BESA(ME): **B**iogeochemistry and **E**cology of the **S**ub-**A**ntarctic (and **M**ode water **E**xport)

William "Barney" Balch

Bigelow Laboratory for Ocean Sciences

E. Boothbay, ME 04544 USA

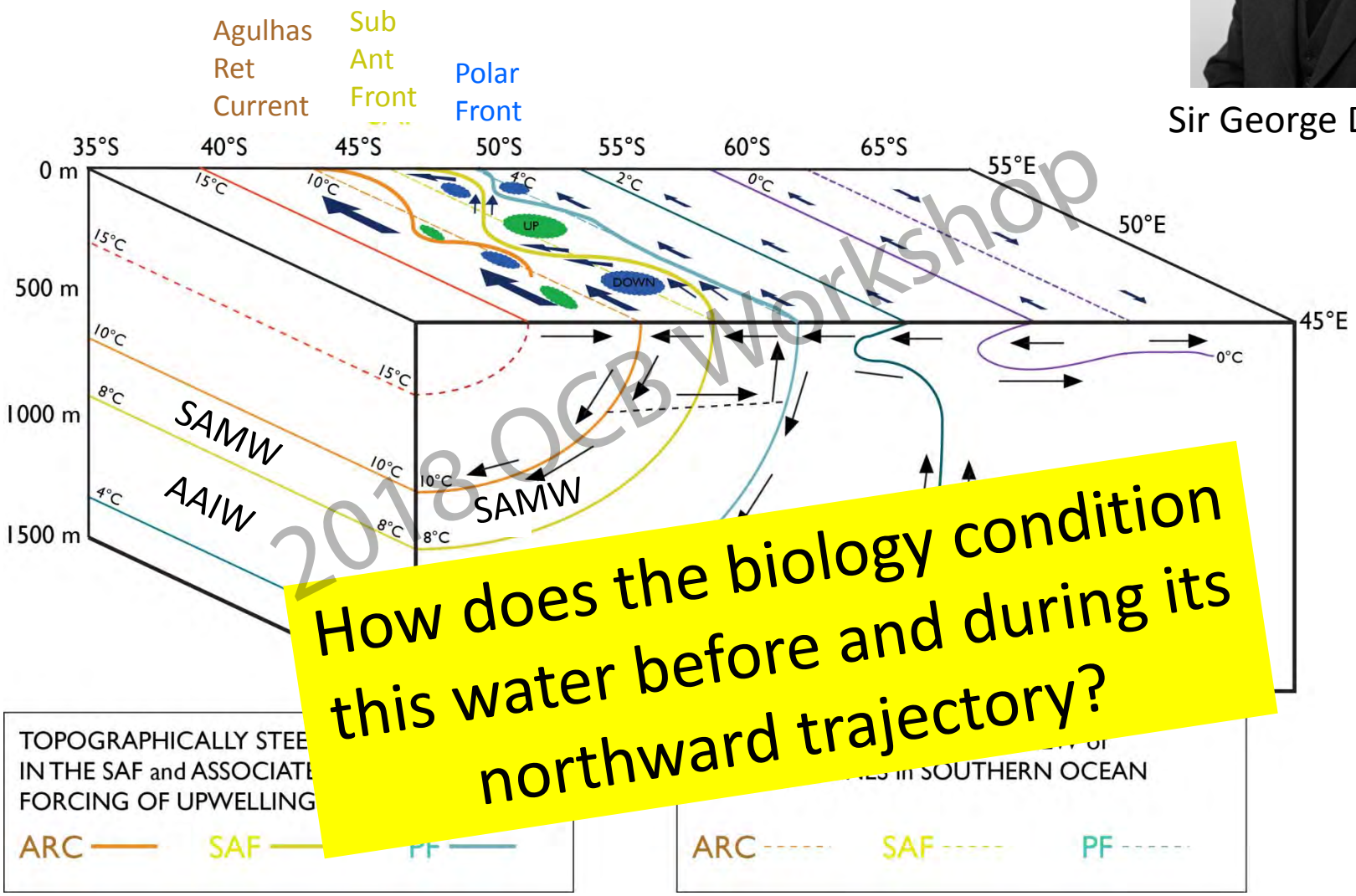
Bigelow | Laboratory for Ocean Sciences

Roadmap- A few vignettes

- Brief review of physics of the Southern Ocean system and Subantarctic Mode Water
- The Great Calcite Belt and SAMW associations
- Chemical and biological conditioning of SAMW by coccolithophores and diatoms
- Eddy influences in the Subantarctic
- View of the Great Calcite Belt from the Atlantic basin and a conceptual model
- Summary

Southern Ocean- Deacon defined the physics of the global system of ocean circulation…

Sir George Deacon



How does the biology condition this water before and during its northward trajectory?

Deacon, G. E. R. (1933), A general account of the hydrology of the South Atlantic Ocean, *Discovery Rep.*, *7*, 171-238.

Sub-Antarctic Mode Water:

- is a homogeneous layer with uniform density; sits over lower salinity AAIW
- formation is associated with deep mixed layers, well ventilated with 95% oxygen saturation; 17-18 Sv produced in all three ocean basins
- density σ_θ =26.5 to 27.1
- silicate is depleted relative to nitrate (residual nitrate)
- exchange FW and heat between the Southern Ocean and Subtropical gyres
- supply nutrients to adjacent Subtropical gyres
- shows circulation time scales of decades

