Indian J. Met. Geophys. (1973), **24**, 3, 251-256

551·54 : 551·506

A time series analysis of the global atmospheric pressure*

B. M. MISRA

Indian Institute of Tropical Meteorology, Poona

(*Received 20 April 1972*)

ABSTRACT. 12 GMT surface pressure data for 188 stations for the IGY period have been analysed as a time series. The first difference filter has been utilised in order to eliminate the low frequency trend in the series. Mean periodicities in the pressure tendency oscillations are computed. All the stations show values scattered between 4 and 5 days. The tendency series are then subjected to power spectrum analysis, which brings out the peak in the period range of 4-5 days. Cross-spectrum analysis on stations arranged in the order of increasing longitude shows that the oscillations result from a westward propagating pressure wave with zonal wavelength equal to the latitude circle.

1. Introduction

1.1. Recently a number of studies have furnished evidence that various atmospheric parameters in the tropical region show quasi-periodicities of the order of 4-5 days (Wallace and Chang 1969; Yanai *et al.* 1968, Nitta 1970, Chang *et al.* 1970). These studies are mainly concentrated over the equatorial Pacific. In a much earlier study Eliot (1895) had found evidence for short period barometric oscillation of period 4-5 days over the Indian monsoon region. Subsequent work by Frolow (1942) and Palmer and Ohmstede (1956) showed the existence of similar oscillations over other parts of the tropics.

1.2. Examining the daily pressure tendency data at selected Indian stations for a 12-year period, Ananthakrishnan and Misra (1970 a, b) confirmed the earlier findings of Eliot. They also found that the oscillations have no association with the phase of the sunspot cycle and hence could not be attributed to extra-terrestrial causes like solar flares as suggested by Palmer and others. The period of the oscillations was found to be practically independent of latitude and season although the amplitude was more at higher latitudes. Examination of the pressure tendency data at seven extra-Indian stations in the zonal belt 35°-60°N showed that the oscillations were present at all these stations suggesting that 4-5 day oscillation is perhaps global in character (1970 c).

1.3. Studying the surface pressure data of seven stations in the equatorial belt of the northern hemisphere by the technique of spectrum analysis, Wallace and Chang found that about half the power was contained in oscillations of periods of 10 to 100 days. They also found a distinct peak corresponding to a period of about 4 days at all stations. The cross-spectrum analysis showed that the 4-5 days pressure oscillation results from a westward propagating wave with a zonal wave length equal to the circumference of the earth. Also, from an analysis of the geopotential heights of the standard isobaric levels for the northern hemisphere by spherical harmonics, Eliasen and Machenhauer (1965) found the 24-hour tendency field showing a 'more or less regular westward propagation with mean period of about 5 days for wave numbers 1, 2 and 3'.

1.4. It was considered to be of interest to extend the study of Wallace and Chang, mentioned earlier by selecting stations round the globe in different zonal belts of both the hemispheres, covering a wide range of latitudes to understand the extent to which the 4-5 days oscillation could be traced in the two hemispheres and also to understand its propagation characteristics. The results of such a study are reported in this paper.

2. Data for study

2.1. The study is based on the 12 GMT surface pressure data of 188 stations for the IGY period 1 July 1957 to 31 December 1958, which covers 549 days. The daily values of the sea level pressure were extracted from the IGY microcards To minimise the errors due to pressure reduction, the stations selected were at altitudes less than 100 metres. About ten stations, more or less uniformly distributed in longitude, were chosen

*Presented at the International Symposium on Probability and Statistics in Atmospheric Sciences, Honolulu, Hawaii, June 1-4, 1971

