11th GEOSS workshop, 23-25th October 2018

Impact of Land-Ocean-Atmosphere Interaction on the biogeochemistry of Coastal India

Recent changes and vulnerable regions

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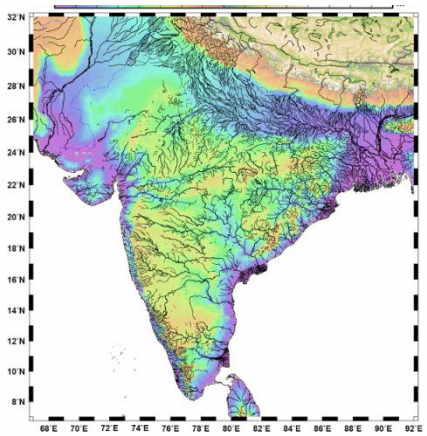
National Institute of Oceanography,
Visakhapatnam

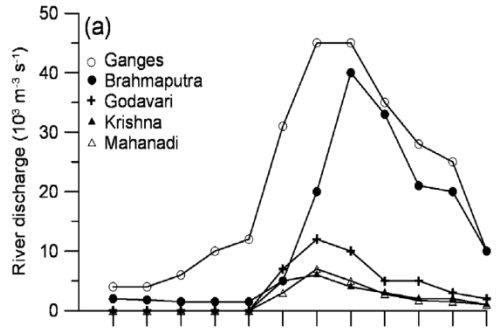
Outline of talk

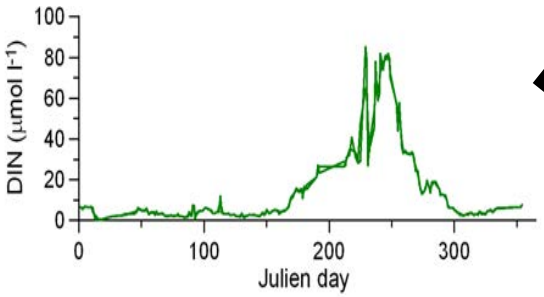
- Importance of Land-Ocean-Atmosphere interactions
- Influence of river discharge on coastal regions
- Impact of atmospheric inputs on coastal processes
- Long-term variations in biogeochemical features
- Ongoing and Future plans

Land – Atmosphere interactions

Land

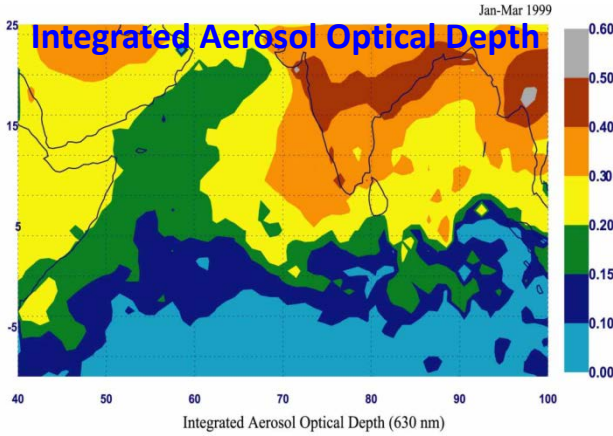






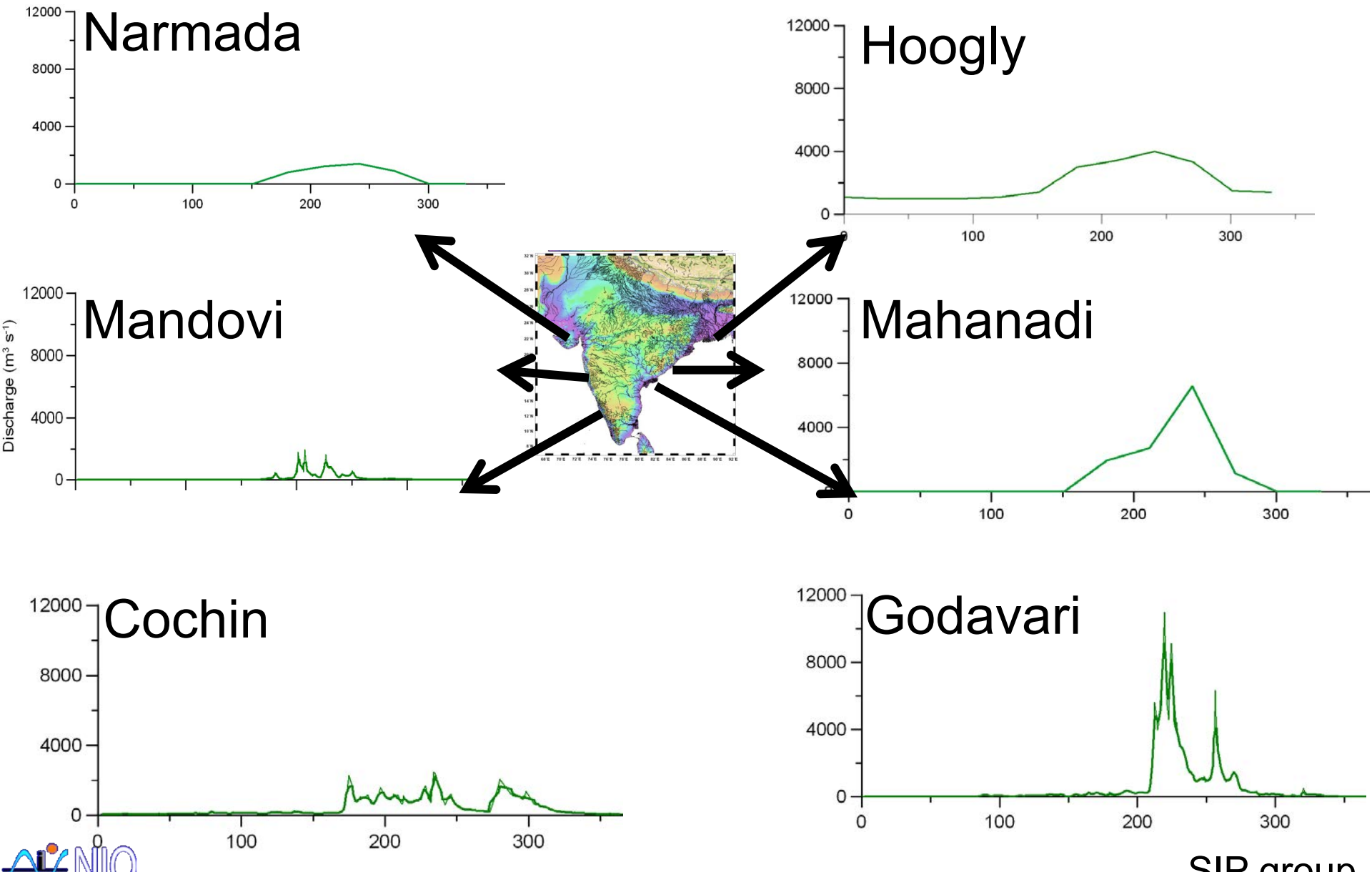
BAY OF BENGAL

Atmosphere



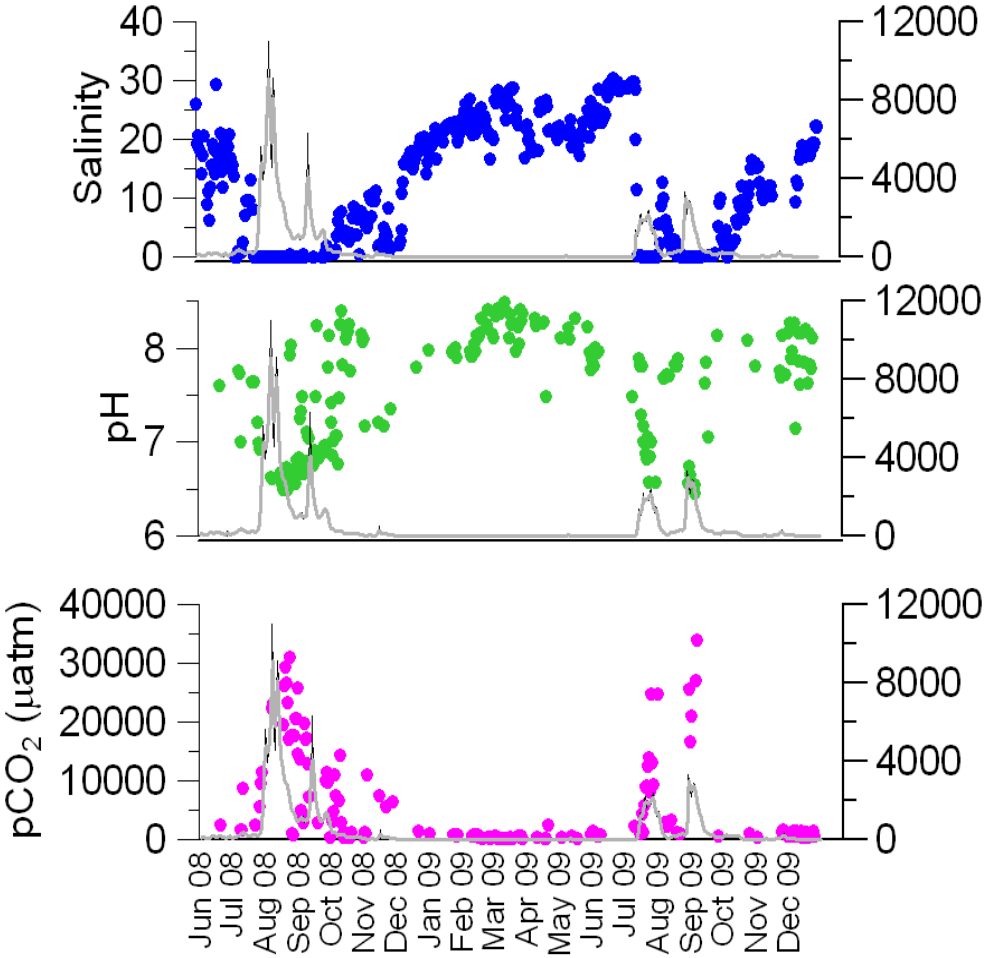
Impact of Land-Ocean Interactions on BGC