Fate of SAMW

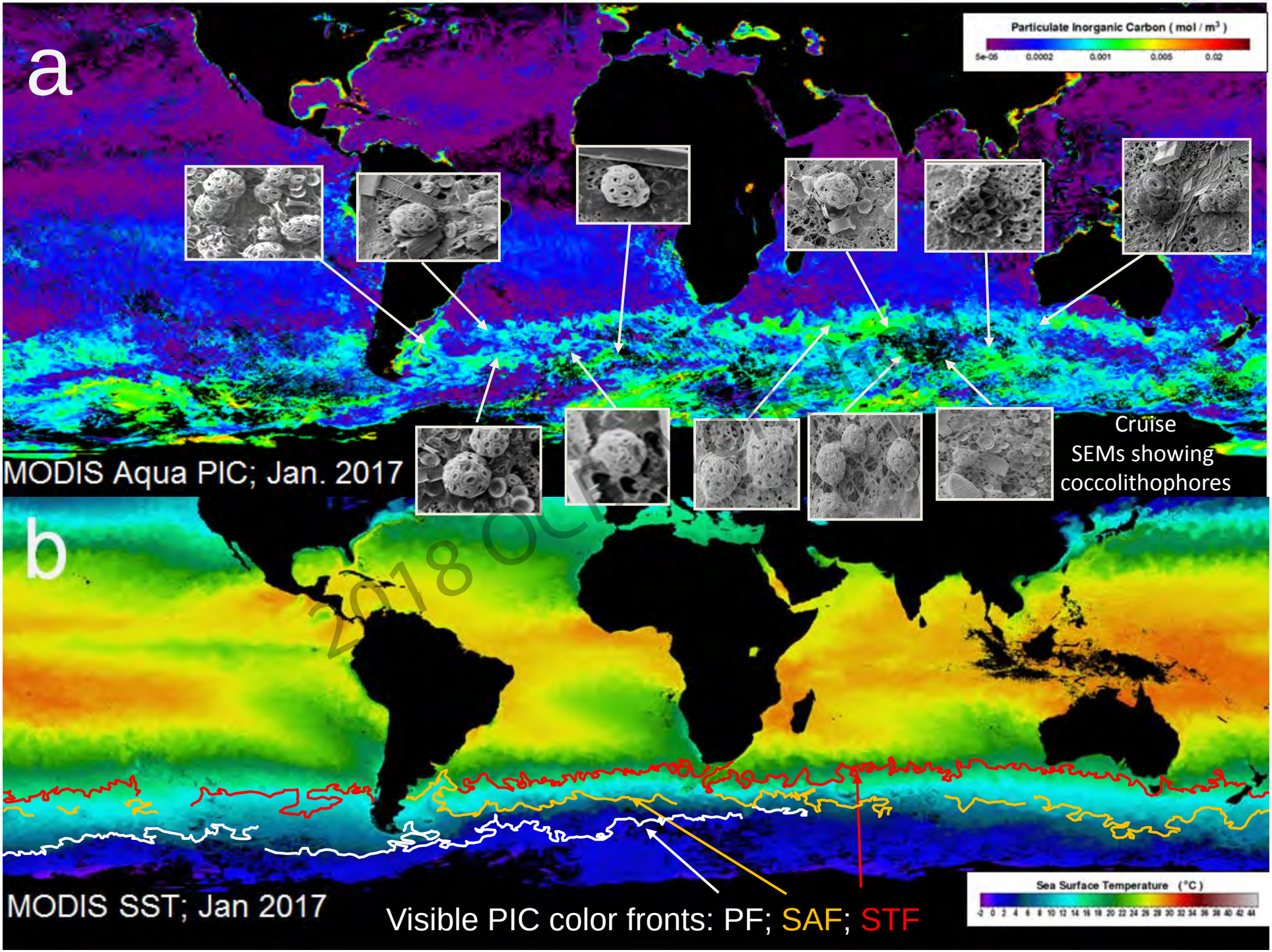
- Estimated to control 75% of the biological production of waters north of 30°S
- Controls functional groups of these waters, depending on the amount of silicate that "leaks" from the Southern Ocean
- Subducted SAMW arrives to the equatorial zone ~40 years later.

High-latitude controls of thermocline nutrients and low latitude biological productivity

J. L. Sarmiento[1], N. Gruber[2], M. A. Brzezinski[3] & J. P. Dunne[4]

[1]*Atmospheric and Oceanic Sciences Program, Princeton University, Princeton, New Jersey 08544, USA*
[2]*IGPP and Department of Atmospheric Sciences, University of California at Los Angeles, Los Angeles, California 90095, USA*
[3]*Department of Ecology, Evolution and Marine Biology and the Marine Science Institute, University of California, Santa Barbara, California 93106, USA*
[4]*NOAA/Geophysical Fluid Dynamics Laboratory, PO Box 308, Forrestal Campus B Site, Princeton, New Jersey 08542, USA*

Sarmiento et al., 2004; Nature


a
Particulate Inorganic Carbon (mol / m³)
5e-05
0.0002
0.001
0.005
0.02
MODIS Aqua PIC; Jan. 2017
Cruise
SEMs showing
coccolithophores
b
MODIS SST; Jan 2017
Visible PIC color fronts: PF; SAF; STF
Sea Surface Temperature (°C)

AGU PUBLICATIONS

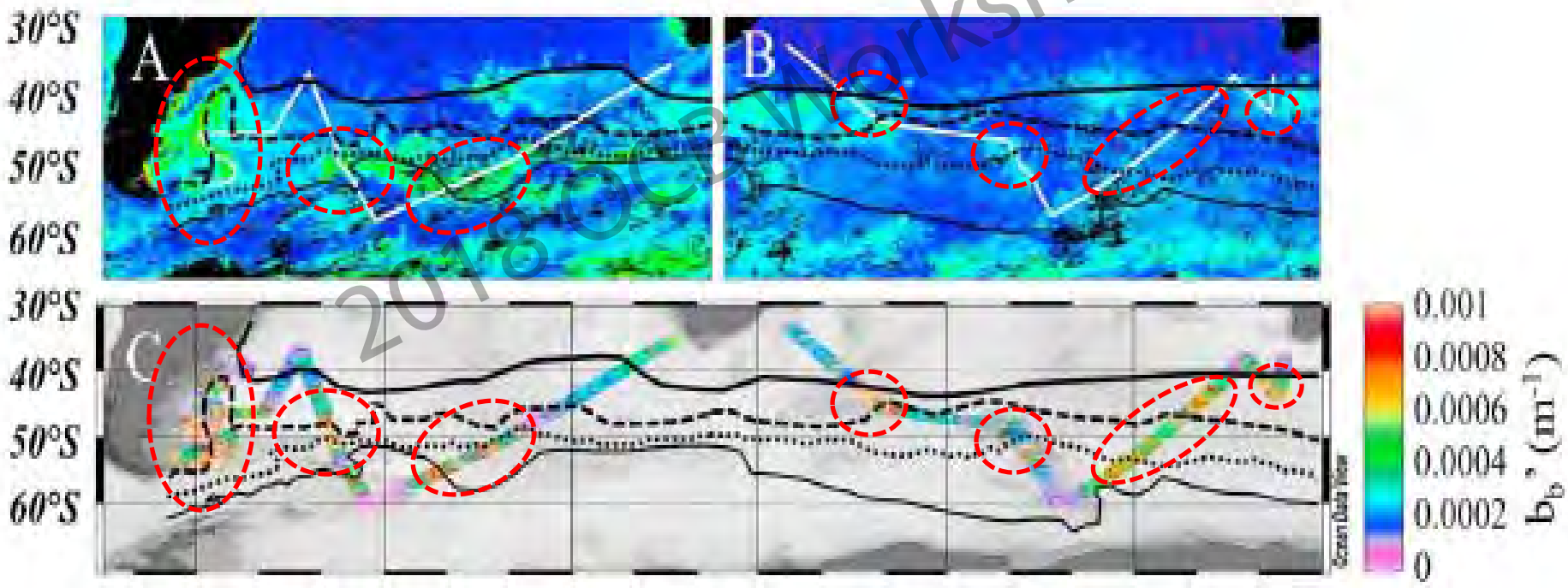
Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1002/2016GB005414

