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**SOME UPPER AIR CIRCULATION AND THERMAL FEATURES IN RELATION TO THE ONSET OF SOUTH-WEST MONSOON OVER KERALA**

1. The general circulation over Asia undergoes abrupt changes during early summer. Various studies have focused on the changes in the atmosphere around the time of onset (Koteswaram, 1958, 1960; Rai Sarcar and Patil, 1962; Ananthakrishnan and Thiruvengadathan,

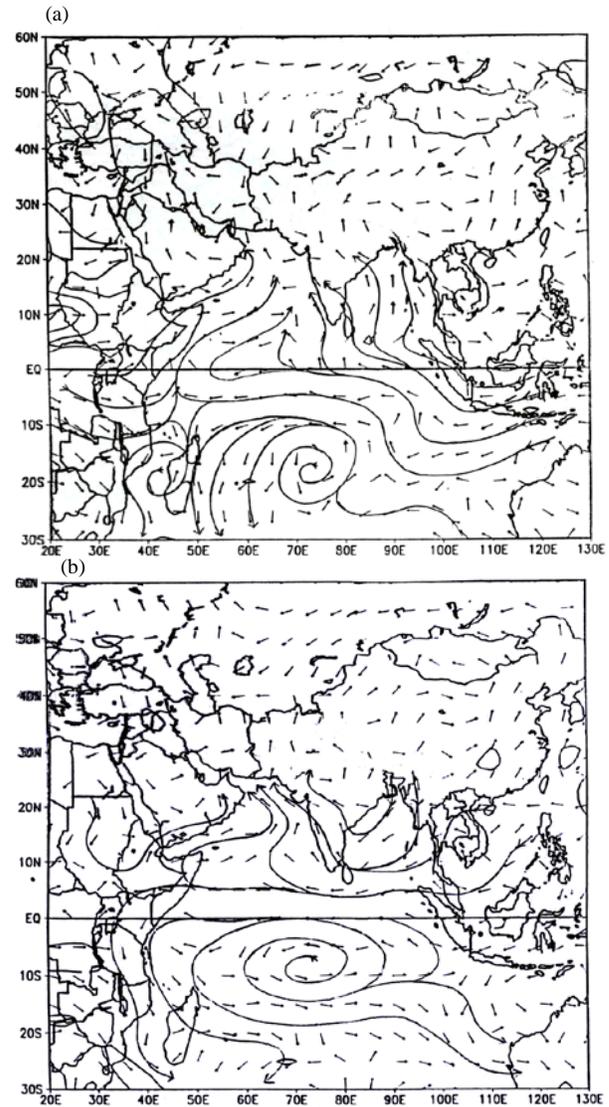
1968; Rao, 1976; Pearce and Mohanty, 1984; Webster and Yang, 1992; Li and Yanai, 1996; Joseph *et al.*, 1994). Koteswaram (1958, 1960) noted that the setting of easterly jet stream over south India coincides with the onset of monsoon. He explained that upper divergence in the left exit sector of jet stream induces convergence in lower level and onset of monsoon. Rai Sarcar and Patil (1962) showed that changes of winds at 0.9 km from the beginning of April to the end of that month give an indication of early or delay onset of monsoon. Decrease of westerly component indicates early onset and increase of westerly component indicates delay onset of monsoon.

Ananthkrishnan and Thiruvengadathan (1968) showed that onset of monsoon takes place when the meridional thermal gradient reversed at all levels between 700 hPa and 200 hPa and reversal starts in the upper troposphere six weeks before the onset of monsoon and between 700 hPa and 500 hPa almost simultaneously with the onset of monsoon.

Rao (1976) in an exhaustive study on southwest monsoon has explained many features associated with onset of monsoon over India. According to him the perceptible changes are : (i) winds from about southwest, (ii) decrease in temperature from the heat of April & May and (iii) increase in rainfall. Pearce and Mohanty (1984) noted that the period prior to onset consists of two main phases (a) a rapid intensification of the Arabian Sea winds and a substantial increase in latent heat release and this follows (b) a moisture buildup phase over the Arabian Sea during which synoptic and meso-scale transient disturbances develop. Webster and Yang (1992) observed that monsoon wind field possesses a combination of interannual and intraseasonal variation. In the early summer, lower tropospheric winds switch rapidly from weak easterlies to rather strong westerlies and are accompanied by an equally rapid acceleration of the upper tropospheric easterlies. From the evolution of annual cycle of broad scale monsoon circulations, averaged over the region between Lat. 5° N to 15° N and Long. 40° E to 100° E and based on data for the years (1986-1989), they noted that the broad scale monsoon circulations developed explosively from April to May, while the phase and amplitude varied considerably from year to year. In their study a monsoon intensity index based on the magnitude of mean vertical shear in this region was defined and was shown to be consistent with the broad scale outgoing long wave radiation fields. Following Webster and Yang (1992), more recent studies (Roy Bhowmik, 2002; Krishnamurti and Goswami, 1999; Wang and Zeng, 1999) have used vertical circulation (zonal and meridional) indices to link the onset and performance of Indian summer monsoon.

