IDEALIZED NUMERICAL EXPERIMENTS TO DIAGNOSE THE SIMULATED ASIAN SUMMER MONSOON CIRCULATION AND RAINFALL

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SOME IDEALIZED NUMERICAL EXPERIMENTS TO DIAGNOSE THE SIMULATED ASIAN SUMMER MONSOON CIRCULATION AND RAINFALL

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1. Introduction

Recently the Center for Ocean–Land–Atmosphere Interactions (COLA) has conducted a number of GCM experiments designed to aid our understanding of both the observed and simulated Asian summer monsoon. For the sake of brevity, only the most interesting results from these experiments will be discussed here. Experiments done to investigate the influence of the seasonal cycle of SST and solar forcing on the monsoon will be discussed in section 2. A small subset of a large number of sensitivity experiments conducted to help us understand and improve the COLA GCM simulation of Asiatic monsoon circulation and rainfall is discussed in section 3.

The control GCMs used for all these experiments are very similar to the one described by Fennessy and Shukla (1991, this report, hereafter FS). Unlike the version of the COLA GCM used by FS, both versions used here utilize an enhanced envelope orography (Mesinger et al., 1988). The version used for the experiments described in section 2 also does not include a gravity wave drag parameterization. Otherwise, the control GCM used by FS and those used here are identical. Please refer to FS for further information on the GCM.

2. Seasonal cycle of SST and solar forcing

According to the traditional view, the onset of the Asiatic summer monsoon is caused by asymmetric solar heating of the land masses in the north and the Indian ocean in the south. This is quite reasonable because the low pressure belt over the land and the associated convergence regions move with the sun with a small lag. However, it is observed that there is a seasonal northward shift of the maximum sea surface temperature also. Therefore, it is natural to ask: What is the relative importance of the northward moving solar heating of the land masses, and the northward moving maximum SST in the Indian and the Pacific Oceans for the onset and the intensity of the Asiatic summer monsoon circulation and rainfall. We have attempted to answer this hypothetical question in this paper. The question is hypothetical because the annual cycle of solar heating is also the cause for SST changes. We were motivated to carry out these experiments firstly to verify the traditional view about the role of heating of the land for the onset of monsoon, and secondly, and more importantly, to ascertain the possible effects of inaccurate simulations of the annual cycle of SST by coupled ocean–atmosphere models.

We have carried out two 180 day integrations started from the observed atmospheric state on 1 March 1987. In the first experiment, to be referred to as the <u>Fixed SST</u> experiment, the SST is invariant with time and is prescribed to correspond to the observed climatological SST for 1 March, but the solar forcing varies normally with season. In the second experiment, to be referred to as the <u>Fixed Sun</u> experiment, the solar forcing is invariant with time and is prescribed to correspond to 21 March, but the SST changes according to the observed climatological annual cycle. We will compare the boreal summer (JJA) monsoon simulations of these experiments with that from a control integration started on 1 January 1987, which used both normal seasonally varying solar forcing and seasonally varying climatological SST.

Compared to the JJA proxy observed precipitation (FS, Fig. 1a) the control integration JJA precipitation has a well placed but perhaps somewhat weak African monsoon, and a seriously deficient Indian monsoon with two maxima, one south of India and one over Bangladesh, leaving most of peninsular India with far too little precipitation. This deficiency and other features of a very similar control integration with the COLA GCM are discussed further in section 3. Even this already weak monsoon is drastically weakened in the Fixed SST experiment, as can be seen in the Fixed SST minus control JJA precipitation difference (Fig. 1b) The Fixed SST Asian monsoon rainfall is half or less of the control rainfall. An equally drastic reduction in the Asian monsoon rainfall is depicted in the Fixed Solar minus control JJA precipitation difference (Fig. 1c). Although there are some differences in the response to fixing either the SST or the solar forcing, these experiments show that the seasonal cycle of each is crucial to the Asian summer monsoon. The devastation of the Asian summer monsoon circulation by fixing either the SST or the solar forcing was also reflected in the upper level and lower level wind fields (not shown).

3. GCM sensitivity experiments

In conjunction with several other researchers we have carried out a large number of sensitivity experiments designed to help us improve the COLA GCM's simulation of the time mean Asiatic monsoon circulation and rainfall. In these experiments we have tested the GCM's Asian monsoon simulation sensitivity to cloud parameterization and cloud amount, surface vegetation type, surface soil wetness, snow cover, and orography type. A detailed report on these experiments is currently being prepared (Fennessy et al., 1991). While many of these experiments showed some positive impact on the Asian monsoon simulation, only one experiment really corrected the main model deficiency of having two rainfall maxima and a relative minima over much of India. For the sake of brevity, only this most successful experiment will be discussed here.