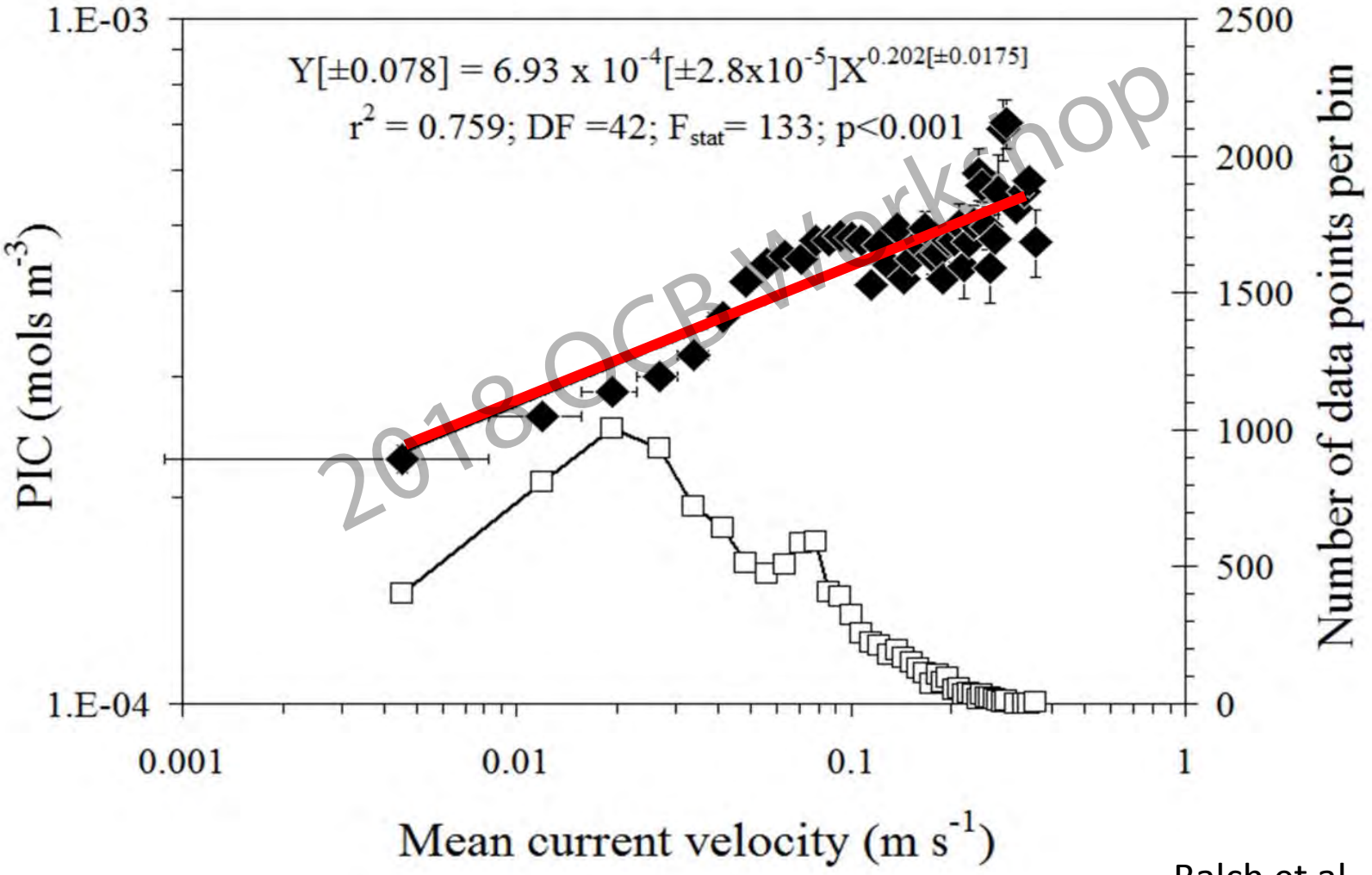
2016

Factors regulating the Great Calcite Belt in the Southern Ocean and its biogeochemical significance

William M. Balch[1], Nicholas R. Bates[2,3], Phoebe J. Lam[4,5], Benjamin S. Twining[1], Sarah Z. Rosengard[4,6], Bruce C. Bowler[1], Dave T. Drapeau[1], Rebecca Garley[2], Laura C. Lubelczyk[1], Catherine Mitchell[1], and Sara Rauschenberg[1]

