Scoping for Interdisciplinary Coordinated Experiment of the Southern Ocean Carbon Cycle (ICESOCC)

Funded by NASA OBB 2/2014 – 7/2015

Goals Specified in Proposal:

"To define an interdisciplinary and international field campaign to develop improved capability for measuring seasonal variations in NCP and subsurface ventilation at the scale of the entire Southern Ocean and to constrain satellite-derived estimates with atmospheric and oceanic observations and models."

ICESOCC co-Investigators

CO-I	INSTITUTION	EXPERTISE
Arrigo, K.	Stanford	Plankton ecology, phytoplankton physiology, satellite remote sensing, lead author IOCCG Polar Algorithms NPP chapter
Barbeau, K.	SIO	Iron Biogeochemistry iron regulation of phytoplankton physiology
Boss, E.	Univ. of Maine	Ocean optics, optical sensors, autonomous systems
Ducklow, H.	Columbia U.	Plankton ecology, bacterial processes, lead PI NSF Palmer LTER
Frouin, R.	SIO	Radiative transfer, atmospheric correction, surface radiation, clouds and ice, co-author IOCCG Polar Algorithms atmospheric corrections
Kahru, M	SIO	Bio-optical algorithms, satellite remote sensing
Keeling, R.	SIO	Air sea gas exchange, ocean and atmosphere biogeochemical modeling
Lee, Z.	U. Mass Boston	Radiative transfer, ocean optics inverse models, satellite remote sensing of ocean primary production
Mitchell, G	SIO	Chair ICESCOCC Steering Committee. Plankton ecology, phytoplankton physiology, satellite remote sensing co author IOCCG Polar Algorithms IOP/AOP and NPP chapters
Nevison, C	Univ. of Colo.	Air sea gas exchange, measurement and modeling of atmosphere N_2O
Reynolds, R.	SIO	Phytoplankton physiology, ocean optical properties, bio-optical modeling, lead author IOCCG Polar Algorithms IOP/AOP
Sarmiento, J.	Princeton U.	Ocean-atmosphere biogeochemistry, coupled models of ocean and atmosphere climate feedbacks. Lead PI for C-SOBOM
Talley, L.	SIO	Physical oceanography, Southern Ocean convective mixing, co-Chair CLIVAR Southern Ocean Panel lead PI at SIO for C-SOBOM

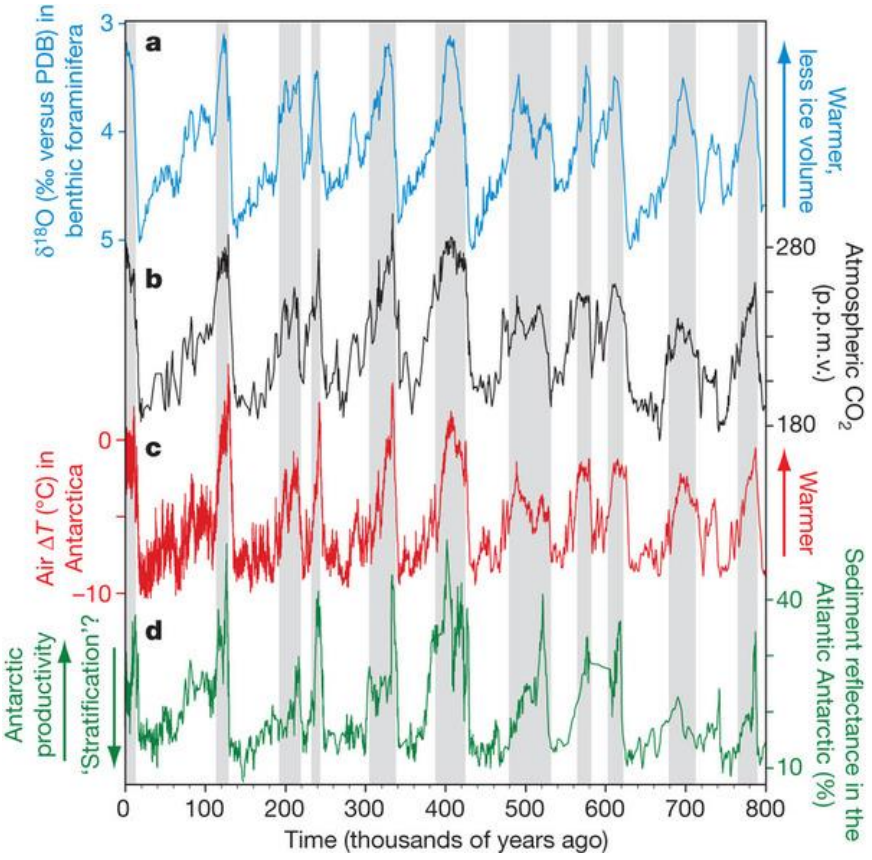
Motivation for Southern Ocean Focus

Modeling studies have demonstrated that the nutrient and carbon cycles in the Southern Ocean play a central role in setting the air–sea balance of CO_2 and global biological production. (Marinov et al. Nature, 2006)

