GCM SIMULATIONS OF ACTIVE AND BREAK MONSOON PERIODS

M. J. Fennessy and J. Shukla
Center for Ocean-Land-Atmosphere Studies
Calverton, Maryland U.S.A.

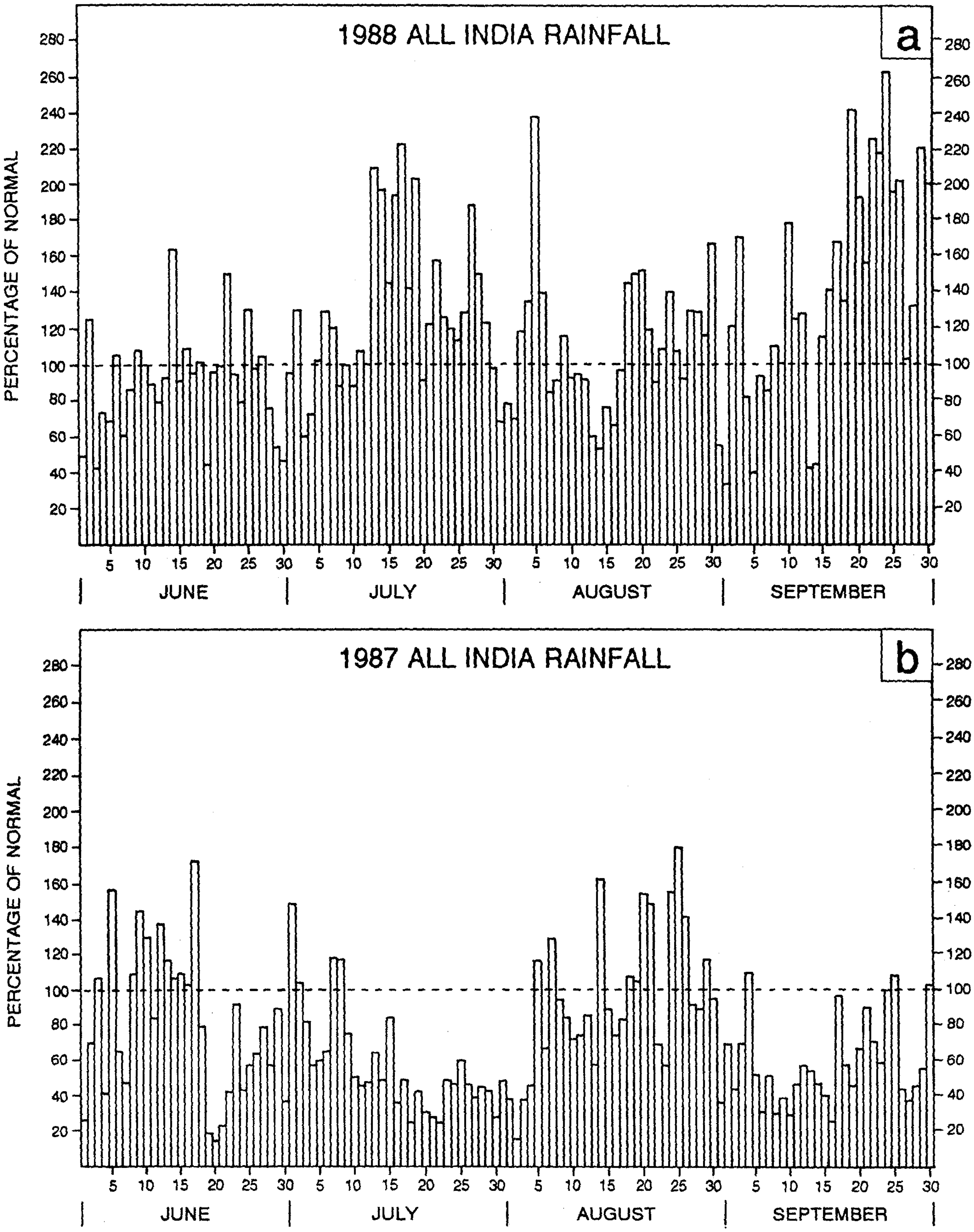
1. Introduction

Seasonal integrations with the Center for Ocean-Land-Atmosphere Studies (COLA) GCM have obtained reasonably good simulations of the JJA mean Indian monsoon circulation and precipitation (Shukla and Fennessy, 1994, Fig. 3c, in this report). The COLA GCM has also been able to simulate much of the interannual variability in the Indian monsoon circulation and precipitation between 1987 and 1988 (Shukla and Fennessy, 1994, Fig. 4c, in this report). Following this success in simulating the seasonal mean, an attempt is made to analyze the intraseasonal variability of the COLA GCM precipitation, and in particular the phenomena of "active" versus "break" monsoon periods.