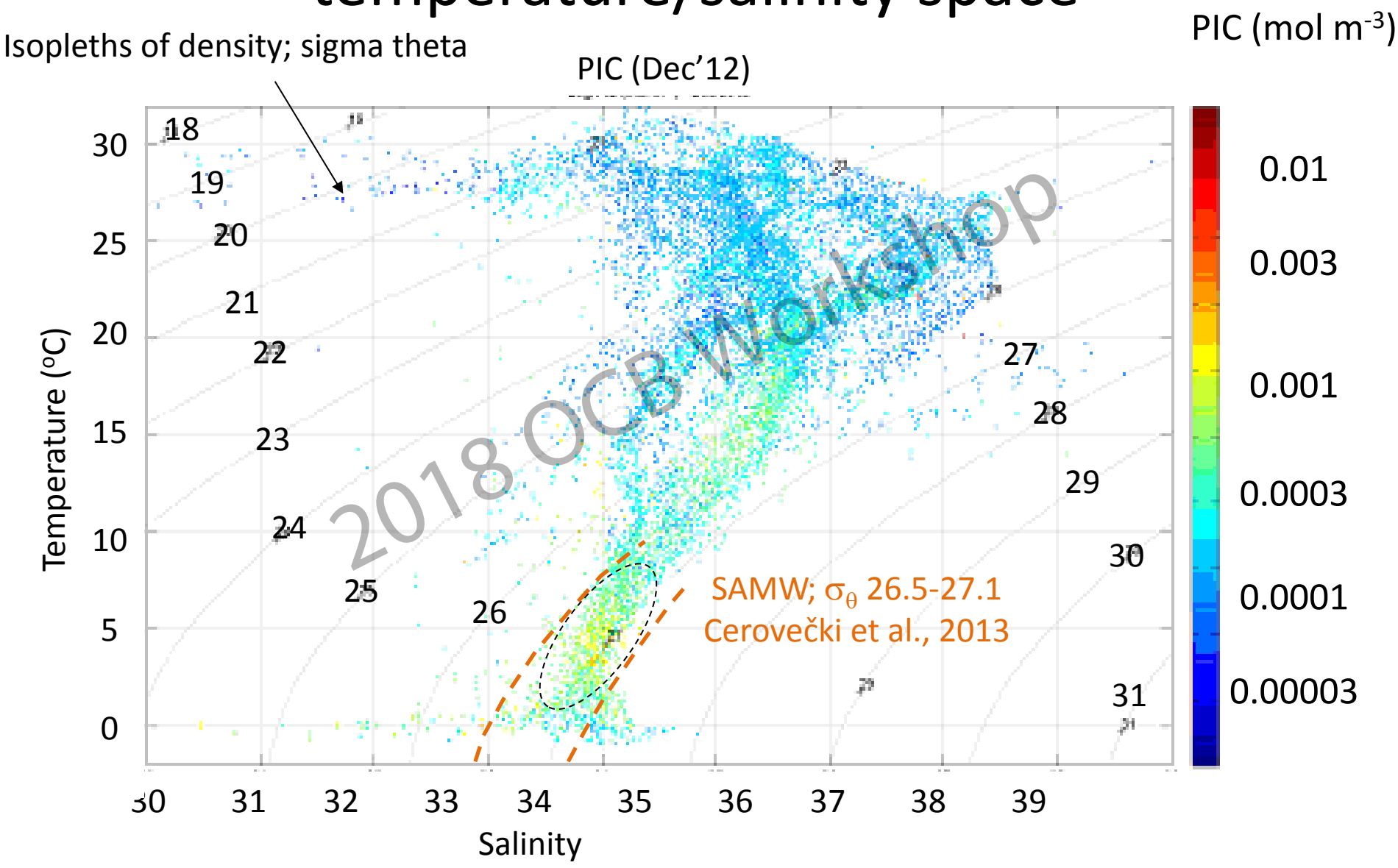


Great Calcite Belt sits in high-velocity circumpolar currents of the Southern Ocean…likely sites of high Ekman pumping