RELATIVE TEMPERATURE

ATMOSPHERE CO2

S. OCEAN DIATOMS



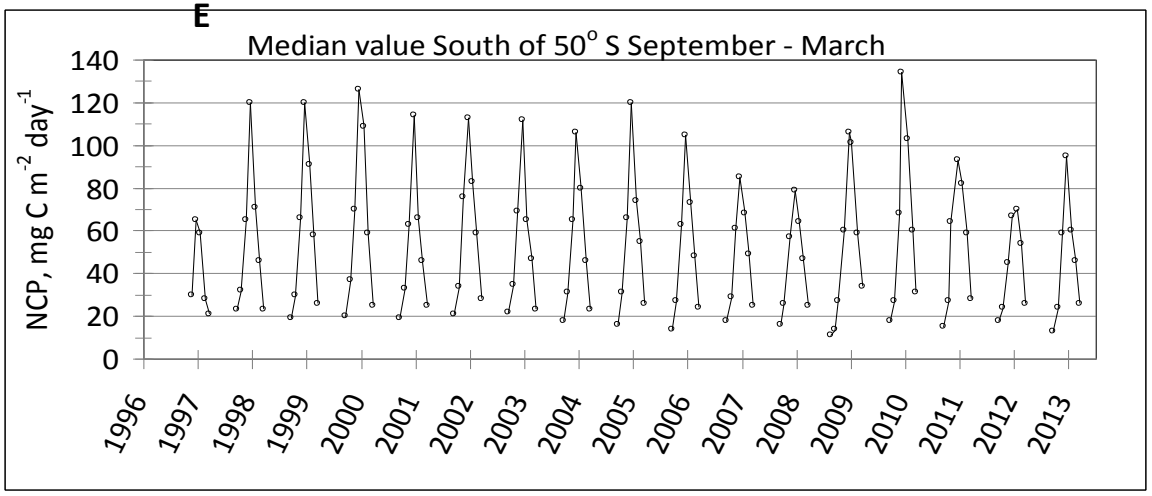
From Sigman et al. (Nature, 2010)

From Sigman et al. 2010

"….In the Antarctic, both light (Mitchell et al. 1991) and the trace nutrient iron (Martin et al. 1990) are thought to control the productivity of phytoplankton and the export of their organic matter…..

If iron is the central limiter of annual Antarctic productivity, then the degree of consumption of the major nutrients (nitrate and phosphate) should depend on the supply ratio of iron relative to the major nutrients…."

