Measurement of Aerosol Particles along a Section from 8°N Latitude to Antarctica in the Southwestern Region of the Indian Ocean

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ABSTRACT

Measurements of aerosol particles along a transect in the southwestern Indian Ocean showed a gradual decrease of the particles towards Antarctica. The concentrations varied from 65.3 ± 1.9 µg/m^3 at 8°37'N latitude to 0 in Antarctica. Peaks were recorded at places where the air coming from other continents seemed to influence the atmosphere. The observed peak in the zone of antarctic convergence may be due to the effect of the flow of surface air from the Antarctica towards the equator. Katabatic wind is probably the cause of another peak observed near the Antarctic continent. An inverse relation has been found between the wind speed and aerosol content which is presumably due to "scrubbing effect" and dispersion.

INTRODUCTION

Data on the aerosol particles over the Indian Ocean are few and discontinuous. The only record available for the aerosol particles and their chemical composition over the Arabian Sea is by Sadasivan (1978).

The most significant source for the transport of particles and other material to the Southern Ocean and to Antarctica is by the atmosphere. However, the effect of the continental air in these regions can hardly be felt in areas beyond 60°S. This is because the air can be expected to be continuously 'scrubbed' as a result of its long residence time during its transport. Also aerosol particles can be lost due to the formation of condensation nuclei in the clouds.

The normal surface and near-surface air flow in the region of 60°S is towards the equator (Hogan, 1975). It is extremely unlikely that winds in the direction of the south pole would exist for sufficiently long periods to be able to carry the continental surface air or the air coming from major island systems towards Antarctica. The Southern Ocean is a region of nearly continuous storm and cloudiness. Continental air reaching 60°S from the lower latitudes or from the higher latitudes via the region of antarctic convergence would probably be well scrubbed of any traces of continental aerosol.

Some data on the concentration and sizes of aerosol particles over parts of the Antarctic continent and the surrounding oceans are on record (Voskresenskii, 1968; Hogan 1975, 1979, 1981). These authors have concluded that it is extremely difficult to measure small quantities of aerosol over Antarctica (sometimes as low as 2 X 10^{-10}g.m^3). There is, however, a vertical gradient of aerosol particles. The particles increase in numbers as we go higher up in the atmosphere. Similarly, during the katabatic winds their concentration increases as we go down towards the surface of frozen ice.

Several hypotheses have been developed to account for the transport of particulate material to Antarctica, e.g. the occurrence of a stratospheric source and a region of transport near 80°S during the summer (Cadle *et al,* 1968) and also their transport up to 90°S through the upper layers (Zoller *et al,* 1974). Hogan *et al* (1979) concluded that the most frequent route of transport for the particulate material to Antarctica is from its origin in the Southern Ocean through the same lower layers which transport heat and moisture to the polar cap.

Although many studies have been conducted on the polar aerosol, only a few observations on its concentration at the surface of the Southern Ocean and around the periphery of the Antarctic continent

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are on record (Meszaros and Vissy, 1974; Fischer, 1967; Hofmann *etal,* 1977; Hogan and Mohnen, 1979). We, therefore, undertook asurvey in which the concentrations of aerosol particles from 8°N latitude to the edge of the Antarctic continent and all along the Indian Ocean during the austral summer of 1981-82, were measured. This study was carried out as a part of the scientific programme during the First Indian Expedition to Antarctica.

MATERIAL AND METHODS

The instrument used was fabricated at the National Institute of Oceanography. Basically, it was a calibrated air pump, having a suction rate of 1.46 m^3/min. At the intake, a holder made of steel and electroplated, along with a perforated disc was fitted between two plates. The perforated holder was of an appropriate size to hold membrane filters of 47 mm in diameter. Another perforated holder was fitted at the exhaust end of the pump. Two pre-weighed membrane filters, 47 mm in diameter and 0.45 µm in pore size were fitted one on top of the other, on the perforated disc at the intake end. The pump was placed on top of the deck foreward of the navigation bridge in the upwind direction. Much care was exercised to avoid the soot particles coming from the ship's funnel and the salt water spray. The height of the bridge was about 9 m above the sea level. The pump was run while the ship was in motion. During strong winds and high seas, the pump could not be run because of sea water spray reaching the height of the bridge deck. For every sampling, the pump was run for 3-4 hours. The distance covered and the volume of air filtered during this interval were calculated from the ship's speed, direction and the suction rate of the pump. Both the filters were preserved on board in well-cleaned plastic boxes. The second filter was a back up filter and was used as a blank. Samples were also collected when the ship was on oceanographic stations. Wind observations were taken simultaneously.