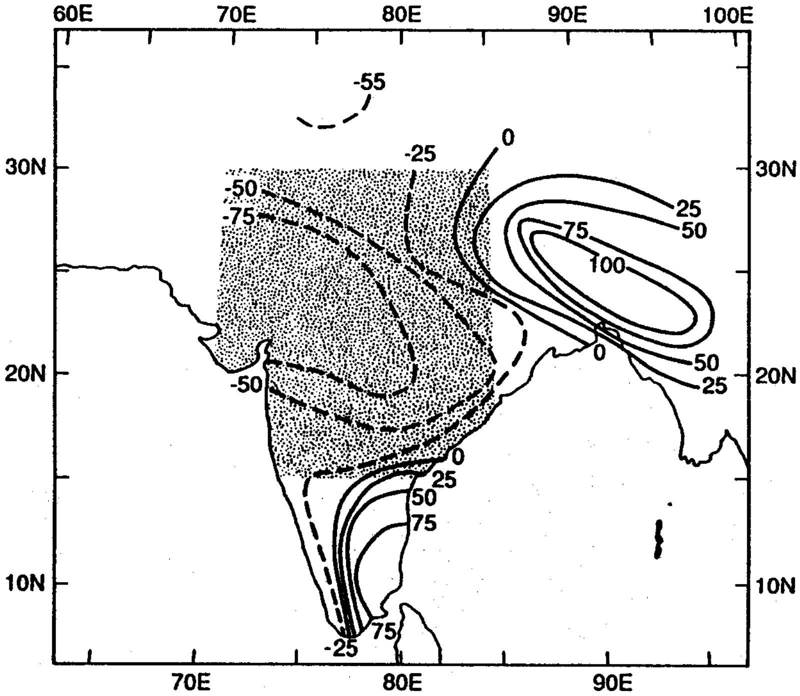
2. Active and break simulations for 1987 and 1988

The daily all India station rainfall for the 1988 and 1987 monsoon seasons is shown in Figs. 1a and 1b, respectively, expressed as a percentage of normal (Bhalme, personal communication). The contrast between the prevalent active periods (rainfall at or above normal) during 1988 and the prevalent break periods (rainfall below normal) during 1987 is similar to that noted in studies of historical "good" versus "bad" monsoon years (Krishnamurti and Bhalme, 1976; Sikka, 1980). Fig. 2 shows the precipitation percentage departure from normal during historical breaks as composited by Ramamurthy (1969) and presented by Gadgil and Asha (1992). The stippled area in Fig. 2 (70-85° E, 15-30° N, land only) was chosen to coincide with the precipitation deficit region associated with the historical breaks, and is used to compute the GCM areal averages discussed below.

In this preliminary study, daily mean data from four different 90 day simulations have been examined, two from 1987 initial states and two from 1988 initial states, all using observed SST as a boundary condition (Reynolds, 1988). The daily area-averaged precipitation for the two 1987 integrations is shown in Figs. 3a and 3b, and for the two 1988 integrations in Figs. 3c and 3d. The simulated active/break monsoon periods are defined as continuous periods of 5 days length or longer in which the area averaged central India precipitation remained above/below the mean value for the four integrations, 4 mm/day. According to this somewhat arbitrary definition, the two 1988 simulations contained an average of 47 active days and 29 break days, and the two 1987 simulations had an average of 17 active days and 60 break days. The magnitude of the active and break periods were similar among the four simulations, with break periods ranging from 1 to 3 mm/day and active periods ranging from 5 to 15 mm/day. Thus, the simulated good/bad monsoon of 1988/1987 is associated with more/less active monsoon days and less/more break monsoon days, rather than with a change in the magnitude of the precipitation rate during active or break monsoon periods, in agreement with historical observations (Krishnamurti and Bhalme, 1976; Sikka, 1980). However, the simulated variability of the daily monsoon precipitation is less than that observed, which ranges from 0 to more than 20 mm/day (not shown).



