Excess carbon dioxide in the Weddell Sea

C. T. A. CHEN

College of Oceanography
Oregon State University
Corvallis, Oregon 97331

A. POISSON

Laboratoire de Physique et Chimie Marines
Université Pierre et Marie Curie
4 Place Jussieu, Tour 24-25
75230 Paris Cedex 05, France

We recently suggested that the antarctic bottom water (AABW) contains little or no excess carbon dioxide because, as is well known, AABW was largely blocked from the air by ice when formed. The conclusion was uncertain, however, because the excess carbon dioxide results which were based on the GEOSECS (Geochemical Ocean Section Studies) and IGY (International Geophysical Year) data had a large scatter about the oxygen value masking possible small trends of increased near-bottom excess carbon dioxide. To confirm our previous results, we participated in the U.S.-U.S.S.R. Weddell Polynya Expedition on the Soviet research vessel/icebreaker *Somov* between 9 October and 25 November 1981. The more precise *Somov* data indicated that AABW indeed contains only 6 ± 5 micromoles per kilogram of excess carbon dioxide. The pre-industrial carbon dioxide concentration in the atmosphere was estimated to be 268 ± 13 microatmospheres.

In 1979, Chen and Millero used the GEOSECS data to calculate the excess carbon dioxide concentrations. They published the first vertical excess-carbon-dioxide profile in the oceans based on GEOSECS carbonate data at station 79. The surface water was found to contain 40 micromoles per kilogram of excess carbon dioxide and the excess carbon dioxide concentration decreases gradually with depth to 700 meters. No excess carbon dioxide could be detected below this depth.

In 1982 Chen studied in more detail the distribution of excess carbon dioxide in the southern ocean using GEOSECS and IGY data. He found less than 5 micromoles per kilogram of excess carbon dioxide in the AABW, and then only when the water is colder than 0°C. These results, however, need to be confirmed because of the large scatter of the data.

We have calculated the excess carbon dioxide concentrations for the GEOSECS southern South Atlantic stations (figure 1). Surface waters generally contain 40 micromoles per kilogram of excess carbon dioxide, whereas little can be found below the maximum temperature layer (denoted by arrows on figure 1). We have plotted the available tritium and carbon-14 profiles in figure 2. It is obvious that the shapes of these profiles are similar to those shown in figure 1 and all three sets of profiles provide the same information: younger waters (more excess carbon dioxide, higher tritium and less negative carbon-14) are found on the surface, and older waters are found in the deep and bottom waters. It is less clear, however, whether some component of young water exists in AABW, which, after all, has been considered as a new water mass. Chen and Rodman (*Antarctic Journal*, this issue) indicate that AABW indeed contains more tritium and carbon-14 than the deep water. The *Somov* carbonate data indicate that a little excess carbon dioxide also exists in AABW.

We have calculated the excess-carbon-dioxide signal based on *Somov* data (Huber et al. 1983; Chen 1984). Rather than plotting the excess carbon dioxide concentrations vertically, we have plotted the data vs. potential density (σ_θ) in figure 3. It is clear that the smallest amount of excess carbon dioxide is found at or below the maximum temperature layer where the old circumpolar deep water dominates. On the other hand, at greater depths where there is a component of recently sunk surface water [generally at potential temperatures (θ) of less than 0°C] the excess carbon dioxide concentration increases with depth to a value of 6 ± 5 micromoles per kilogram. Calculations based on the surface values yield a pre-industrial carbon dioxide concentration of 268 ± 13 microatmospheres per kilogram.

We thank the Weddell Polynya Expedition co-chief-scientists E. Sarukhanyan and A.L. Gordon for their assistance. Financial support was provided by the Department of Energy (sub-

