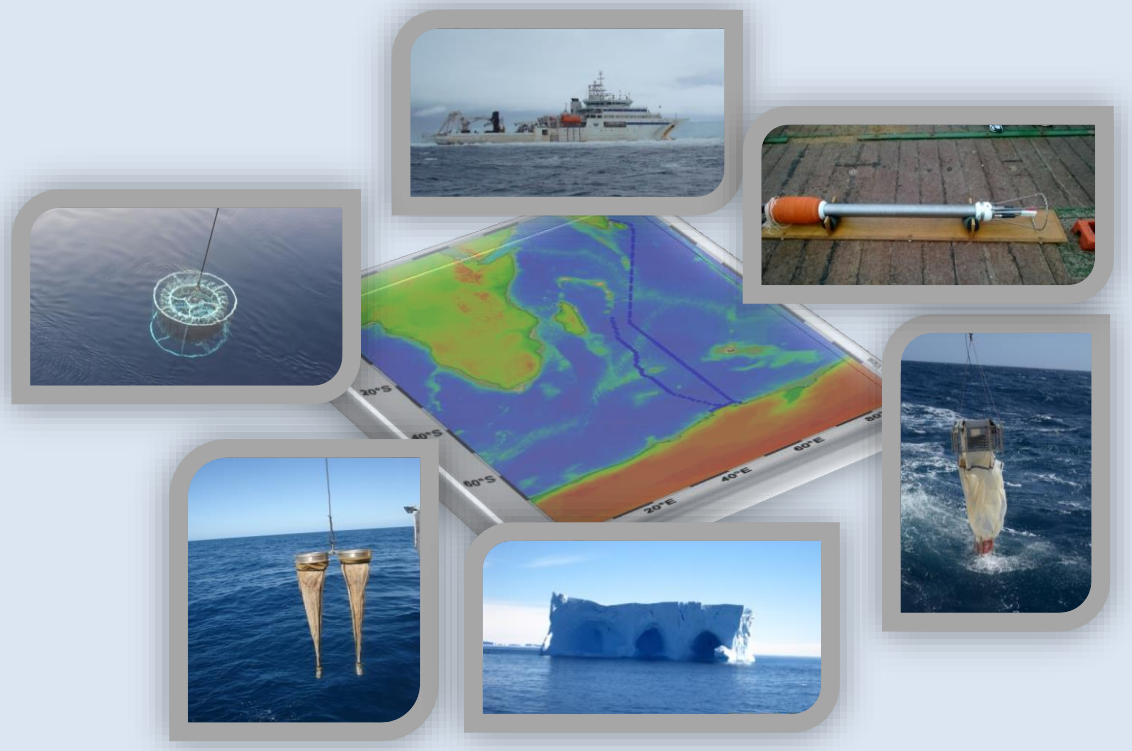
Role of Southern Ocean in Global Climate Change: Perspectives from Indian Southern Ocean Expeditions

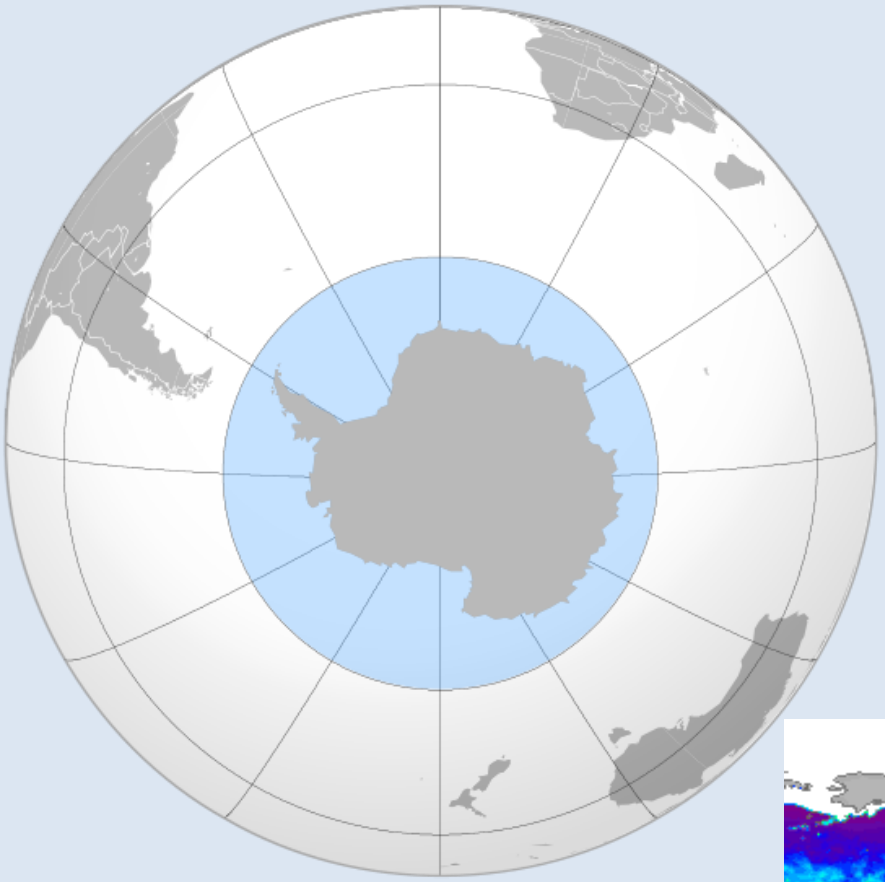


Sarat C. Tripathy

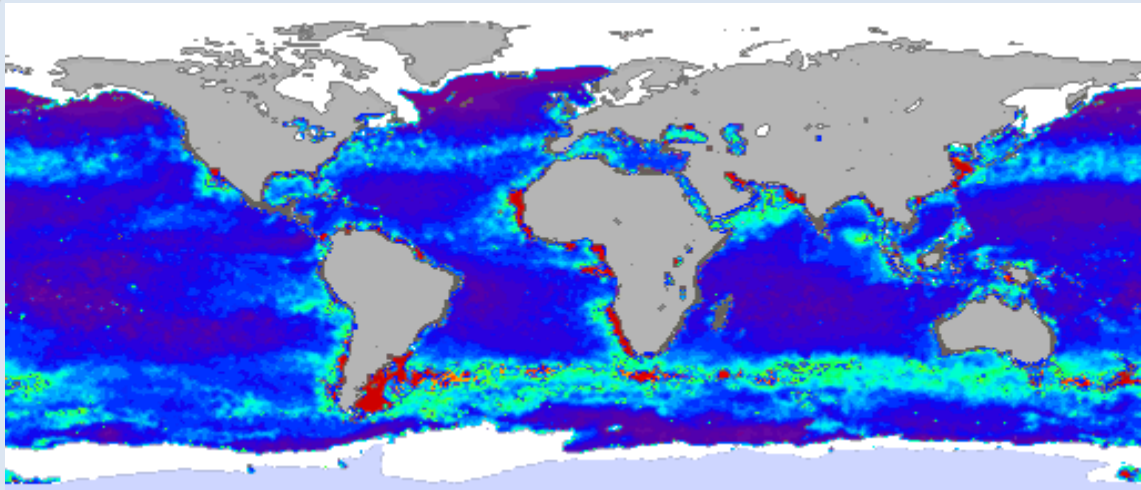
Scientist-E, Ocean Sciences Group, ESSO-NCAOR, Goa

4th conference on SaGHAA, Nov. 30 - Dec. 1, 2017, JNU, New Delhi

Where is Southern Ocean (SO)?

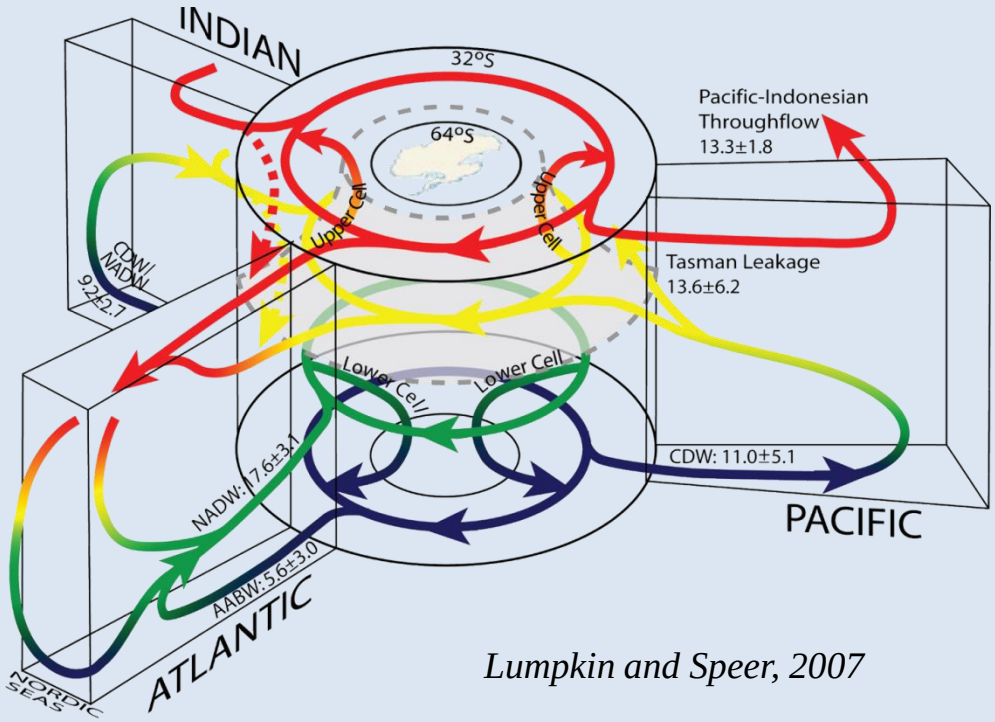


Antarctic Ocean: Inseparable part of Antarctic Ecosystem



Source: Wikipedia

Why Study Southern Ocean?

