

## Apparent Relationship between Thermal Regime in Antarctic Waters & Indian Summer Monsoon

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Received 17 August 1987; revised received 2 November 1987

Austral winter seasonal and intra-seasonal variabilities of Sub-Tropical Convergence and Antarctic Polar Front are examined using sea surface temperature patterns published in GOSSTCOMP (Global Operational Sea Surface Temperature Computations) charts for the Indian Ocean sector of the Southern Ocean during 2 contrasting years (1977 and 1979) of summer monsoon over India. The results suggest an apparent relationship between the thermal regimes in the Antarctic waters of the Indian Ocean sector and the summer monsoon activity over India, through a link of the Mascarene High southern sub-tropical high pressure zone.

Sea surface temperature (SST) distribution is the result of combination of several processes like effective solar radiative transfer, evaporative and sensible heat fluxes, oceanic advection and mixing. The feedback effect of SST on climate in delayed mode is well known. Though considerable attention has been paid to the association between the SST field in the nearby Arabian Sea and monsoon activity over India<sup>1-6</sup>, Das and Datta<sup>7</sup> have suggested some teleconnections between the ice cover in the Southern Ocean and Indian summer monsoon. It is also pointed out that the southern hemispheric subtropical high pressure zone (Mascarene High) around 50°S constitutes one of the important elements of large scale monsoon systems<sup>8,9</sup>. Varma *et al.*<sup>10</sup> have mentioned that summer monsoon rainfall over India has negative correlation with the environmental temperature of Antarctica. The knowledge of surface temperature field in Antarctic waters on large spatial and time scales is, therefore, necessary for a better understanding of the behaviour of monsoon and its long range forecast. SST monitoring has greatly been improved after the advent of operational NOAA polar orbiting satellites equipped with very high resolution radiometer sensors.

Southern Ocean is basically divided into 2 areas, Antarctic and sub-Antarctic zones. The Antarctic Polar Front (APF) at about 54°S is a boundary between 2 juxtaposed watermasses with distinct characteristics of cold and low saline polar and warm and low saline sub-polar waters. It is also a region of sinking for the heavier polar watermass leading to the formation of Antarctic Intermediate Watermass which spreads later towards north at intermediate

depths. The Sub-Tropical Convergence (STC) zone forms around 46°S where relatively cold sub-polar waters meet the less denser warm sub-tropical waters and slide down below the latter. Though these convergence fronts in general are continuous around the globe, some regional differences in their latitudinal positions are known to exist especially in the Pacific and Atlantic sectors of the Southern Ocean<sup>11</sup>. As far as Indian Ocean sector is concerned, information on their positions is fragmentary. In this study, an attempt is made to understand the seasonal and intra-seasonal characteristics of the polar fronts in the Indian Ocean sector of Southern Ocean in relation to 2 different contrasting years of Indian summer monsoon and an apparent relation between thermal regime in Antarctic waters and monsoon activity is brought out.

### Data and Methods

In the present study, SST patterns for June-September (austral winter) over the Indian Ocean sector (36°-50°S; 42°-84°E) of the Southern Ocean, as published in satellite data derived GOSSTCOMP (Global Operational Sea Surface Temperature Computations) charts, were examined separately for 1977 and 1979 representing the contrast monsoon activities. During 1977, the monsoon rainfall over India was mainly above normal (av. 89 cm) while in 1979 there was a wide spread deficit of rainfall (av. 71 cm).

The positions of thermal fronts at every 2° longitude interval from 45° to 84°E were determined from GOSSTCOMP charts considering that at these thermal fronts the temperature gradient suddenly

rises in the meridional direction. The APF was identified as the region where a relatively larger drop of SST around the range 2°-3°C encountered while progressing northward. In a similar way, STC was fixed further north of APF normally around 6°-8°C range of SST<sup>12</sup>.

**Results**

*Sub-tropical convergence*—The seasonal average picture (Fig. 1A) of STC shows its presence between 40° and 46°S in the Indian Ocean and a general southward shift from west to east up to 70°E. Further east, the zonal slope is greatly reduced. The zonal inclination is worked out to be around 1°30' latitude for 10°E. It is conspicuously seen that STC has a more northward penetration in 1977. The separation in its position between the 2 contrasting years is on an average around 1° latitude. Though STC maintains its general seasonal tendency of being more closer to Antarctica continent in the east, its zonal topography undergoes some intra-seasonal variability during June-September (Figs 1 B to E). During the season, August is seen as a month of relatively low intensity in the zonal slope. Maximum separation between 1977 and 1979 axes is also noticed in this month.

