Mausam, (1989), **40**, 1, 95-100

551.524.2 (239.9)

Temperature anomaly over Antarctica and monsoon activity

R. K. DATTA

Meteorological Office, New Delhi

(*Received 16 March 1988*)

सार — अंटार्कटिका, दक्षिणी गोलार्द्ध के महत्वपूर्ण भाग पर आच्छादित है जहाँ विषुवतीय प्रदेश के 28° से० भूतलीय ताप की तुलना में —70 से० से भी कम भूतलीय ताप हो सकता है। इस अध्ययन में अंटार्कटिका पर भूतलीय ताप की असंगतियों और मानसून क्रिया के मध्य संभव सम्बन्धों की जांच की गई है।

यह देखा गया है कि अंटार्कटिका पर पूर्ववर्ती जनवरी भूतलीय ताप असंगति प्रतिमान का अनुवर्ती मानसून की क्रिया के साथ सम्बन्ध होता है। अंटार्कटिका सूखे वर्षों से पूर्व प्रबल ऊष्ण असंगति से सूखे वर्ष प्रारम्भ होते हैं। अच्छे मानसून वर्ष प्रारम्भ के पूर्व वैसे ही विशिष्ट शीत असंगति देखी जाती है।

ABSTRACT. Antarctica covers a significant portion of the southern hemisphere where surface temperature can be as low as —70°C compared to the surface temperature of 28°C over equatorial region. In this study a possible linkage between anomalies of surface temperature over Antarctica and the performance of monsoon has been examined.

It is observed that the preceding January surface temperature anomaly pattern over Antarctica has an association with the performance of the following monsoon. Drought years are preceded by predominantly warm anomalies over Antarctica and good monsoon years are preceded by equally marked cold anomalies.

1. Introduction

Right from the beginning man has been seeking linkages of weather events occurring at different places. The lag in their occurrence becomes a useful predictor. The linkages could be on a smaller or regional scale with lag relationship of a few hours to a few days. This knowledge is used by conventional weather forecasters. The linkages could also be on a planetary or global scale with lag relationship varying from a few weeks to months, season or more. These long period links are generally associated with low frequency motions, which in the case of monsoon are associated with 10-20 day, 30-50 day time-scales to several longer time scale such as semi-annual, the annual and still longer period.

Since the last century, meteorologists have been searching for relationships of monsoon rainfall with weather events of distant regions. Above normal snowfall over the Himalayas in the pre-monsoon period was found to be negatively correlated with subsequent monsoon rainfall over India. Indian droughts were also associated with high pressure over Mauritius and Australia. Among other studies on the distant relationship (Hildrebrandson 1987; Lockyer and Lockyer 1902) the studies by Sir Gilbert Walker (1923, 1924) were significant. He observed that there are three dominant circulation features which he called North Atlantic, North Pacific and southern oscillations. The two northern oscillations can be represented by the contrasting sub-tropical anticyclones and the low pressure areas on their poleward sides. One measure of this contrast is a measure of the strength of the westerlies of mid-latitudes. The southern oscillation (SO) is, however, regarded as a large seasaw of atmospheric mass between the Pacific and the Indian Ocean in the tropics and subtropics. The main opposing centres of action of the SO are located near Indonesia and the South Pacific anticyclone covering the sub-tropical eastern Pacific.

'SO' out of the above three oscillations gained prominance in the mid-sixties, when the observational, theoretical and modelling studies showed a strong relationship of sea surface temperature anomalies (SSTA) over the tropical eastern Pacific well known as *El Nino* with SO and associated atmospheric response characteristics. Various workers (Berlage 1966 and Debertiz 1968) provided support of strong relationship between SSTA and atmospheric characteristics. The studies by Bjerknes (1969, 1972) and information from satellite clearly showed physical linkage of the interannual fluctuations of SST over the broad expanse of the eastern equatorial Pacific (*El Nino*), with SO related changes in the atmospheric fields such as changes in the zonal wind components near the equator and the large scale equatorial Pacific precipitation regimes. Notably, thus *El Nino* (also called warm event) is considered an important index of SO and more broadly these phenomena synthesized are into one and also sometimes referred to as ENSO.