The COLA GCM has evolved from a 1985 version of the NMC MRF model and is now largely different from that or any current NMC model (see FS for details). One feature of the model which until now was not changed from the original NMC version was the orography used, which was an enhanced "envelope" orography (Mesinger et al., 1988). In conjunction with A. Vernekar, B. Kirtman and J. Zhou, a variety of experiments have been conducted to determine the COLA GCM monsoon simulation sensitivity to the orography used (Fennessy et al., 1991). The most successful Asian monsoon simulation was obtained using a slightly smoothed version of a mean (non-enhanced) orography derived from the U.S. Navy topography data set. This mean orography has been adopted for all future COLA GCM experiments and was used by FS. To show the impact of using this mean orography, we will compare JJA 1988 time mean simulations from an integration initialized from 2 June 1988 using observed SST and the old envelope orography (hereafter ENV88) to the SST88 ensemble of FS. The GCM used in the FS SST88 integration ensemble is identical to that used in ENV88 aside from the different orography used.

The two orographies used are quite different, and the highest peaks (Himalayas, Andes) in the new mean orography are up to 1000 meters lower than in the previously used envelope orography (not shown). The mean orography also has greatly reduced Gibbs phenomena "holes" (negative topography values) over the ocean adjacent to high mountains, and is generally closer to the original data than is the envelope orography (not shown).

The African and Asian monsoons in the SST88 JJA precipitation (FS, Fig. 1b) are quite realistic compared to the proxy observed JJA 1988 precipitation (FS, Fig. 1a), whereas the ENV88 JJA 1988 precipitation (Fig. 2a) has a split Asian monsoon maximum with very deficient rainfall over most of India. This Indian monsoon deficiency is almost identical to that noted for the control experiment used in section 2 of this paper, and in fact was the motivation for carrying out the wide range of monsoon sensitivity experiments which includes this successful orography experiment. At first glance the ENV88 JJA 850 mb vector wind field (Fig. 2b) looks quite comparable to the JJA 88 ECMWF observations

(FS, Fig. 2a) and the SST88 JJA winds (FS, Fig. 2b). However, the ENV88 850 mb SW monsoon flow penetrates much too far north into India. At 200 mb the SST88 JJA winds (FS, Fig. 3b) also appear to be more realistic compared to the JJA ECMWF analysis (FS, Fig. 3a) than the ENV88 JJA winds (Fig. 2c), which have even weaker westerlies at 30–40°N.

A preliminary examination of the global circulation and rainfall fields reveals that the GCM simulations with the new mean orography are generally equal or superior to those with the old envelope orography (not shown). However, none of the other differences in the simulations noted thus far approach the magnitude of the change in the quality of the Indian monsoon simulation. This improvement in the mean monsoon simulation has also had a strong impact on the model's ability to simulate the interannual variability of the monsoon. Fennessy and Shukla (1990) failed to simulate any 1987 versus 1988 variability in the Indian monsoon using a previous version of the COLA GCM which used enhanced orography, whereas FS have shown reasonable success at simulating that same variability. Further analysis is being done in order to further our understanding of the exact nature of the impact of the new orography on the monsoon simulation. The results of this analysis will be reported in Fennessy et al. (1991).

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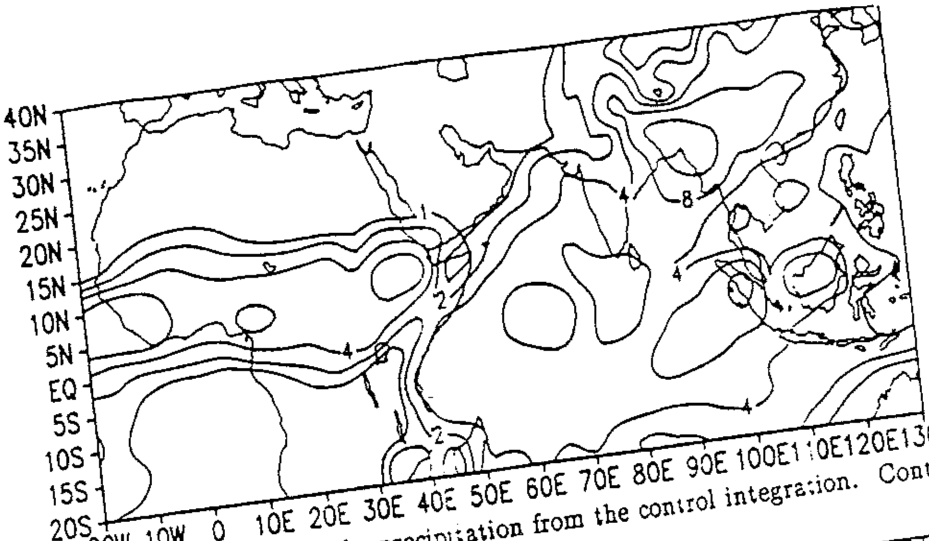

Fig. 1a. The JJA mean of the precipitation from the control integration. Contours are 1,2,4,8,16 mm/day.

