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# Integrated ocean monitoring including ozone

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**सार** — दक्षिण एशिया में मौसम के संबंध में महासागर, विशेषकर हिन्दमहासागर पर समेकित मॉनीटरन के महत्व के बारे में अनेक वैज्ञानिकों ने विचार प्रस्तुत किए हैं।

1981-82 और 1982-83 में दिसंबर से फरवरी के दौरान अरबसागर, हिन्दमहासागर एवं दक्षिण महासागर में भारतीय वैज्ञानिकों ने दो वैज्ञानिक जलपोतों से मौसम संबंधी समेकित आंकड़े और समुद्री आंकड़े एकत्रित किए। इस शोधपत्र में 1982-83 की अवधि में जलपोत पर समुद्री पृष्ठ तापमान (एस. एम. टी), पृष्ठ दाब, आसपास का तापमान, पवन, ऊपरी वायु के मौसमी प्राचलों और समुद्री पृष्ठ के निकट के वायुमंडलीय क्षेत्र के आंकड़ों का अध्ययन करके विश्लेषण किया गया है।

इस शोधपत्र से प्राप्त निष्कर्ष दक्षिण एशिया में सामान्य मौसम, विशेषकर मानसून को प्रभावित करने वाली हिन्द महासागर और दक्षिण महासागर के वायुमंडल की विभिन्न प्रक्रियाओं का, अध्ययन करने वाले वैज्ञानिकों को अतिरिक्त जानकारी देने में सहायक होंगे।

ABSTRACT. The importance of integrated ocean monitoring in relation to weather over the South Asia, particularly over the Indian Ocean has been discussed by many scientists.

During December to February 1981-82 and 1982-83 two scientific cruises were undertaken by the Indian scientists over the Arabian Sea, Indian Ocean and Southern Ocean and a large volume of integrated meteorological and ocean data were collected. The present paper deals with the study and analysis of the data of sea surface temperature (SST), surface pressure, ambient temperature, wind, upper air meteorological parameters and atmospheric ozone near the sea surface, collected during the 1982-83 cruise.

The findings of this paper may provide additional inputs to the scientists studying various atmospheric processes over the Indian Ocean and Southern Ocean affecting monsoon in particular and weather in general over the South Asia.

## 1. Introduction

During December to February 1981-82 and 1982-83 two scientific cruises were undertaken by the Indian scientists over the Arabian Sea, Indian Ocean and Southern Ocean. During these cruises an integrated ocean monitoring of ocean and meteorological parameters like sea surface temperature, surface pressure, temperature, wind, upper air parameters and atmospheric ozone near the sea surface were conducted.

The importance of integrated ocean monitoring in relation to weather over the South Asia, particularly over the Indian Ocean has been discussed by many scientists (Keshavamurty 1981; Cadet 1981; Okooka & Asnani 1981).

## 2. Data and analysis

2.1. *Sea surface temperature (SST)*

Expendable Bathy Thermographs were used from the ship deck for measurement of sea surface temperature (SST) and sea temperature profile upto 500 m depth.

In this paper only SST has been discussed and not the temperature profile upto 500 m.

The climate of the earth is greatly controlled by the temperature of the oceans. WMO report *on detection of possible climate change* (WCP-29) has brought out various aspects of the importance of SST in relation to climatic studies, Namias (1969) studied the use of SST in long range prediction, Keshavamurty (1981) discussed the importance of the SST anomalies and Southern Oscillations (SO) in the study of the inter-annual variability of southwest Asian monsoon. Rasmusson and Carpenter (1982) have also discussed the importance of the study of the variations in tropical SST and surface wind fields in association with Southern Oscillations (SO).

Latitudinal variation of SST during the period 6 December 1981 to 9 January 1982, over the Arabian Sea, Indian Ocean and Southern Ocean is plotted in Fig. 1. It depicts that between 14° N & 30° S over the Arabian Sea and the Indian Ocean, the sea surface is quite warm and does not exhibit much variation in day to day measurement. Beyond 30° S the SST started falling rapidly. Starting from the Roaring Forties the SST exhibited a steep fall. In fact, the sea surface temperature had fallen from 17.5° C to 10° C within two degree latitude between 42° S & 44° S. This sudden change of temperature gives a

