# *INFLUENCE OF GLOBAL SST ON GCM SIMULATIONS OF THE NORTHERN HEMISPHERE MONSOON CIRCULATIONS OF 1987 AND 1988*

M. J. Fennessy and J. Shukla

*Report of the Monsoon Numerical Experimentation Group Workshop on Interannual and Intraseasonal Variability of Monsoons.*
October 21–24, 1991

WMO, WCRP–68

**WMO/TD–NO. 470**

1992

# INFLUENCE OF GLOBAL SST ON GCM SIMULATIONS OF THE NORTHERN HEMISPHERE MONSOON CIRCULATIONS OF 1987 AND 1988

M. J. Fennessy and J .Shukla
Center for Ocean–Land–Atmosphere Interactions
Department of Meteorology
University of Maryland
College Park, Maryland 20742, USA

## 1. Introduction

The Northern Hemisphere (NH) summer monsoon rainfall was very deficient in 1987 and quite abundant in 1988 over both India and Africa (Arkin 1988; Ropelewski 1988; Folland et al. 1990; Palmer and Brankovic 1989). Between these two summers the Southern Oscillation changed phase, going from the negative phase with warm SST (El Niño) and low atmospheric pressure in the central equatorial Pacific in JJA 1987, to the positive phase with cold SST (La Niña) and high atmospheric pressure in the central equatorial Pacific in JJA 1988 (Arkin 1988; Ropelewski 1988). We investigate the possibility of a relationship between global SST, Southern Oscillation atmospheric circulation features and NH monsoon circulations during the boreal summers of 1987 and 1988 using an atmospheric general circulation model (GCM).

## 2. Experiment and model

The Center for Ocean–Land–Atmosphere Interactions (COLA) GCM is integrated for 90 days, starting from the NMC observed atmospheric initial states at 00UTC on 1, 2, 3 June 1987 and 1, 2, 3 June 1988, respectively. For each initial state two integrations are done, the first with the COADS/ICE global climatological SST (Reynolds 1988), and the second with real–time SST (Reynolds 1988) from 50°S to 60°N and the COADS/ICE climatological SST elsewhere.

The COLA GCM was derived from a version of the NMC MRF spectral GCM and still contains NMC spectral dynamics with rhomboidal truncation at 40 wave numbers (Sela 1980). The GCM has undergone several revisions and is considerably different from the version described by Kinter et al. (1988). It has 18 uneven sigma layers in the vertical with emphasis on the PBL and tropopause. Surface parameterizations are done using a simplified version of the Simplified Biosphere Model of Sellers et al. (1986), as modified by Xue et al. (1991). The Mellor and Yamada (1982) 2.0 second order closure scheme is used for vertical diffusion in the PBL. The convection is after Kuo (1965), and shallow convection (Tiedtke et al. 1984) is also included. The longwave radiation scheme is based on that of Harshvardhan and Corsetti (1984) and the shortwave radiation scheme follows that of Lacis and Hansen (1974). Moisture is carried at all 18 sigma levels and both predicted super–saturation clouds and predicted cumulus clouds interact with the radiation schemes (Hou 1990). The most recent modifications are the inclusion of gravity wave drag and the use of slightly smoothed mean orography rather than the previously used envelope orography.

In section 3 we examine the model's ability to simulate the time mean NH monsoon circulations. In section 4 we examine it's ability to simulate the differences between 1987 and 1988. The June through August time mean (JJA) of the ensemble of the 3 initial states for each case are referred to as CLI88, SST88, CLI87 and SST87, respectively. To determine which of the simulated circulation differences are due to the effect of using realistic SST, we compare both the difference in integrations using realistic SST (SST88–SST87) and the difference in integrations using climatological SST (CLI88–CLI87) to the observed circulation differences in section 4.

3. Time mean circulation features

We have examined the GCM's mean boreal summer simulations in general, and believe that they are realistic enough to justify using this GCM to conduct the current study. For the sake of brevity only selected results from the 1988 real–time SST integration (SST88) in the immediate monsoon region are shown.

The JJA SST88 precipitation field contains a good representation of the ITCZ and South Pacific Convergence Zone (SPCZ) in the Pacific, as well as the ITCZ across South America and the Atlantic (not shown). Also well simulated are the precipitation maxima of the African and Indian monsoons (Fig. 1b). For reference a JJA 1988 observed precipitation proxy field obtained from the OLR via an empirical relation (P. Arkin, personal communication) is shown in Fig. 1a.