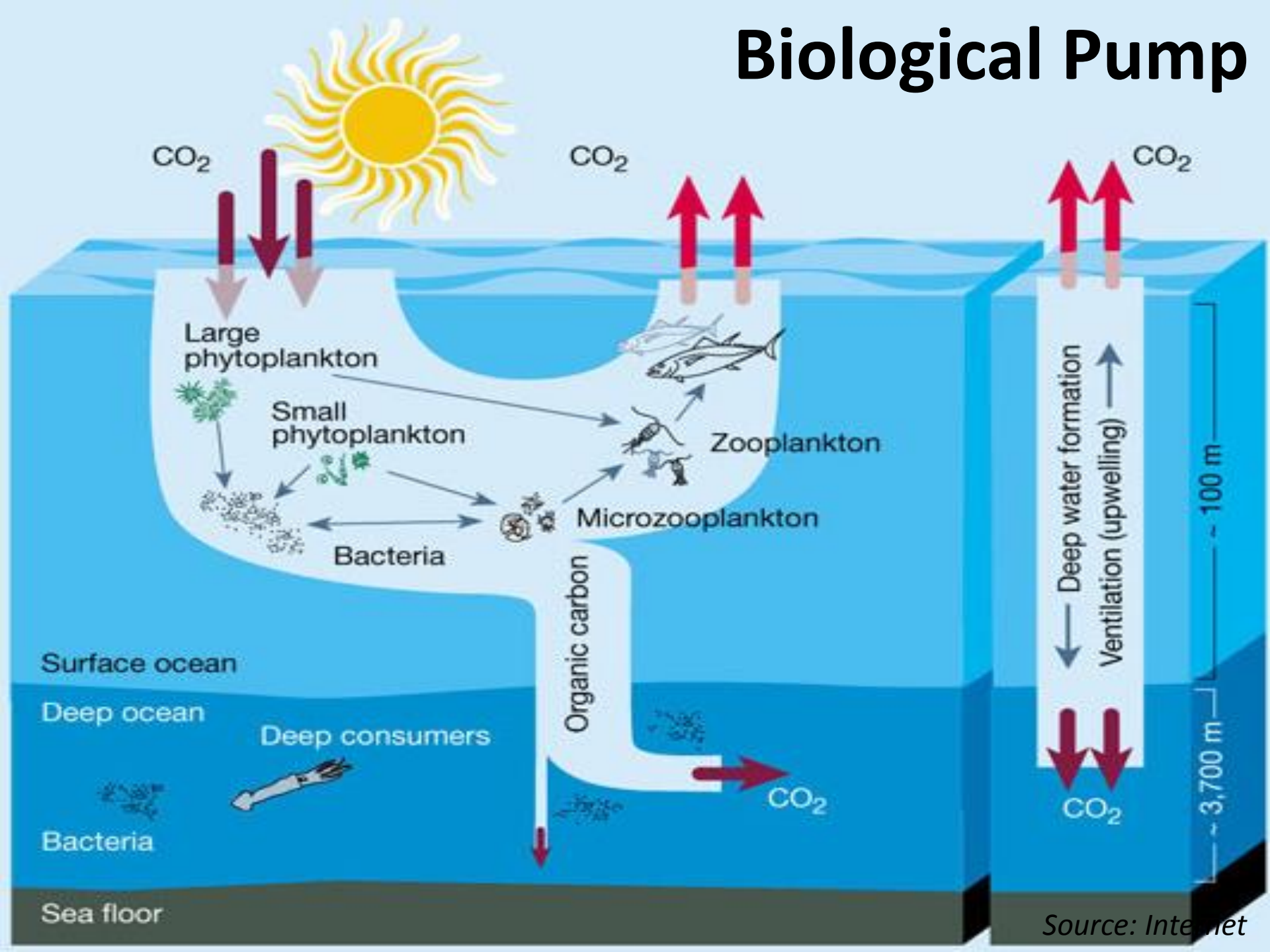


Lumpkin and Speer, 2007

- **Connects all** ocean basins
- Site of key **water mass formation**
- Drives global **ocean circulation**
- Significant drawdown of CO_2
- Affects global **sea level**
- HNLC region in the world ocean. (Nutrients are underutilised)
- SO Nutrient supply accounts for 3/4 of PP north of 30°S

- **Plays a central role** in the global carbon cycle and biological productivity, and in the response of these to **climate change**.
- **25-30%** of total **anthropogenic CO_2** uptake by the oceans takes place here mainly via **primary production or "Biological Pump"**.

Biological Pump

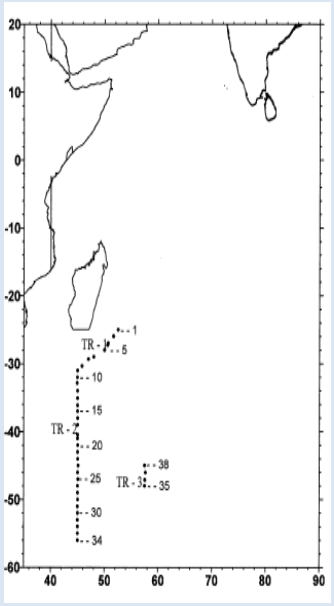


Source: Internet

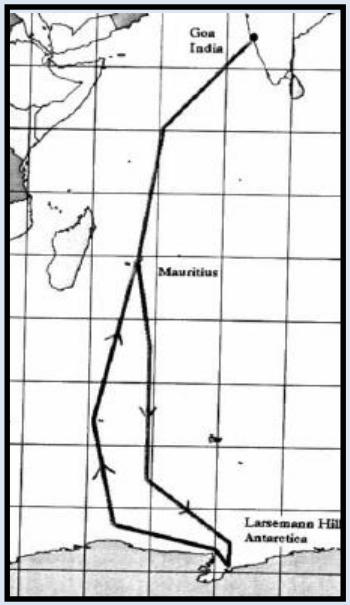
Basis for SO Expeditions

- Polar Regions - identified as the areas where signatures of global changes are more pronounced.
- Improved understanding of Southern Ocean processes, global climate, biogeochemical cycles and marine productivity.
- Southern Ocean is known to play a role in regulating the Indian Ocean circulation and Global circulation.
- Availability of long-term sea truth data from the Southern Ocean is imperative in understanding the various processes affecting the climate so as to evolve suitable mitigating measures.
- India being the largest Indian Ocean Rim country, has taken initiative for addressing these issues.
- MoES has taken up a long-term monitoring and data collection program on atmospheric and ocean processes in the Indian sector of Southern Ocean with ESSO-NCAOR as the nodal agency.

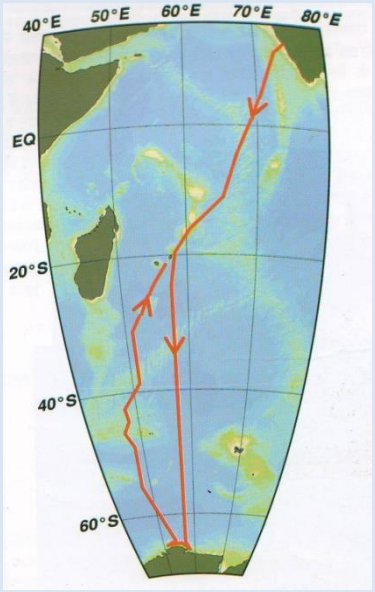
CRUISE TRACK: So far, 09 expeditions have been carried out in the Indian Sector of SO