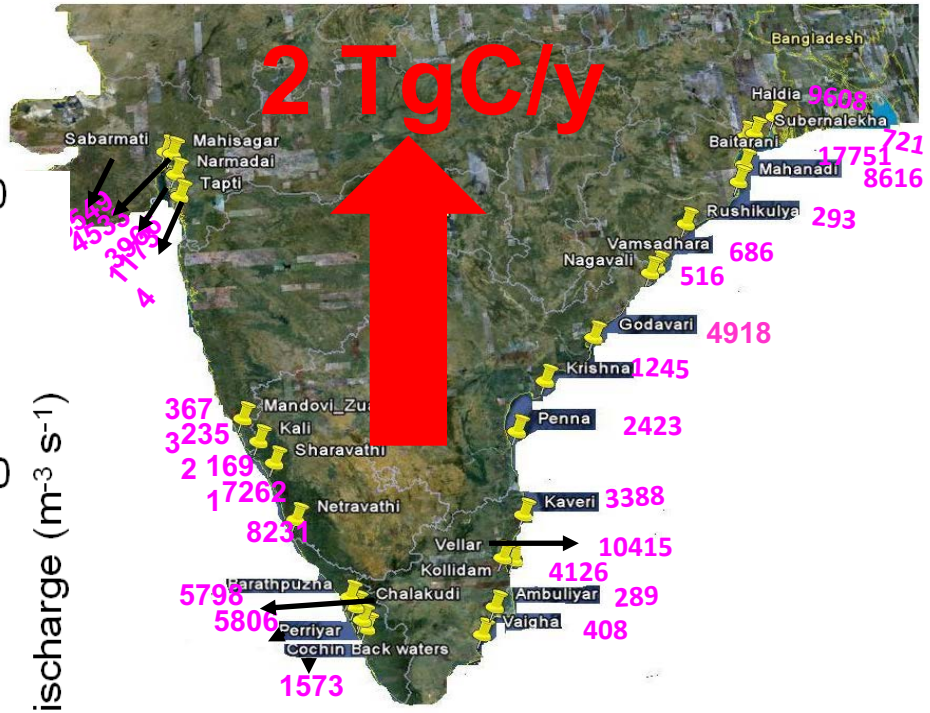
Variable river discharges…

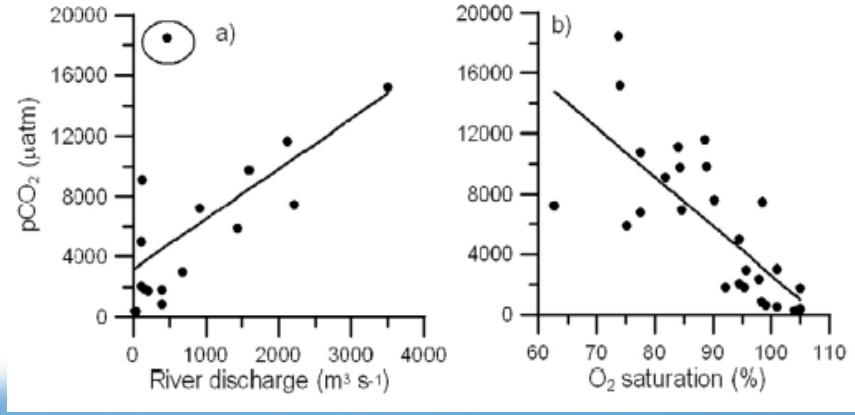


SIP group

pCO_2 in the Indian estuaries





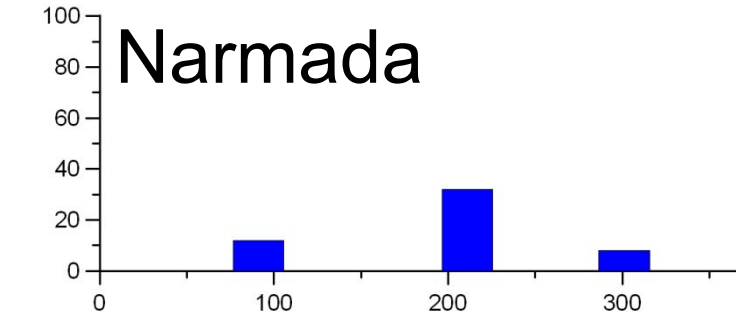


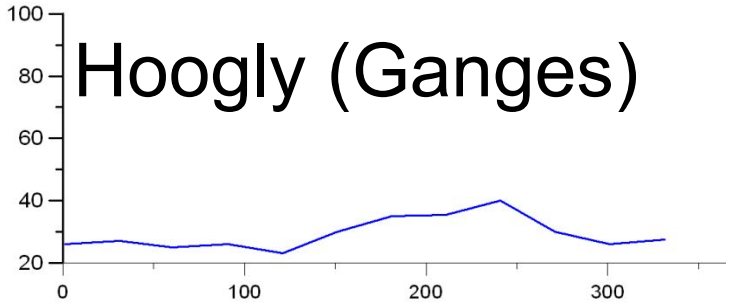
Estuarine trace gas fluxes

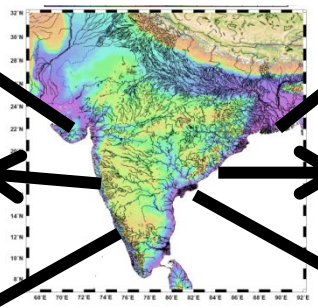
Region	CO_2 ($M\ m^{-2}\ d^{-1}$)	N_2O ($\mu M\ m^{-2}\ d^{-1}$)	CH_4 ($\mu M\ m^{-2}\ d^{-1}$)
Europe	0.25	0.24	0.13
USA	0.22	--	0.18
China	0.26	0.05	0.12
India	0.02	0.003	0.02

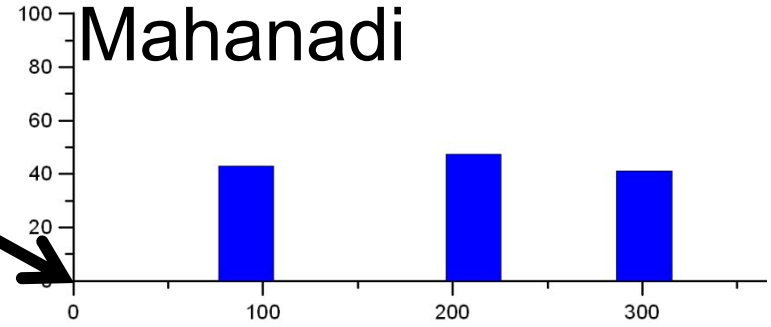
Low residence time and high dilution are prime factors for low trace gases production

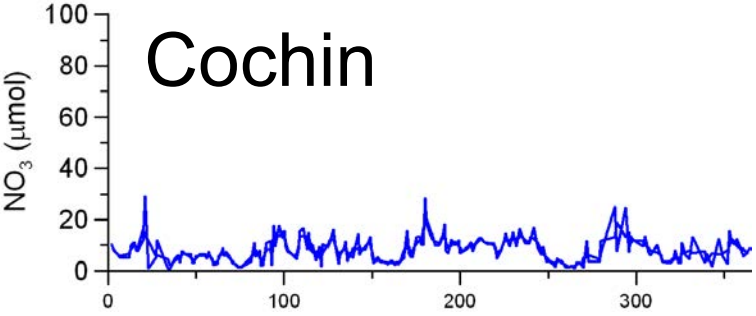
Variable Nutrient inputs…

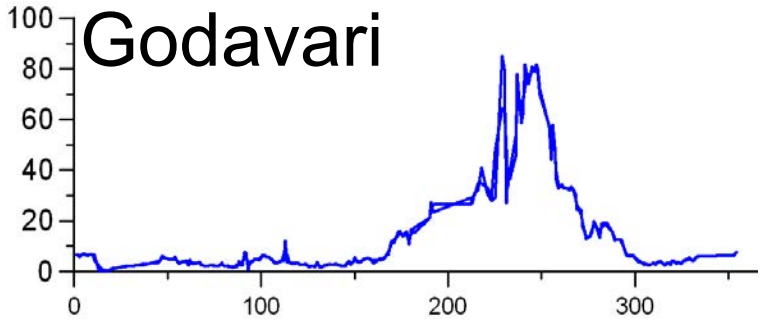






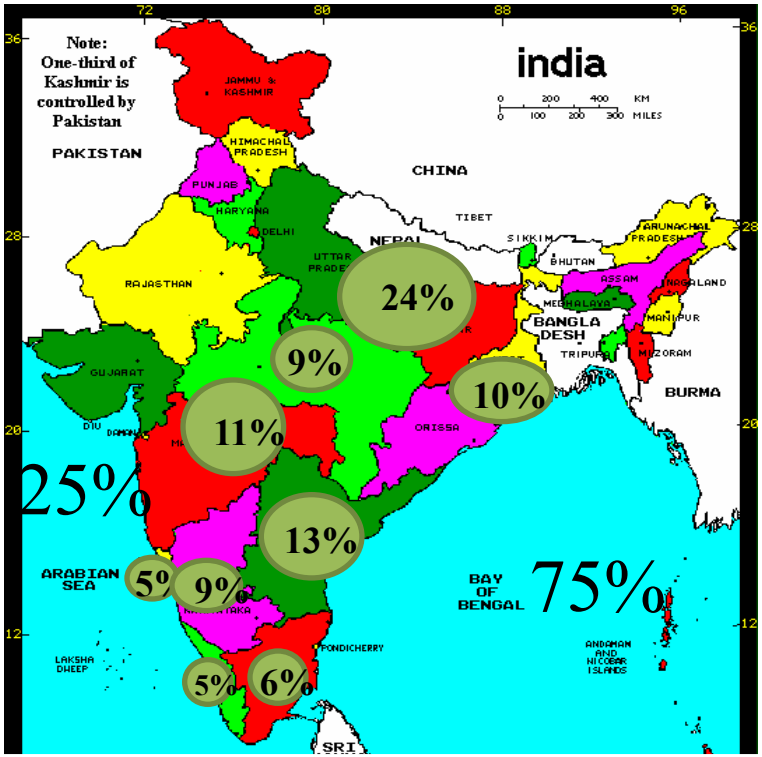


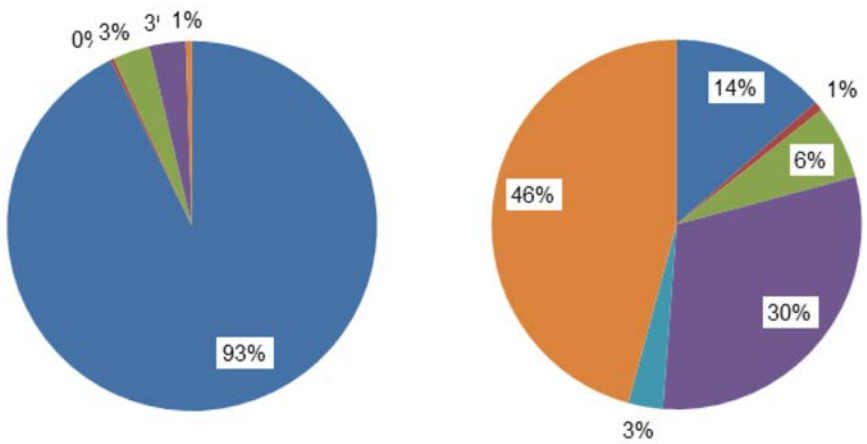




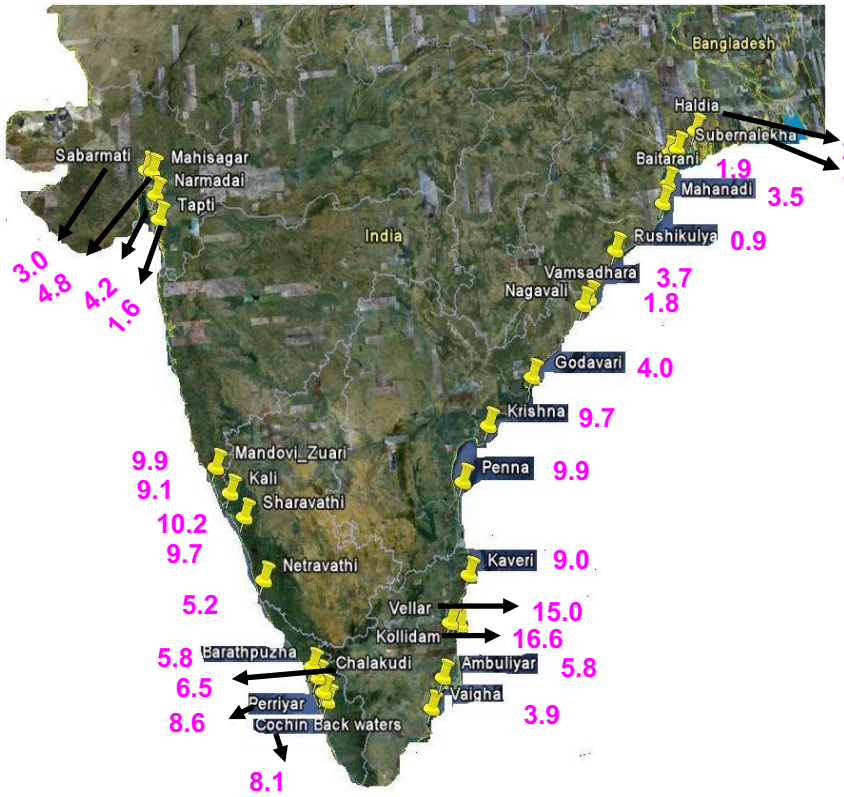
SIP group

Fertilizers may modify composition of plankton





$\delta^{15}N_{PN}$ (per mil)