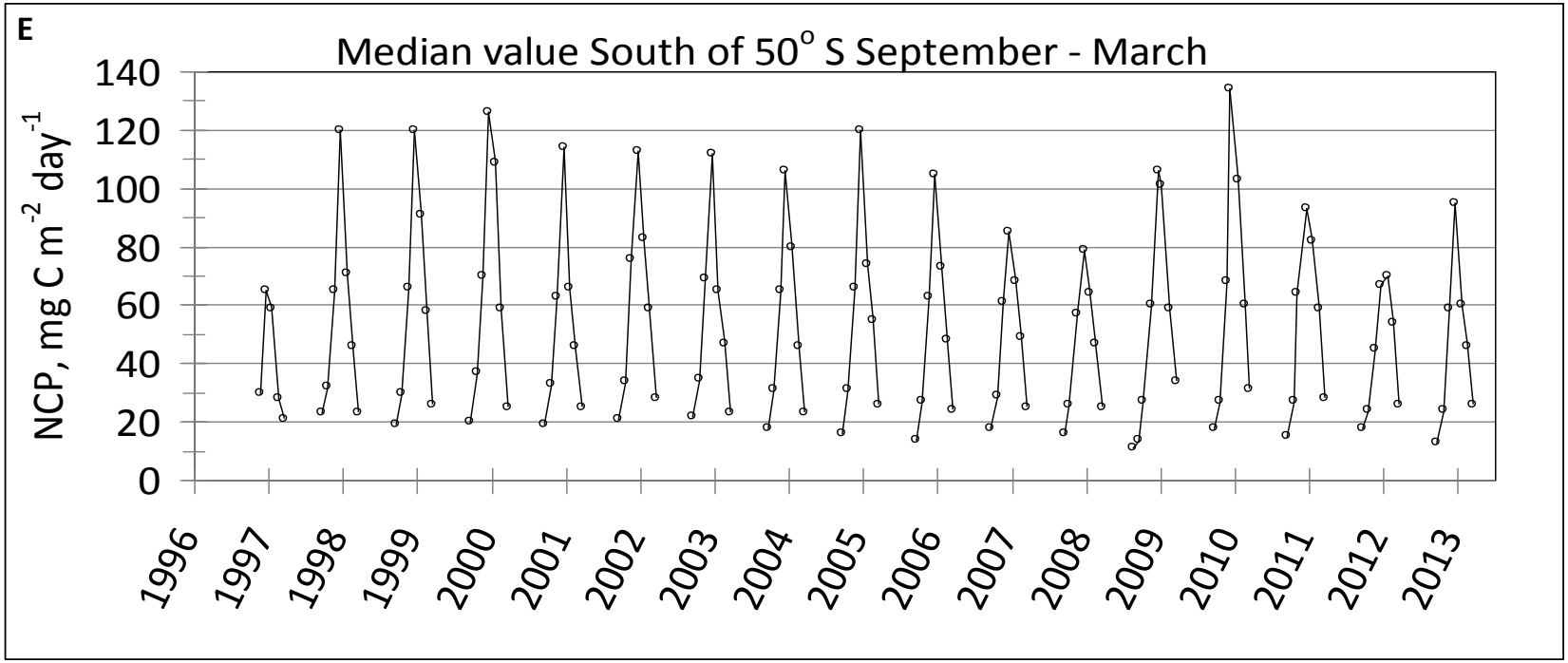
Is there *REALLY* a 2x difference in the interannual supply of iron???