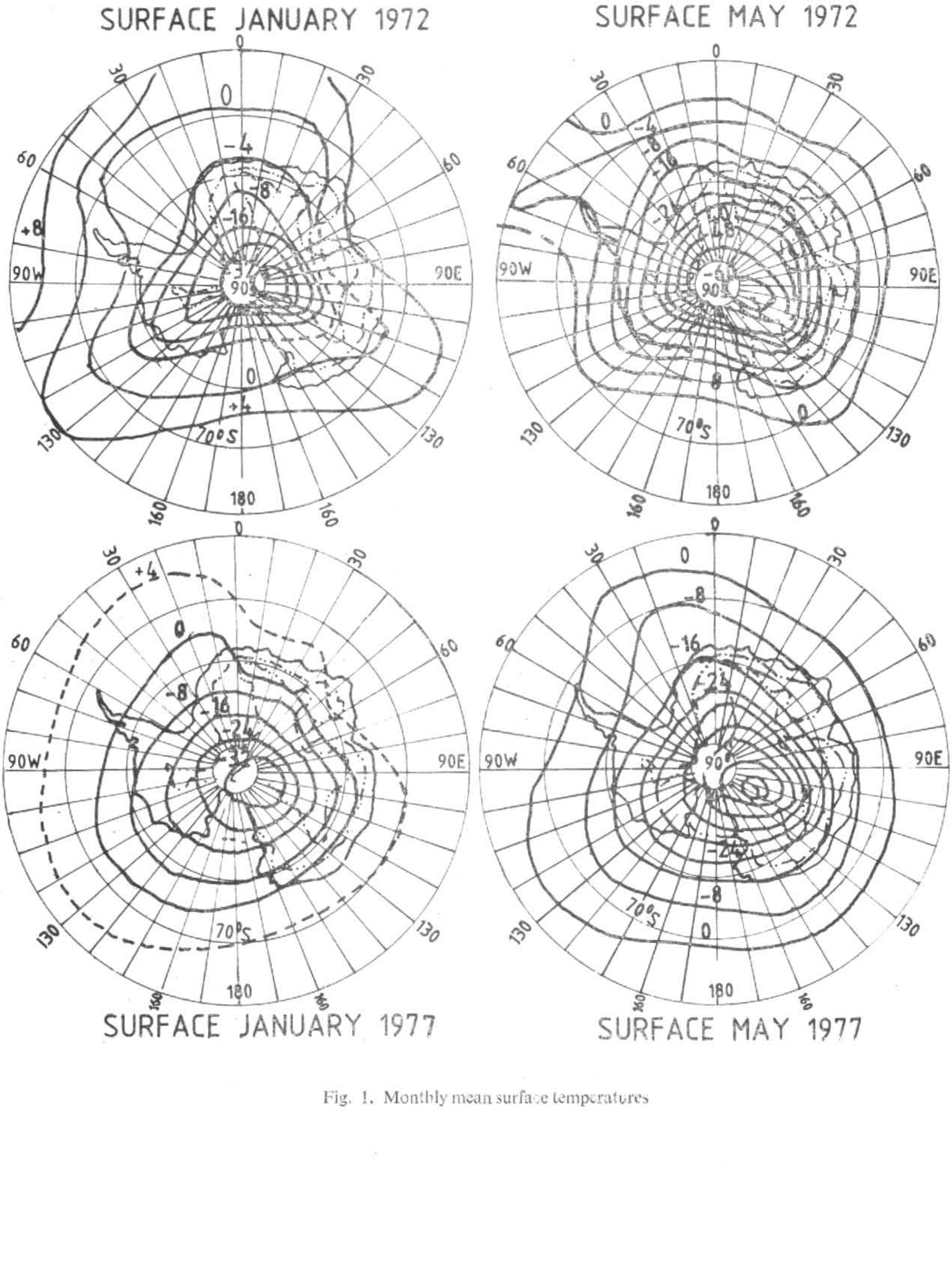


Fig. 1. Monthly mean surface temperatures

Sikka (1980), Shukla and Paolino (1983) and Datta (1985,1987) in their studies on the association of *El Nino* with the performance of the monsoon concluded that:

(*i*) *El Nino* or warm events in a majority of cases are associated with poor performance of the summer monsoon activity.