For a better understanding of transient variations in the latitudinal positions of STC and APF, 3 areas have been considered separately representing the western (45°E), central (65°E), and eastern (80°E) parts of the Indian Ocean sector of the Southern Ocean (Fig. 2). The intra-seasonal variability is well pronounced in the east while in the central part, it is not significant. The axis of STC during 1977 shows a general northward increase until August and thereafter, a reverse trend encounters. Further it is also seen that the intra-seasonal trends are opposite in nature during 2 contrasting years suggesting opposite processes which are at work. At the same time, the similarity in the variations in the eastern and western areas indicates simultaneous forcing at the lateral boundaries of the study domain.

*Antarctic polar front*—The east-west topography of APF shows comparatively less zonal slope in contrast to STC (Fig. 3A). However it shows more northward migration in 1977 like STC. The separation between the axes of 1977 and 1979 is around 2° which is higher than that observed in STC. In the beginning of austral winter (June), the axis of STC has a curved shape with its maximum southward extension around 68°E and as season progresses, it tends to be more horizontal with respect to increasing longitude (Figs 3B-E). Further, APF has a seasonal northward migration till August in 1977, while in 1979 its northerly movement is absent with the re-

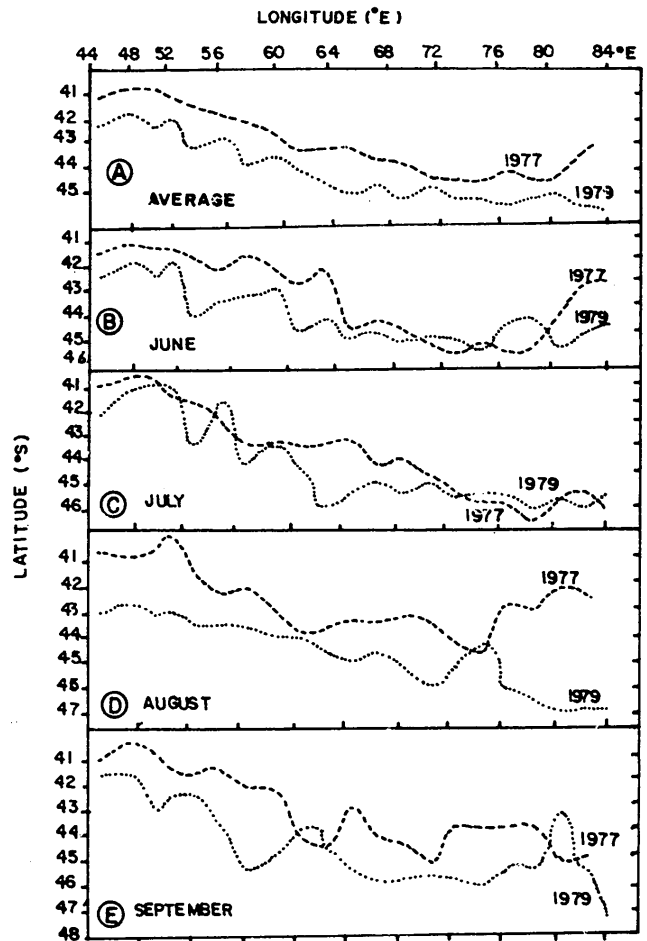


Fig. 1—Intra-seasonal variability in the zonal axis of STC in 1977 and 1979

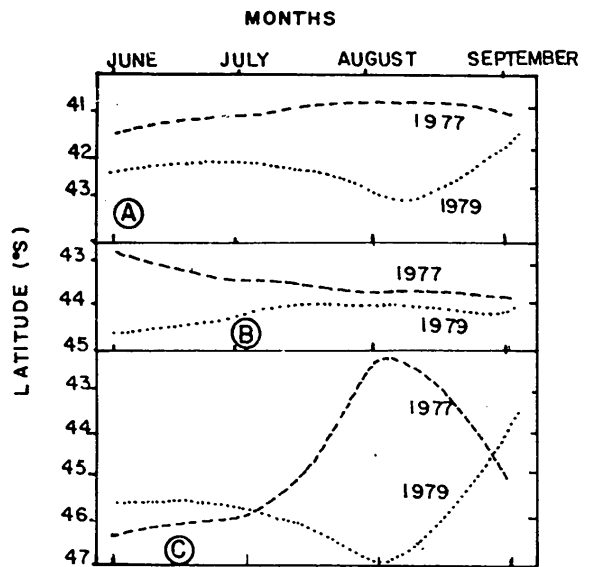


Fig. 2—Monthly variation in the axis of STC at (A) 45°E, (B) 65°E, (C) 80°E

sult that the separation between the axes of 1977 and 1979 is maximum in August. However the distance of separation between 2 contrasting years is