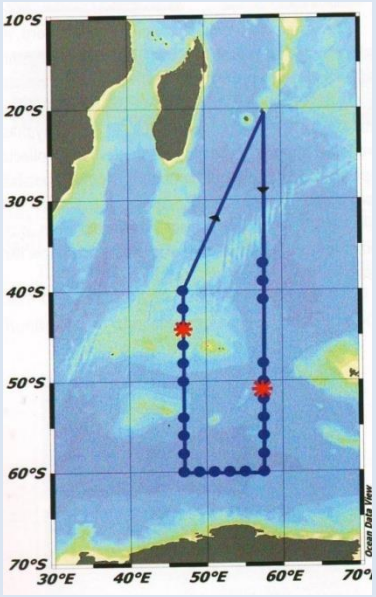
1st:2004



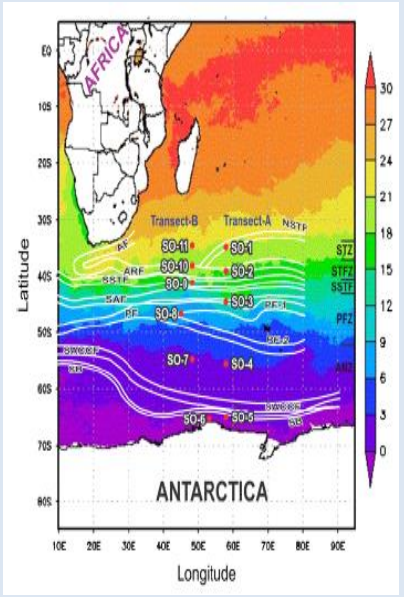
2nd:2006



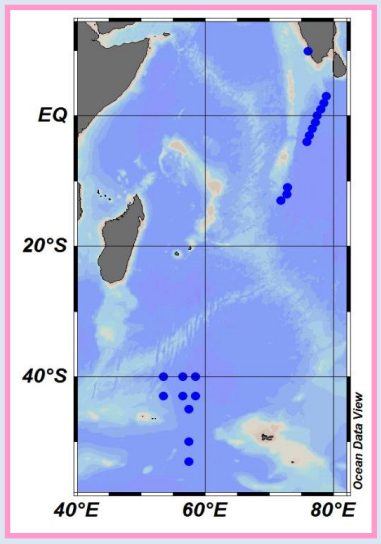
3rd:2009



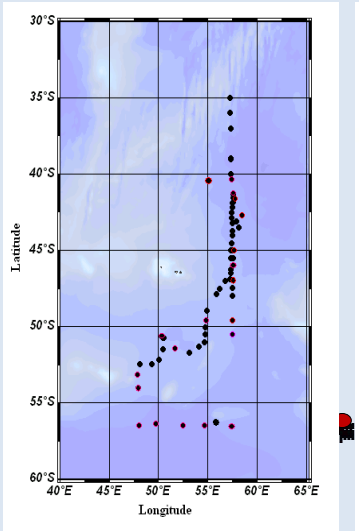
4th:2010



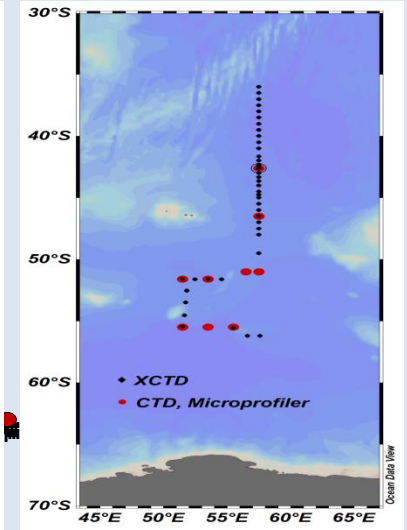
5th:2011



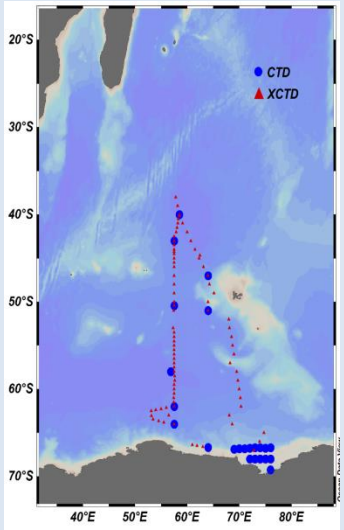
6th:2012



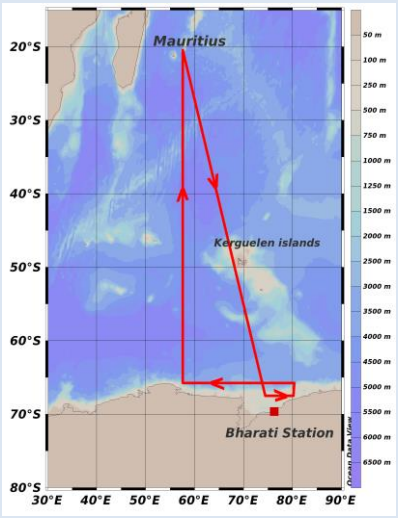
7th:2013



8th:2015



9th:2017



10th:2017-18

NCAOR: Nodal agency

Broad Objective:

"Role and response of the Southern Ocean (SO) to the regional and global climate variability"

Indan Collaborative Institutions (>15):

- NCAOR, Goa
- NIO, Goa & Kochi
- Goa University, Goa
- CAS, Annamalai University
- CMLRE, Kochi
- CIFT, Kochi
- IISc, Bangalore
- BIT, Ranchi
- CMFRI, Kochi
- PRL and SAC, Ahmedabad
- ICMAM, Chennai
- IITM, Pune
- NIOT, Chennai
- SPL, Trivandrum
- IMD, Delhi

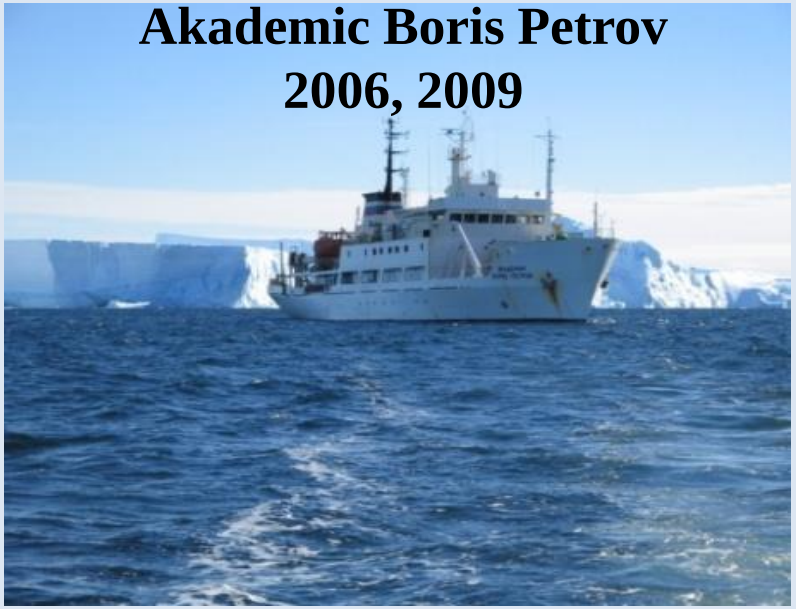
Hydrodynamics, Biogeochemistry, Atmospheric studies, Microbiology, Paleoclimatology in the Indian sector of SO

(Brazil, France, UK, ??)

Research Platforms used for the Expeditions

ORV Sagar Kanya
2004

Akademic Boris Petrov
2006, 2009



ORV Sagar Nidhi
2010, 2011, 2012, 2013, 2015

MV S.A. Agulhas
2017, 2018

Ongoing Research Activities

Measurements carried out:

1. CTD, XCTD, Microturbulence & currents
2. Plankton/productivity studies (phytoplankton, zooplankton)
3. Microbial processes: uptake, respiration etc.
4. Marine mammals, squid diversity and food habits
5. DIC, Nutrient dynamics, OC inventory
6. Sediment sampling (Palaeoclimate)
7. Aerosol & Black carbon measurements
8. Hyperspectral radiometry, a_{ph}, a_d, a_{CDOM}

...rried out

Aerosols & Black carbon

Microbial uptake rates, diversity, microbiology

Eddies, stratification & heat fluxes

Sub-surface Mooring

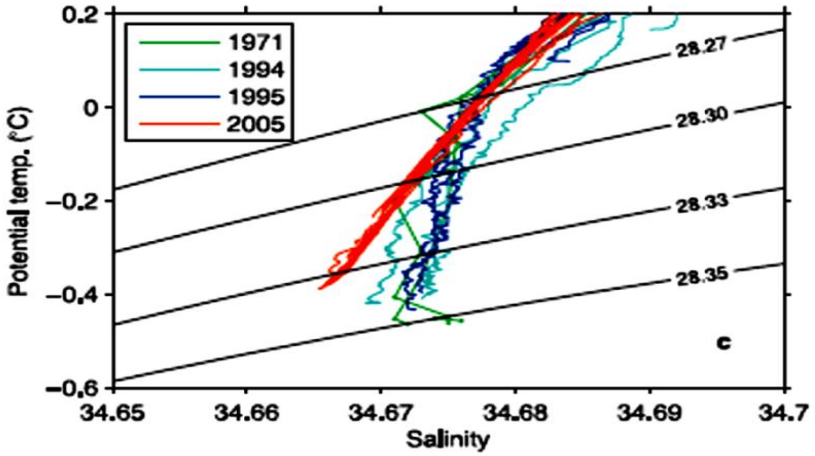
The first ever sub-surface sediment trap mooring, by Indian initiatives was deployed at **40°S & 57.5°E** during the 9th SOE and the same will be retrieved and re-deployed this year.