(*ii*) Information on the establishment of *El Nino* clubbed with the regional information (*i.e.*, rainfall records of last over 100 years show that there are just 3 cases of two consecutive years being drought years and never three consecutive years) can be used as good guidance for long range forecasting of monsoon rainfall.

(*iii*) Existence or otherwise of *El Nino* any year can be used only for guidance purpose and not a definite tool for long range forecasting of monsoon as there were drought during non *El Nino* years, *e.g.*, during 1964 and 1979 and good monsoon performance during *El Nino* years, *e.g.*, 1917, 1926 and 1942.

It is generally believed that the south hemispheric circulation features play a significant role on the onset and various other phases of monsoon activity (Kumar *et al.* 1983). The basic concept of Sir George Simpson (1921), that the monsoon is a continuation of southeasterly trade winds of the Indian Ocean, which after crossing the equator attain southwesterly direction due to the turning effect of coriolis force, is still valid. A conventional forecaster looks for cross-equatorial flow as an important signal for the onset of monsoon over Indian sub-continent. Datta *et al.* (1981) have also shown a northward shift of the equatorial trough as well as penetration of flow from southern hemisphere associated with the progress of monsoon over India. The intensity and location of the well known Mascerene high, a part of the southern hemispheric sub-tropical anticyclonic belt, is also observed to have a great influence on the onset processes and activity of monsoon. Thus, there is evidently a linkage between anomalies in the circulation features over southern hemisphere and performance of monsoon over Indian sub-continent. Antarctica covers a significant portion of the southern hemisphere. Moreover, compared to Arctic, where the surface temperatures are of the order of —40° C, the temperatures over Antarctica fall below —70° C. The temperatures over and near the equatorial region remaining the same, of the order of 28° C, the temperature gradients in the southern hemisphere are much steeper. As a result the exchanges taking place between poles and equator are more marked in the southern hemisphere compared to the northern hemisphere. Anomalies in surface temperature (which is to great degree related to ice cover) and other circulation features over Antarctica could, we believe, considerably influence the circulation features over southern hemisphere and, in turn, the monsoon circulation. The study of Antarctica is, thus, very interesting for understanding its possible relationship with the anomalies in monsoon circulation.

While seeking the distant relationship, Sir Gilbert Walker (1924) also observed that the December-February pressure of Mcmurdo Sound (77.5° S, 166.4° E) in Antarctica has positive correlation coefficient of 0.8 with the pressure over northwest India during the following March-May period and correlation coefficient of 0.6 with the rainfall over Peninsular India during the subsequent June-August period.

Das and Datta (1985), who examined the temperature anomalies over Sane (70.19° S & 2.21° W) in Antarctica for the year 1971—80 observed, though qualitatively, that the poor monsoon years of 1972, 1974 and 1979 followed warm anomalies and the rest of the years which had normal and above normal monsoon rainfall followed cold epochs. These preliminary results encouraged us to study the temperature anomalies over Antarctica in more details.

We have analysed the temperature field over Antarctica for the period 1960-1982. Out of these, we have picked up contrasting set of years, namely, two drought years of 1972 and 1979, and two good monsoon years 1977 and 1978. Anomaly patterns for these years are discussed in this paper for their possible relationship with the performance of the monsoon.

Based on all available data for the period 1960-1982, we have also worked out the monthly mean temperature over Antarctica and its anomalies during January to May which are related to the anomalies of subsequent monsoon performance. The results of this analysis are also discussed in this paper.

2. Data used

Data used in the study consist of the following:

(*i*) Antarctica monthly mean surface temperature for the years 1960-1982 from the WMO publication on climate data;

(*ii*) Computer printouts of monthly mean data for the same period supplied by Dr. D.J. Shea and Dr. H.Van Loon of NCAR, USA;

(*iii*) Long term mean grid point value from '*Climate of Upper Air, Southern Hemisphere*, Vol. **1**, Sept, 1969, NAVAIR 50-IC 55 (NCAR).