The studies of Li and Yanai (1996) also noted that onset of the monsoon was concurrent with the reversal of meridional temperature gradient in the upper troposphere south of the Tibetan Plateau. They further defined a thermal index based on vertical temperature differences. The time evolution of these temperature anomalies revealed that anomalies began to change from negative to positive in April over the Tibetan Plateau between Long. 90° E to 100° E.

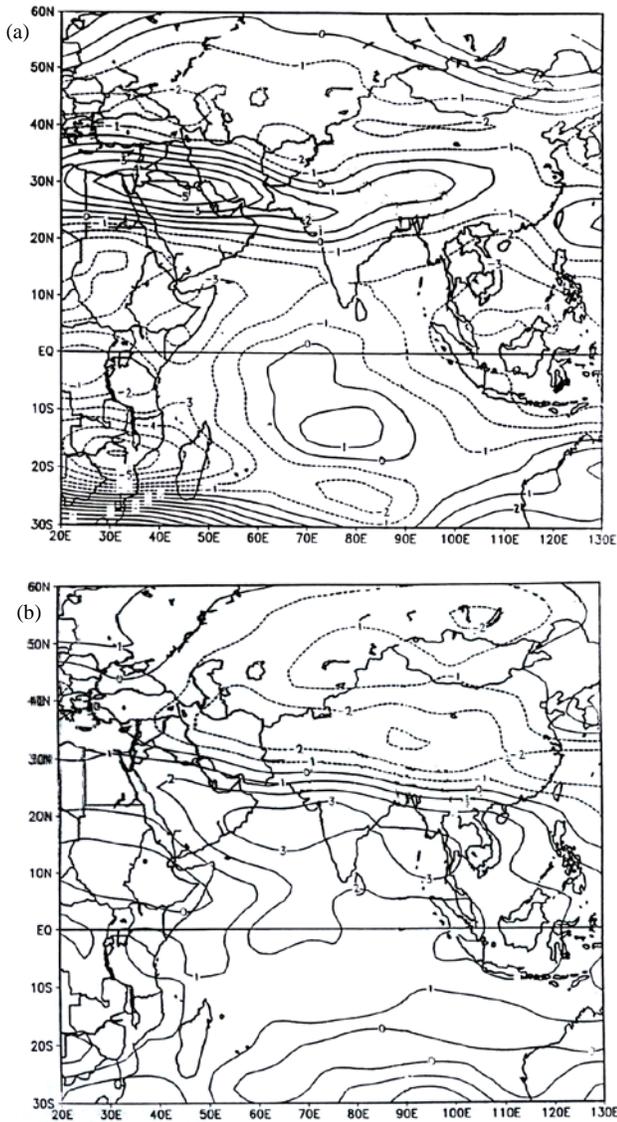
Roy Bhowmik (2002) assessed the use of these indices in a predictive mode for the monsoon onset