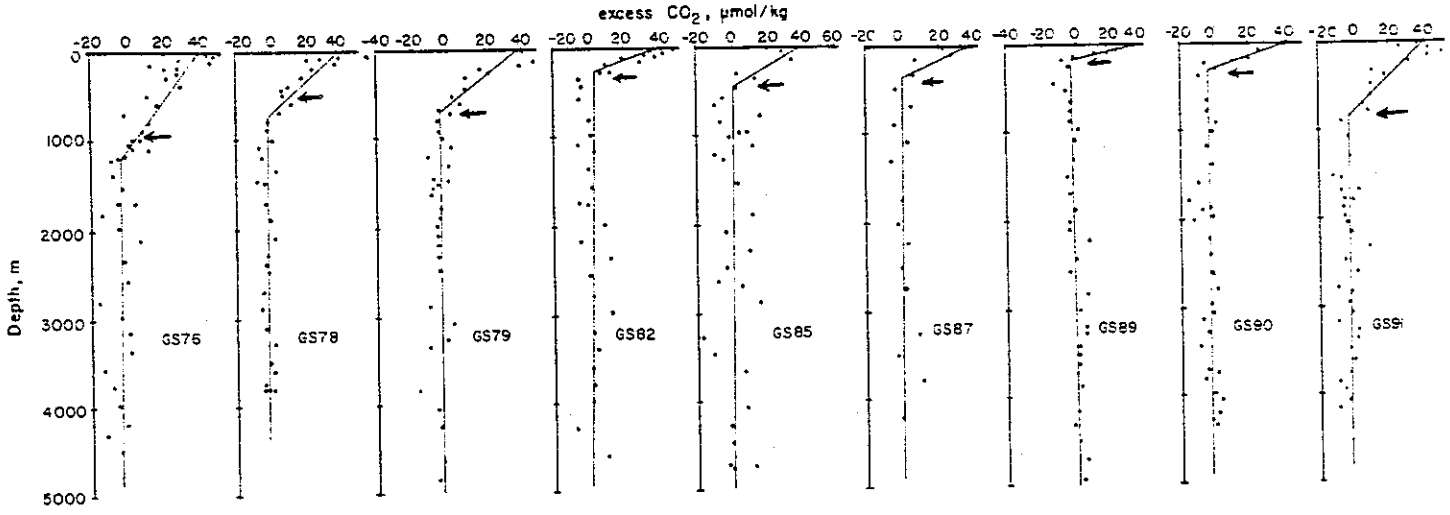

Figure 1. Variation of excess carbon dioxide with depth for GEOSECS stations (GS numbers) in the Atlantic side of the southern ocean. The arrows show the depth of maximum temperature. ("CO_2, µmol/kg" denotes carbon dioxide in micromoles per kilogram.)

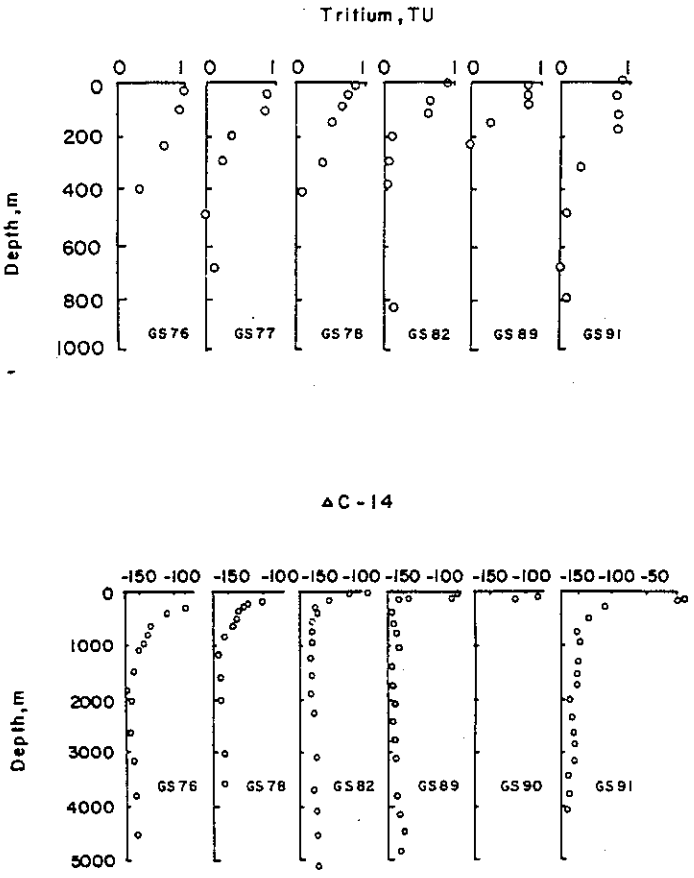

Figure 2. Variations of tritium (TU) and radiocarbon (ΔC-14) with depth (in meters) for the GEOSECS stations (GS numbers) in the Atlantic side of the southern ocean. (Data are from Ostlund, Dorsey, and Brescher 1976 and Stuiver and Ostlund 1980).