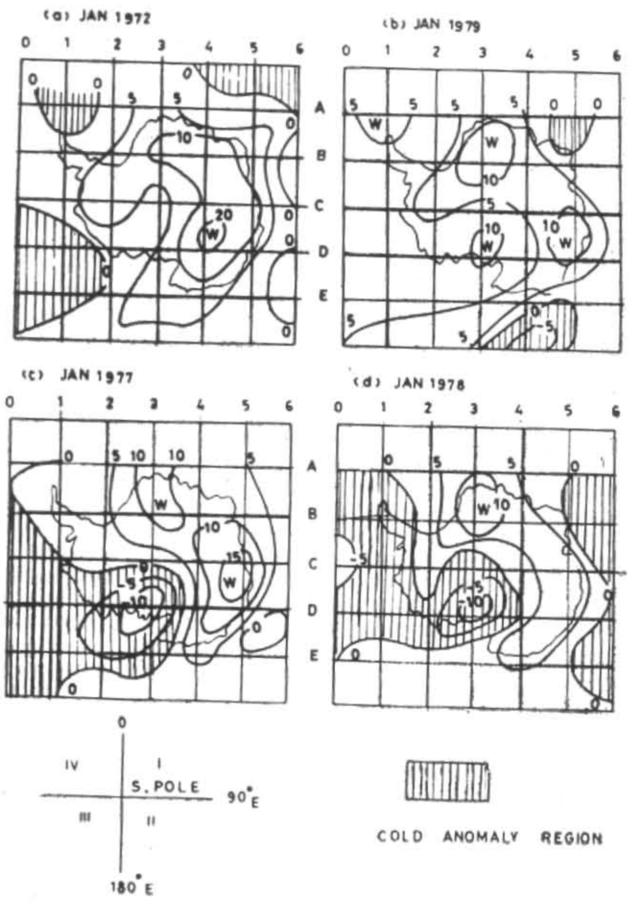
3. Data analysis and discussion of results

3.1. *Analysis of temperature field and temperature anomaly pattern.*

Monthly mean data of surface temperature were plotted and manually analysed. A sample chart for January and May 1972 and 1977 are shown in Fig. 1.

It is interesting to see that the region of the lowest temperature does not lie at the south pole but east of it, centred near Vostok (78.5°S, 106.9°E). Although there are some interesting differences in the mean monthly temperature patterns between 1972 and 1978 but the differences are very significant when we consider the anomaly patterns (deviation of temperature from long time mean).

The anomaly fields for the years 1972 & 1979 (drought years) and 1977 & 1978 (good monsoon years) for the five months prior to the monsoon season, *viz.*, January to May, were prepared. The anomalies show contrasting



Figs. 2 (a-d). Mean surface temperature anomalies for January (a) 1972, (b) 1979, (c) 1977 and (d) 1978

features between the good and poor monsoon years. The patterns of January show remarkable contrasting features and are, therefore, presented in the Figs. 2 (a-d).

It is interesting to note that the evolution of anomaly patterns during 1972 & 1979 (years of poor monsoon) are distinctly different from those during 1977 and 1978 (good monsoon years). But between themselves, *i.e,* 1972, 1979 on one side, and 1977, 1978 on the other side, there is a great similarity of patterns. Salient characteristics of these patterns are summarised below. As the presentation of the patterns are on polar stereographic projection with south pole at the centre, it is convenient to consider the location of anomalies with respect to the quadrants. For simplicity we call region of Antarctica between 0° & 90°E as quadrant I, between 90° & 180° E as quadrant II, between 180° E & 90° W as quadrant III and between 90° W & 90° E as quadrant IV.

(*i*) During January 1972, marked positive temperature anomalies (10°-20° C) are shown in quadrants I and II with central portion in the quadrant II and a warm anomaly tongue into western parts of the Antarctica. Mild negative anomaly exists in quadrants III and IV.

(*ii*) During 1979, the anomaly pattern is broadly similar to that of 1972, except negative anomalies are slightly more prominent than in 1972 in the quadrant II.

