Net Community Production in the northern Indian Ocean

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Outline

How important NCP in the NW Indian Ocean

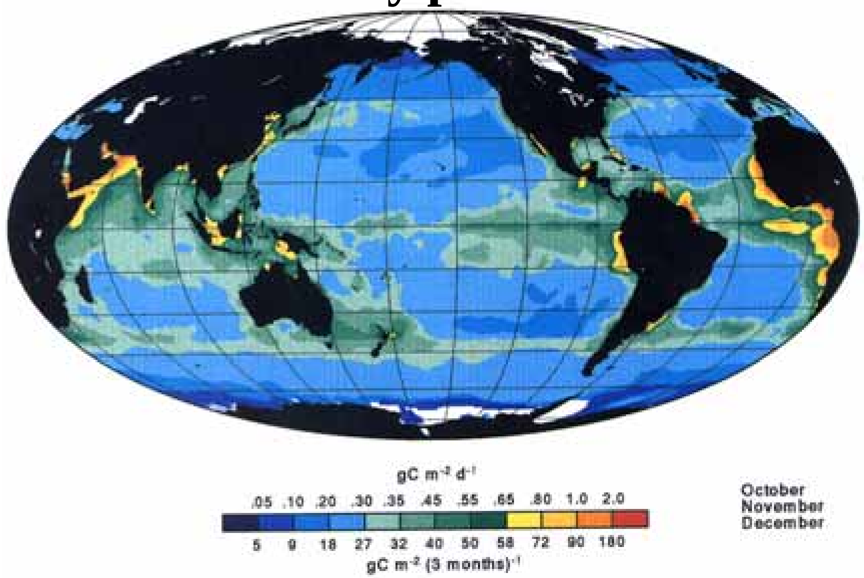
Regional Biogeochemistry versus NCP

Estimation of NCP from models

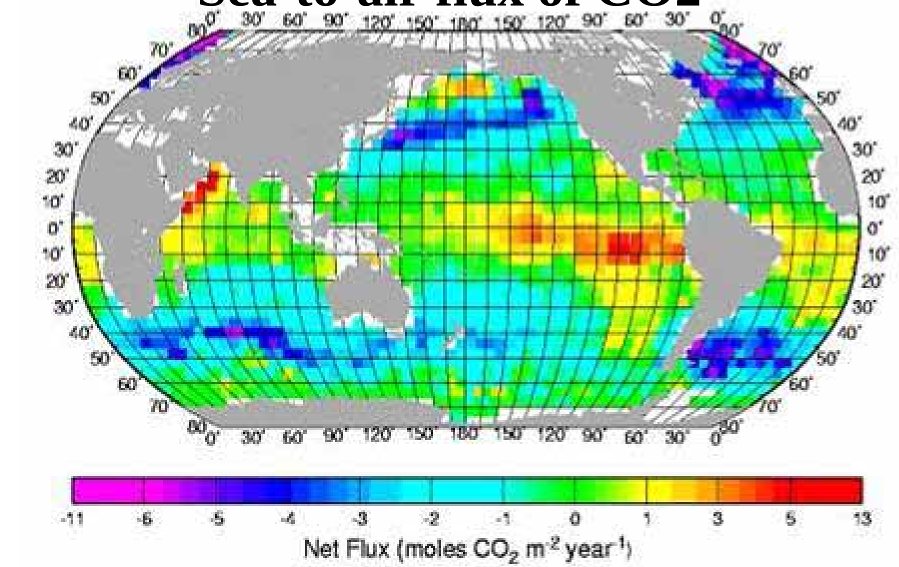
What does the future hold

Importance of N. Indian Ocean

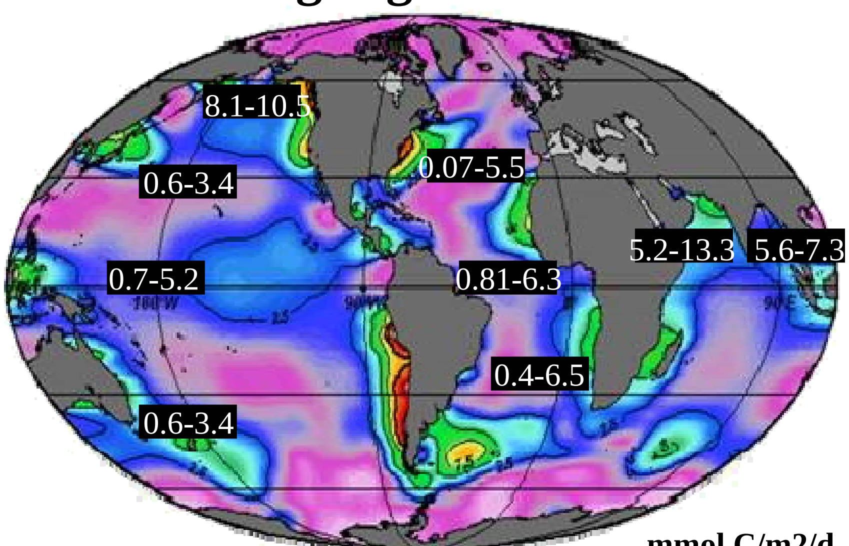
Primary production



Sea-to-air flux of CO2

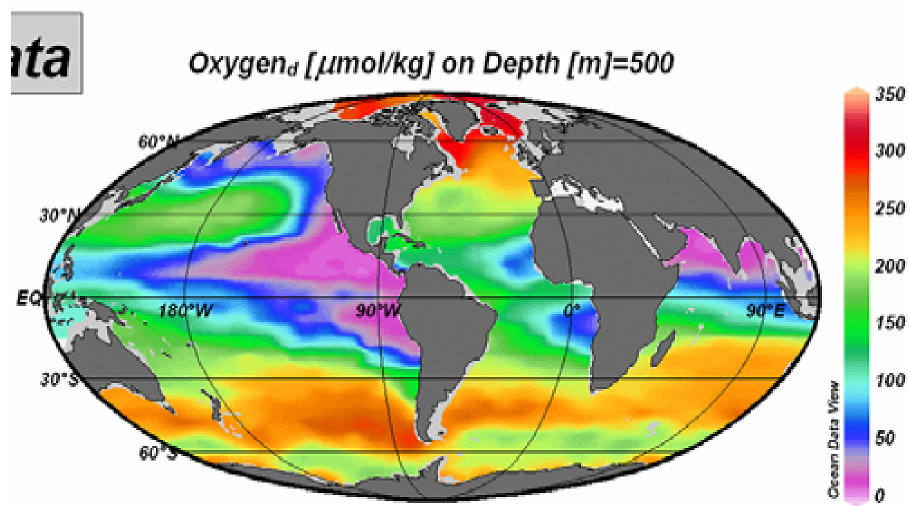


Sinking organic carbon

