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An attempt to trace the Monsoon Flow using Natural Radon

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ABSTRACT. Measurements of radon concentration in air over the Arabian Sea and the Indian Ocean are reported. They enable an identification of southeast trades and of continental air in the monsoon current.

1. Introduction

Recently, there has arisen a controversy about a very basic aspect of Indian summer monsoon, *i.e.*, whether the monsoon current is constituted primarily of the deflected south east trades from the Indian Ocean or of air primarily from the north African continent (Desai 1966, Pisharoty 1966). It is difficult to decide the issue with the help of some conventional measurements of surface winds at a few spots over the Arabian Sea.

A suggestion (Rama 1966) was recently made that it may be possible to settle the issue with the help of measurements of radon (half-life 3·8 days) in the monsoon current over the Arabian Sea. The underlying idea is that the maritime southeast trades should be very poor in radon, while continental air from north Africa should be comparatively very rich in radon. It should, therefore, be possible to discern which one of the two constitutes the monsoon current over the Arabian Sea. In order to test the validity of the above idea and the feasibility of the proposed method, some exploratory measurements were recently made over the Arabian Sea and the Indian Ocean. These measurements demonstrate that the idea is basically correct and the method quite suitable for distinguishing the maritime southern airmasses from the continental north African airmasses when and if they intrude over the Arabian Sea during the monsoon season.

2. Experimental

Radon content of air was assessed by measuring the activity of its decay products which were collected on a glass fibre filter by passing the air through it (Rama and Chhabra 1966). The measurements were made aboard *State of Bombay* and S. S. *Mozaffari*. A few exploratory measurements were made aboard I.N.S. *Kistna* near the Bombay coast in March 1966. All these measurements refer to the deck level air.

3. Errors

The overall accuracy of most measurements is believed to be better than 20 per cent, except in the cases where the activities are extremely low and the error then may be as large as 50 per cent; these accuracies are considered quite adequate for the problem in hand.

The absolute values of the concentrations are expected to be accurate to about 30 per cent, the uncertainty arising mainly in the calibration of the counter. A study based on relative variation is not subject to this source of error.

4. Results

The results of measurements made during the oceanic cruises are shown in Figs. 1 to 4; the radon concentrations are shown in bold letters (dpm/m^3) against the date and approximate location of sampling.

The following features of these observations may be noted—

(1) During the first cruise (Fig. 1), the radon concentration stayed at about 30 to 35 dpm/m^3 from Bombay to a location 5° N in the central Arabian Sea and then suddenly dropped to about 3 dpm/m^3 and stayed constant at this value in the entire region of S. E. trades.

(2) The pattern described above was essentially repeated on the return journey (Fig. 2) except that the concentration of radon started increasing just north of equator and reached a constant value of about 25 dpm/m^3 at about Lat. 5° N.

(3) The concentration near the East African coast varied between 45 and 110 dpm/m^3.

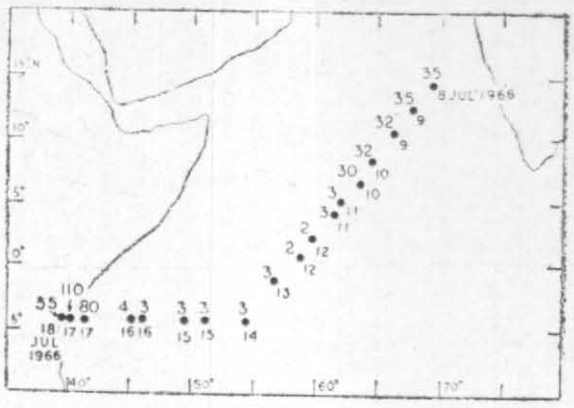

Fig. 1

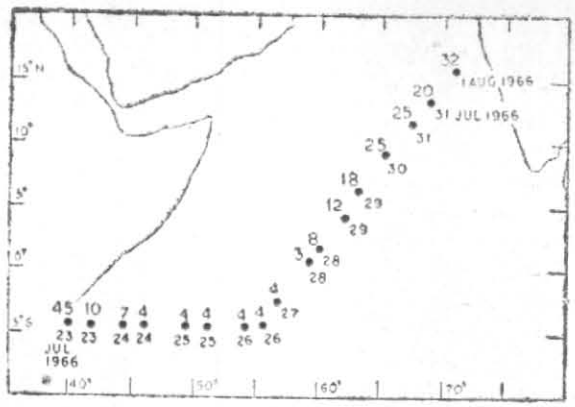

Fig. 2

Figs. 1-2. Concentration of radon in surface air over the Arabian Sea and the Indian Ocean during monsoon period (unit : dpm/m³)

The upper figure indicate the concentration of radon and the lower ones the date of observation

(4) During Bombay-Aden and back cruises, the concentrations often were around 20 dpm/m³. Sharp decreases to values 4 to 8 dpm/m³ were also sometimes observed near Long. 60°E.

(5) The concentrations close to the Arabian and Somalia coast ranged between 50 and 160 dpm/m³.

(6) The concentrations near the Bombay coast ranged between 40 and 160 dpm/m³ in the first week of March 1966 (details of measurements are not given here).

5. Discussion and interpretation of results

It is well-known that radon is continuously exhaled out of land surface from where it is transported upwards by convective and mixing processes. Its concentration in the surface air (over the land) therefore depends not only at the rate at which it is exhaled from the ground but also other meteorological variables, the important one being vertical mixing. The decay of radon during its transport upwards often results in considerable vertical gradients in its concentration (*see* Jacobi and Andre 1963). Unlike most other radionuclides, removal of radon from the atmosphere by wet precipitation is negligible; only important process for its destruction in the atmosphere is its radioactive decay.

