Do small scales make a big difference?

Building a South African Southern Ocean Carbon - Climate research capability (the journey, direction and some science highlights)

Sandy Thomalla, Pedro Monteiro, Luke Gregor, Precious Mongwe, Hazel Little, Sarah Nicholson

SOCCO
Southern Ocean Carbon and Climate Observatory

CSIR
our future through science

T- 0

The IPY BONUS-GOODHOPE cruise: Feb - March 2008

Humble beginnings

SANAE 48: Dec 2008 – Feb 2009

SA Agulhas

Underway pCO_2, O_2/Ar NCP

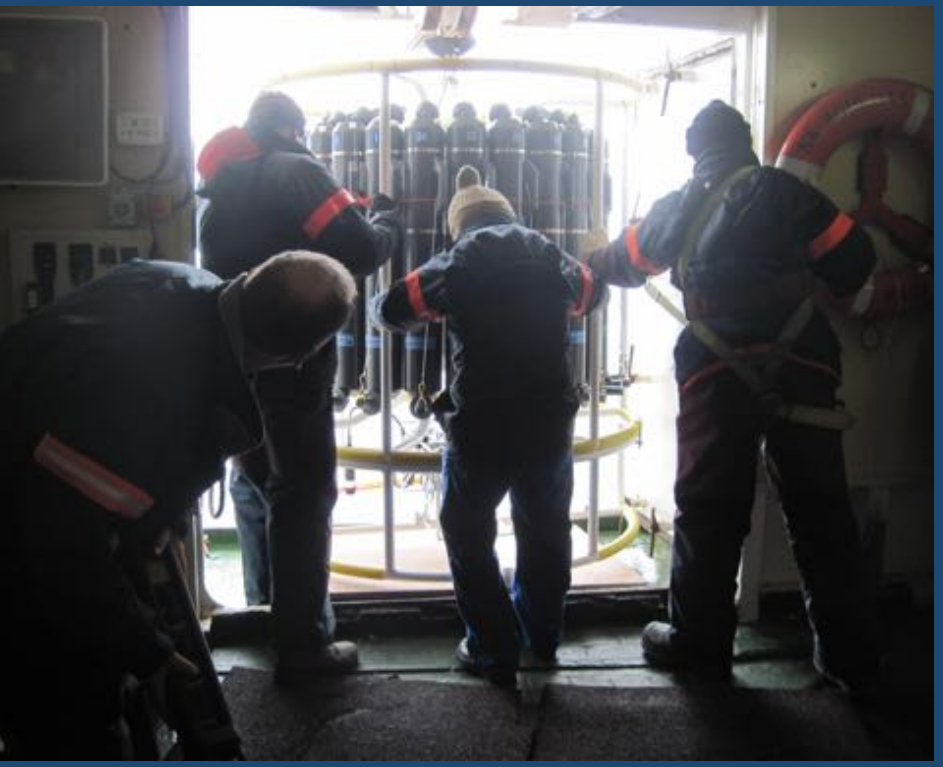
Humble beginnings

CTD

Antique NIO bottles

Upgrade

SANAE 49: Dec 2009 – Feb 2010



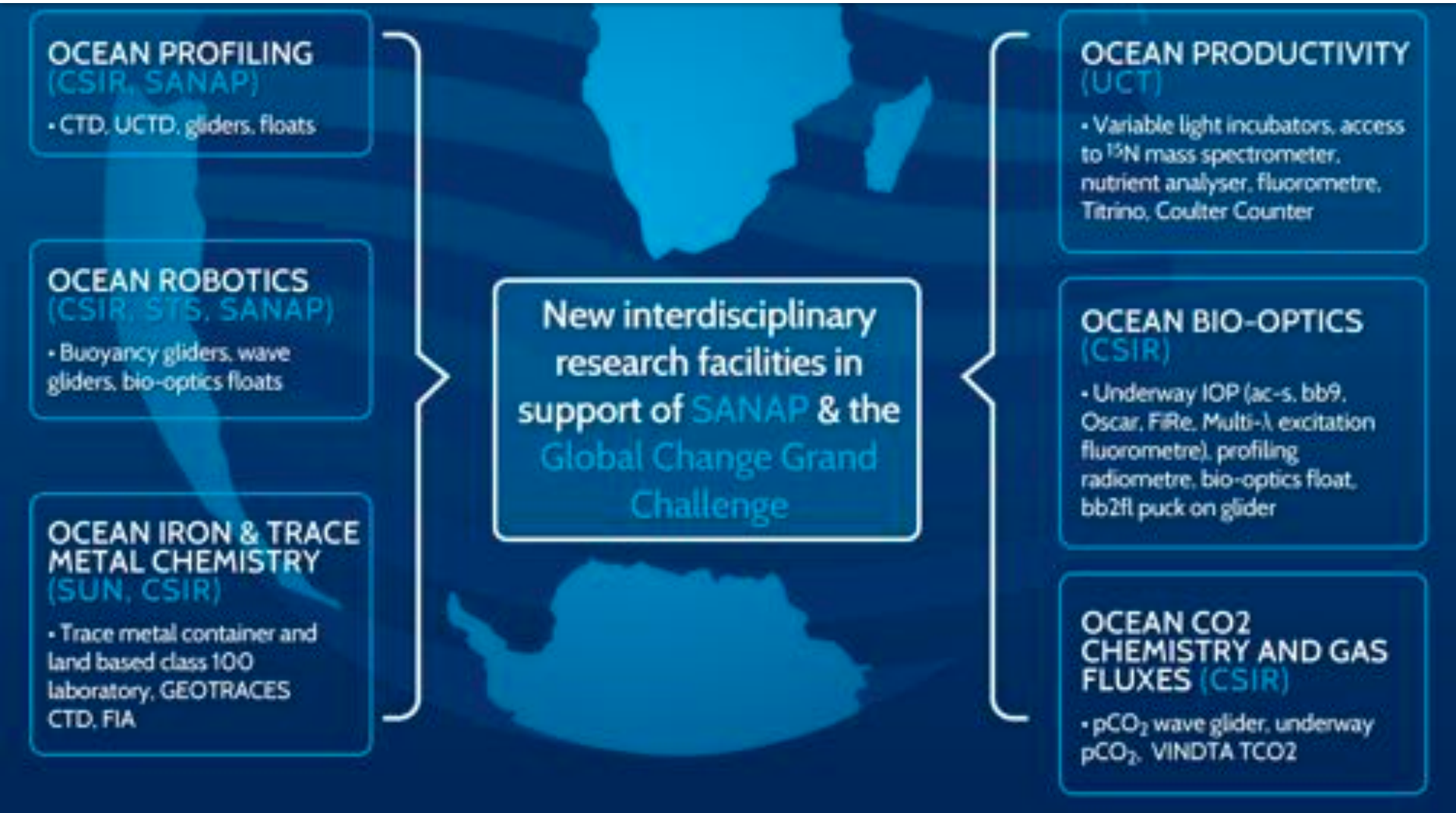
CTD

UCTD

SA Agulhas II - 2012

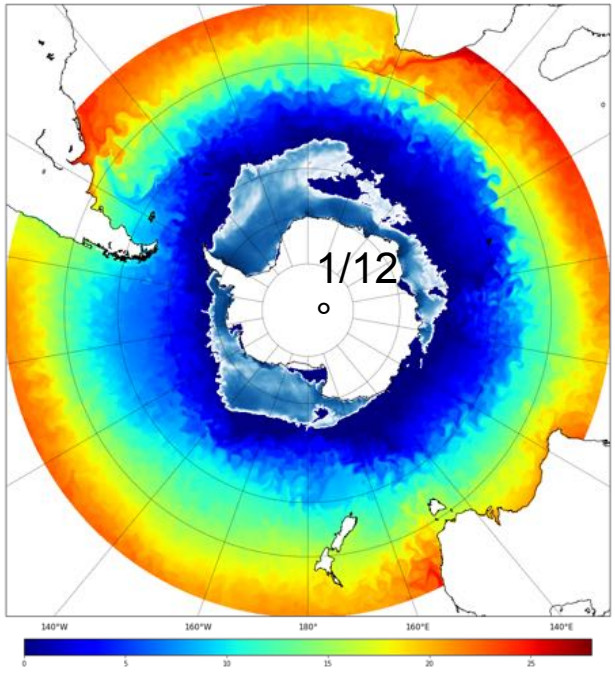
SOCCO

Southern Ocean Carbon and Climate Observatory



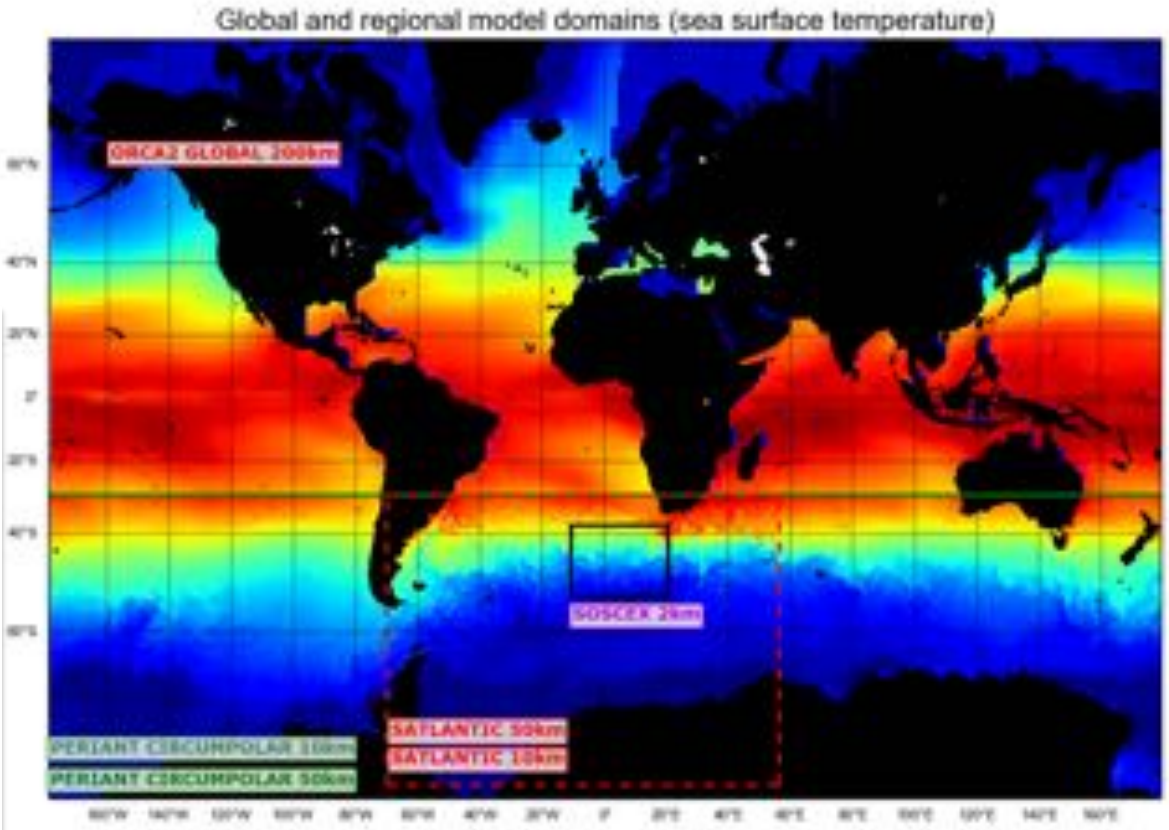
Modelling

BIOPERIANT12



NEMO v3.4 Hierarchy of models

Ocean + Ice + PISCES BGC



Periant/ Satlantic runs: 1989 – 2008
SOSCEx runs: 2006 - 2008

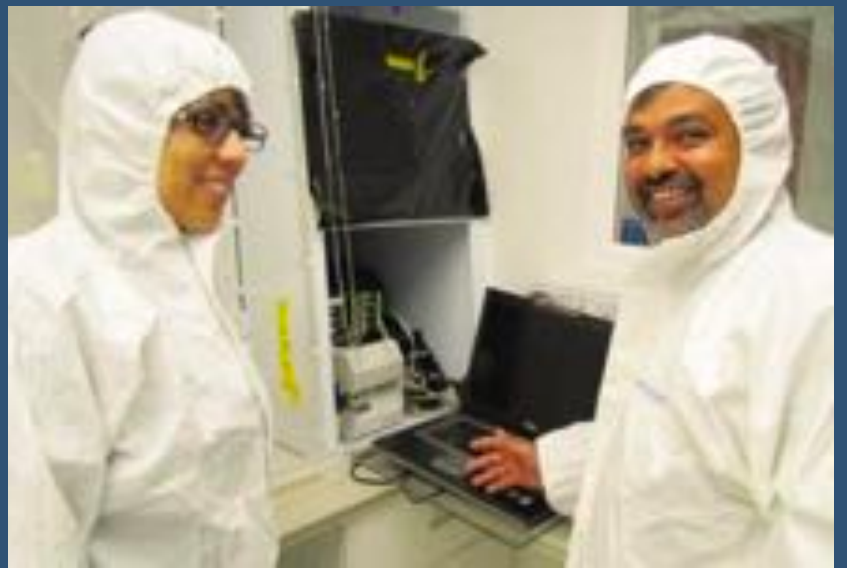
Ocean robotics

SAMERC

SOUTH AFRICAN MARINE ENGINEERING & ROBOTICS CENTRE

SA RobOTIC

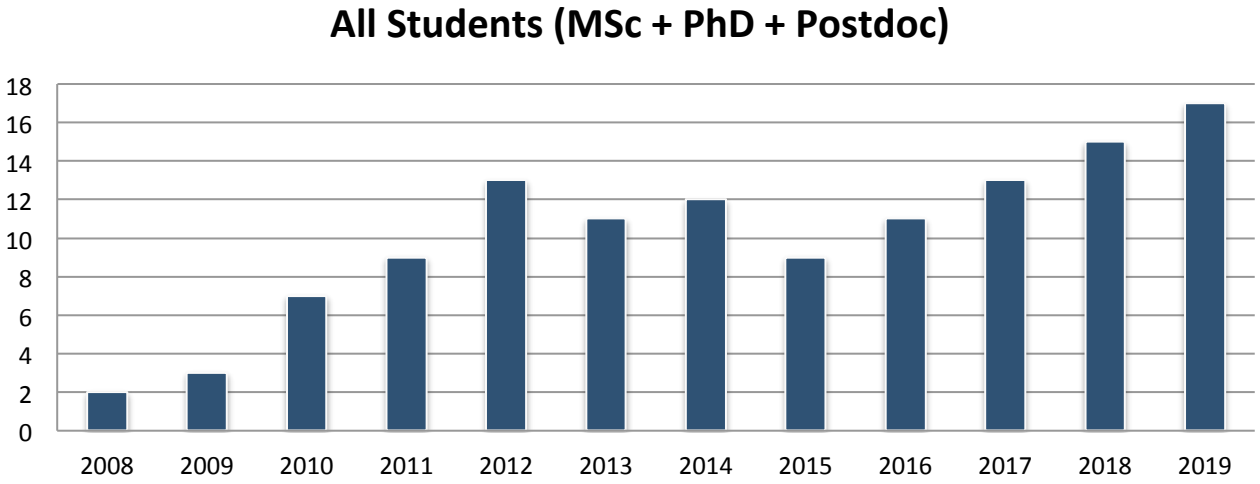