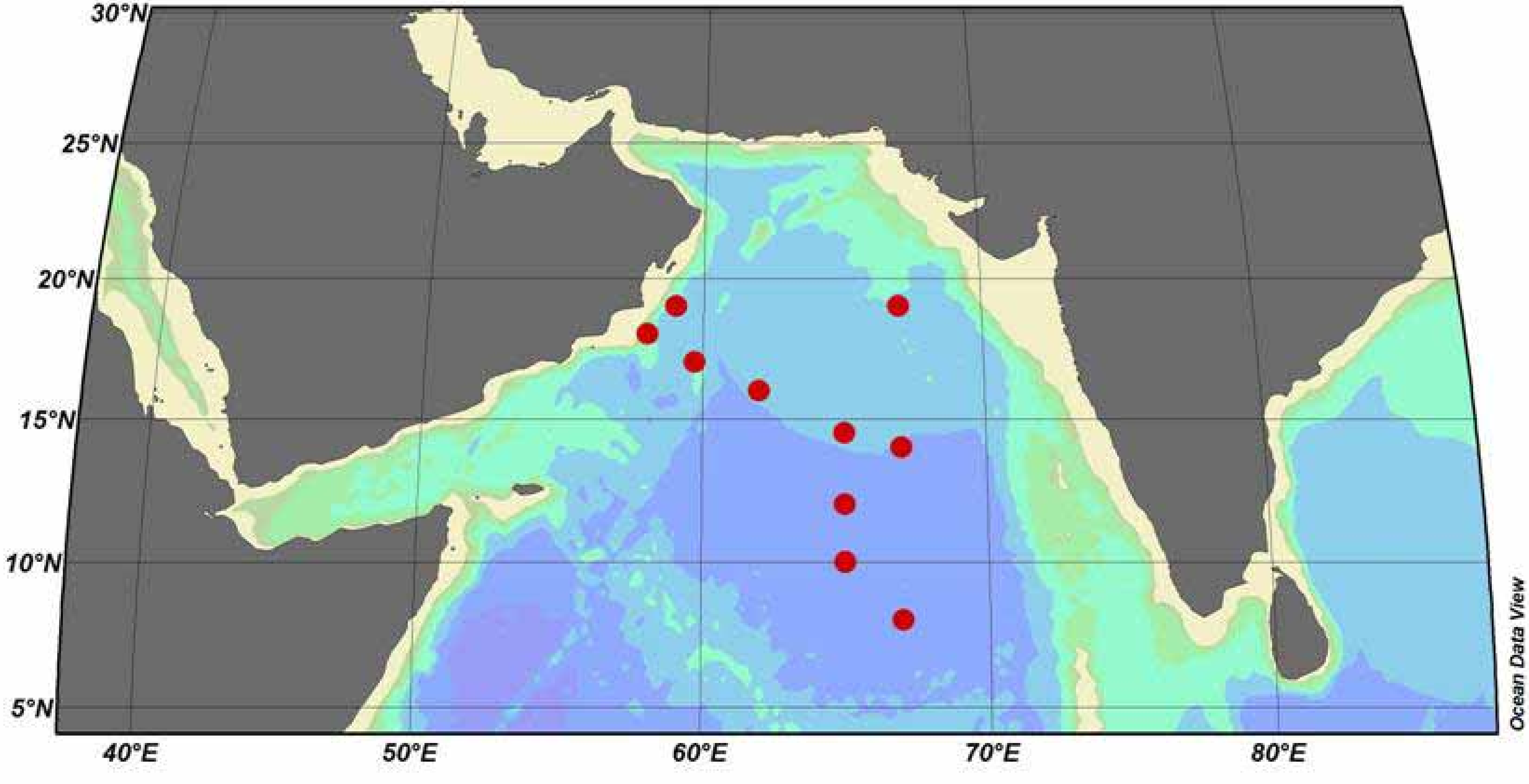


mmol C/m2/d

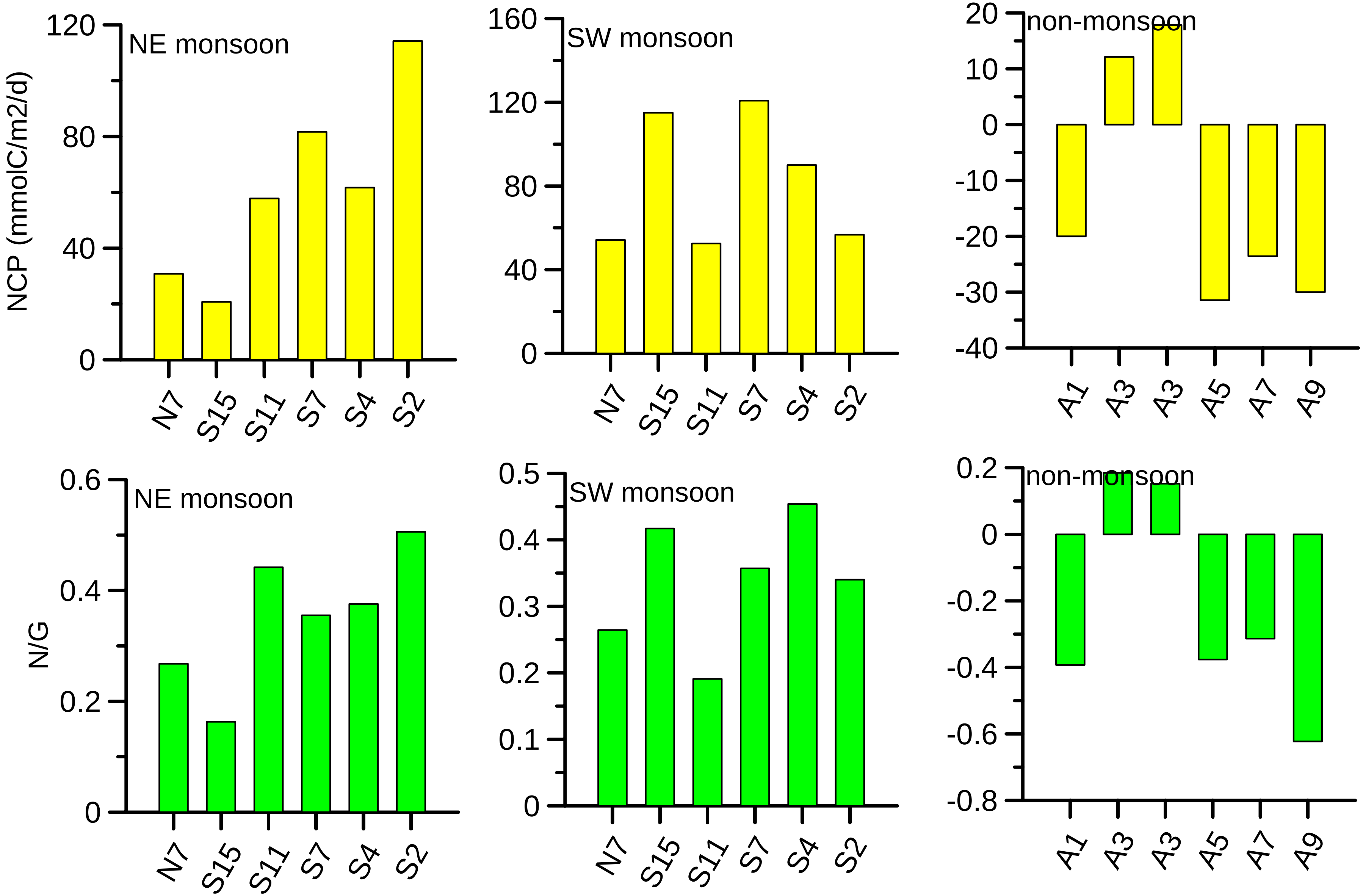
Oxygen at 500 m deep



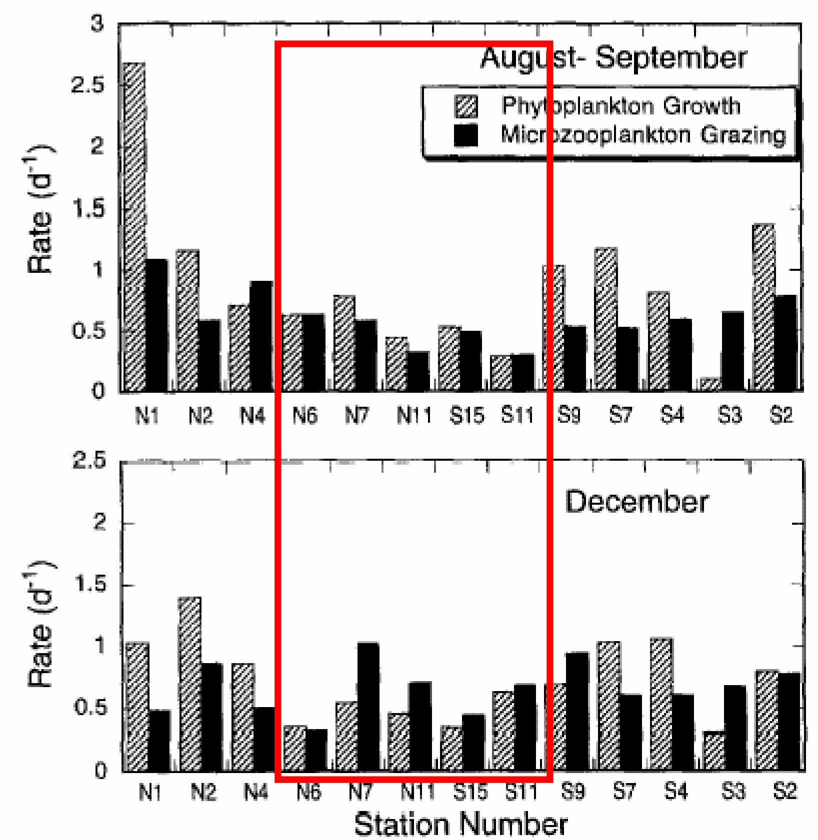
Station locations of measurements



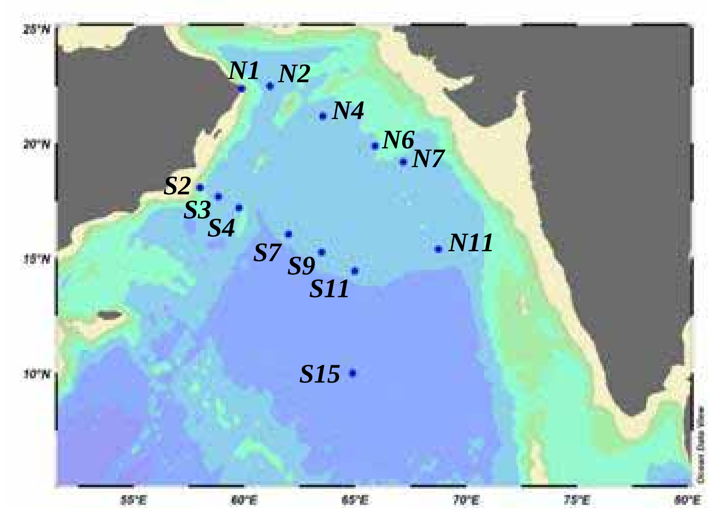
NCP & N/G


NCP (mmolC/m2/d)
NE monsoon
SW monsoon
non-monsoon
0
40
80
120
160
20
10
-10
-20
-30
-40
N7
S15
S11
S7
S4
S2
A1
A3
A5
A7
A9
N/G
0.6
0.4
0.2
0.5
0.3
0.1
-0.2
-0.4
-0.6
-0.8

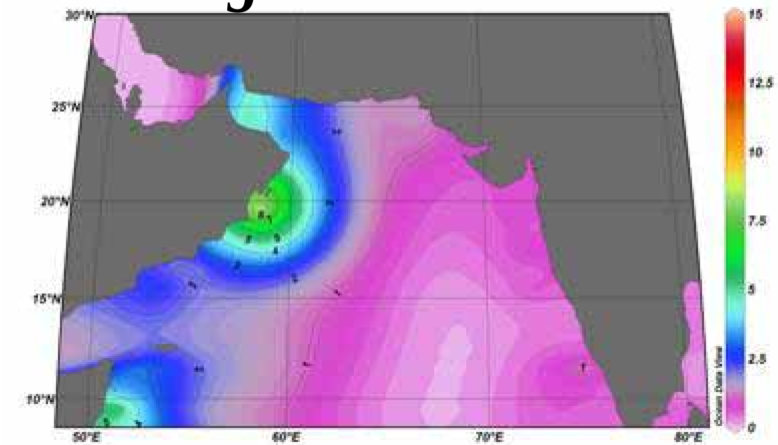
Phytoplankton growth versus microzooplankton grazing