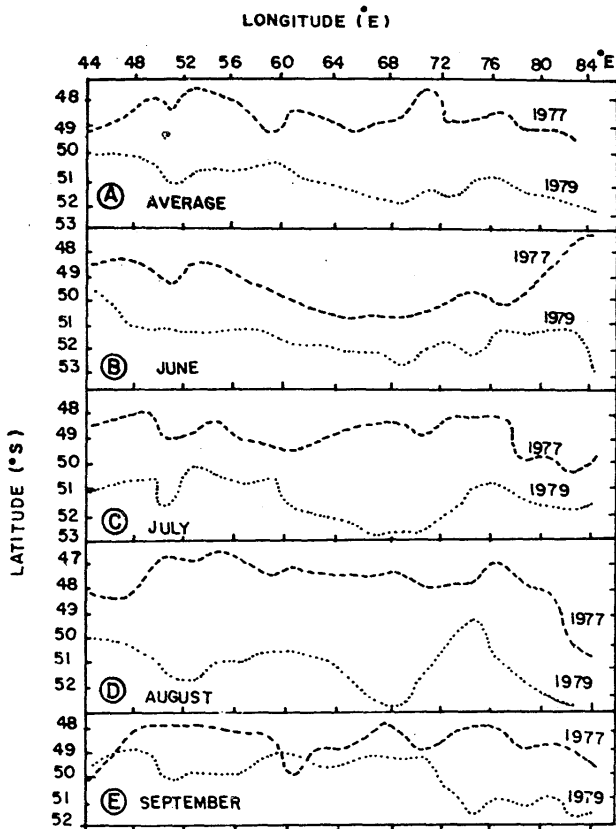


Fig. 3—Intra-seasonal variability in the zonal axis of APF in 1977 and 1979

suddenly reduced in subsequent month (September) due to reversals in their meridional migrations which are seen southward in 1977 and northward in 1979.

The relatively high inertial characteristic of APF in 1979 is a conspicuous feature in the present study. Its variability in different areas is shown in Fig. 4. In the eastern as well as in the western parts of study area, the latitudinal shift of APF is of order of  $1^\circ$  while in the central part it is well pronounced as seen from a higher change of about  $3^\circ$ . This is opposite to the variability of STC in which the central region encounters lesser intra-seasonal fluctuation. Further, the seasonal trends in APF are opposite during the 2 contrasting years especially after August as observed in STC.

**Discussion**

The more northerly penetration of both STC and APF during 1977 suggests a linkage between the thermal regime of Antarctic waters and Indian summer monsoon. It indicates larger fall in SST in the Southern Ocean with a possible greater sea ice extent in 1977 than in 1979. As a result of this, the boundary heating of the lower atmosphere is expected to be less, thereby paving way for greater sta-

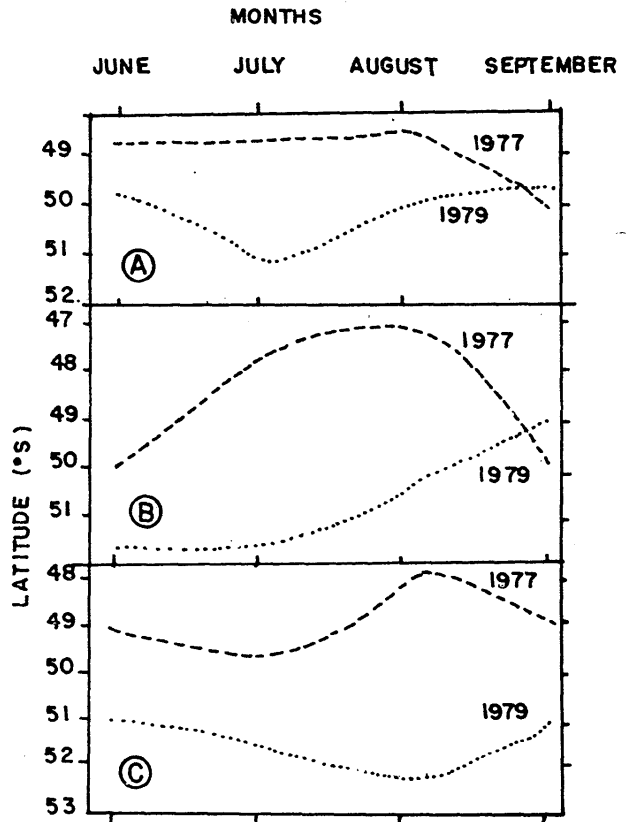


Fig. 4—Monthly variations in the axis of APF at (A)  $45^\circ\text{E}$ , (B)  $65^\circ\text{E}$ , (C)  $80^\circ\text{E}$

bility of the lower atmosphere and higher subsidence. Krishnamurthy and Bhalme<sup>7</sup> have shown that the intensity of Mascarene High with its axis around  $30^\circ\text{S}$  oscillates near to a bi-weekly period which is one of the strongest intra-seasonal modes in Indian summer monsoon rainfall.

