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THE UPPER ATMOSPHERIC WIND FLOW STRUCTURE OVER INDIA DURING THE FIRST GARP GLOBAL EXPERIMENT FGGE-1979

During the Summer Monsoon Experiment-1979, weekly meteorological rocket M-100 launchings were made from Thumba (Lat. 08 deg. 30′ N, Long. 76 deg. 54′ E) and RH-200 from Sriharikota (SHAR) (Lat. 13 deg. 42′ N, Long. 80 deg. 12′ E) and Balasore (Lat. 21 deg. 51′ N, Long. 86 deg. 53′ E) to obtain the stratospheric and mesospheric wind data. From the data so obtained zonal and meridional wind components were computed and vertical time sections were prepared for the three stations and analysed in order to study upper atmospheric circulation over the Indian tropical region. Data for October were missing over Thumba and analysis was extrapolated for this period. The picture that emerged has been discussed here with the help of mean monthly components of winds.

Zonal component — Figs. 1 (a-c) show the vertical time section of the mean zonal winds over Thumba, SHAR and Balasore in the height range of 20 to 60 km. The data available for other heights are also included. The easterlies are the main feature of circulation below 40 km over the three stations during January to September while westerlies appear in the later part of the year. The westerlies above 50 km in the mesosphere come down to the lowest level of 37 km in the month of March over Balasore, 40 km in April over SHAR and 37 km in May over Thumba. Thereafter they begin to withdraw to be finally replaced by easterlies during the month of June to August over Balasore, June and July over SHAR and July over Thumba. These are the summer easterlies which have been ascribed due to the warm anticyclone over high latitudes approximately concentric with pole (Labitzke 1981) and appear to have spread gradually from Balasore to Thumba equatorward. The westerlies reappear and begin to descend from August over Thumba and from September over SHAR and Balasore. They come down to the lowest level of 26 km in November and December over Thumba and 30 km over both SHAR and Balasore. Over Thumba, from the only launch available for November, it is observed that the westerlies which come down to 44 km in September withdraw and are replaced by easterlies from 36 to 55 km with maximum wind of 31 m/s appearing at 42 km. Easterlies are observed between 38 and 45 km in December as well. A common feature in the flow over the three tropical stations is the semi-annual oscillation in the vertical plane and downward propagation of the mesospheric westerlies. The maximum descent has been observed between November and December with a secondary maximum occurring around April. Westerly and easterly phases of the zonal flow which alternate, form an annual oscillation above 50 km and semi-annual oscillation in the height range 35-50 km. The deeper downward propagation of westerlies below 35 km from September onward appear to form the westerly phase of the so called quasi-biennial oscillation in the zonal wind field of the stratosphere (Reed 1965, Lindzen and Holton 1968 etc). Thus the phenomenon of the

