Surface Water Saturations

Surface water saturations were calculated from WOCE CFC-11 and CFC-12 concentrations in the Indian Ocean using the potential temperature and salinity in the Warner and Weiss (1985) solubility equations and Walker et al. (2000) reconstructed atmospheric concentrations. Walker et al.'s (2000) Northern and Southern Hemisphere atmospheric concentrations were used north of 30ºN and south of 30ºS, respectively, and were linearly interpolated between these latitudes. This interpolation was used to simulate the effects of monsoonal mixing in these latitudes. Shipboard air measurements during WOCE were compared with AGAGE network values (Walker et al., 2000) to assess data quality. The internal consistency of shipboard data are very good, and these measurements compared well with the Walker et al. values - almost half are within 1.0% and all are within 2.8%. The Walker et al. atmospheric concentrations were used rather than shipboard data to avoid any high frequency variability or influences of local contamination in the shipboard atmospheric data.

Both gases, CFC-11 and CFC-12, show similar patterns in CFC saturations of surface water (Fig. 4). Over most of the subtropical and tropical Indian Ocean surface water is in equilibrium with the present atmosphere (Walker et al., 2000) to within ±2%. Near the Omani coast, there are saturations of less than 90% due to upwelling during the southwest monsoon. As mentioned above, it is probable that similar conditions existed off the Somali coast during the southwest monsoon, but these conditions were not sampled. The surface water of the Agulhas retroflection region also is undersaturated a couple of percent due to winter cooling when the line I5W was occupied. Along lines S4I, I8S, and I9S the deviations from equilibrium with the present atmosphere of greater than 10% increase toward the Antarctic continent. These undersaturations are correlated with colder surface temperatures. In contrast, there are areas of supersaturation due to *in situ* warming (e.g., Warner, 1988) particularly in the eastern Indian Ocean. Surface saturations of dissolved oxygen show similar patterns to those of the CFCs. Due to bubble injection and photosynthesis, dissolved oxygen is 2-4% more saturated than the CFCs, and oxygen is supersaturated north of 40ºS. For example, oxygen saturations are at 100% in the Omani upwelling region. There is an area of strong oxygen supersaturation (>10%) due to biological activity off the southwest coast of the Indian continent.

Seasonal variations of surface CFC saturations in the Arabian Sea were investigated using WOCE repeat hydrography cruises in the Arabian Sea during 1995. Rhein et al. (1997) found supersaturations during the inter-monsoon period of March-April. These supersaturations were caused by warming and reduced gas exchange due to weaker winds. As the mixed layer deepened and coastal upwelling increased with the onset of the summer monsoon, CFC surface saturations decreased to 70% along the coast. By August-September, the onset of strong winds brought the surface saturations to near equilibrium with the atmosphere. The average saturation of summer I7 line surface water was 101%, excluding filaments from the upwelling regions. Haines et al. (1997) obtained similar results using a numerical model to extend the space and time scales of the WOCE one-time observations.