The SST88 850 mb wind field (Fig. 2b) contains a reasonable simulation of the Somali jet off the east coast of Africa and the SW monsoon flow into India, although both are a bit weak compared to that observed (ECMWF, Fig. 2a). The southerly jet over SE China which is related to the SE Asian monsoon (Lau et al. 1988) is also simulated, albeit somewhat stronger than that observed. Also fairly well simulated is the convergence of the NE and SW trades over Africa at 15° N.

At 200 mb, SST88 (Fig. 3b) correctly simulates the strong equatorial easterlies observed (ECMWF, Fig. 3a) throughout the monsoon belt, as well as the maximum over the Arabian Sea and southern India. The south Asian anticyclone associated with the monsoon is also fairly well simulated at the correct latitude (25–30° N), although it appears to be centered somewhat west of that observed. The westerlies at 30–40° N are well placed, but weaker than those observed.

4. Differences between 1987 and 1988

In this section we attempt to determine which aspects of the monsoon related observed circulation differences between 1987 and 1988 are due to the influence of realistic SST by comparing the JJA time mean differences: OBS88–OBS87, SST88–SST87 and CLI88–CLI87.

The 1988 La Niña minus 1987 El Niño large negative precipitation differences in the equatorial Pacific, as well as the positive differences to the north and west, and the shift in the position of the SPCZ are all simulated by SST88–SST87, but not by CLI88–CLI87 (not shown). The proxy JJA 1988 – 1987 observed precipitation difference (mm/day, Fig. 4a) is obtained by dividing the OLR difference (W/m*m) by –5.7, an empirical relation obtained from P. Arkin (personal communication). SST88–SST87 (Fig. 4b) correctly simulates the band of positive precipitation differences which stretches across central Africa and the Arabian Sea and NW over India. The CLI88–CLI87 precipitation difference (Fig. 4c) contains a much weaker and discontinuous positive signal over Africa and India. Both SST88–SST87 and CLI88–CLI87 contain a negative signal somewhat similar to that observed over SE Asia.

Over Africa, the JJA OBS88–OBS87 850 mb wind difference (ECMWF, Fig. 5a) contains westerlies from the equator to 10° N, and south–westerlies from 15° N to 20° N indicative of enhanced convergence over Africa at 15–20° N. These signals are fairly well simulated by SST88–SST87, but completely missed by CLI88–CLI87. The weak signals observed to the south and southwest of India (Fig. 5a) were quite different in the NMC observed analyses (not shown) and are not represented by either SST88–SST87 (Fig. 5b) or CLI88–CLI87 (Fig. 5c).

The JJA OBS88–OBS87 200mb wind difference (ECMWF. Fig. 6a) contains easterlies between 20°S and the equator across the entire monsoon belt. as well as over all of Africa from 20°S to 30°N. SST88–SST87 (Fig. 6b) correctly simulates these easterlies, although the strongest easterlies at 10–15°S across Africa are weaker than those observed. CLI88–CLI87 contains only a small easterly signal south of the equator across Africa. Both SST88–SST87 and CLI88–CLI87 contain an easterly signal over the east coast of China, which is similar, but south of the observed easterly signal.

## 5. Summary

Recently completed northern hemisphere summer integration ensembles with the COLA GCM appear to contain fairly realistic representations of the time mean northern hemisphere summer monsoon circulations and rainfall. Further analysis of these ensembles is required, particularly of their transient evolution.

Observed global SST during 1987 and 1988 definitely improves the GCM's ability to simulate the observed interannual variability in the monsoon circulations. In integration ensembles including observed global SST the COLA GCM correctly simulates stronger African and Indian monsoon rainfall, as well as weaker SE Asia monsoon rainfall in 1988 versus 1987. The observed global SST ensembles also correctly simulate most of the 1988 versus 1987 variability in the monsoon region upper level winds and some of the variability in the lower level winds. The GCM ensembles which used climatological SST simulated much weaker interannual variability in the monsoon rainfall, and very little variability in the monsoon region upper and lower level winds. The climatological SST ensembles did however appear to simulate the SE Asia monsoon variability roughly as well as did the SST ensembles. Further analysis is required in order to better understand both the GCM's simulation of the interannual variability and it's dependence on the observed SST.