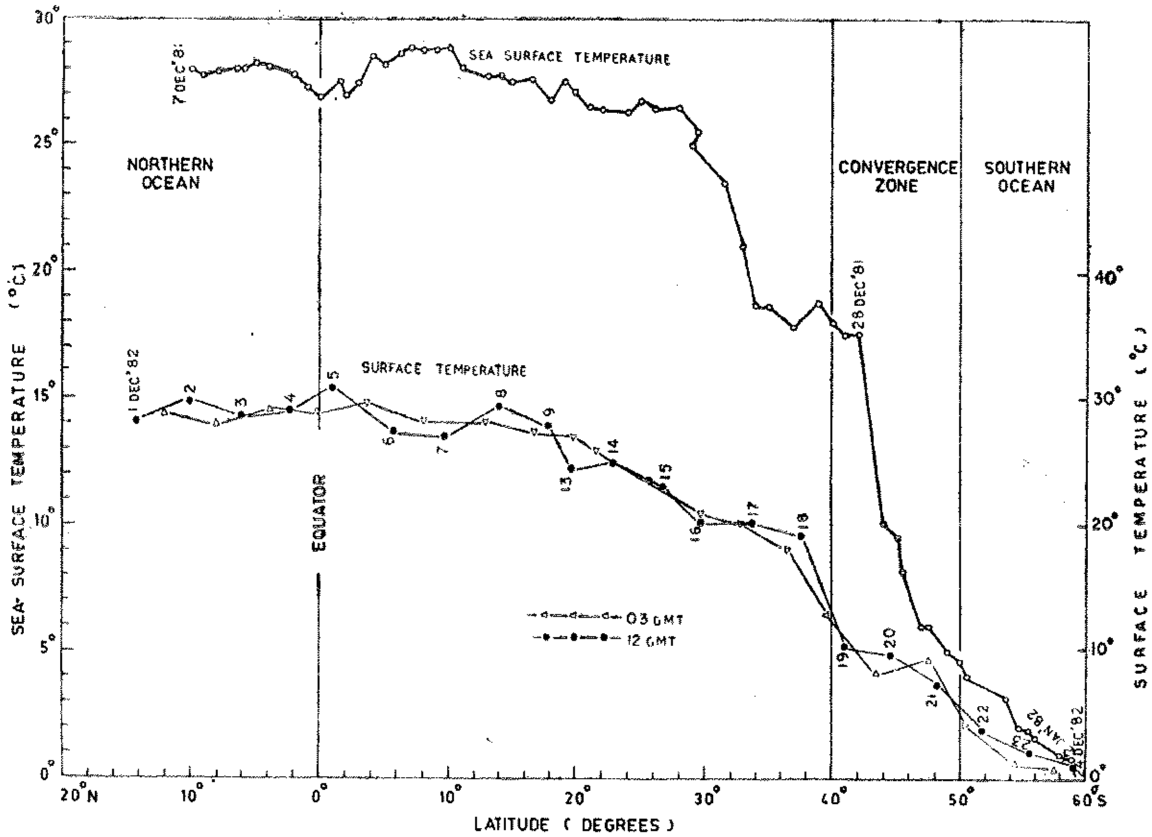


Fig. 1. Latitudinal variation of sea surface temperature and surface temperature (observation timings : 03 and 12 GMT)

clear indication of convergence zone, where the cold water from the Southern Ocean meets the warm water from the tropical seas.

2.2. *Surface pressure*

Latitudinal variation of surface pressure (12 GMT observations) recorded during the cruise of 1982 between latitude 14 ° N and 60° S has been plotted in Fig. 2. The surface pressure between 14° N & 14° S remained practically constant (*i.e.,* 1011 mb). Beyond 14° S, surface pressure started rising, reaching a peak on 19 December 1981 near about 42 ° S where southern hemispheric subtropical ridge is located. Thereafter the surface pressure had fallen very rapidly from 1025 mb to 972 mb at 56 ° S on 23 December 1982. This fall of pressure is associated with a deep depression which passed across the ship over the Southern Ocean.

Physick & Tucker (1981) made similar studies of mean sea level pressure in the southern hemisphere during the FGGE period. *In situ* measurement of surface pressure over ocean provides a valuable information on ocean climate and a check on the performance of pressure measurement by drifting ocean buoys.