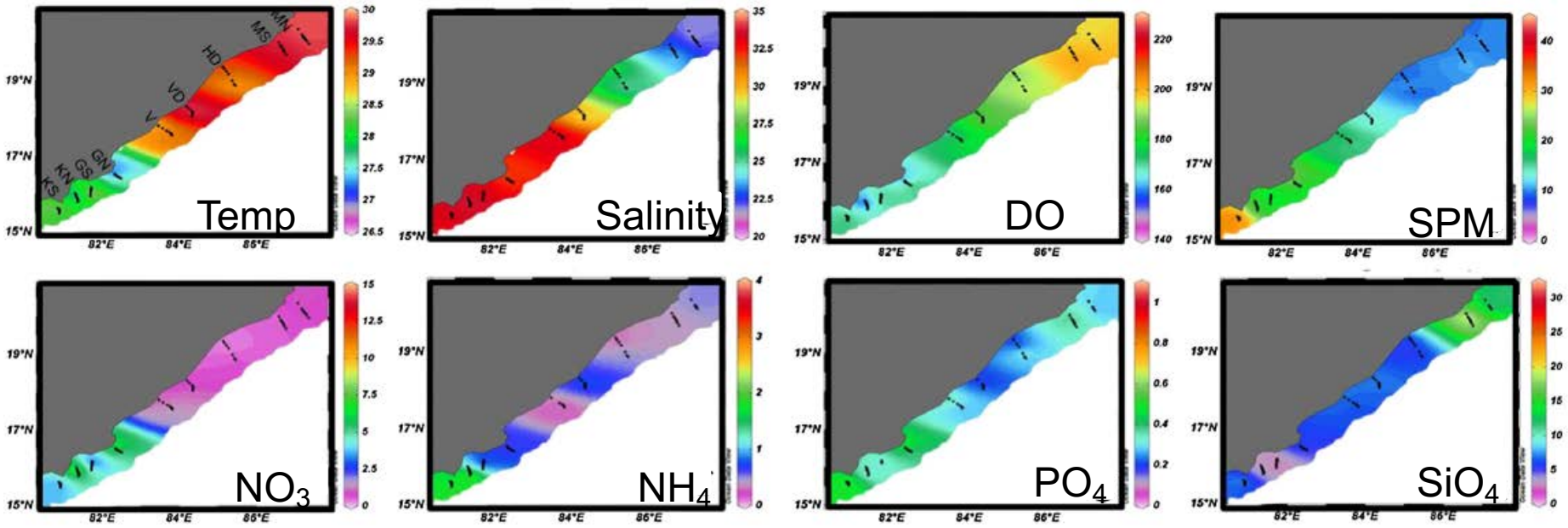
Mean

2.9

8.8

- Bacillariophyceae
- Dinophyceae
- Chlorophycaea
- Cynophyceae
- Cryptophycaea
- Euglenophyceae

Coasts do not receive much nutrients

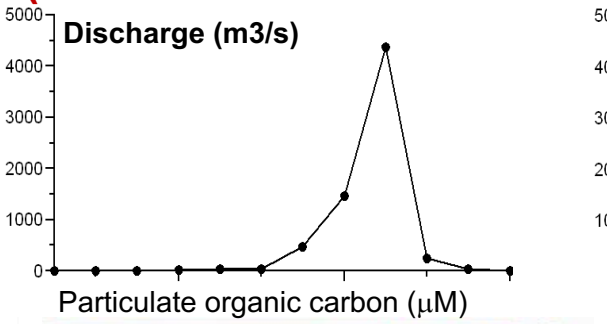


Only <5% of the riverine nutrients are reaching to the Indian Coastal waters
Krishna et al., GCA, 2016

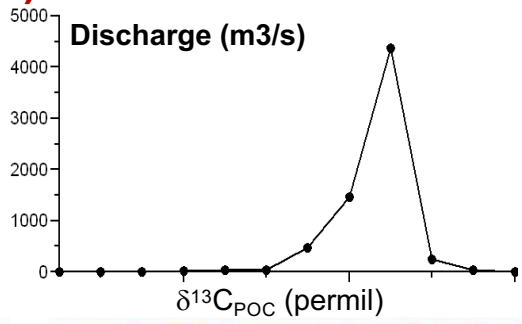
Discharge turns net autotrophy to heterotrophy

(Off Godavari river mouth)

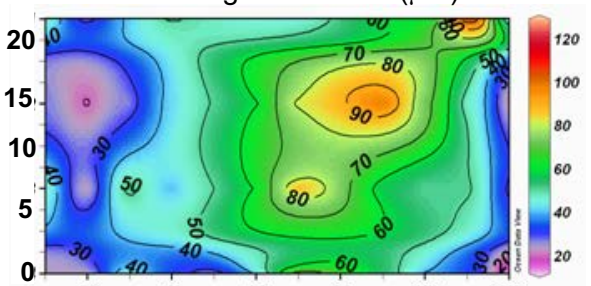
Enhanced suspended load decreases production & Increased DOC load Increases heterotrophic Activity resulting in turning Of net autotrophy to net Heterotrophy and sink to Source of CO_2 to the atmosphere



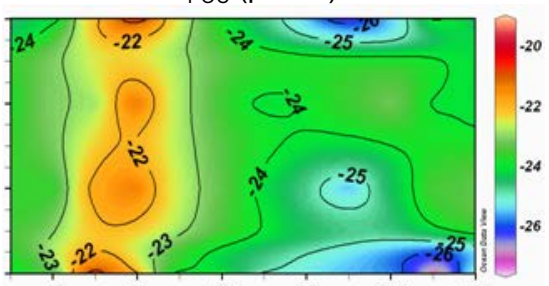
Particulate organic carbon (μM)



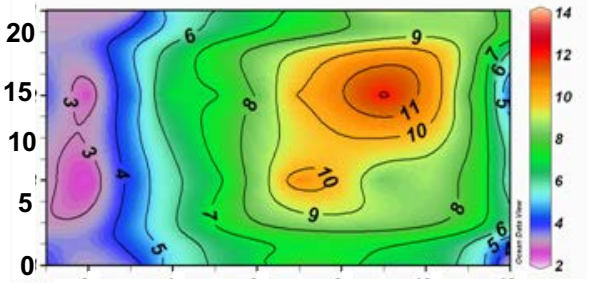
$\delta^{13}C_{POC}$ (permil)



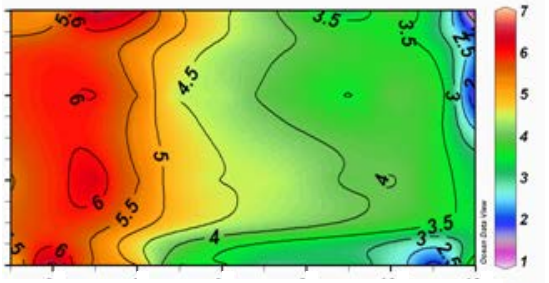
Particulate organic nitrogen (μM)



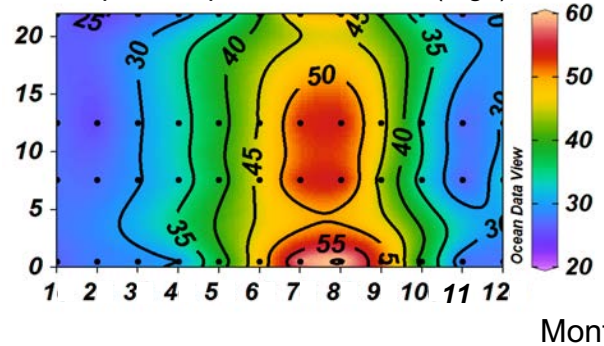
$\delta^{15}N_{PN}$ (permil)

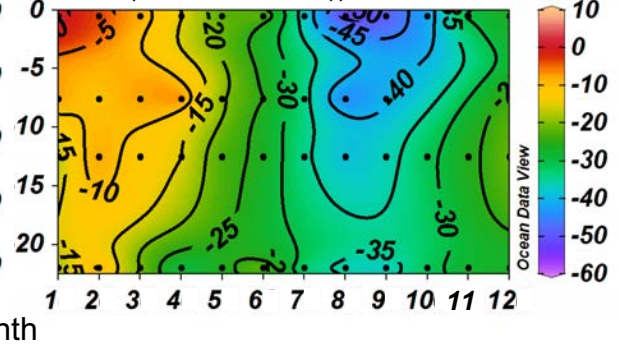


Suspended particulate matter(mg/l)



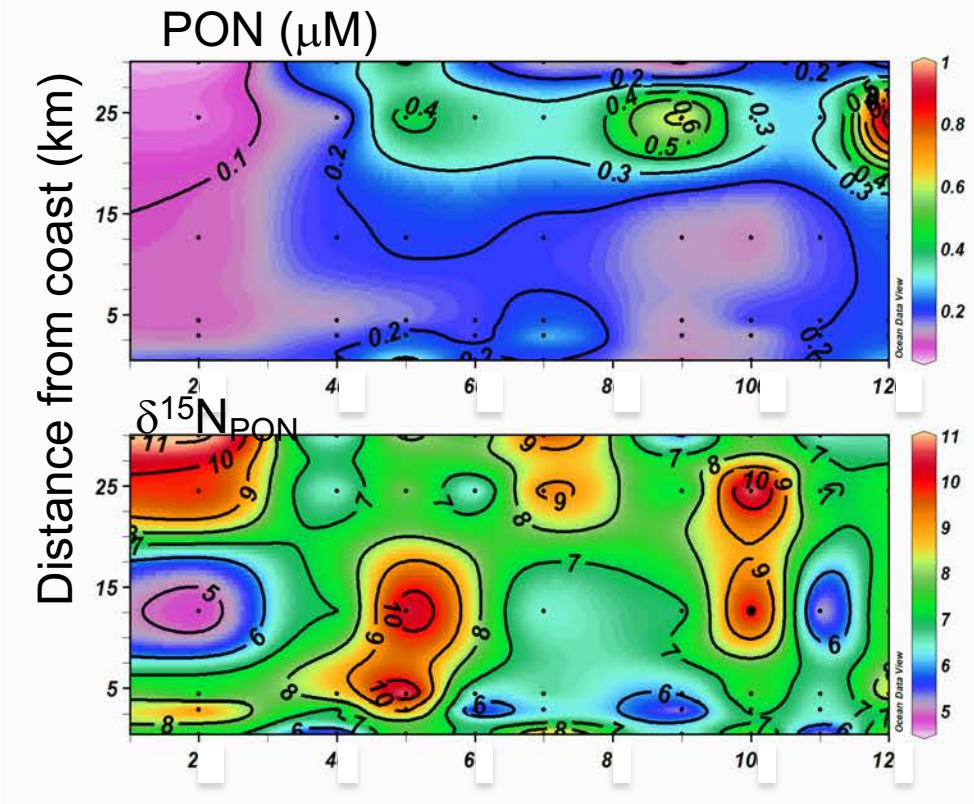
NCP (mmol O2/m2/d))