The results presented here are preliminary in that they are based on a limited analysis of recently completed integrations. Interpretation of these results is also complicated by uncertainties in the observations. Observed precipitation data is either sparse due to a limited number of stations, or uncertain due to satellite estimates. Disagreement between the observed analyses from ECMWF and NMC also complicates verification of GCM simulations of the interannual variability, particularly for low level winds. We believe the limitations of the observed analyses would be greatly reduced in a coherent re–analyzed observed data set for 1987 and 1988.

## REFERENCES


Arkin, P. A., 1988: The global climate for June–August 1987: Mature phase of an ENSO warm episode persists. *J. Climate*, 1, 1153–1174.

Folland, C. K, J. A. Owen, M. N. Ward and A. Colman, 1990: Prediction of seasonal rainfall in the Sahel using empirical and dynamical methods. *J. Forecasting*, Special Issue on Environmental Forecasting (to be published).

Harshvardhan, and T. G. Corsetti, 1984: Longwave radiation parameterization for the UCLA/GLAS GCM. NASA Tech. Memo. 86072, p. 65.

Hou, Y. T., 1990: Cloud–Radiation–Dynamics Interaction. Ph.D Thesis, Dept. of Meteorology, U. of Maryland, College Park, MD 20742

Kinter III, J. L., J. Shukla, L. Marx and E. K. Schneider, 1988: A simulation of the winter and summer circulations with the NMC global spectral model. *J. Atmos. Sci.*, 45, 2486–2522.

Kuo, H. L., 1965: On the formation and intensification of tropical cyclones through latent heat release by cumulus convection. *J. Atmos. Sci.*, 22, 40–63.

..is, A. A. and J. E. Hansen, 1974: A parameterization for the absorption of solar radiation in the earth's atmosphere. *J. Atmos. Sci.* ,31, 118–133.

..u, K. M., G. J. Yang and S. H. Shen, 1988: Seasonal and intraseasonal climatology of summer monsoon rainfall over East Asia. *Mon. Wea. Rev.*, **116**, 18–37.

..llor, G. L. and T. Yamada, 1982: Development of a turbulence closure model for geophysical fluid problems. *Rev. Geophys. Space Phys.*, 20, 851–875.

..mer, T. N. and C. Brankovic, 1989: Prediction of monthly mean tropical rainfall. *Trop. Ocean-Atmos. Newslett.*, Jan 1989, 3–5.

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

..pelewski, C. F., 1988: The global climate for June–August 1988: A Swing to the positive phase of the Southern Oscillation, drought in the United States, and abundant rain in monsoon areas. *J. Climate*, 1, 1153–1174.

.. .. .., 1980: Spectral modeling at the National Meteorological Center. *Mon. Wea. Rev.*, 108, 1279–1292.

..ers, P. J., Y. Mintz, Y. C. Sud and A. Dalcher, 1986: A simple biosphere model (SiB) for use within general circulation models. *J. Atmos. Sci.*, 43, 505–531.

..e, Y., P. J. Sellers, J. L. Kinter and J. Shukla, 1991: A simplified biosphere model for global climate studies. *J. Climate*, 4, 345–364.