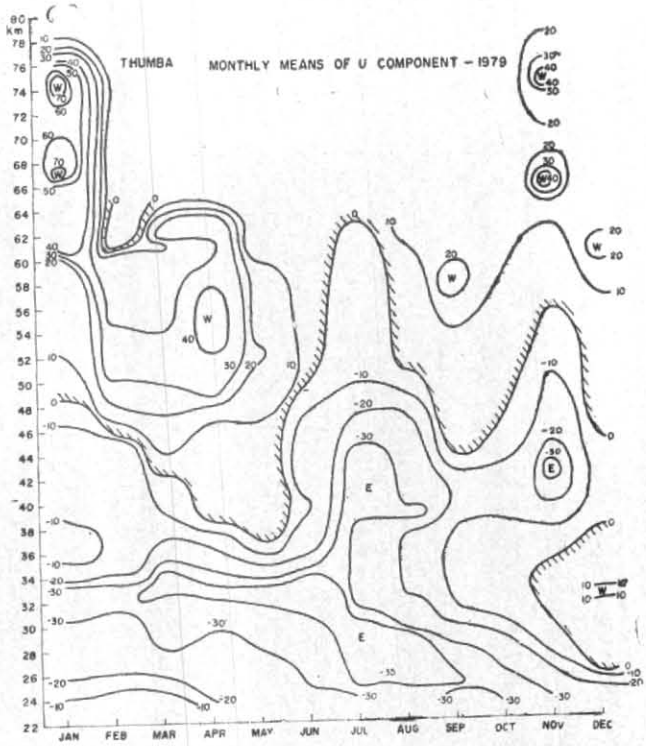

Fig. 1 (a). Vertical time section of mean zonal wind

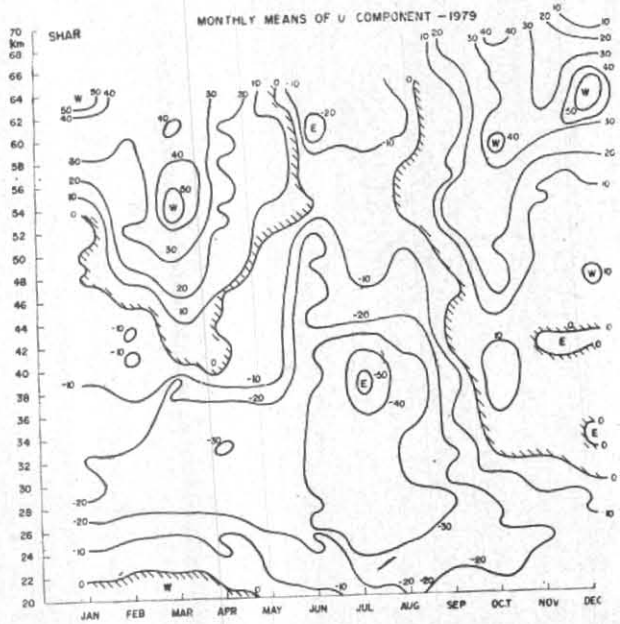

Fig. 1 (b). Vertical time section of mean zonal wind

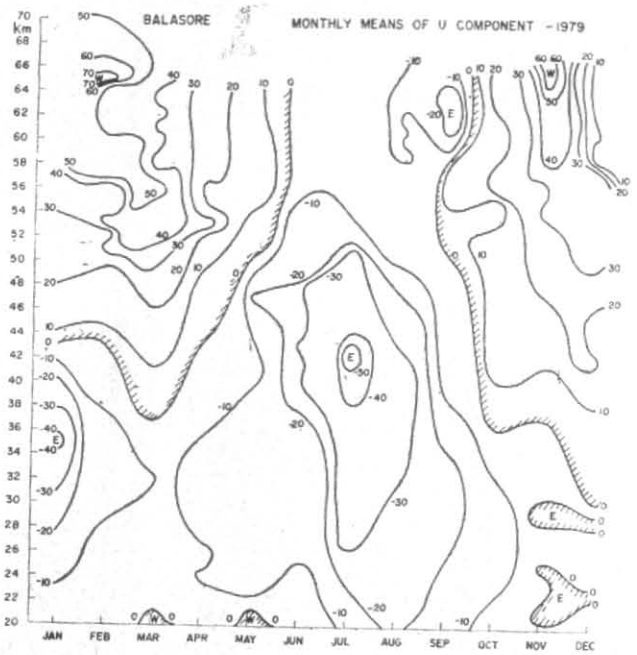

Fig. 1 (c). Vertical time section of mean zonal wind

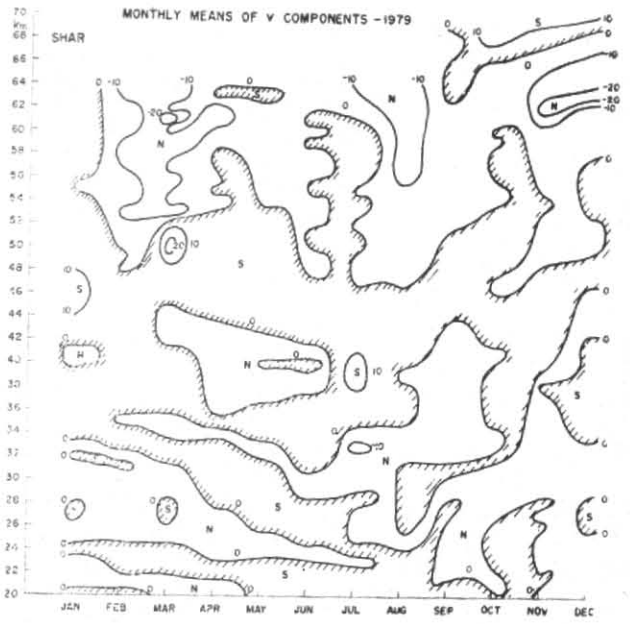

Fig. 2(b). Vertical structure of mean meridional wind

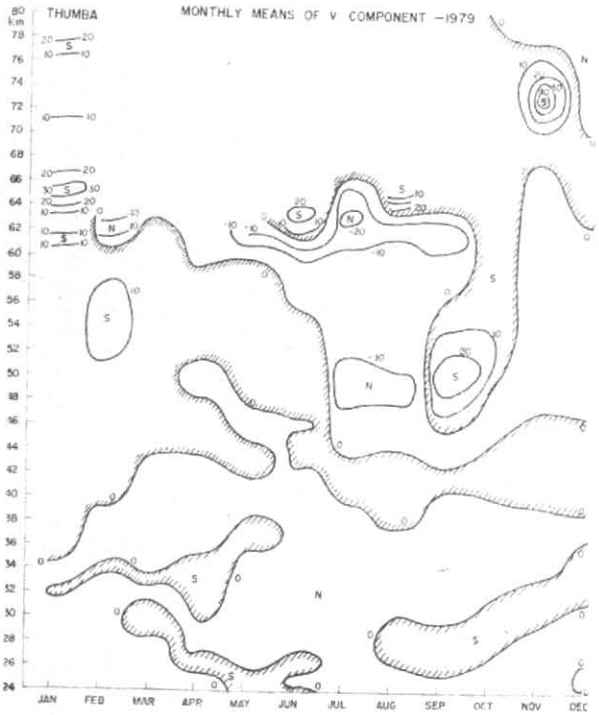

Fig. 2(a). Vertical structure of mean meridional wind

stratospheric quasi-biennial oscillation (QBO) has been observed to extend upto the latitude of Balasore. It is also obvious from the above discussion and from the earlier studies with Thumba data (George and Narayanan 1975, Raja Rao *et al.* 1978) that the stratospheric circulation during summer monsoon period, June to August is always easterly. In this study it has been again observed that this circulation is easterly during January to May in this year when the monsoon activity is below normal over India.

Strong easterlies (30-33 m/s) are observed in the range 25-35 km over Thumba uniformly from January to September. In July a secondary maximum (30 m/s) appear in the region 39-44 km. Strong easterlies exceeding 30 m/s are observed in a vertically deeper layer of the stratosphere from June to August over SHAR and Balasore with maximum speed reaching 50 m/s centred around 40 km in July. Strong easterlies reaching a speed of 40 m/s around 40 km are also noticed over Balasore in January. Easterlies exceeding 60 m/s over Thumba and SHAR and 70 m/s over Balasore are observed in individual launchings. Tropospheric easterly jet stream TEJ (Koteswaram 1958) is an important feature of monsoon circulation over Indian region. Unlike TEJ, stratospheric equatorial easterly jet stream SEJ has been observed over Thumba in other months also and is a global phenomenon (Raja Rao *et al.* 1975). However, during monsoon period the stratospheric easterly jet stream is observed to spread over most of the tropics with core located around 40 km, at least between the latitudes of Balasore and Thumba.

