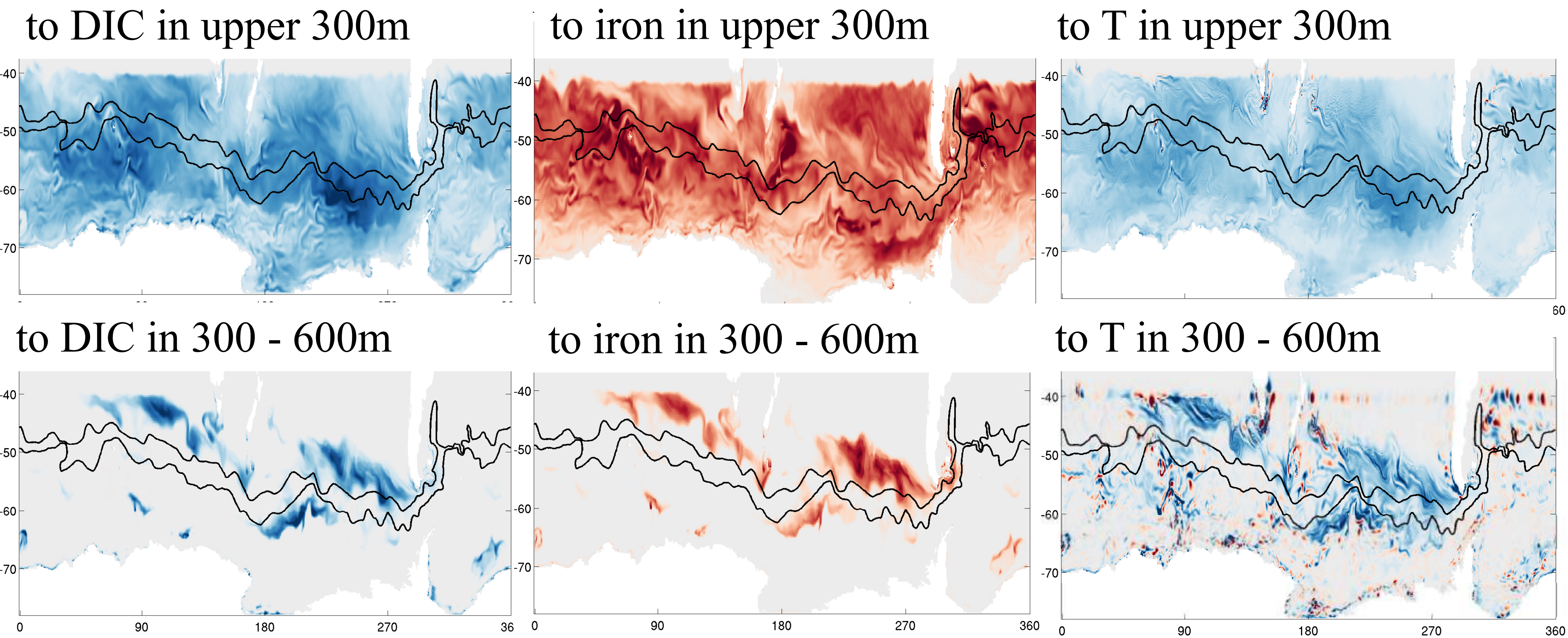
What is the sensitivity of October air-sea carbon exchange poleward of 40°S?



Sensitivity calculated as RMS of adjoint gradient normalized by standard deviation of respective property.

SOCCOM

Sensitivity of October air-sea CO_2 flux to properties in September:

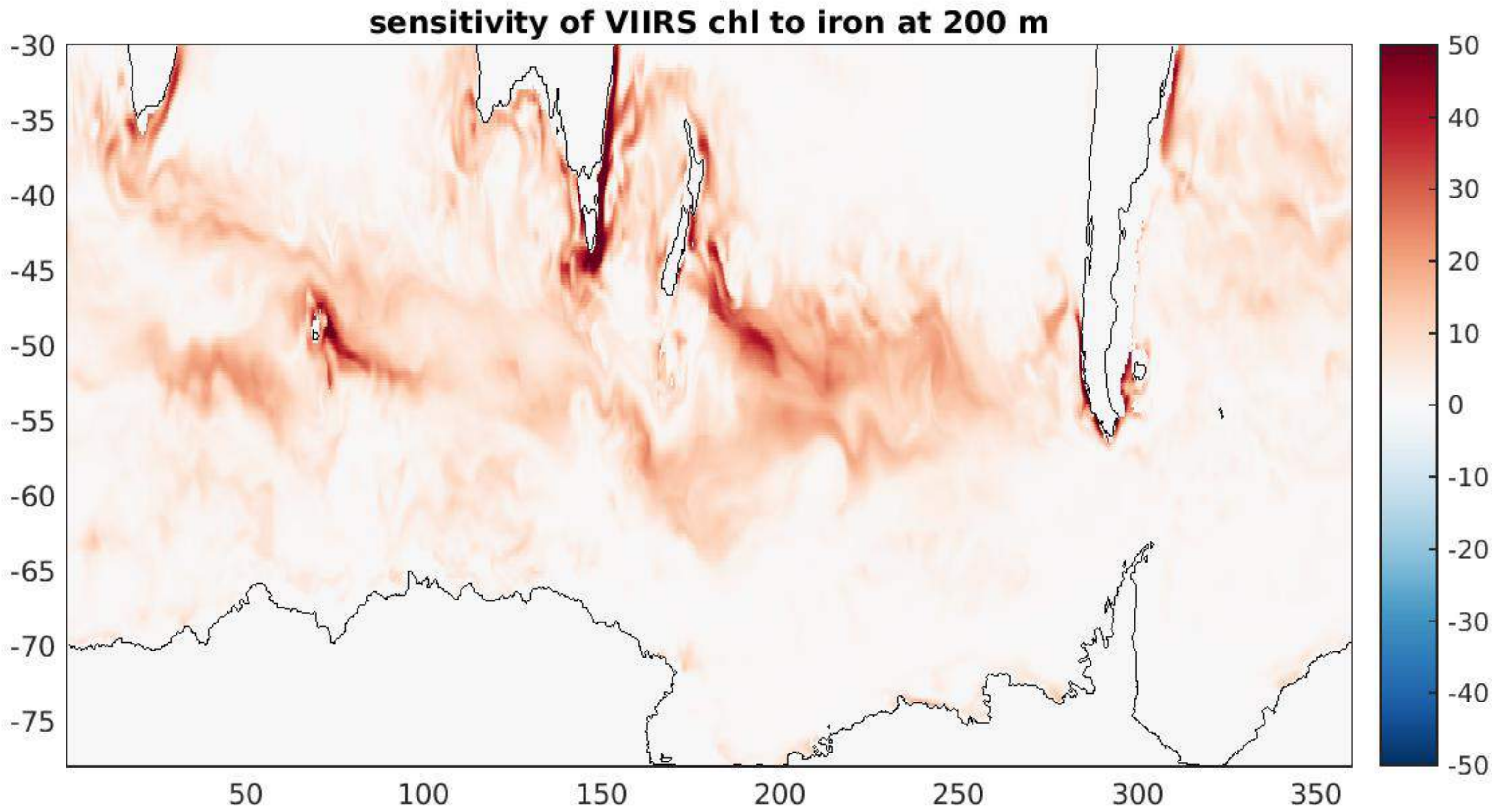


Warm colors denote increasing property increases oceanic sink.
Cool colors denote increasing property increases outgassing.

