The CLIVAR Trace Element Program: Results and Implications for GEOTRACES Planning

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The US CLIVAR-CO_2 Repeat Hydrography Program has provided an unprecedented opportunity to acquire high resolution trace element distributions on a global scale. The inclusion of a trace element component into this carbon program was motivated by the recognition that the availability of dissolved Fe in the surface waters of the ocean plays an important role in mediating carbon dioxide uptake by biological organisms. Thus, developing realistic global models of climate feedback requires both a good understanding of the processes that deliver and maintain dissolved Fe in the surface waters of the ocean, as well as a high resolution data base with which to test these ideas. In addition to dissolved Fe, we have determined the abundance of dissolved Al, which has been used as a tracer of the location and magnitude of mineral dust deposition to the surface ocean, believed to be an important vector for the delivery of Fe to the surface ocean.

Between 2003 and 2005, we have participated in 10 CLIVAR cruises covering all the major ice-free ocean basins. The results from these sections have shown a variety of features that are well resolved by the approximately 1˚ spacing of the vertical profiles that have sampled the upper 1,000 m of the water column. In the North Atlantic, a subsurface plume of enriched Fe coincides with the oxygen minima and sits below an intense input of mineral dust emanating from the desert regions of North Africa, indicating a close connection between atmospheric input and biologically mediated vertical transport of Fe. In the North Pacific Ocean, atmospheric inputs are seen to decrease rapidly across the basin away from Asia and the subsurface Fe concentrations decrease along with this. In the southern hemisphere, Australia appears to be a significant source of mineral dust to the surface waters of the South Pacific and Indian Oceans. In the northern Indian Ocean, the Brahmaputra-Ganges system contributes distinct trace element signals to the surface waters of the Bay of Bengal.

From a global perspective, the subsurface distribution of dissolved Fe concentrations seems to be well correlated with surface water dust inputs, with lower Fe concentrations in the low dust deposition regions of the Southern Ocean and much higher concentrations in the equatorial and northern parts of the sections which are receiving higher dust loads. Surface water availability of Fe also matches dust inputs close to their source, e.g., in the coastal regions of Africa and Australia, but this

relationship appears to decouple towards the centre of the South Pacific and Indian Ocean gyres. Presumably this is a result of the much shorter residence time of Fe in surface waters than that of Al.

The wealth of geochemical insights that the high resolution CLIVAR sections have provided from just two trace elements in the upper 1,000 m not only provides an important survey tool for planning the sampling strategy of the new global geochemical program GEOTRACES, but it also indicates the wealth of geochemical understanding that is waiting to be discovered when the determination of a large number of key trace elements and isotopes are undertaken on the same water samples across the important hydrographic and geochemical gradients of the world's oceans. The successful completion of this task will require close collaboration and sharing of resources and experience amongst geochemists from all of the world's oceanographically capable countries.