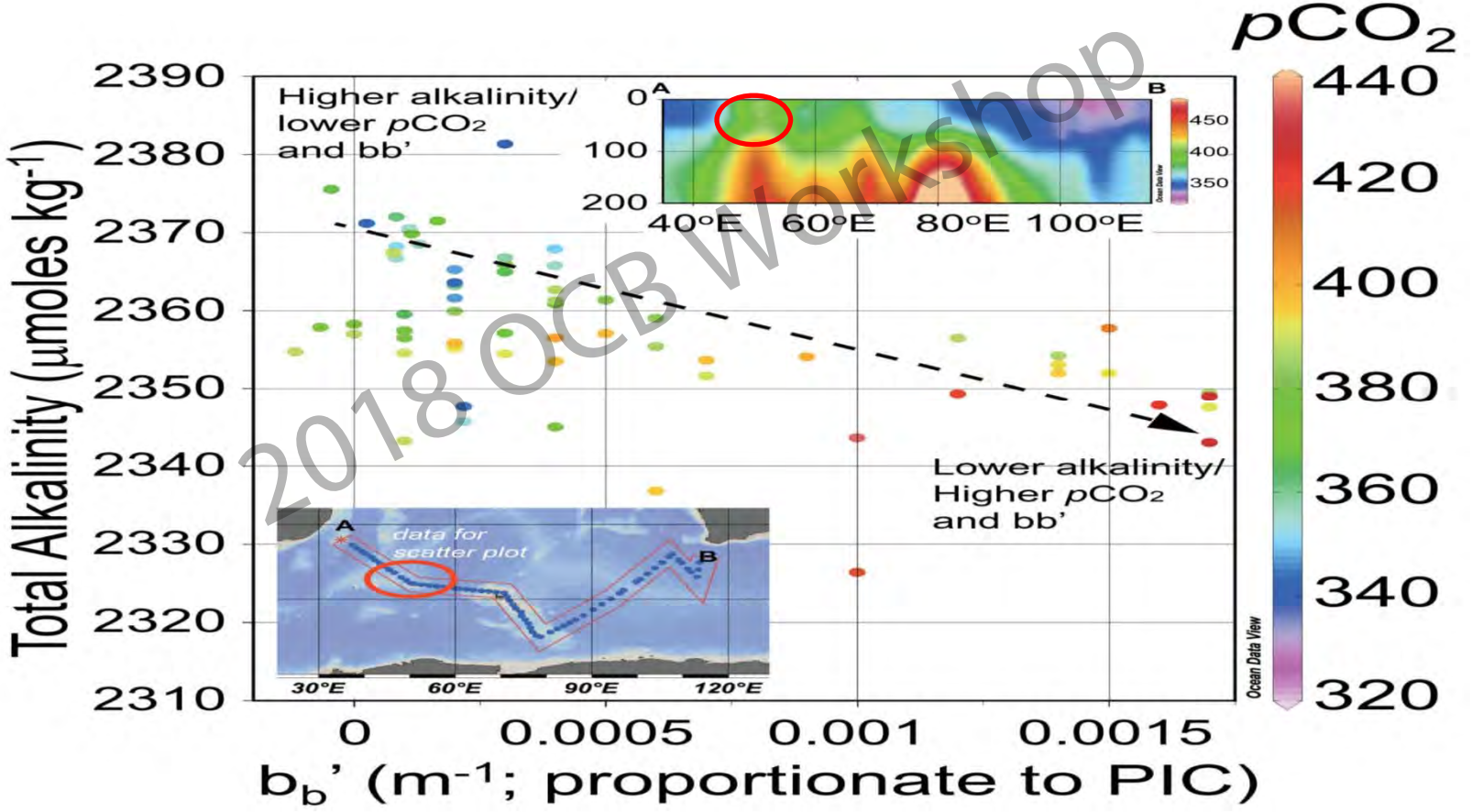


Balch et al., 2016; GBC

Plot surface PIC concentration in temperature/salinity space



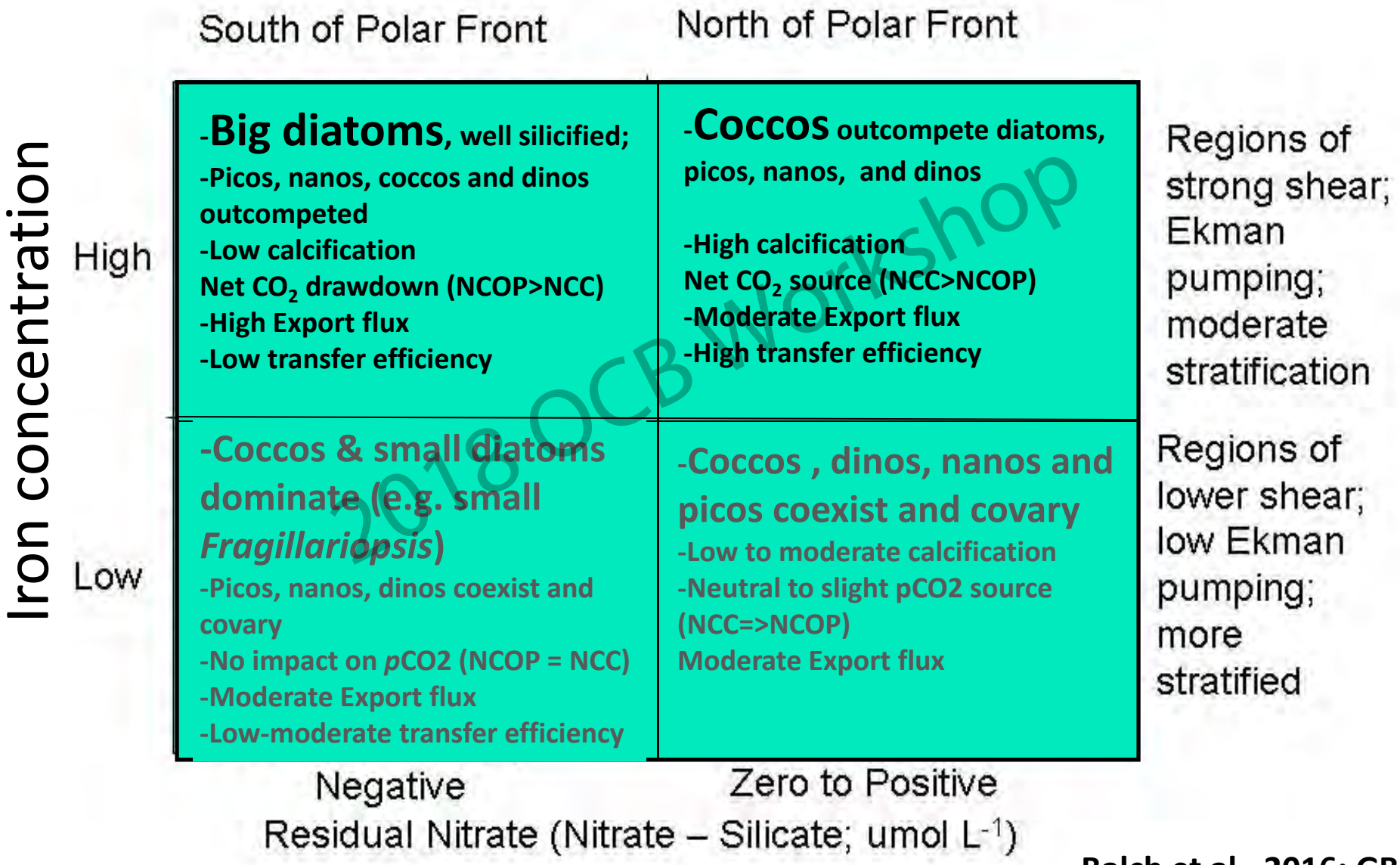
Coccolithophore calcification lowers the alkalinity and increases the pCO_2



