Editorial

Oceans constitute a massive reservoir of carbon dioxide, about 50 times larger than the atmosphere. Even minor variations in its carbon content therefore affect the atmospheric inventory significantly. The Joint Global Ocean Flux Study (JGOFS) was accordingly designed as the Core Project aimed at addressing the biogeochemistry of carbon in the ocean, particularly the upper ocean biogeochemical processes which by mediating exchanges between the ocean interior and the atmosphere, lead to climate change. Such studies are expected to yield information on the magnitudes of spatial and temporal variabilities, and exchanges among various terrestrial reservoirs. The main objectives of this project are to determine and understand the factors controlling the time-varying carbon fluxes in the ocean, to evaluate related exchanges with other reservoirs, and to use this knowledge in developing predictive models of the earth system response to anthropogenic perturbations.

JGOFS has been executed in two modes since its inception in 1988. Measurements of time-series at fixed locations and intense process studies in some regions of global biogeochemical significance. the regions identified for the latter studies were the North Atlantic (1989–92), the North Pacific (1998–2000), the Equatorial Pacific (1991–95), the Arabian Sea (1992–1997) and the Southern Ocean (1990–1998). The Arabian Sea Process studies were carried out by scientists from several countries (France, Germany, Netherlands, UK and USA) including India, Pakistan and Oman.

The tropical Arabian Sea has been regarded as a complex arena of dimly understood biogeochemical processes that have significant global implications. For instance, the Arabian Sea makes a disproportionately large contribution to denitrification in the world oceans and maintains super saturation of carbon dioxide in its surface waters round the year. Yet, details of the processes responsible for sustaining these states still remain to be elucidated. Is it physics or biology? To examine these questions in the light of newly acquired information from the Arabian Sea process study, the JGOFS organized an International Symposium on **Biogeochemistry of the Arabian Sea** at Bangalore during January 18–20, 1999, followed by a week long training course on **Modelling and Synthesis**. This issue of the *Proceedings of the Indian Academy of Sciences* (*Earth and Planetary sciences*) contains a set of eleven papers selected from those presented at this symposium.

Fundamental to the driving of chemical and biological processes in the upper ocean is circulation that is, in turn, controlled by density gradients. The two key parameters governing these differences are temperature and salinity. High resolution sea surface temperature fields offer valuable insights into this global surface phenomena. **Ajoy Kumar et al.** provide a critical analysis of the use of the global Pathfinder Algorithm under regional conditions. They make use of extensive Pathfinder Matchup Data Base (PMDB) consisting of coincident Advanced Very High Resolution Radiometer (AVHRR) and *in situ* surface data obtained from moored and drifting buoys. Of the many regions (North and South Atlantic, North and South Pacific, the Indian, Mediterranean and the Caribbean) studied, the Indian Ocean is found to have the strongest seasonal signals in SST residuals. The authors caution against an uncritical use of the satellite channel data which will be used to perform atmospheric water vapour correction, as it might lead to an underestimation of SST under strong seasonal variability. These findings are important and suggest that satellite derived SST data will have to be judiciously used in interpreting surface processes in the Indian Ocean.

Availability of nutrients together with Photosynthetically Active Radiation (PAR) fuels photosynthetic fixation of carbon in the surface ocean. **Devred et al.** provide a tool, Radiative Transfer Code, to evaluate PAR. Through their solution of radiative transfer equation in the atmosphere and the surface ocean, they show that although PAR does not depend on the cloud type, it attenuation is non-linear when the sky is cloudy. A conversion factor proposed here has been found to be useful in estimating primary production using satellite derived PAR data. Estimation of primary production based on satellite derived parameters, exemplified by Devred *et al.* will be of immense significance in understanding basin wide biogeochemical processes in the ocean.

From a study of optical measurements made on gelbstoff (dissolved yellow organic substance that absorb light) **Breves and Reuter** caution the use of absorption versus fluorescence ratio when this organic constituent varies over a small range in oceanic waters as extrapolation of a single wavelength data to other spectral regions might lead to systematic errors. This study also highlights the paucity of surface data for validating remotely sensed information.