2.3. *Surface temperature*

During the two cruises surface temperature (ambient air temperature) was measured by using YSI thermistor installed on the roof of the ship. The temperature reading was remotely displayed in the meteorological laboratory of the ship. Fig. 1 gives the latitudinal variation of surface temperature at 03 GMT & 12 GMT hours. The surface temperature started falling gradually soon after crossing the equator. The surface temperature over the Indian Ocean in the northern hemisphere was in the range of 28 deg. C to 30 deg. C and that of over the Indian Ocean in the southern hemisphere and Southern Ocean was between 30 deg. C & 0 deg. C within the latitudes 0 deg. to 60 deg. S. Near the 'Roaring Forties' the gradient of surface temperature fall was maximum. It is interesting to note that diurnal variation of surface temperaure right from 14 deg. N to 60 deg. S over the Indian Ocean & the Southern Ocean was very small and in some areas between 20 deg. S & 33 deg. S the surface temperature did not exhibit any diurnal variation. The temperature was nearly constant between 28 deg. C and 30 deg. C from 14 deg. N to 20 deg. S. Between 20 deg. S and 38 deg. S temperature gradually fell by 10 deg. C from 28 deg. C to 18 deg. C, followed by a sharp fall of 10 deg. C near the convergence zone between 38 deg. S and 44 deg. S. Thereafter temperature fell slowly reaching nearly 0 deg. C at 60 deg. S.

2.4. *Surface humidity*

A hair hygrograph was installed on the roof of the ship for measurement of humidity. The humidity was digitally displayed and simultaneously recorded in the meteorological laboratory. The latitudinal variation of surface humidity for 12 GMT observations is plotted in Fig. 2.