SOCCOM

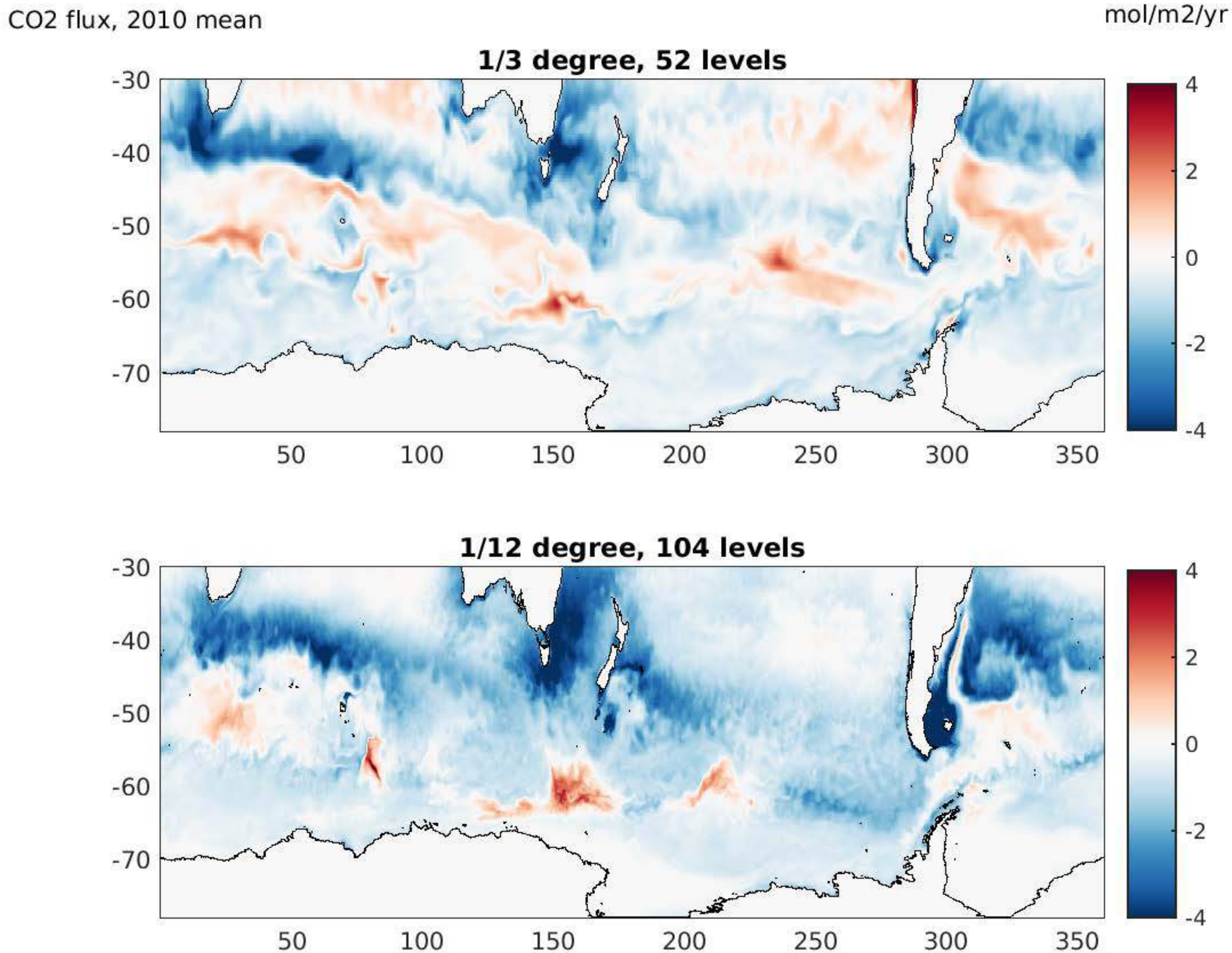
Assimilating ocean color observations

cost function = surface chlorophyll from VIIRS satellite, 2013



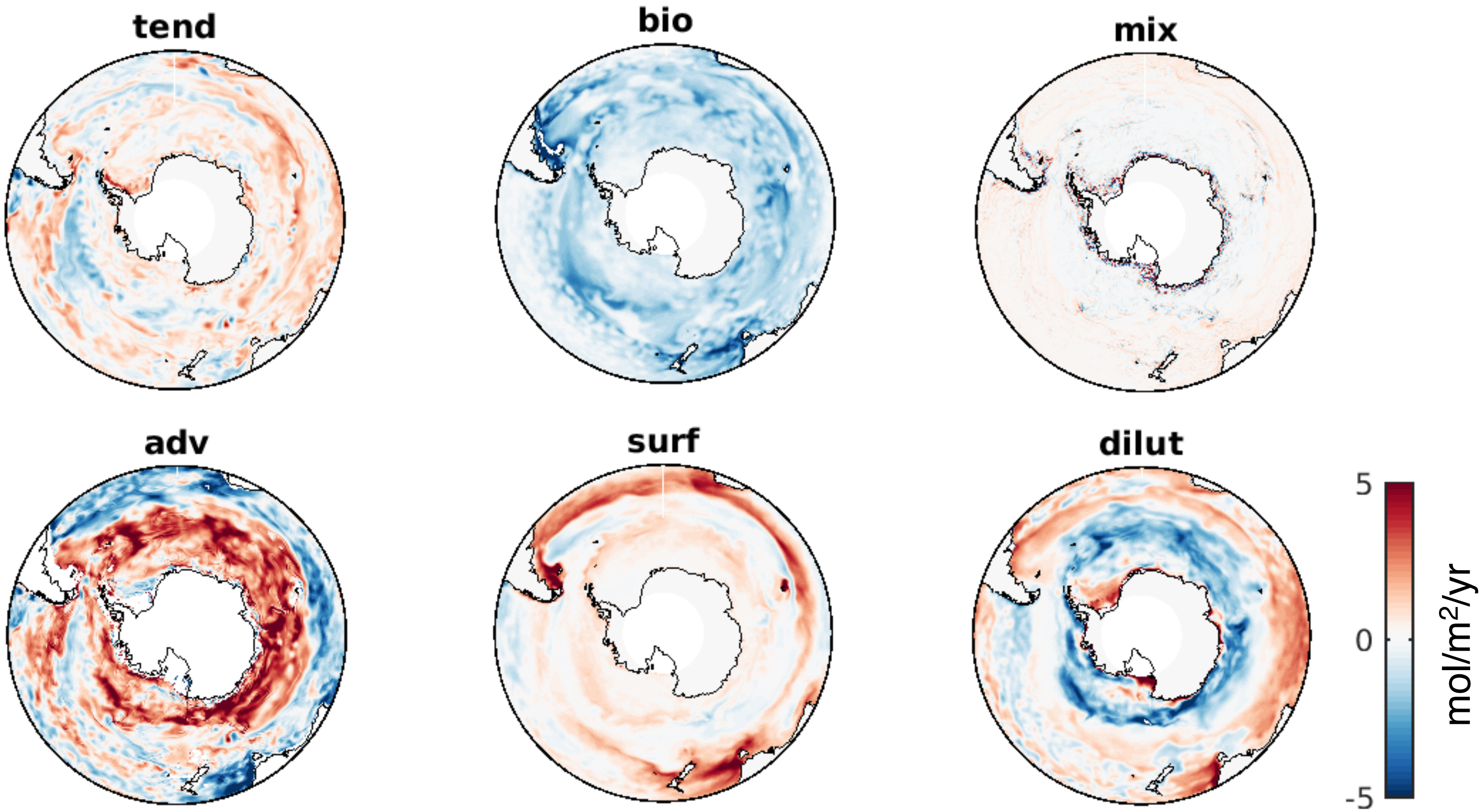
red = where adding iron would reduce the misfit with observations