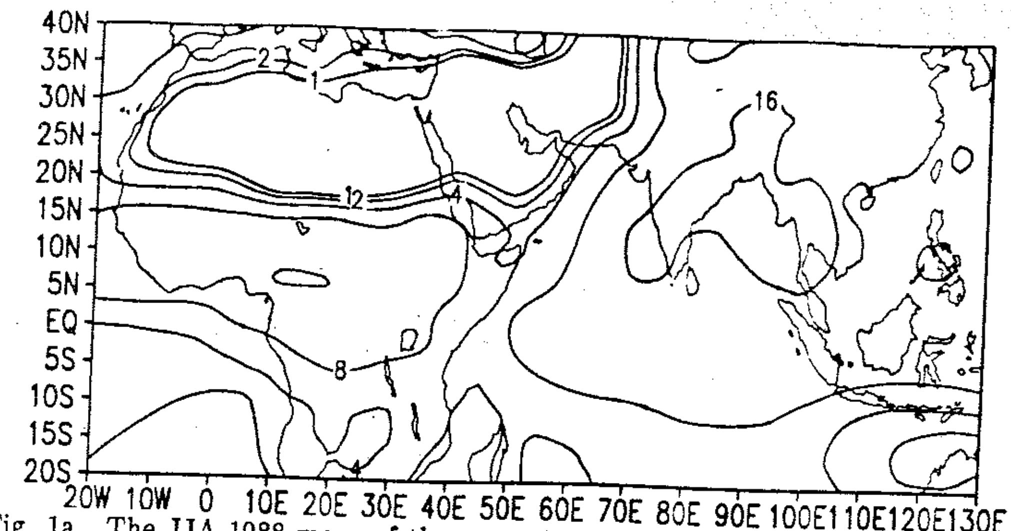


Fig. 1a. The JJA 1988 mean of the approximate observed precipitation (obtained from OLR, see text). Contours are 1,2,4,8,16,32 mm/day.

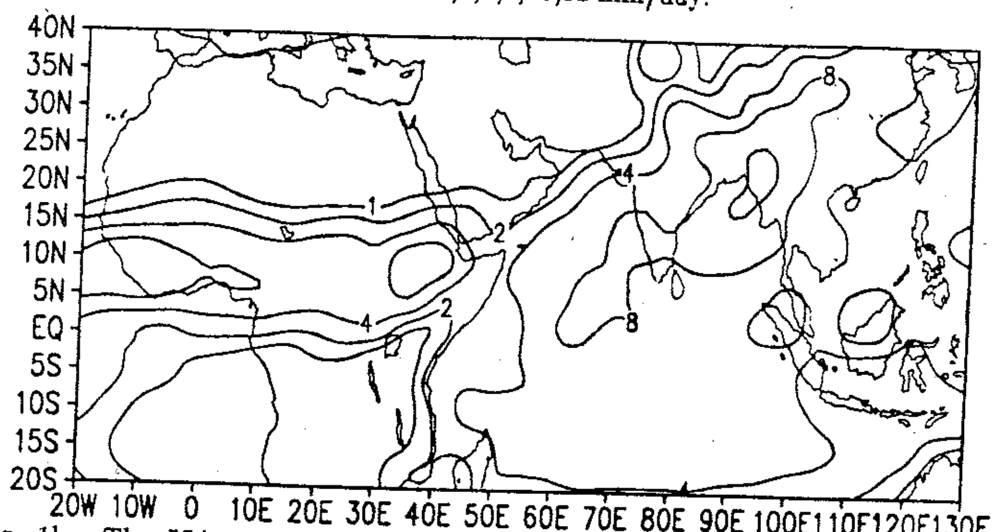


Fig. 1b. The JJA 1988 mean of the precipitation from realistic SST integration ensemble. Contours are 1,2,4,8,16,32 mm/day.