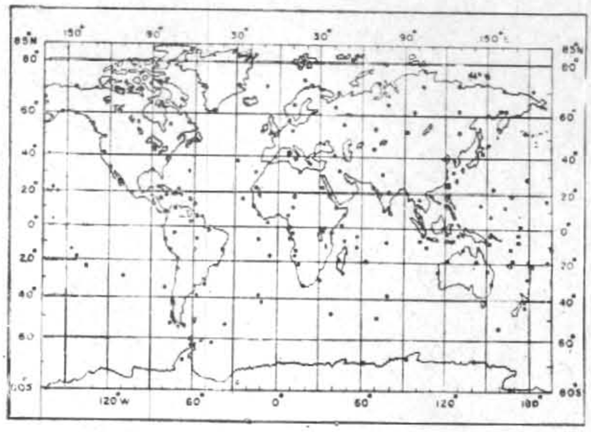

Fig. 1

Geographical locations of the stations used in the time series analysis

TABLE 1

Index No. of stations in different zonal belts with corresponding mean periodicities in days (within brackets) of oscillations of pressure tendency

Zonal belt	Northern Hemisphere	Southern Hemisphere
0°-5°	64500 (4·0), 63260 (3·8), 96694 (3·9), 91610 (4·1), 91487 (3·8); 80411(4·2), 65592 (3·9)	64503 (4·1), 63820 (4·3), 63980 (4·6), 96253 (3·6), 97724 (3·9), 97760 (3·7), 94085 (4·1), 91700 (4·6), 84377 (4·1), 82191 (4·8)
5°-10°	65271 (3·7), 63230 (3·5), 43371 (3·9), 48568 (3·9), 98754 (3·9), 91334 (4·6), 91376 (4·5), 78806 (4·5), 81002 (4·5), 61866 (4·0)	66160 (3·6), 63894 (3·9), 61967 (4·3), 96745 (3·8), 97900 (3·9), 91503 (3·1), 91724 (4·0), 91920 (4·0), 84452 (3·9), 82861 (3·5), 61900 (4·0)
10°-15°	65073 (4·1), 63043 (3·7), 43279 (4·3), 48455 (4·1). 98439 (4·7), 91218 (4·5), 91250 (4·8), 78700 (4·3), 78954 (4·1), 61695 (3·8)	66305 (3·5), 61974 (4·2), 96995 (4·6), 94120 (4·4) 91543 (3·6), 91811 (5·4), 91943 (5·1), 84691 (4·7), 83262 (3·4), 83248 (4·0)
15°-20°	61017 (4·5), 62341 (4·1), 43003 (4·3), 48378 (4·4), 98223 (4·4), 91245 (4·7), 91275 (4·5), 91285 (4·7), 76654 (4·2), 78501 (4·6), 78897 (4·5), 08583 (4·1).	66422 (3·5), 67073 (4·2), 61988 (4·6), 94203 (4·4), 94267 (3·6), 91558 (5·4), 91822 (5·1), 91942 (4·7), 85406 (3·4), 61901 (4·0)
20°-25°	62414 (4·4), 42867 (4·5), 46692 (4·3), 91131 (4·8), 91165 (4·9), 76405 (4·2), 78119 (4·8), 60096 (4·5),	68110 (3·8), 67197 (4·5), 94300 (4·7), 94374 (4·7), 91699 (5·1), 91948 (5·0), 85442 (3·6), 83743 (4·5)
25°-35°	62016 (4·7), 40650 (4·2), 41640 (3·9), 47184 (4·4), 91066 (4·8), 72295 (4·5), 72234 (4·9), 78016 (4·6), 08521 (5·1)	68816 (3·8), 68588 (3·7), 67198 (4·1), 94649 (4·3), 94791 (4·9), 93997 (5·5), 85469 (4·4), 85585 (4·2), 83995 (4·4), 68902 (4·2)
35°-45°	07761 (4·7), 17038 (4·1), 38081 (4·1), 47058 (4·5), 47420 (4·8), 72594 (4·1), 72405 (4·3), 72815 (4·0), 08506 (5·0)	68994 (3·5), 67199 (3·5), 94697 (4·4), 93986 (4·6), 85834 (4·4), 87692 (4·2), 68906 (3·7)
45°-55°	10147 (4·4), 27612 (4·3), 28679 (4·1), 29865 (4·3), 31388 (4·4), 32411 (4·4), 70454 (4·2), 70398 (4·0), 72892 (3·9), 72905 (3·5), 74098 (3·9), 03953 (4·4)	94998 (4·0), 85930 (4·2), 88890 (3·8), 88903 (3·9)
55°-65°	01262 (4·5), 22550 (4·6), 23552 (4·3), 23891 (4·4), 24959 (4·5), 25821 (4·6), 25594 (4·5), 70360 (4·5), 72934 (4·0), 72915 (4·8), 04270 (3·9), 04018 (4·4)	94986 (3·9), 89592 (3·6), 95502 (3·9), 88959 (4·0), 88925 (3·6).
65°-75°	01028 (4·2), 01098 (4·6), 20667 (4·7), 20891 (4·7), 21824 (4·7), 21965 (4·6), 21982 (4·8), 70086 (4·4), 72925 (4·5), 72918 (4·8), 04212 (3·9), 01001 (4·1)	89664 (3·9), 89162 (4·1), 89043 (4·1), 89022 (4·0)
75°-85°	01005 (4·4), 20047 (4·7), 20069 (5·1), 20292 (5·0), 21432 (4·6), 74074 (4·5), 74082 (4·2), 04310 (3·8).	