Higher resolution, multi-grid assimilation



Budgets http://sose.ucsd.edu/budgets/

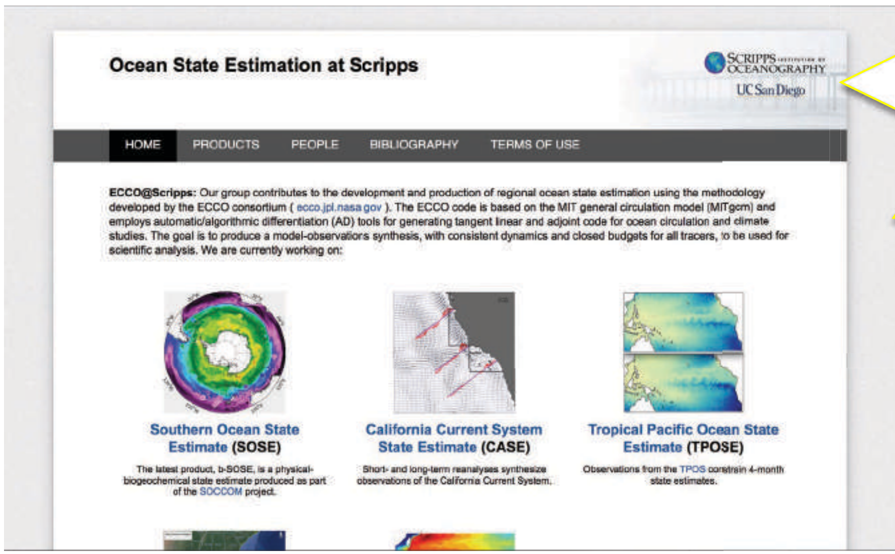
DIC in the top 650 m, 2008-2012



Rosso et al. (2017), Space and time variability of the Southern Ocean carbon budget. JGR-Oceans.

Getting the products

B-SOSE output: sose.ucsd.edu
+ validation
+ documentation



- netCDF
- CF compliant
- **available for model comparisons**

MITgcm BLING model and adjoint: github.com/MITgcm/MITgcm biogeochemical-argo.org

biogeochemical Argo

An extension of the Argo program to include biogeochemical observations

SCIENCE & IMPLEMENTATION PLAN

- ABOUT US
- PROGRAM LIFE
- SCIENTIFIC QUESTIONS
- MEASURED VARIABLES
- KEY AREAS & PROJECTS
- DATA
- LIBRARY
- DISSEMINATION
- FLOAT MAP & STATISTICS

BIOGEOCHEMICAL ARGO

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An extension of the Argo program to include biogeochemical observations

Email:
contact@biogeochemical-argo.org

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  - Past meetings
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  - Ocean acidification
  - Biological Carbon pump
  - Phytoplankton communities
  - Living marine resources
  - Carbon budget verification
  - Emergent phenomena
- Float map & Statistics
  - Interactive Map
  - Network Status Maps
  - Satellite Matchup Tool
  - Statistics