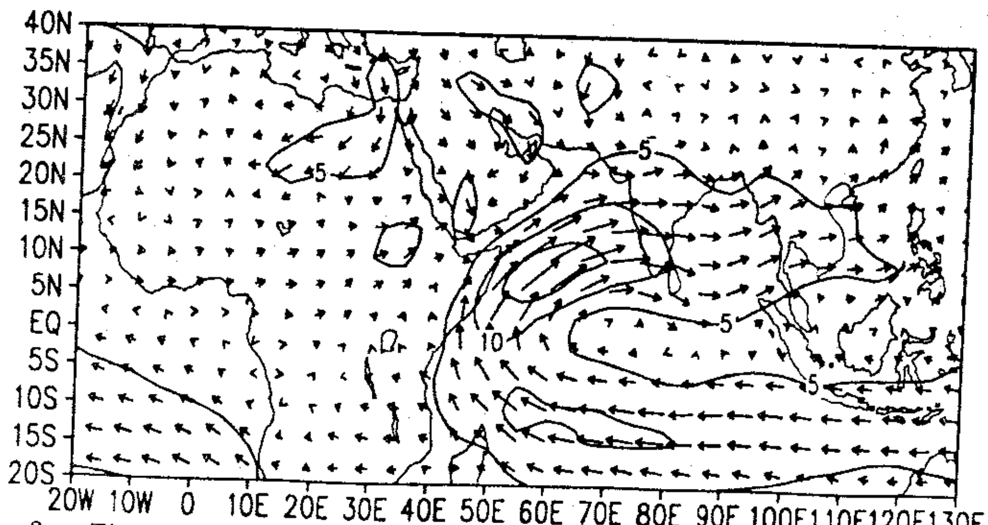


Fig. 2a. The JJA 1988 mean of the 850 mb vector wind for ECMWF

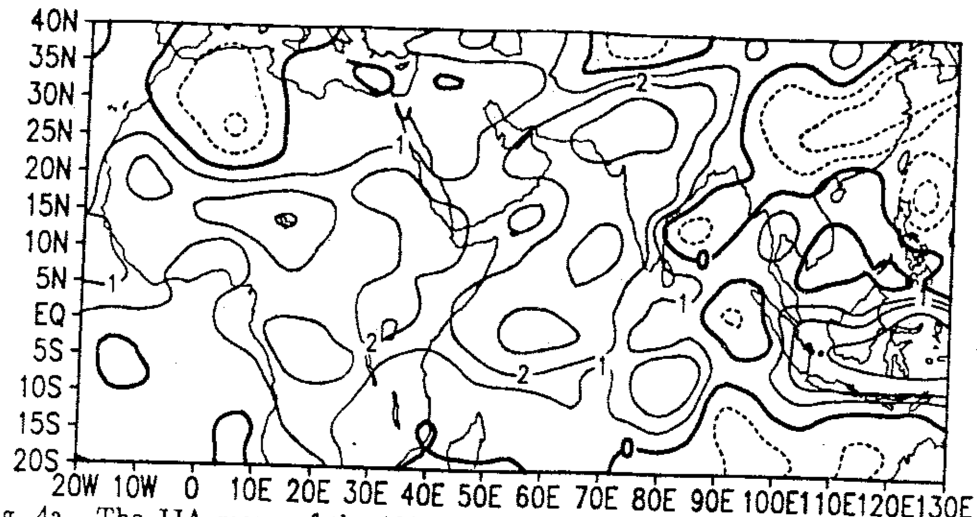


Fig. 4a. The JJA mean of the 1988 – 1987 difference in observed precipitation . Contours are –4,–2,–1,0,1,2,4 mm/day. Dashed Contours are negative.

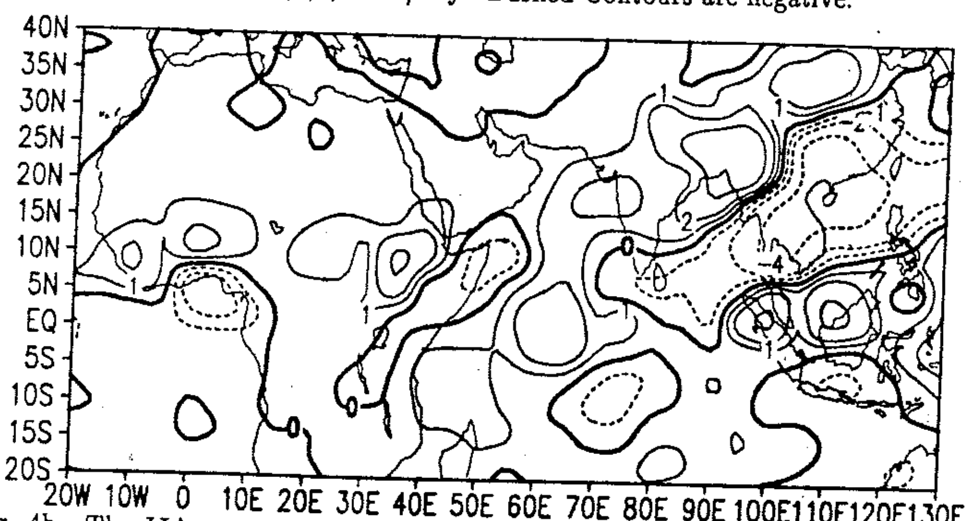


Fig. 4b. The JJA mean of the 1988 – 1987 difference in precipitation from realistic SST integration ensemble. Contours are –4,–2,–1,0,1,2,4 mm/day.