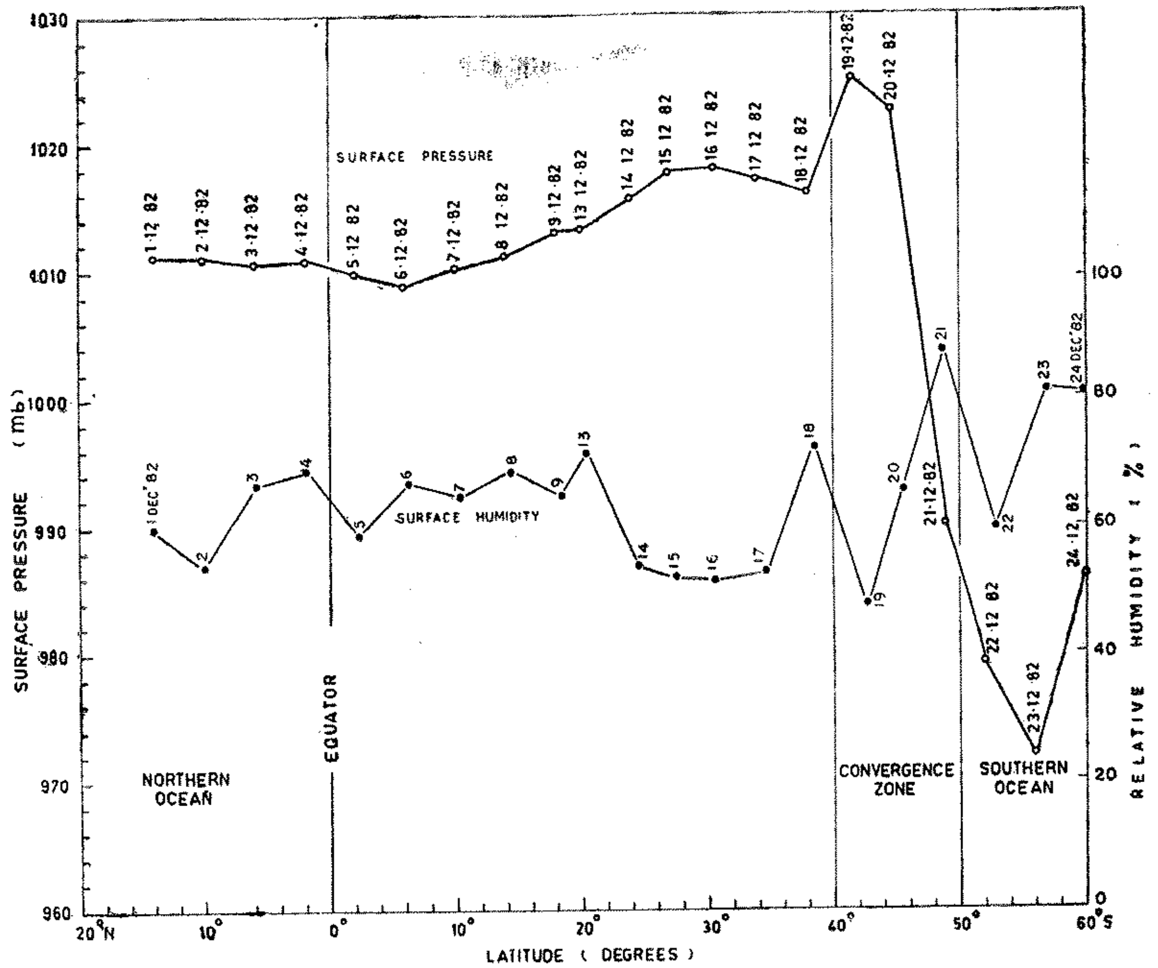


Fig. 2. Latitudinal variation of surface pressure (observation time : 12 GMT) and surface humidity (observation time 12 GMT)

Per cent Relative Humidity (PRH) value over the Arabian Sea and the Indian Ocean between 14 deg. N and equator varied from 54% to 69% and thereafter decreased very rapidly beyond 20 deg. S from 72% to 54% and then remained more or less constant until 34 deg. S, where PRH increased very rapidly to value of 73% at 38 deg. S. There was another steep rise of PRH at 48 deg. S to 88%. The region between 40 deg. S and 50 deg. S is generally known as convergence zone where the cool polar airmass meets the warm tropical airmass. The high value of relative humidity may be due to this aspect.

2.5. *Upper air observations*

On board, two upper air instruments were installed (1) India Make Radiosonde Ground Equipment and the other (2) Vaisalla Omegasonde System for upper air measurement of temperature, humidity and winds. Radiosonde balloons were launched from the upper deck of the ship. In all, about sixty upper air soundings were made during the cruises; out of these only twelve soundings have been selected for the presentation in this paper.

Fig. 3 gives the temperature, humidity & wind profiles between 10 deg. N & 23 deg. S latitudes over the Indian Ocean. All the heights are expressed in geopotential metre. Following salient features are worth to mention :

(*i*) The lower layers were well mixed. The surface temperature was between 24 deg. C & 28 deg. C and the vertical profiles upto about 12 km were all overlapping, exhibiting same type of air mass upto this level. Beyond 12 km the vertical profiles were separated.

(*ii*) The zero degree isotherm occurred near about 5 km. The tropopause heights between 10 deg. N & 23 deg. S over the Indian Ocean varied between 16 and 17 km.

(*iii*) Tropopause over the Indian Ocean in the northern hemisphere was much cooler than over the Indian Ocean in the southern hemisphere and Southern Ocean. The tropopause temperature varied from —80 deg. C at 6 deg. N to —68 deg. C at 14 deg. S.

