NOTES AND CORRESPONDENCE

Comments on "Effects of Arabian Sea-Surface Temperature Anomaly on Indian Summer Monsoon: A Numerical Experiment with the GFDL Model"

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In an interesting numerical experiment with the Geophysical Fluid Dynamics Laboratory (GFDL) general circulation model, Shukla (1975) has tested the hypothesis that the colder sea-surface temperature (SST) anomalies in the western Arabian Sea may significantly influence the monsoon rainfall over India. His experiment has shown that the imposition of a persistent 1–3°C colder temperature anomaly gives rise to an increase of surface pressure and a significant reduction of cross-equatorial moisture flux in the belt 50°–90°E which in turn is associated with a decrease of evaporation. The most spectacular result of his experiment is the reduction in the rate of precipitation by 40–50% over India and the adjoining seas. From this he has concluded that the cold SST anomalies over the western Arabian Sea would *drastically* decrease the rainfall over India and the adjoining seas.

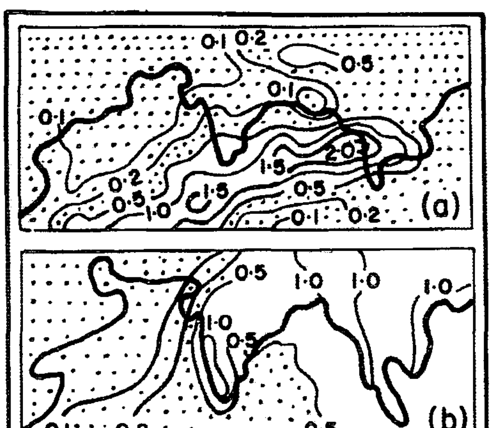

FIG. 1. Precipitation rate (a) computed by GFDL model for July (Hahn and Manabe, 1975), (b) observed for the period June–August and (c) observed for July. Units in cm day^{-1}.

One of the important features of the GFDL model is that the precipitation rate in the tropics is related to SST anomalies. Manabe *et al.* (1974) and Manabe and Holloway (1975) have shown that in the tropical oceans the heavy precipitation area approximately coincides with warmer SST's and the precipitation rates are less over areas of colder SST's. In an extension of these experiments, Shukla's study has examined the influence of SST anomalies on the precipitation over regions downstream from the anomaly region. As this is of great relevance to a proper understanding of the physical causes of the monsoon rainfall variations over India, we have been tempted to examine its results critically.

Since Shukla finds the precipitation reduction quantitatively drastic, it is necessary at first to examine whether the GFDL model is suitable for a quantitative assessment of this type, though it has achieved a commendable degree of success in simulating large-scale monsoon circulation features. Hahn and Manabe (1975) have shown the GFDL model-computed rainfall for periods of 5 days. The precipitation rate and distribution for the 5-day periods are naturally reflected in the computed mean monthly rainfall rate which, together with the observed rainfall rate, is reproduced in Fig. 1 for ready reference. This shows that the computed rainfall is mostly over the southern parts of the Bay of Bengal and the Arabian Sea close to the equator

(0.5–1.5 cm day^{-1}) while the observed rainfall is mainly over the Indian mainland (0.5–1.0 cm day^{-1}). Lack of data, unfortunately, makes it impossible to determine whether such rainfall (15–45 cm per month) actually occurs over the near-equatorial regions of the Arabian Sea and the Bay of Bengal. However, available evidence in the form of frequencies of precipitation, convective cloud cover and satellite-observed cloud clusters do suggest that the rainfall over this belt is significantly less than that around 20°N over the Indian region. It may be noted that the model-computed rainfall is for July (Fig. 1a) while the observed rainfall is the mean for the period June–August (Fig. 1b). In order to facilitate a more reasonable comparison between the computed and observed rainfall we show in Fig. 1c the observed precipitation rate over India in July. This shows that the observed precipitation rate over most of India is 1.0–1.5 cm day^{-1} (monthly total 30–45 cm) whereas the computed rate is 0.1–0.5 cm day^{-1} (monthly total 3–15 cm). This agrees with the assessment of the performance of the model by Manabe and Holloway (1975) that the *monsoon rainfall is unrealistically low in the plains of India*. The large disparity between the computed and observed rainfall may therefore be considered as an inherent limitation of using the GFDL model for testing at least any hypothesis on the variation of monsoon rainfall.

Through a 15-day running mean curve Shukla has shown that his experimental (anomaly run) rainfall over the region comprising India and the adjoining seas is 40–50% less than the model-computed (standard run) rainfall. Considering the economic importance of rainfall over India one would have expected him to show a similar curve indicating the magnitude of rainfall reduction separately over the Indian mainland (area 3.27×10^6 km^2) which is large enough to be considered in a GCM experiment. One can, however, understand from his Fig. 10a that the rainfall reduction is remarkable at and near the colder SST anomaly region while over India it is negligibly small. Fig. 10b, where the signal-to-noise ratio is depicted, further reveals that the small reduction noticed over India is not genuine, i.e., not statistically significant. The significant reduction at and near the SST anomaly region is understandable since, as pointed out earlier, the GFDL model precipitation is intimately related to SST's. Thus the experiment, as it is, does not support the hypothesis that the cold SST anomaly in the western Arabian Sea significantly reduces the monsoon rainfall downstream.

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