Trace metal chemistry

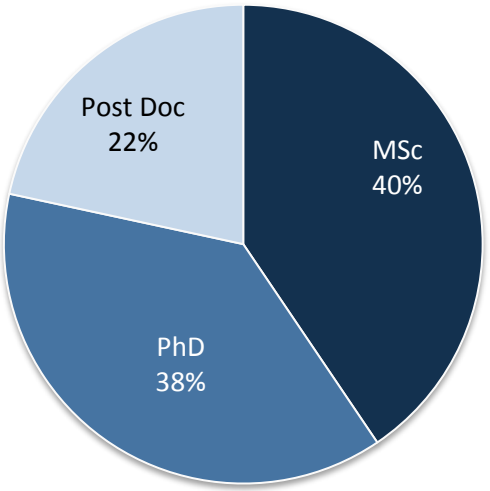


Bio-optics

CO_2 chemistry

SOCCO HCD

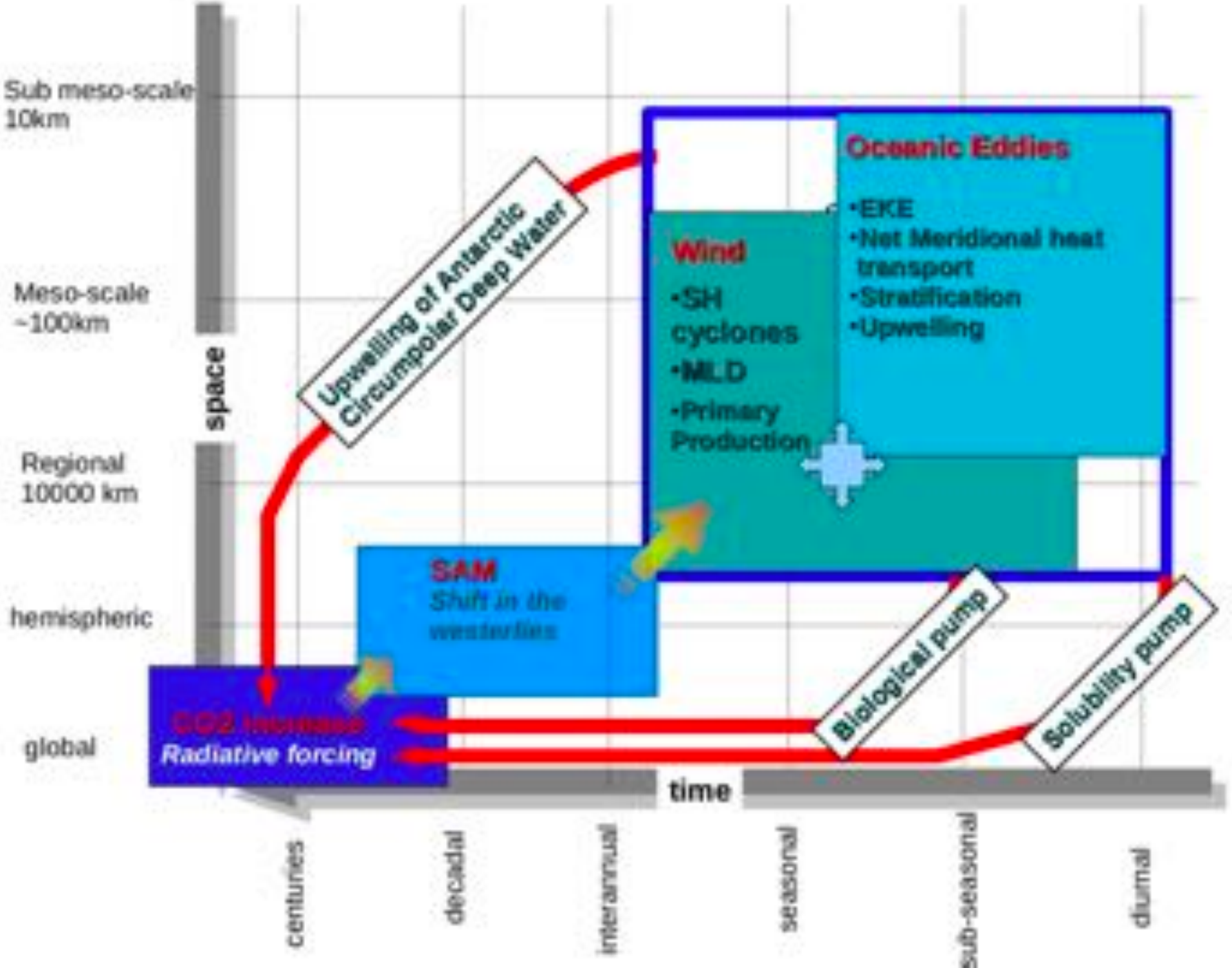




Currently
- 6 Staff members
- 17 Students

OK … but what about our scientific journey

What is your NICHE?


Sub meso-scale
10km
Meso-scale
~100km
Regional
10000 km
hemispheric
global
space
time
Upwelling of Antarctic Circumpolar Deep Water
Oceanic Eddies
•EKE
•Net Meridional heat transport
•Stratification
•Upwelling
Wind
•SH cyclones
•MLD
•Primary Production
SAM
Shift in the westerlies
CO2 increase
Radiative forcing
Biological pump
Solubility pump
centuries
decadal
interannual
seasonal
sub-seasonal
diurnal

SOCCO Hypothesis

"Fine scale ocean dynamics are key to understanding the role of the Southern Ocean in global century-scale trends of atmospheric CO_2 and regional climate change."

Empirical estimates of pCO_2 from satellite data

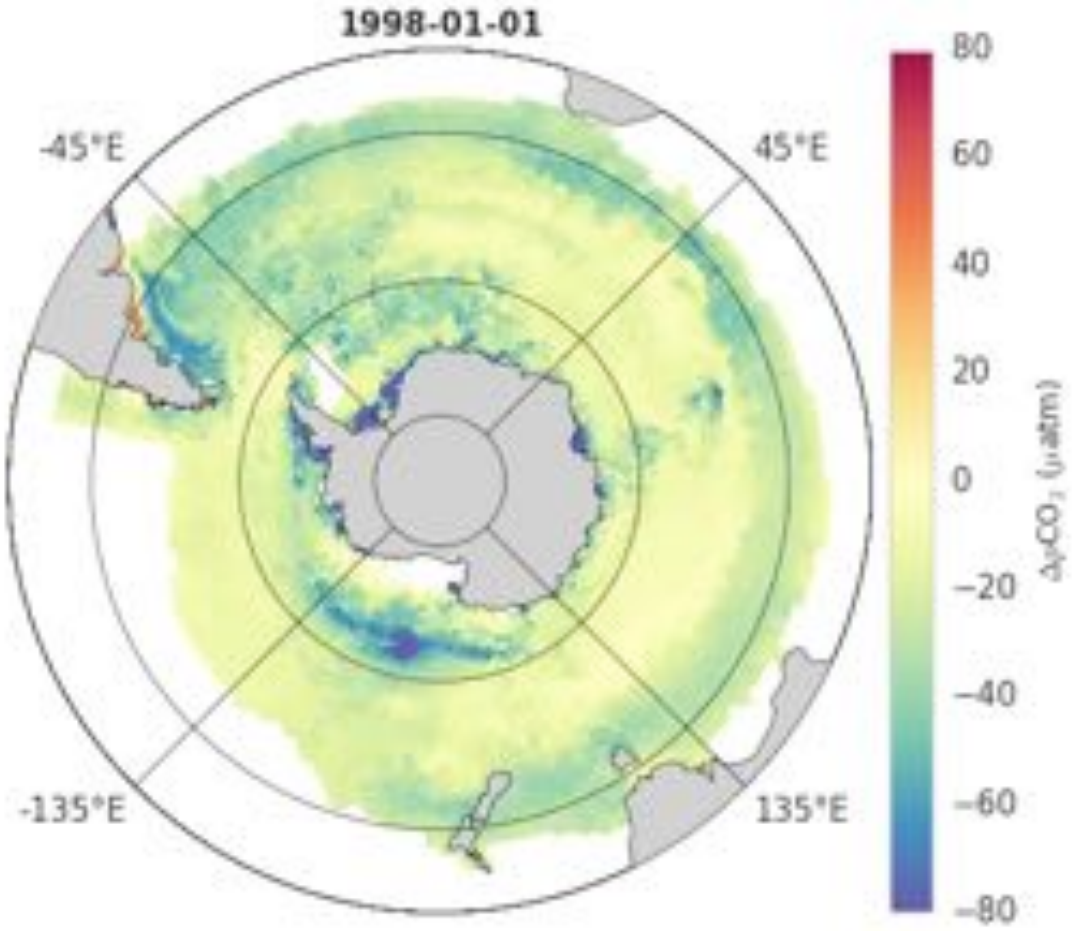
Gregor et al., Biogeosciences 2017

Data:

- SOCAT(v3) fCO_2
- CDIAC $_xCO_2^{atm}$
- GlobColour chlorophyll
- GHRSST
- $ECCO_2$: MLD, Salinity

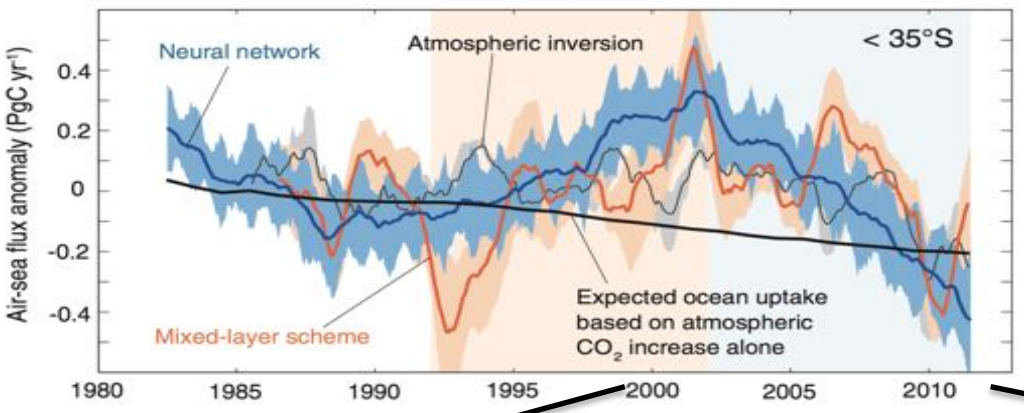
Methods:

- Support vector regression and random forest regression

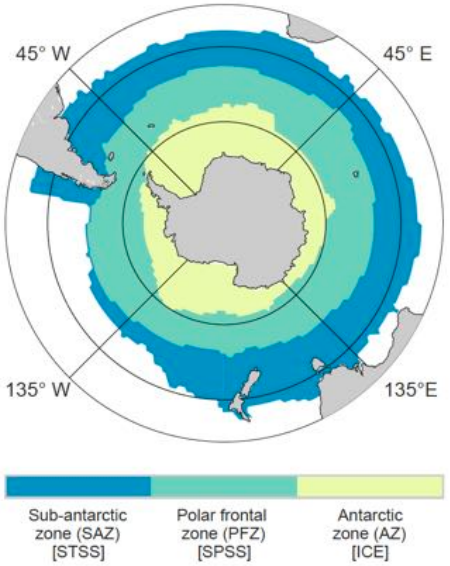


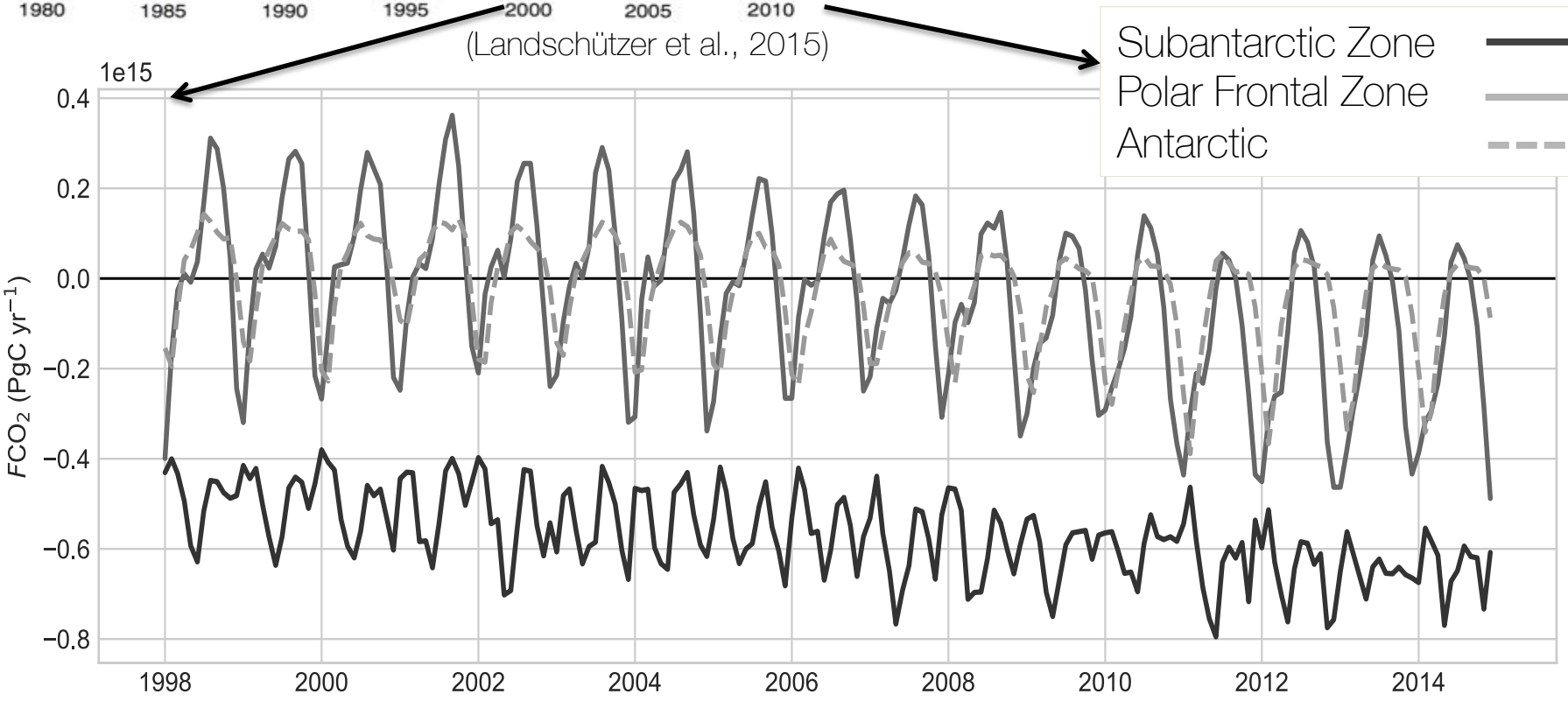
Decoupled seasonal drivers of CO_2

Gregor et al., Biogeosciences 2018



(Landschützer et al., 2015)

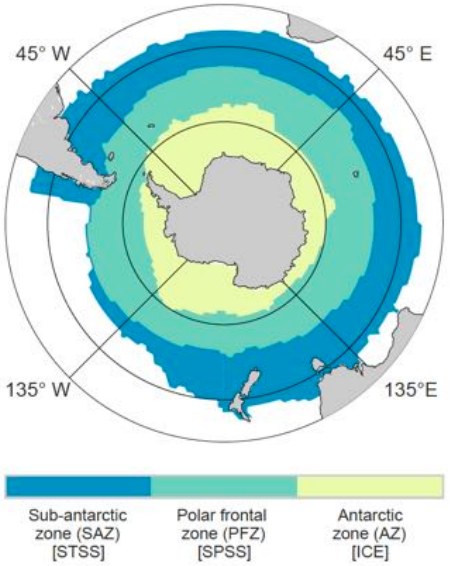


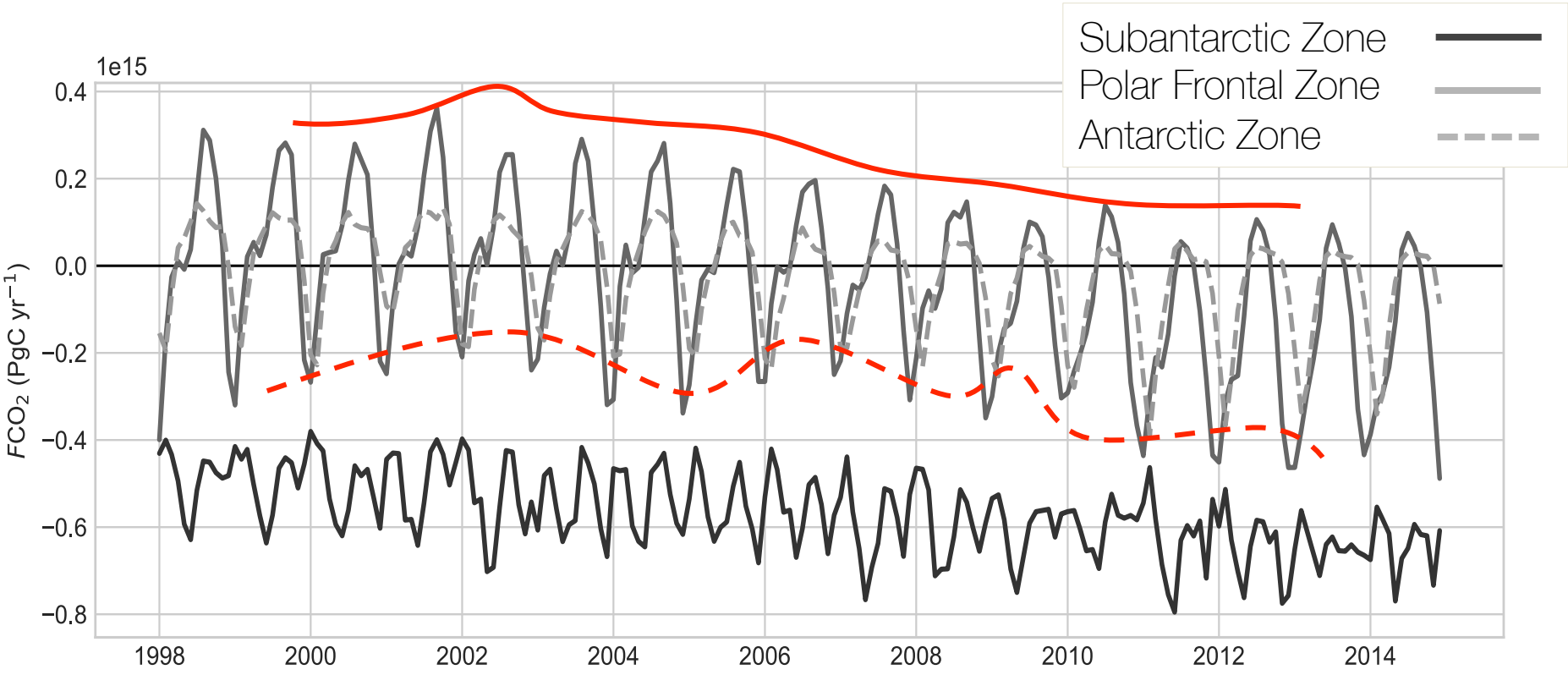


Decoupled seasonal drivers of CO_2

Gregor et al., Biogeosciences 2018

- Long term variability driven by winter in the PFZ (solid red line)
- Short term variability influenced by summer (dashed red line)





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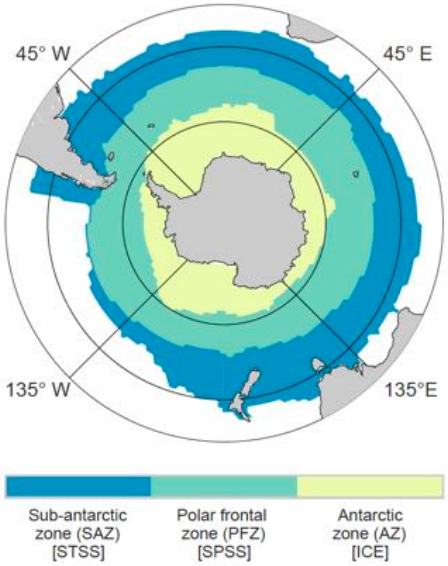
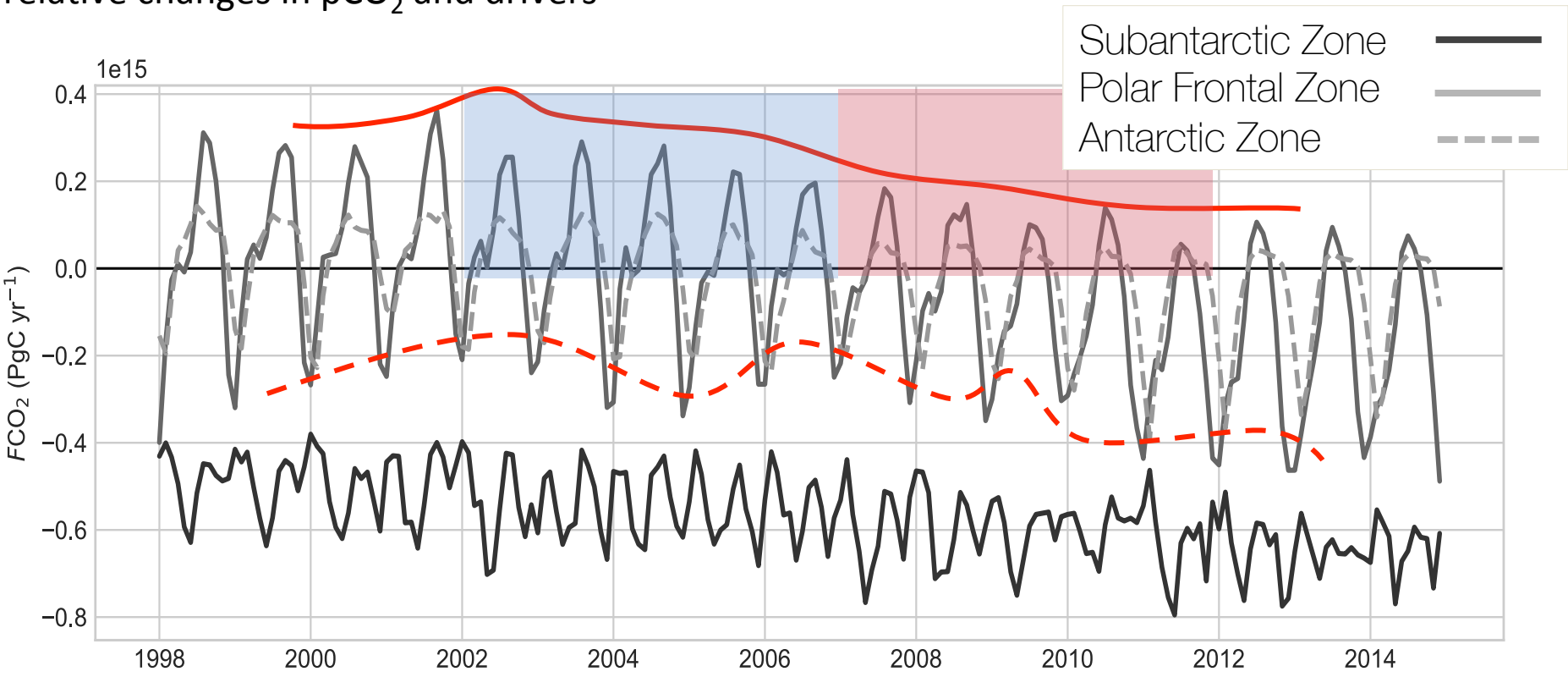
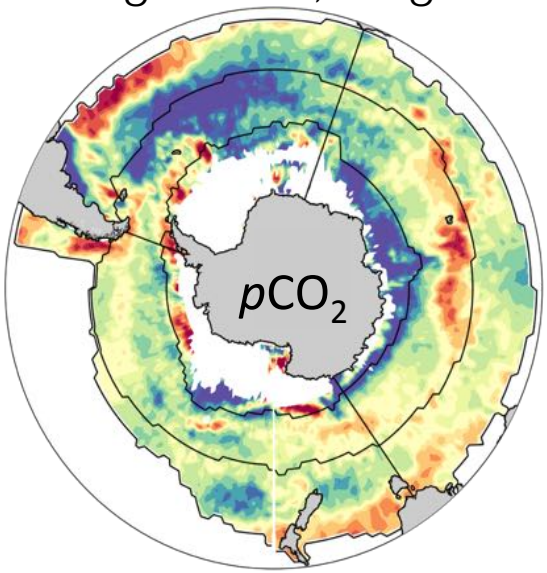


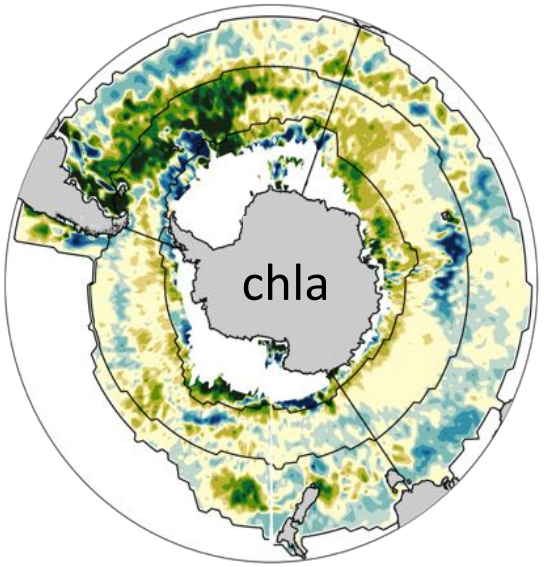
Subtract the average of two periods and the difference shows relative changes in pCO_2 and drivers