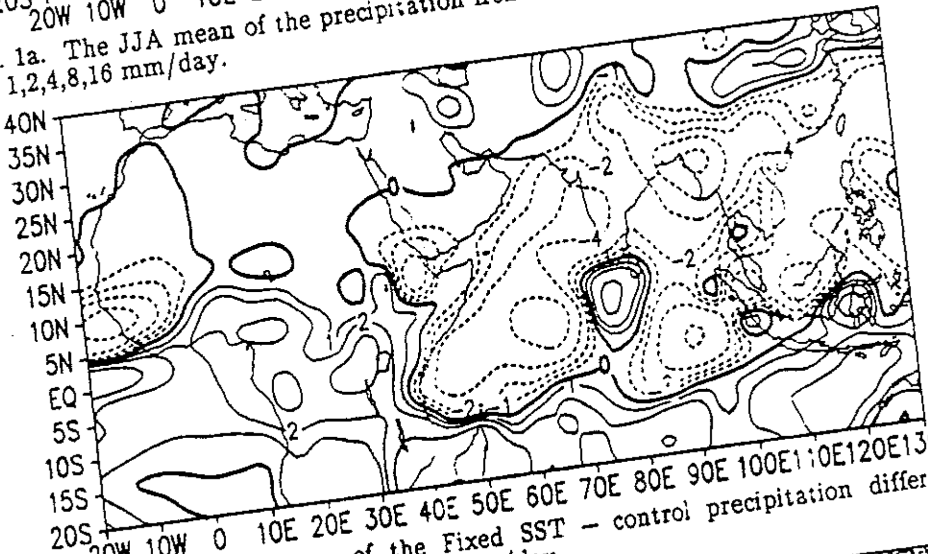

Fig. 1b. The JJA mean of the Fixed SST – control precipitation differenc Contours are –16,–8,–4,–2,–1,0,1,2,4 mm/day.

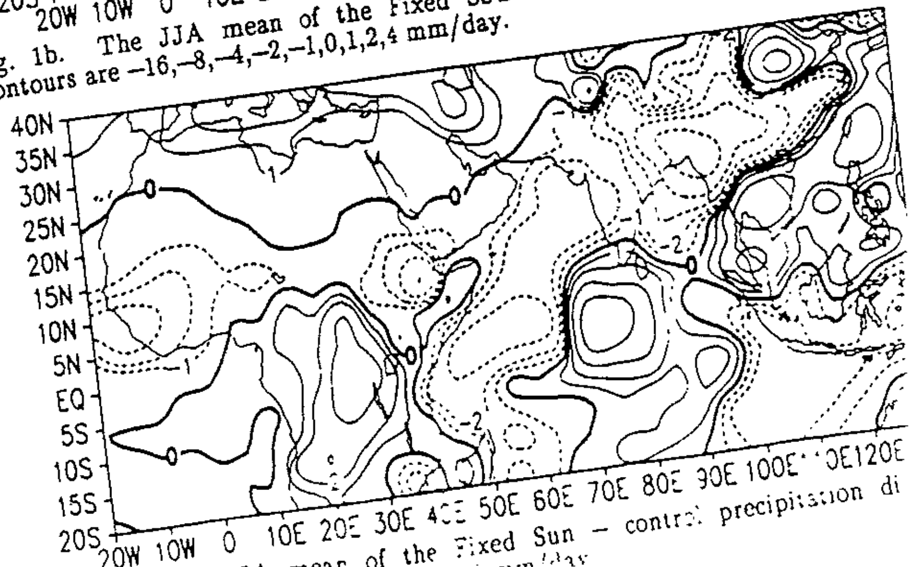

Fig. 1c The JJA mean of the Fixed Sun – control precipitation di [illegible] mm/day

[illegible]