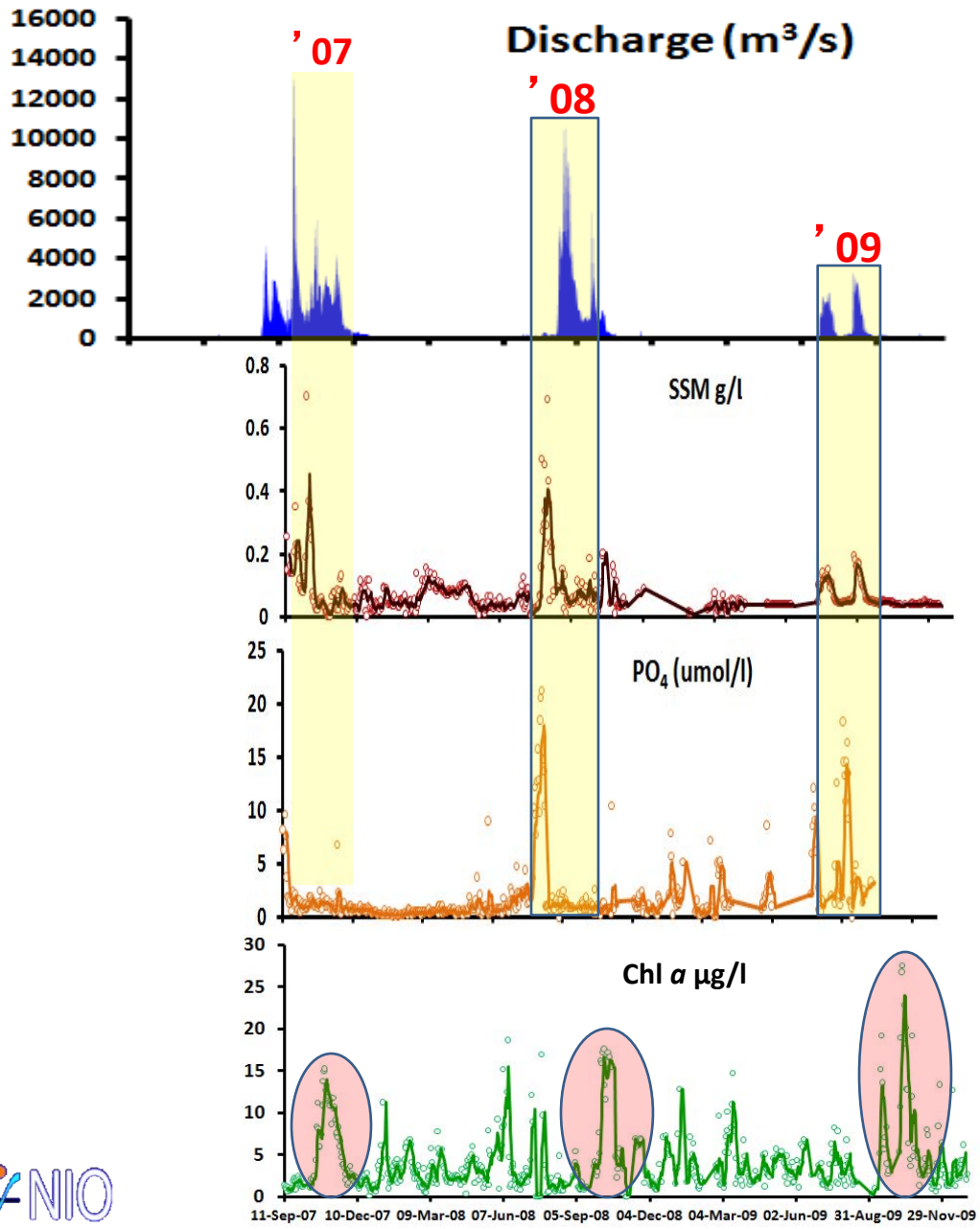
Month

No traces of anthropogenic nutrients in the coastal waters



Isotopic composition
Of nitrogen in POM
Suggests in situ nutrients
Supported plankton
Production in the
Coastal Bay of Bengal
No significant signals of
Either atmospheric or
Anthropogenic nutrients

Modification of discharge enhances blooms in the estuaries

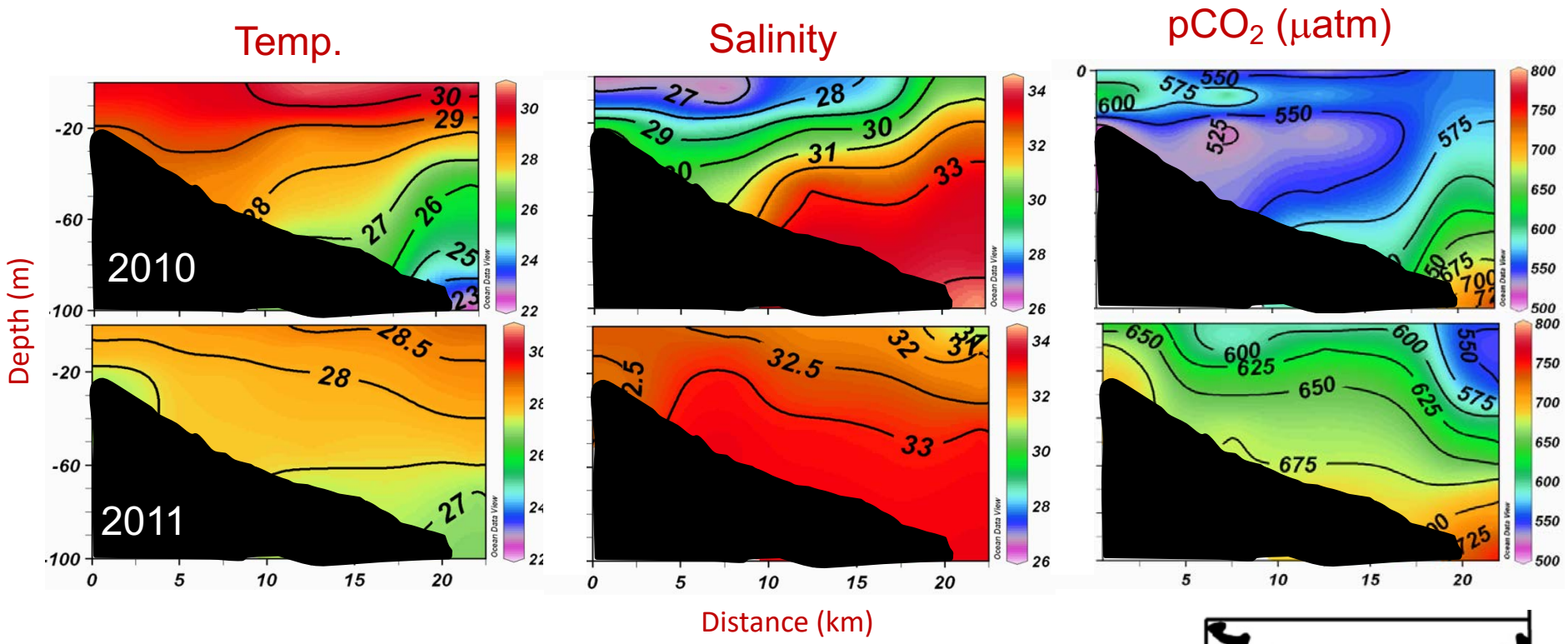


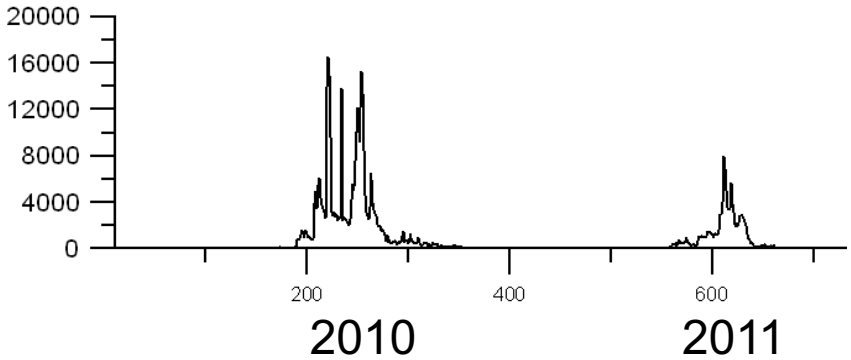
Reduced river discharge
Enhances stratification
And decreases suspended
Load leading to formation
Of phytoplankton blooms
And undersaturation of
Dissolved oxygen

NIO

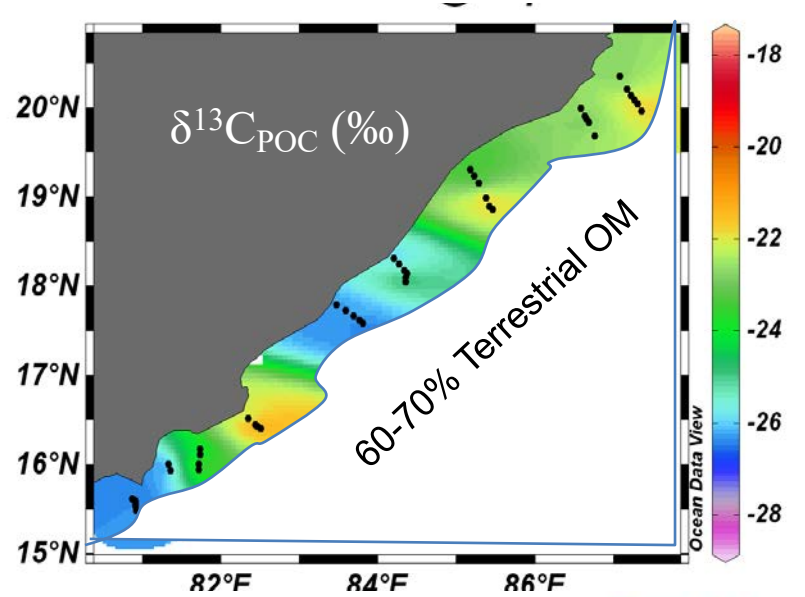
Reduced discharge enhances coastal upwelling

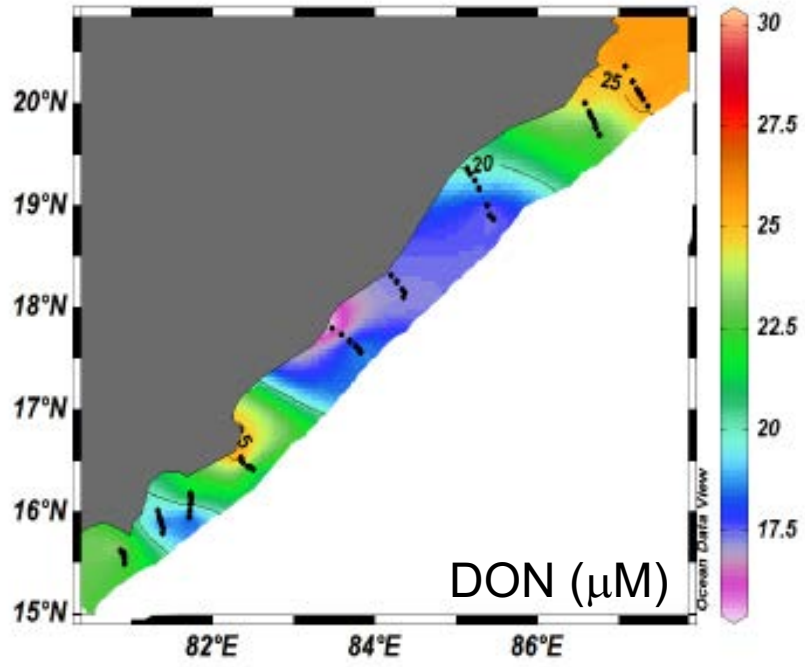
Off Godavari river mouth



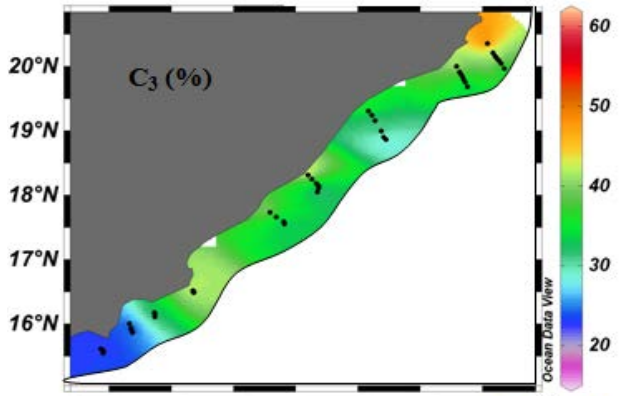


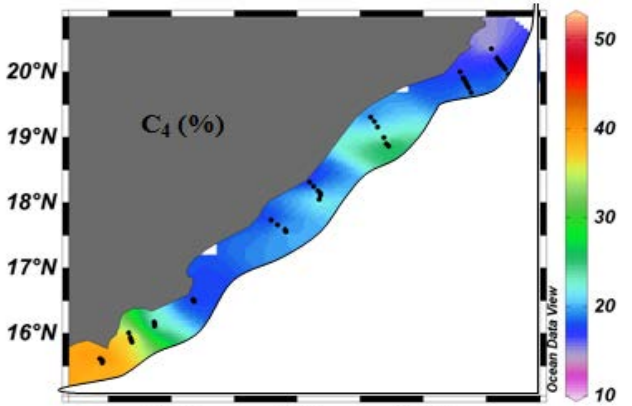
Role of terrestrial OC and N on plankton is unknown