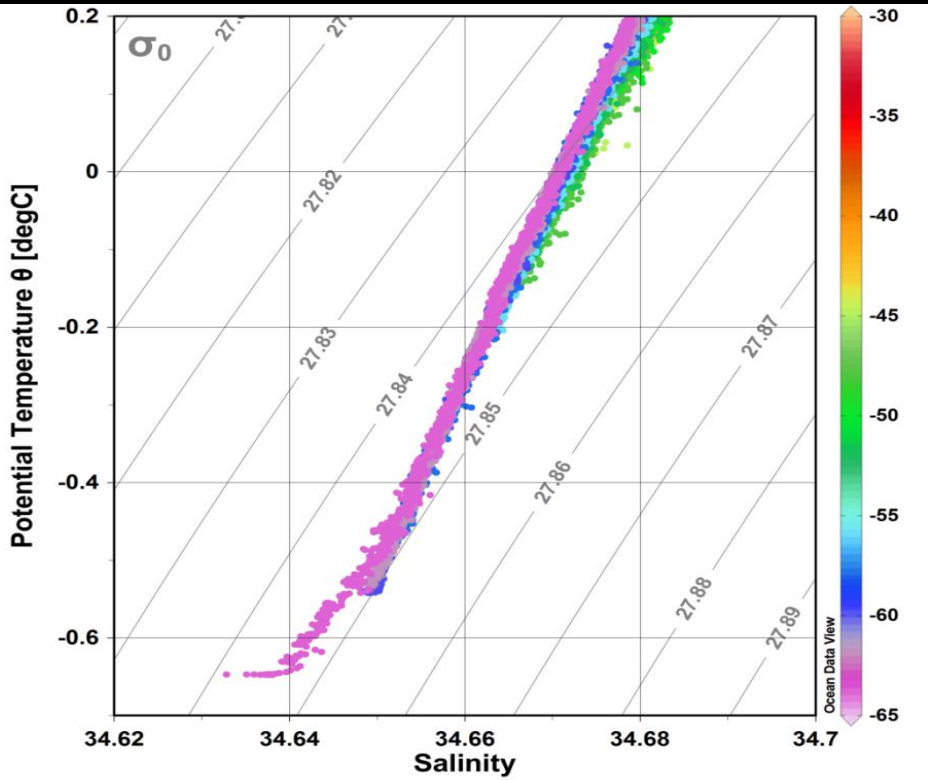
- More than 60 research papers published in the national and international journals

- Special Issues: Current Science [2010]
  Deep-Sea Research II [2015]

Scientific Highlights

Freshening of Antarctic Bottom Water





Salinity of ABW decreased from 34.675 in 1971 to 34.672 in 1990 and further to 34.665 in 2005 (*Rintoul, 2007*).

***In-situ* observation during 2010 in the nearby area shows salinity ~34.635**

Decrease of salinity:

~ 0.003 from 1970's to 1990's

~ 0.01 from 90's to 2005

~ 0.03 from 2005 to 2010

Anilkumar et al, DSR II 2015

The influence of air–sea–ice interactions on an anomalous phytoplankton bloom in the Indian Ocean sector of the Antarctic Zone of the Southern Ocean during the austral summer, 2011

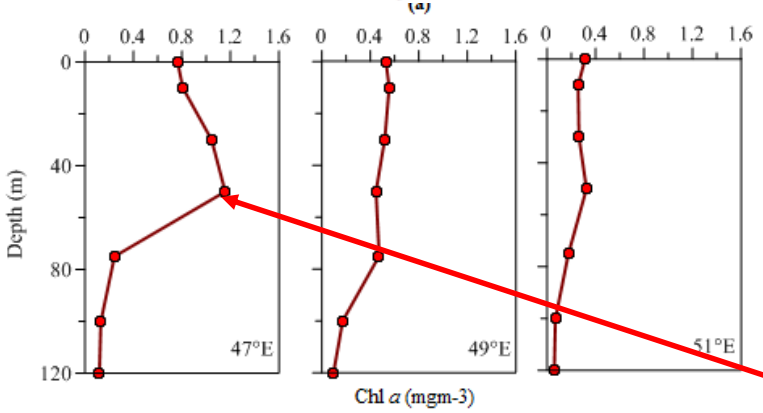
ELSEVIER

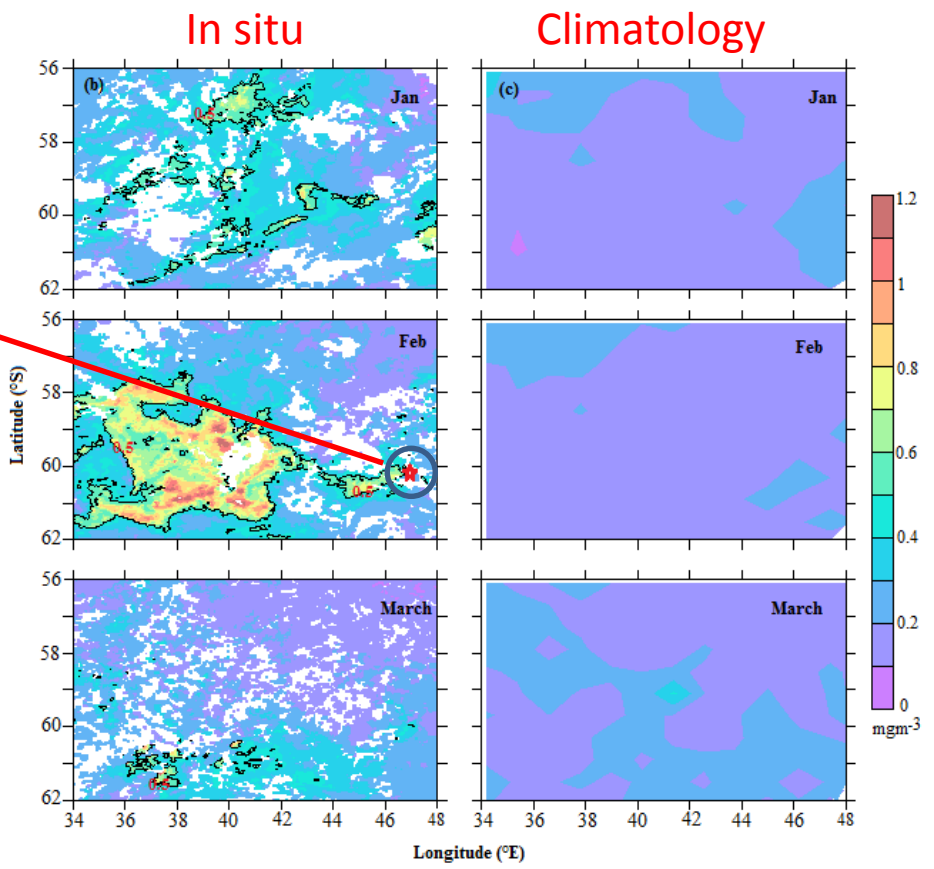
POLAR SCIENCE

s.elsevier.com/polar/

P. Sabu*, N. Anilkumar, Jenson V. George, Racheal Chacko, S.C. Tripathy, C.T. Achuthankutty

National Centre for Antarctic and Ocean Research, Ministry of Earth Sciences, Headland Sada, Vasco-da-Gama, Goa 403804, India

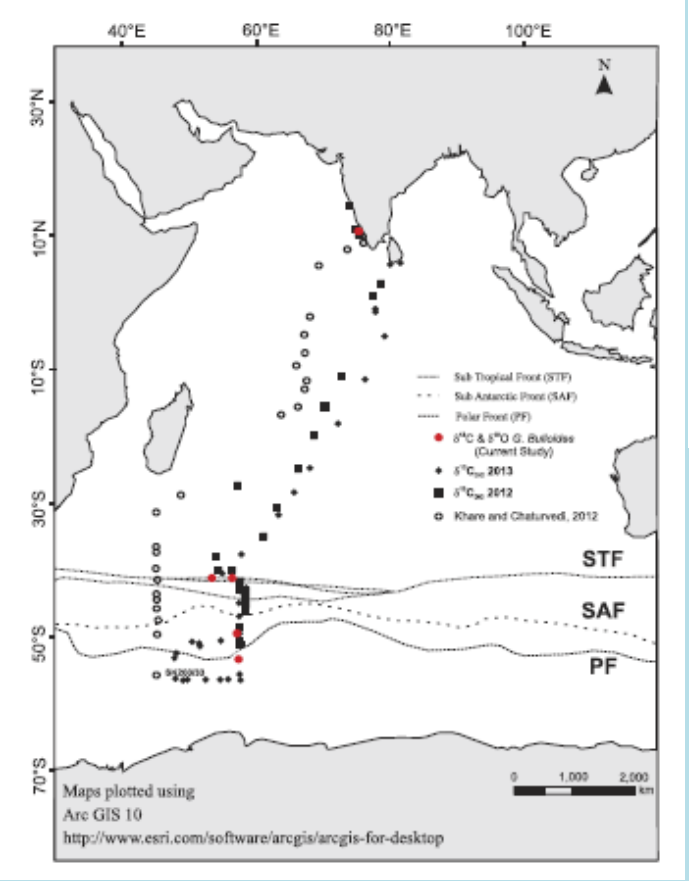




The **enhanced Chl a (phytoplankton bloom)** observed in the study region likely resulted from the influx of **nutrient-laden freshwater** derived from **melting sea ice**.

A **positive SAM** (with a resultant northward horizontal advection) and an **intense La Nina** during 2010-2011 are possible reasons for the **high sea-ice concentrations**.