Landry et al., 1998

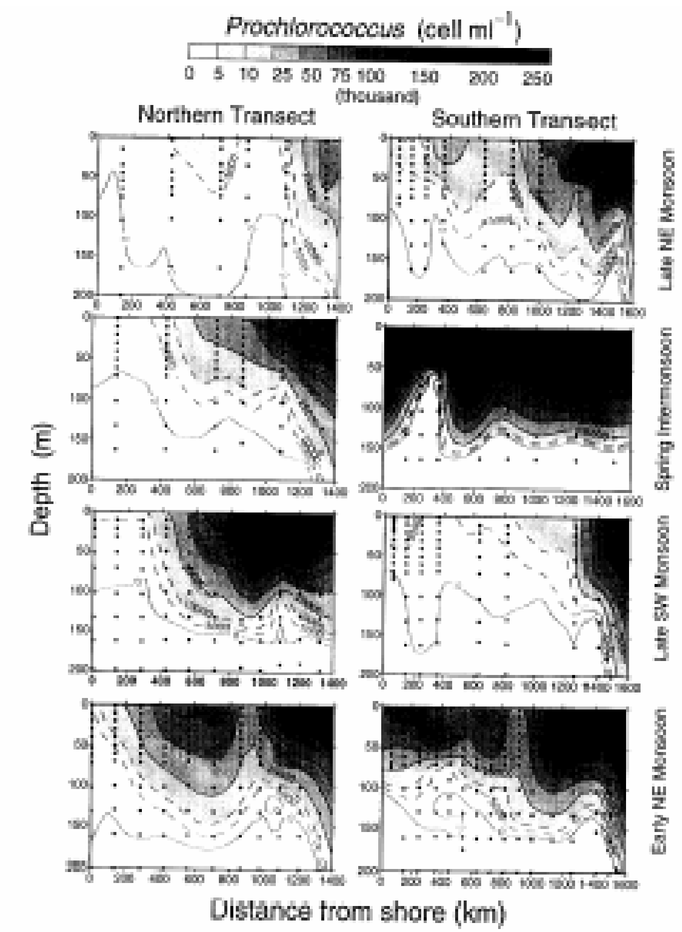


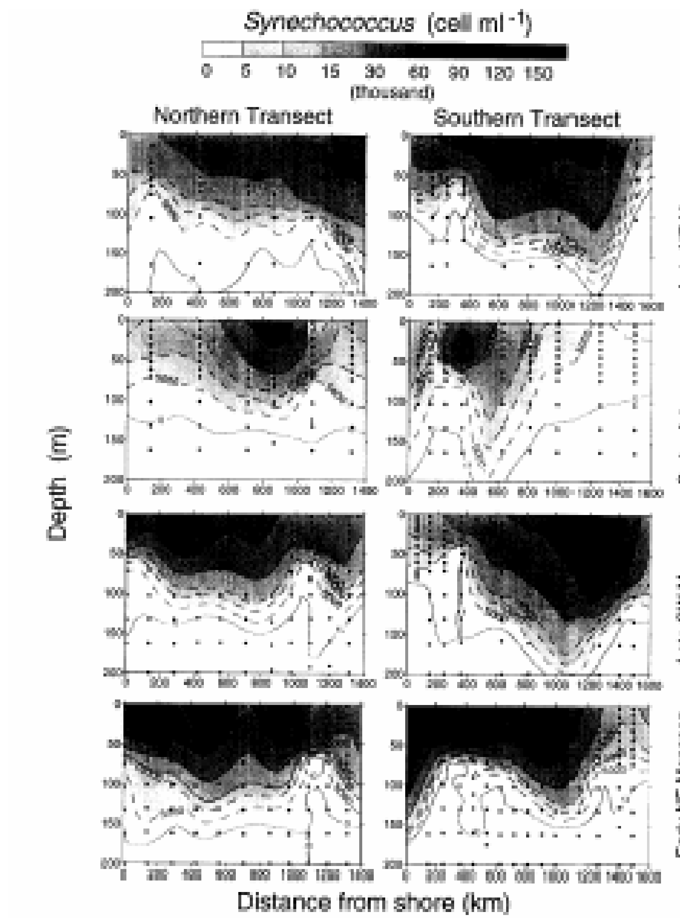
Climatological annual mean NO3

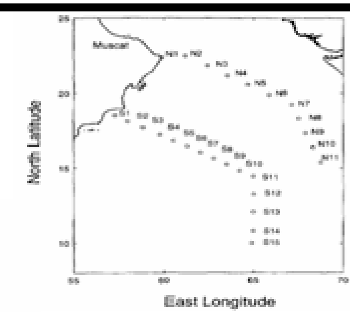


Conkright et al., 2002

Picoplankton cell abundance in the Arabian Sea







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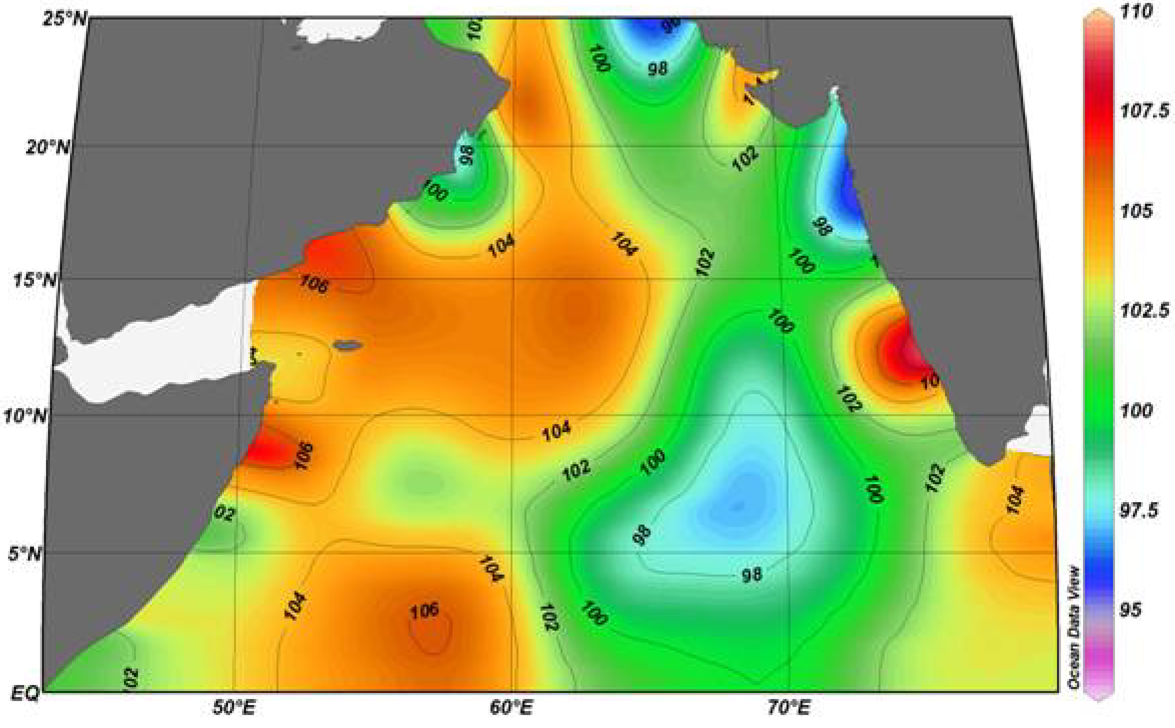
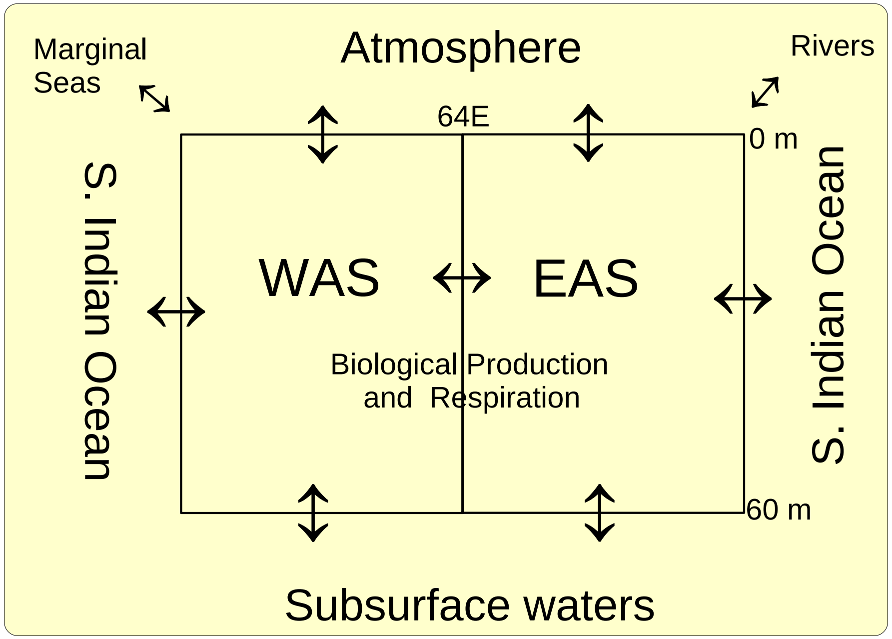
Liu et al., 1998