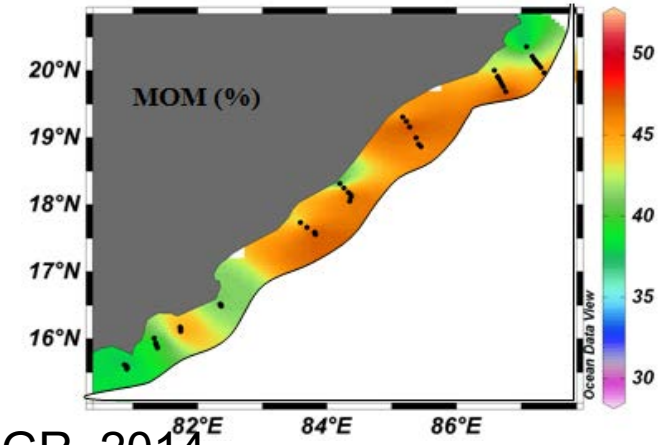




Use of organic Nitrogen as Alternative Source of Nutrient is unclear

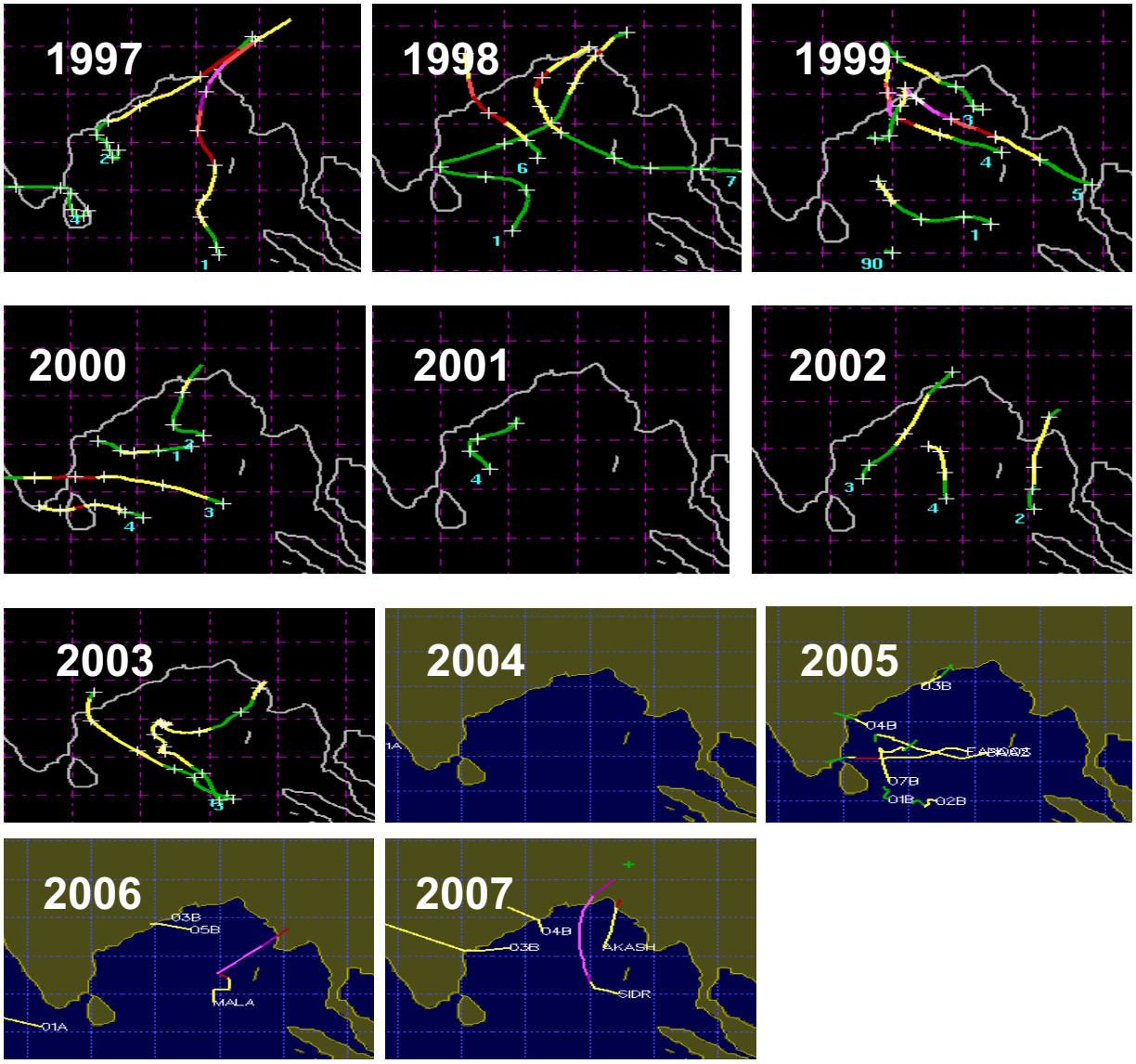






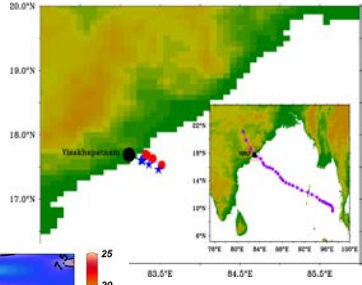
Krishna et al., JGR, 2014

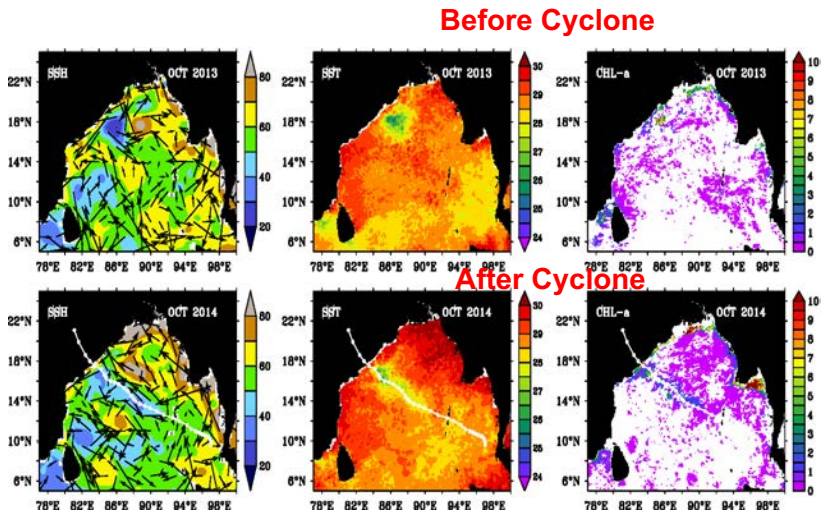
Perennial occurrence of cyclones and depressions