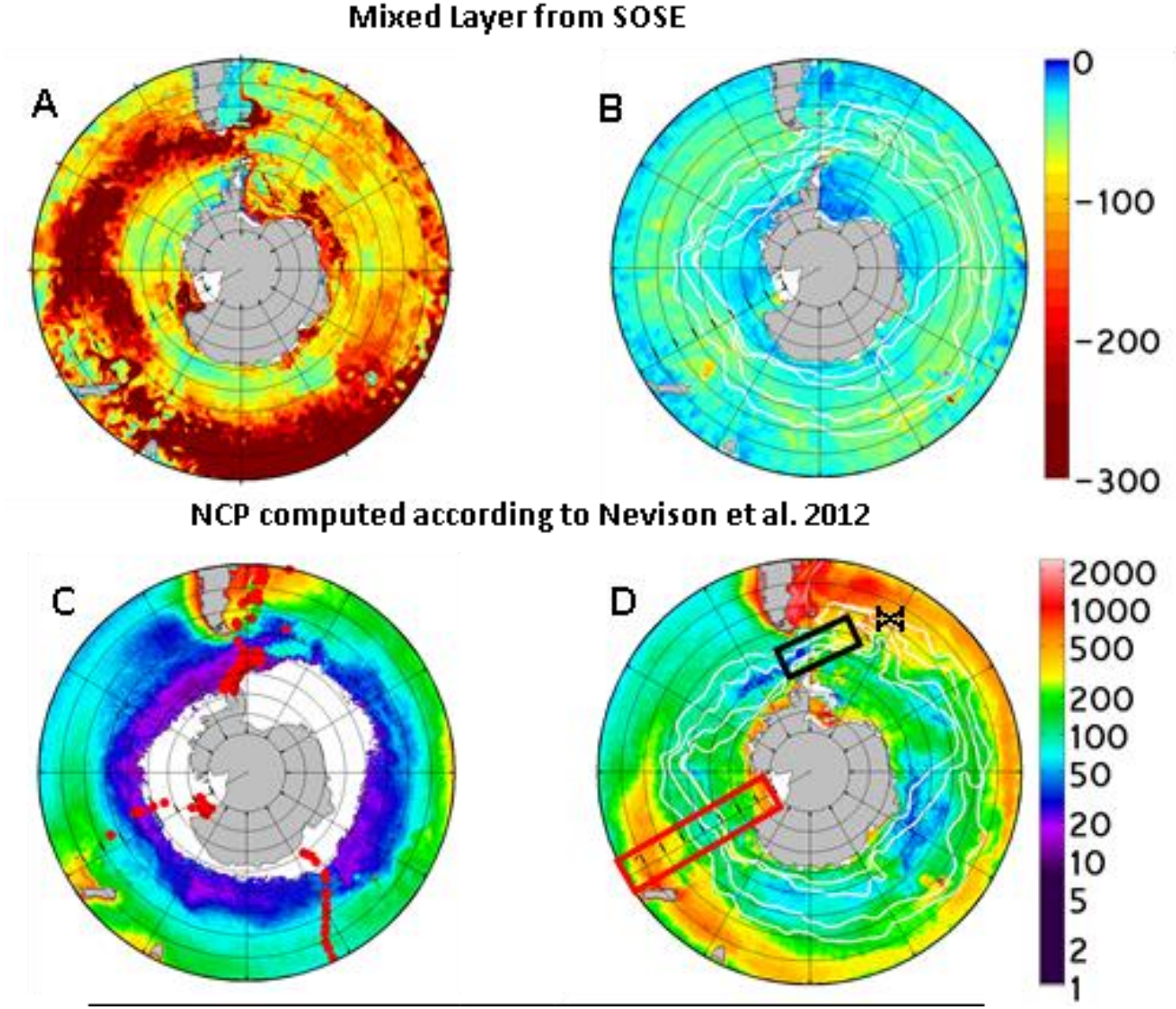


Large (2x) Interannual Variations in Mean S. Ocean NCP From Satellite Forward Model mid-Summer Estimates Ranging From 60-130 mgC m^{-2} day^{-1}

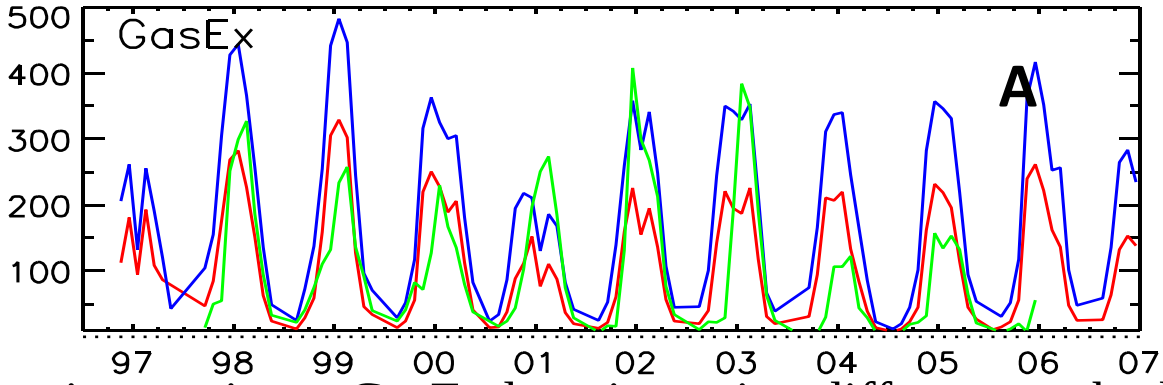
Are these real?? If so what is the cause?
Fe delivery? Clouds? Stratification? Other? All of above?

How can we constrain satellite estimates with independent observations?
How can we separate different mechanisms regulating regional, seasonal and interannual and climate-scale variability in NCP?
How will these mechanisms change with future changes in climate forcing???



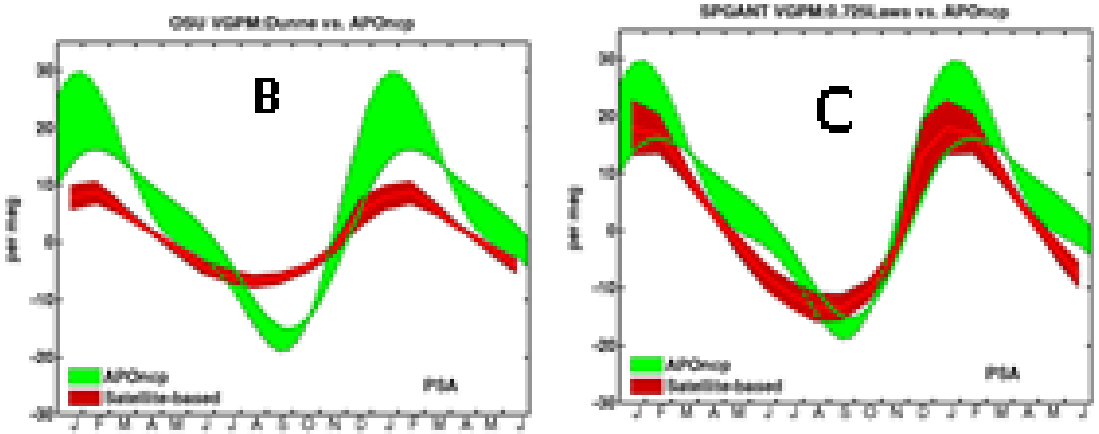

Mixed Layer from SOSE
A
B
0
-100
-200
-300
NCP computed according to Nevison et al. 2012
C
D
2000
1000
500
200
100
50
20
10
5
2
1
September
February

