THERMAL CHANGES IN THE TROPOSPHERE ASSOCIATED WITH SEASONAL TRANSITIONS OVER INDIA

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THE summer monsoon circulation over South Asia—the most pronounced among the monsoon circulations of the world—is brought about by the progressive thermal changes in the atmosphere with the changing declination of the sun as a result of the large land-sea contrasts over this part of the globe. In the winter months, temperatures across India decrease from south to north below 200 mb.; in the summer monsoon months temperatures increase from south to north throughout the troposphere. In conformity with this temperature distribution, the zonal westerlies increase in strength up to about 200 mb. in the winter months; in the summer monsoon months the zonal westerlies over peninsular India decrease in strength up to 500 mb. level above which they are replaced by easterlies which increase in strength almost up to the tropopause. The maximum strength of the zonal westerlies in winter (the sub-tropical westerly jet stream) is reached near 200 mb level at about the parallel of 27° N.; the zonal easterlies of the summer monsoon months attain the maximum strength (the tropical easterly jet stream) near 150 mb. level at about the latitude of 13° N. These are the broad features of the winter and summer monsoon circulations over India.

2. The transition from the winter to the summer monsoon circulation which sets in towards the end of May or the beginning of June heralds the onset of the south-west monsoon rains over the extreme south-west of the Indian peninsula. The retreat of the monsoon from north-west India begins by about the middle of September.

3. There have been several studies relating to the meteorological features associated with the onset and retreat of the south-west monsoon.[1-5] An interesting aspect of this problem is the manner in which the reversal of the thermal gradients across the country takes place both in space and in time. Insight into this is provided by the study of the vertical shears of the zonal winds at selected stations across the country. We have made such a study on the basis of the mean zonal winds at selected Rawin stations for the six-year period 1961-1966. As monthly mean winds are not sufficient to reveal the nature of the transition in all its details we have made use of 10-day mean winds for all the months, each month being split into three such periods. From the mean zonal winds at the standard reporting levels, shears between adjacent levels were worked out. If the winds are geostrophic the vertical shears of the zonal winds will be directly proportional to the meridional temperature gradients.

4. The results of the study for the three stations Trivandrum, Nagpur and New Delhi which lie approximately along the meridian of 78° E. and cover the latitude span from 8° to 28° N. are shown diagrammatically in Fig. 1. In the figure regions of shear which correspond to easterlies increasing with height (negative shears) are shown dotted. The broken thick line separates the areas of positive and negative shears. Positive shears (westerlies increasing with height) can be interpreted as temperatures increasing from north to south and *vice versa*.

5. Referring to the diagram for Trivandrum, it will be seen that during the months of January and February, a wedge of negative shears occurs between 700 and 500 mb. Negative shears also occur at the upper tropospheric levels. Elsewhere the shears are positive in the troposphere. By the middle of March the shears are positive practically at all levels below 150 mb. except in the lowest levels below 700 mb. By the first week of April, the temperature gradient changes sign near 150 mb. level. With the advance of the season, the reversal of temperature gradient marches progressively downwards, reaching the level of about 600 mb. by the end of May. Thus a period of nearly six weeks elapses between the establishment of summer monsoon type of temperature gradient at 150 mb. and at 600 mb. levels. The change-over from positive to negative vertical shear or the reversal of the horizontal thermal gradient takes place in the layer between 700 and 500 mb. almost simultaneous with the onset of the south-west monsoon rains over Kerala. By this date the gradients have already got reversed in the layers above and below.

