Reply

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27 April 1976 and 21 July 1976

In the paper by Shukla (1975) it was stated that "The results of this numerical experiment tend to suggest that cold sea surface temperature (SST) anomalies over the western Arabian Sea may cause a reduction in monsoon rainfall over India and adjoining areas." This conclusion was arrived at by examining the rate of precipitation, as simulated by the GFDL model with and without an SST anomaly imposed over the Arabian Sea.

Sikka and Raghavan, hereafter referred to as SR, seem to believe that if the verification area were not so large and, in particular, if the verification area did not include the anomaly region, the conclusions of my paper may not remain valid. It may be pointed out that this inference by SR is based neither on model calculations nor on analysis of observed data. SR have stated that rainfall reduction noticed over India is not genuine and statistically significant. The basis of this statement is not understood. There seems to be some misunderstanding regarding the interpretation of Figs. 10a and 10b of my paper.

It was noted in Shukla (1975) that due to parameterization of physical processes and application of numerical techniques, etc., model statistics may contain large fluctuations (noise). In order to arrive at meaningful conclusions from the results of numerical experiments,

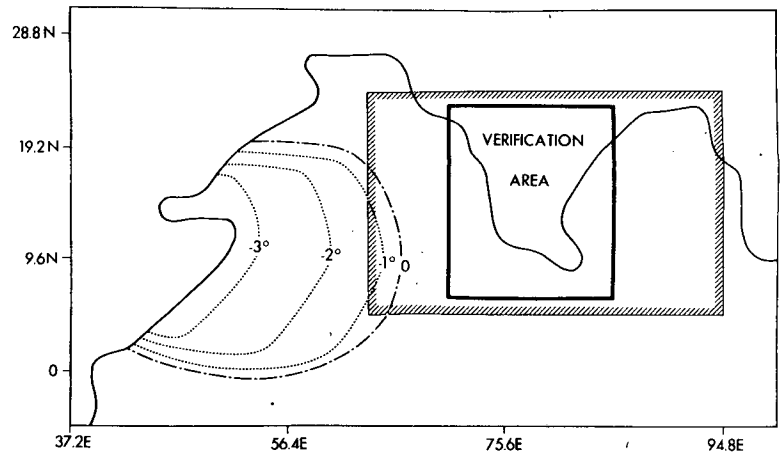

FIG. 1. SST (°C) anomaly over western Arabian Sea and location of verification area. Solid lines enclose the new verification area.

one must be able to distinguish between the "signal" (the change in the value of the climatic mean) and the "noise." In order to do this the "mean model state" is defined as an average over a large area and a large time interval. It would not be appropriate to examine the anomaly response in a general circulation model (with a grid resolution of 270 km) over a very limited domain. The significance of such a result would be questionable.

It was also pointed out (Hahn and Manabe, 1975) that the simulation of the rate of precipitation by the GFDL model is not satisfactory over northern India. However, the model has shown a remarkable degree of success in simulating the large-scale features of the monsoon circulation (Hahn and Manabe, 1975). Therefore, it has been considered meaningful to use this model to study the effect of an Arabian Sea SST anomaly on the large-scale circulation of the Indian summer monsoon. In this context it seems relevant to raise the following question: should we postpone all numerical experiments with GCM's until we have a model which simulates the atmosphere perfectly? The answer must be no! After the initial success of the general circulation models in simulating the mean climate, the next useful step should be to carry out numerical experiments. However, the kind of questions we may address using a GCM would depend upon the degree of success the GCM has achieved in simulating the detailed features of the global circulation. Since the GFDL model has simulated only the large-scale features of the monsoon circulation, it would not be

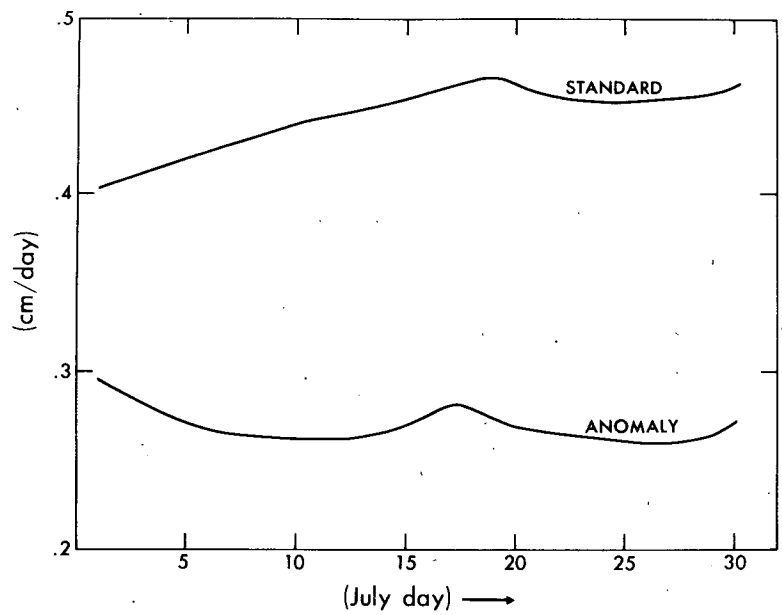

FIG. 2. Rate of precipitation (cm day^{-1}) averaged over the new verification area for the standard and anomaly runs.

appropriate to examine the SST effect over small spatial domains.

In order to further examine the question regarding the size of the verification area quantitatively, I have computed the average rate of precipitation for a smaller area (the inner verification area) shown in Fig. 1. The results for the standard and the anomaly runs are shown in Fig. 2. It is clear from this figure that, even for a smaller verification area, the rate of precipitation for the anomaly run is much smaller than the rate of precipitation for the standard run. These calculations further support the hypothesis that a cold SST anomaly in the western Arabian Sea may reduce rainfall over India and adjoining areas.

REFERENCES

Hahn, D. G., and S. Manabe, 1975: The role of mountains in the south Asian monsoon circulation. *J. Atmos. Sci.*, **32**, 1515–1541.

Shukla, J., 1975: Effect of Arabian sea-surface temperature anomaly on Indian summer monsoon: A numerical experiment with the GFDL model. *J. Atmos. Sci.*, **32**, 503–511.