Export Production (NCP)



A. Satellite time-series at GasEx location using different methods.

Forward models remain fraught with uncertainty. Can we constrain them??



Annual cycle climatology of APO-based NCP estimate (green) compared to satellite estimates (red). **B.** Satellite based on standard NASA OC4 into VGPM into standard Laws et al, (2004). **C**. using regional chl, VGPM (Mitchell and Kahru, 2009) and modified Laws to fit Schlitzer (2001). From Nevison et al 2012

NPP, NCP Satellite
From forward models

Conservation of
Mass Constraint

APOncp
Atmospheric Gases
e.g Nevison et al. 2012

$CO_2, O_2, N_2O,$

fixation of C, N
by phytoplankton

grazing

respiration

excretion

Floats - Physical
Biogeochemical
ARGO C-SOBOM
e.g. Alkire et al. 2012

Physical mixing DOC
N,P, Si, Fe

egestion

aggregate
formation

break up

Lateral
advection

Base of euphotic zone

Depth of winter mixing

active
vertical migration

passive
sinking of
POC, PIC

consumption,
repackaging

(zooplankton)

respiration

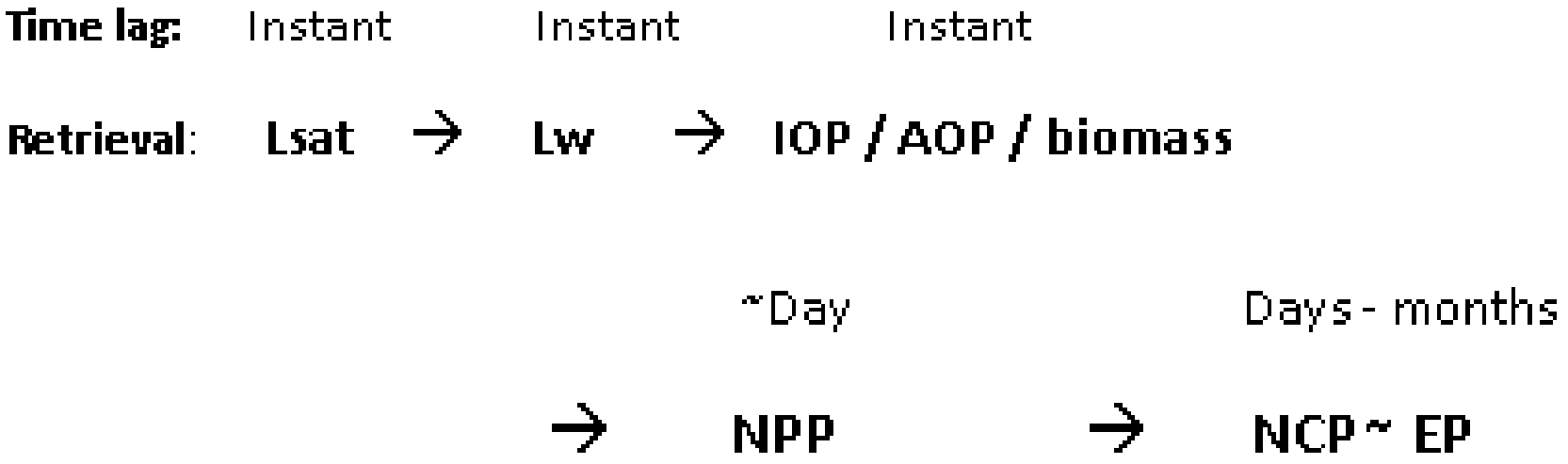
excretion

decomposition

(bacteria)