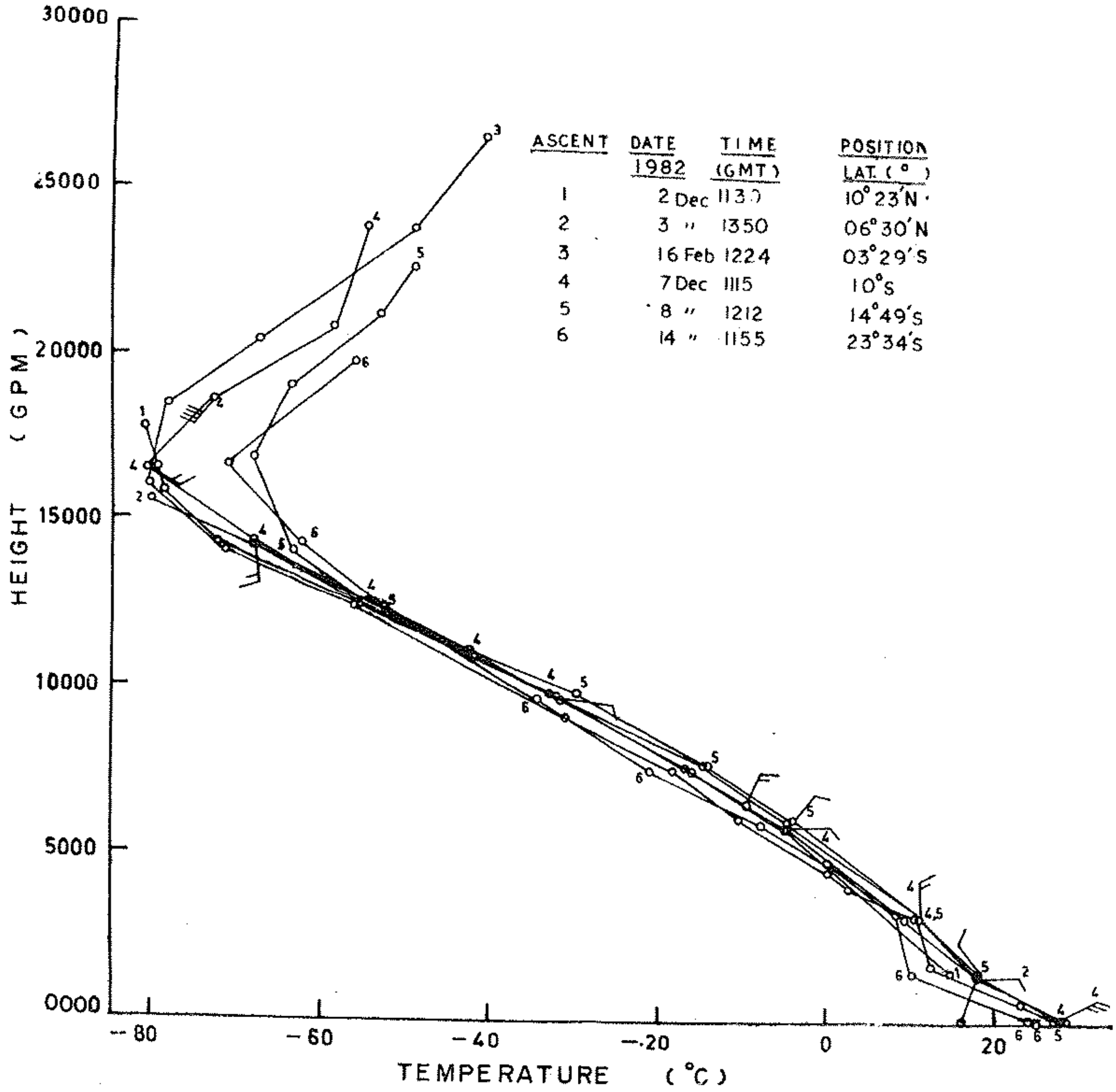


Fig. 3. Vertical profile of temperature and wind over the Indian Ocean and Southern Ocean