Sabu et al., 2014



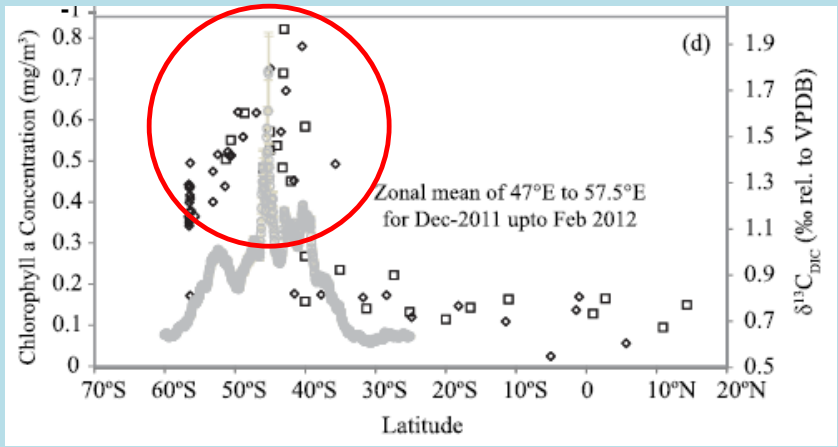
SCIENTIFIC REPORTS

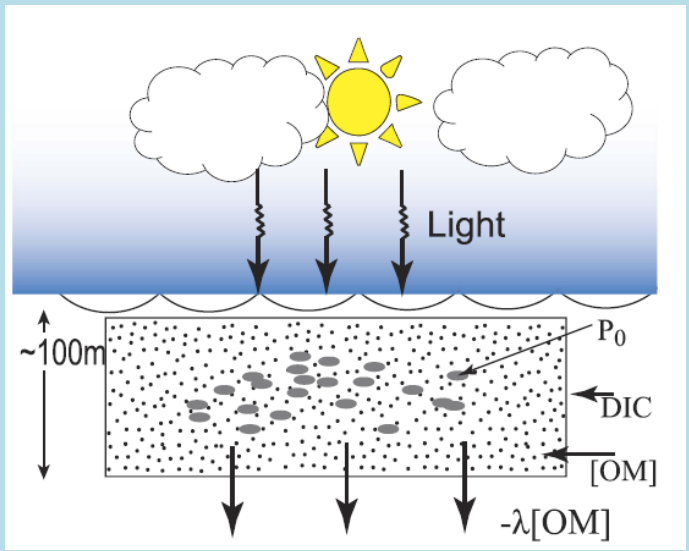
OPEN

Received: 05 October 2015
Accepted: 14 January 2016
Published: 23 February 2016

Isotopic disequilibrium in *Globigerina bulloides* and carbon isotope response to productivity increase in Southern Ocean

K. Prasanna[1], Prosenjit Ghosh[1,2], S. K. Bhattacharya[1], K. Mohan[3] & N. Anilkumar[4]



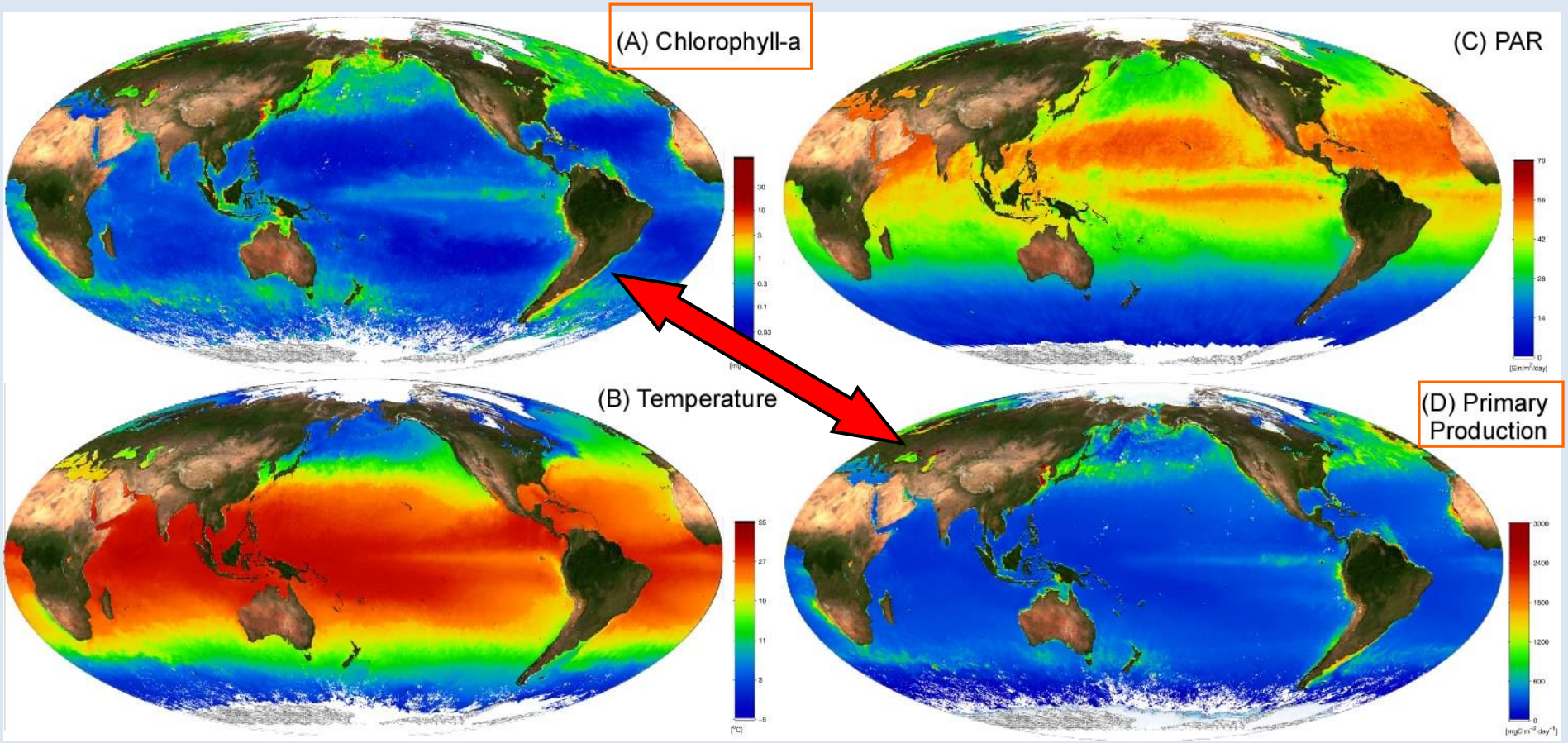


From 40° S to 55° S the measured $\delta^{18}O$ and $\delta^{13}C$ values are higher than the expected values by ~2‰ and ~1‰ respectively could be due to a 'vital effect' or a higher calcification rate.

An **increase in the $\delta^{13}C$ (DIC)** value is observed between **35° S and~ 60° S**, with a peak at~ 42° S, is attributed to the **increased organic matter production** and associated removal.

Prasanna et al., 2016

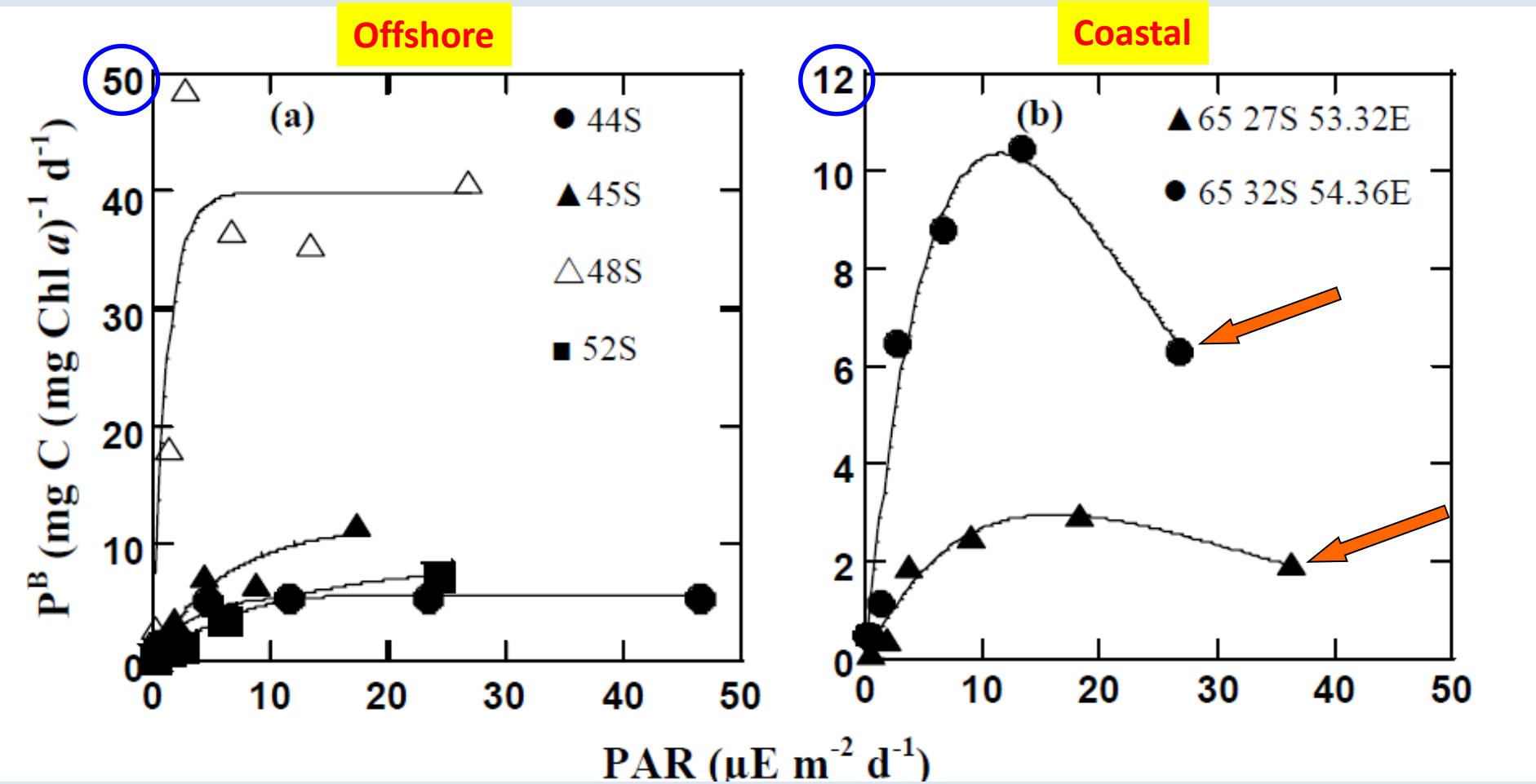
High Biomass is High Productivity!!