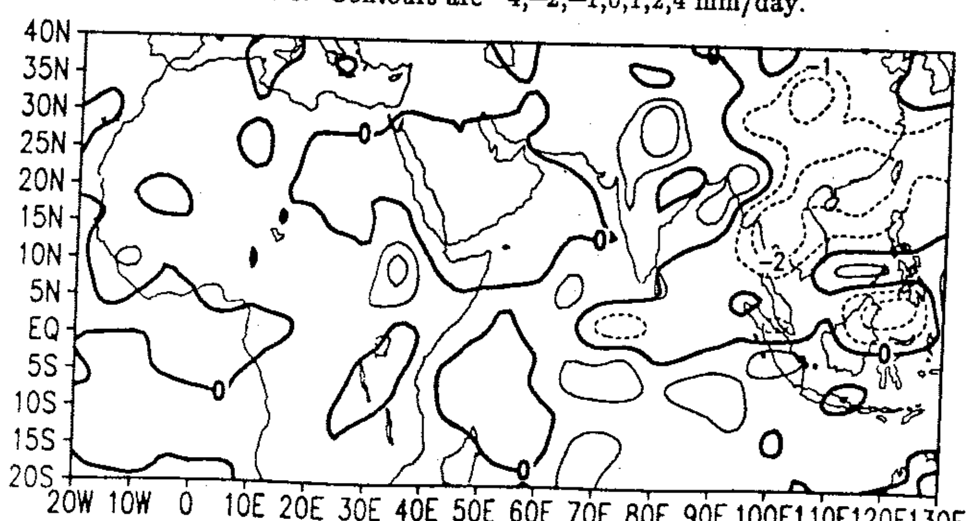


Fig. 4c. The JJA mean of the 1988 – 1987 difference in precipitation from climatological SST integration ensemble. Contours are –4,–2,–1,0,1,2,4 mm/day.

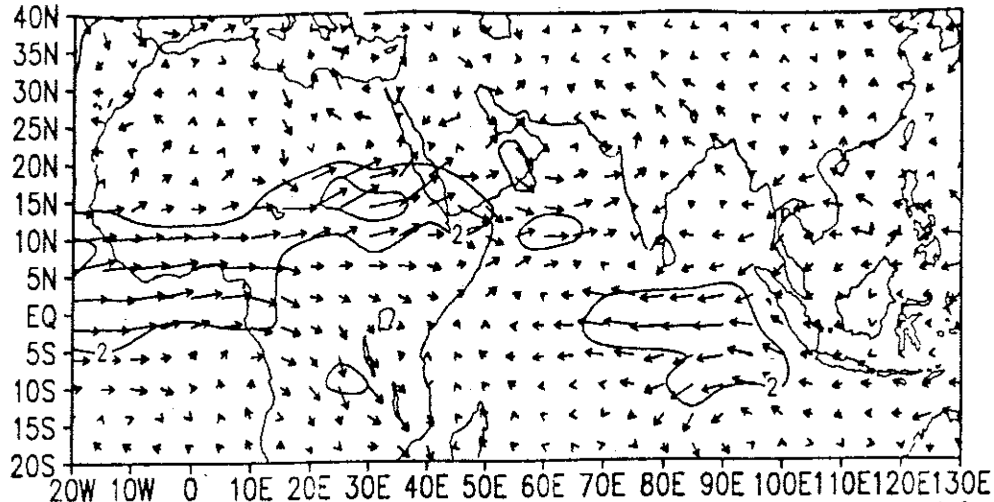


Fig. 5a. The JJA mean of the 1988 – 1987 difference in 850 mb vector wind from ECMWF analyses. Contour interval is 2 m/s.