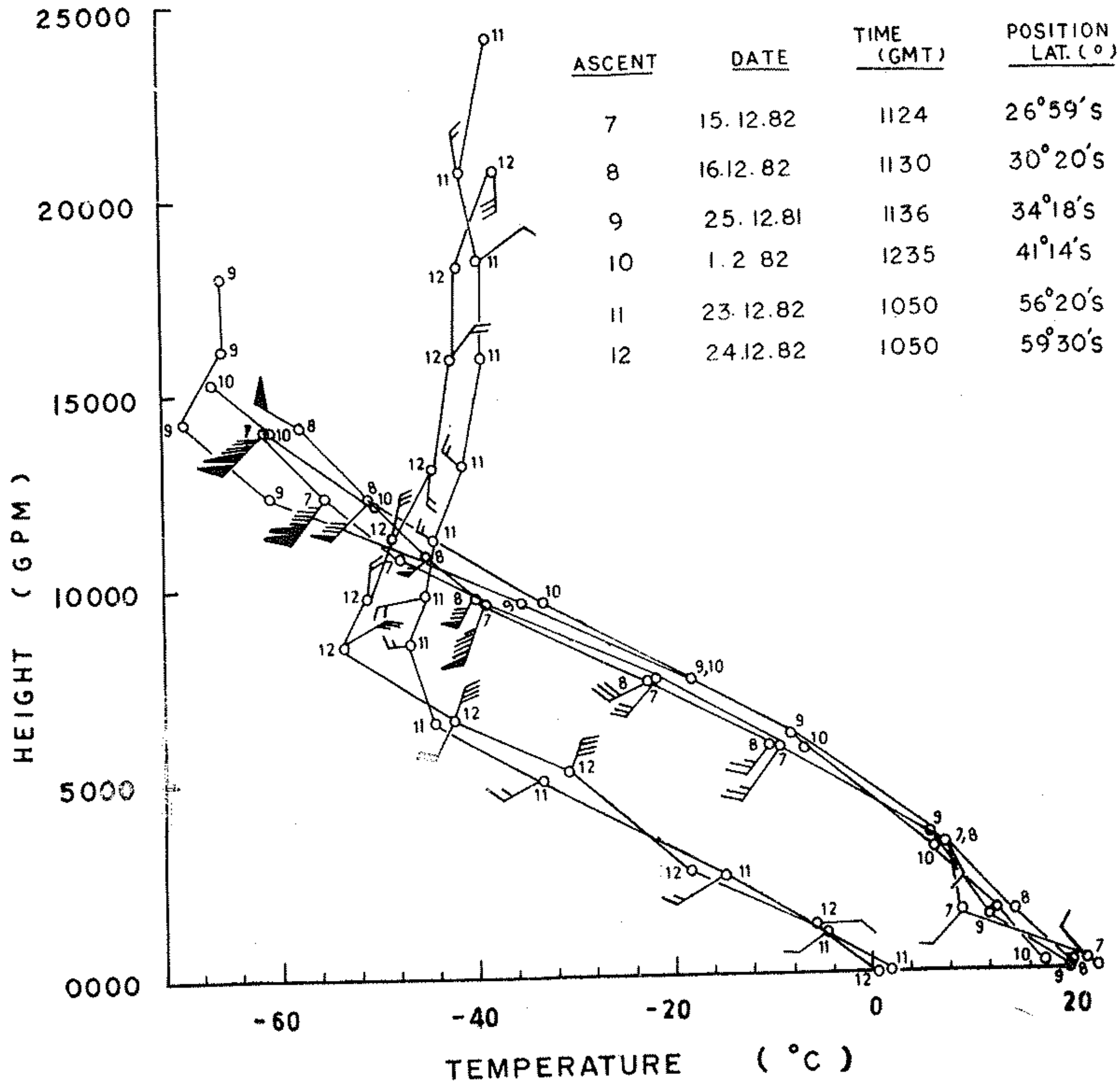


Fig. 4. Vertical profile of temperature and wind over the Indian Ocean and Southern Ocean

Upper winds were plotted on the temperature profiles obtained from the Omegasondes. The lower level winds were easterly to northerly and were light in comparison to winds between 14 km and 19 km, where it was predominantly southerly to southwesterly and were strong. Upper winds near about the tropopause and above were mostly southerly.

Vertical temperature and wind profiles between 27 deg. S & 60 deg. S were plotted in Fig. 4. The following salient features are brought out :

(*i*) The temperature profiles between 27 deg. S & 41 deg. S over the Indian Ocean and the temperature profiles between 56 deg. S & 60 deg. S over the Southern Ocean have separated out into two distinct groups. But the temperature lapse rates in both the groups were almost constant (*i.e.*, 6.5 deg. C/km).

(*ii*) The surface temperature between 27 deg. S & 41 deg. S was about 20 deg. C whereas the surface temperature between 56 deg. S & 60 deg. S was about 0 deg. C. The freezing level was at about 4.5 km between 27 deg. S & 41 deg. S. The two groups of temperature profiles clearly delineate the convergence zone which was found to be between 42 deg. S & 44 deg. S in Fig. 1.

(*iii*) The tropopause height between 27 deg. S & 41 deg. S was about 15 km whereas the tropopause height between 56 deg. S & 60 deg. S after the convergence zone came down to 8.5 km. The tropopause was much cooler between 27 deg. S & 41 deg. S over the Indian Ocean than tropopause over the Southern Ocean. The tropopause temperature

