Correspondence and Notes

551.557.3 : 551.577.2(547)

THE INFLUENCE OF CROSS-EQUATORIAL FLOW OVER KENYA ON THE RAINFALL OF WESTERN INDIA

By K. Raghavan, D. R. Sikka and S. V. Gujjar

According to Findlater (1969) the low-level cross-equatorial winds over Kenya have a regulating influence on the rainfall over western India during the monsoon months July and August. This has evoked considerable interest in India and elsewhere.

Findlater's finding is based on a comparison of a plot of the wind speeds over Garissa (00°29'N 39°38'E) in Kenya with the rainfall curve for western India during July and August 1962. He calculated the wind speed at Garissa for each day by adding the speed of winds at three levels 3000, 4000 and 5000 ft - the layer which responds strongly to the variations in the low-level flow. The values so obtained were smoothed by producing overlapping five-day means which were further smoothed by forming overlapping means of three successive values. This he called the cross-equatorial index. In the case of rainfall the daily values at four selected stations in western India were added and their overlapping five-day totals were calculated for the four stations combined.

The plot of Garissa wind (cross-equatorial index) and western India rainfall indicated that the winds reached their maxima on 9 and 20 July and again on 12 August while the rainfall maxima occurred subsequently on 10 and 22 July and 13 August. The lag of 1–2 days between the maxima of wind and rainfall was taken by Findlater as an indication of an intimate relation between Garissa winds and western India rainfall and therefore of predictive value.

Findlater selected four stations, viz. Veraval (12°52'N 74°51'E), Bombay (18°54'N 72°49'E), Poona (18°32'N 73°51'E) and Mangalore (12°52'N 74°51'E) to represent the rainfall for western India. It is not clear what were his considerations for selecting these stations from the point of view of seasonal rainfall as well as synoptic features. That these stations do not represent a homogeneous region is amply clear from the following rainfall figures, showing the sum of the normal rainfall for July and August (cm)

<table>
<thead>
<tr>
<th>Station</th>
<th>1635.5</th>
<th>193.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangalore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombay</td>
<td>1144.8</td>
<td>450.6</td>
</tr>
</tbody>
</table>

Mangalore and Bombay lie in the heavy rainfall belt along the west coast on the windward side of the Western Ghats, while Poona lies in the rainshadow region of the Western Ghats to the east of Bombay, and Veraval lies in the northern part of the west coast in a region free from any nearby orographic features and on the boundary of a desert region to the north. Taking into account the seasonal rainfall regimes and synoptic features that usually influence the rainfall distribution over the west coast of India, we have looked into the rainfall data to verify the findings of Findlater. The stations selected by us are Vengurla, Devgadh, Ratnagiri, Harnai, Bombay and Dahanu.

Figure 1. Location map.
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<table>
<thead>
<tr>
<th>Date of wind maxima at Garissa</th>
<th>Date of rainfall maxima over Konkan</th>
<th>Number of days between wind and rainfall maxima</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 July</td>
<td>7 July</td>
<td>2</td>
</tr>
<tr>
<td>20 July</td>
<td>23 July</td>
<td>3</td>
</tr>
<tr>
<td>12 August</td>
<td>9 August</td>
<td>3</td>
</tr>
</tbody>
</table>

(Fig. 1) which constitute a usually recognized meteorologically homogeneous region (Konkan sub-division). The rainfall data for these stations were extracted from the original records and combined for the preparation of overlapping totals employing the method used by Findlater. The results are graphically presented in Fig. 2 and summarized in Table 1. Fig. 2 shows that there were 3 distinct maxima for Garissa wind as well as for the Konkan rainfall. But the rainfall peak preceded the wind maximum by 2-3 days on two occasions, whereas on one occasion it followed the wind maximum 3 days later (Table 1). This shows that it is difficult to agree with Findlater's conclusion that the rainfall of western India follows the Garissa wind curve with a lag of one to two days.

![Figure 2. Cross equatorial airflow at Garissa, Kenya, in relation to rainfall in Konkan sub-division (smoothed values).](image)

We have also done similar rainfall analyses for different sets of coastal stations from Mangalore to Bhavnagar (Fig. 1) but this did not reveal any such intimate relationship in which the peaks in rainfall curve followed the wind maxima at Garissa. The major variations of the rainfall were found to have occurred in association with distinct synoptic scale perturbations the details of which have been published in the Indian Daily Weather Report.

A general influence of the deflected SE trades on the Indian rainfall is understandable as this is the main artery which transports low level moisture towards India. The rainfall mechanism is perhaps more intimately linked with the development of disturbances over the Indian region itself. To what extent these developments can be attributed to the day-to-day variations in the cross-equatorial flow is not yet understood.

REFERENCE


Indian Institute of Tropical Meteorology, Poona-5, India. 9 December 1974.
CORRESPONDENCE AND NOTES

Reply

By J. Findlater

I was most interested to see the analysis of Messrs. Raghavan and Sikka and Miss Gujar, following the lines of enquiry set out in my paper.

During the course of the work leading up to that paper I examined the rainfall records from many stations in western India, for the 1962 monsoon season, to find which areas responded best to fluctuations in the strength of the low-level cross-equatorial flow over eastern Kenya. By repeated grouping of stations and smoothing of the resulting values as described it became clear that the responsive area was approximately from north of Veraval to south of Mangalore, and from Bombay on the coast to an area east of Poona. The data were then reduced by selecting Veraval to represent the northern low-rainfall stations, Mangalore to represent the southern high-rainfall stations, Bombay for the windward side of the Western Ghats, and Poona for the leeward side. These four stations were then considered to be generally representative of the whole area.

Fig. 2 of Raghavan, Sikka and Gujar is rather confusing if it is meant to be compared with Fig. 15 of Findlater (1969), because of the very contracted ordinate for the wind index. If their diagram is replotted using the same style and the same ordinate for the wind index as in my earlier diagram it is immediately apparent that there is a strong correspondence between the trends of the wind index at Garissa and the trends in the rainfall data presented by the writers. Generally, a rising wind index is associated with rising rainfall, and vice versa. The fact that the lag in the peaks and troughs is not discernible is, I believe, due to the selection of only high-rainfall coastal stations where intense convectional rainfall, or the lack of them, can significantly influence the time of occurrence of the maximum and minimum values.

It is understandable that the writers may wish to test my findings on smaller areas, especially coastal areas, but when such tests yield a difference in the results the findings of the original paper cannot be called into question. Indeed, during my investigations I found the same result as the writers now present, i.e. a variable or negative lag, when small groups of stations, smaller areas, or stations in similar geographical areas were used.

Finally, the results presented in my paper refer only to the 1962 monsoon season. Similar but unpublished analyses for other years confirm that the trend of rainfall over western India corresponds with the trend of the wind index over eastern Kenya whilst the lag, as indicated above, varies with the selection of stations. The lag is usually positive and well marked when the rainfall is measured over a large area. However, much further work needs to be done to investigate these intriguing relationships.

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THE ASSIGNMENT OF RAINFALL STATIONS INTO HOMOGENEOUS GROUPS:
AN APPLICATION OF PRINCIPAL COMPONENT ANALYSIS

By T. G. J. Dyer

Summary.

The calculation of eigenvectors has been used to describe annual precipitation totals over an area of large extent. Rotation of the eigenvectors brought about further clarification of the system of recording stations. By noting the eigenvector of most importance to each station, delimitation of an area was made possible. Reduction in records, a necessary prelude to our future work on forecasting models, was obtained by discarding those stations most closely related to eigenvectors whose eigenvalue was less than 0.6.