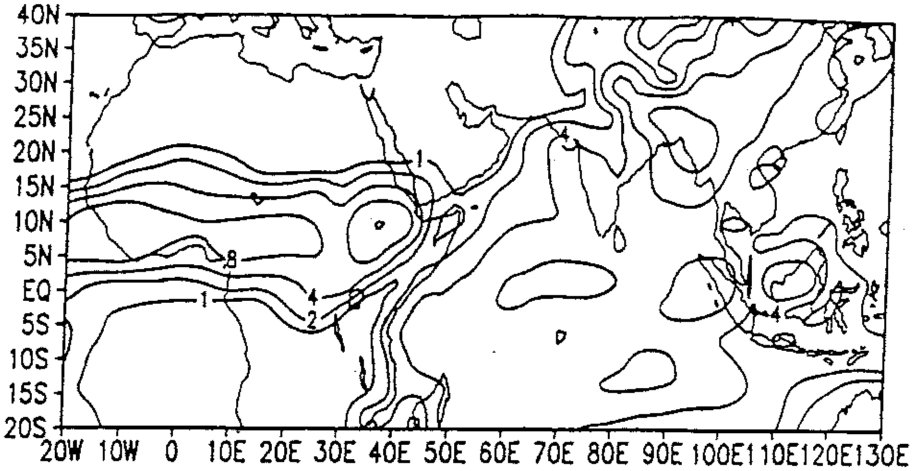

Fig. 2a. The JJA 1988 mean of the precipitation from ENV88 integration. Contours are 1,2,4,8,16 mm/day.

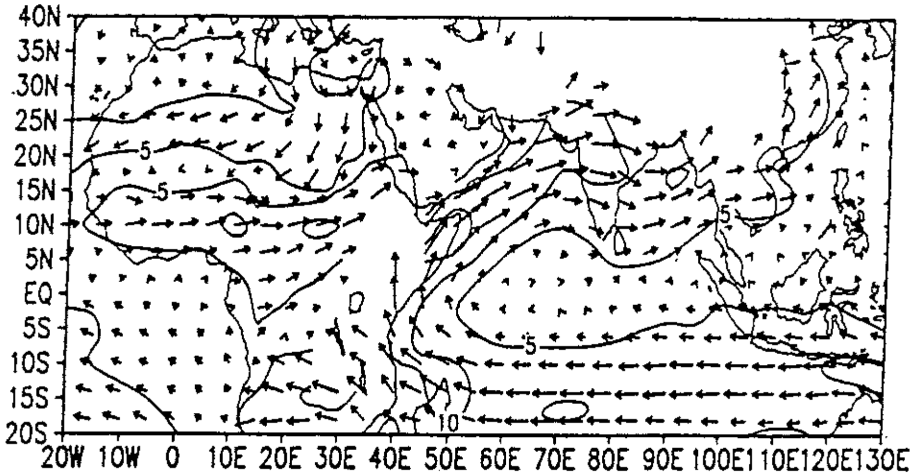

Fig. 2b. The JJA 1988 mean of the 850 mb vector wind from ENV88 integration. Contour interval is 5 m/s.

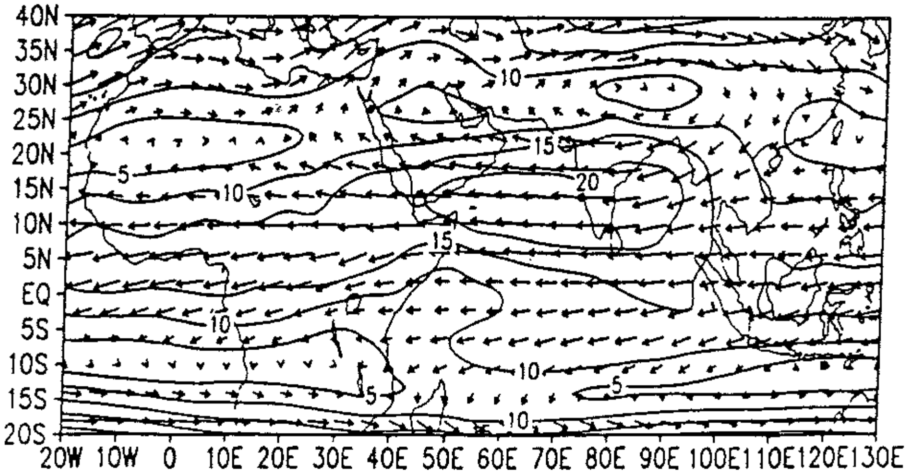

Fig. 2c. The JJA 1988 mean of the 200 mb vector wind from ENV88 integration. Contour interval is 5 m/s.

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