(*iii*) The evolution of anomaly pattern consisting of marked negative anomalies during 1977 and 1978 are very similar amongst themselves. Major centres of negative anomaly are located in quadrant III and adjoining quadrant IV.

Significant contrasting patterns being dominance of negative cold anomalies over most of the Antarctica (especially over most of quadrant III and to lesser degree over adjoining quadrants II and IV) preceding good monsoon, *i.e.*, January 1977 and 1978 compared to dominance of positive warm anomalies preceding droughts/deficit monsoon years of 1972 and 1979.

3.2. *Analysis of mean temperature anomaly over Antarctica*

We also worked out mean monthly temperature value for the month of January to May for the years 1960 to 1982. Anomalies have been worked out for each month as

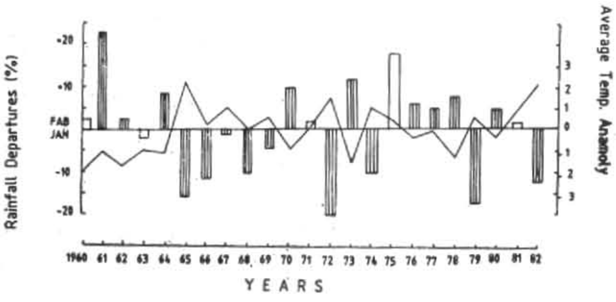


Fig. 3. Mean temperature anomaly over Antarctica (Jan-Feb) *versus* performance of monsoon rainfall (percentage departure)

well as for the combination of the months. The procedure adopted to work out this anomaly index is :

(*i*) Monthly mean data for every year for all available stations is manually analysed.

(*ii*) Data is then picked up at regular grid points and mean computed.

(*iii*) The difference of monthly mean of every year from the long time mean gives the anomaly index.

This anomaly index is compared with the performance of monsoon. In Fig. 3 we present the January-February anomalies *versus* monsoon anomaly for year 1960-1982. It is interesting to note that the negative relationship between January & February anomalies with the performance of the monsoon during June to September over India is valid in most of the cases. One significant case where it has failed is 1975. The analysis clearly shows that the relationship is consistent and is not just fortuitous.

4. Physical basis of such relationship

Krauss (1977) observed that during 1972 (a general drought year) 700 mb surface over Antarctica was abnormally warm and height of 700 mb and 500 mb higher than the normal. The similar situation was reflected in the mean 500 mb height over Antarctica, where for the group of two contrasting years 1958, 1964 (generally good monsoon years) and 1968, 1974 (a number of drought years), the mean 500 mb height during dry years was higher than the other years. The difference between these groups was significant and almost double the standard error. Meridional slope from tropic to Antarctica of 500 mb surface is, therefore, reduced in the case of dry years compared to other years (1958-1964). This observation when combined with surface temperature anomaly patterns presented above, may show that these teleconnections are not accidental.

These contrasting features of temperature anomaly over Antarctica lead one to hypothesize that intense negative anomaly brings in steep temperature gradient between equator and Antarctica (the changes over the equator being small). This results in stronger westerly thermal/shear winds and thereby stronger sub-tropical westerlies over the southern hemisphere. The stronger westerlies, in turn, result in greater momentum transfer through the equator, *i.e.,* stronger cross-equatorial flow and stronger monsoon activity. The reverse would be the situation when there is positive temperature anomaly over Antarctica.

5. Concluding remarks

The analysis of surface temperature anomaly over Antarctica *vis-a-vis* performance of the monsoon lead us to the following conclusion:

(*i*) January surface temperature anomaly patterns over Antarctica depict contrasting features during poor and good monsoon years. Although the sample studied here is small (2 samples of good and poor monsoon years), but it shows interesting relationship, *viz.*, drought years are preceded by predominantly warm anomalies over Antarctica and good monsoon years are preceded by equally marked cold anomalies. Moreover, there is characteristic pattern of anomalies which distinguished 1972, 1979 from 1977 and 1978. It may be noted that whereas 1972 was an intense *El Nino* year but 1979 was not, although both were drought years. Nevertheless, both these years were drought years as far as performance of monsoon is concerned and Antarctica surface temperature anomaly patterns are more or less similar.