Decoupled seasonal drivers of CO_2

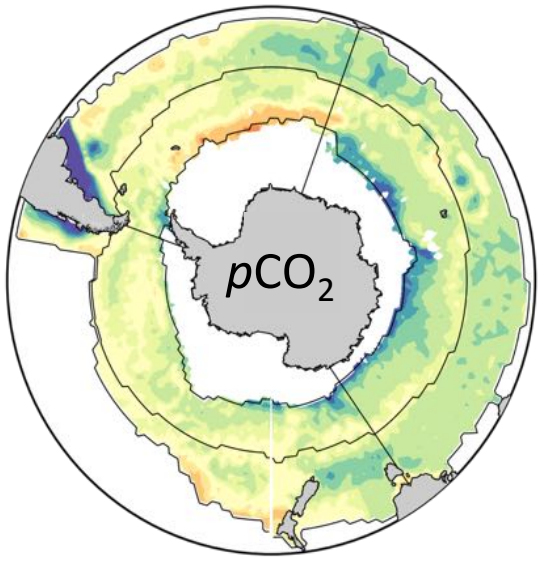
Gregor et al., Biogeosciences 2018

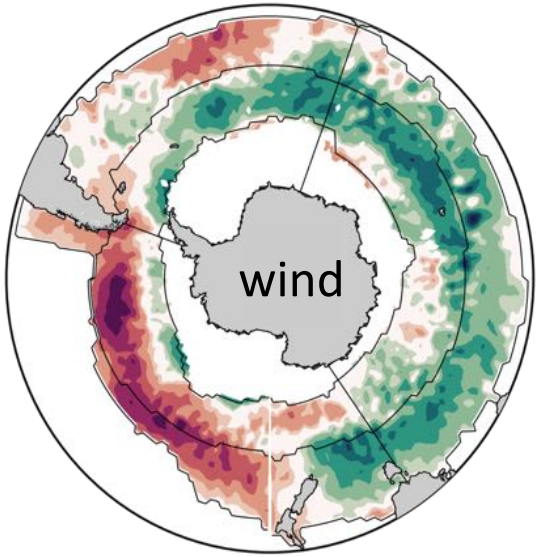




Summer

Short term anomalies are driven by changes in chlorophyll-a





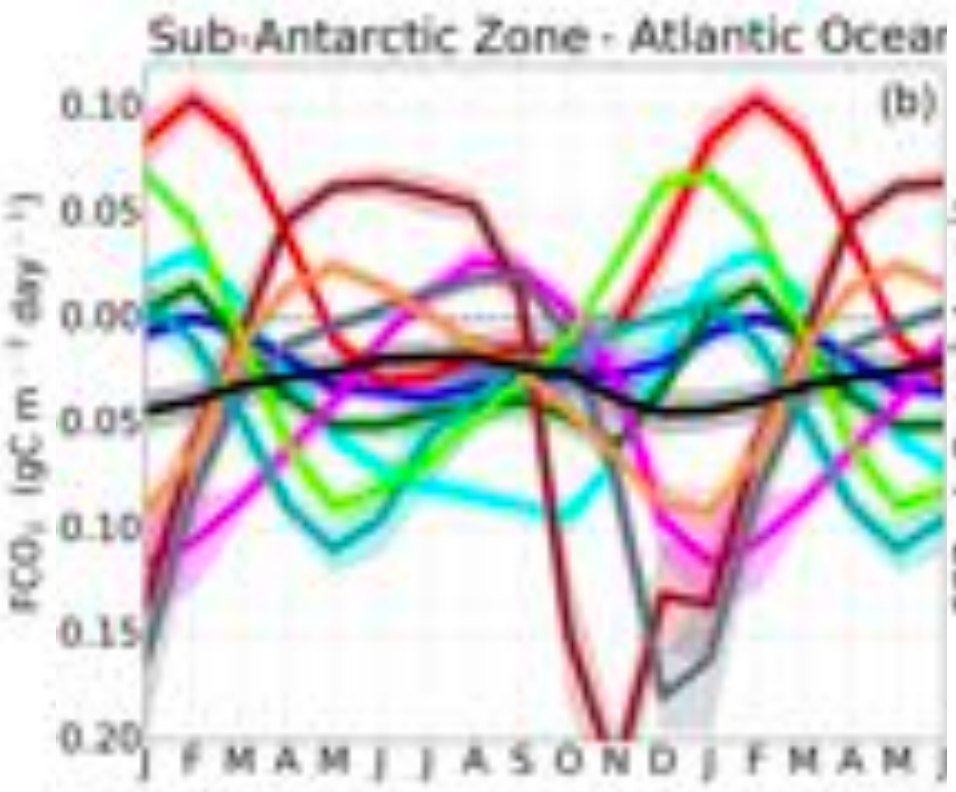
Winter

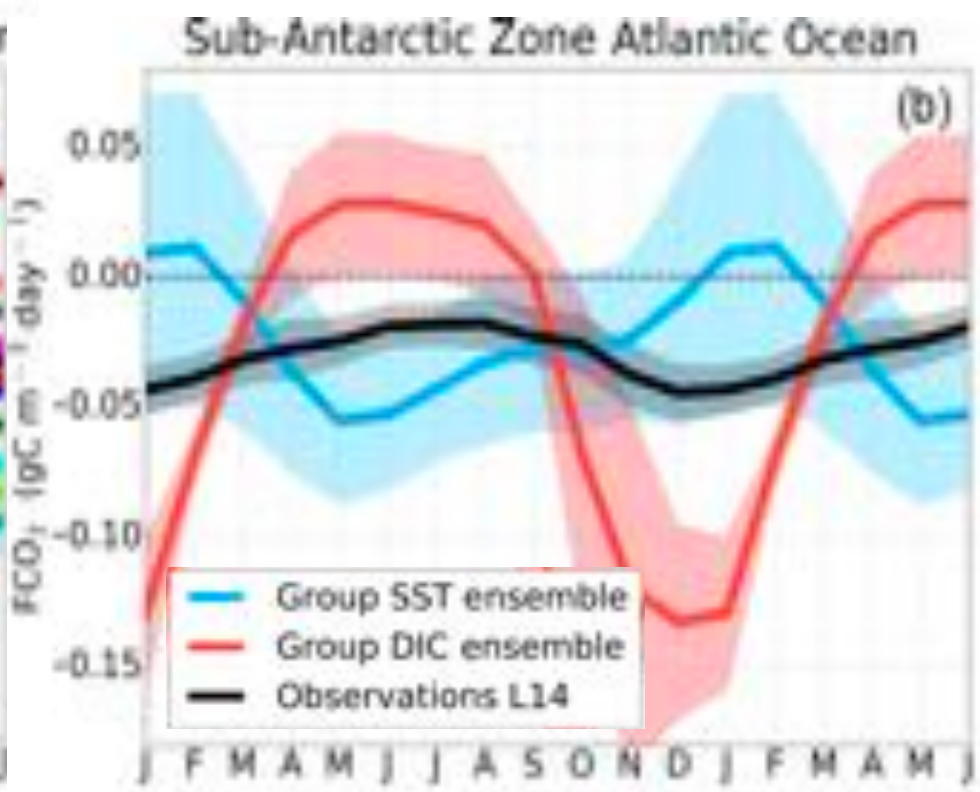
Decadal trend driven by weaker winds (linked to SAM)

Anomalies between two periods: (2007 : 2011) – (2002 : 2006)

The Seasonal Cycle as mode to diagnose biases in CO_2 flux in CMIP5 Models

Mongwe et al., Ocean Model, 2016; Biogeosciences, 2018





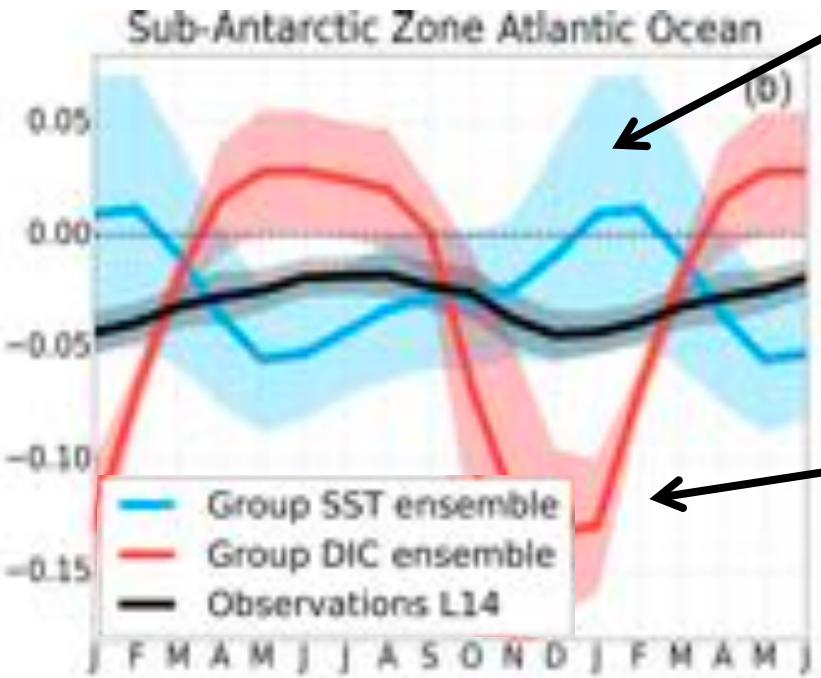
FCO_2 for 10 CMIP5 ESMs and L14 Obs

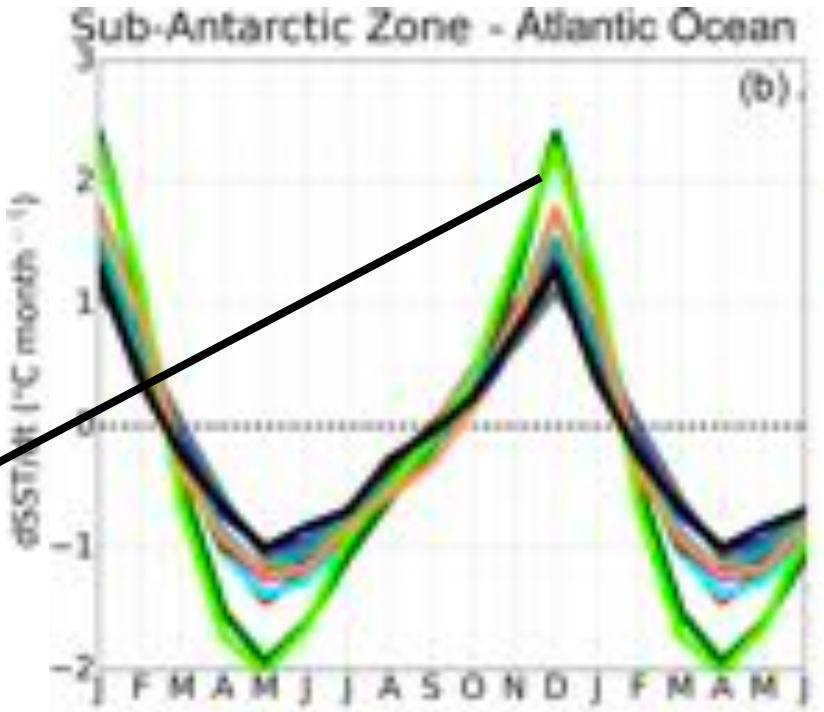
Split into two bias groups:

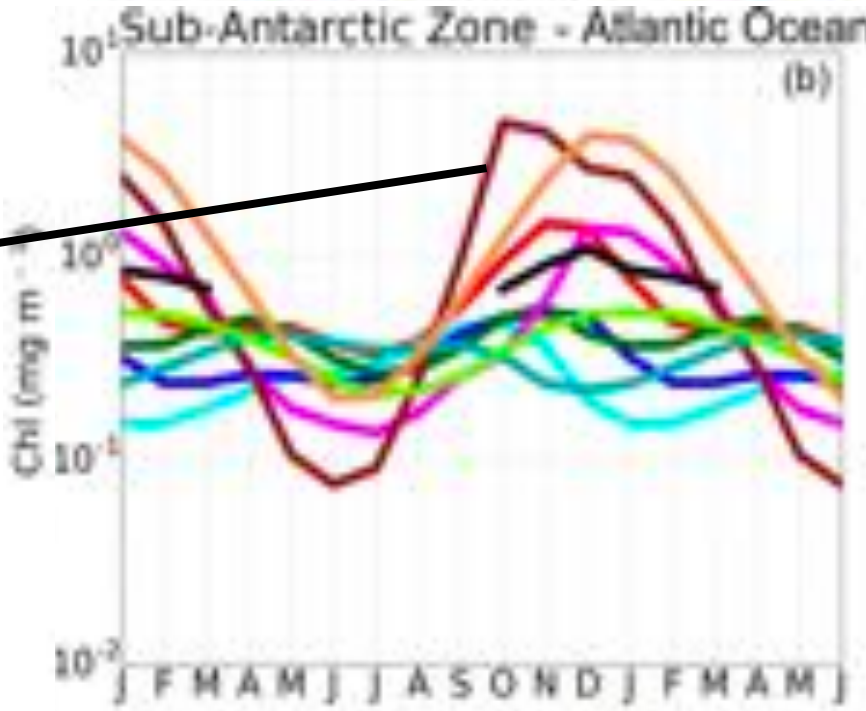
- SST
- DIC (phyto)