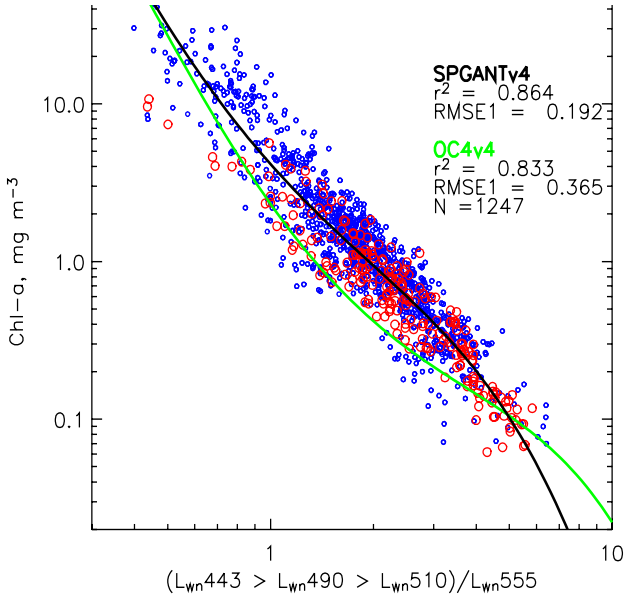
Seabed

Time relationships related to satellite estimates of net community production



Large time-lag between observed optics / biomass/ NPP estimate and NCP estimates are part of the challenge to relate satellite retrievals to the carbon export. However proxies such as atmospheric APO and *in situ* biogeochemical observations (O2, NO3, attenuation) will integrate and can be used as mass constraint of satellite estimates.

Preliminary synthesis and analysis of algorithms and models

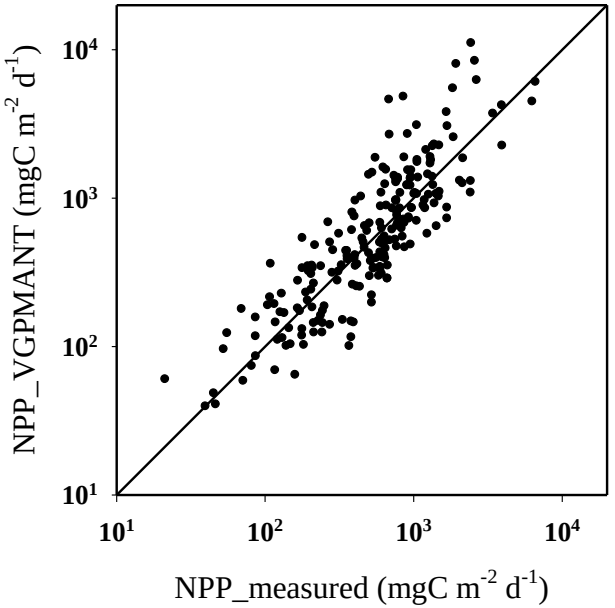


MBR Chlorophyll relationships for S. Ocean compared to standard NASA fit to NOMAD

Green curve = OC4v4 Black curve = SPGANTv4

Red circles = SPG Southern Ocean stations (AMLR, NBP, REV, LMG)

Blue circles = non-SPG Southern Ocean (lon < -55) stations



Modeled vs Measured NPP ; VGPM-ANT

- Synthesis of *in situ* data collected by SPG since 1997 and Saba et al data set
- Reasonable relationship (e.g. typical of NPP comparisons)
- Better fit than standard VGPM or other models tested
- Compounded uncertainty of chla and NPP used as input for NCP satellite models remains a challenge

Concept for Understanding – Intensive Ship Studies

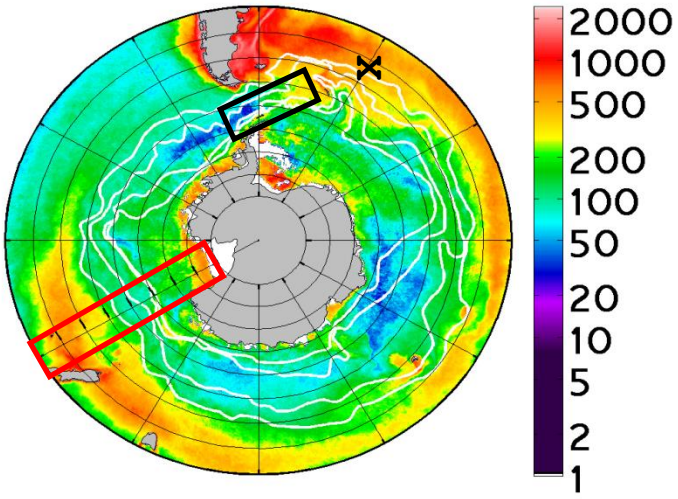
Although physics (salt, temperature) are zonally structu5red, that is not true for chl, NPP, NCP for entire S. Ocean

- 170 W is zonal
- Drake Passage is meridional
- Both regions convenient for USA logistics

Intensive studies to explore two domains with very different gradients

- How do shelf, atmosphere, deep sources of iron vary?
- How does stratification affect light climate?
- How do the plankton communities differ between regions and across gradients?