Nick Bates, BIOS

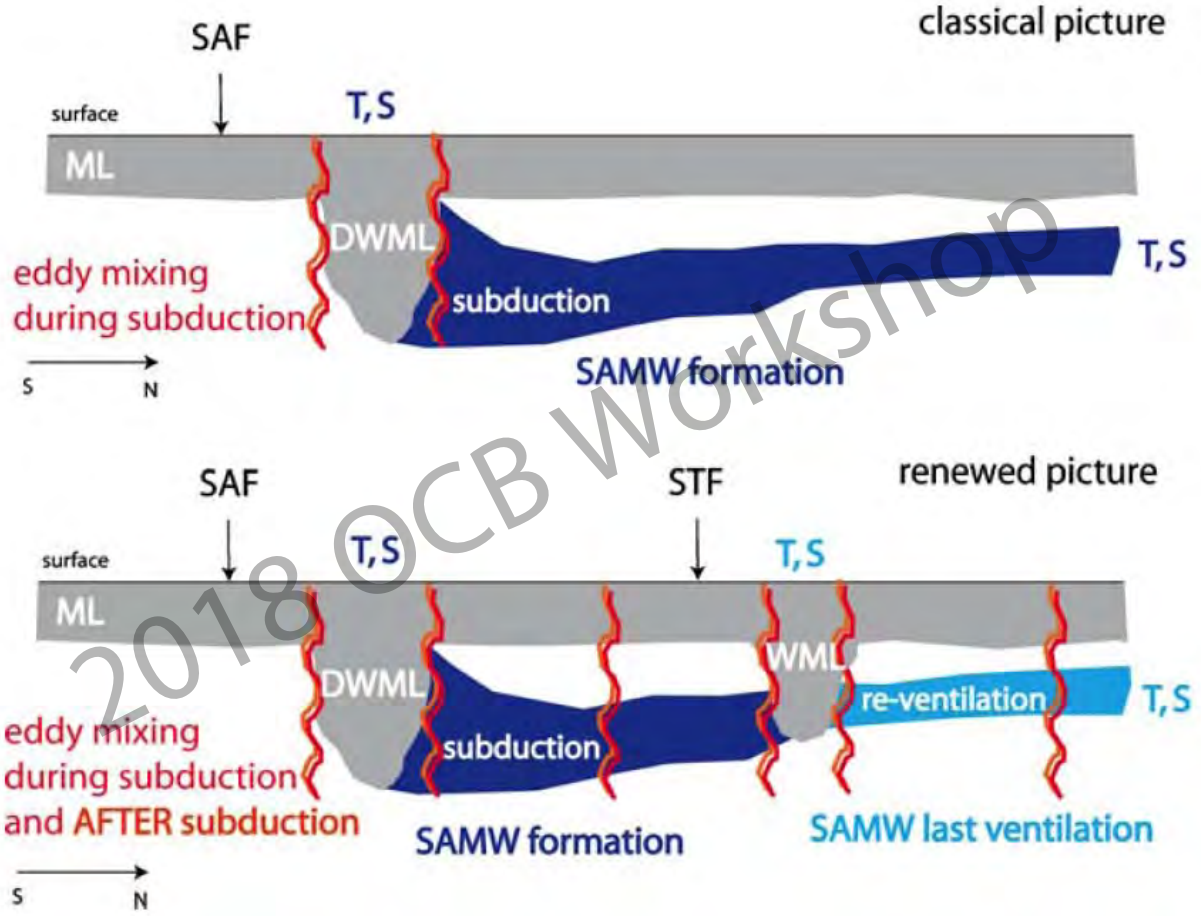
Balch et al., 2016; GBC

Mandala for biogeochemistry and ecology in the GCB



Balch et al., 2016; GBC

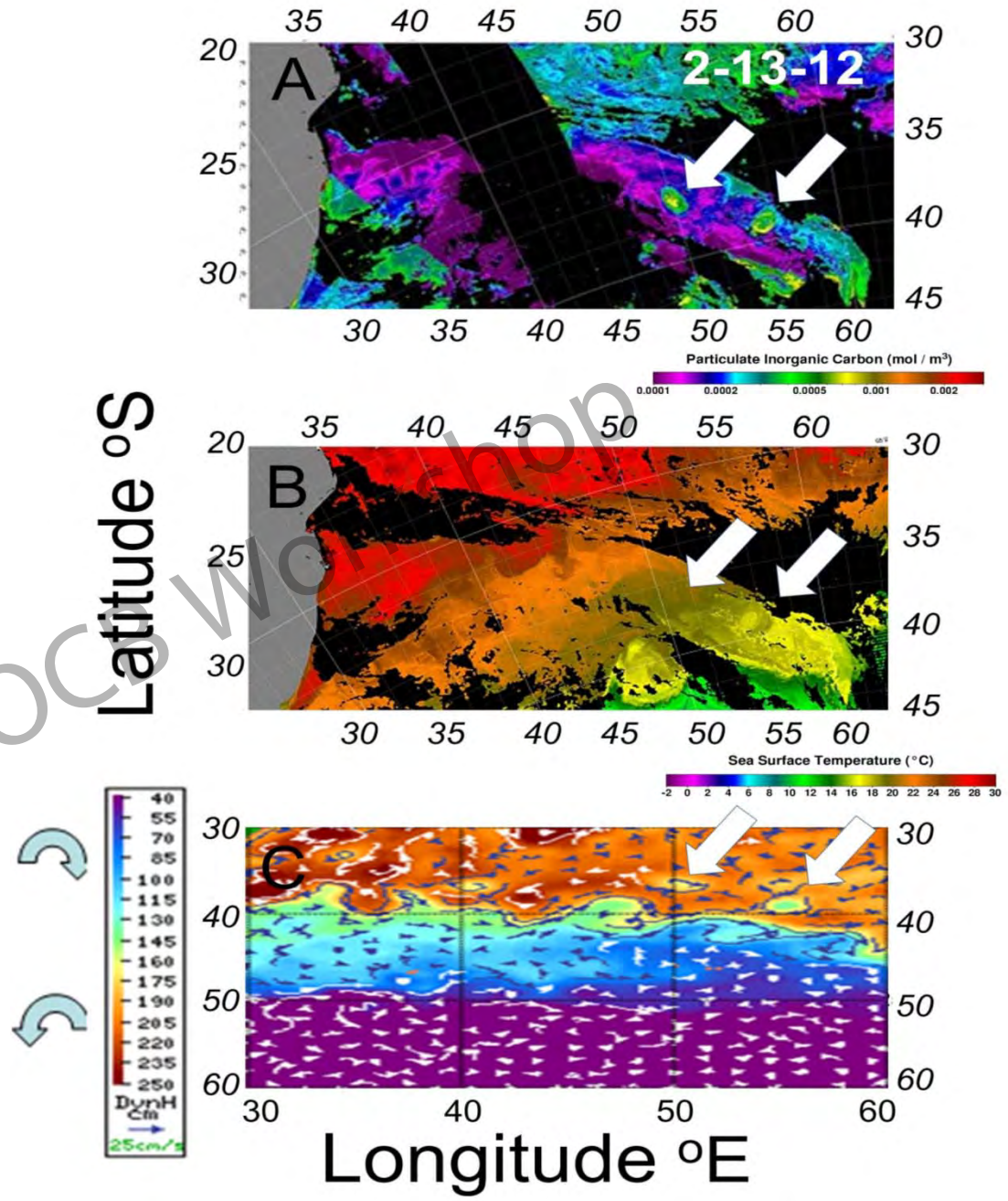
Eddies and Sub-Antarctic Mode Water



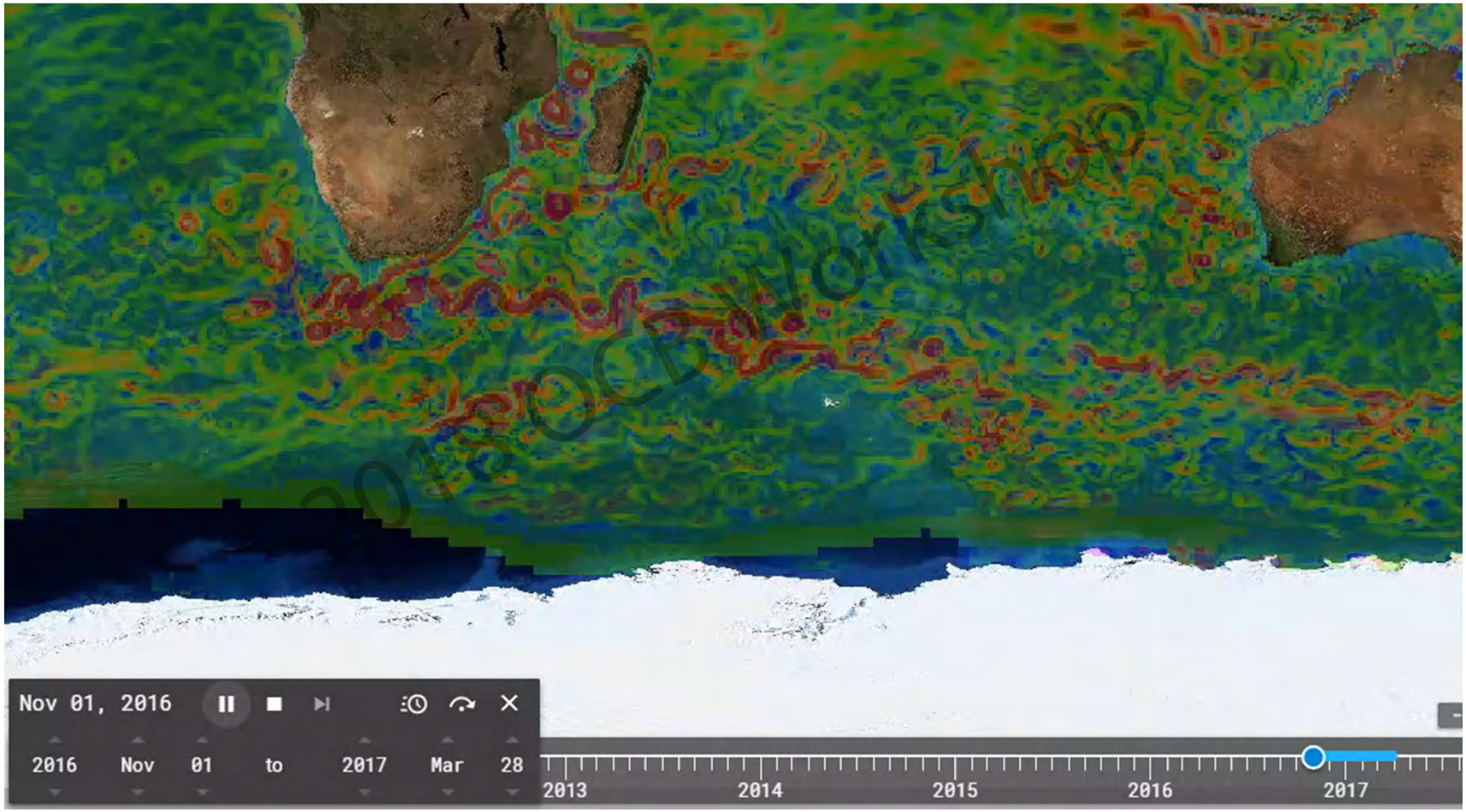
Koch-Larrouy et al. 2010, *Ocean Dynamics*

PIC-rich eddies

- Eddies spinning off of SAF
- PIC rich eddies survive for months
- Seen previously Read JF et al.(2007) DSR II