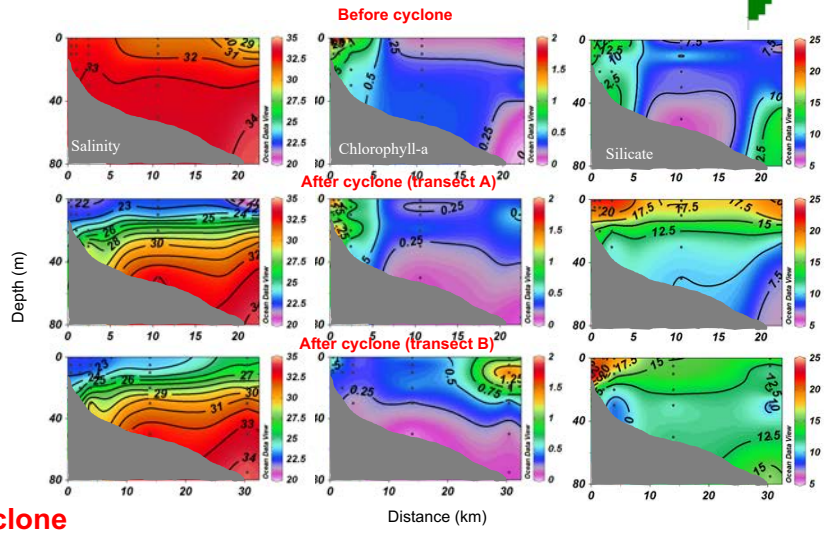


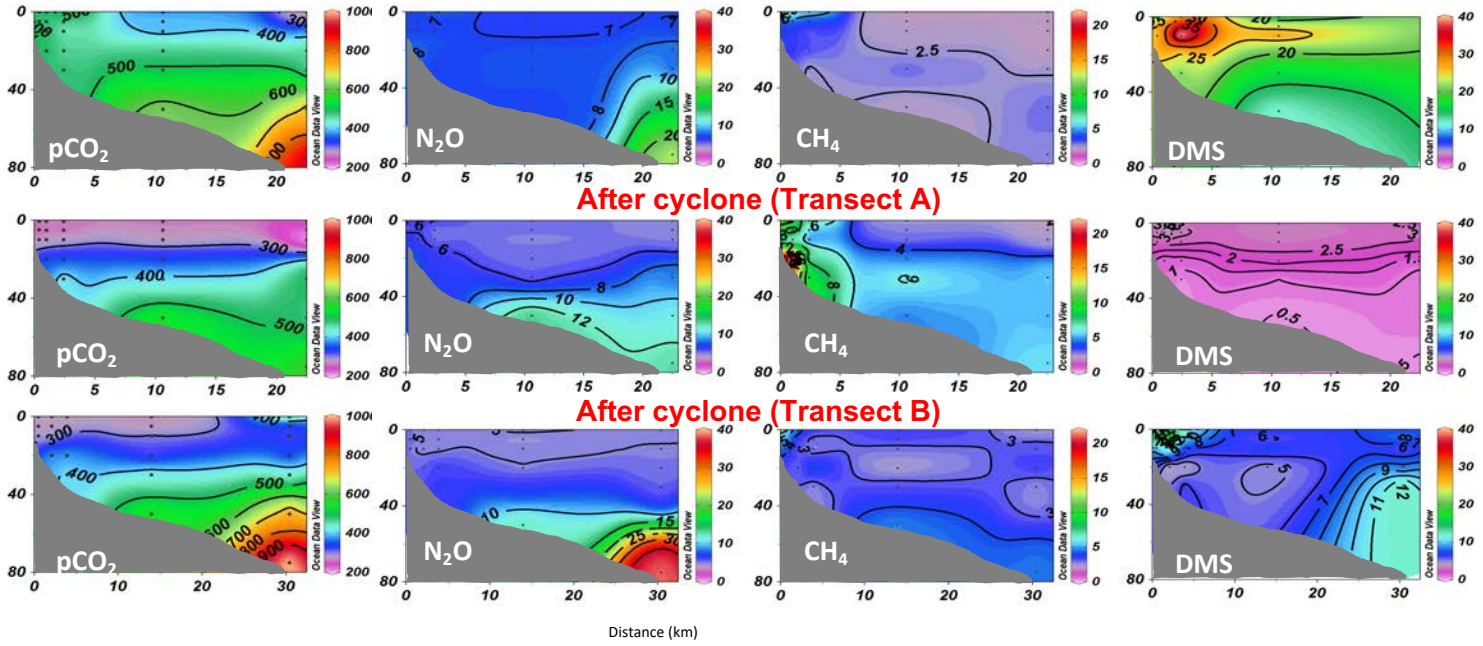
Source : http://www.weather.unisys.com

Cyclones do not increase all trace gases fluxes



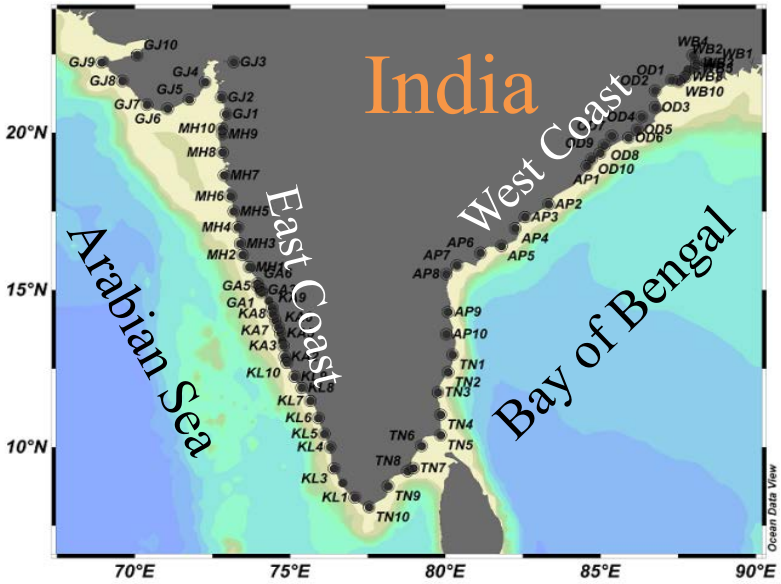


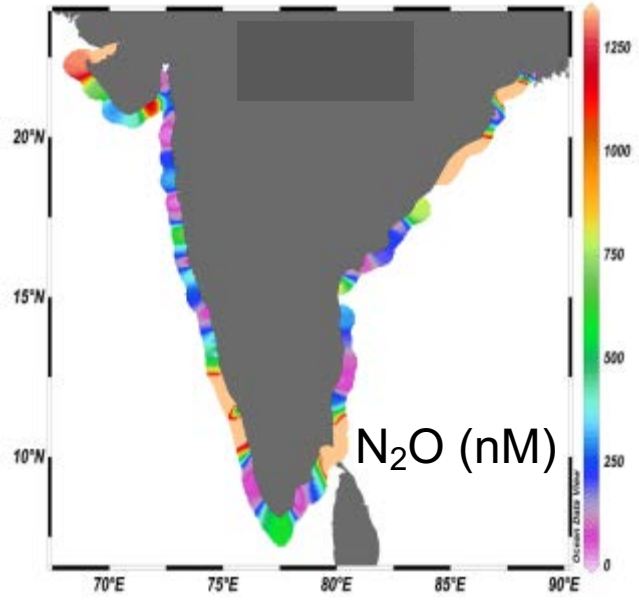


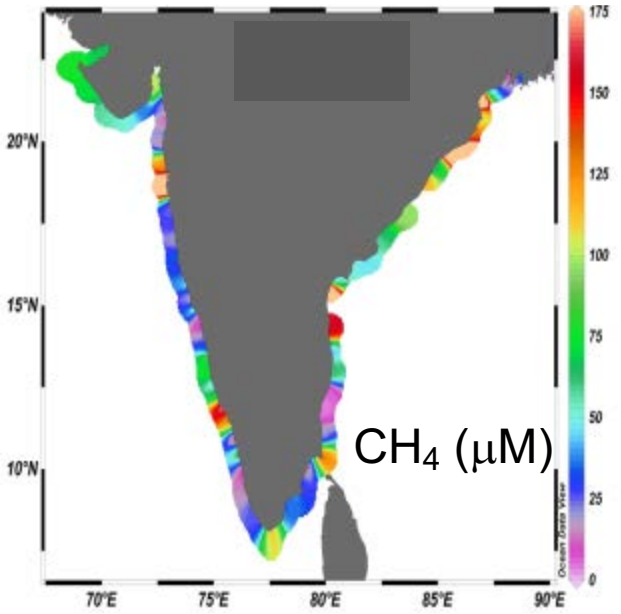


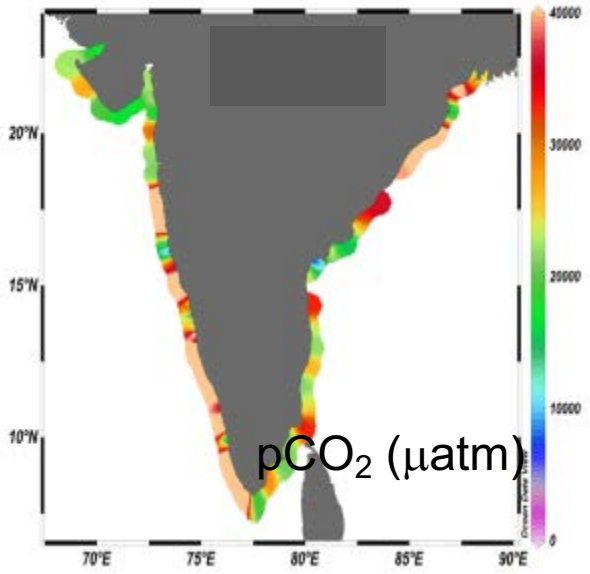
Decrease in Fluxes of CO2, N2O and DMS But increase In CH4

High trace gases levels In the ground water









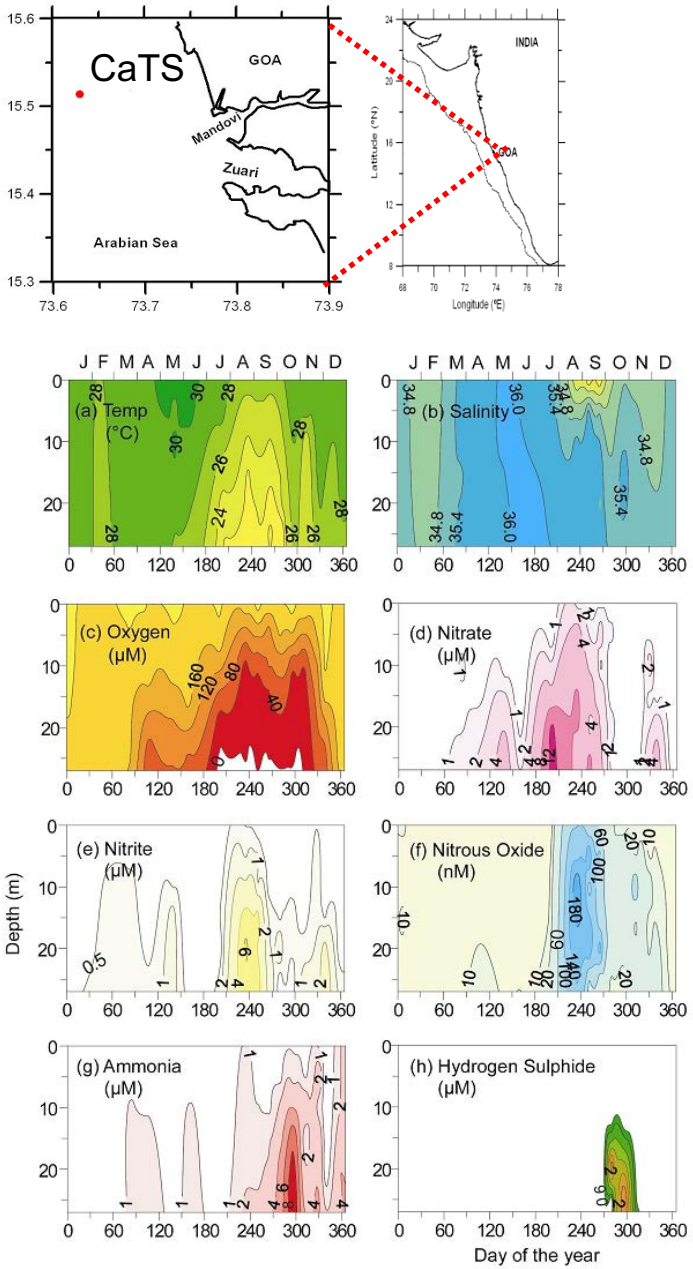
Contribution to coastal trace gases fluxes are unknown

Fluxes of trace gases

Region	CO_2	N_2O	CH_4	DMS
Estuaries	(10^{12} g y^{-1})		(10^{7} g y^{-1})	
East coast	1.27	0.82	0.20	1.80
West coast	0.69	1.04	8.43	0.80
TOTAL	1.96	1.86	8.63	2.60
Coastal region (10^{12} g y^{-1})				
Bay of Bengal	1.30	-0.03	0.08	0.04
Arabian Sea	5.03	0.33	0.09	0.006
TOTAL	6.33	0.30	0.17	0.046

Oxygen Minimum Zones along the Indian coasts

SEASONAL HYPOXIA OVER WESTERN INDIAN SHELF

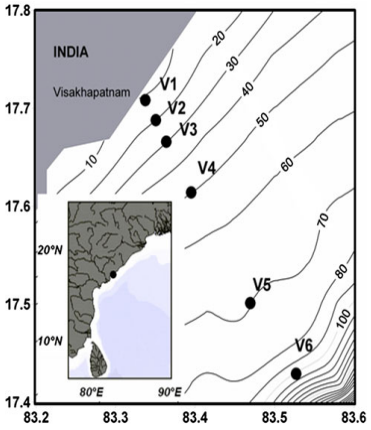


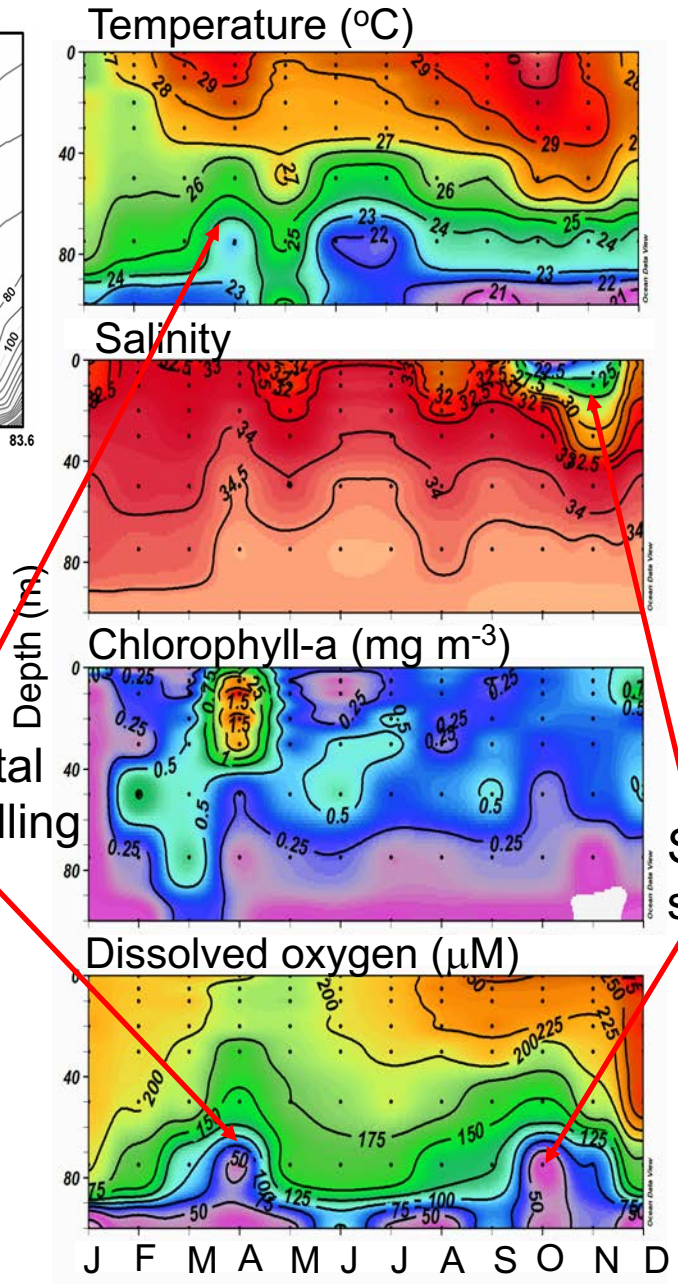
Seasonal strong upwelling and weak salinity stratification leads to formation of hypoxia/anoxia along the west coast of India

Occurrence of denitrification and sulphate reduction were found resulting in accumulation of H_2S, NH_4^+ and N_2O