How does this affect IOP-AOP-BGC relationships



Concepts for constraining estimates of NCP

Independent methods

- Satellite forward models
  - Improved observation methods (e.g. EXPORTS)
  - Data synthesis, analysis and new models
- Ocean inverse models (e.g. Schlitzer 2001)
  - Improved with data synthesis, ARGO, Bio-Argo (SOBOM)
- Atmospheric gases (e.g. Nevison et al. 2012)
  - More stations, strategically located
  - Higher temporal resolution
- Numerical modeling
  - Integrate biogeochemical models to SOSE

Modular Implemenation

- Budget to be scaled, modular,
- More funding more results but not all or nothing

Concepts for constraining estimates of NCP

Extensive buoy observations. SOBOM collaboration. Proposal for Bio-ARGO floats in S. Ocean proposed to NSF by co-Is Sarmiento and Talley. Optics proposed (?) to NASA by co-I Boss

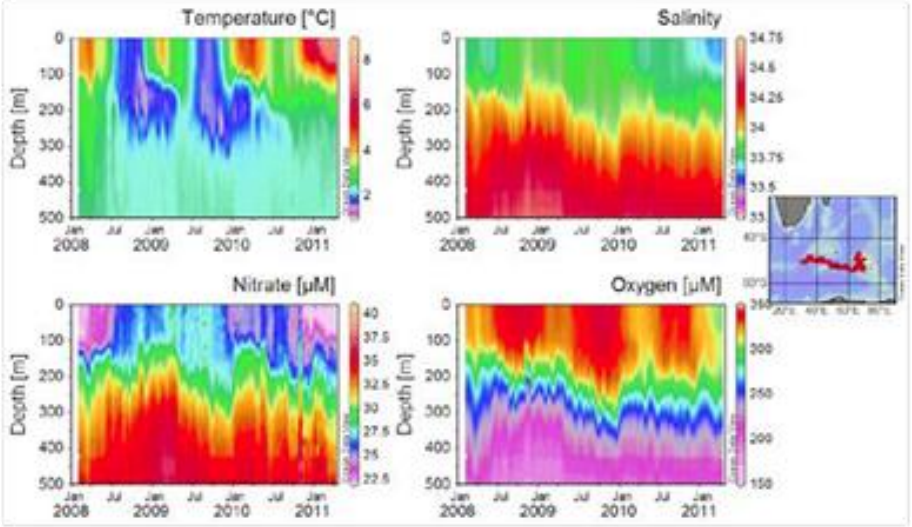


Figure 3. Temperature, salinity, nitrate and oxygen measured from 2/2008 to 3/2011 by float 5146 in the Southern Ocean. Batteries on this first generation profiling float were depleted after 221 vertical profiles. 2nd generation floats are capable of 300+ profiles. This float profiled to 1000 m, but only the upper 500 m of data is shown. (K. Johnson and S. Riser, unpub.data).

Data courtesy K. Johnson and S. Riser

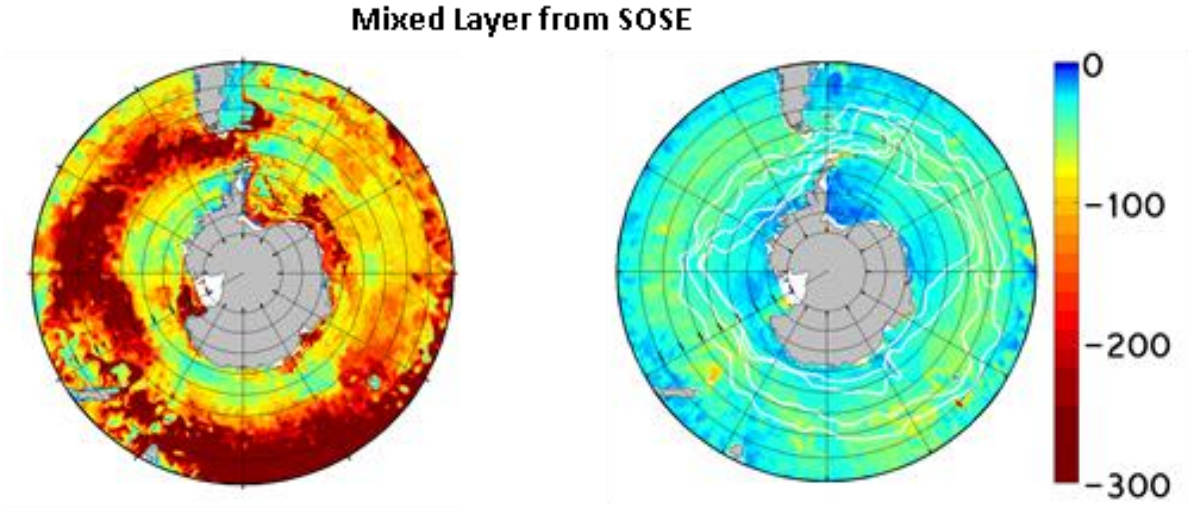
Concepts for constraining estimates of NCP