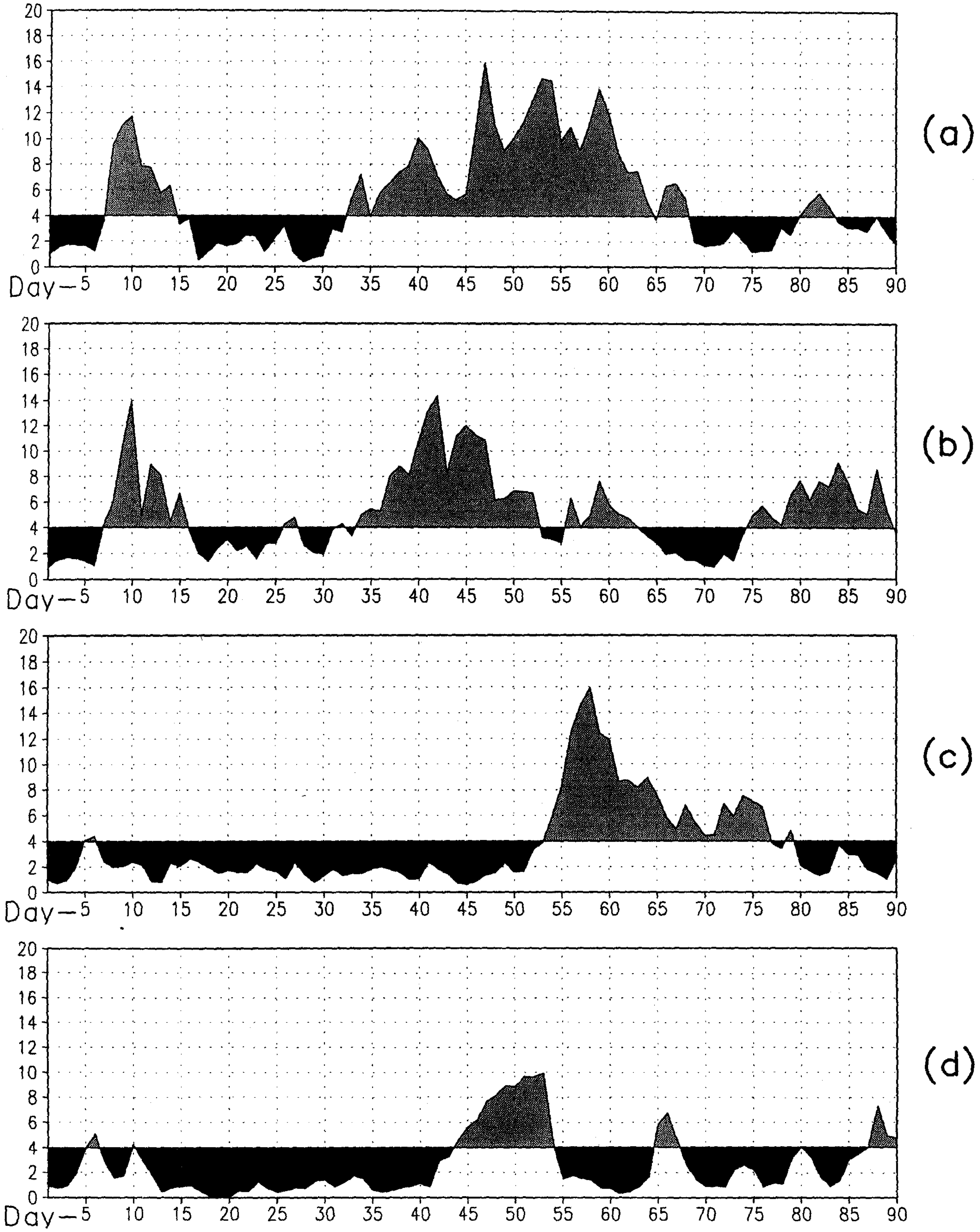
1. Daily all India station rainfall for (a) 1988 and (b) 1987. Expressed as a percentage of normal. Normal dashed.



