

## CHAPTER 5

### *Contributions by Conference Participants*

#### *A Strategy for the Development of an Improved Model for the Uptake of Fossil Fuel CO<sub>2</sub> by the Ocean*

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To date almost all the calculations with regard to the uptake of fossil fuel CO<sub>2</sub> by the ocean have been carried out using a laterally homogeneous ocean. In our opinion the Oeschger *et al.* (1975) model carries this approach about as far as is feasible. The one remaining improvement might be to add upwelling (i.e., take water off the top of the model, cool it at equilibrium with the atmosphere, and add at the base of the deep sea reservoir). Any further elaboration which might be envisioned (i.e., add particulate cycle, dissolve sedimentary CaCO<sub>3</sub>, use more complicated assumptions regarding deep water formation and addition at depth . . .) would not likely increase the absolute accuracy of our uptake estimates. Rather, we must begin the very difficult task of creating a 3D model of oceanic mixing. Our comments concern the way in which we might move toward such a model.

One does not have to think about this problem long to realize that we know far too little about the ocean to do this yet. We must therefore make some sweeping simplifications. Our thought is to restrict the time scale (as measured by the mean age of the fossil fuel CO<sub>2</sub>) over which the calculation is carried out to about 30 years. The mean age of the CO<sub>2</sub> now in the system is about 28 years. As long as we continue to increase our rate of consumption of fossil fuels by 2 to 4% a year this mean age will not change very much. Thus within the bounds of our simplification, we can model through the period of heavy energy growth and strong dependence on fossil fuels.

This time scale is the one over which our transient tracer data (C<sup>14</sup>, H<sup>3</sup>, Kr<sup>85</sup> . . .) will permit analogue modeling. The major inputs of these tracers to the ocean atmosphere system was in the period 1962–1964. Thus their penetration time is now about 16 years. By the year 1990 the penetration time will be 27 years.

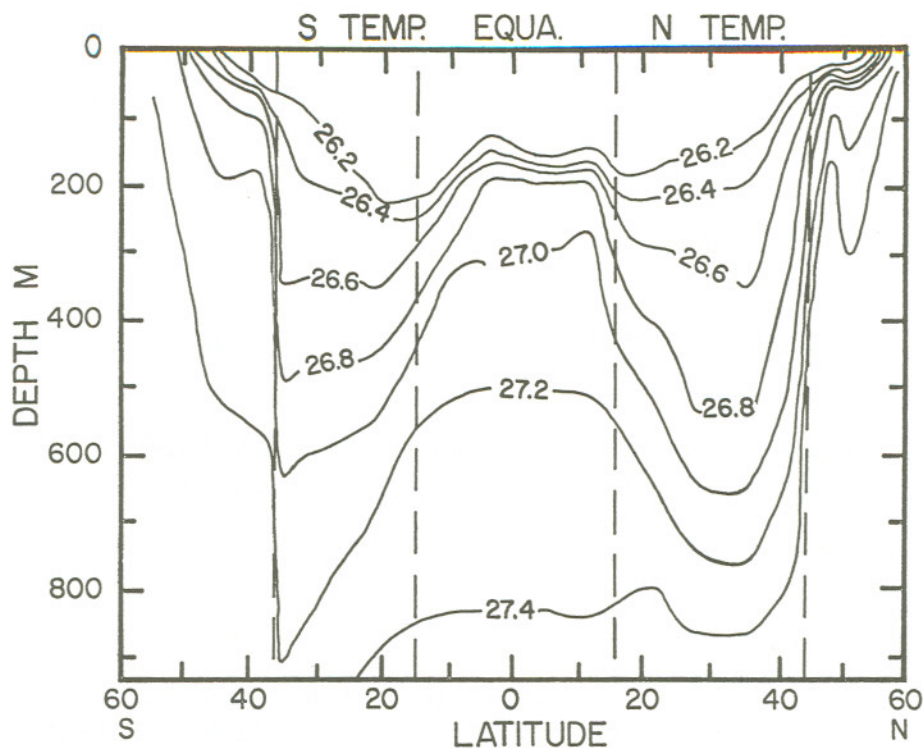


Figure 1: Density (given as  $\sigma_t$ ) versus depth along the western Atlantic GEOSECS track. The dashed lines separate the deep temperate thermocline from the shallow equatorial thermocline.

The processes of importance over this period will be

- 1) ventilation of the main oceanic thermocline.
- 2) formation of deep water.