Westerlies exceeding 30 m/s are observed over Thumba between 50 & 54 km during February and March. They strengthen further with maximum speed centred around 55 km in April after which they weaken. Strengthening of westerlies is observed again

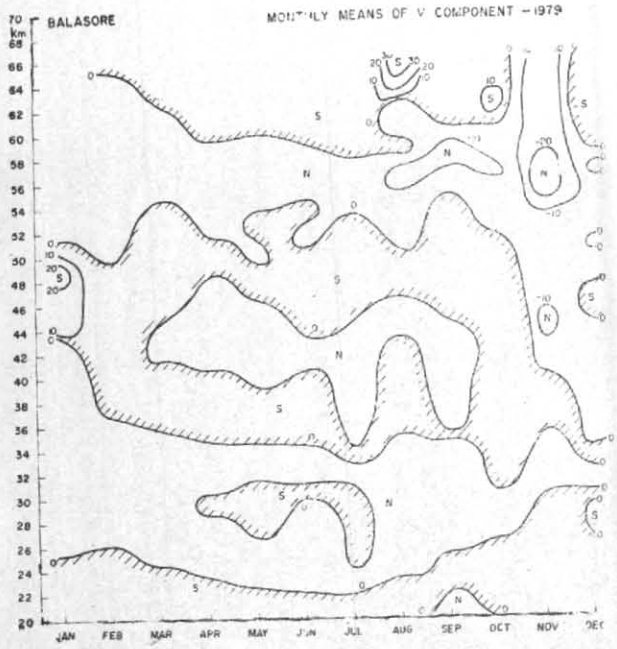

Fig. 2 (c). Vertical structure of meridional wind

from September onward. Over Thumba during the month of January when the data are available upto 80 km, two distinct maxima in the westerlies (70 m/s) at 67 and 75 km are recognised. Westerlies strengthen over SHAR and Balasore between January and March. A maximum speed exceeding 50 m/s is reached about 56 km during March when weakening appears from April onward. Westerlies reappear again in September and strengthen to the order of 55 m/s and 62 m/s over SHAR and Balasore during November and December. Westerlies of the order 88 m/s around 60 km over SHAR and 94 m/s around the same height over Balasore are observed in individual launchings in January and February respectively.

Meridional component — Figs. 2 (a-c) depict the vertical structure of the meridional wind components over Thumba, SHAR and Balasore. Meridional components are one order smaller than the zonal components. Over Thumba the flow below 40 km is mostly northerly from January to August with ill defined embedded narrow southerly streams. The southerly components mainly dominate the flow above, from January to June and again in September. The northerly component makes appearance in upper parts in April and May, begins to descend in June and covers almost the entire upper atmosphere during July and August. In December, however, southerlies dominate the stratosphere overlain by mostly northerlies in mesosphere. Strong northerly components exceeding 10-20 m/s are noticed in July while southerlies exceeding 10-20 m/s appear in February and September. The structural patterns over Balasore and SHAR comprise mostly alternate flows of southerly and northerly winds in the vertical. However, no significant information emerges at present from these meridional circulation patterns.

To conclude, the easterlies generally characterise the wind flow pattern in the stratosphere while westerlies replaced by easterlies during monsoon season comprise the flow pattern in mesosphere. The mesospheric westerles attain the speed of jet stream near equinoxes and exhibit a semi-annual oscillation in the vertical plane in their downward propagation below 50 km. The above two factors are responsible for the occurrence of an annual oscillation above 50 km and semi-annual oscillations between 50 & 35 km. The deeper downward propagation of the mesospheric westerlies below 35 km appear to form the westerly phase of quasi-biennial oscillation in stratosphere. The summer easterlies in the lower mesosphere appear to expand gradually from Balasore to Thumba. The stratospheric easterly jet stream with core located around 40 km and spread over most of the tropics may again be an important feature of monsoon period over Indian region.

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