O_2 saturation during Fall monsoon

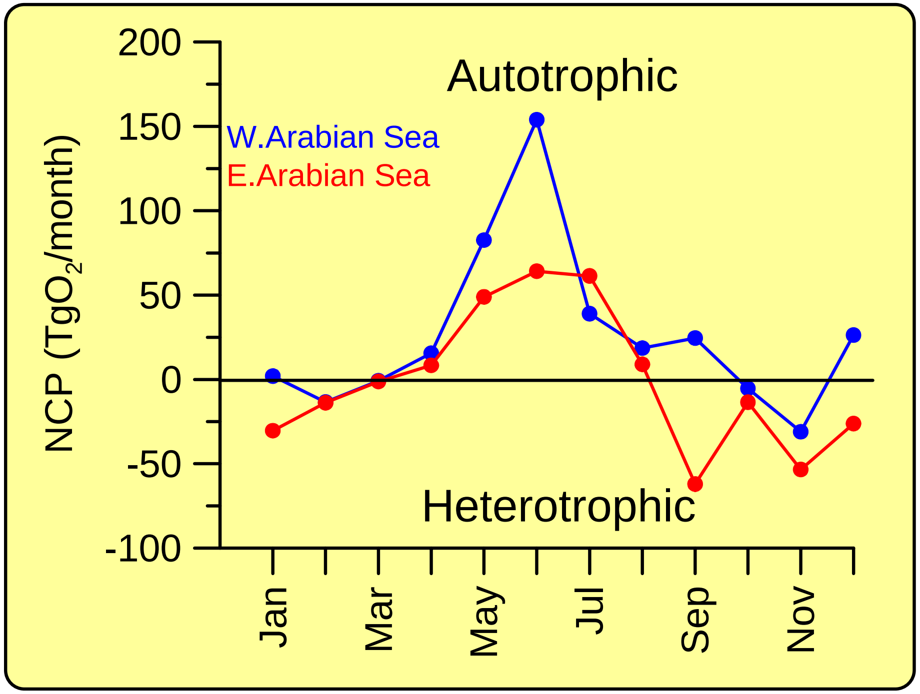


Conkright et al., 2002

NCP in the Arabian Sea by O_2 mass balance model



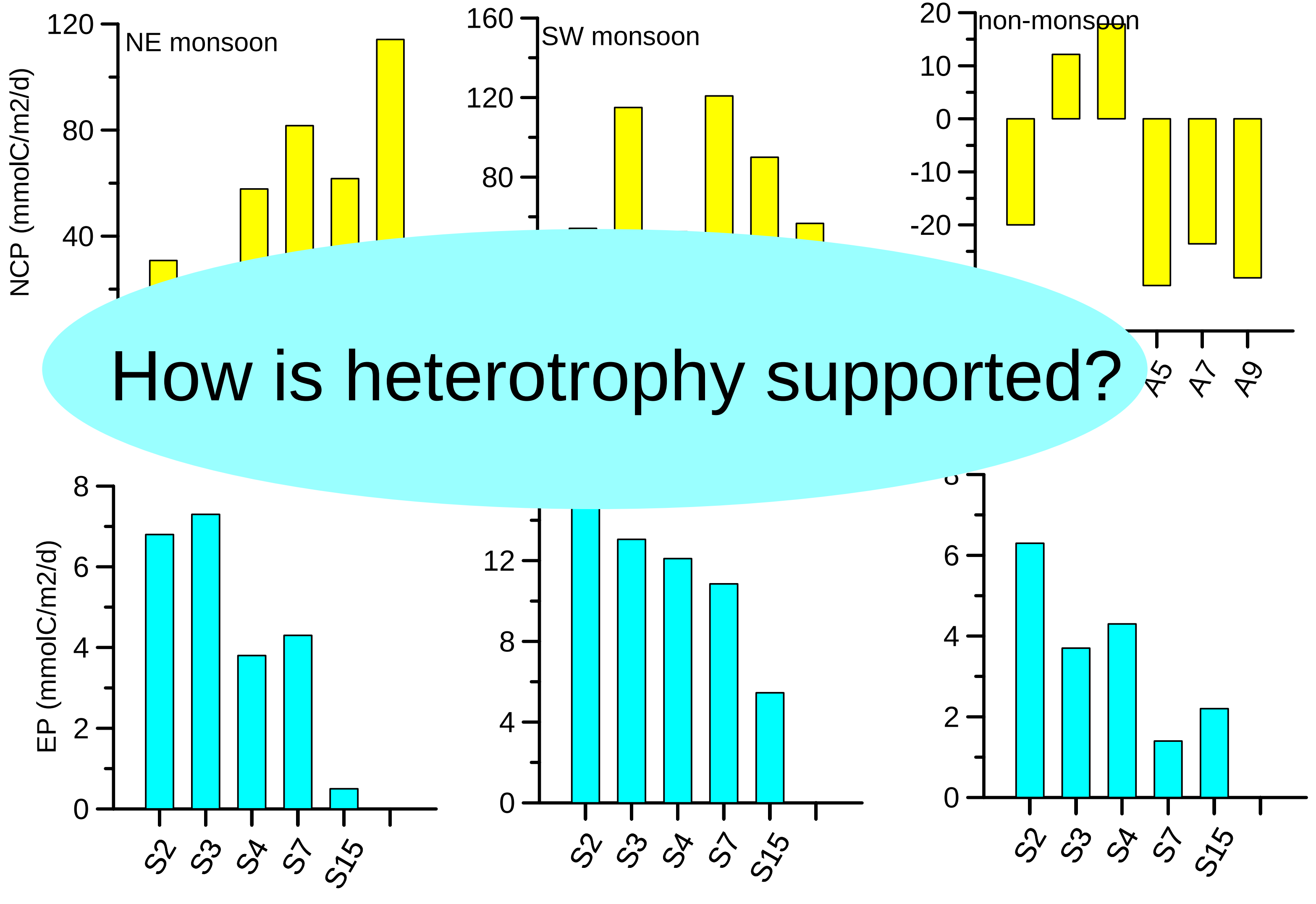
$$\int_{EZ}^{0} [O2]z = BP - R - O2h - O2v - O2m - O2f$$



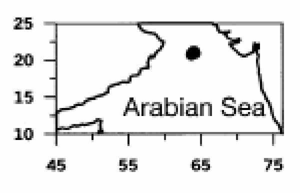
Annual NCP = 240 TgC/y

Sarma, 2004

Net community and Export productions in the Arabian Sea



Accumulation of DOC during monsoon in the Arabian Sea



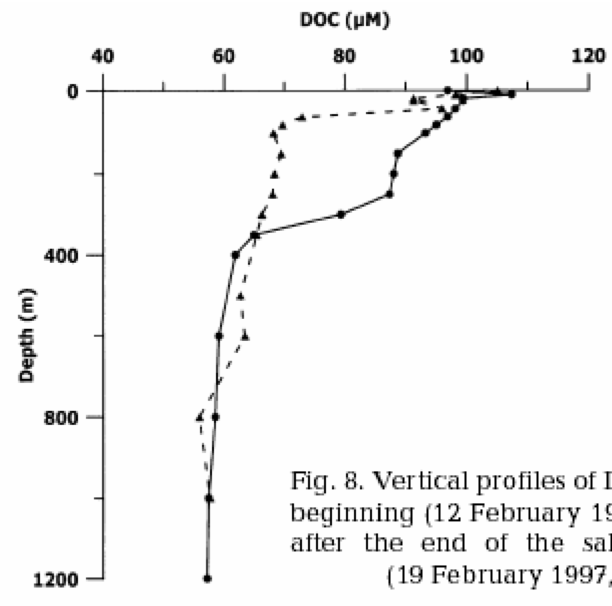
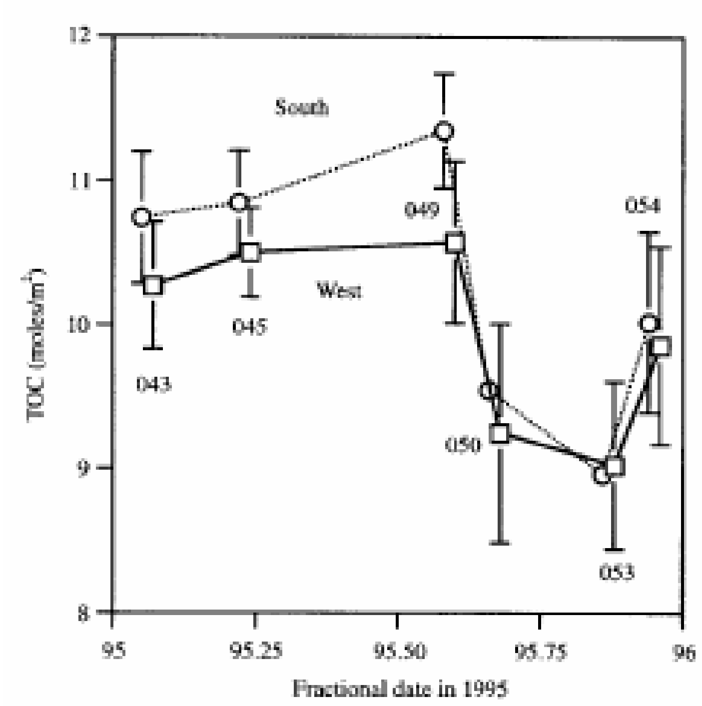


Fig. 8. Vertical profiles of DOC at the beginning (12 February 1997, ▲) and after the end of the salp swarms (19 February 1997, ●)



Naqvi et al., 2002

Hansell & Peltzer, 1998

What is the fate of NCP in the Arabian Sea?

What is the fate of NCP in the Arabian Sea?