in zonal belts of 5 degrees width in the tropics and 10 degrees width beyond. The index numbers of the stations in the different zonal belts, whose data were utilised in the study, are given in Table 1. The geographical locations of the stations are shown in Fig. 1.

3. Method of analysis

3.1. Since the object of the present study was to investigate the nature of the 4-5 days oscillation, it was considered desirable to remove the low frequency trend from the pressure series. This was accomplished by utilising the first difference filter, which reduces the original series to a series of 24-hour pressure tendencies. The gain function of the filter is presented in Fig. 2. It will be seen that periodicities greater than ten days are practically eliminated in the filtered series while periodicities of less than six days are almost fully retained.

3.2. The computation of the spectra in the present study follows the procedure given by Jenkins and Watts (1968). Though the process is similar to that of Munk *et al.* (1959) and Maruyama (1968), there is a small difference in the estimation of the covariance functions. Following Parzen (1961) the divisor N (=total number of data points) is employed in the estimation of these functions in preference to $N—L$ (L=Lag).

3.3. A preliminary study was undertaken to examine the behaviour of the filtered series to statistical analysis. Lags of 10, 20 and 40 were used associated with the Tukey and Parzen lag windows. From this study, a lag of 20 with the Tukey window, giving the weights at lag L as

$$W(L)=0.5\ (1+\cos \pi\ L/M)\ L=1,\ M\text{-}1$$

where, M=the maximum lag, was chosen. This gives sufficient resolution and smoothing for the present study, where we are not interested in periodicities resolved to a degree less than 0.5 day. This allows the degrees of freedom to be as high as 73, with a bandwidth of 0.067.

4. Results

4.1. The mean periodicities of oscillations in the pressure tendency are also tabulated in Table 1. The values show a scatter between 4 to 5 days, the values coming below 4 and above 5 in a few cases. Not much difference is exhibited between stations in the tropical and extra-tropical belts. The data of the stations in different zonal belts were next subjected to cross-spectral analysis. To check the coherency estimates,

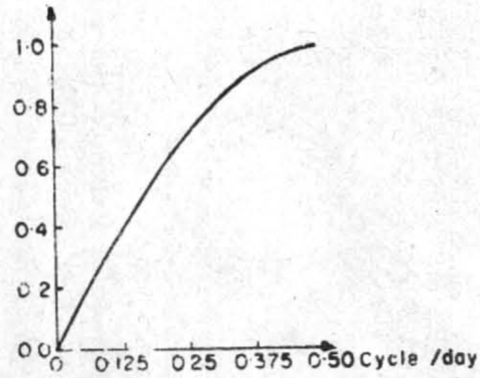

Fig. 2

Gain-fraction of the fish-difference filter

the reference station in a zonal belt was successively altered and the estimates examined. The frequency domain in the 4-5 days region showed coherences ranging from 0.2 to 0.7 in various combinations.