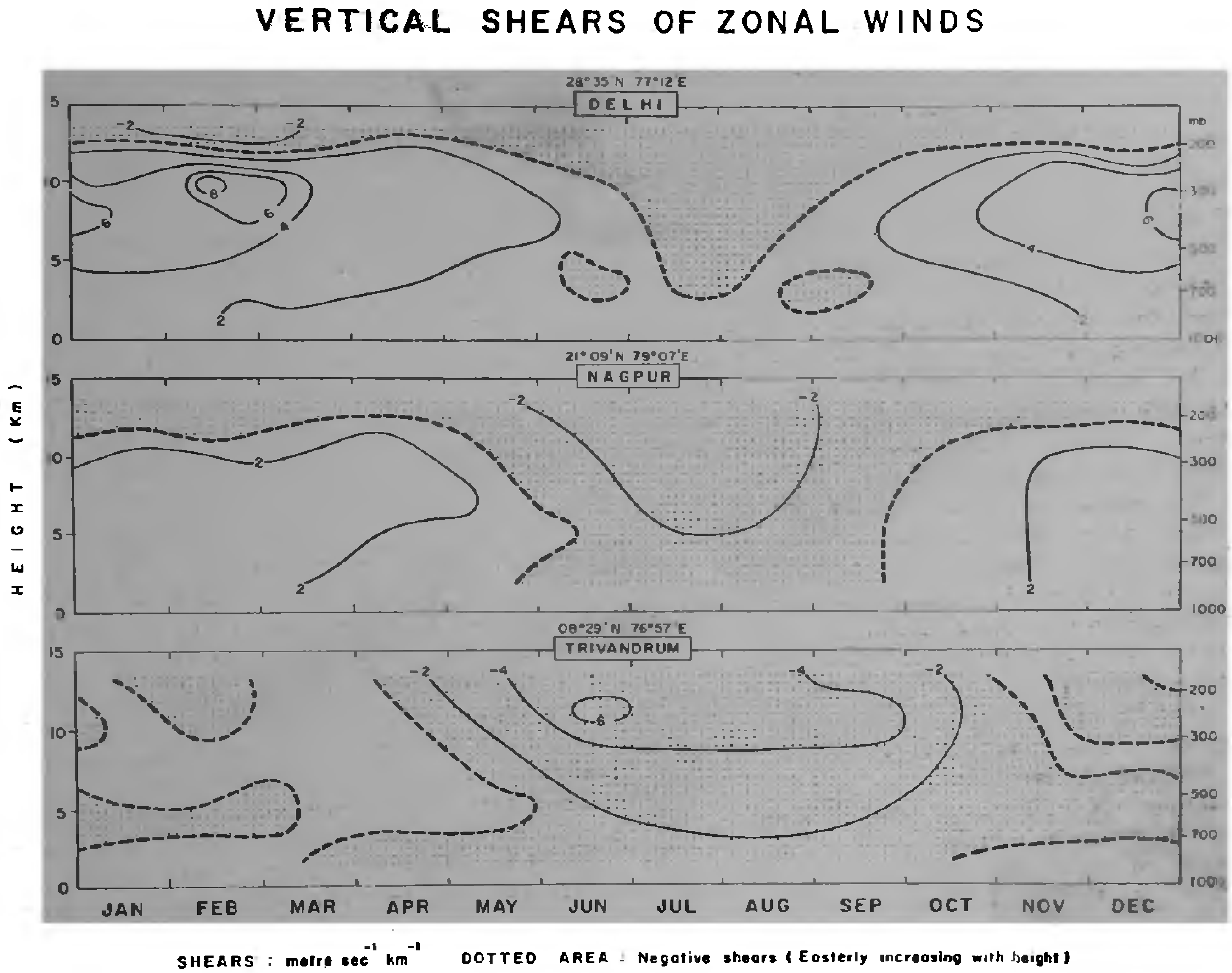

FIG. 1

6. Over Nagpur, the winter circulation is very much more pronounced than over Trivandrum, vertical shears between 350 mb. and 200 mb. levels being positive till the end of April. By the first week of May, the thermal gradient undergoes reversal at the 200 mb. level and there is a general weakening of the westerly circulation at all levels. As in the case of Trivandrum, the reversal of thermal gradient progresses steadily downwards and reaches 600 mb. level by about 10 June. In the lower layers, the thermal gradient reverses by the last week of May and the reversal gradually progresses upwards to the 600 mb. level by 10 June which is about the normal date of onset of monsoon rains over this area. It is again seen that the reversal of the thermal gradient between 700 and 500 mb. is almost synchronous with the onset of the monsoon rains over this area.