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  - Data management rules
  - Data Access
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  - Peer review articles
  - Relevant Reports
- Dissemination
  - Scientific Highlights
  - Outreach
  - Media & Resources

TOTAL PROFILES	2019 PROFILES
165055 TOTAL O_2 PROFILES	1062 2019 O_2 PROFILES ACQUIRED BY 277 ACTIVE SENSORS
32507 TOTAL NO_3 PROFILES	428 2019 NO_3 PROFILES ACQUIRED BY 133 ACTIVE SENSORS
11877 TOTAL PH PROFILES	311 2019 PH PROFILES ACQUIRED BY 113 ACTIVE SENSORS
66141 TOTAL CHL A PROFILES	697 2019 CHL A PROFILES ACQUIRED BY 193 ACTIVE SENSORS
65237 TOTAL SUSPENDED PARTICLES PROFILES	697 2019 SUSPENDED PARTICLES PROFILES ACQUIRED BY

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Satellite Matchup Tool
Outreach
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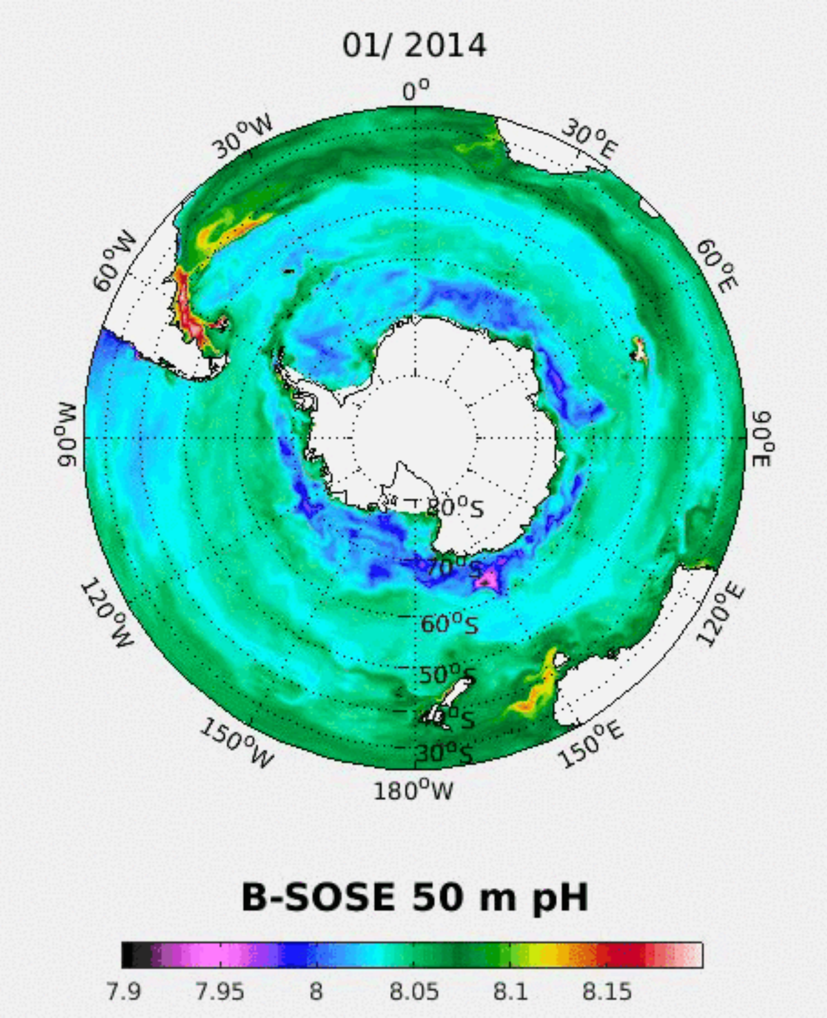
biogeochemical-argo.org



pH at 50m.
Floats superimposed on B-SOSE

SOCCOM

Biogeochemical Southern Ocean State Estimates (B-SOSE)

http://sose.ucsd.edu/

- Have produced a 1/6^{o} resolution 2008-2012 pre-SOCCOM B-SOSE
- Produced a 1/6^{o} resolution 2013 - 2017 SOCCOM era B-SOSE and now extending it.

Providing biogeochemical and physical budgets, extensive validation, and analysis software, enabling researchers and stakeholders to understand the variability in our marine resources

Verdy and Mazloff, 2017. A data assimilating model for estimating Southern Ocean biogeochemistry. JGR.