5.0 Biogeochemical impacts and global implications

Concern about long-term impacts of climate variability and anthropogenic CO_2 increases in the oceans has prompted North Pacific researchers to re-examine the fundamental processes controlling the organic carbon and $CaCO_3$ budgets in the region. The primary motivation for this research is that biological production and export of organic matter, and $CaCO_3$ production and export are important mechanisms by which carbon is exported from the surface ocean to the abyss. By looking at data in the main thermocline, longer-term secular trends and cycles have been observed. This approach takes advantage of the fact that the residence times of waters, and hence, biogeochemical properties increase with depth, and that flow in the ocean interior is primarily along constant potential density surfaces. Biogeochemical variations along isopycnal surfaces may therefore reflect past variations. Recent studies in the North Pacific have suggested that oxygen in the upper thermocline has decreased 10 – 15% over the past two decades (Emerson *et al*., 2001; Ono *et al*., 2001a; Keller *et al*., 2002). In the eastern Pacific, the observed 8 – 40 $\mu mol\ kg^{-1}$ oxygen decrease between 100 and 500 m from 1991 to 1997 may reflect large-scale changes in thermocline ventilation and/or ecosystem dynamics. Similarly, Feely *et al*. (2002) found substantial upward migration of aragonite and calcite saturation horizons in the upper thermocline of the North Pacific, which they attributed to decreases in carbonate ion concentrations resulting from anthropogenic CO_2 penetration into the water column since pre-industrial time.

These biogeochemical effects follow other studies that have suggested large-scale variations in the Pacific. McPhaden and Zhang (2002) observed a 25% decrease in transport convergences and meridional overturning over the past 25 years, consistent with a decrease in thermocline ventilation. Karl and co-workers (Karl *et al*., 1997; Karl, 1999) found a two-fold primary production increase and corresponding increases in suspended particle N:P ratios at HOT between the 1980s and the 1990s. They attributed these changes to a major ecosystem domain shift from nitrate-based diatom-dominated ecosystem to a *Prochlorococcus*-dominated N_2 fixation ecosystem. Karl (1999) suggests that the shift may be related to the persistence of unusually warm waters in the Subtropical Pacific resulting from the long succession of ENSO events. These observations are also consistent with a regime shift from a negative to a positive phase of the Pacific Decadal Oscillation (PDO).

All of these independent observations indicate that the North Pacific Ocean is undergoing substantial physical, chemical and biological changes over time. The response of the ocean carbon cycle to climate variability and global warming will continue to undergo varying degrees of both positive and negative climate feedbacks. The magnitude of these feedbacks and their interactions are currently not well understood, but potentially could lead to significant changes in the ability of the ocean to sequester anthropogenic CO_2 in the future. If, as many models suggest, the net feedbacks are positive (*i.e.*, reduced uptake of anthropogenic CO_2 by the ocean in a warming world) the required socio-economical strategies to stabilize CO_2 in the future will be much more stringent than in the absence of such feedbacks. Future studies of the carbon system in the North Pacific should be designed to identify and quantitatively assess these feedback mechanisms in order to provide input to models that will determine their importance on the ocean's future capacity to absorb the anthropogenic CO_2 from the atmosphere.