Nutrients in the Indian Ocean

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SIBER
Monsoon circulation
Primary Production
Nutrients – Nitrogen biogeochemistry

Nitrogen, phosphorus & silicate
Trace metals

• Distribution
• Processes
• Driving forces
Meridional variability in nutrients – geographic domains

Polar
Southern Subtropical Gyre
Monsoon Gyre

**Oxygen [μmol/kg]**

**Nitrate [μmol/kg]**

Distance (km)

Depth (m)
Zonal variability in nutrients
Monsoons as driving force

Monsoon forcing: North Indian Ocean
River discharges & differential vertical mixing

SPM $0.2 \times 10^9$ tons/y
WATER $0.3 \times 10^{12}$ m$^3$/y

1.4x10$^9$ tons/y
1.6x10$^{12}$ m$^3$/y

Arabian Sea
Indian Subcontinent
Bay of Bengal
Global Primary production  Behrenfeld and Falkowski (1997)
Nitrate deficits, global significance of del N and N$_2$O fluxes

Del N = 1/3 Global?  N$_2$O flux = ~8% Global

from Naqvi (2006)

Gruber & Sarmiento (2002)

Codispoti et al. (2001)

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Decoupled active denitrification region

Naqvi (1991)
## Redfield ratios – anomalies

<table>
<thead>
<tr>
<th>O₂: C: N: P</th>
<th>Reference</th>
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<tbody>
<tr>
<td>138:106:16:1</td>
<td>Redfield et al (1963)</td>
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### Denitrification

| 130:94:10.3:1 | (θ < 12°C) EQIO; Li & Peng (2002) |

Partial conversion of organic nitrogen to ………..
Redfield ratios – phosphate accumulation in $O_2$ deficient waters

Samples collected from < 200 m

Bange et al (2005)
Nitrate deficits in the East Indian Ocean?

Kumar (2001)
North supplies materials to the South Indian Ocean

Broecker et al. (1980)

Kumar & Li (1996)
How much do we know about forcings?

Inputs to North Indian Ocean (*Naqvi, 2006*)

- **River & groundwater**: 0.56
- **Atmospheric deposition – trace metals**: 2.9
- **Fixation**: 3.8
- **Sedimentary fluxes**: ???
- **Exchanges with marginal seas**: 0.7
- **Vertical mixing – upwelling**: ???
Evaluation of nutrient supplies – rivers

Seitzinger et al. (2002)

Naqvi et al. (2000)

Kumar (2004)

No reliable data available for realistic estimates
Evaluation of nutrient supplies –
Upwelling ……Eurasian Snow Cover !!!

Goes et al. (2005) SIBER
We have reasonable knowledge on distributions….

**BUT ……. very little on the**

- variability in abundances
- quantitative nutrient transfers and transformations

We NEED to have integrated time-series measurement systems strategically placed (Process expeditions-moorings-satellites)

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Thank You!