The Seasonal Cycle as mode to diagnose biases in CO_2 flux in CMIP5 Models

Mongwe et al., Biogeosciences, 2018



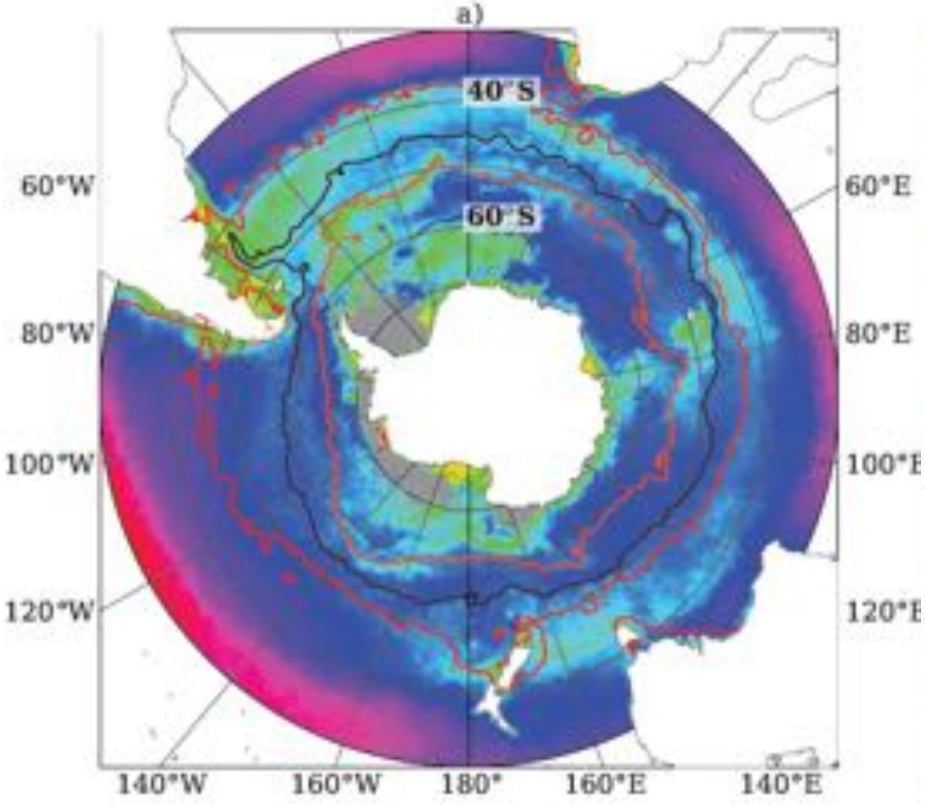




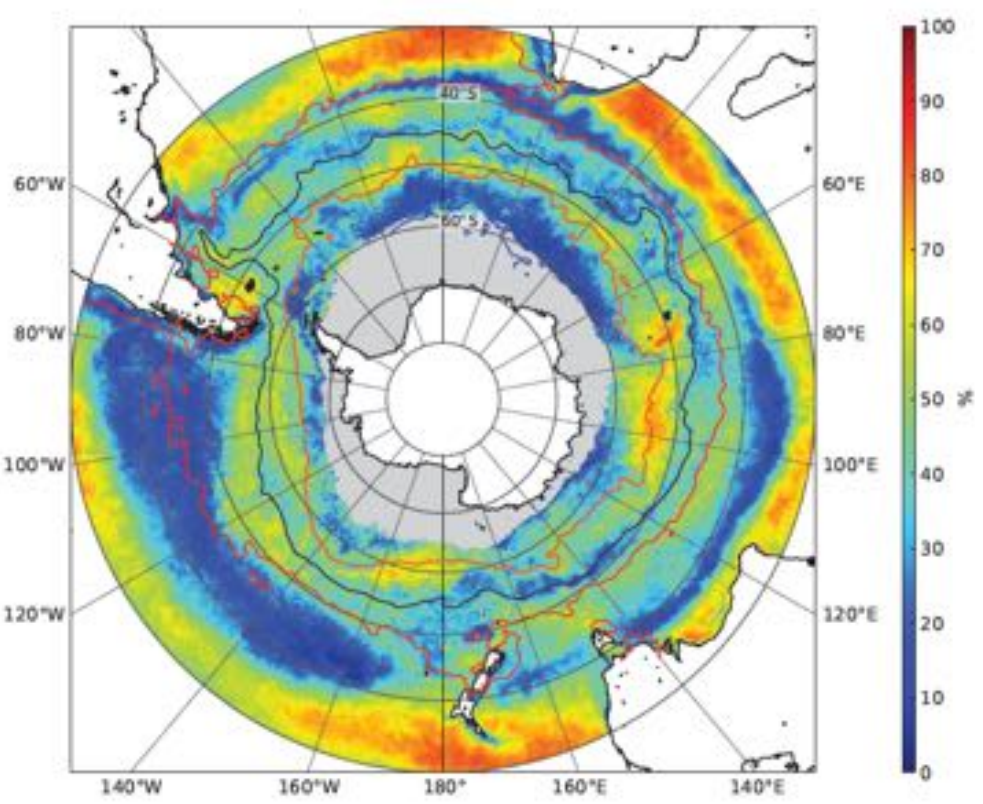
Characterising the Southern Ocean seasonal cycle

Thomalla et al., 2011, Biogeosciences

Mean summer chlorophyll



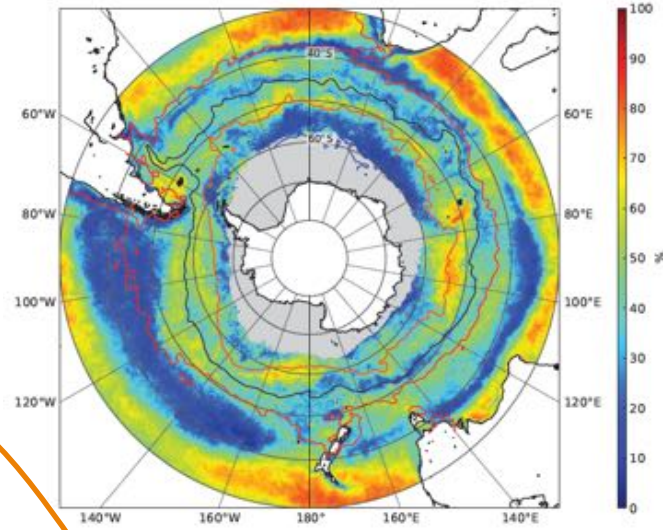
Seasonal Cycle Reproducibility

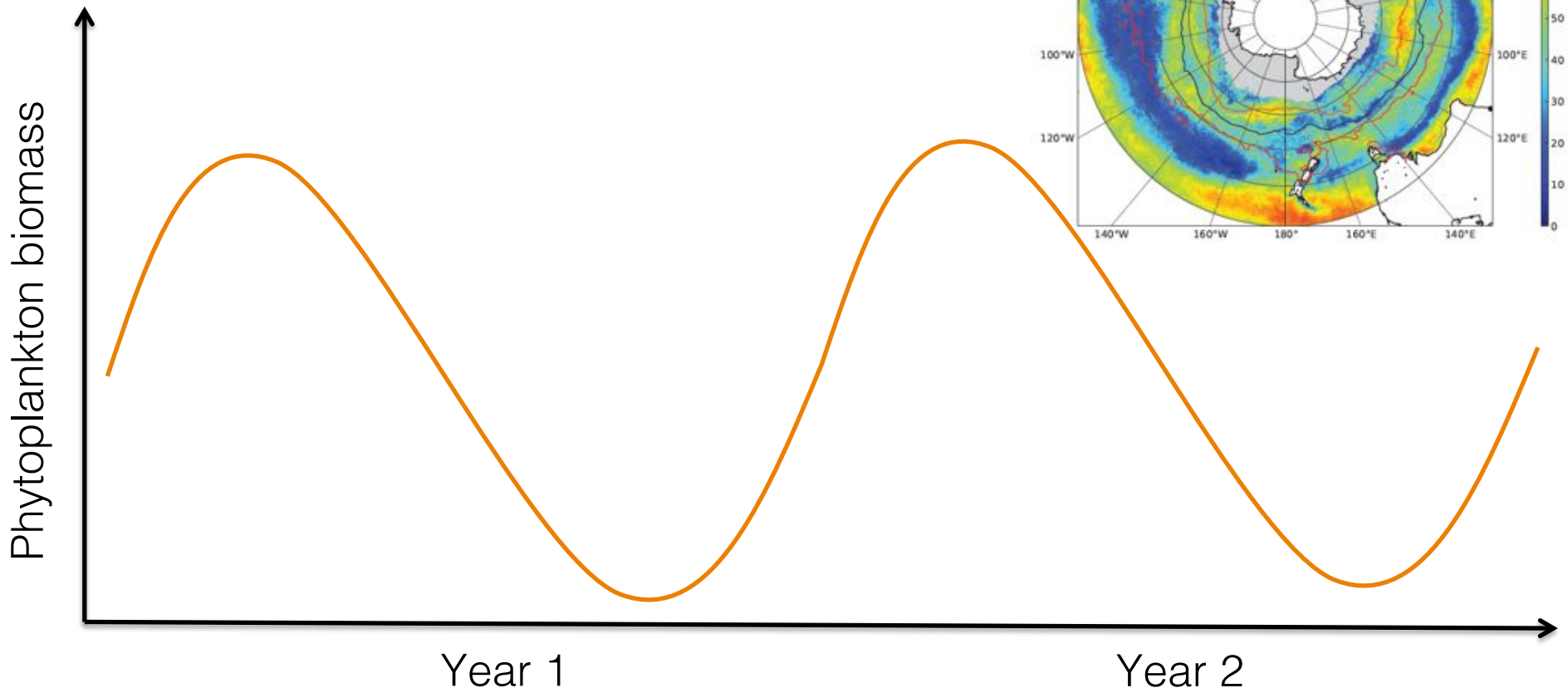


Characterising the Southern Ocean seasonal cycle

Thomalla et al., 2011, Biogeosciences

High seasonal cycle reproducibility





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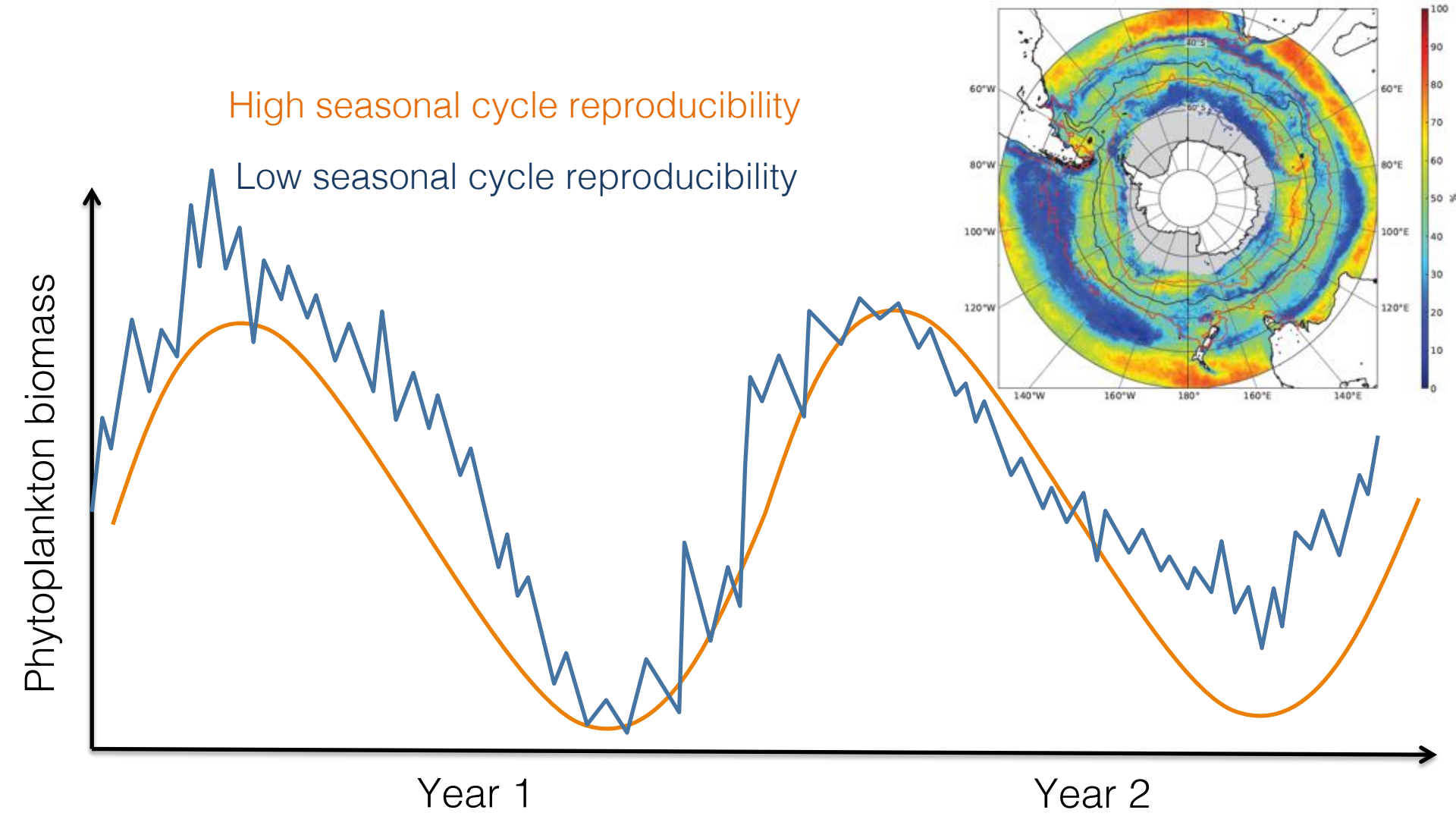

