Mausam, (1979), **30**, 4, 523-527

Letters to the Editor

551.513 : 551.515.5 : 551.577.3 (547)

TROPICAL DISTURBANCES AS A RELATIONSHIP BETWEEN THE CROSS-EQUATORIAL FLOW OVER KENYA AND RAINFALL OVER THE SOUTHERN TIP OF THE WESTERN INDIAN COAST

Analysing data relative to July and August 1962, Findlater (1969) finds a strong correlation between the low-level cross-equatorial winds over Kenya and rainfall over the western coast of India. He shows that rainfall is maximum over the western coast 2 or 3 days after the winds reach their maxima at Garissa (0.3° S, 39.4° E) in Kenya. However, Raghavan *et al.* (1975) show that this question deserves careful examination. They feel that the rainfall mechanism is more intimately linked with the development of disturbances over the Indian region itself.

In analysing daily satellite images during the 1975 summer monsoon, Cadet and Olory-Togbe (1977) evidence the existence of moving disturbances over the Indian Ocean : eastward-moving ones over its northern part and westward-moving ones over its southern part. This study also shows the influence of these disturbances on the low-level air flow circulation over the Indian Ocean. These perturbations occur with a quasi-biweekly period for the eastward-moving ones as well as for the westward-moving ones. This two-week period seems to be a natural oscillation of the monsoon system. Thus by means of spectral analysis of some elements of the broad-scale monsoon system, Krishnamurti and Bhalme (1976) show that the intensity of the East-African low-level jet, Mascarene high pressure (30°S, 60° E) and rainfall over India oscillate with a quasi-biweekly period. These studies suggest a relationship between the tropical disturbances and the quasi-biweekly oscillation of the elements of the monsoon system. In this note, the relationship between the wind intensity over Kenya, rainfall amounts over western India and tropical disturbances moving over the northern Indian Ocean is investigated. There exists some correlation between all these elements. It is thus suggested that the tropical disturbances moving eastwards over the Indian Ocean may be the phenomenon relating cross-equatorial flow over Kenya to rainfall over the western Indian coast.

2. The data for stations in India are extracted from the Indian daily weather reports provided by India Meteorological Department. From these daily values taken at 12 GMT, running five-day means are computed to eliminate short-period fluctuations. The selected stations are Calicut, Cochin and Trivandrum (Kerala State), and Honavar and Mangalore (Karnataka State), located in the southern part of the western Indian coast.

The wind index is provided by J. Findlater. This index is the mean of the south components of the wind at 1000, 2000, 3000, 4000 and 5000 feet above sea level at Mombasa (Kenya) (4°S, 39.5° E) and an additional smoothing of these data is obtained by computing running 7-day means.

The tropical disturbances occurring during the 1975 summer monsoon are studied by Cadet and Olory-Togbe (1977). An overall view of the various tropical disturbances crossing the Indian Ocean during one month and a half of the 1975 summer has been shown in Fig. 2 of Cadet (1978). In this paper we are only concerned with the three eastward-moving ones which are crossing the northern Indian Ocean, time-separated by about 15 days. The latitude band where they are more evidenced is 0°—2.5° N.

For all these data the sample extends from 25 June to 10 August and this reduced period limits the scope of the study.

3. The wind index at Mombasa has been shown according to Findlater (private communication). The quasi-biweekly oscillation of the wind index at Mombasa (Fig. 7 of Cadet 1978) is evidenced ($\simeq$ 12 days) and three major increases occur during the studied period, on 4, 16 and 28 July. One can see when comparing Figs. 2 and 7 of Cadet (1978) that these three increases of the wind index at Mombasa are well related to the occurrence of the eastward-moving tropical disturbances which originate over the western Arabian Sea. The increases occur 1 or two days before or after the disturbances are moving over western Arabian Sea.

4. Cadet also presented the pressure records at selected stations (Figs. 8a & 8c of Cadet 1978). When referring to Fig. 2, the eastward-moving tropical disturbances are at the longitude of the western coast of India (73°E to 77°E) on 13-14, 21-22 July and 6-7 August. The pressure at stations along coastal Kerala and Karnataka States is minimum on these days; the time inaccuracy being of the order of 1 or 2 days.

The study of synoptic charts over India shows that the pressure minimum can also be associated to the westward-moving monsoon lows from the Bay of Bengal or the general strengthening of the monsoon trough over India. So it is difficult to find strong evidence of lowering of pressure in India due to an eastward-moving tropical dirturbance from the western Arabian Sea. However, Cadet and Olory-Togbe (1977) show that at the equator the influence of eastward moving tropical disturbances is noticeable and one can expect some influence of these phenomena over the southern tip of India.

Figs. 8(b) and 8(d) of Cadet (1978) give the rainfall amounts at the selected stations along the western coast. For the Kerala State stations, the maxima of rainfall occur roughly during three periods on 8-9-10-11-12 July, on 22-23-24 July and on 30-31 July—1-2-3 August. The second relative maximum is not quite well stressed and it corresponds to a "break" in the activity of the monsoon (Cadet and Olory-Togbe 1977). One can also note that important rainfall occurs just before the beginning of the studied period. A strong correlation exists between the minima of pressure and the maxima of rainfall rates. The rainfall maximum around 10 July is well centred on the pressure minimum whereas the last large rainfall rate occurs a few days (2 or 3) before the last pressure minimum. As for Mangalore and Honavar, which are located in the heavy rainfall belt along the western coast on the windward side of the Western Ghats, the correspondence between rainfall rates and pressure records is less evident. For Mangalore, no correlation exists except for the break period already mentioned. For Honavar, the maximum rainfall rates occur a few days before the pressure minimum. When looking at rainfall records for stations over central India, the correlation between the pressure minimum and rainfall amount is also less evident. Thus, the correlation between rainfall amount and pressure fluctuations seems to be only well defined over the southern tip of India.

5. A possible link between cross-equatorial winds over Eastern Africa and rainfall over the western coast of India has been investigated. It is suggested that the tropical disturbances moving eastwards over the northern Indian Ocean during the summer monsoon may be the phenomenon which gives rise to this intriguing relationship. Thus an increase of the low-level jet is associated with the initiation of a tropical disturbance over the western Arabian Sea. Since the mean phase speed of such a perturbation is about 5° longitude/day, it reaches the vicinity of the southern tip of India after 5-6 days and may enhance rainfall in this region. However due to the restricted period we focus on in this study, much further work needs to be done to investigate this relationship thoroughly.

6. I am very much indebted to Mr. John Findlater of the East-African Meteorological Office in Nairobi (Kenya) for providing us with the Mombasa wind data relative to the 1975 summer monsoon as well as his analysis of rainfall over the western coast concerning the same period.

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22 November 1978