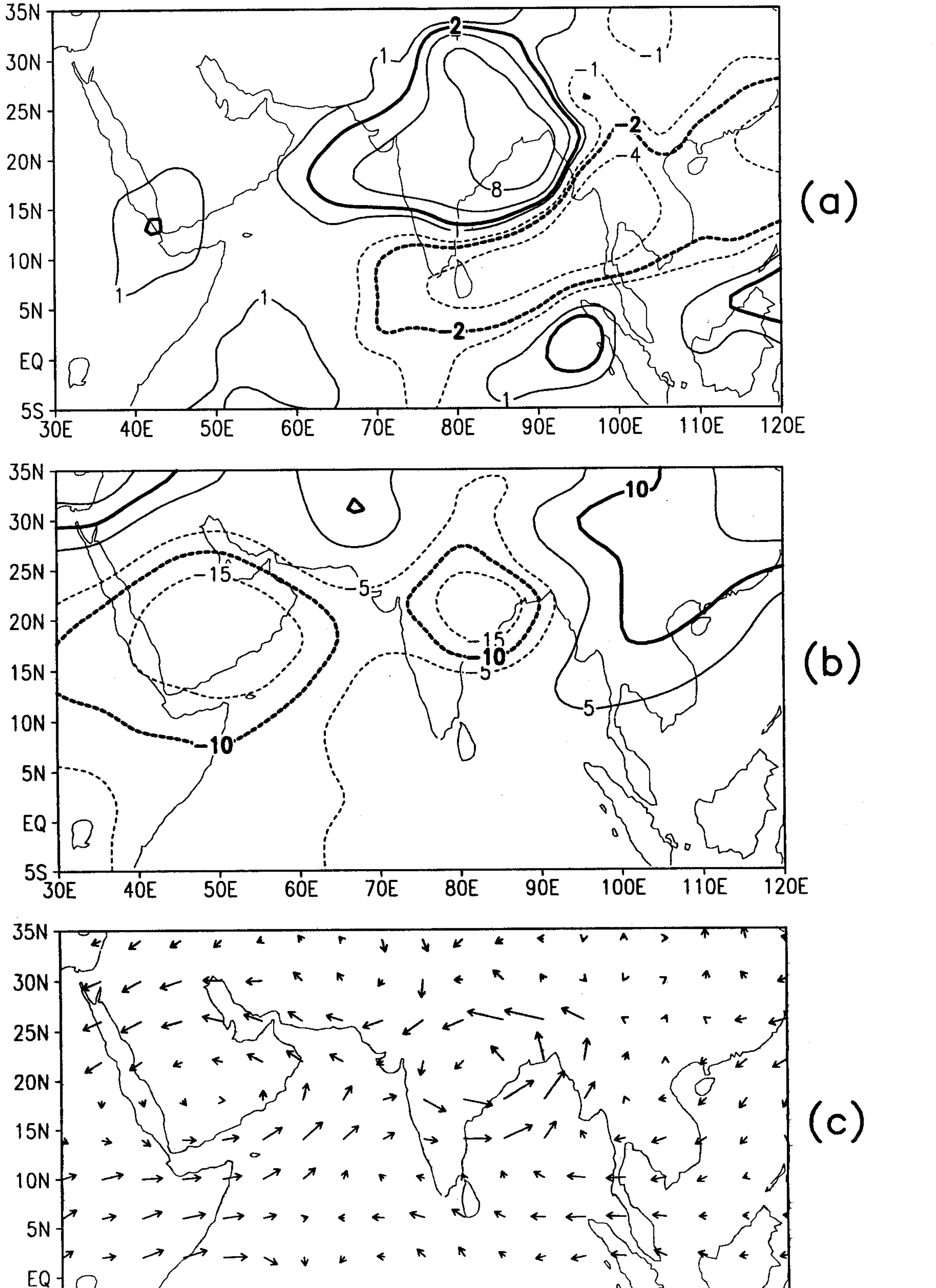
2. Mean departure (%) of rainfall during breaks (from Ramamurthy ,1969; and Gadgil and Asha, 1992). Stippled area used for GCM areal averages.

Composite maps of the simulated precipitation and atmospheric circulation were produced for active and break periods for 1987, 1988 and the two years combined. An examination of these maps confirmed the qualitative similarity of the active and break monsoon periods between these two years. The simulated active composite minus break composite precipitation difference pattern (Fig. 4a) is similar to the historical break departure from normal precipitation map (Fig.2, with opposite sign), with a very dry central India, but relatively wet conditions over SE India and to the NE over the Himalayan foothills during break periods. The simulated break minus active relatively wet conditions over SE India are part of a larger wet pattern over the Indian ocean south of India. Thus, the break minus active composite precipitation field is suggestive of a southward shift in the tropical convergence zone to an oceanic position during the simulated break monsoon, in accordance with the observations of Gadgil and Srinivasan (1990). The great similarity of the active minus break composite precipitation field (Fig. 4a) to the 1988 minus 1987 ensemble seasonal precipitation difference simulated with the same model (Shukla and Fennessy, 1994, Fig. 5c, in this report) suggests a close relation between the intraseasonal variability and the interannual variability of the monsoon.

Simulated active, break and difference composite maps of 850, 700, 500 and 200 mb heights and winds were compared to the flow patterns associated with historical active/break monsoon periods presented by Ramamurthy (1969). The simulated active minus break composite 700 mb geopotential height and wind differences are shown in Figs. 4b and 4c, respectively, and clearly show an enhanced trough and cyclonic circulation over India, features which were also simulated at 850 mb and 500 mb (not shown). Also simulated were enhanced low level south-



3. Area averaged (70-85° E, 15-30° N, land only) daily precipitation for (a) and (b), 1988 integrations, and for (c) and (d), 1987 integrations. Units are mm day^{-1} .