Courtesy: HyARC, Nagoya Univ., Japan

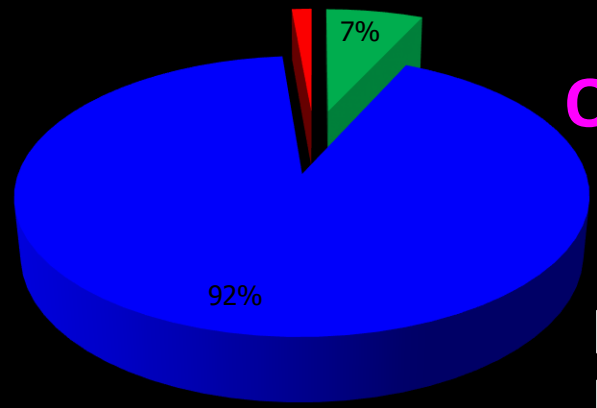
Chl *a*-specific PP (P^B) vs. PAR

P^B is an indicator of phytoplankton physiological adaptation to environmental factors

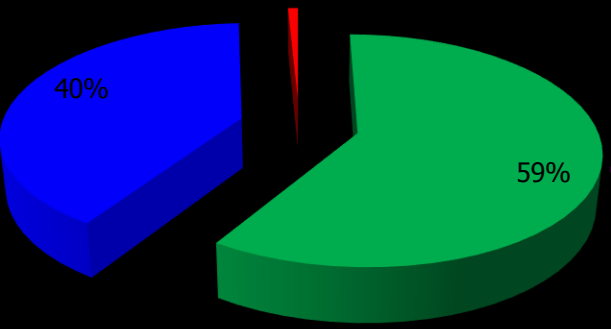


Tripathy et al., 2014

Diagnostic Pigments measured by HPLC



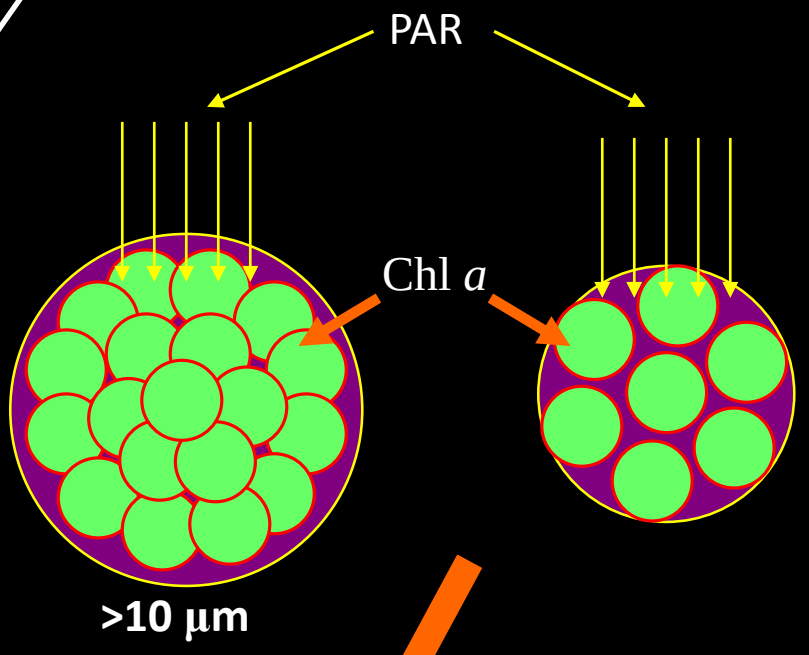
Offshore



Coastal

Diatom DP
Flagellates DP
Prokaryotes DP

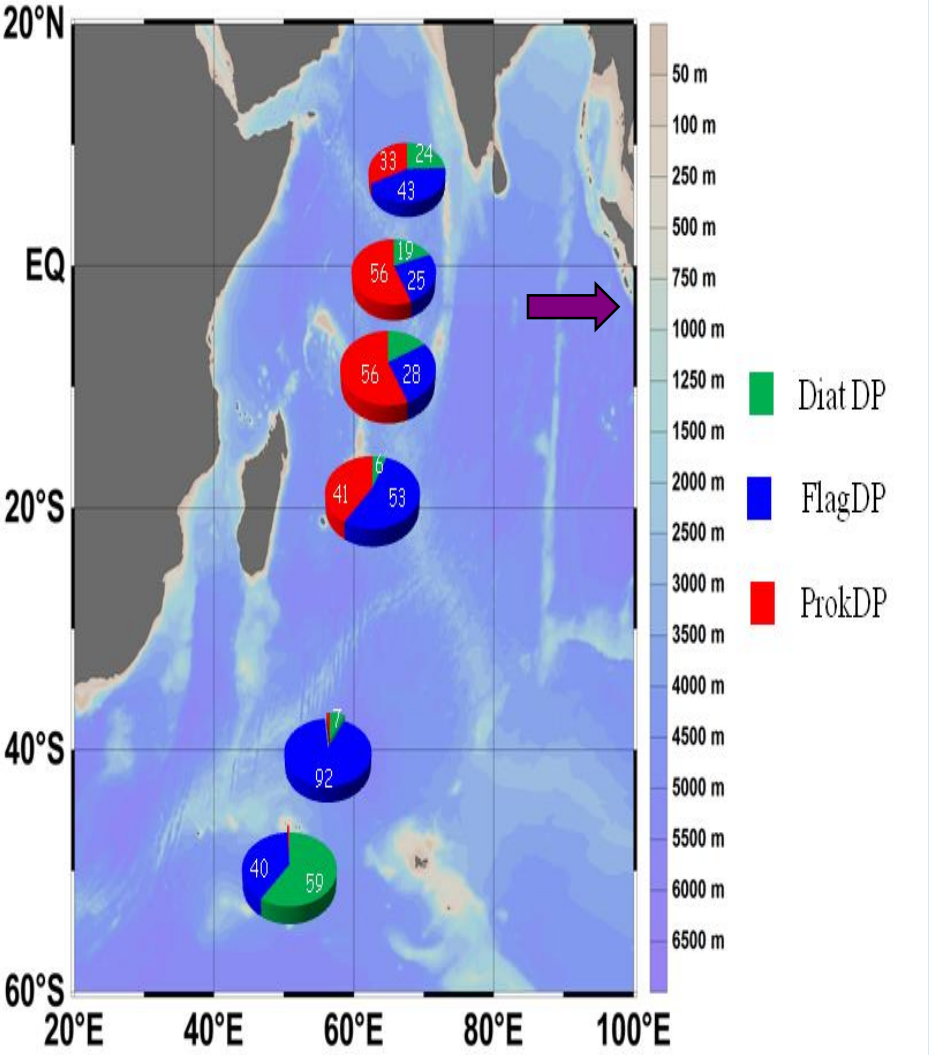
Package Effect



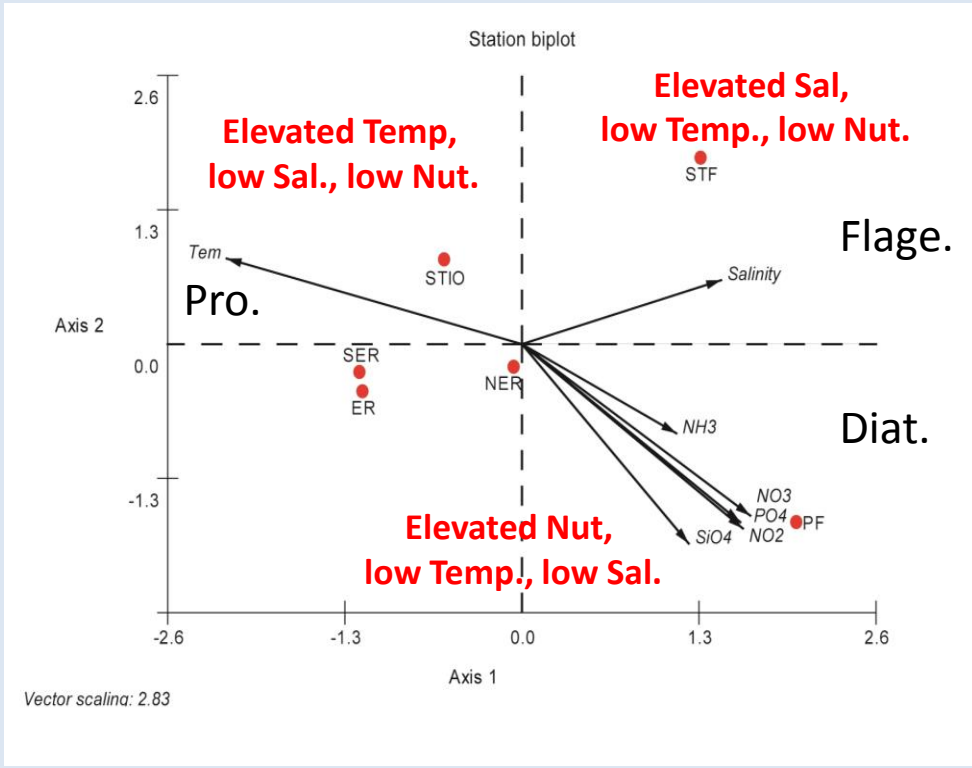
In general, when Chl a increases, cell size also increases

