

CHAPTER 11

ISOTOPIC TRACER TECHNIQUES FOR MEASUREMENT OF PHYSICAL PROCESSES IN THE SEA AND THE ATMOSPHERE¹

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I. Introduction

THROUGHOUT this report reference has been made to the need for a fundamental understanding, on a long-term basis, of mixing phenomena in the ocean and the atmosphere. In a general sense the ocean and the atmosphere may be regarded as a two-phase system, in which the phases are separated by the fundamental discontinuity of the ocean-atmosphere interface. Each phase is further divided into two parts by a second order discontinuity; the atmosphere, divided by the tropopause at about 12 km, into the troposphere and the stratosphere, etc., and the oceans, divided by the thermocline at some 100 meters, into an upper and lower layer.

The basic problems in determining the effects of both radioactive waste disposal and the dispersal of debris from nuclear explosions may be formulated in terms of a single objective. Given the ocean-atmosphere system under normal steady state conditions, and given some substance introduced at any point in one of the four designated zones, we wish to be able to predict quantitatively the concentration of the substance as a function of latitude, longitude, altitude or depth, and time. These problems thus involve studies of (1) the intra-phase mixing, above, below, and across the second-order discontinuities within each phase, and (2) the inter-phase mixing across the ocean-atmosphere interface, with the aim of predicting the effects of perturbations on the system.

The dominant mixing processes in the various spheres are processes of mass movement or turbulent mixing. In such processes, for elements undergoing no change of phase, there is little or no separation of components, and thus, in general, isotopic tracer techniques may in-

volve a wide range of materials of quite different chemistry. It is this phenomenon of mass movement dominance, and the relative unimportance of diffusive transfer except in special cases, that makes the tracer technique so powerful; a tagged isotope for each element is not required, and one can choose for each particular study the elements most useful for tracing the movement of a mass of heterogeneous material.

As mentioned at several points in this report, both artificial and natural isotopic tracers may be used for the study of transfer phenomena in the sea and the atmosphere. Artificial tracers are of value in such studies because they allow the investigator to introduce perturbations in the system at convenient times and places; they are especially valuable for the study of short term fluctuations in local systems. However, for the general understanding of mass transfer phenomena, artificial tracers are of value mainly as experimental checks on deductions based on other data, with the exceptions of a few special cases to be described below. The reason for this is that mass transfer phenomena are by nature subject to long term periodic fluctuations such as convection, with periods often longer than the time range available for observation. A second reason for this is the high cost of radioisotopes and the large amounts of activity required to tag adequately the large masses of water necessary for ocean studies.

Revelle, Folsom, Goldberg and Isaacs (1955) have discussed in their Geneva report the problems involved in adapting radioisotope tracer techniques to transfer studies in the ocean, and the requirements for usable isotopes. If one introduces some 10 curies of a gamma emitter in solution at some point below the thermocline, it is found that within a reasonable duration of observation time the activity will be concentrated in a layer of the order of 1 meter thick

¹ Contribution from the Scripps Institution of Oceanography, New Series, No. 902.

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