**Fig. 1(a&b).** Anomaly fields of wind vector at 850 hPa in (a) early and (b) delayed onset years of monsoon

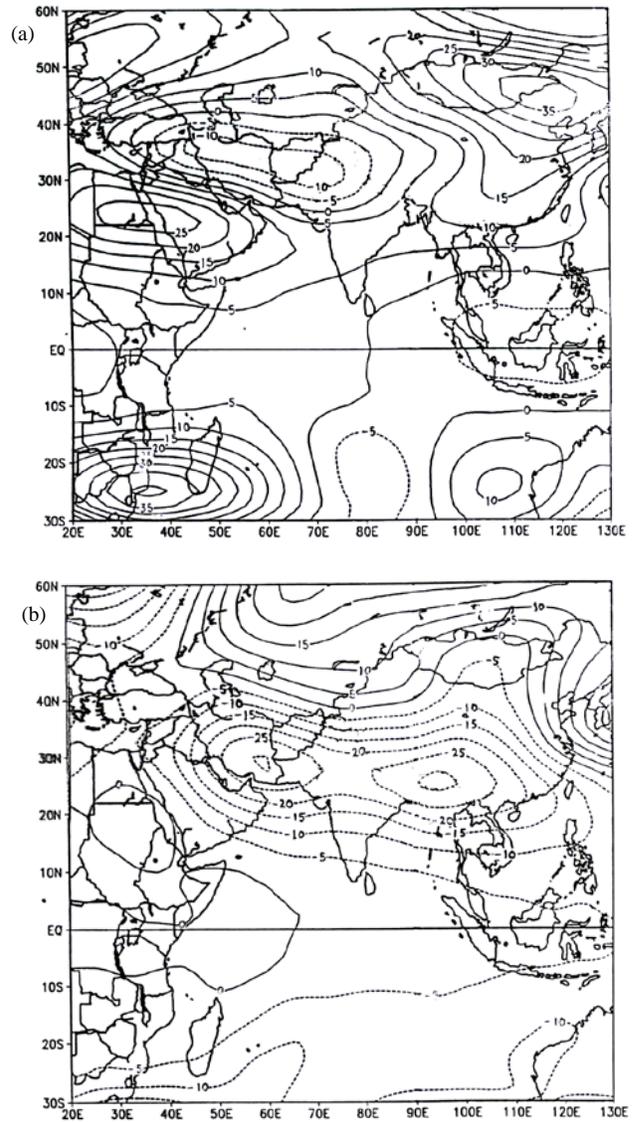
over Kerala, by examining the spatial pattern of these indices during pre-monsoon months (April and May) for an individual year of delayed onset (1997), early onset (1999) and normal monsoon onset (2000) based on model analysis field of India Meteorological Department. In this paper, we examined the anomalies of circulation and thermal features in relation to onset of summer monsoon over Kerala using National Center for Environment Prediction (NCEP), USA reanalysis data for the period 1950-2001.

2. Normal date of onset of monsoon over Kerala is 1 June with a standard deviation of around 8 days (Rao, 1976). In this study a year is considered as



**Figs. 2(a&b).** Anomaly fields of zonal wind ( $\text{ms}^{-1}$ ) component at 200 hPa in (a) early and (b) delayed onset years of monsoon

early monsoon onset if the onset over Kerala is early by 7 days or more. When onset is delayed by 7 days or more the year is considered as delayed onset year. For this data period (1950-2001), there are 8 early onset years (namely 1952, 1956, 1960, 1961, 1962, 1969, 1990, 2001) and 8 delayed years (namely 1958, 1967, 1968, 1972, 1979, 1983, 1995, 1997). Anomalies of circulation and thermal fields for the month of April for the early onset years are computed based on 8 early onset years data. Similarly for computation of anomalies for the delayed onset years, data of 8 delayed onset years are considered. The study is carried out using the NCEP/NCAR reanalysis data for the period (1950-2001). The anomalies for the month of April



**Figs. 3(a&b).** Anomaly fields of geopotential height (gpm) at 200 hPa in (a) early and (b) delayed onset years of monsoon

were derived over the region between Lat.  $30^{\circ}$  S to  $60^{\circ}$  N and Long.  $20^{\circ}$  E to  $130^{\circ}$  E using climatological data (1968-96). Circulation and thermal fields examined are : wind vector anomaly at 850 hPa; zonal wind component at 200 hPa and geopotential height at 200 hPa.

**3.1. Wind vector at 850 hPa** – Figs. 1(a&b) presents the mean anomaly fields of wind vector at 850 hPa of April for the early and delayed monsoon onset years respectively. Easterlies were found to be dominated over the area between equator to Lat.  $5^{\circ}$  N and Long.  $40^{\circ}$  E to  $100^{\circ}$  E during delayed onset years. Mostly southeasterlies

along the equator and then southwesterlies upto Lat. 10° N were observed during early onset years. The southwesterlies over Somali coast extending upto 10° S along the coast were noticed during early onset years of monsoon. Where as the reverse flow dominated during delayed onset years. Easterlies prevailed over the region between equator to 10° S and Long. 50° E to 90° E during early onset years. In contrast, anticyclonic flow is observed between equator to 15° S during delayed onset years of monsoon. Another difference observed is the northeasterly flow over the Bay of Bengal during delayed onset years and south/southeasterly flow during early onset years of monsoon. During early onset years anomaly pattern exhibits cross equatorial flow extending from southern hemisphere to the southern part of Arabian Sea and Bay of Bengal which is absent during delayed onset years of monsoon.