Naqvi et al., 2006

SEASONAL SUBOXIA OVER EASTERN INDIAN SHELF





Coastal upwelling

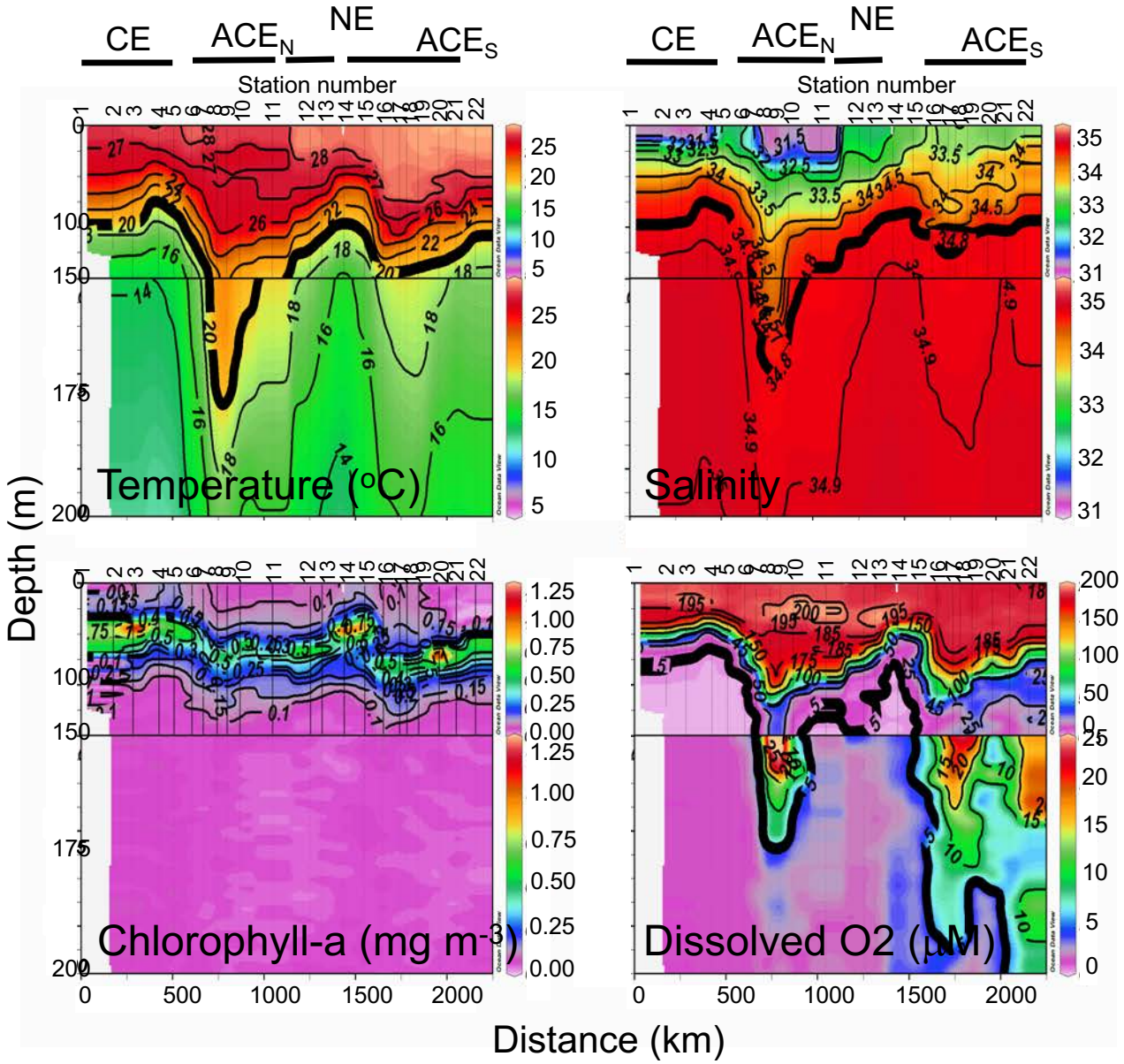
Salinity stratification

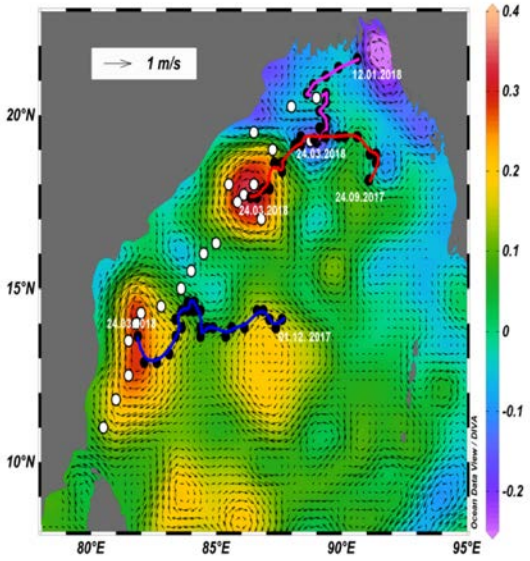
Seasonal <u>weak</u> upwelling and <u>strong</u> salinity stratification leads to formation of suboxic conditions along the west coast of India

Occurrence of denitrification and sulphate reduction were **NOT** found due to weaker OMZ and persistent for shorter period

Sarma et al., 2013a,b; 2018

EDDIES MODIFY OMZ IN THE BAY OF BENGAL





Oxygen minimum zone intensifies Under the cyclonic eddy due to Enrichment of surface waters with Nutrients due to divergence leading To increase in primary and export Production

Weakening of oxygen minimum zone Is observed under the anticyclonic Eddy due to convergence of upper Ocean and injection of oxygen to OMZ

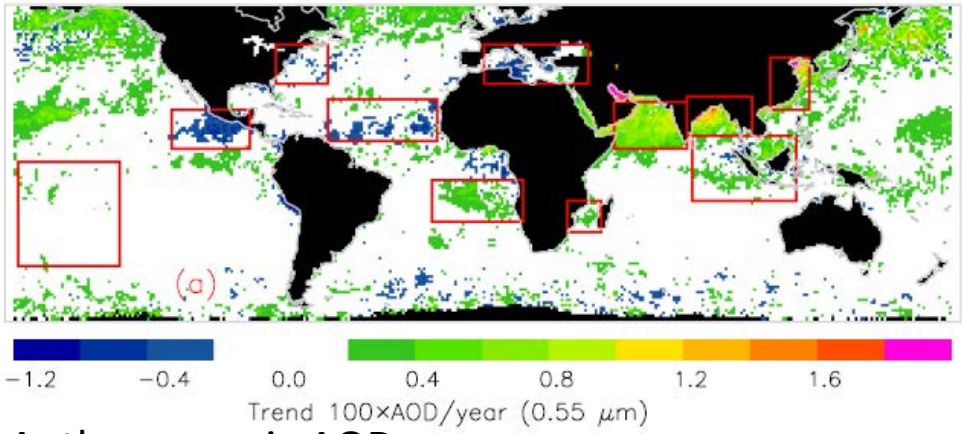
Sarma et al., 2018

Atmosphere-Ocean Interactions on BCG

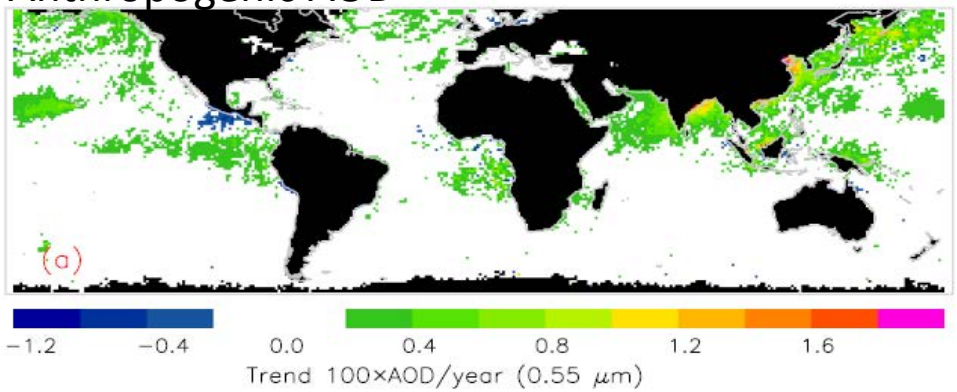
A decadal regional and global trend analysis of the aerosol optical depth using a data-assimilation grade over-water MODIS and Level 2 MISR aerosol products

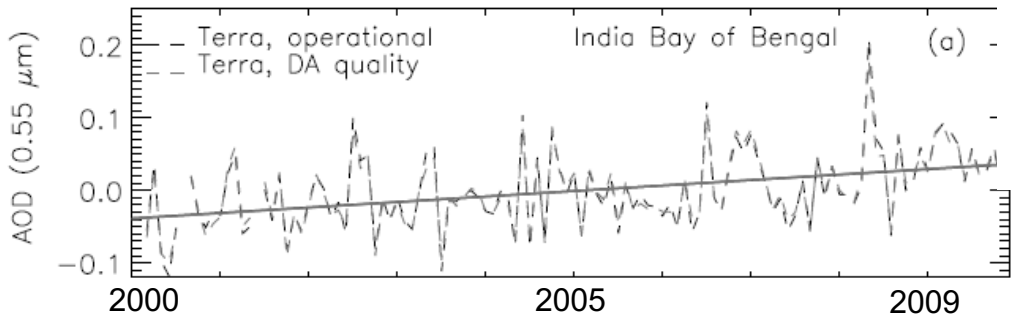
Atmospheric Chemistry and Physics

AOD



Anthropogenic AOD



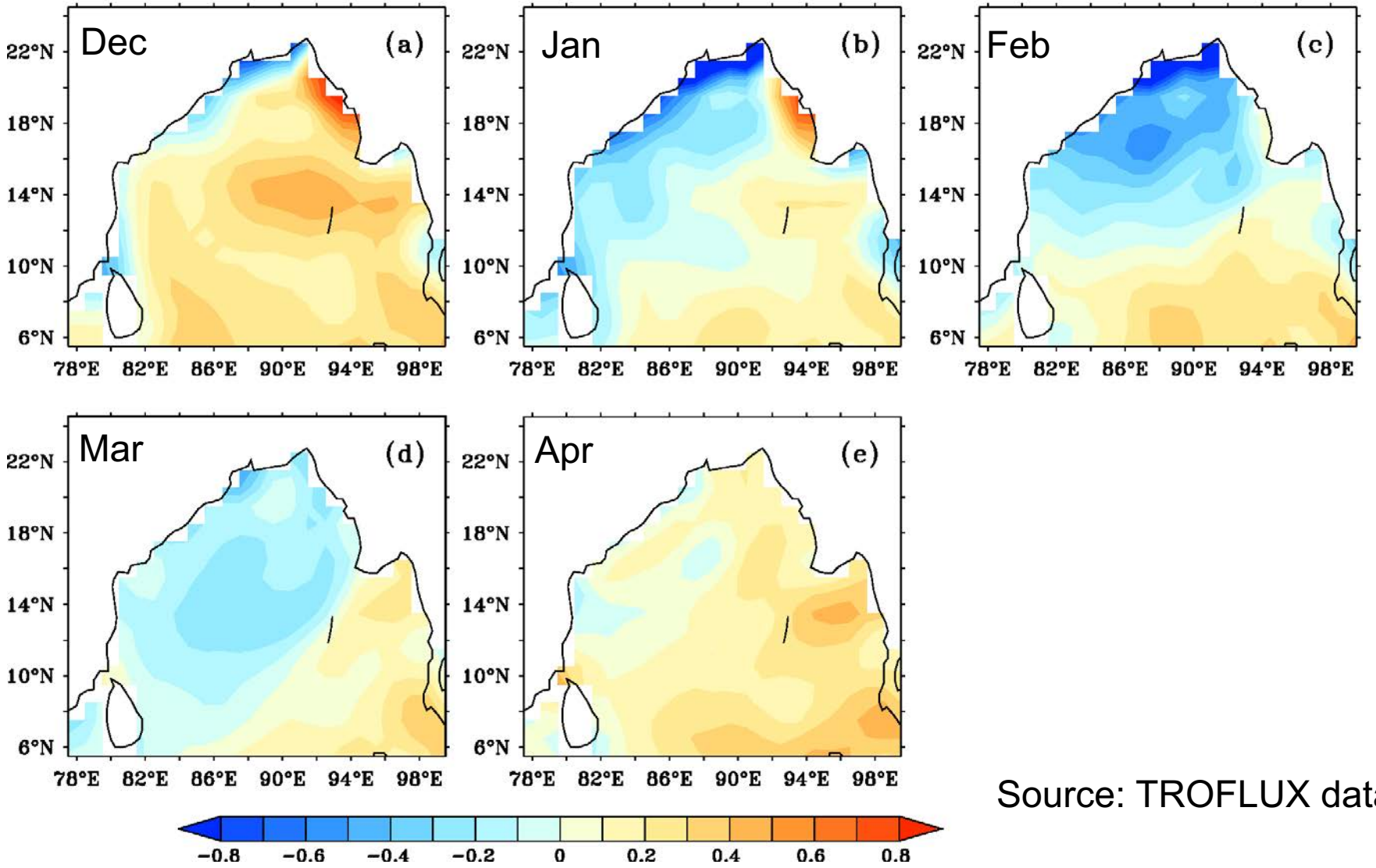


10 years AOD trend analysis (2000-2009)