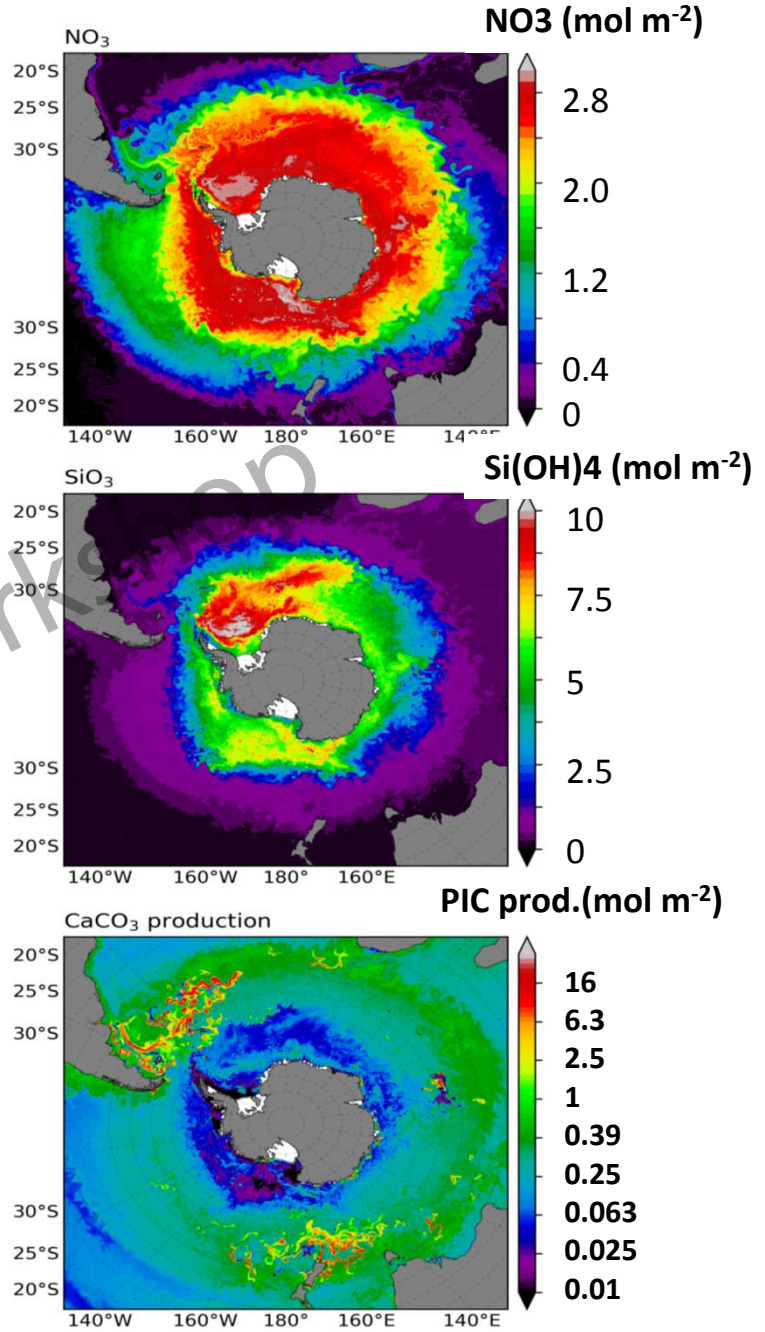


Altimetry day shows importance of eddy mixing…



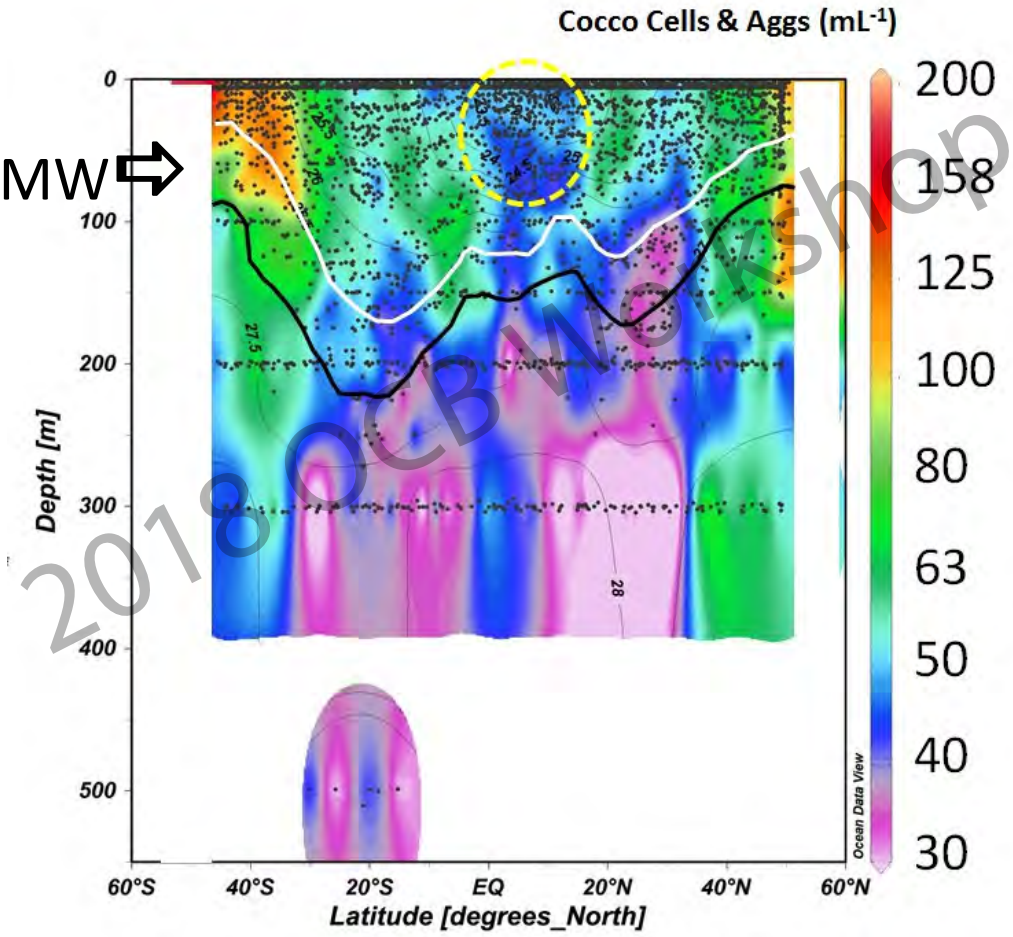
Community Earth System model (CESM)

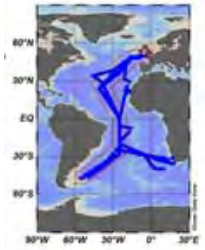
- **Global eddy-resolving** integration of CESM Upper 100m integrals
- Includes ocean BGC component called the Biogeochemical Elemental Cycle (BEC) mode
- Represents multiple nutrient co-limitation (N, P, Si, and Fe)
- 3 explicit phytoplankton functional groups (diatoms, diazotrophs, and "small" pico/nano phytoplankton), and one implicit group (calcifiers)



Long, NCAR

Low [coccolithophores] in the Equatorial Atlantic…why?