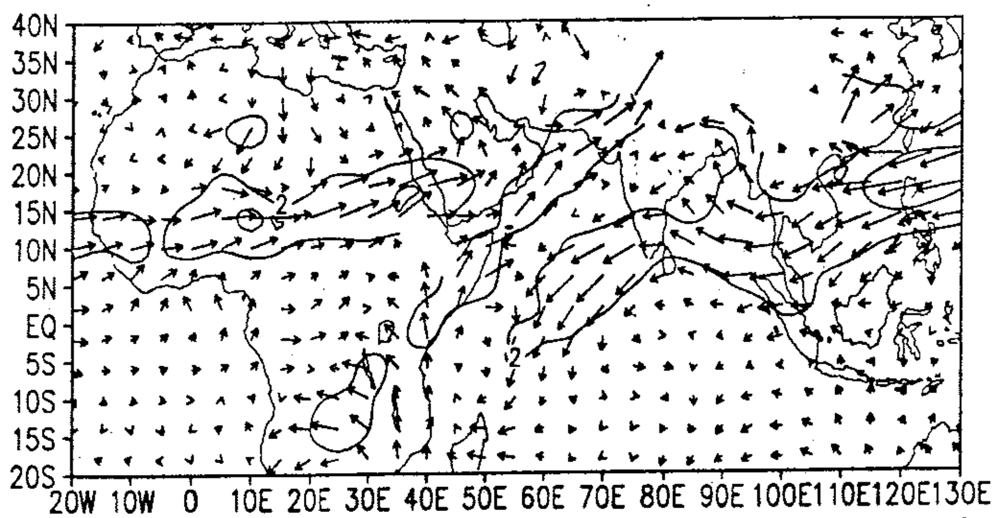


Fig. 5b. The JJA mean of the 1988 – 1987 difference in 850 mb vector wind from realistic SST integration ensemble. Contour interval is 2 m/s

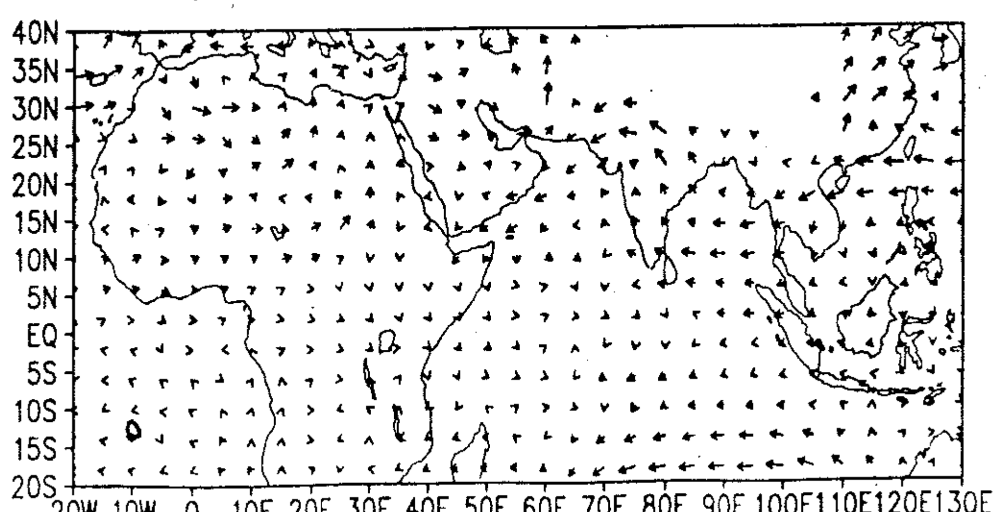


Fig. 5c. The JJA mean of the 1988 – 1987 difference in 850 mb vector wind from climatological SST integration ensemble. Contour interval is 2 m/s

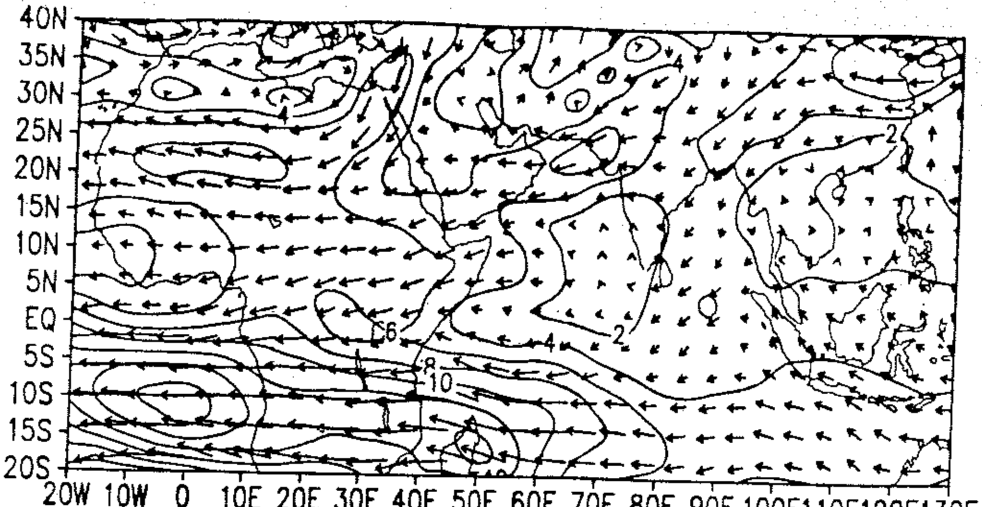


Fig. 6a. The JJA mean of the 1988 – 1987 difference in 200 mb vector wind from ECMWF analyses. Contour interval is 2 m/s.

