

Data

The quality of the one-time WOCE Indian Ocean CFC data are excellent and generally meet the relaxed WOCE standards defined as precisions better than 3% of the concentrations or $0.015 \text{ pmol kg}^{-1}$ (whichever is greater). The station locations and dates are given in Fig. 1 and its caption. The data are presented relative to the SIO-98 calibration scale (Prinn et al., 2000). All groups measured the CFCs using a slightly-modified procedure of Bullister and Weiss (1988). The WOCE CFC Indian Ocean data are available on DVDs (WOCE Data Products Committee, 2002). For additional analytical details please contact each measurement group: for I1 Warner et al.; for I2 and I8S/I9S Bullister et al.; for I3 Weiss et al.; for I8N/I5E Smethie et al.; for I4/I5W, I7N, I9N and I10 Fine et al.; for I6S Poisson et al.; for S4I Smethie et al.

The individual measurement groups performed the initial quality control of the CFC-11 and CFC-12 data. Basin-wide quality control consisted of an evaluation based on property-property plots, maps and sections, comparisons with θ and S, oxygen distributions, and examination of crossover stations. There were no significant crossover offsets among cruises.

Near the Persian Gulf, anomalously high CFC-11 and CFC-12 concentrations were measured during WOCE, which could not have entered the ocean by normal air-sea gas exchange. Rhein et al. (1997) and Plähn et al. (1999) described CFC-12 concentration anomalies 8-40 times higher than normal above 400 m. The anomalies were coincident with Persian Gulf Water (PGW), and were traced southwestward to 12°N in the Arabian Sea. Since CFC-11 concentrations were at normal levels, they concluded that the sources of the CFC-12 anomalies were solvents and fire extinguishers related to the Gulf War.

Additionally, elevated CFC-11 and CFC-12 concentrations were also observed below 2500 m in the Gulf of Oman and southwestward to 12°N, similar to the location of the upper water contamination. Based on concentrations further southward (e.g. lines I3, I2), these waters should still have been at blank levels. Yet CFC-12 concentrations reached 0.15 pmol kg⁻¹, and CFC-11 concentrations reached 0.04 pmol kg⁻¹ (I7 stations along the Omani coast north of 19°N, I1 stations in the Gulf of Aden and northward along the Omani coast). Although CFC-12 was higher than CFC-11, both were anomalously high. The oxygen and salinities of these waters are consistent with climatology. There were also elevated CFC-11 concentrations at a station at 8.5°N, 75°E in the bottom waters (I1) west of India, which could be due to a local contamination source (e.g., dumped refrigerators). The analytical quality of the I7 and I1 data meet relaxed WOCE standards (Table 1), and CFC contamination of deep waters has also been discussed elsewhere (Min, 1999). For these reasons the data are not flagged. However, the anomalous data were not included in the sections, maps, and inventories.

Vertical sections of CFC-11 and CFC-12 are similar (Fig. 3), except for the northern Arabian Sea the site of the anomalously high CFC-12 concentrations discussed above. Due to the CFC-12 contamination and its smaller dynamic range, only CFC-11 concentration data are presented. The sections show that the Indian Ocean north of 40°S is ventilated with CFCs down through intermediate depths, and CFC vertical gradients are strongest between thermocline and intermediate layers. The deep waters had blank-level CFC concentrations, and the bottom waters were transporting low levels of CFCs into the Indian Ocean in several deep western boundary currents. Along lines I8S and

I9S, which extended southward from the eastern subtropical gyre to the Antarctic continent, the full water column had measurable concentrations of CFC-11 and CFC-12.

For the maps discussed below, surface water properties (Fig. 4) were taken from the shallowest bottle within 10 db of the surface. For some lines due to a paucity of samples in the upper 10 db and deeper mixed layers, the surface depth had to be extended: to 15 db for I2, I8S, and I9S; and to 20 db for I6S, I9N, and S4I.

Maps on isopycnal surfaces (Figs. 5 and 6) were made by interpolation of properties. Densities were chosen to both represent water column distributions, and to coincide with the major water masses (Fig. 2). At each station, CTD data were used to linearly interpolate pressure values to the chosen sigma-theta levels. Once pressures at the sigma-theta levels were found, an Akima (1970) spline was used to interpolate the other bottle data (CFCs, θ , S, oxygen, etc.) to the pressure values (e.g., Orsi et al., 1999). For age maps θ , S, and CFCs were interpolated to the pressure values, then ages were calculated from the interpolated values. Contouring of properties was done using GMT (Generic Mapping Tools, Wessel and Smith, 1991) with a $5^\circ \times 5^\circ$ grid. The chosen grid level gave the most consistent picture of the circulation, and is the most similar to other property distributions. GMT maps were then evaluated and portions thereof were re-contoured by hand.