NCP in EZ

240±14 TgC

Sinking POC

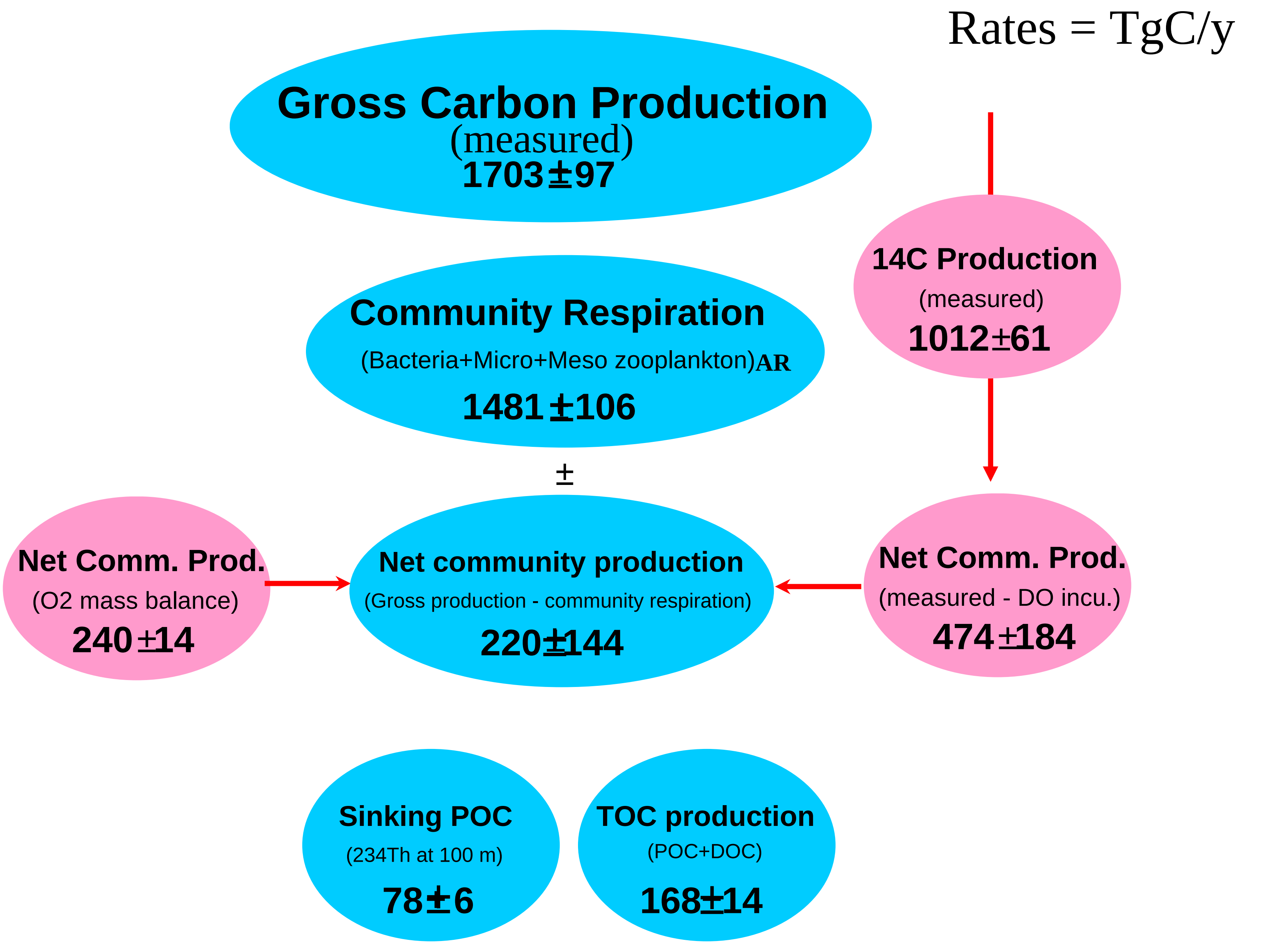
78±5 TgC

Bacterial Carbon Demand in OMZ

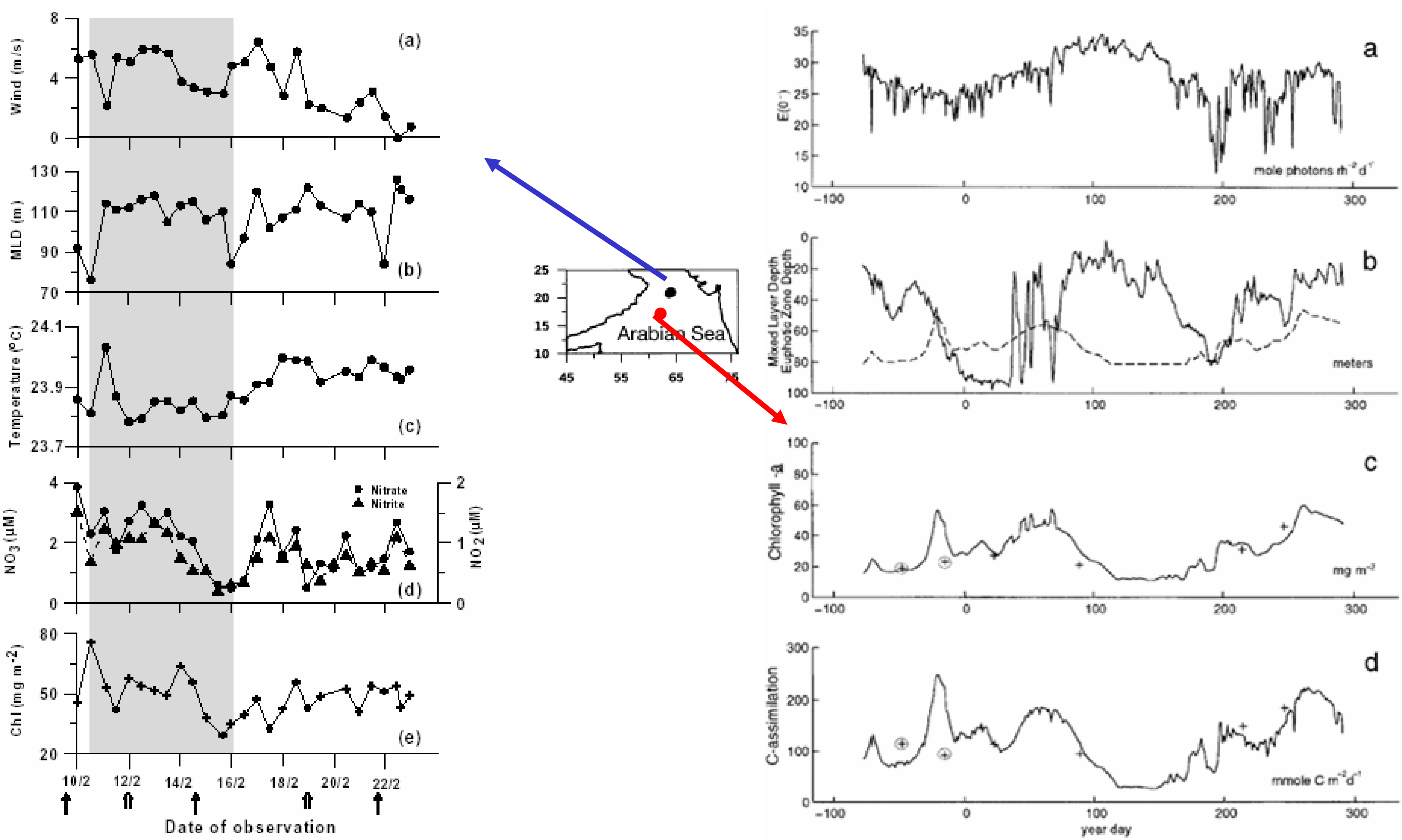
150-610 TgC (mean 316)

NCP includes DOC production. Is DOC sink down to OMZ or Transports horizontally??