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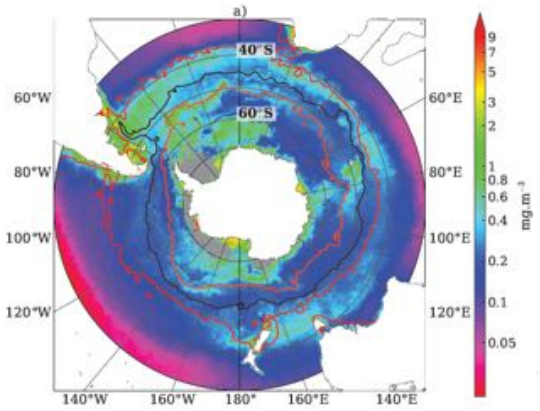
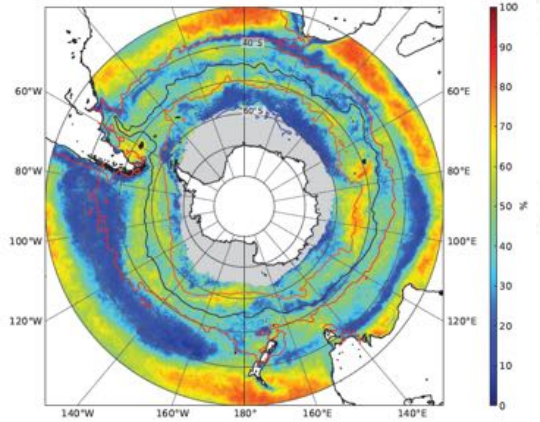
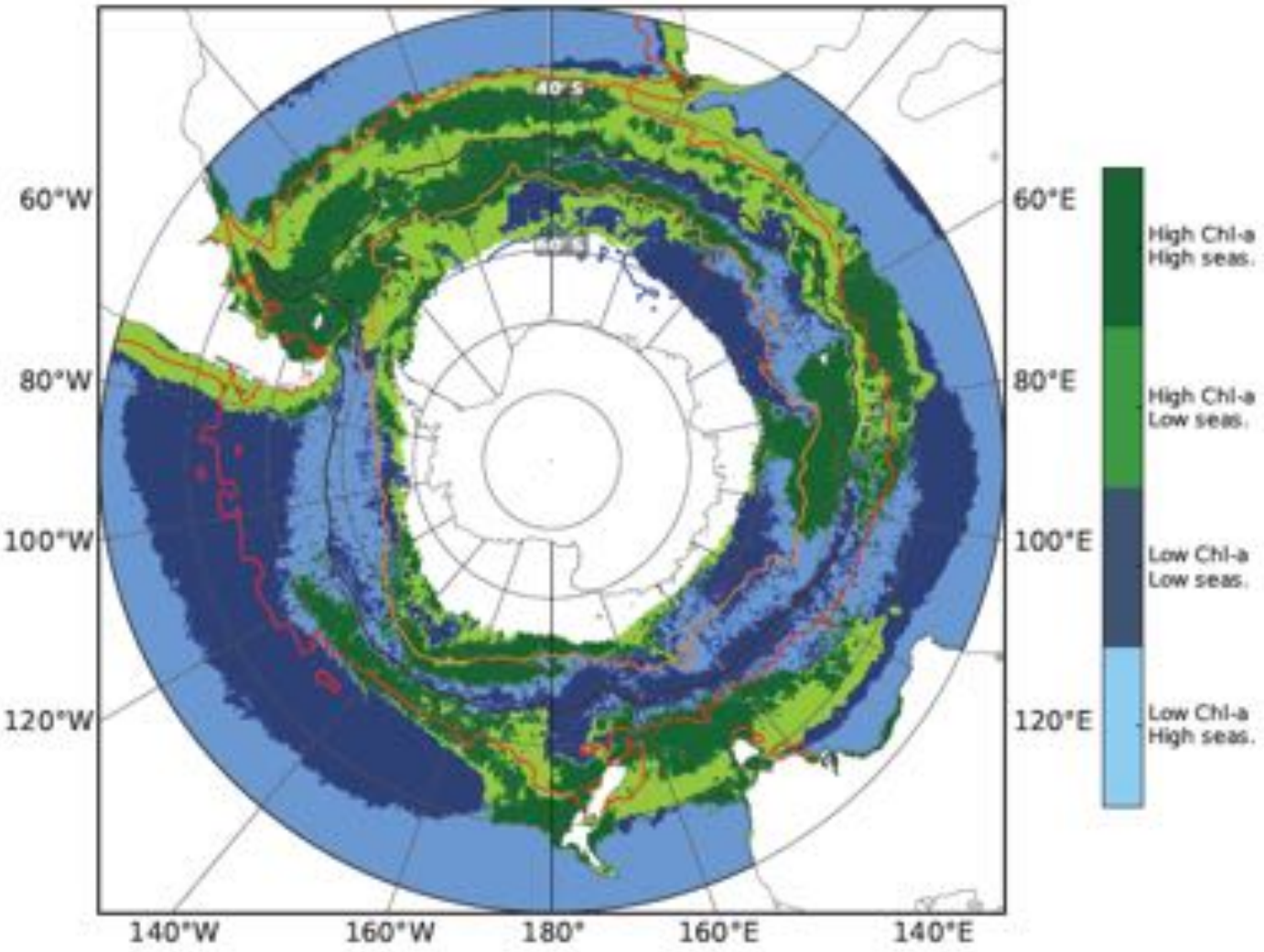


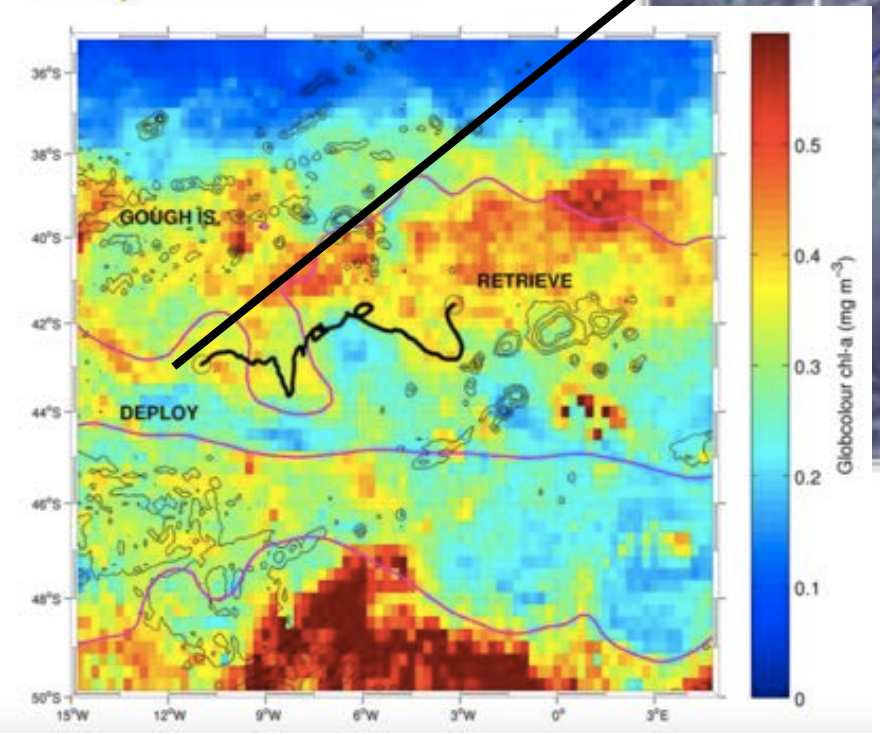


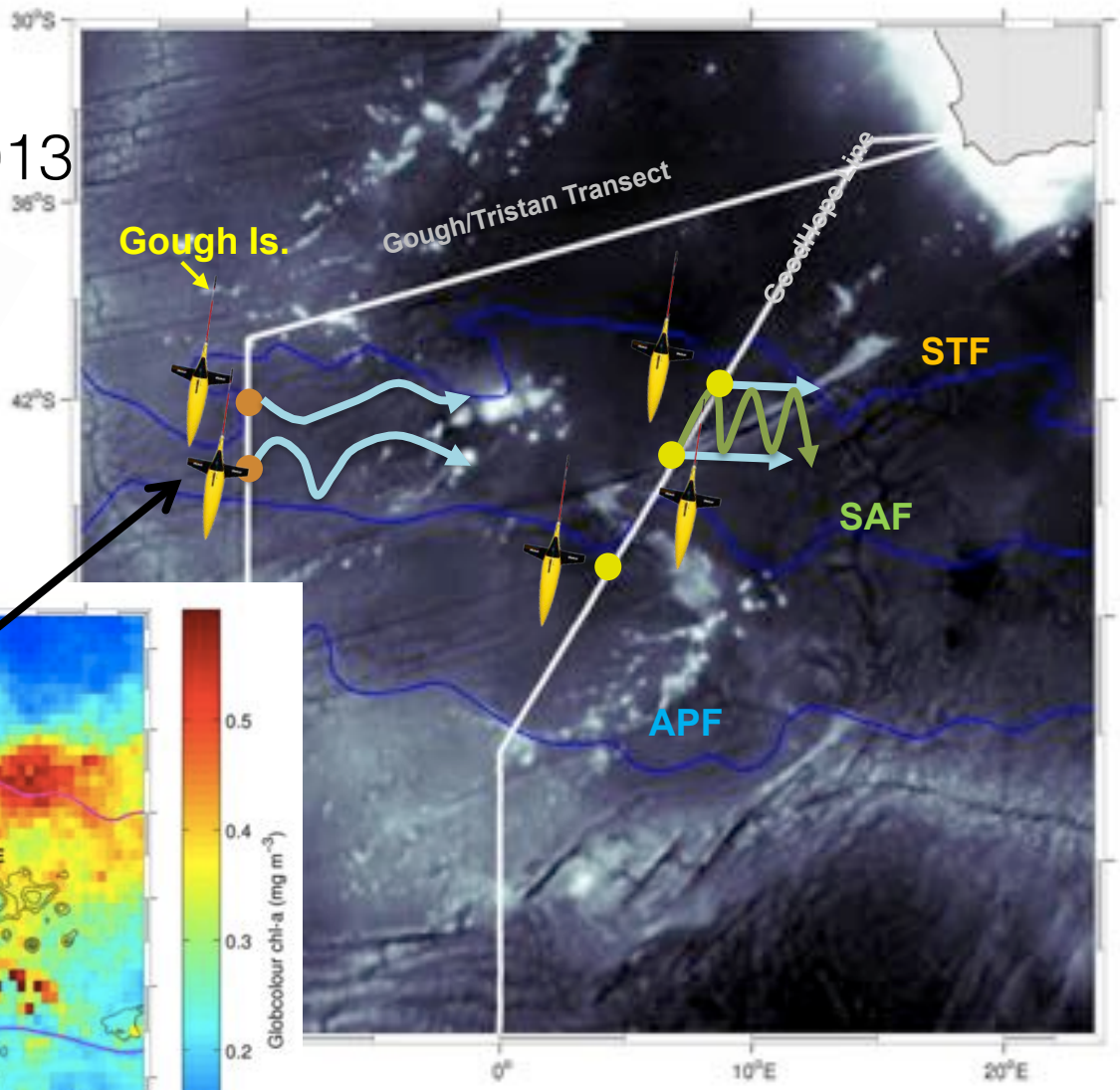


Southern Ocean Seasonal Cycle Experiment
SOSCEx I

Sept 2012 – Mar 2013

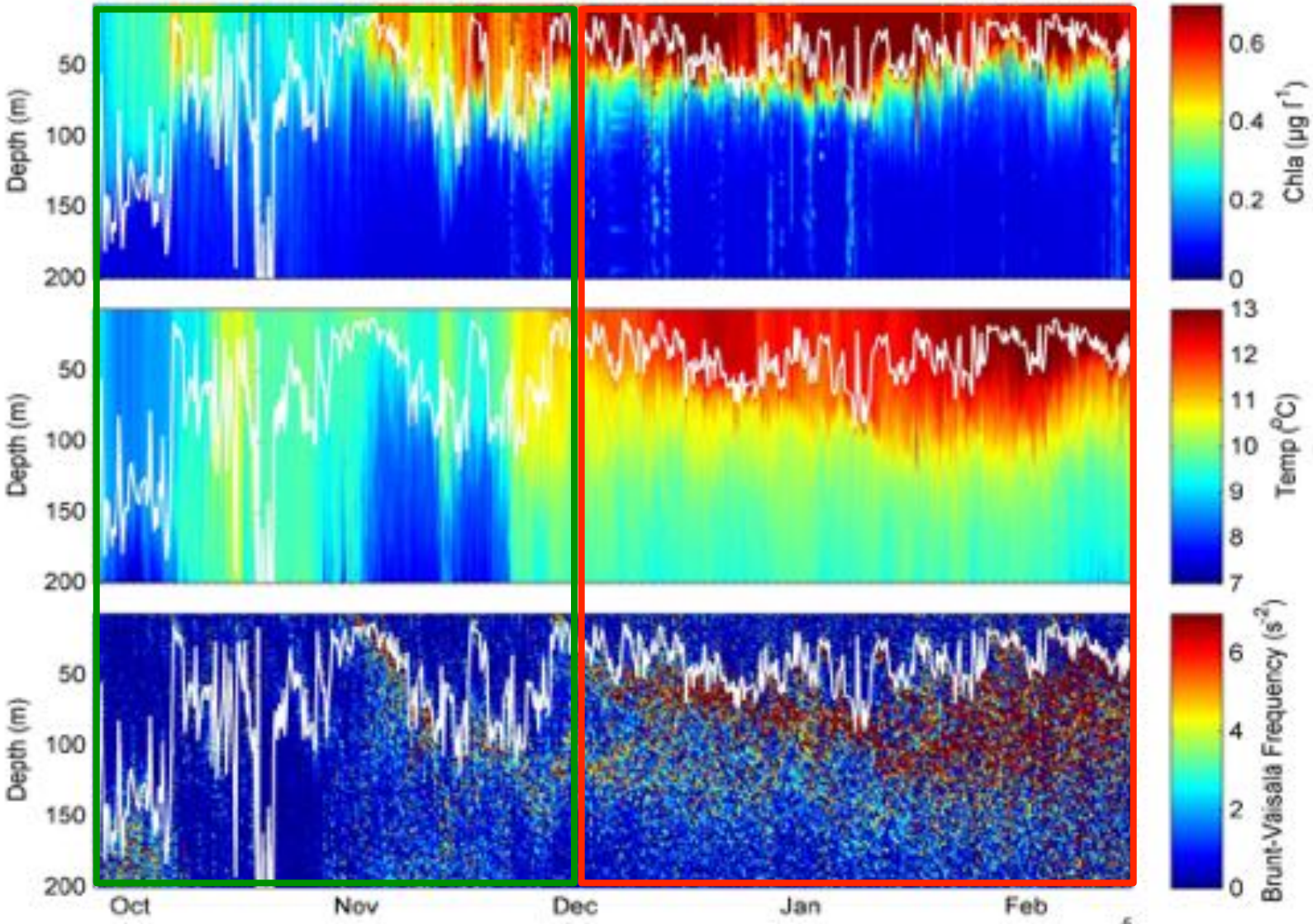
SG 543





The seasonal cycle of mixed layer dynamics and phytoplankton biomass in the SAZ

Swart et al., 2015, Journal of Marine Systems



Spring Bloom Priming Period

Summer Bloom Sustaining Period

Bloom initiation and Net Community Production in the SAZ

Thomalla et al., 2015, ICES Journal of Marine Science

Convert b_{bp} into C_{phyto}
Behrenfeld et al., (2005)