4. Active minus break composite (a) precipitation, contours are ± 1, 2, 4, 8 mm day^{-1} , (b) 700 mb geopotential height, contours are ± 5, 10, 15 geopotential meters and (c) 700 mb wind, vector at bottom right denotes magnitude. Dashed contours are negative.

westerly flow impinging upon India (Fig. 4c) and anomalous 200 mb tropical easterlies south and south-west of India (not shown). These simulated active versus break circulation features are all in accord with observed active versus break circulation features composited by Ramamurthy (1969, not shown).

The results presented here are somewhat tentative, as they are based on just four 90-day simulations from only two different years. However, it does appear that the COLA GCM has correctly simulated many of the observed features associated with historical active versus break monsoon periods, as well as their relation to good versus bad monsoon years. Furthermore, it is encouraging that the 1987 integrations do simulate very persistent break conditions during June and July (Figs. 3c and 3d), a highly unusual occurrence which was observed at that time (Fig. 2b).

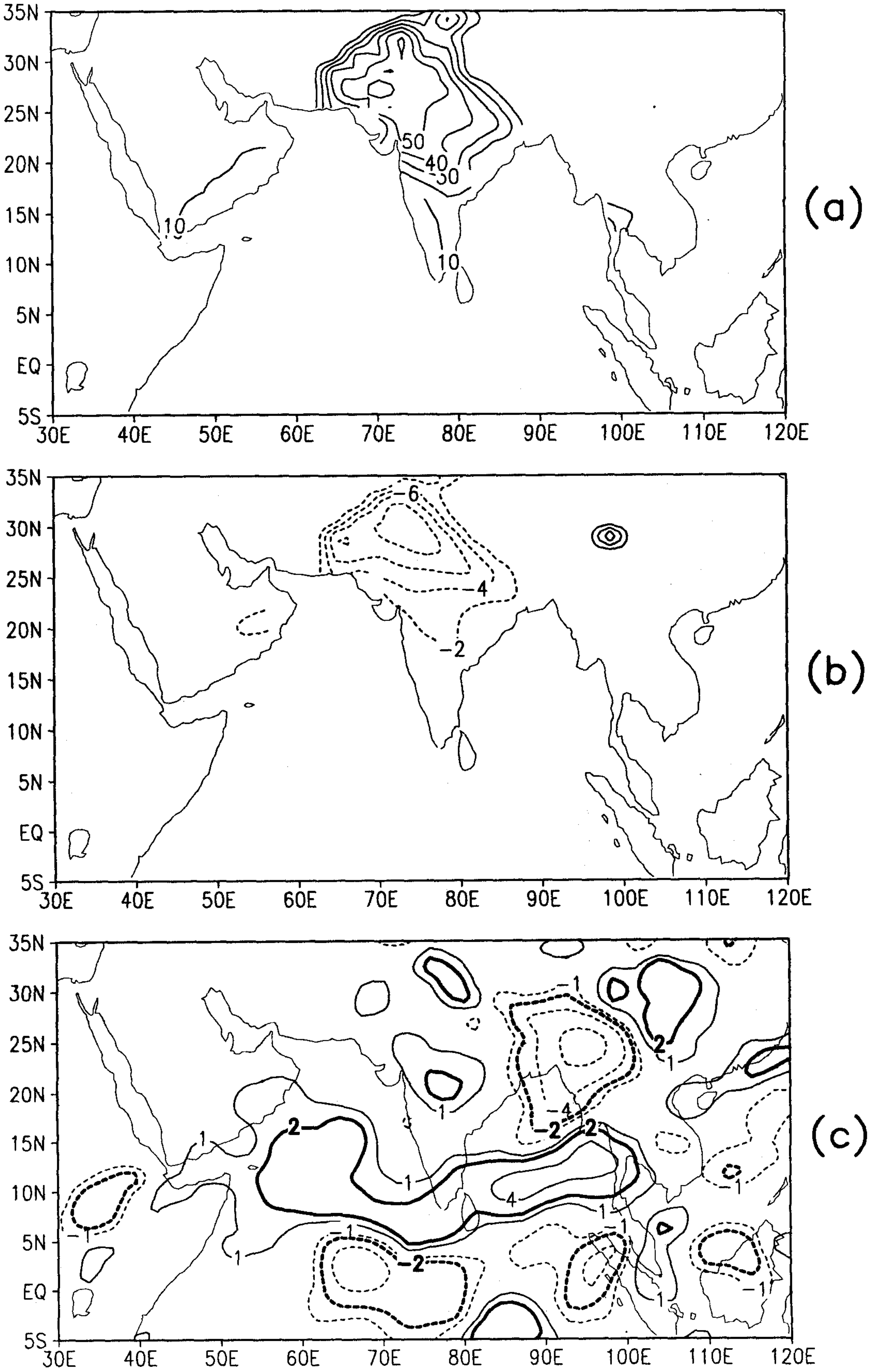
3. Role of land surface boundary conditions