Plankton metabolic rates in the Arabian Sea



Short-term variations in Chl-a and Primary production in the Arabian Sea

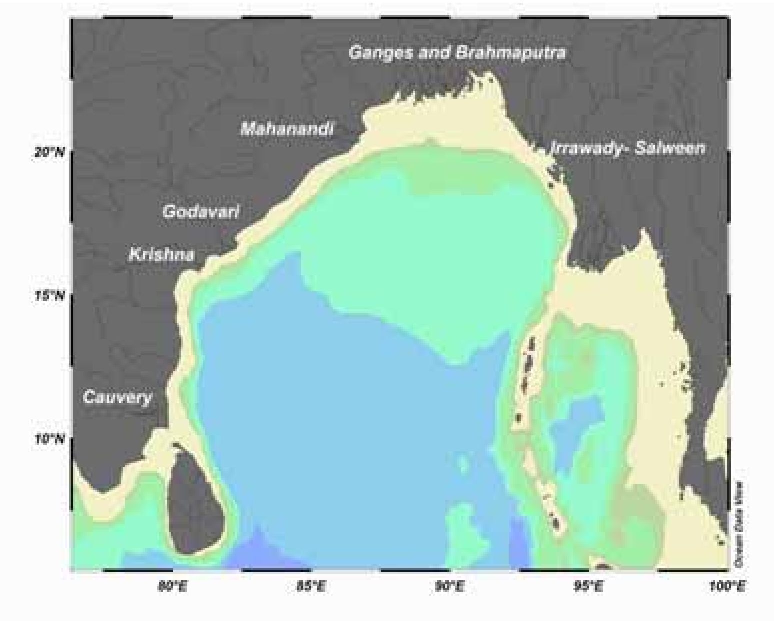


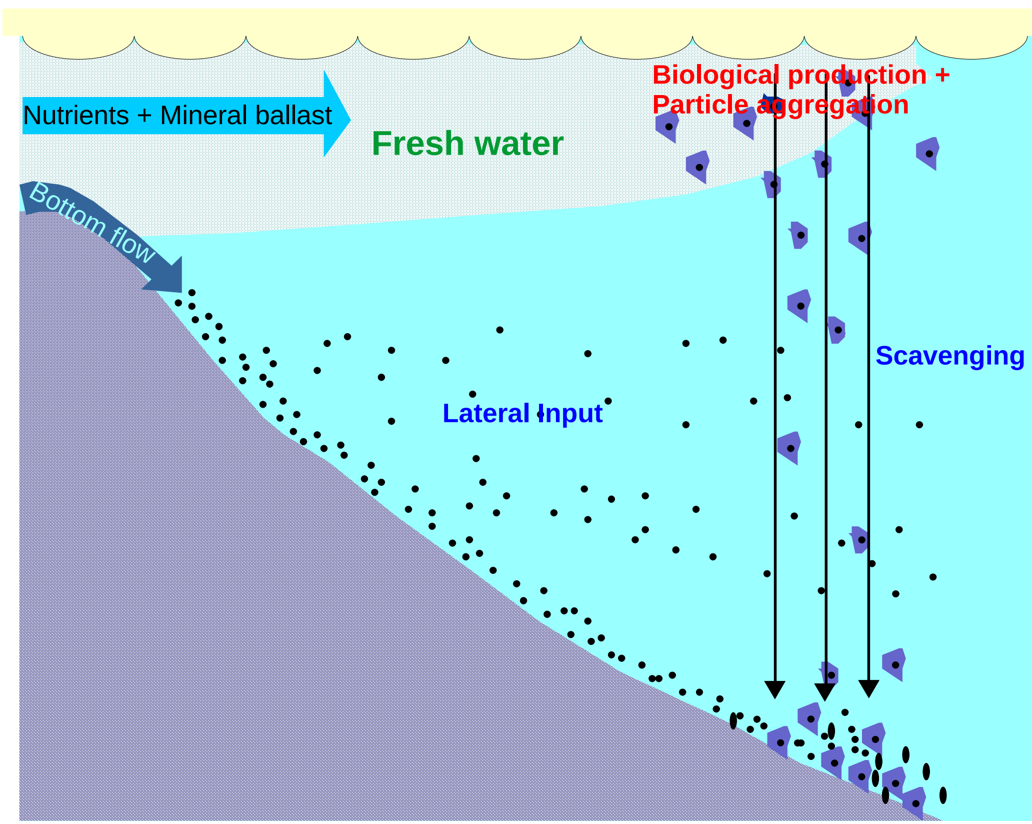
Naqvi et al., 2002

Dickey et al., 1998

Net Community Production
in the Bay of Bengal

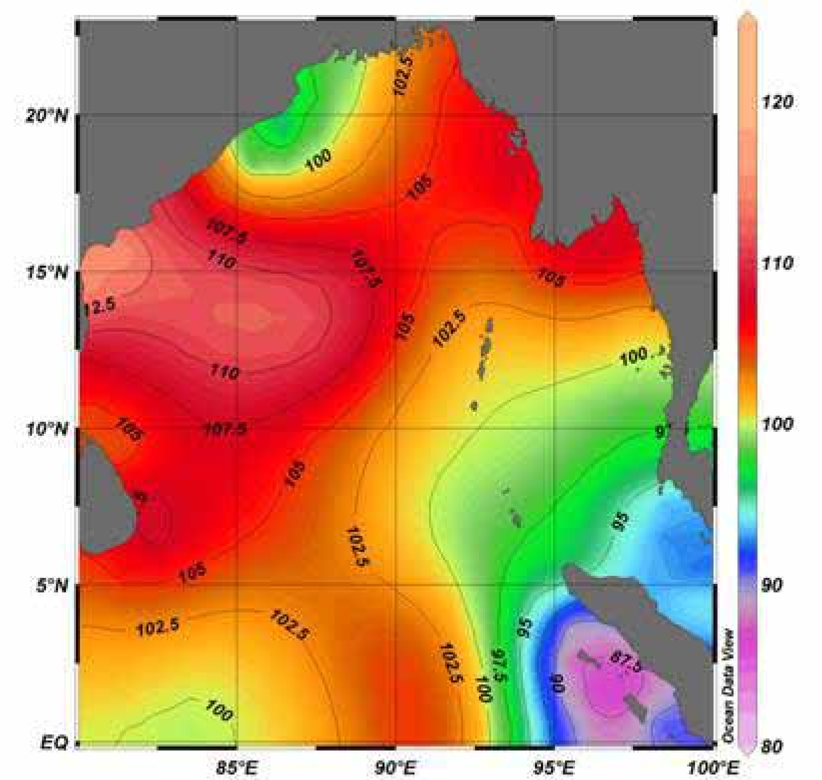
Bay of Bengal



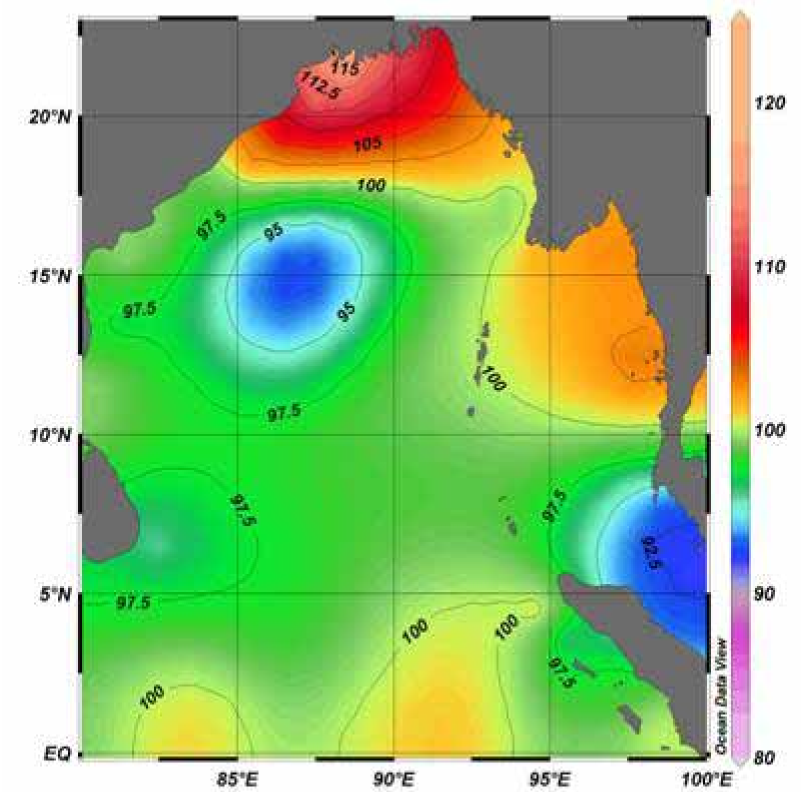


O_2 saturation in Bay of Bengal

April

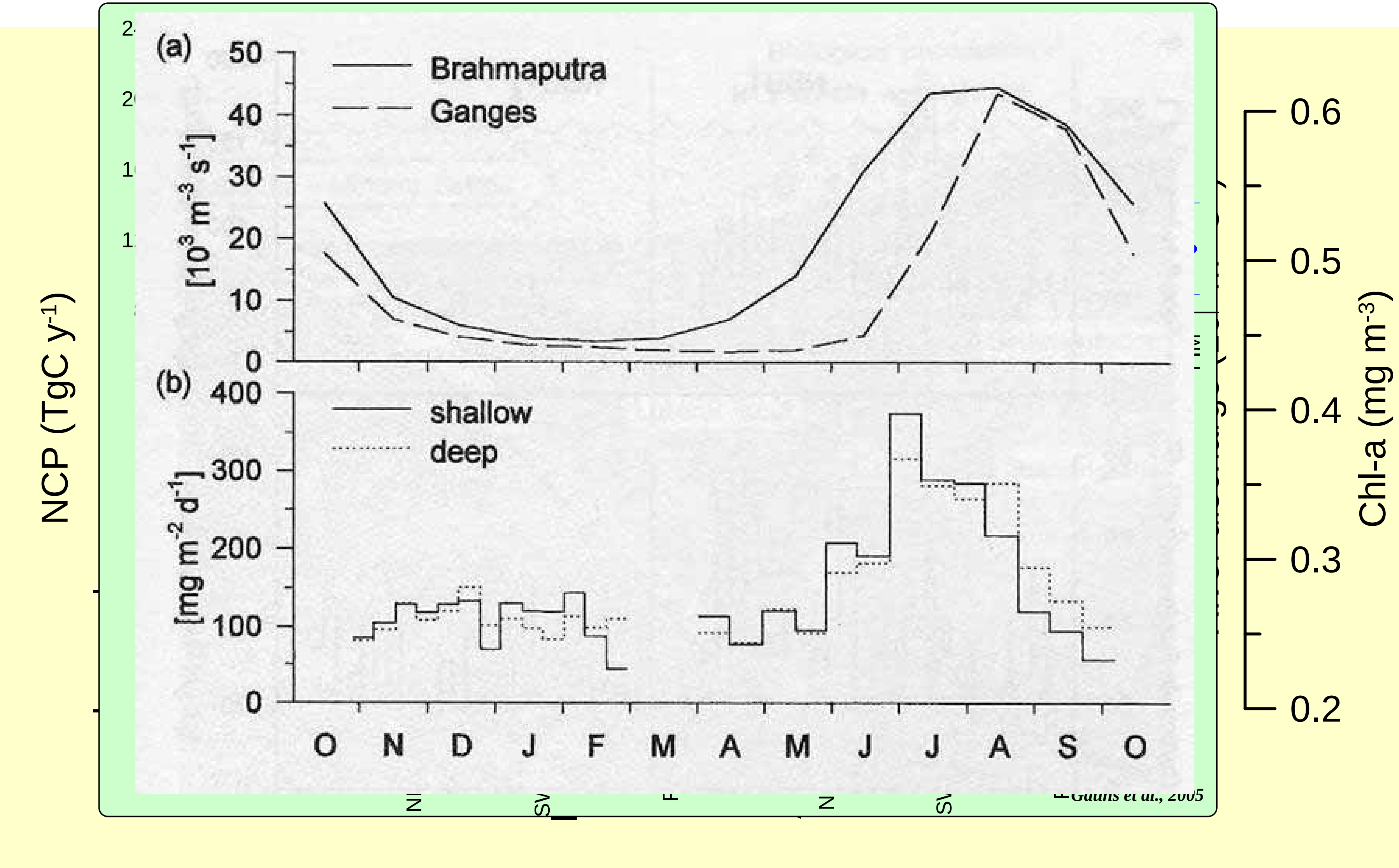


July



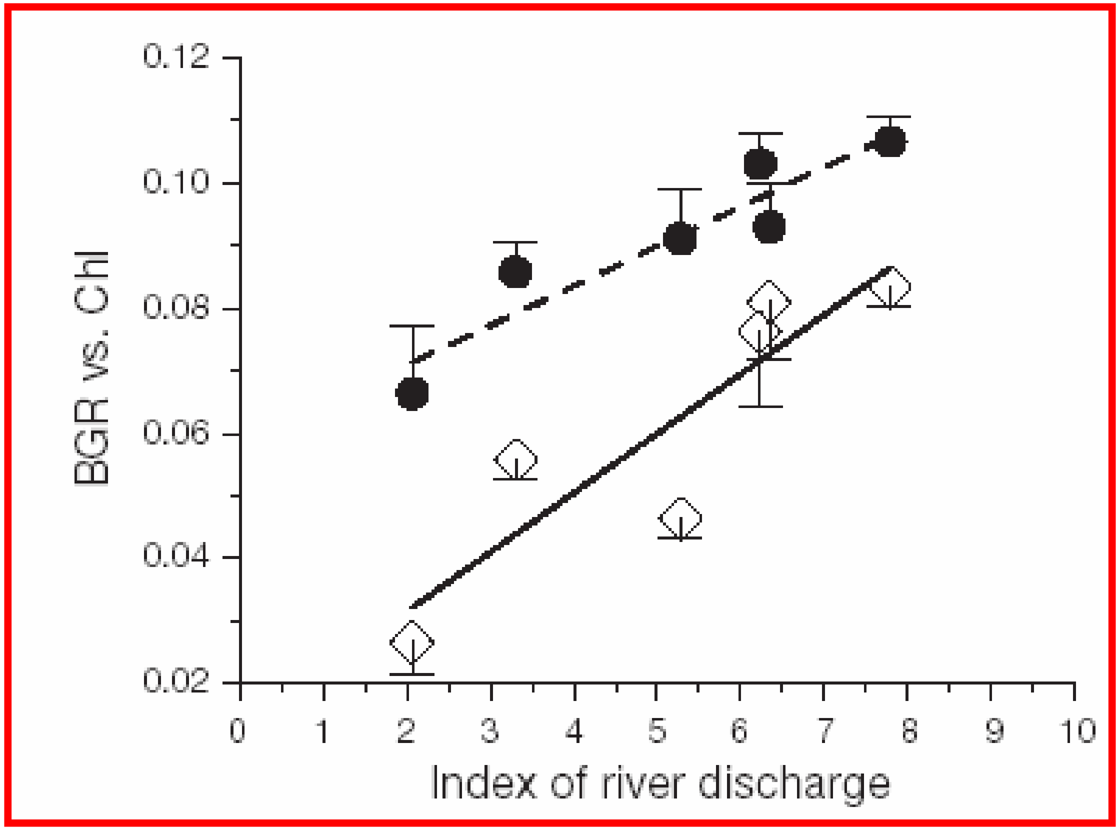
Conkright et al., 2002

NCP in the Bay of Bengal



Sarma, 2006

Effects of ChangJiang River discharge on bacterial growth



Shiah et al., 2006 AME, in press

What is the fate of NCP in the Bay of Bengal?

