Summer-winter comparison of Weddell Sea surface water and its productivity

C.-T.A. CHEN*

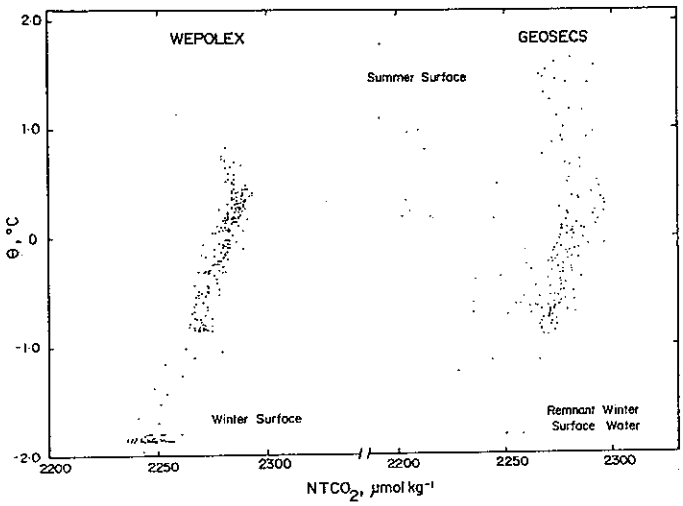
Institute of Marine Geology
National Sun Yat-Sen University
Kaohsiung, Taiwan
Republic of China

The U.S.-U.S.S.R. Weddell Polynya Expedition (WEPOLEX) (Chen 1982; Gordon 1982; Jennings, Nelson, and Gordon 1982) generated chemical data near the outflow region of the Weddell Sea in the late winter/early spring. These data permitted investigation for the first time of the cumulative winter effects on the distribution of chemical properties in the Weddell Sea surface water.

Temperature, salinity, oxygen, and nutrient data all indicate that the temperature-minimum layer found in summer is the remnant winter surface water. In summer, solar heating and melting of sea ice transform the top layer of the winter surface water into a warmer, less saline water than the winter surface water which in summer is partially preserved beneath the top layer. Subsequently, biological activity reduces the nutrient concentration in the summer surface layer. The oxygen concentration in the surface layer, however, increases in summer because the oxygen-depleted winter surface water picks up oxygen from the atmosphere after sea ice is melted. In summary, the winter Weddell Sea surface water is colder, saltier, contains more nutrients but less oxygen than the summer surface water (Chen 1984; Gordon, Chen, and Metcalf 1984; Jennings, Gordon, and Nelson 1984).

Comparison of WEPOLEX and GEOSECS (Geochemical Ocean Section Studies) normalized total carbon dioxide ($NTCO_2 = TCO_2 \times 35/\text{salinity}$, TCO_2 is the total amount of carbonate spe-

* On leave from College of Oceanography, Oregon State University, Corvallis, Oregon 97331.



Potential temperature (O) plotted vs. normalized total carbon dioxide ($NTCO_2$; "µ mol/kg" denotes "micromoles per kilogram") for the WEPOLEX data (all stations) and the GEOSECS data (stations 79, 82, 85, and 89).

cies dissolved in sea water) data (Takahashi et al. 1980; Huber et al. 1983; Chen 1984) also indicate that the winter $NTCO_2$ values in the surface layer agree with the GEOSECS summer values in the temperature-minimum layer (figure). The summer surface $NTCO_2$ and normalized alkalinity values are lower than the winter values by about 50 micromoles per kilogram and 10 microequivalents per kilogram, respectively. These data indicate a production of 5 micromoles per kilogram of calcium carbonate and 45 micromoles per kilogram of soft tissue, a ratio somewhat lower than an average ratio of 1-to-4 for the world oceans (Broecker and Peng 1982). The lower ratio is expected because siliceous rather than calcareous organisms dominate in the cold waters of the southern oceans.

The average amount of soft tissue production in the surface layer above the temperature-minimum layer is about 22.5 micromoles per kilogram. This value translates to a productivity of 300–450 milligrams per square meter per day between late winter WEPOLEX and summer (GEOSECS) if we assume average surface layer to be 100 meters thick. The average calcium carbonate productivity is 33–50 milligrams per square meter per day. Although the effect of meltwater in summer would decrease the estimated productivity by about 2 percent, the effect of air-to-sea transport of carbon dioxide would probably offset the meltwater effect.

Primary productivity in the southern oceans shows much spatial and temporal variability (Balech et al. 1968; Koblentz-Mishke et al. 1970; El-Sayed 1970; Lisitzin 1970; Goodell 1973). For instance, Lisitzin (1970) reports the diatom concentration in seawater to be between 0.5×10^6 and 1.0×10^9 per cubic meter. Such a large variability may explain partially why some direct productivity measurements have yielded low values when the general assumption is that the productivity is high in the southern oceans (El-Sayed and Turner 1977; Jennings et al. 1984).

Our estimates were obtained following the method of Jennings et al. (1984) based on nutrient data. This method gives a temporally and spatially averaged result. Our estimated productivity of 300–450 milligrams per square meter per day agrees very well with the results of Jennings et al. (220–420 milligrams per square meter per day) and supports the notion that the productivity is indeed high in the southern oceans. Even if we assume that the average yearly productivity is reduced by half as a result of the winter ice cover, we still have a high organic carbon productivity of 55–82 grams per square meter per year and calcium carbonate productivity of 6–9 grams per square meter per year. These values agree very well with the result, 54 and 7.6 grams per square meter per year, respectively, obtained from the recent sediment trap experiments in the southern oceans (Noriki, Harada, and Tsunogai 1985).

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