On reaching the shore laboratory the filters were weighed and the amount of material collected on them was calculated. Whenever any soot or salt particles were observed on the filters, the observations were not used for calculation.

An attempt was also made to ascertain the sizes of the particles under a microscope, but they were less than 1 µm in diameter. Hogan (1975) observed that the geometric mean radius of Antarctic aerosol particles varied from 0.5 to 0.7 x 10^{-6}cm.

RESULTS AND DISCUSSION

A total of 40 samples were collected between 09°45'N and 69°59'S latitudes. Rejecting the filters containing either soot or salt particles, a total of 21 samples was used for this study. The locations where sampling was done are shown in Fig. 1.

All the filters were preserved in a dessicator. They were weighed at intervals of one month and over a period of three months the accuracy of their weighings was checked. Standard errors were calculated for all the weighings. The results along with the location, distance covered and the wind speed are presented in Table 1.

Fig. 2 gives the latitudinal variation of aerosol particles. The highest concentration of 65.3 µg/m^3 was recorded at the latitude 08°37.5'N. This place is not very far from the landmasses of Africa and India. Moreover, it is along one of the busy shipping lanes across the Arabian Sea.

The effect of the continental air becomes less pronounced southward and the concentration of particles gradually decreases upto 04°48'N. Thereafter, it becomes almost steady. However, from.l7°S it starts increasing again reaching another peak at 21°33'S. This region is not far from the island of Mauritius. Another peak was recorded at 30°26'S which again was close to the island of Madagascar and the South African peninsula.