The possible role of land surface boundary conditions in modulating the magnitude and/or frequency of the active/break monsoon cycle is also being investigated. If the active/break cycle is driven or modulated by intraseasonal heating/cooling, then the soil wetness may affect it through its' impact on the land surface intraseasonal temperature variability. The role of soil wetness in the local surface heating is a key part of the low-frequency monsoon variability mechanism proposed by Webster (1983). We preform an extreme experiment designed to greatly reduce the local surface intraseasonal heating/cooling by artificially saturating the soil over India and Pakistan throughout the course of a 90-day integration. This integration (hereafter WetSoil) is compared to a control integration in which the soil wetness is predicted by the model. Both integrations are initialized from the observed atmospheric state on 1 June 1988 and use observed SST (Reynolds, 1988).

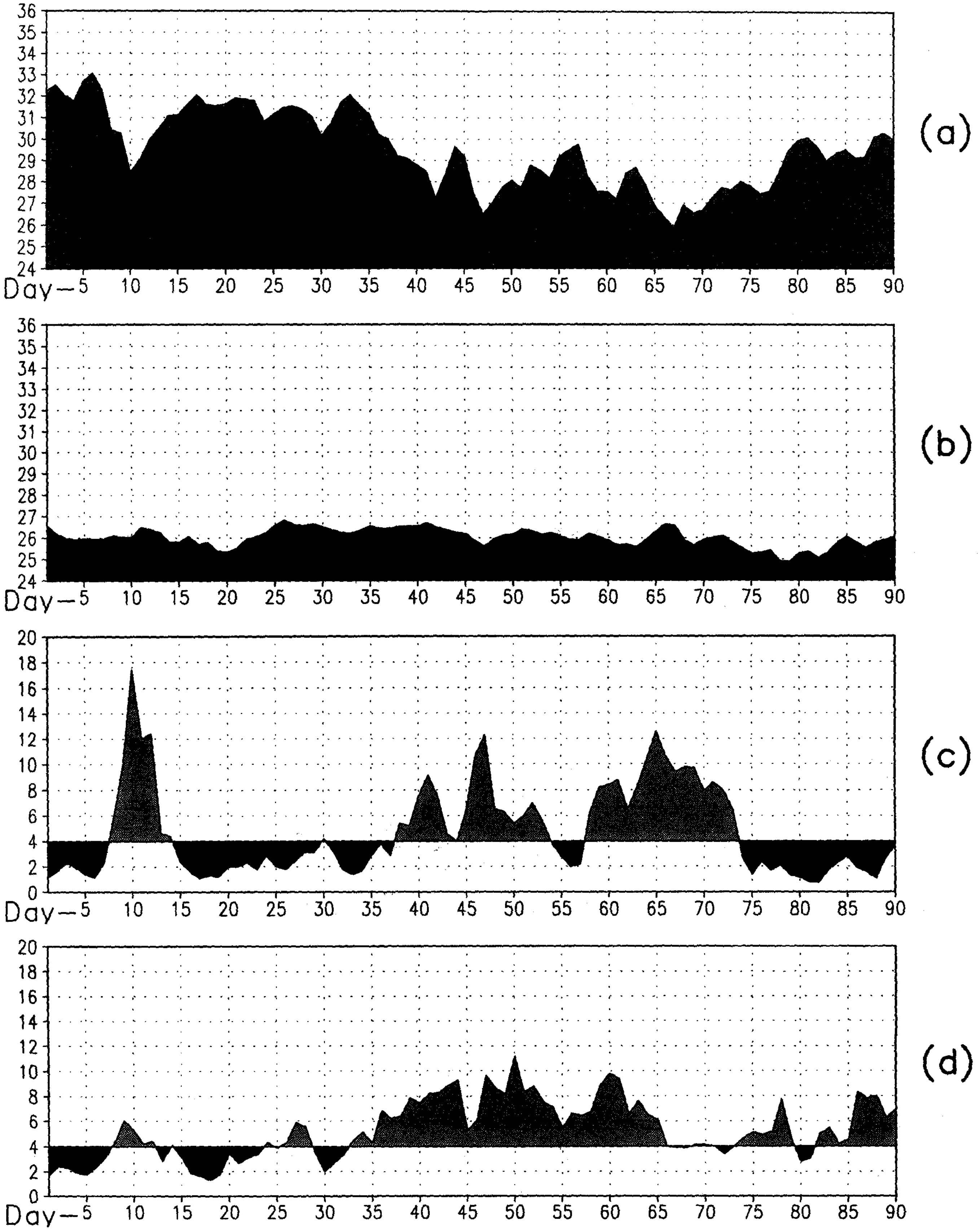
Although we are primarily interested in the impact of the soil wetness on the intraseasonal variability, we must also examine the impact on the seasonal mean, as the variability and the mean are related. The seasonal mean (JJA) soil wetness of the control integration ranges from 20 to 50 % of saturation over most of the India-Pakistan region (not shown). The JJA mean soil wetness anomaly resulting from fixing the soil wetness at saturated values in the WetSoil integration ranges from 30 to 60 % over most of this region (Fig. 5a). The JJA mean surface temperature in this region is reduced by 2-8 °C (Fig. 5b), but the JJA mean precipitation is increased by just 1 mm day^{-1} over parts of this region (Fig. 5c). There is a greater impact on the JJA mean precipitation to the east over Bangladesh, eastern India and Burma, where there is a reduction of 2-8 mm day^{-1} ; and to the south, where the precipitation increased by 2-4 mm day^{-1} over a broad band centered at roughly 10°N.