What supports organic carbon demand in the OMZ?

NCP in EZ

59 - 77 TgC

Sinking POC

???

Bacterial Carbon Demand in OMZ

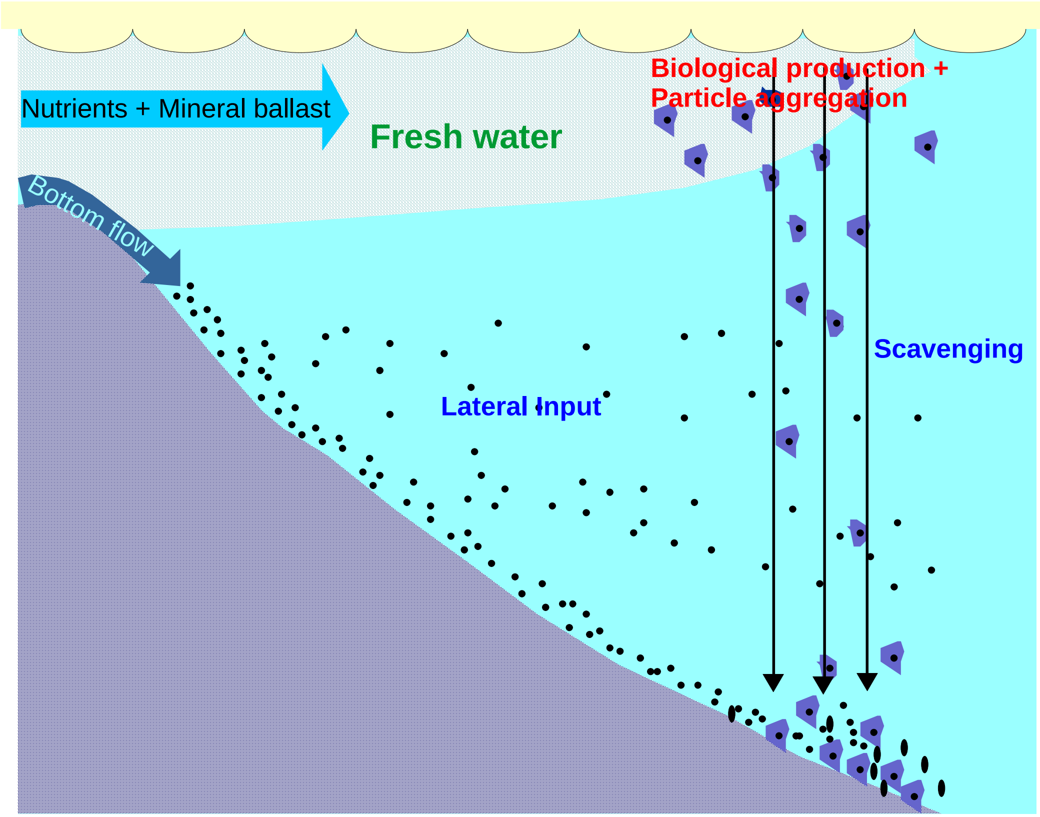
20-200 TgC (mean 94)

We do not know what fraction of NCP released as DOC and how It was transported in the Bay of Bengal?

NCP and sea-to-air fluxes of CO_2 ($PgC\ y^{-1}$)

Region	Sea-to-air flux (F)	New/NCP(NP)	F/NP Ratio
Eq.Pacific (HNLC) (1980-2000)	0.80 to 1.00 (*Feely et al.*, 2002)	0.65 to 0.98 (*LeBorgne et al.*, 2002)	1.0-1.2
Arabian Sea (1995)	0.07 to 0.09 (*Sarma.*, 2003)	0.17 to 0.20 (*Sarma*, 2004)	0.4-0.45
Bay of Bengal	0.0025 to 0.005 (*Takahashi et al.*, 2002)	0.059-0.077 (*Sarma*, 2006)	0.19-0.22

How to validate NCP models in the Bay of Bengal?



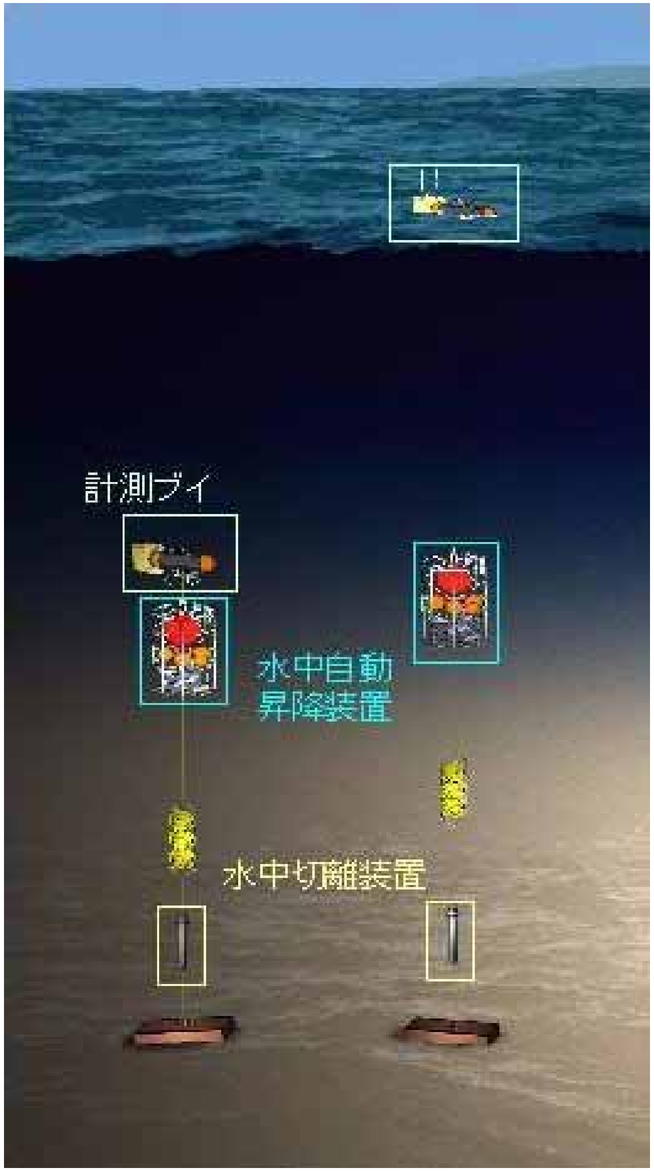
Future Directions

Therefore, in vivo, continuous and/or time-integrated Production rates are essential to understand biogeochemistry Of carbon in the northern Indian Ocean and also to validate the models.

Such data can be derived using

1. ***In situ mooring of productivity sensors***
2. ***Natural oxygen isotopes of dissolved oxygen.***

Fast Repetition Rate Fluorometer - Buoy System



Plankton metabolic rates using O_2 isotopes

Fractionation of oxygen isotopes

On the earth surface

Mass dependent fractionation:

$\delta^{17}O / \delta^{18}O = 0.52$

In the stratosphere

Mass independent fractionation:

$\delta^{17}O / \delta^{18}O = >0.5$

Anomaly ($^{17}\Delta$) = ($\delta^{17}O - 0.518\ \delta^{18}O$)×1000

Gross Oxygen production

$$GOP = KC_o\,[{}^{17}\Delta_{anomaly} - \Delta_{eq}]/[\Delta_{max} - {}^{17}\Delta_{anomaly}]$$

Luz and Barkan, 2000

K=Piston velocity

Co= solubility of oxygen at *in situ* temp. & salinity

${}^{17}\Delta_{anomaly}$ = ${}^{17}\Delta$anomaly of dissolved oxygen

Δ eq = equilibrium anomaly (16 per meg)

Δ max = maximum value of pure biological O_2 (249 per meg)