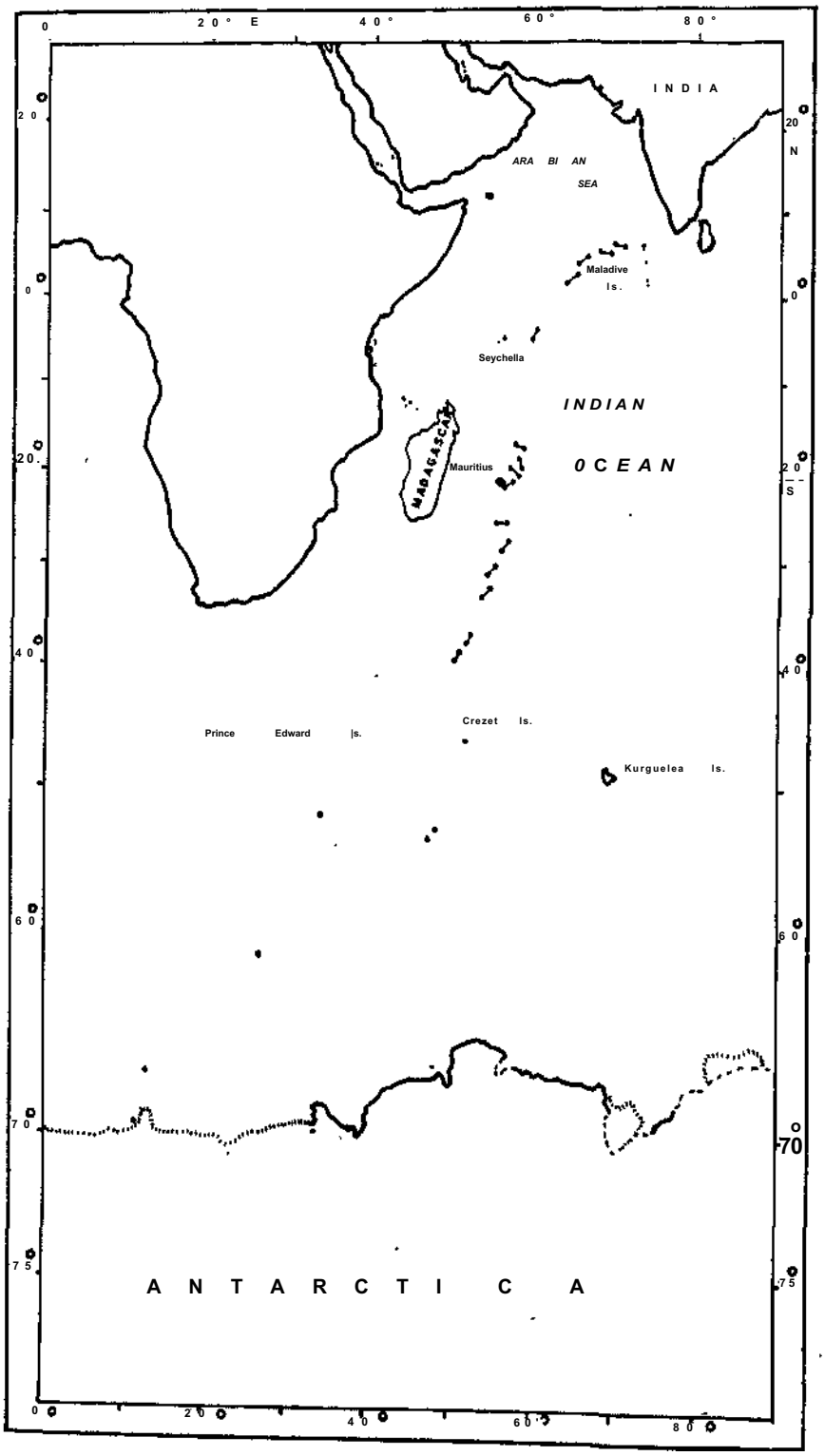

Fig. 1 : **Network of observation points.**

TABLE 1

Details of sampling, concentration and prevailing wind speed for aerosol particles.

FROM		TO		Distance km	Particle Conc. ($\mu g/m^3$)	Wind speed km/hr.
Lat.	Long.	Lat.	Long.			
08°37'5N	68°02'8E	08°16'4N	67°53'1E	44	65.3 ± 1.9	8
06°30'8N	66°50'1E	06°07'1N	66°35'9E	51	22.7 ± 1.2	9
04°48'4N	65°49'4E	04°28'5N	65°38'7E	42	11.0 ± 1.6	9.5
02°27'2N	64°26'7E	01°53'8N	64°10'7E	64	1.9 ± 0.7	9.5
04°46'1S	60°09'1E	05°12'2S	59°50'3E	63	1.5 ± 0.5	20
17°46'4S	57°38'1E	18°22'0S	57°35'1E	64	0.6	40
19°16'6S	57°28'9E	19°52'4S	57°26'6E	64	1.7 ± 0.2	41
20°16'1S	57°18'0E	20°51'0S	57°01'6E	64	2.2 ± 0.3	42
21°33'3S	56°53'8E	22°06'6S	56°48'3E	69	5.7 ± 0.1	20
25°58'2S	56°15'7E	26°36'1S	56°09'4E	76	3.1 ± 0.2	10
28°39'0S	55°46'8E	29°19'4S	55°34'3E	77	1.0 ±0.1	12
30°26'3S	55°09'6E	30°58'1S	54°53'8E	63	8.7 ±0.2	13
32°58'7S	54°05'5E	33°37'1S	53°49'6E	76	0.6 ± 0.2	22
37°25'9S	52°21'9E	37°58'8S	52°09'6E	65	2.0 ±0.1	40
39°00'3S	51°36'7E	39°33'8S	51°22'2E	67	3.3 ± 0.2	40
53°44'0S	47°55'0E	54°23'2S	47°38'0E	76	21.6 ± 2.5	28
69°58'7S	11°58'0E	—	—	0	0	11
67°46'4S	12°00'E	—	—	0	5.2 ± 0.2	25
61°28'2S	25°01'1E	—	—	0	2.2 ± 0.5	23
52°48'1S	34°25'4E	—	—	0	1.4	28
47°23'3S	39°02'4E	—	—	0	1.5 ± 0.1	30

At 53°44'S, which is the area of antarctic convergence, another peak was noted. The continental air during its course can be expected to be sufficiently scrubbed by the time it reaches this area. This peak can be expected to be due to the influence of air blowing from Antarctica towards the equator. We expect that some influence might also come from the salt nuclei present in the atmosphere.

The peak, therefore, seen near the Antarctic continent, though somewhat strange, is not unlikely. A greater concentration of aerosol can probably be expected near the snow surface because this region being cooler than the air can act as a thermal precipitator. It can thus remove the smaller particles because of the temperature gradient (inversion) which exists at times, as the air is warmer above than at the ice surface (Hogan, 1975). The katabatic wind in the Antarctica has also its influence on the higher aerosol content near the snow surface (Hogan, 1979). However, all these phenomena occur periodically. In the absence of any such effects, the surface aerosol can be expected to be less or zero (as recorded in the last observation) because of the increasing vertical gradient upwards toward the tropopause (Hogan, 1981).