(*ii*) The combined mean, January-February temperature anomaly of Antarctica when compared with the departure of rainfall over India during subsequent June to September, shows that two anomalies are negatively correlated. These results are in conformity with earlier hypotheses (Das and Datta 1985) that warm epochs over Antarctica are followed by poor performance of monsoon and *vice versa.*

To further explore this feature, we are also in the process of analysis of the mean upper air data of Antarctica, the result of which will be presented in a subsequent paper.

Acknowledgements

The author is grateful to Dr. R.P. Sarker for his encouragenent. He is also grateful to Professors Herbert Riehl, T.N. Krishnamurti and J. Shukla for useful comments. Grateful thanks are also due to :

(*a*) M/s G.R. Gupta and K. Prasad for editing.

(*b*) Dr. Hary Van Loon and Dr. D.J. Shea for providing print out of Antarctica data from NCAR.

(*c*) M/s Manohar Lal and Satish Chander of NHAC for help in plotting and analysis.

(*d*) Smt. Usha C. Balani and Ramesh Kumar Khowal for typing the manuscript.

(*e*) Shri S.K. Arora for drawing work.

References

Berlage, H.P., 1966, The Southern Oscillation and World Weather, K Ned. Meteolo. Inst. Meded Verh 88, 152 pp.

Bjerknes, J., 1966, A possible response of the atmosphere Hadley circulation to equatorial anomalies of ocean temperature, *Tellus*, **18**, 820-829.

Bjerknes, J., 1972, Lage scale atmospheric response to the 1964-65 Pacific equatorial warming, *J. phys. Oceanogr.*, **2**, 212-217.

Das, S.K. and Datta, R.K., 1985, Antarctica and Indian monsoon, *Mausam,* **36**, pp. 525-26.

Datta, R.K. *et al.*, 1981, Proc, Inter Conf. on Scientific Results on Monex, Denspar, Bali (Indonesia), WMO, Geneva, Oct 1981, pp. 6-35.

Datta, R.K., 1986, India Met. Dep. Pre-publ. Sci. Rep., 86/3.

Datta, R.K. 1987, Monsoon rainfall and Teleconnections, *Vayu Mandal,* **7** pp. 87-93.

Debertiz, R., 1968, Cross spectrum analysis of rainfall and sea temperature of the equatorial Pacific related to the intertropical convergence zone of the winds, *Deep-Sea Res.*, **27A**, 693-714.

Hildebrandsson, H.N., 1897, Quelques vecherches sur les entres d'action de l' Atmosphere Kon Svesnska Vetens, Akad Hand, **29**, 33 pp.

Kraus, E.B., 1977, Subtropical Droughts and Cross-Equatorial Energy Transport, *Mon. Weath. Rev.*, **105**, 1009-1018.

Kumar, S.K., Seethumadhavan and Rao, M.K., 1983, Influence of frontal systems moving across southern Africa and southwest Indian Ocean on the onset of southwest monsoon over west coast of India, *Mausam*, **34**, 4, pp. 405–410.

Lockyer, N. and Lockyer, W.J.S., 1902, On the similarity of the short period pressure variations over large areas, *Proc. Roy. Soc. London*, **73**, 457.

Shukla, J. and Paolino, D.A., 1983, The southern oscillation and long range forecasting of the summer monsoon rainfall over India, *Mon. Weath. Rev.*, **111**, 1830-1837.

Sikka, D.R., 1980, Some aspects of the large scale fluctuations of summer monsoon rainfall over India in relation to fluctuations in the planetary and regional scale circulation parameters, *Proc. Indian Acad. Sci.* (Earth & Planetary Science), **89**, 179-195.

Walker, G.T., 1923, Correlation in seasonal variations of weather, VIII. A preliminary study of World Weather, *Mem. India Met. Dep.*, **24**, 75-131.

Walker, G.T., 1924, Correlation in seasonal variations of weather, *Mem. India Met. Dep.*, **24**, 275-332.