Extrapolate PAR profile to get surface PAR

Model Primary Production
Platt and Sathyendranath (1993)

Determine bloom initiation date

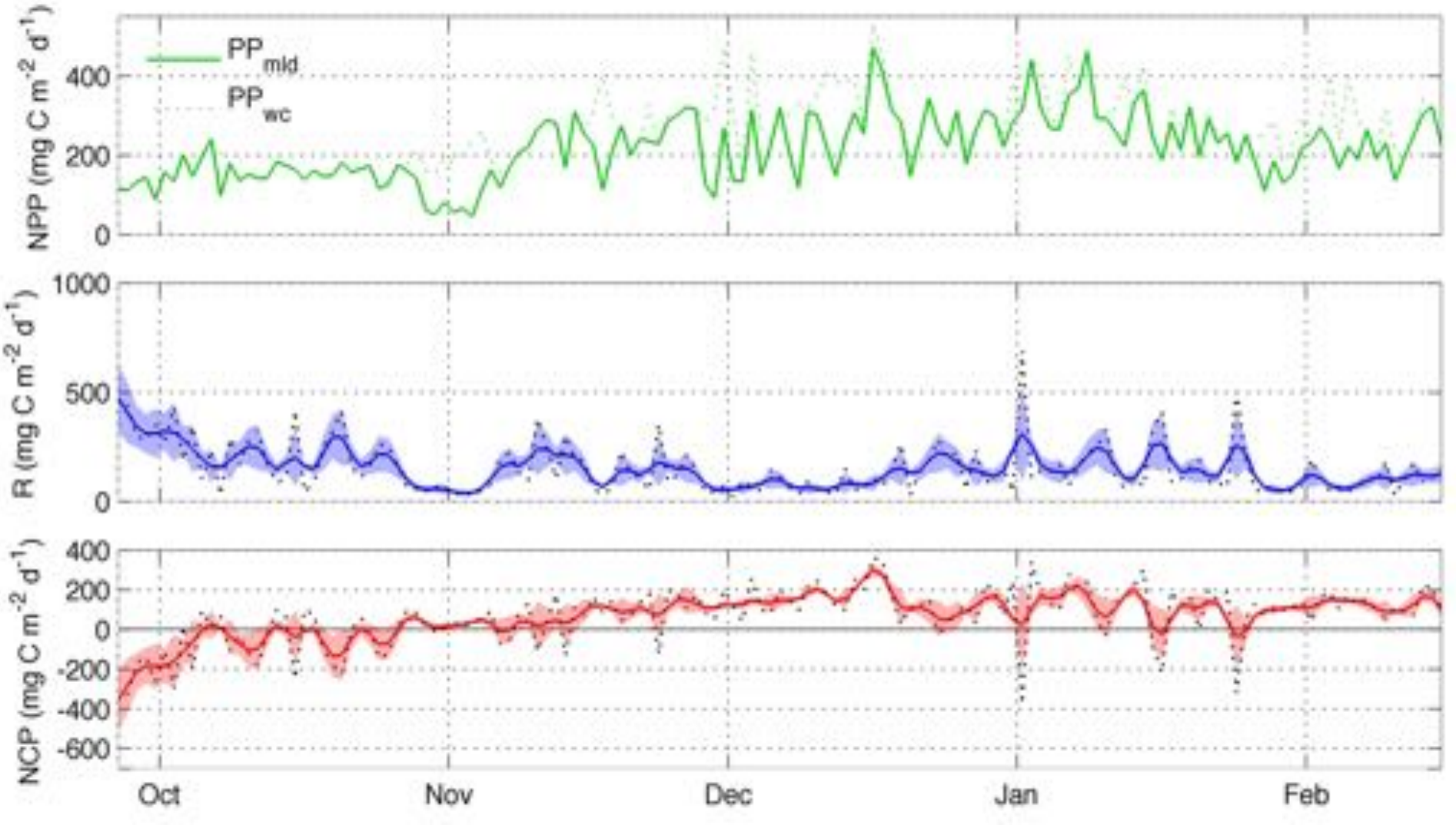
Calculate MLD

Resolve Sverdrup's critical depth model
Sverdrup (1953)

Output time series of daily rates of respiration and NCP

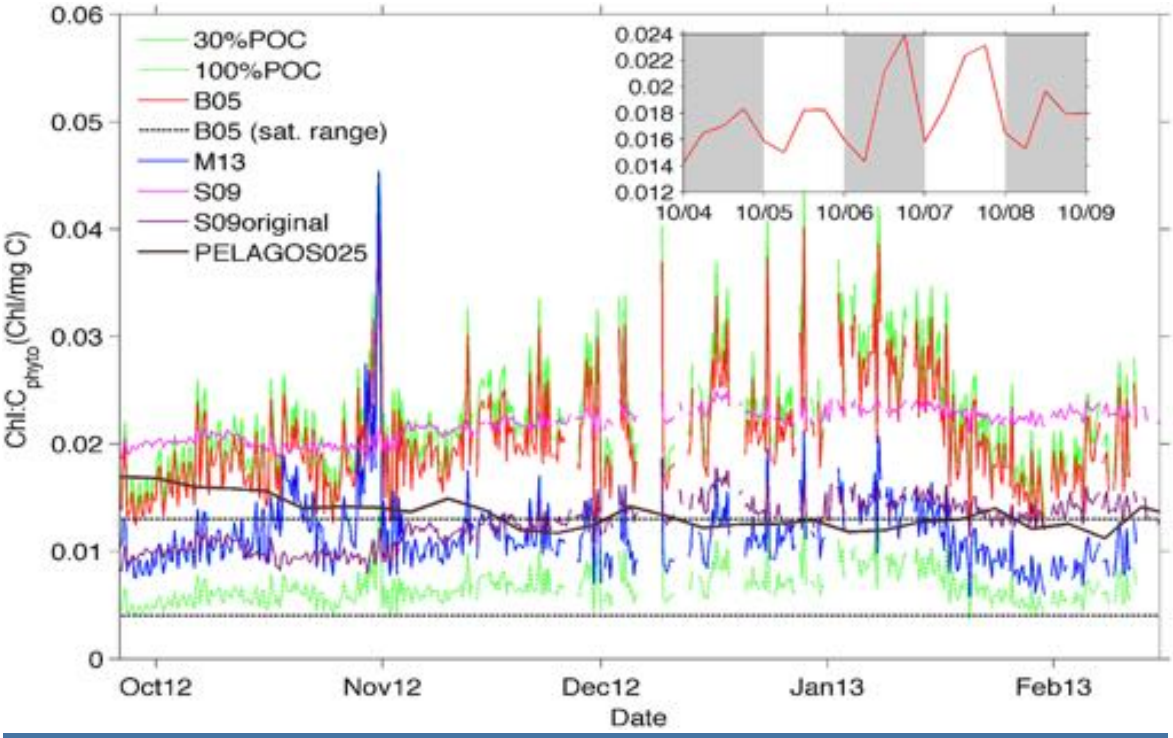
Bloom initiation and Net Community Production in the SAZ

Thomalla et al., 2015, ICES Journal of Marine Science



Phytoplankton carbon (C_{phyto}) and Chla:C_{phyto} ratios from optical sensors on gliders

Thomalla et al., 2017, Frontiers in Marine Science



The model misrepresents the seasonal cycle of chla:C_{phyto} ratios

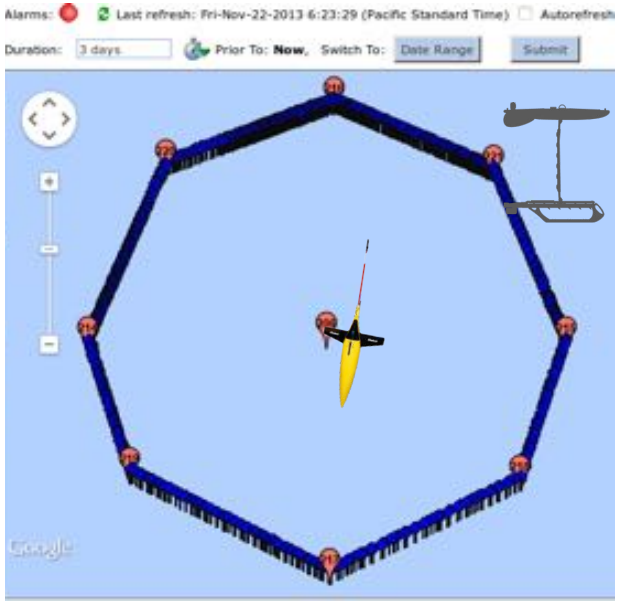
1.Models need to allow chla:C_{phyto} ratios that account for low light adaptation in spring and higher optimal chla:C_{phyto} ratios with increasing growth rates in summer

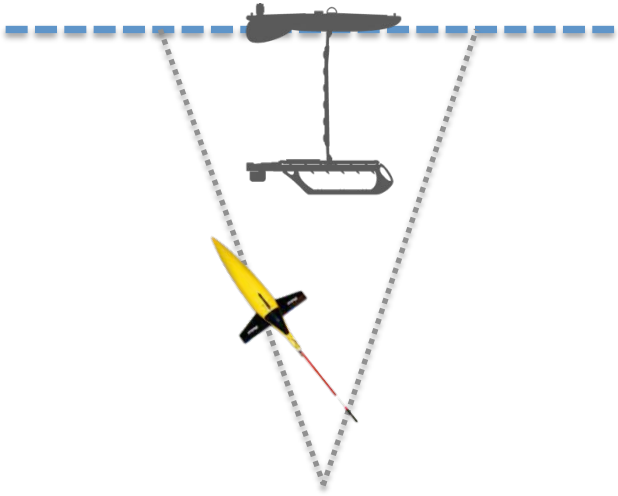
OR

2. There is a decrease in % contribution of C_{phyto} to b_{bp} as seasonal bloom develops i.e. methods need to account for variability of non-algal contributions to b_{bp}