4.2. The autospectra of stations, one per zonal belt are given in Fig. 3. Even though the pattern is not the same in all cases, but a peak in the 4-5 days region is available in almost all of them.

4.3. The most important part of the study has been the phase spectra of the time series between different stations. As already mentioned, the phases of all stations with respect to a particular one are computed for all frequencies between 0 to 0.5 cycle with a lag 20. Out of these values of phases, we will focus our attention to the periodicities of 5, 4.4 and 4 days corresponding to the points 8, 9 and 10 in the phase spectra. The phases of different stations with respect to the reference station of various zonal belts of the two hemispheres are shown graphically in Fig. 4. The figure shows that in the belt $\pm 20°$ latitude, there is a uniform phase progression with longitude. Starting with a reference station as we move to stations of increasing longitude eastward, the phase builds upto 2π for a complete traverse round the zonal belt. This shows that the 4-5 days oscillation in the zonal belts of the tropics is a westward propagating wave of wavenumber one. This characteristic does not change as the reference station is shifted. The nature of the phase progression for three reference stations in each zonal belt is shown in the figure.

4.4. Beyond 20° in the northern hemisphere the phase progression appears to be rather irregular. In the highest belt 75°-85° there is suggestion, that the progression may even be in the

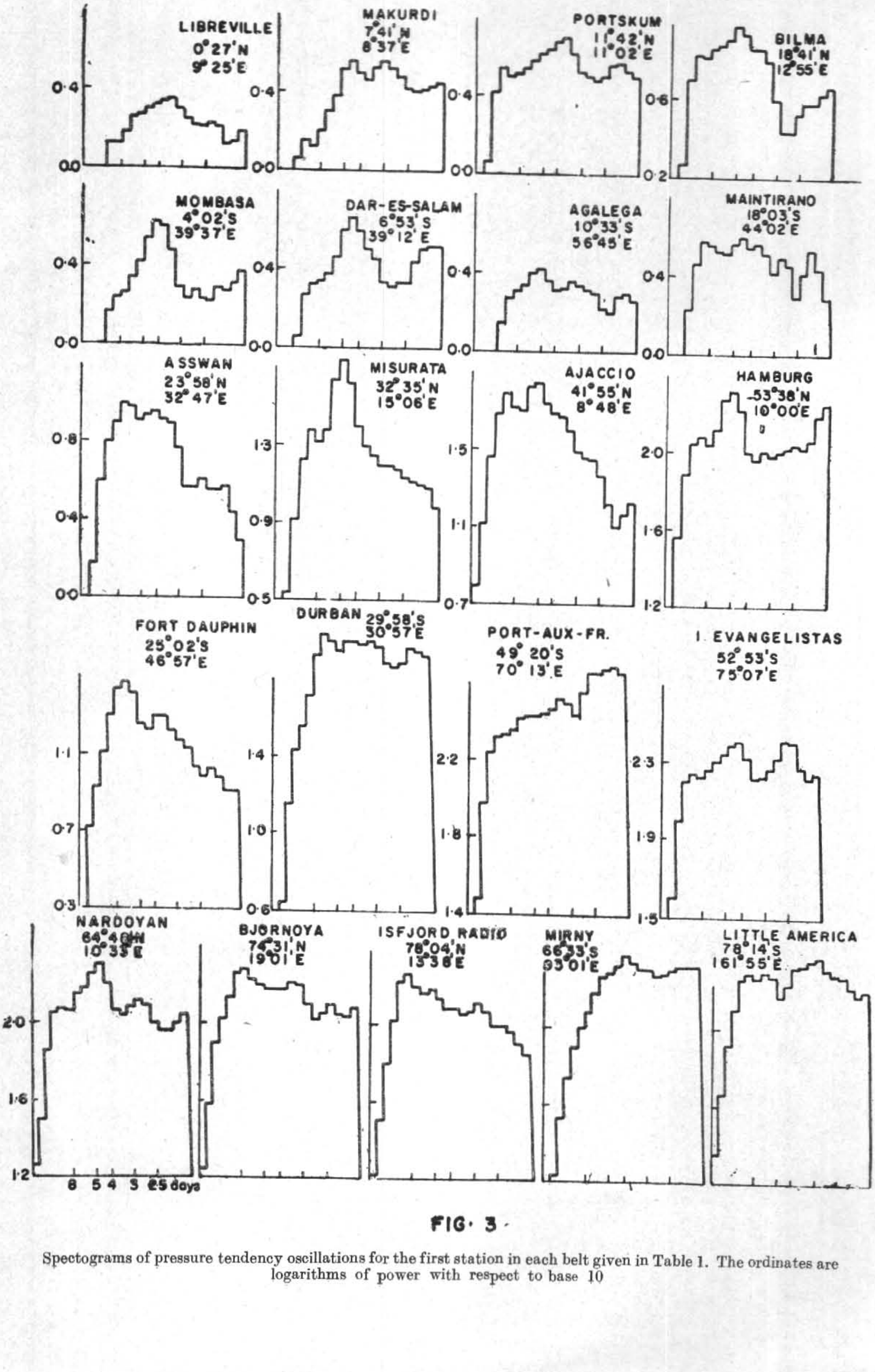

FIG. 3

Spectograms of pressure tendency oscillations for the first station in each belt given in Table 1. The ordinates are logarithms of power with respect to base 10