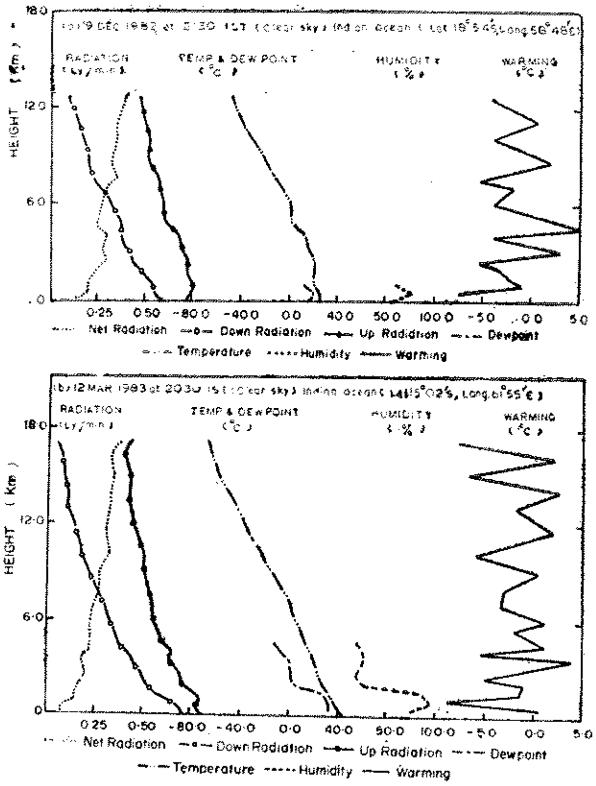


Fig. 5. Vertical distribution of radiation (ly/min), temperature & dew point (°C), humidity (%) and warming (°C) in clear sky over Indian Ocean of (a) 9 Dec 1982 (2130 IST) at 18°54′S, 58°48′E and (b) 12 March 1983 (2030 IST) at 15°02′S, 61°55′E

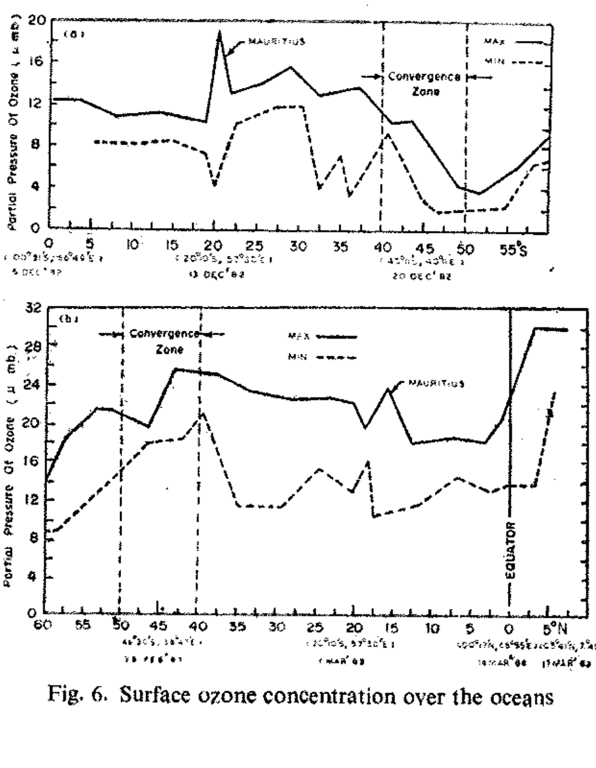


Fig. 6. Surface ozone concentration over the oceans

range varied between —77 deg. C at 34 deg. S & —46 deg. C at 56 deg. S. The winds in the lower levels between ground & 3 km were very light over the Indian Ocean between 27 deg. S & 41 deg. S. The winds were stronger in this zone in the upper levels reaching a maximum at 14 km where the winds were predominantly southwesterly. The upper winds between 10 km & 14 km gave indication of the presence of sub-tropical westerly jet over this part of the Indian Ocean. As we cross the convergence zone the wind profiles between 56 deg. S & 60 deg. S exhibit predominantly moderate southwesterly winds.

2.6. *Vertical radiative flows*

During the cruises study of the vertical distribution of infra-red radiative fluxes over the Indian Ocean was undertaken. The data obtained from the radiometersonde ascents have been utilised to compute the upward radiative flux, the downward radiative flux, the net radiative flux, temperature, dew point and the infra-red radiative cooling/warming for every 50 mb upto 200 mb and for every 25 mb above it. Fig. 5 gives the vertical profiles of the upward radiative flux, downward radiative flux, net radiative flux, temperature, humidity, dew point and infra-red radiative cooling/warming obtained from balloon radiometer soundings taken on 9 December 1982 and 12 March 1983 at Lat. 18° 54′ S, Long. 58° 29′ E and at Lat. 15° 02′ S, Long. 61° 55′ E respectively over the Indian Ocean. The radiative fluxes are given in langley per minute and the radiative warming in deg. C/day.