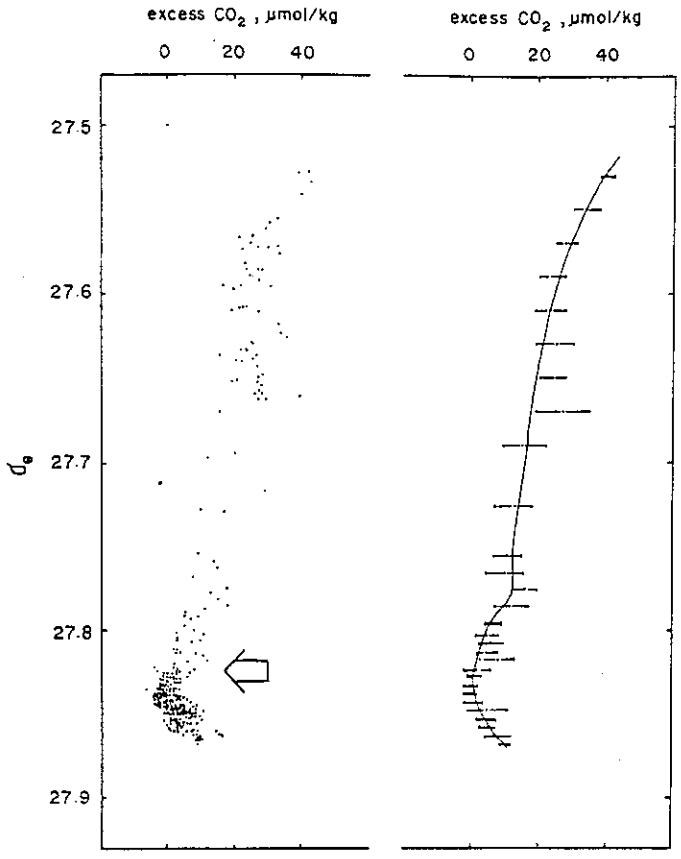

Figure 3. Excess carbon dioxide in micromoles per kilogram ("CO_2, μm/kg" on the figure) versus potential density (σ_θ) for all WEPOLEX stations. The arrow shows the depth of maximum temperature. The curve is the best fit, by eye, of average excess carbon dioxide values.

contract 19X-89608C under Martin Marietta Energy Systems, Inc., contract DE-AC05-84 or 214OD with the Department of Energy) and the National Science Foundation (OCE 82-15053). Alain Poisson acknowledges the support of the Centre National de la Recherche Scientifique (contrats: CNRS/DGRST, PIREN, cycle du carbone 070278/03, and ATP Océanographie Chimique 071278).

References

Chen, C.T. 1982. On the distribution of anthropogenic CO_2 in the Atlantic and Southern Oceans. *Deep-Sea Research*, 29, 563–580.

Chen, C.T. 1984. *Carbonate chemistry of the Weddell Sea.* (Department of Energy report DOE/EV/10611-4.) Washington, D.C.: U.S. Government Printing Office.

Chen, C.T., and F.J. Millero. 1979. Gradual increase of oceanic carbon dioxide. *Nature*, 277, 205–206.

Chen, C.T., and M.R. Rodman. 1984. The inhomogeneous distribution of tracers in the abyssal southern ocean. *Antarctic Journal of the U.S.*, 19(5).

Huber, B.A., J. Jennings, C.T. Chen, J. Marra, S. Rennie, P. Mele, and A. Gordon. 1983. *Reports of the US-USSR Weddell Polynya Expedition.* (Vol. II—hydrographical data LDGO 83-1.) Palisades, NY: Lamont-Doherty Geological Observatory of Columbia University.

Ostlund, H.G., H.G. Dorsey, and R. Brescher. 1976. *Tritium laboratory data report no. 5.* Miami: University of Miami.

Stuiver, M., and H.G. Ostlund. 1980. GEOSECS Atlantic radiocarbon. *Radiocarbon*, 22, 1–24.