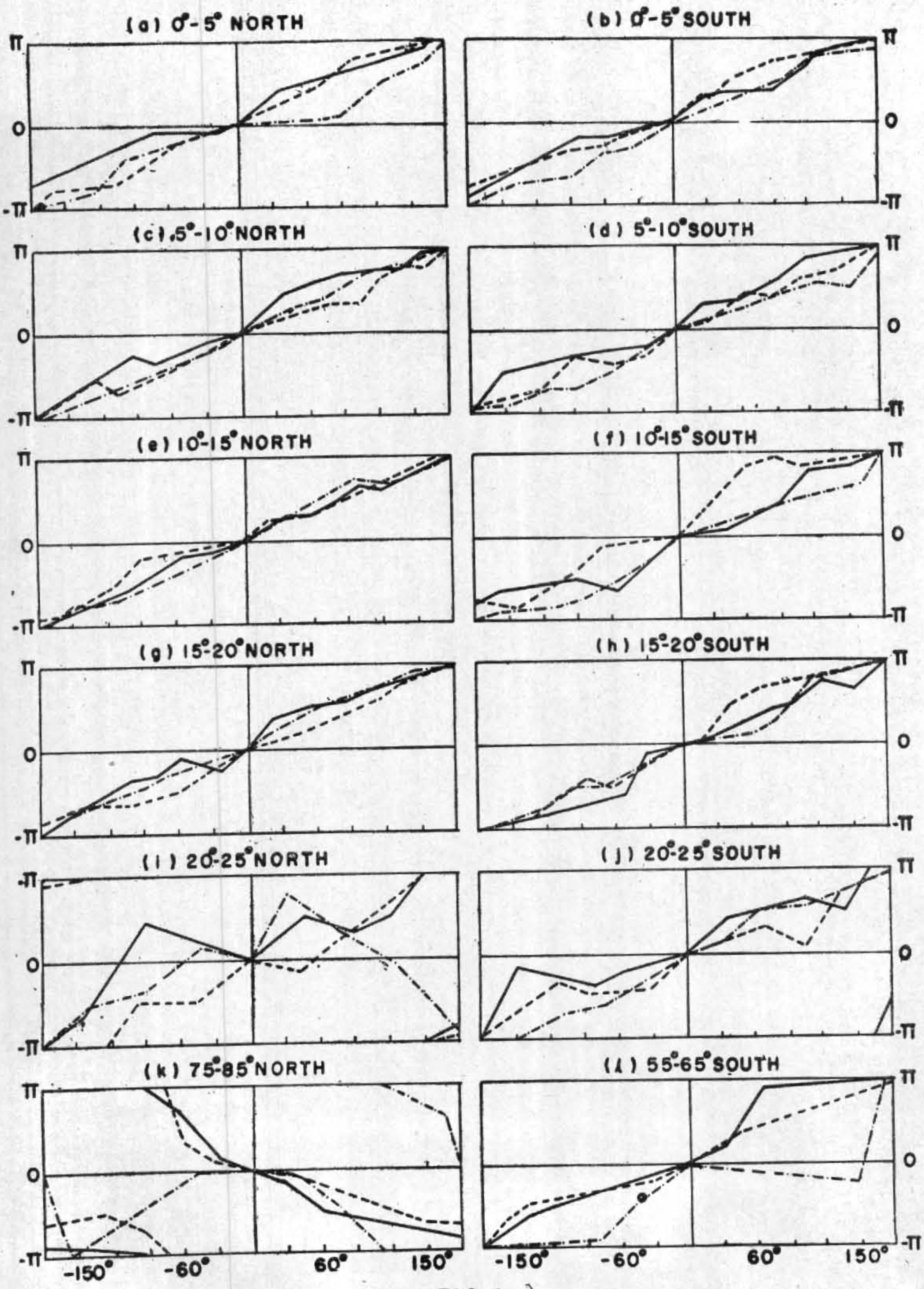

FIG. 4

The plot of phase difference against the longitude difference for various zonal belts in two hemispheres opposite direction, however this is not conclusive. In the southern hemisphere on the other hand, the characteristics of the westward phase progression persist at higher latitudes also.

5. Conclusion

The present study brings out the existence of the westward propagating pressure wave of 4-5 days period and wave number one in the tropical belts of both the hemispheres. The results for the southern hemisphere also show that the pressure wave can be traced to much higher latitudes in this hemisphere. The irregularity at higher latitudes in the northern hemisphere results presumably from the inhomogeneity of the surface features of this hemisphere compared to that of southern hemisphere. A further complication at higher latitudes in the northern hemisphere is the superposition of the eastward moving extratropical disturbances and the pressure variations associated with them.

Acknowledgement

The author takes the opportunity to express his sincere gratitude to Dr. R. Ananthakrishnan, formerly Director, Institute of Tropical Meteorology, Poona (now retired) for his encouragement and kind guidance. Thanks are due to Shri Y. Ramanathan and Shri C. M. Dixit