The observed wind speed at the time of sampling has also been plotted in Fig. 2 to study its effect on the aerosol concentrations. In general, the relation is inverse. High aerosol concentration is associated with low wind speed and vice versa. In the region studied, because of the effect of the air coming from the continent, the particle content can be expected to be very low. Wind of high velocity disperses the particles (with salt nuclei) and this feature leads to concentrations of low particles in the samples.

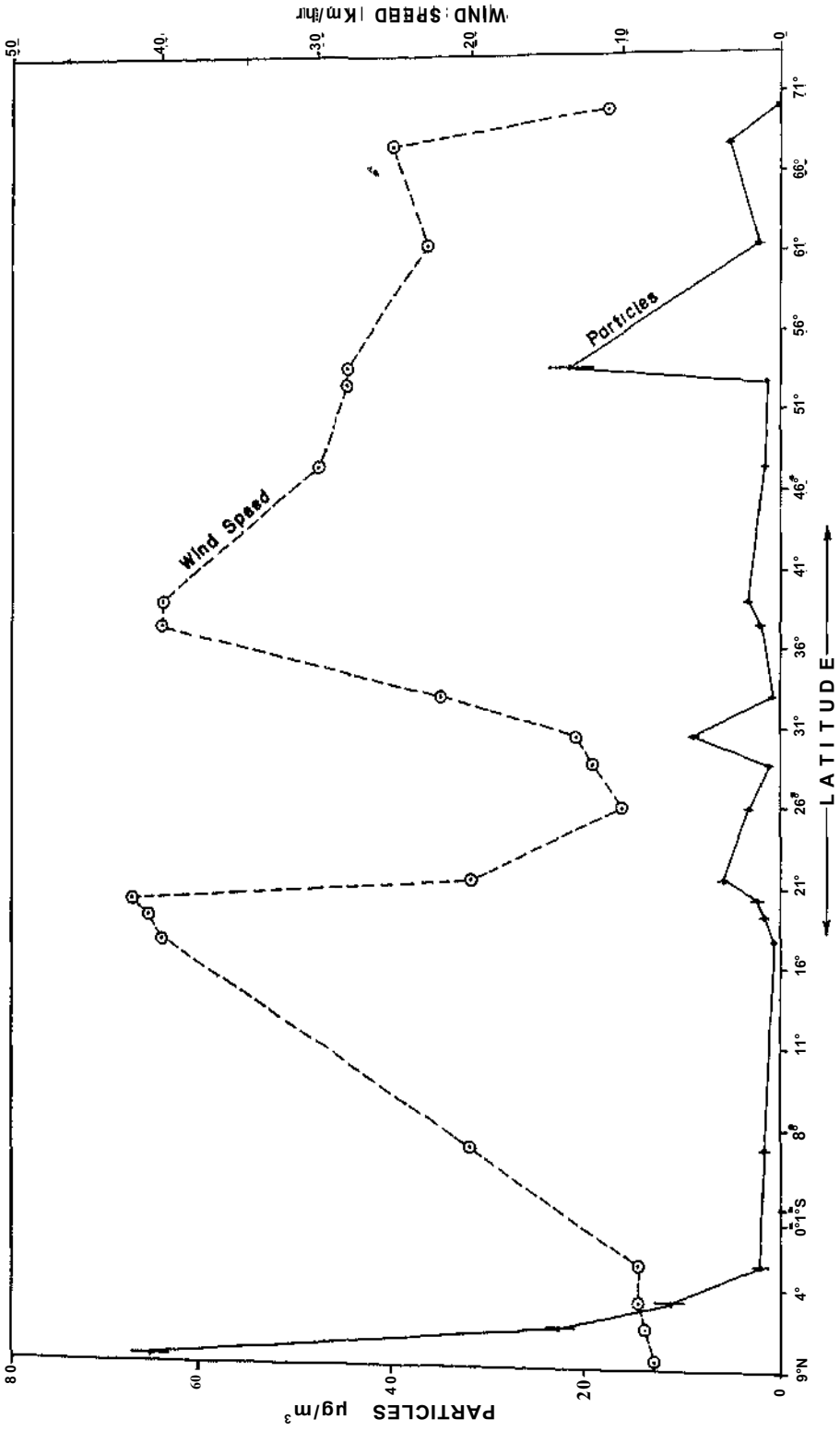

Fig. 2 : Variation of particles and wind speed with latitudes

The main objective of these measurements was to study the poleward transport of material. Therefore, for the study of chemical composition of the air there is a need to filter a large volume of air. In fact, filtering for at least two days should give just enough material for chemical analysis (Meszaros and Vissy. 1974). The limitation of our instrument did not enable us to collect enough material for chemical studies.

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