7. The winter westerly circulation is strongest at Delhi and continues till the end of May. By the beginning of June, the thermal gradient reverses at 200 mb. and at the same time, the westerly circulation weakens considerably at all the lower levels. Thereafter, the vertical shears and thermal gradients are generally feeble. By the first week of July, the temperature gradients reverse at all levels above 700 mb. by which time the monsoon rains also extend to Delhi.

8. Even by the end of August, the thermal gradients characteristic of winter circulation gradually begin to get established in the lower tropospheric levels over Delhi and by the middle of September the winter type of thermal gradients are established at all levels up to 200 mb. By this date the monsoon withdraws from the Delhi region. It is interesting to note that during the summer-winter transition, large positive shears begin to build up initially near (400–500) mb. levels and extend gradually to lower and higher levels. Conversely, during the winter-summer transition

large positive shears persist in this layer for the longest duration.

9. Over Nagpur, the winter type of thermal gradient begins to appear in the lower troposphere towards the end of September and extends upwards to 200 mb. level by about the second week of October which is approximately the normal date of withdrawal of monsoon from this area.

10. At Trivandrum, the thermal gradient characteristic of the monsoon circulation begins to weaken by the end of September. By about the middle of November, the winter type of thermal gradients begin to appear in the upper troposphere and become increasingly prominent by the beginning of January. The normal date of withdrawal of monsoon rains from Trivandrum is about the beginning of December. However, it is more difficult to fix this date for Trivandrum than for Nagpur and New Delhi.

11. The main conclusions from the present study are the following:

(*i*) The onset of the monsoon rains at each of the three stations takes place when the meridional thermal gradients have reversed at all tropospheric levels between 200 and 700 mb.

(*ii*) The reversal starts in the upper troposphere about six weeks before the onset of the monsoon rains and progresses downwards, reaching 600 mb. level at about the time of onset of the monsoon rains.

(*iii*) The reversal of thermal gradient in the layer between 700 and 500 mb. takes place last and is almost simultaneous with the onset of the monsoon rains.

(*iv*) The pattern of thermal changes associated with summer-winter transition at Delhi has a broad similarity with the winter-summer transition. The similarity is less at Nagpur, while at Trivandrum there are substantial differences.

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THE EPARCHAEAN UNCONFORMITY AND THE ARCHAEAN-PURANA BOUNDARY

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THE eparchæan interval in Indian geology is defined as the gap between the Puranas and the Archæans. The Archæans are defined as those rock formations which occur below the eparchæan unconformity. Does the eparchæan unconformity become evident by recognising Archæan and Purana formations or are the Archæans and Puranas recognised by identifying the eparchæan unconformity? These are questions for which we do not have definite answers.

The vast area of Peninsular India is by and large made up of Precambrian rocks. In these Precambrian provinces we do not have any definite demarcation between the Archæan and Purana rocks. Unlike the breaks that occur higher up in the geological time scale, the eparchæan break does not have the strong support that faunal evidence affords and we are obliged to depend entirely on geological evidence,

The main problem of these two groups of rocks is in their distinction. What are the diagnostic characters of the Archæans and Puranas and what differences are there in these characters which allow us to distinguish them? The answer is indefinite and vague. We do not have any really diagnostic characters. However, metamorphic grade and intensity of diastrophism have served as a basis for the distinction of these two groups of ancient rocks. The result of this is that almost everything that is metamorphosed has been placed under the Archæan group. A careful consideration of the problem clearly shows that the two criteria are really inadequate and can never be of such importance as to unfailingly serve as a basis of differentiation of these two groups of rocks.

In Indian geology since the creation of the Dharwar system every other system or series in a similar stratigraphic situation was referred