Cell size increases ---- packaging increases ---- absorption efficiency decreases ----- assimilation number (P^B) decreases

Controlling factors for phytoplankton community structure

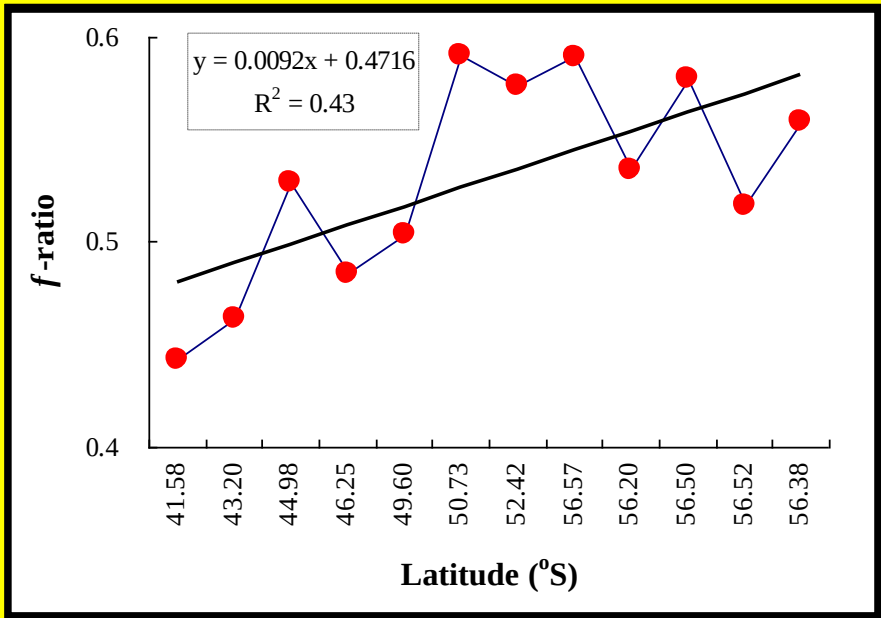


Environmental Parameters Vs. Regions

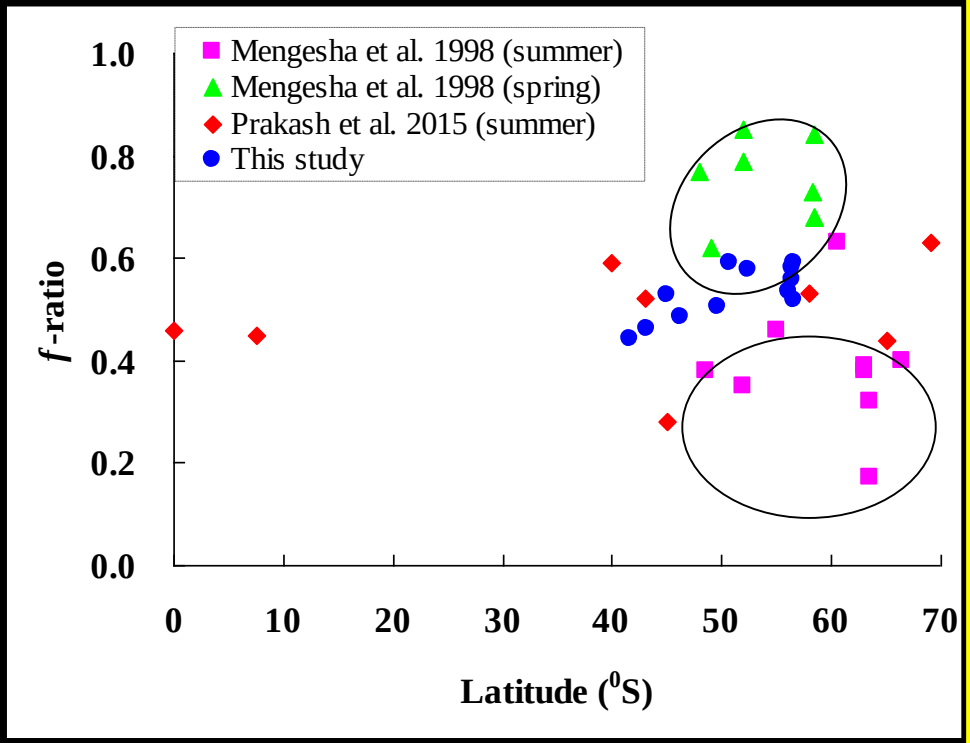


Naik et al. (Under prep.)

Variation in *f*-ratio:



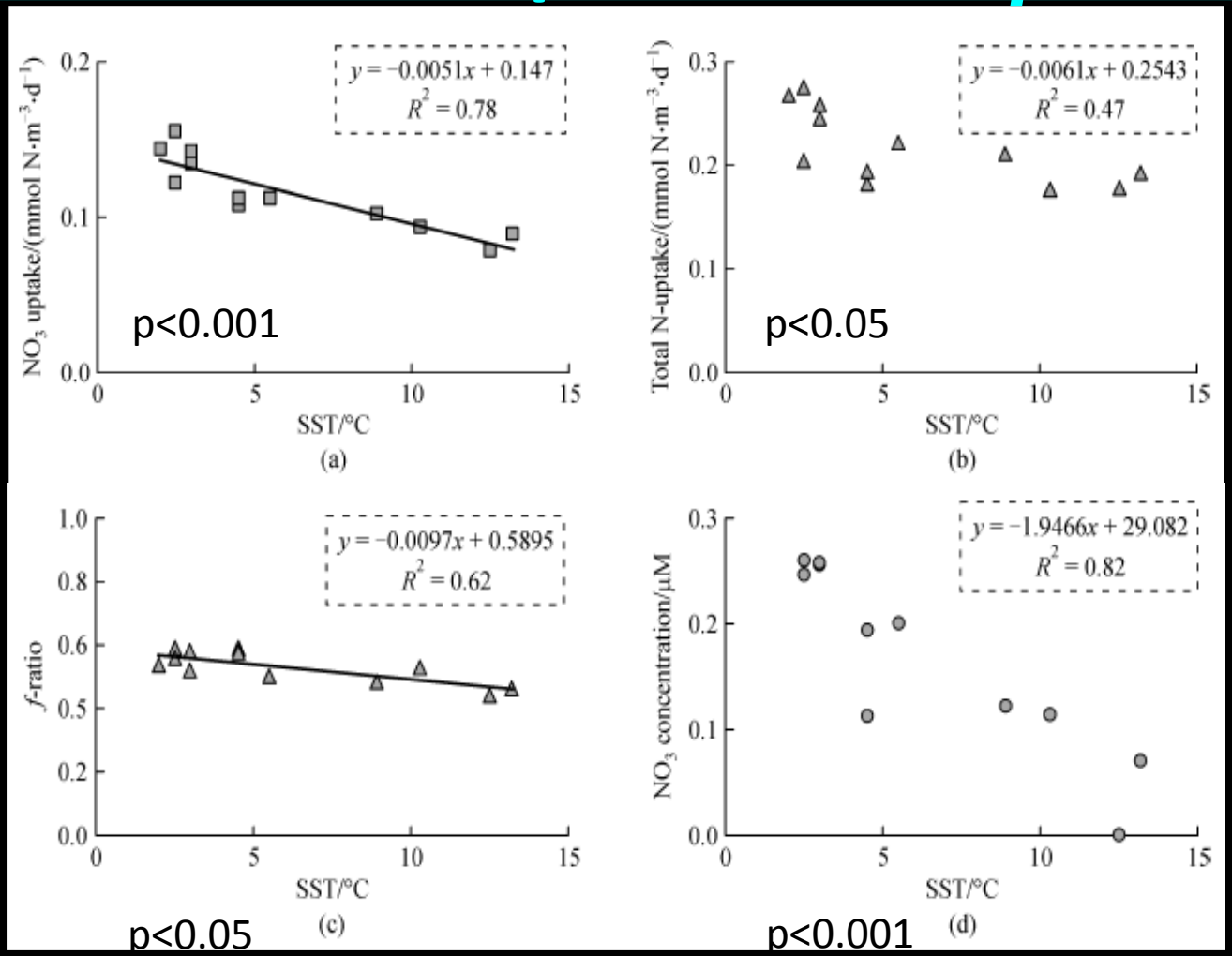
- varied from 0.44-0.59 (avg. 0.53) & increased with latitude (-ve SST)
- potentially ~equal contribution of NP (53%)and RP (47%)