GOP = gross oxygen production

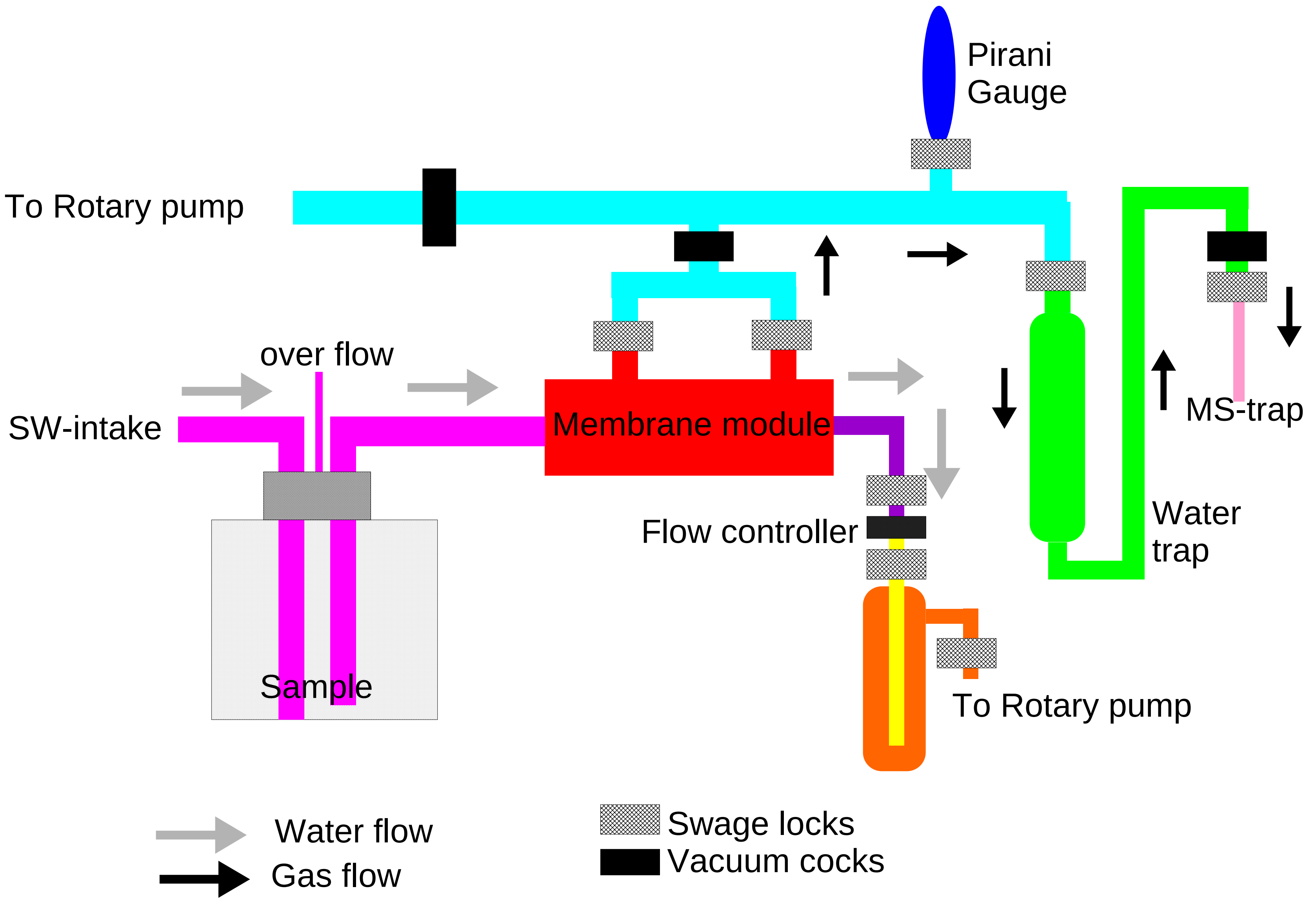
Net to Gross production ratio

$$N/G = \left(\frac{C}{C_{sat}} - 1\right) \frac{\Delta_{max} - \Delta_{dis}}{\Delta_{dis} - \Delta_{eq}}$$

C_{sat}= biological oxygen saturation

Hendricks et al., 2004

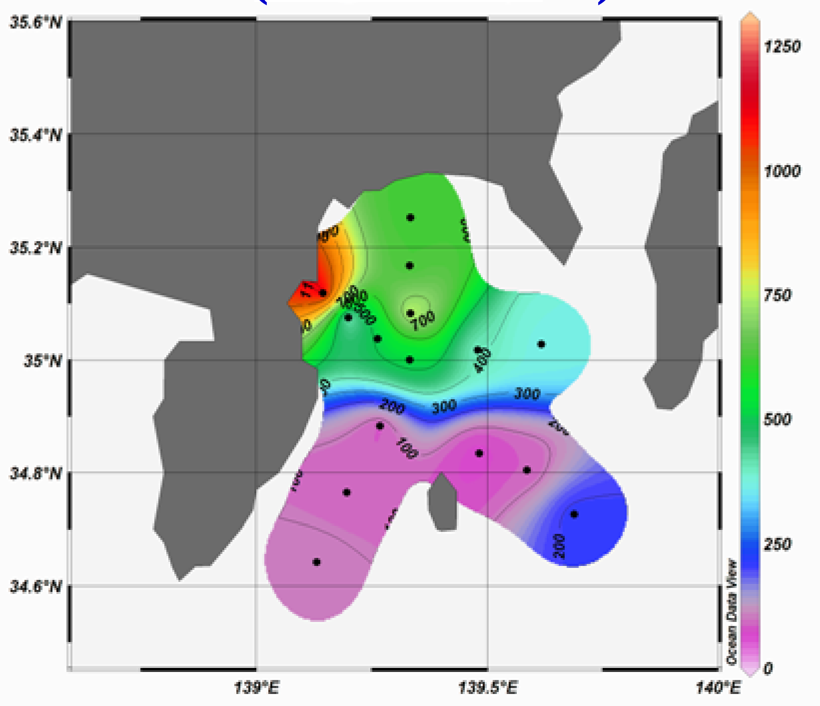
Schematic diagram of membrane gas extraction unit



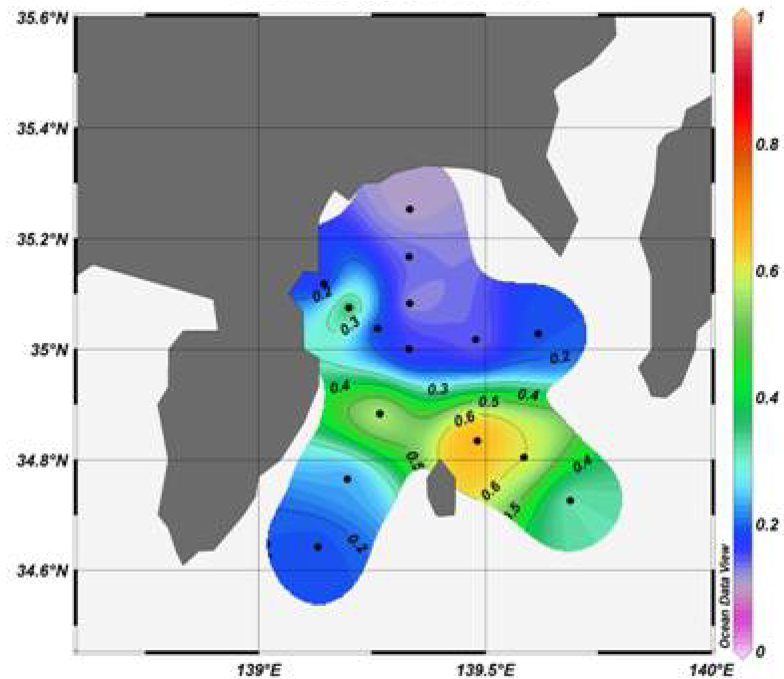
Sarma et al., 2006

Gross production and net to gross production ratios in the Sagami Bay using O_2 isotopes and O_2/Ar ratios

GOP (mmolO2/m2/d)

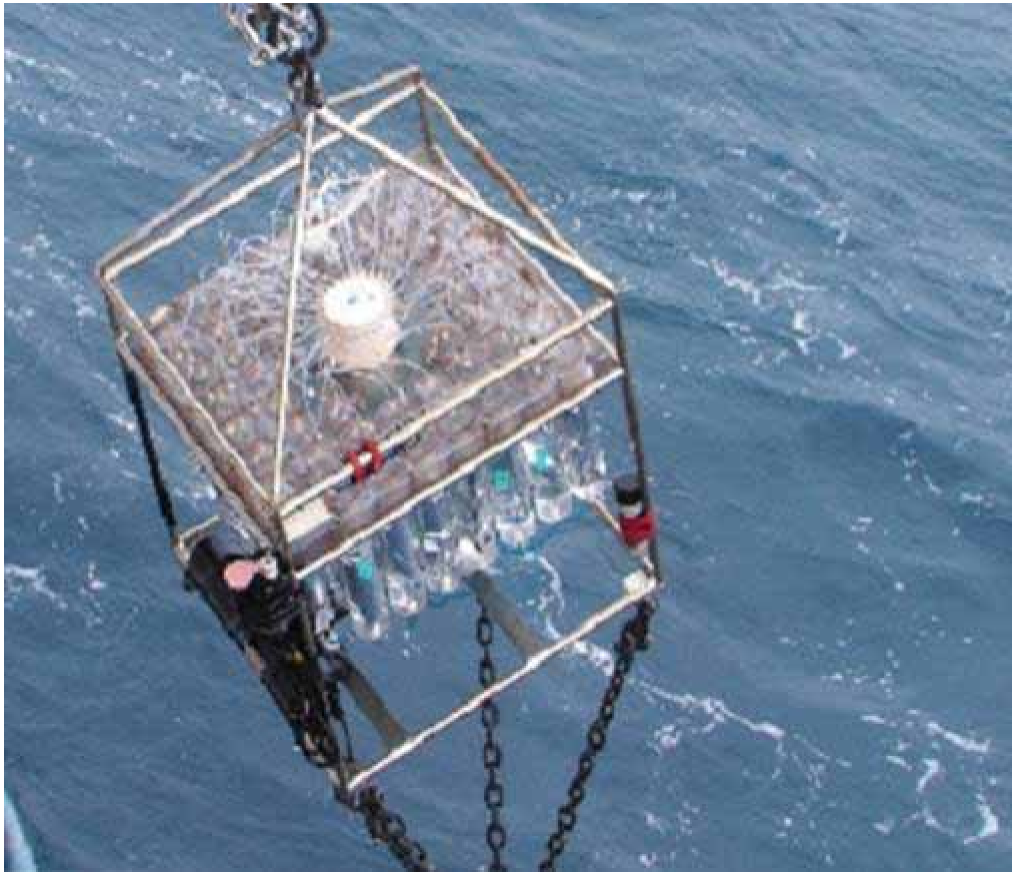


NOP/GOP ratio



Sarma et al., 2006

Remote Access Sampler (RAS)



Sample from mixed layer- once in a week interval.

RAS can take 48 samples therefore once it is moored samples for one year can be collected and annual plankton meta-bolic rates can be derived.

Needs to be tested or modified sampling tubes for long storage.

Conclusions

Autotrophy exists during monsoon and heterotrophy in non-monsoon in the Arabian Sea and vice versa in the Bay of Bengal.

Understanding short-term variability in production and their relations to physical processes are very important.

N. Indian Ocean pumping carbon to the twilight zone, which is 200-2000 time higher than the air-sea exchange at the air-water interface.

Geochemical tracers involving no incubation or *in situ* mooring sensors may be more appropriate methods for NCP estimates in the Bay of Bengal.