The Distribution of Natural and Bomb-Produced Radiocarbon in the Pacific Ocean determined during the World Ocean Circulation Experiment

R. M. Key

Department of Geosciences, Princeton University, Princeton, NJ USA 08544

During the early 1990s, as part of the World Ocean Circulation Experiment, the most ambitious radiocarbon sampling program ever attempted was carried out in the Pacific Ocean. Both the number of stations sampled (~400) and the total number of samples collected (~8000) were approximately an order of magnitude greater than the combined existing data set. During the WOCE Pacific program, most of the deep waters were sampled using the old large volume technique followed by low-level β-counting while all of the upper waters were sampled using the new small volume sampling technique and measurement by accelerator mass spectrometry. A total of 6 laboratories were involved - 3 sampling and 3 measurement.

Almost all of the WOCE Pacific radiocarbon measurements are now completed and approximately 40% made public (Key, et al., 1997; Stuiver et al., 1997). After measurement, the results are subjected to a strict quality control procedure. Once finalized, all of the results are submitted to the various WOCE data centers where they are merged with other hydrographic measurements. Quality control checks carried out thus far on the new data set show no significant difference between the two measurement techniques. Furthermore, in waters which are too remote to have been contaminated by bomb-produced radiocarbon, the new data are compatible with existing data.

Prior to WOCE, the GEOSECS program provided the only ocean wide survey of the radiocarbon distribution. To first order, the new data support the GEOSECS results, however, the data density provided by WOCE has allowed better definition of all of the distribution features seen by GEOSECS and clearly identified numerous features that were totally missed by the prior study. Specific, totally new discoveries include:

• Two apparent pathways for the southward return flow at mid-depth of North Pacific Deep Water.

• Location of the North Pacific radiocarbon minimum significantly separated from both the northern and eastern coastal boundary.

• Clear definition of the pathway of northward flowing bottom waters (Fig. 1).

Approximately 20 years lapsed between GEOSECS and WOCE. During that time the radiocarbon spike which resulted from atmospheric nuclear weapons testing has had time to be subducted from the ocean surface into the upper thermocline. These changes alone provide important new information regarding ventilation processes in the Pacific. Changes in the South Pacific are more dramatic than in the north for two primary reasons:

• Most of the weapons tests were carried out in the northern hemisphere.

• The South Pacific ventilation is accelerated due to strong communication with the circumpolar circulation regime. Isopycnal surfaces which outcrop at high southern latitudes allow easy access of the bomb signal into the interior.

In 1995 Broecker, et al. reported a method based on correlation with silicate to separate bomb-produced and natural radiocarbon. The WOCE data set has demonstrated some problems with this method and allowed the generation of an improved method.
Figure 1: Near bottom radiocarbon distribution in the Pacific. The flow pathway of Antarctic origin waters toward the western boundary is clearly shown by the contours. Only regions with a depth greater than 3500m are included.

The radiocarbon distribution, the bomb-produced distribution and the change in radiocarbon distribution between GEOSECS and WOCE all place strong constraints upon numerical ocean models. Comparison of the new data with the models indicates that the models are moderately wrong in many places and grossly in error in others. Thus far the largest differences are in high southern latitudes where the models can be shown to have far too much vertical mixing.

Final quantitative evaluation of the above mentioned topics awaits the full Pacific data set, however, all are clearly demonstrated qualitatively and graphically.

References