- higher *f*-ratio at PF region: supply of micronutrients (Fe) from meltwater
- NO_3 limitation at STF: slightly low *f*-ratio

Tripathy et al., 2017

Effect of SST on N-uptake rate & *f*-ratio:



N-uptake

***f*-ratio**

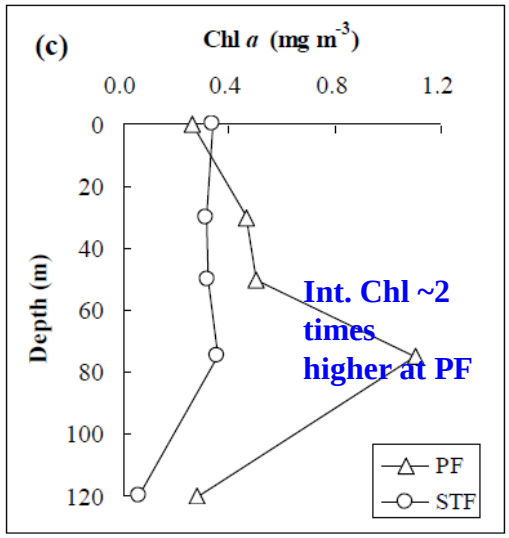
NO_3 conc.

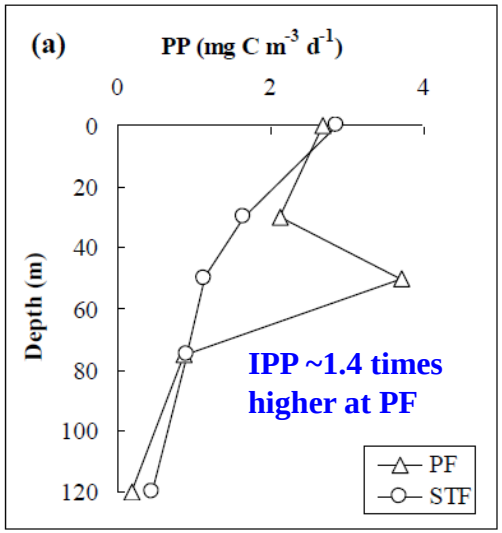
- Export production can reach up to **61%** in conducive environment
- Moderately **high avg. *f*-ratio (0.53)** re-emphasizes the role of SO in global ocean-atm. **C-balance** despite its **HNLC** status.

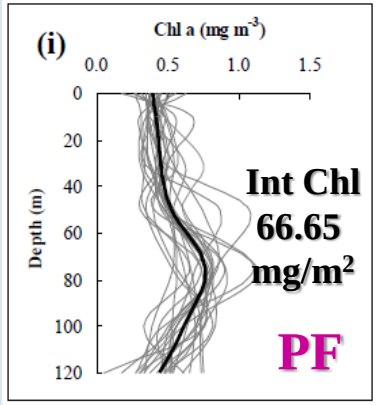
Deep chlorophyll maximum and primary productivity in Indian Ocean sector of the Southern Ocean: Case study in the Subtropical and Polar Front during austral summer 2011

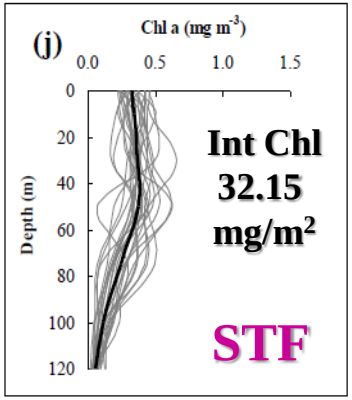
S.C. Tripathy [a,*], S. Pavithran [a], P. Sabu [a], H.U.K. Pillai [b], D.R.G. Dessai [a], N. Anilkumar [a]

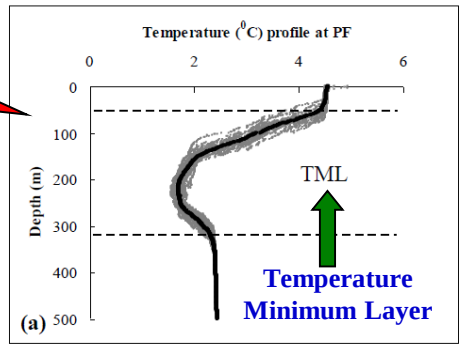
[a] National Centre for Antarctic and Ocean Research, Earth System Science Organization, Ministry of Earth Sciences, Vasco-Da-Gama, Goa 403804, India
[b] Centre for Marine Living Resources and Ecology, Earth System Science Organization, Ministry of Earth Sciences, P.B. no. 5415, Kochi 682037, India











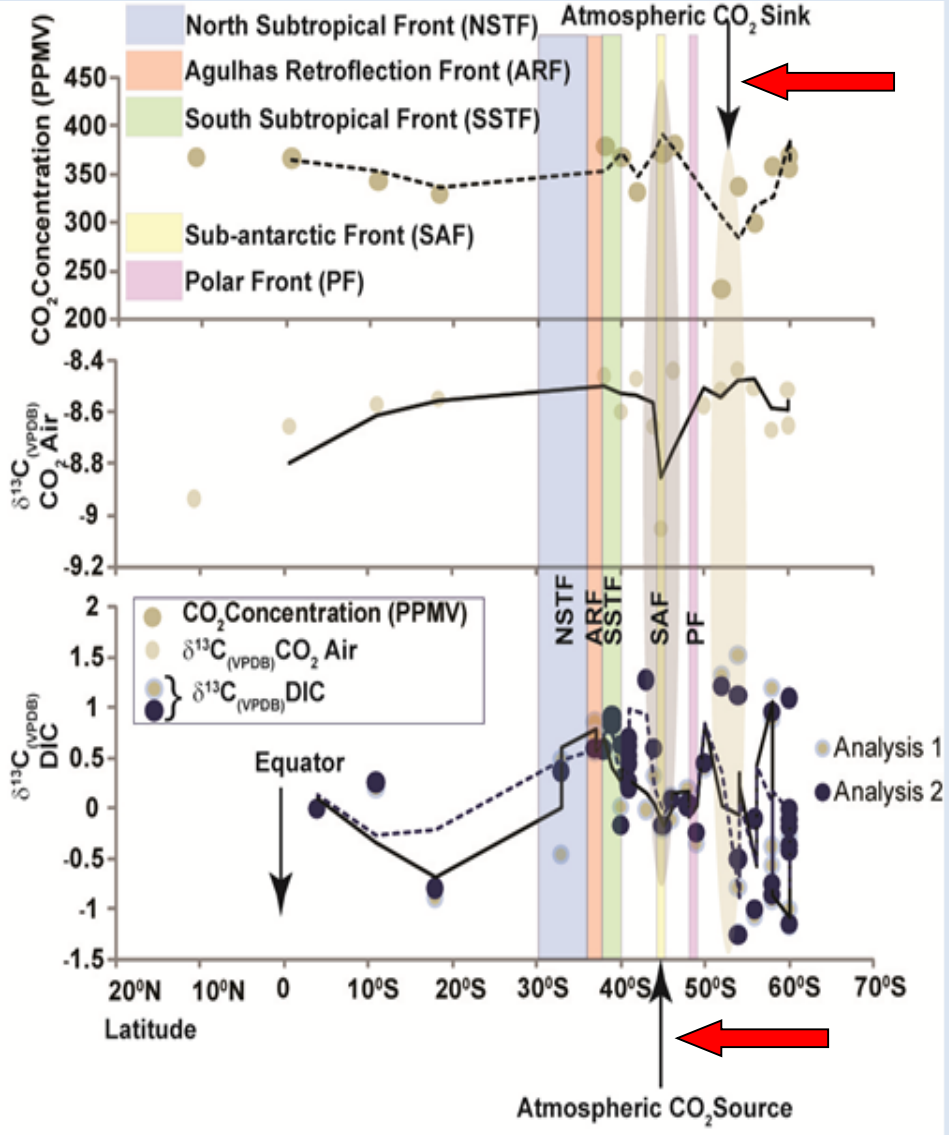
- **DCM** observed at PF (~75 m) was **more prominent** than that of STF.
- Chl *a* at DCM was much higher than in the MLD suggesting that the limiting nutrient (presumably iron) was in higher conc. at DCM, which lied within the TML.
- The mismatch in PP_{max} and DCM depth could be due to the interactive effects of light and nutrient limitation on phytoplankton growth.

Tripathy et al., 2015, DSR II

Stable isotopic signature of Southern Ocean deep water CO_2 ventilation

K. Prasanna [a], Prosenjit Ghosh [a,b,*], N. Anil Kumar [c]

- A zone of CO_2 Sink has been identified near 52° S (**PF**)
- A zone of CO_2 ventilation has been identified near 45° S (**SAF**: *Degeneration of DIC in warm water*)
- Productivity being the main driving force for CO_2 Sinking in southern ocean



Prasanna et al., 2015, DSR II

Summary

Signatures of global changes in climate can be more pronounced/well reflected in the SO processes and distribution of organisms inhabiting it. Hence we need to monitor and understand these processes time to time so as to predict future climate change scenarios.


Thank You for listening!