	Latitude (°)	Longitude (°)	Slope AOD/ per decade
Global Oceans			0.010
Africa (NW Coast)	8° N–24° N	60° W–18° W	−0.006
Africa (SE Coast)	27° S–15° S	32° E–45° E	0.017
Africa (SW Coast)	23° S–7° S	20° W–15° E	0.016
Arabian Sea	5° N–23° N	50° E–78° E	0.065
Central America	5° N–20° N	120° W–90° W	−0.016
Coastal China	20° N–40° N	110° E–125° E	0.069
Indian Bay of Bengal	10° N–25° N	78° E–103° E	0.076
Mediterranean Sea	30° N–45° N	0° E–40° E	−0.009
North America (E Coast)	30° N–45° N	80° W–60° W	−0.008
Southeast Asia	15° S–10° N	80° E–120° E	0.014

4. Our study finds large AOD increases over Coastal China, Indian Bay of Bengal, and Arabian Sea regions for the past ten years with a 95% confident level. Especially over the coastal India region, the increase in AOD indicates a worsening scenario to the already heavily polluted air, and could have a strong impact on local regional climate. Further analysis reveals that the increasing trends are caused mostly by the increased intensity of anthropogenic aerosol events for coastal China and the Bay of Bengal regions, whereas the Arabian Sea regions experience a stronger influence from dust events.

Monthly mean SST difference between (2002-2012) and (1982-1991)



Source: TROFLUX data

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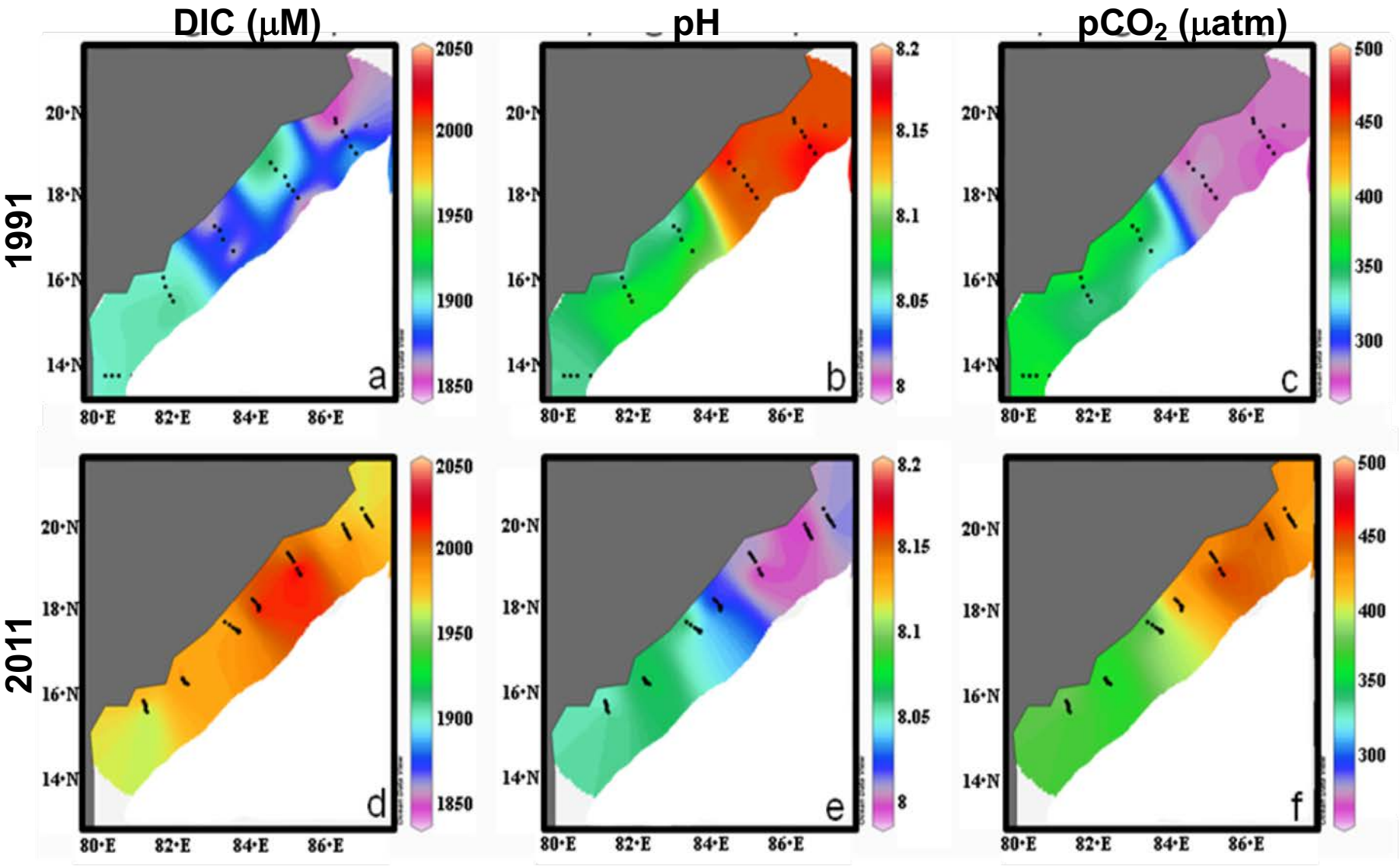
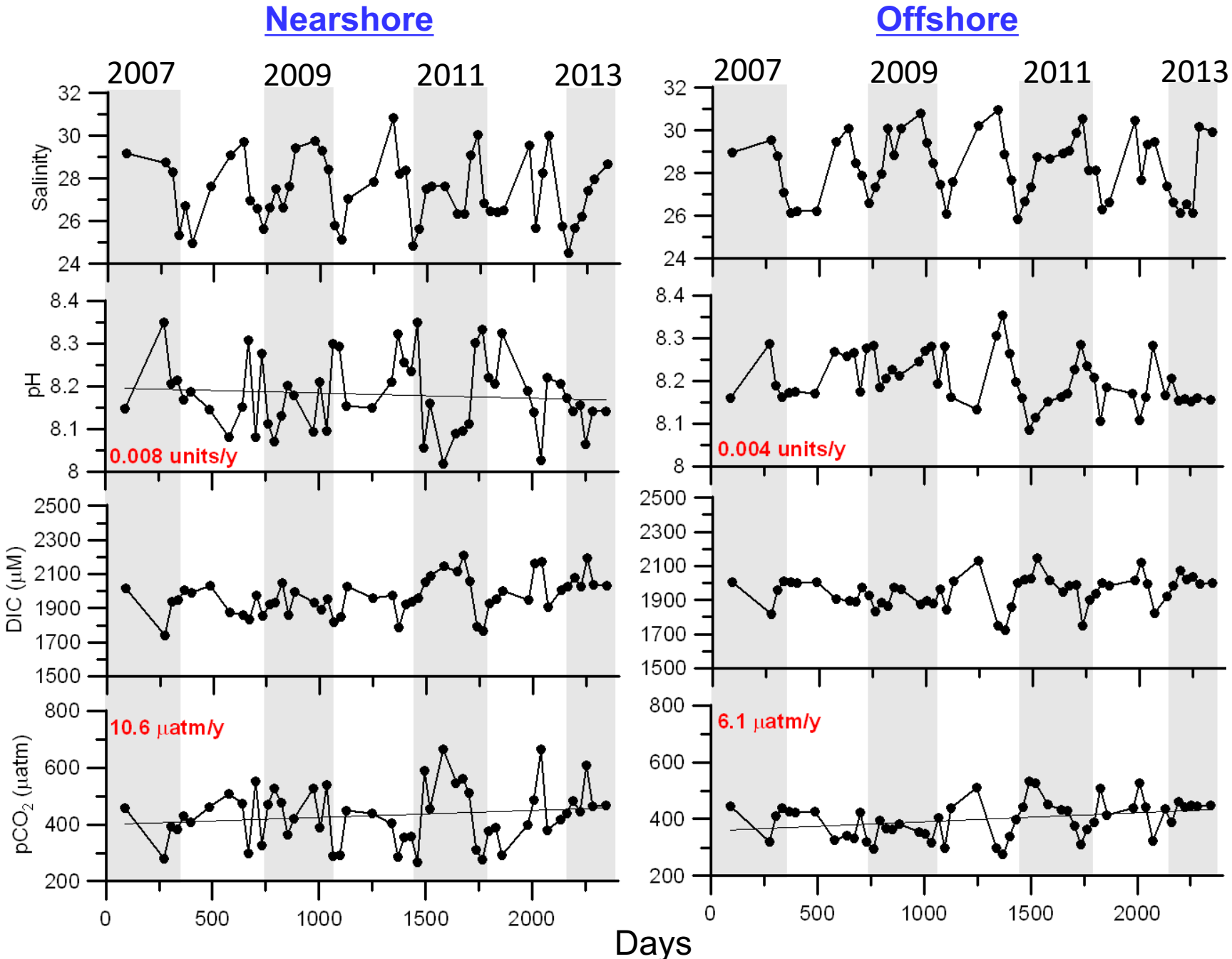
Variations in inorganic carbon system in past 2 decades



Long-term variations in inorganic carbon components at VOTS



Rates of changes in the world ocean

Region	DIC (μmol kg^{-1} y^{-1})	pH (y^{-1})	pCO_2 (μatm y^{-1})	Reference
N. Pacific (HOTS)	1.2±0.1	-0.0017±0.0001	2.5±0.1	*Dore et al.*, 2003, *Keeling et al.*, 2004; *Church et al.*, 2013
N. Atlantic (BATS)	1.4±0.2	-0.0018±0.0001	1.7±0.3	*Bates*, 2007; *Schuster et al.*, 2009; *Astor et al.*, 2013
S. Indian	---	---	2.1±0.2	*Metzl*, 2009
SWCBB 1991-2011 2005-2013	 1.6±0.4 2.3±0.3	 -0.0019±0.0001 -0.0022±0.0001	 1.5±0.8 2.2±0.6	This study
NWCBB 1991-2011 2005-2011	 8.2±0.5 ---	 -0.007±0.0001 -0.005±0.0001	 6.7±0.4 5.4±0.3	This study

Sarma et al., Tellus B 2014

Ongoing efforts and future plans

- Proposed to set up 6 coastal moorings along the Indian coast to monitor at high resolution under MOSAIC program

- Initiated atmospheric dust collection at various stations along the Indian Coasts

- Mission – Submarine Ground Water (SGD) is initiated

- Mesocosm experiments are being conducted to understand the controlling processes

- Numerical models are being developed to examine changes of OMZ and trace gases fluxes and nutrient inputs to the Indian coasts

Thank You