2.6.1. *Salient features of radiometer sounding taken on* 9 *December* 1982

(*i*) Upward flux decreased from 0.763 ly/min at 1010 mb to 0.479 ly/min at 200 mb with an inversion at 1000 mb. The downward flux also decreased correspondingly from 0.607 ly/min to 0.091 ly/min.

(*ii*) The net radiative flux increased from 0.156 ly/min to 0.388 ly/min at 200 mb and then decreased near 100 mb.

(*iii*) The relative warmings at 700, 600 and 500 mb may be due to some thin trace of clouds which could not be observed from the ship during night. The value of 0.369 ly/min is usually reached beyond 200 mb when the sky is clear.

2.6.2. *Salient features of radiometer sounding taken on* 12 *March* 1983

(*i*) The upward radiative flux decreased from 0.791 ly/min at sea level to 0.428 ly/min at 100 mb with a corresponding decrease of downward radiation from 0.715 ly/min to 0.058 ly/min.

(*ii*) The clear weather value of 0.369 ly/min was reached at 100 mb.

2.7. *Latitudinal variation of surface ozone over Indian and Southern Oceans*

Extensive measurements of ozone concentration above the surface of the earth have been reported from all parts of the globe by various workers using chemical and optical methods (Regener 1974, Aldaz 1969, Galbally and Roy 1980, Pruchniewicz 1973, Sreedharan and Tiwari 1971).

Most of these measurements, however, are from land areas since measurements of ozone concentration over the ocean surface was beset with difficulties. Since two thirds of the globe is covered with the oceans there was an urgent need to take more observations over the ocean surface, so that the global estimate of ozone destruction rates become more realistic.

*Instrumentation* — Surface ozone measurements over the Indian Ocean was attempted earlier by Indian workers during the MONEX-79 without much success. The two main problems in successful recording of surface ozone over the seas were, interference by salt spray and destruction of ozone at the long intake tubing. The Indian electro-chemical surface ozone recording system was suitably modified for the scientific cruise of 1982-83. Special care was taken to ensure that a very short intake tubing (0.8 m) was used to sample the air. Thus, for the first time continuous records of ozone 8 m above the sea surface was obtained almost during the entire cruise.

The recorder is calibrated by micro-ampere current source. From the record, the ozone current in $\mu$ A is determined and the partial pressure of ozone is calculated from the formula $P$ ($\mu$mb) $= 4.31 \times 10^{-3} \times iTt$ where $P$ is the partial pressure of ozone in $\mu$mb, $i$ the ozone sensor current in $\mu$ A, $T$ is the temperature of air being sampled in degree Kelvin and it is the time in seconds for pumping 100 ml of air. The ozone density $\rho$ in $\mu$ gm$^{-3}$ is calculated from the relation :

$$P\ (\mu\ \text{mb}) = 1.732 \times 10^{-3} T\rho$$

## 3. Results

Fig. 6 presents the latitudinal variation of daily maximum and minimum surface ozone concentration recorded between equator and 60 deg. S over the Indian Ocean and the Southern Ocean during outgoing and return cruises respectively.

Salient features of the ozone observations are :

(*i*) In general, the ozone concentration over the open seas was only about 50% of that over the adjoining land areas. This may be the results of greater ozone destruction rates over the sea surface than hitherto estimated. The land to sea contrast in ozone concentration was conclusively brought out in the increase of ozone in the vicinity of the Mauritius Islands in the Indian Ocean. Maximum value of surface ozone jumped near Mauritius from 10 $\mu$ mb to 19 $\mu$ mb during outgoing cruise and from 17 $\mu$mb to 23.5 $\mu$mb during return.

(*ii*) A detailed examination of the hourly ozone concentration showed that the diurnal variation over the open seas was only about 20% of the maximum ozone concentration.

(*iii*) There was a gradual increase in the surface ozone concentration along the return route. This reflects the seasonal change in the surface ozone in these areas.

**4. Conclusion**

The findings of the present paper may provide additional inputs to the scientists studying various atmospheric processes over the Indian Ocean and Southern Ocean affecting monsoon in particular and weather, in general, over the South Asia.

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