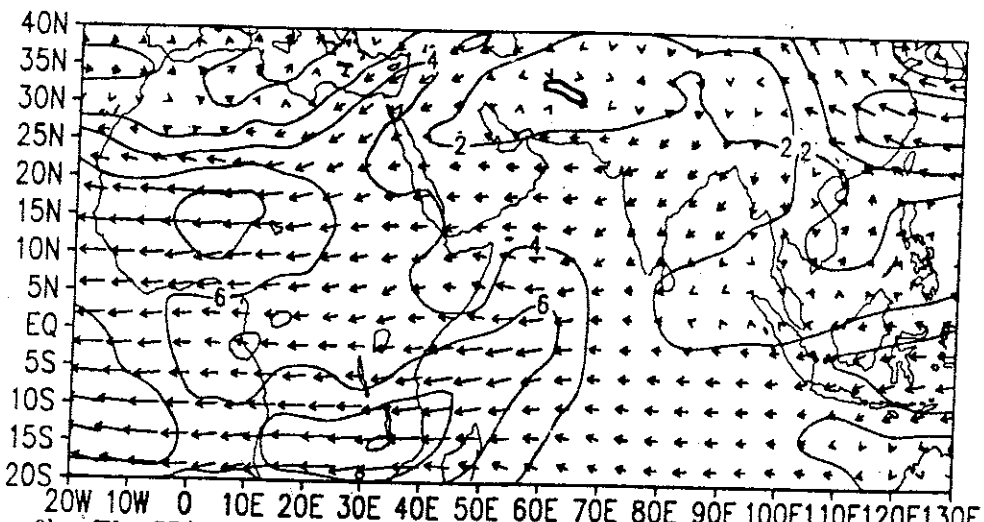


Fig. 6b. The JJA mean of the 1988 – 1987 difference in 200 mb vector wind from realistic SST integration ensemble. Contour interval is 2 m/s

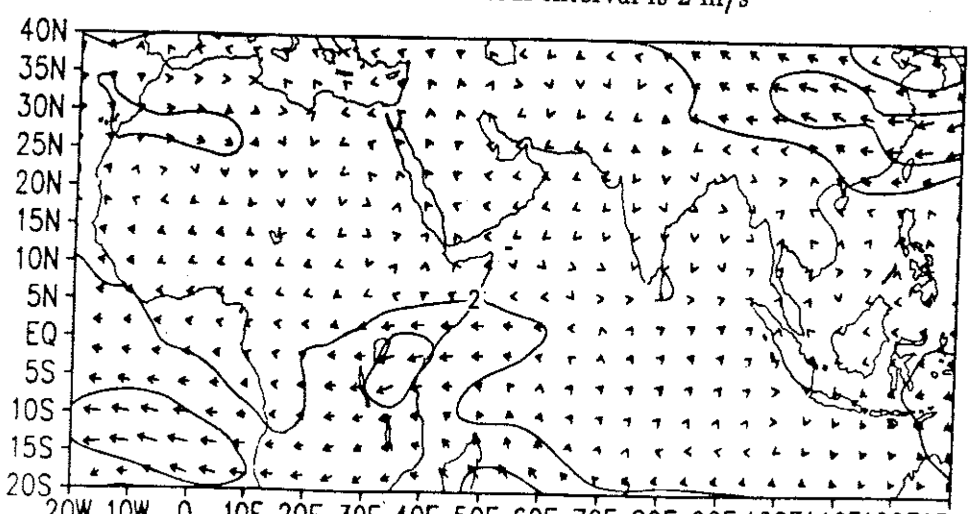


Fig. 6c. The JJA mean of the 1988 – 1987 difference in 200 mb vector wind from climatological SST integration ensemble. Contour interval is 2 m/s