Using the Coastal Zone Colour Scanner (CZCS) **Yapa** reports estimates of chlorophyll concentrations in excess of $0.5\,\mathrm{mg\,m^{-3}}$ in Sri Lanka waters following the southwest monsoon and emphasizes the effects of suspended solids and dissolved organic matter on CZCS signals particularly in the turbid coastal waters of the Palk Bay and the Gulf of Mannar.

Although physics largely controls the productivity pattern in the ocean, details of the mechanisms that fashion variability in productivity and associated processes in the Arabian Sea are still obscure. **Prasanna Kumar *et al.*** address this issue on a seasonal basis and find that entrainment during the winter and southwest monsoons control surface production whereas surface waters remain stratified in other seasons when sub-surface chlorophyll maxima generally occur. They propose that the unrecognized high open ocean production and the subsequent sinking of organic matter in the Arabian Sea might be the cause of intense denitrification.

A puzzling question to biogeochemists has been the identification of the carbon source that supports high carbon demands of the water column denitrifiers in the Arabian Sea. An important constituent in the particulate organic carbon pool in seawater is Transparent Exopolymer Particle (TEP), which is easily hydrolysable. Studies on these substances in the open ocean are sparse and its role in carbon cycle is still unresolved. **Ramaiah *et al.*** make a comprehensive study of the importance of these substances in supporting bacterial demands during the southwest monsoon season through simultaneous measurements of carbon and bacterial parameters. Their results clearly indicate that TEP support bacterial metabolism and preliminary calculations show that TEP can sustain bacterial demands in the denitrifying layers of the Arabian Sea.

Aggregation is an important aspect of particle dynamics in aquatic environments and phytoplankton is no exception. **Kriest and Evans** present a one-dimensional model of the vertical distribution and flux of phytoplankton aggregates, with constant physical forcing. This model applied to the Arabian Sea reveals different settlement speeds for different particles. Aggregation and the sinking flux of carbon could therefore play an important role in deep sedimentation.

Having established the Arabian Sea to be a perennial source of carbon to the atmosphere, it is essential to understand the factors regulating super saturation of carbon dioxide in its surface waters. Using physico-chemical and biological data, **Sarma *et al.*** show that physical processes such as convection and upwelling are important during the monsoon seasons, while thermodynamics and sea-to-air exchanges become significant at other times. These results have a significant bearing on our understanding of the carbon dioxide dynamics in the upper layers of the Arabian Sea.

The study of stable isotope variations provide a potential tool for unfolding the climate change records of the past. **Muzuka** uses stable carbon isotopes to study the effects of past changes in monsoonal variability on the deposition of organic carbon on the Oman continental margin. They show that while strong upwelling resulted in the depletion of ^{13}C in organic carbon at stage 3, its low values during stages 8 and 10 appear to have been caused primarily by terrestrial inputs.

Finally, to gain an insightful understanding of the biogeochemical processes from their integral results represented in observed phenomena and to develop predictive capabilities, one must develop realistic models. A 4D space-time-Var Data Assimilation System for a coupled physical-biological model is discussed by **Lellouche *et al.*** towards elucidating and quantifying physical and biological processes in the Adriatic Sea. Such an approach is pivotal to prediction of carbon turnover in aquatic systems, and should spur such studies in other oceans, particularly in the more complex Indian Ocean **Swathi *et al.*** present a potentially illuminating model for the Indian Ocean that appears to satisfactorily depict biogeochemical settings, particularly in simulating the high biological production in and higher carbon dioxide emissions from the Arabian Sea.

I am deeply indebted to the Guest Editors of this volume, Peter Burkill, Roger Hanson, Dileep Kumar and P S Swathi for an extremely painstaking and critical review of manuscripts and for a most incisive selection of papers which I am sure would provide landmark contributions to the JGOFS study.

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Editor