Very often, peaks in rainfall over India are found soon after an intensification of several elements of the summer monsoon system including the Mascarene High also. The subsident air from this southern high pressure zone feeds the south-eastern trades which are further sucked in due to the presence of seasonal low pressure over Indian sub-continent through a strong low level flow across equator especially near the east coast of Africa. Several studies<sup>13-16</sup> also confirm that southwesterlies over India are not distinct from the southeast trades of southern hemisphere which are deflected due to Coriolis force after crossing the equator. The Mascarene High in the vicinity of STC is likely to be influenced by the lower boundary fluxes and its possible intensification in 1977 due to more northward extension of cold sub-Antarctic waters causes a greater push of south-east trades. Thapliyal and Singh<sup>17</sup> have also suggested that the behaviour of Mascarene High is different in good and bad monsoon years and also

on intra-seasonal time scale and its location and intensity help in forecasting the monsoon rainfall. The present study suggests a linkage between the thermal field in the Indian Ocean sector of Southern Ocean and monsoon rainfall over India via Mascarene High whose intensity is related to SST patterns. Although not precisely known certain physical explanation has also been given by Datta<sup>18</sup>. According to him the northward penetration of cold water helps in setting up a steep temperature gradient between the equator and southern latitude thereby building up stronger sub-tropical westerlies which in turn would cause greater momentum transfer across the equator. |

### Acknowledgement

The authors thank Dr B N Desai, Director for his interest. One of the authors (HBM) acknowledges CSIR, New Delhi for the fellowship.

### References

- 1 Shukla J, *J Atmos Sci*, **312** (1975) 503.
- 2 Shukla J & Misra B M, *Mon Wea Rev*, **105** (1977) 998.
- 3 Washington W, Chervin R M & Rao G V, *Pure App Geophys*, **115** (1977) 1335.
- 4 Ramesh Babu V, Rao M V & Sadhuram Y, *Tropical Ocean-atmosphere Newsletter*, **31** (1985) 6.
- 5 Ramesh Babu V Rao M S & Rao M V, *Influence of the eastern Arabian sea on the summer monsoon rainfall at west coast of India*, paper presented at IMS/JMS/RMS seminar on Long Range Forecasting of Monsoon Rainfall over India, New Delhi, April 1986.
- 6 Ramesh Kumar M R, Viswambharam N K & Rao L V G, *Proc Indian Acad Sci (Earth Planet Sci)*, **95** (1986) 435.
- 7 Das S K & Datta R K, *Mausam*, **36** (1985) 525.
- 8 Krishnamurti T N & Bhalme H N, *J Atom Sci*, **33** (1976) 1937.
- 9 Cadet D, *Indian J Met Hydrol Geophys*, **29** (1978) 1380.
- 10 Varma R K, Dugam S S & Subramanian K, *Interannual variability of the Antarctica temperature and its relationship with monsoon rainfall*, paper presented at IMS/JMS/RMS seminar on Long Range Forecasting of Monsoon Rainfall over India, New Delhi, April 1986.
- 11 Tcherina P, *Descriptive regional oceanography* (Pergamon Press, Oxford), 1980.
- 12 Luthjeharms J R E, *Deep-Sea Res*, **32** (1985) 1499.
- 13 Cadet D & Ovarler H, *Quart J R Met Soc*, **102** (1976) 805.
- 14 Cadet D, Olory-Togbe P & Sommeria G, *Indian J Met Hydrol Geophys*, **29** (1978) 435.
- 15 Cadet D & Olory-Togbe P, *Quart J R Met Soc*, **104** (1978) 971.
- 16 Cadet D & Desbois M, *Nature Lond*, **278** (1979) 538.
- 17 Thapliyal V & Singh S S, *Influence of Mascarene High on Indian summer monsoon*, paper presented at IMS/JMS/RMS seminar on Long Range Forecasting of Monsoon Rainfall over India, New Delhi, April 1986.
- 18 Datta R K, *Monsoon rainfall and teleconnections*, paper presented at IMS/JMS/RMS seminar on Long Range Forecasting of Monsoon Rainfall over India, New Delhi, April 1986.