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CARBON CYCLE & OCEAN MODELLING

Biogeochemical cycling of carbon, oxygen and nitrogen and trace elements (phosphorous, silica, iron etc) plays a key role in climate change. The next IPCC report is expected to feature a detailed analysis of biogeochemistry-climate feedback in its assessment of future climate. Regional estimates of the carbon and nitrogen fluxes between land, ocean and atmosphere need to be robust and accurate for acceptance by the international community in compliance to commitments. For the COP 21 Paris accords, India has committed to 35-38% improvement in emission intensity and creating an additional forest sink of 0.6-0.8 GTC/yr (2.5-3 $GTCO_2$/yr). This calls for generation of data of the highest quality which are traceable to international standards and adoption of state-of-the-art methodologies to extract robust information from this data.

At CSIR-4PI, our approach to estimate the fluxes of carbon, nitrogen and oxygen is (i) to model the sources, sinks and transport of biogeochemical components in detail, by integrating complex models of biogeochemical cycles with general circulation models and data and (ii) assimilate greenhouse gas measurements of the highest quality which will be generated in-house, into an inverse transport model to yield robust regional carbon fluxes. Some of these studies are carried out under SIBER Programme funded by MoES and a few project proposals related to estimation of Green House Gas Fluxes have been submitted to CSIR, MoES and MoEF&CC for funding.

Key outcomes of this study will include identification of specific carbon and nitrogen sinks/sources or sequestering processes which might mitigate the factors contributing to the global warming, and the estimation of marine living resources, extent of ocean acidification, and oceanic health which is affected by anoxia, hypoxia and eutrophication.

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1.1 Simulating CH_4 and CO_2 over South and East Asia using the zoomed chemistry transport model LMDzINCA

The increasing availability of atmospheric measurements of greenhouse gases (GHGs) from surface stations can improve the retrieval of their fluxes at higher spatial and temporal resolutions by inversions, provided that chemistry transport models are able to properly represent the variability of concentrations observed at different stations. South and East Asia (SEA) is a region with large and very uncertain emissions of carbon dioxide (CO_2) and methane (CH_4), the most potent anthropogenic greenhouse gases. Monitoring networks have expanded greatly during the past decade in this region, which should contribute to reducing uncertainties in estimates of regional GHG budgets. In this study, we simulate concentrations of CH_4 and CO_2 using a zoomed version of the global chemistry transport model LMDzINCA during the period 2006–2013. The zoomed version has a fine horizontal resolution of ~0.66° in longitude and ~0.51° in latitude over SEA and a coarser resolution elsewhere. The concentrations of CH_4 and CO_2 simulated from the zoomed model (abbreviated as 'ZASIA') are compared to those from the same model but with a uniform regular grid of 2.50° in longitude and 1.27° in latitude (abbreviated as 'REG'), both having the same vertical 19 sigma pressure levels and prescribed with the same biogenic and anthropogenic fluxes. Model performance is evaluated for annual gradients between sites,

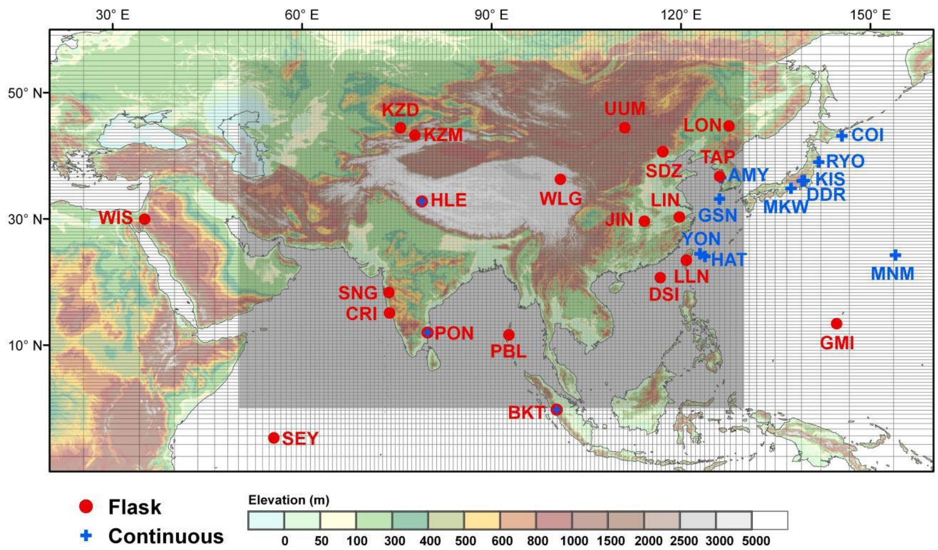

Figure 1.1 Map of locations of stations used in this study. The zoomed grid of the LMDz-INCA model is also plotted with the NASA Shuttle Radar Topographic Mission (SRTM) 1km digital elevation data (DEM) as background (http://srtm.csi.cgiar.org). The grey shaded area indicates the region with a horizontal resolution of 0.66° × 0.51°. The red close circle (blue cross) represents the atmospheric station where flask (in-situ) measurements are available and used in this study

seasonal, synoptic and diurnal variations, against a new dataset including 30 surface stations (of which Hanle, Pondicherry and Port Blair are run by CSIR-4PI) over SEA and adjacent regions. Our results show that, when prescribed with identical surface fluxes, compared to REG, the ZASIA version moderately improves the representation of CH_4 mean annual gradients between stations as well as the seasonal and synoptic variations of this trace gas within the zoomed region. This moderate improvement probably results from reduction of representation errors and a better description of the CH_4 concentration gradients related to the skewed spatial distribution of surface CH_4 emissions, suggesting that the zoom transport model will be better suited for inversions of CH_4 fluxes in SEA.