3.2. *Zonal wind anomaly at 200 hPa* - Figs. 2(a&b) illustrate the composite anomaly fields of zonal wind component at 200 hPa respectively for early and delayed onset years of monsoon. It reveals that negative anomalies of zonal wind component ( $-1$  to  $-4$   $\text{ms}^{-1}$ ) over the area between equator to around Lat. 20° N and Long. 20° E to 130° E and positive anomalies ( $1$  to  $5$   $\text{ms}^{-1}$ ) between Lat. 20° N to 35° N and Long. 20° E to 110° E with its core elongated along Lat. 30° N prevail during early onset year. In delayed onset year positive anomalies ( $2$  to  $3$   $\text{ms}^{-1}$ ) were observed over the area between equator to Lat. 30° N and Long. 20° E to 130° E with its higher value concentrated along Lat. 20° N. North of Lat. 30° N was dominated by negative anomalies ( $-1$  to  $-3$   $\text{ms}^{-1}$ ) with its core elongated along Lat. 35° N. The comparison suggest that during delayed onset year stronger westerlies between equator to around Lat. 25° N over Indian region in the upper troposphere prevail in the month of April and weak westerlies over the region in early onset years of monsoon.

3.3. *Geopotential height anomaly at 200 hPa* - Figs. 3(a&b) show the anomaly fields of geopotential height at 200 hPa for early and delayed onset years of monsoon respectively. Positive anomalies (10 to 35 gpm) of geopotential height at 200 hPa is seen over the area between Lat. 10° N to 50° N and Long. 80° E to 130° E with its core centered at 45° N/115° E and negative anomalies ( $-10$  gpm) over the area between Lat. 25° N to 40° N and west of Long. 80° E were found in early onset years. The whole belt is dominated by negative anomalies ( $-10$  to  $-30$  gpm) in delayed onset years with its core elongated along Lat. 25° N. This appears to be a significant feature in relation to the onset of monsoon over Kerala.

4. The study showed that the southwesterly flow in the lower tropospheric levels (850 hPa) dominates during pre-monsoon months (April) over the area between equator to Lat. 10° N and Long. 40° E to 100° E extending upto 10° S over Somali coast for the early onset years. Negative anomalies of zonal wind at 200 hPa were observed during pre-monsoon months from equator to around Lat. 20° N and positive anomalies between Lat. 20° N to 35° N over Indian region in early onset year. On the other hand positive anomalies from equator to around Lat. 30° N and negative anomalies north of Lat. 30° N were observed in delayed onset year. Geopotential height anomaly at 200 hPa over the area between Lat. 10° N to 50° N and east of Long. 80° E was positive in early onset year. This area was dominated by negative anomalies in delayed onset year of monsoon.

The signals in the upper air noticed during pre-monsoon months may be useful for assessing the onset date over Kerala. However synoptic scale changes in the time scale of 3-5 day may often give a clearer indication of onset over Kerala than the monthly anomaly, but the former has a greater lead time.

#### References

- Ananthakrishnan, R. and Thiruvengadathan, A., 1968, "Thermal changes in the troposphere associated with seasonal transitions over India", *Curr. Sc.*, XXXVII, 184-186.
- Joseph, P. V., Fishchild, J. K. and Pile, R., 1994, "Interannual variability of onset of Indian summer monsoon and its association with atmospheric features, El-nino and sea surface temperature anomalies", *J. Clim.*, 7, 81-105.
- Koteswaram, P., 1958, "Easterly jet streams in the tropics", *Tellus*, 10, 43-57.
- Koteswaram, P., 1960, "Asian summer monsoon and the general circulation over the tropics", *Monsoons of the world*, 105-110.
- Krishnamurti, V. and Goswami, B. N., 1999, "A broad scale circulation index for the interannual variability of Indian monsoon", *Quart. J. Roy. Meteor. Soc.*, 125, 611-627.
- Li, C. and Yanai, M., 1996, "The onset and interannual variability of the Asian summer monsoon in relation to land sea thermal contrast", *J. Clim.*, 9, 358-375.
- Pears, R. P. and Mohanty, U. C., 1984, "Onset of Asian summer monsoon 1979-1982", *J. Atmos. Sci.*, 41, 1622-1639.
- Rao, Y. P., 1976, "Southwest monsoon", Meteorological monograph, Synoptic Meteorology No.1/1976, 35-51.

Roy Bhowmik, S. K., 2002, "Evaluation of broad scale vertical circulation and thermal Indices in relation to the onset of Indian summer monsoon", *Int. J. Clim.*, **22**, 649-661.

Rai Sarcar, N. C. and Patil, C. D., 1962, "A study of high level wind tendency during pre-monsoon months in relation to time of onset of southwest monsoon in India", *Indian J. Met. Geophys.*, **13**, 468-471.

Wang, B. and Zeng F., 1999, "Choice of south Asian summer monsoon indices", *Bull. Amer. Meteor. Soc.*, **80**, 629-639.

Webster, P. J. and Yang, S., 1992, "Monsoon and ENSO-selectively interactive system", *Quart. J. R. Met. Soc.*, **118**, 877-926.

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