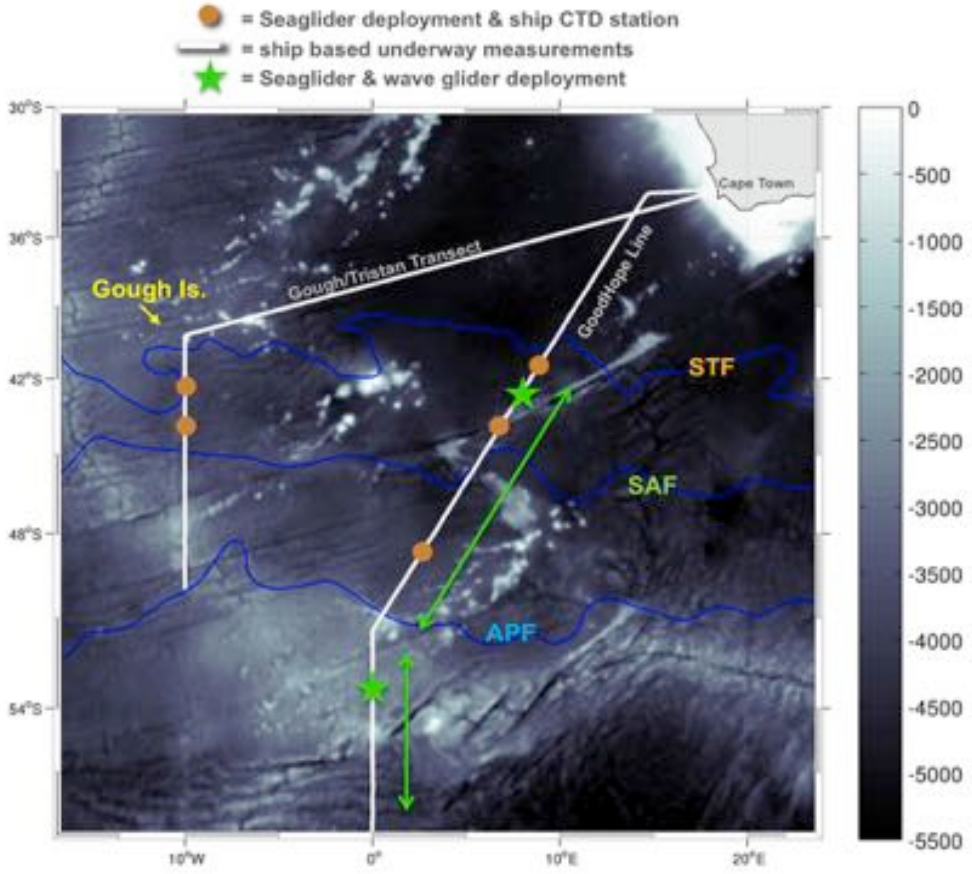
SOSCEx II

Nov 2013 – Feb 2014



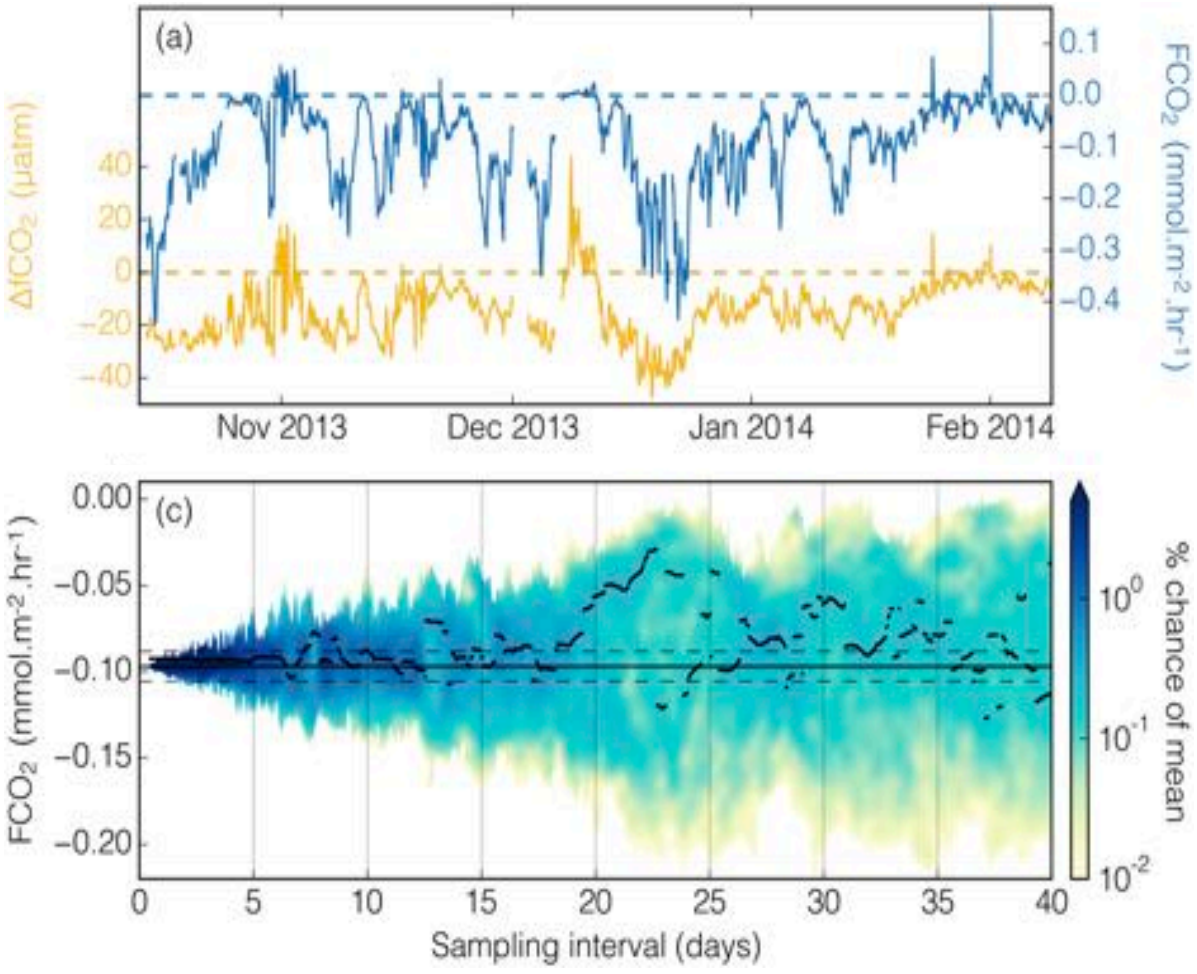


1000m



Intra-seasonal variability linked to sampling alias in CO_2 fluxes

Monteiro et al., GRL 2015



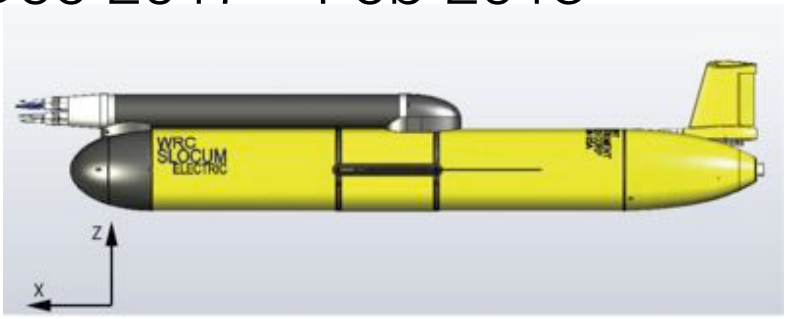
The SO contributes most of the uncertainty in annual flux estimates of CO_2.

Drive to reduce the uncertainty of annual mean flux below the 10% threshold required to reveal climatic trends.

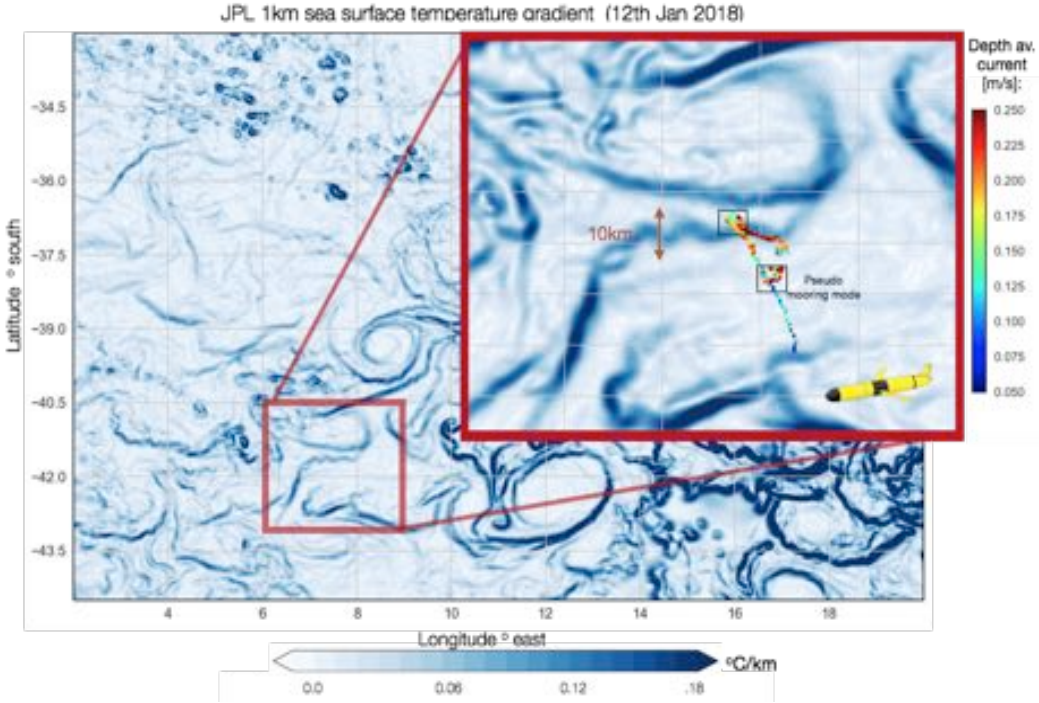
Sampling intervals >2 days alias the seasonal mean flux due to storm-linked intraseasonal variability

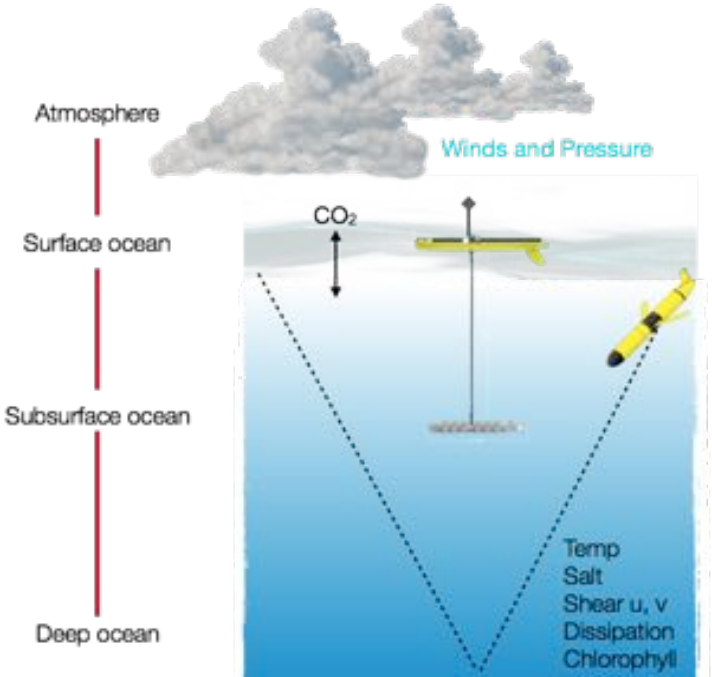
SOSCEx - STORM

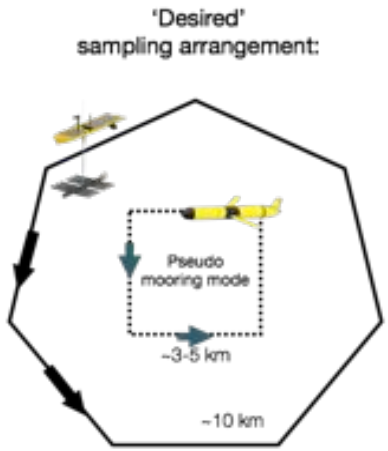
Dec 2017 – Feb 2018



- Slocum glider with turbulence package
- MicroRider: Velocity shear and thermistor probes





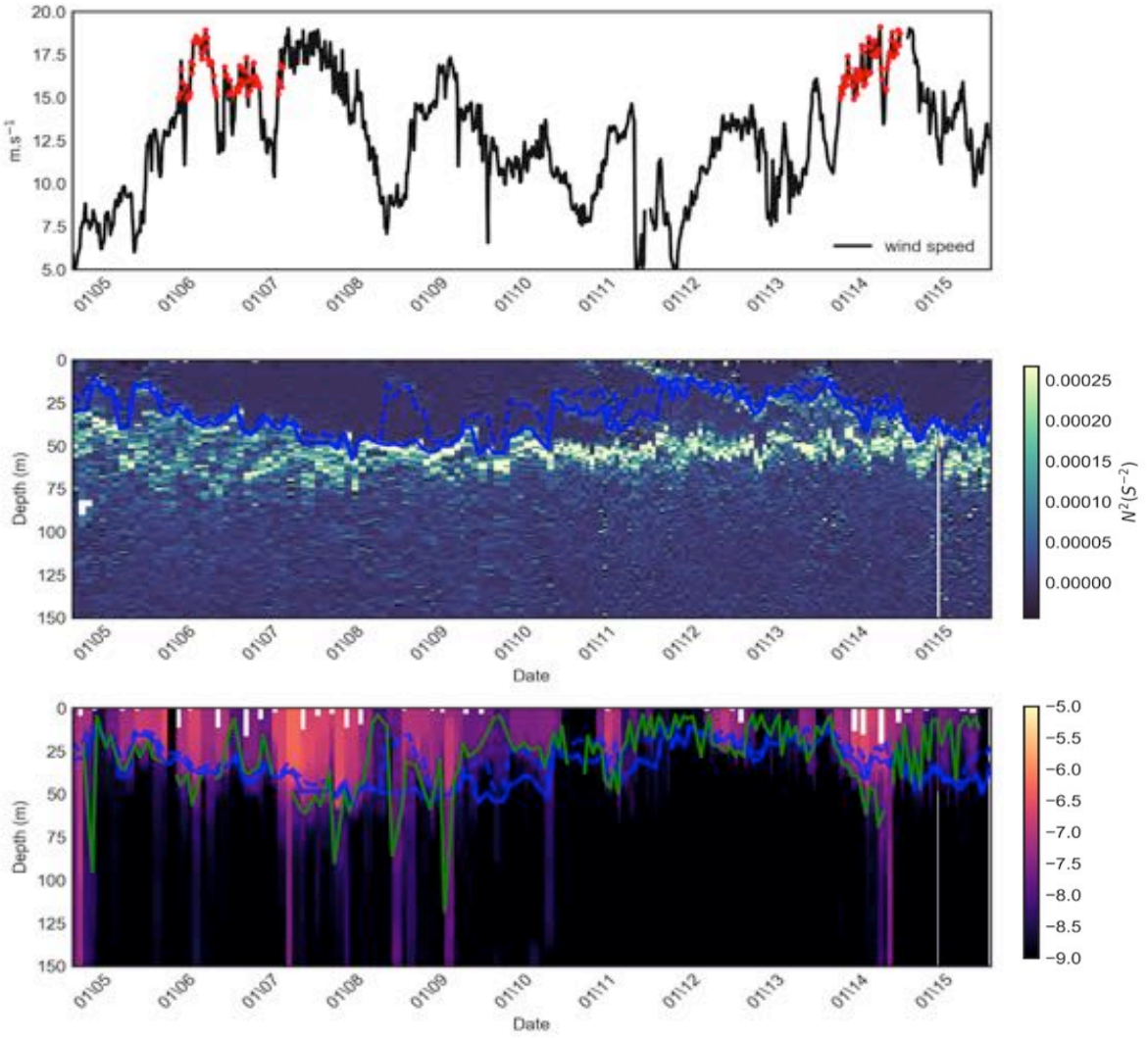


SOSCEx - STORM

Nicholson et al., in prep

Storms Identified when Pressure < 15%, Wind > 85%

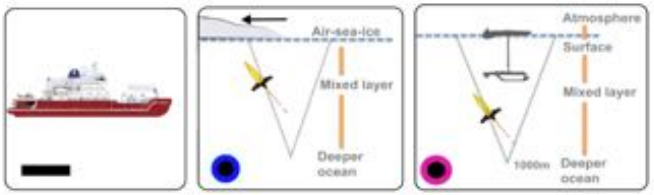
Preliminary results show that both the MLD (blue) and mixing layer extent (green) deepen in response to a storm

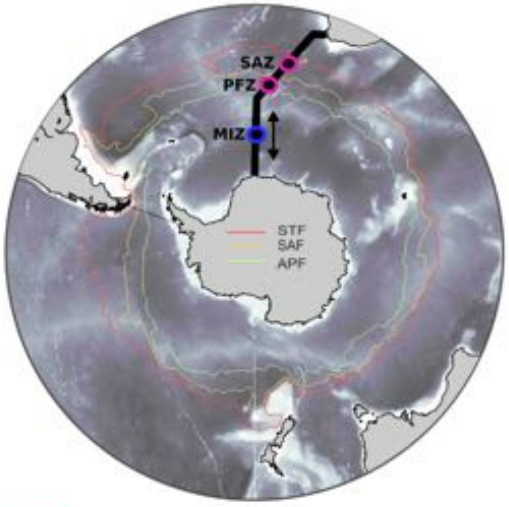


SCALE

Southern oCean seAsonaL Experiment

A novel interdisciplinary experiment that spans seasonal to decadal time scales in the SE Atlantic sector of the Southern Ocean





SCALE HYPOTHESIS
Changes in seasonal modes of variability are a more sensitive indicator of long-term trends than changes in the magnitude of annual means.

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Thank You!

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