The daily area averaged (area stippled in Fig. 2) surface temperature time series shows a great reduction in both the mean and the intraseasonal variability in the WetSoil integration compared to the control (Figs. 6b and 6a, respectively). As hypothesized, the intraseasonal variability of the precipitation over this region was reduced in the Wet Soil integration (Fig. 6d) compared to that in the control (Fig. 6c). Particularly striking is the near absence of break periods (< 4 mm day^{-1}) in the WetSoil integration.

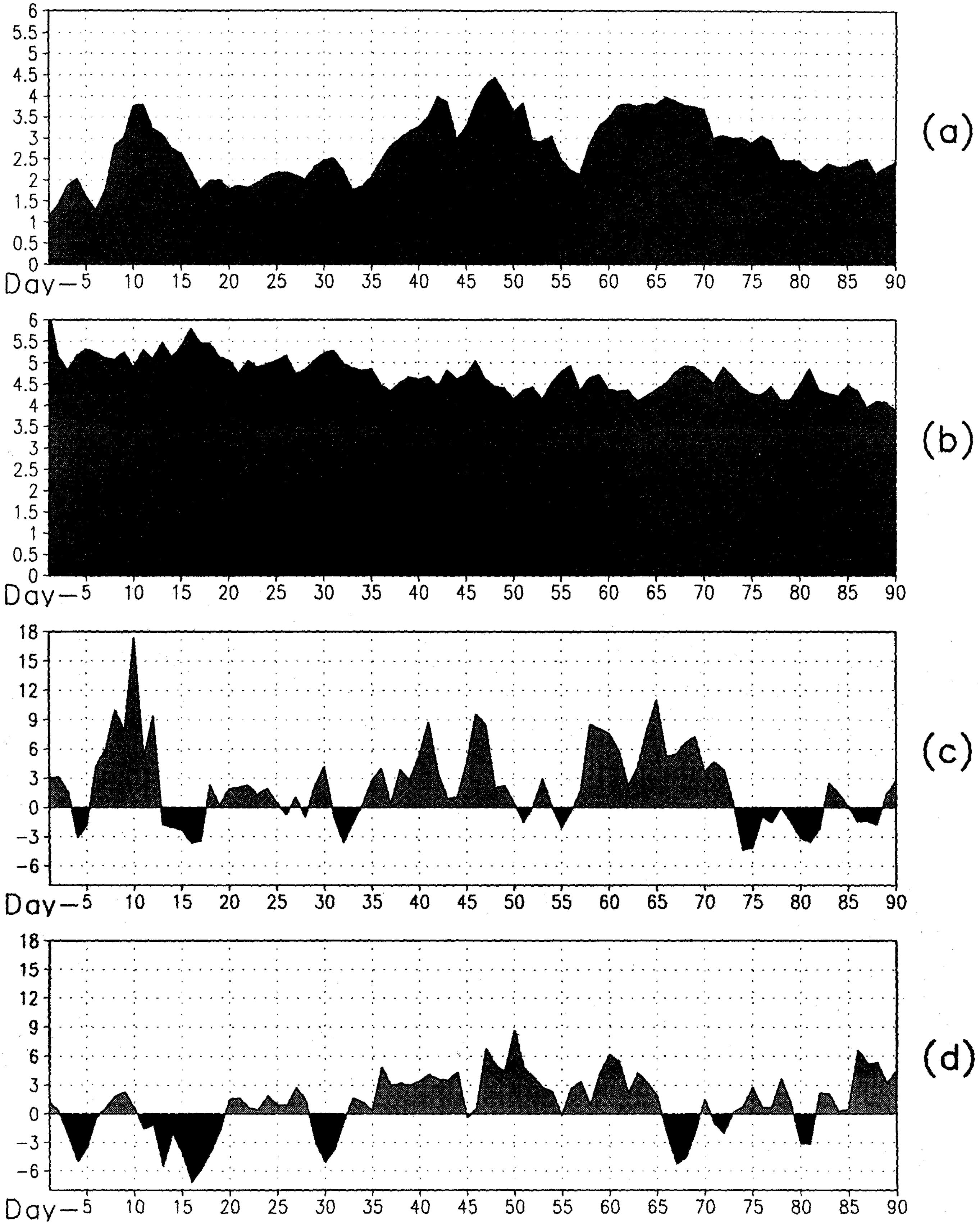
In order to determine whether the reduction in the intraseasonal precipitation variability was due solely to local effects or whether the response of the large scale circulation also played a role, we examine the area averaged time series of evaporation and vertically integrated moisture flux convergence. The evaporation in the control simulation (Fig. 7a) is quite variable and ranges from 1.5 to 4 mm day^{-1} . In the WetSoil integration (Fig. 7b) the evaporation is both higher and