Extensive Atmospheric Gas Observations from international automated and flask sample collaborations essential. Need to expand the time-space scales of this network. Co-Is Keeling and Nevison will coordinate this element.

GASLAB, Macquarie Island, operated by CSIRO, provides comprehensive and precise analysis of the major trace gases in air samples which are collected from the Southern Ocean atmosphere. These data and others were used by us in Nevison et al. (2012)

Concepts for constraining estimates of NCP

Numerical modeling including detailed biogeochemical models interfaced to SOSE. Co-Is Talley, Barbeau and Mitchell to collaborate with modelers to scope plans to link iron, photosynthesis, l light and physics



Summary of Overall Plan: Improved models of NCP and Conservation of Mass Constraints on Satellite Forward Models

Satellites
- Synthesis of existing data
- Collection of new data
- Improved forward models

Intensive Field Campaign with ships
- Build upon EXPORTS framework
- NASA, NSF, NOAA, International
- Essential data to improve forward models

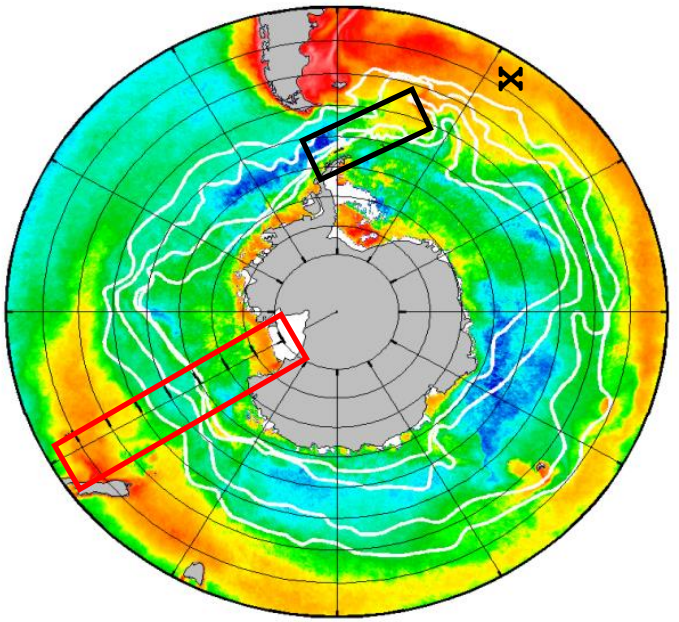
Extensive Field Campaign – Bio-ARGO
- SOBOM

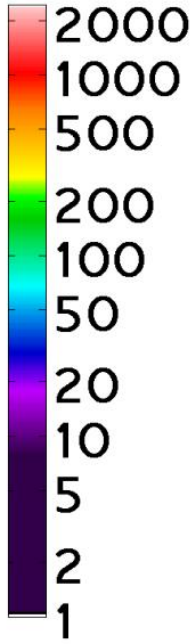
Extensive Atmospheric gases
- US and international
- Expand time and space scales

Extensive Models
- Atmosphere and Ocean transport

Time Line

May 2013	Proposal submitted
2014	
February	Funded by NASA February 2014
March	Funds allocated to UCSD
March	SO EOV International workshop
April	UCSD establishes sub-awards
May	OCRT
May-Sept	Synthesis, analysis; Weekly Telecons with co-Is; Visits with US and International agencies; meetings with major field programs; Drafts of sub-elements
22-26 Sep	Workshop at Scripps
December	AGU Town Hall Meeting
2015	Continue Coordination with agencies, field programs
February	Ocean Sciences Town Hall Meeting
April	Detailed comments by co-Is, reviewers, managers
May	Integrate comments from March 2015 review
June	Robust draft for community comment, revisions
July	Final report submitted to NASA





Thank you!