1.2 Modelling and simulation of subsurface oxygen distribution in the north Indian Ocean

Numerical Simulations of the contemporary three-dimensional prognostic marine biogeochemical model (TOPAZ having more than 25 tracers) are carried out at CSIR-4PI in the global domain for climatological and interannual variability. Model is able to capture all the Oxygen Minimum zones (OMZ) in the global ocean and OMZ extends between 150 to 1200m depth in the Arabian Sea (AS) north of 12° N. Spatial extent of suboxic zone (Oxygen < 6 mmol/m3) shows significant interannual variability. Simulations of the denitrification flux in the Arabian Sea show that (a) it varies between 20 and 40 TgN/yr, comparable with estimates based on nitrate deficit and (b) it depends on the PP and volume of OMZ.

1.3 Effect of iron limitation on primary productivity and carbon flux in the Arabian Sea

There have been many studies on Iron as a limiting factor for productivity in the World Ocean but only a few studies have been done in the Arabian Sea (AS) on Iron limitation. Present study is based on the numerical simulations of a marine biogeochemical model (TOPAZ) in the global domain. Several numerical experiments were carried out to investigate the sensitivity of one of the parameters related to Fe limitation, namely, $(Fe:N)_{irr}$ on Primary productivity (PP), Chlorophyll (Chl), Nitrate (NO_3), pCO_2 and carbon flux in different regions of the AS. Of these two experiments, namely, Exp (a), the control case and Exp (c), where $(Fe:N)_{irr}$ is decreased are highlighted. If $(Fe:N)_{irr}$ is high, there is Fe limitation, and when $(Fe:N)_{irr}$ is decreased Fe limitation is reduced.

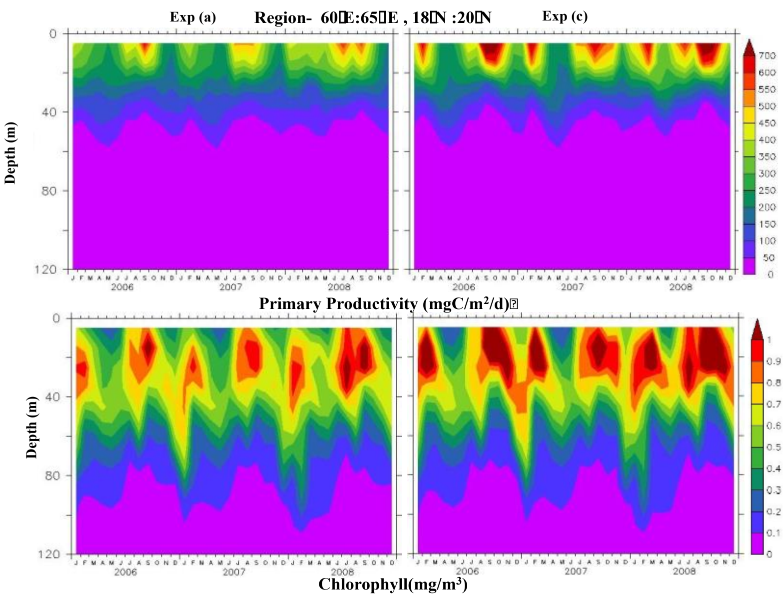

Fig.1.2 Depthwise variation of Primary Productivity ($mgC/m^2/d$) and Chlorophyll (mg/m^3) during 2006 to 2008 in AS for two model simulations

Detailed analysis of the two numerical simulation results on PP, Chl and Nutrients are carried out for different regions in AS during El Nino (2007) and La Nina (2008) years. Depthwise variation of PP and Chl during 2006 to 2008 shows that PP and Chl are higher during 2006 and 2008 compared to 2007 in all the regions in west and north-west AS. Depthwise variation of PP &Chl, during 2006 to 2008 for a region in west AS are shown in Figure 1.2. It is noticed that PP and Chl are higher (Figure 1.2) and Nitrate and Ammonia are lower (not shown) for Exp(c) in the upper 100m when compared to Exp(a). Also, PP and Chl are higher during 2008 compared to 2007 since 2008 is influenced by La Nina event. Also, monthly variation of pCO_2 and Carbon Flux (not shown) from ocean to atmosphere during 2006 to 2008 for the same region shows that pCO_2 and Carbon Flux from ocean to atmosphere for Exp(c) are lower since PP is high. Also, pCO_2 and carbon flux are lower during 2007 compared to 2006 and 2008 since 2007 is influenced by El Nino event. Thus model results show that the trace element iron plays a critical role in nutrient utilization, phytoplankton growth and therefore the uptake of carbon dioxide from the surface waters of the global ocean.

1.3 Calibration of GHG instruments

The calibration facility for GHG measurements at Hoskote was extensively used the past year by CSIR-4PI to tie up the Picarro instruments at Hanle, Pondicherry and Hoskote and the LGR instrument at the last site with NOAA primary standards. The procedure is completely automated to follow the protocols of NOAA and ICOS Europe where six cylinders of gaseous mixtures of CO_2, CH_4, CO and N_2O spanning a large range were used in a predetermined sequence. National Atmospheric Research Laboratory, Gadanki used the facility to calibrate its Picarro G2401 instrument and make its measurements traceable to primary NOAA standards.