for helps in the computer programming. The effort of Shri A. Girijavallabhan for typing the manuscript is gratefully acknowledged. The study was undertaken while the author was under an Air India Fellowship in the Institute.

REFERENCES

Ananthakrishnan, R. and Misra, B. M. 1970 (a) India met. Dep. Sci. Rep. No. 119.
(b) Proc. Symp. Tropical Meteorology, Honolulu, Hawaii.
(c) *Curr. Sci.*, **39**, pp. 386-387.

Chang, C. P. and Wallace, J. M. 1969 *J. atmos. Sci.*, **26**, pp. 1010-1025.

Eliot, J. 1895 *Mem. India met. Dep.*, **6**, pp. 89-160.

Frolow, S. 1942 *Bull. Am. met. Soc.*, **23**, pp. 239-254.

Hayashi, Y., Yanai, M., Maruyama, T. and Nitta, T. 1968 *J. Met. Soc., Japan*, **46**, pp. 308-323.

Machenhauer, B. and Eliasen, E. 1965 *Tellus*, **27**, pp. 220-238.

Maruyama, T. 1968 *J. Met. Soc. Japan*, **46**, pp. 327-342.

Nitta, T. 1970 *Ibid.*, **48**, pp. 47-60.

Ohmstede, D. W. and Palmer, C. E. 1956 *Tellus*, **8**, pp. 495-507.

Parzen, E. 1961 *Technometrics*, **3**, pp. 167-190.

Tucker, M. J., Snodgross, F. E. and Munk, W. H. 1959 *Bull. Scrips Inst. Oceanogr.*, **7**, pp. 283-362

Wallace, J. M., Morris, V. F. and Chang, C. P. 1970 *J. atmos. Sci.*, **27**, pp. 195 201.

Watts, D. G. and Jenkins, G. M. 1968 *Spectral analysis and its applications*, Holden Day, Sanfranscisco, California.