Processes of no particular importance on this time scale are:

- 1) the details of how new deep water permeates the ocean.
- 2)  $\text{CaCO}_3$  dissolution in the deep sea.

Processes which have marginal importance on this time scale include the dynamics of the intermediate waters (depth  $\sim 1000$  m) in the world ocean.

Of the processes affecting the fossil fuel  $\text{CO}_2$  uptake by the sea on a 30 year time scale, ventilation of the main thermocline must dominate. Our first objective has therefore been to develop a better model of the thermocline in the latitude range  $45^\circ\text{N}$  to  $45^\circ\text{S}$  (i.e., 74% of the world ocean). Examination of this region reveals that it in turn may be subdivided into an equatorial zone ( $15^\circ\text{N}$ – $15^\circ\text{S}$ ) in which the isopycnals are shallow (see Figure 1) and in which the penetration of the transient tracers is also shallow (see Figure 2) and two temperate regions ( $15^\circ$ – $45^\circ$ ) in which the isopycnals are deep and the transient tracers penetrate to much greater depth. We

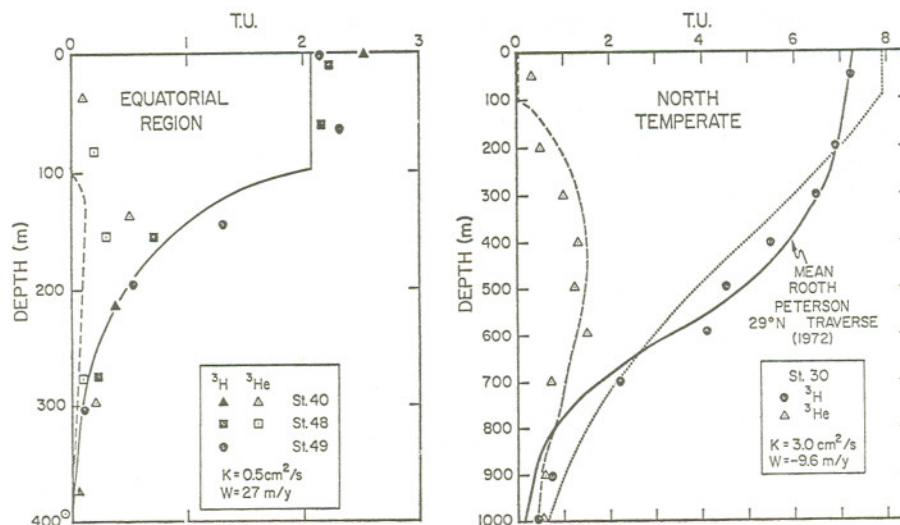


Figure 2: Distribution of tritium and  $^3\text{He}$  in the equatorial Atlantic and north temperate Atlantic oceans. The penetration of tritium in the equatorial region is much shallower than that in the north temperate region.

have shown (Broecker *et al.*, 1978) that this distribution can only be accounted for through strong upwelling in the equatorial zone. The upwelling water must be supplied from beneath the adjacent temperate thermocline (i.e., likely through the Antarctic intermediate water channel). We have further shown that the distribution of bomb produced radiocarbon holds the key to the establishment of the rate of upwelling in the equatorial zone.

Next most important on the 30 year time scale is the formation of new deep water. These waters are generated primarily in the northern Atlantic and around the perimeter of Antarctica.

In order to assess the amount of fossil fuel  $\text{CO}_2$  being carried to the deep sea as the result of deep water formation, the following information is needed.

- 1) The buffer factor for cold water.
- 2) The source and chemical composition of waters converted to new deep sea water.
- 3) The extent to which these waters equilibrate with the  $\text{CO}_2$  in the atmosphere during the period of cooling at high latitudes.
- 4) The flux of these waters into the deep sea.

The Transient Tracer group is concentrating its efforts during the 1980 field season on this problem. A survey of the source regions in the northern Atlantic and of the spread of bomb contaminated waters from these regions will be studied. The goal will be to better our knowledge of the last three of the processes listed above (the first is known from the physical chemical data on sea water).

The dynamics of the intermediate waters in the oceans poses a major challenge in this approach. To what extent can these waters be assumed free of bomb produced isotopes? Is the deep water produced in the northern Atlantic supplied by the northward penetration of intermediate water?

Although rather brief this statement depicts our current strategy with regard to going beyond the laterally homogenized models now in use.

#### REFERENCES

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