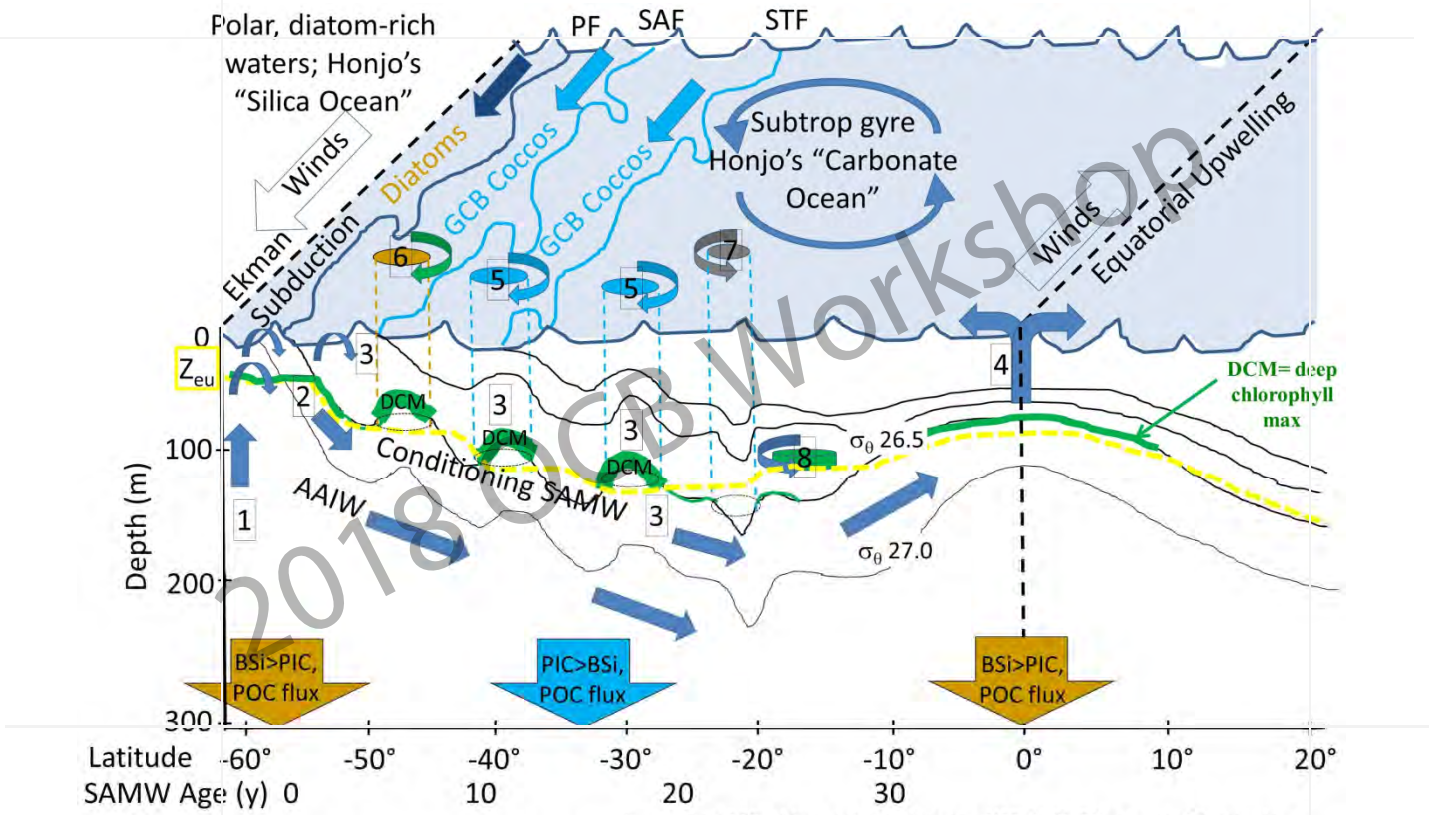




10 AMT Cruises

Balch et al., GBC. in review

Conceptual View of Subantarctic mode water export… "So what?"



1=Upwelled CDW high NO_3, $Si(OH)_4$, high Si*, Mod Fe

2=Mod NO_3,low $Si(OH)_4$, Mod Si*, Low Fe

3= Preconditioning drawdown Alk & $CO_3^=$

4= Eq upwelling; Low coccos, elevated chl, low Alk, low $CO_3^=$, mod $Si(OH_4)$, mod NO_3; low DO, high Fe from dust, elevated BSi

5 = cyclonic SAF eddies, entrained coccos, NCC>NPP; CO_2 source; Alk drawdown

6 = cyclonic PF eddies, entrained diatoms, NPP>>NCC; CO_2 sink; Hi flux

7 = anticyclonic SAF eddies, Low NPP, mod NCC; CO_2 neutral; Low vert flux

8 = Anticyclonic mode water eddies, enhanced DCM, min surf expression

Summary: **BESA(ME)**
Biogeochemistry and **E**cology of the **S**ub-**A**ntarctic (and **M**ode water **E**xport)

- The biogeochemistry and ecology of the Subantarctic (as described in the mandala) likely influence the BGC and ecology of the subtropics and tropics
- The linkages are physical (via SAMW)
- Minerogenic phytoplankton (diatoms and calcifiers) condition SAMW prior to its subduction, which could affect growth of ballast-producers and export of waters well to the north
- BESA(ME) cruises in January 2019, 2020 in Indian Sector of the Southern Ocean (Balch [BLOS], McGillicuddy [WHOI], Long[NCAR], Morton[SFU], Bates[BIOS], Brownlee[MBA,UK])

Thank you!

ACKNOWLEDGEMENTS:

- Bruce Bowler, Dave Drapeau, Laura Lubelczyk & Sarah Rauschenberg (Bigelow Laboratory for Ocean Sciences), Annie Warner & Brittney Honisch (Colby College); Rebecca Garley, Dafydd Evans, Kristen Shake & Andrew Collins (BIOS); Steven Pike, Dan Ohnemus, Sarah Rosengard & Maureen Wisch (WHOI), Rebecca Fowler (Columbia Univ.), Marina Van der Eb (U. Maine Orono), Michael Brown (Rutgers), Patrick Holligan, Jason Hopkins & Helen Smith (NOC), Cecilia Balestreri (MBA, Plymouth, UK), Angel Ruacho, Matt Durham & Daniel Young, Melissa Miller, John Calderwood, Brent Devries (SIO); Norman Kuring- NASA Goddard
- Captains and crew of: *R/V Melville* and *R/V Revelle*
- Goddard Ocean Color Group; Ocean Data View
- NASA and NSF support