The ocean water contains a certain amount of radon originating from the decay of dissolved radium which exists in concentration of about 0·1 dpm per litre of water. Due to finite exchange between the atmosphere and the ocean, a part of this radon can be expected to be released into the atmosphere. Broecker (1966) has, in fact, reported a radon loss of about 35 per cent from the surface, 15 per cent from 30-metre depth and essentially zero from 75-metre depth. It is therefore, certain that some radon is introduced into the atmosphere even over the oceans, but it

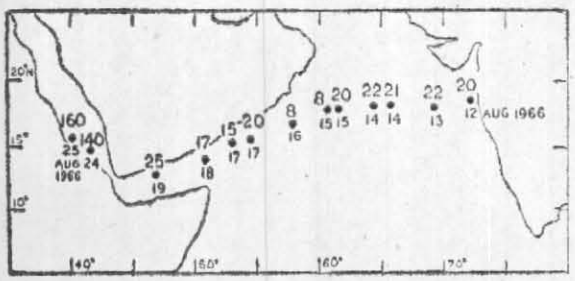

Fig. 3

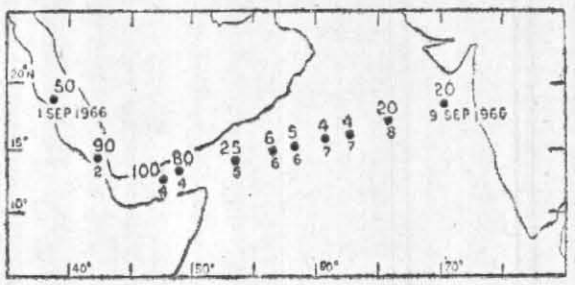

Fig. 4

Figs. 3-4. Concentration of radon in surface air over the Arabian Sea and the Indian Ocean during monsoon period (unit: dpm/m³)

The upper figure indicates the radon concentration and the lower ones the date of observation

can be easily seen that its total amount is extremely small (~0·1 atom/cm² min) in comparison to that introduced over the land (~40 atom/cm² min) (Israel 1951). Radon of oceanic origin is, therefore, of no significance in the present context.

Let us now consider how the radon concentration may change in a continental airmass which moves over to the ocean. Since the surface source of radon is now essentially absent, the concentration in the surface air will decrease as a result of vertical mixing with the radon-deficient air aloft. The magnitude of decrease due to this cause will depend upon the initial gradient in concentration and the extent of vertical mixing in the atmosphere over the ocean. The total radon content of the airmass, as a whole, will also keep decreasing as a result of decay; it gets approximately halved every four days. The decrease will continue to a very small limiting value which is determined by exhalation rate of radon from ocean water; but before this happens the air invariably moves over to some continent.

In the light of the above considerations, the data may now be examined as follows—

(1) Figs. 1 and 2 clearly show that in the entire region of southeast trades investigated south of the equator, the radon concentrations are very low, *i.e.*, 2-4 dpm/m³. If this air crosses the equator and enters the Arabian Sea, it should continue to show low radon concentration. There is no way of increasing its radon content except by mixing with continental air of high radon content. Figs. 1 and 2, in fact, show that the radon-poor air (S. E. trades) did cross the equator on both occasions in the month of July and penetrated upto about Lat. 5° N. Beyond 5° N, there existed an airmass with approximately ten times as much radon. This radon-rich (25–35 dpm/m³) airmass was perhaps a pure continental airmass of north African origin; in any case, it certainly contained sizable proportion of continental air. The fact that there was a sharp discontinuity in the radon concentration around 5°N and that the concentrations were approximately constant north of 5°N would tend to suggest that the airmass north of 5° N is a homogeneous one rather than a gradual mixture of S. E. trades and continental air. One may, therefore, ascribe the surface concentrations of 25–35 dpm/m³ with the continental airmasses from north Africa, the only snag is that the value 25–35 dpm/m³ is much lower than the value 45–160 dpm/m³ observed for the surface air over the coastal waters. The two values may be quite consistent when one considers that the vertical mixing (and some decay) may reduce the surface concentrations in continental air masses from the coastal values of 45–160 dpm/m³ to open ocean values of 20–35 dpm/m³. Therefore it seems reasonable to associate concentration of 20-35 dpm/m³ over the open Arabian Sea with continental airmasses from north Africa. One would not have required to resort to the above deductive reasoning if vertical profiles of radon were available. It can, however, be seen that the above deduction cannot be very wrong in as much as the open ocean values for an airmass of recent continental origin must be considerably smaller than coastal values. As far as the southeast trades are concerned, there is no uncertainty; the low values of 2–4 dpm/m³ are the experimentally observed values just south of the equator. Such low values in air over the Arabian Sea may safely be associated with the deflected S. E. trades.

(2) From Figs. 3 and 4, it can be seen that low concentrations (4–8 dpm/m³), characteristic of almost pure or slightly adulterated southeast trades, were observed as far north as 16–17°N between Long. 55° and 65°E. How frequent and how important such intrusions are, can only be decided by later experiments. The present experiment demonstrates that radon measurements can enable us to distinguish between the deflected southeast trades and the north African continental airmasses when they intrude over the Arabian Sea.

Measurements of vertical profiles may similarly be expected to further reveal certain other aspects of monsoon circulation.

6. Acknowledgements

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