5. WetSoil minus control JJA mean (a) soil wetness (%), (b) evaporation, contour interval is 2 mm day^{-1} and (c) precipitation, contours are ± 1, 2, 4, 8 mm day^{-1}. Dashed contours are negative.



6. Area averaged daily (a) control surface temperature (°C), (b) WetSoil surface temperature (°C), (c) control precipitation (mm day^{-1}) and (d) WetSoil precipitation (mm day^{-1})



7. Area averaged daily (a) control evaporation, (b) WetSoil evaporation, (c) control vertically integrated moisture flux convergence and (d) WetSoil vertically integrated moisture flux convergence. Units are mm day^{-1}.

considerably less variable, ranging from 4 to 5 mm day^{-1} . The variability of the vertically integrated moisture flux convergence is also largely reduced in the Wetsoil integration (Fig. 7d) compared to the control integration (Fig. 7c).

These results imply that the surface hydrology can provide a feedback mechanism which modulates the precipitation intraseasonal variability through both local effects and by influencing the large scale circulation.

REFERENCES

Gadgil, S. and J. Srinivasan, 1990: Low frequency variability of tropical convergence zones. *Meteor. Atmos. Phys.*, **44**, 119-132.

Gadgil, S. and G. Asha, 1992: Intraseasonal variation of the summer monsoon I: Observational aspects. *J. Met. Soc. Japan,* **70,** 387-397.

Krishnamurti, T.N. and H. N. Blame, 1976: Oscillations of a monsoon system. Part 1. Observational aspects. *J. Atmos. Sci.*, **33**, 1937-1954.

Ramamurthy, K., 1969: Monsoon of India: some aspects of the 'break' in Indian southwest monsoon during July and August. *India Met. Dept. Forecasting Manual.*

Reynolds, R. W., 1988: A real-time global sea surface temperature analysis. *J. Climate,* **1,** 75-86.

Shukla, J., and M. J. Fennessy, 1994: Simulation and predictability of monsoons. *Report of The TOGA/WGNE MONEG International Conference on Monsoon Variability and Prediction,* Trieste, Italy, 9-13 May, 1994, WMO, Geneva.

Sikka, D. R., 1980: Some aspects of the large scale fluctuations of summer monsoon rainfall over India in relation to fluctuations in the planetary and regional scale circulation parameters. *Proc. Ind. Acad. Sc. (Earth and Planet Sci.),* **89**, 179-195.

Webster, P. J., 1983: Mechanisms of monsoon low-frequency variability: Surface hydrological effects. *J. Atmos. Sci.,* ***40,*** 2110-2124.

WMO, 1991: *Report of the MONEG workshop on: Simulation of interannual and intraseasonal monsoon variability.* 21-24 October, 1991, WMO/TD - No. 470, WCP, WMO, Geneva, 229 pp.