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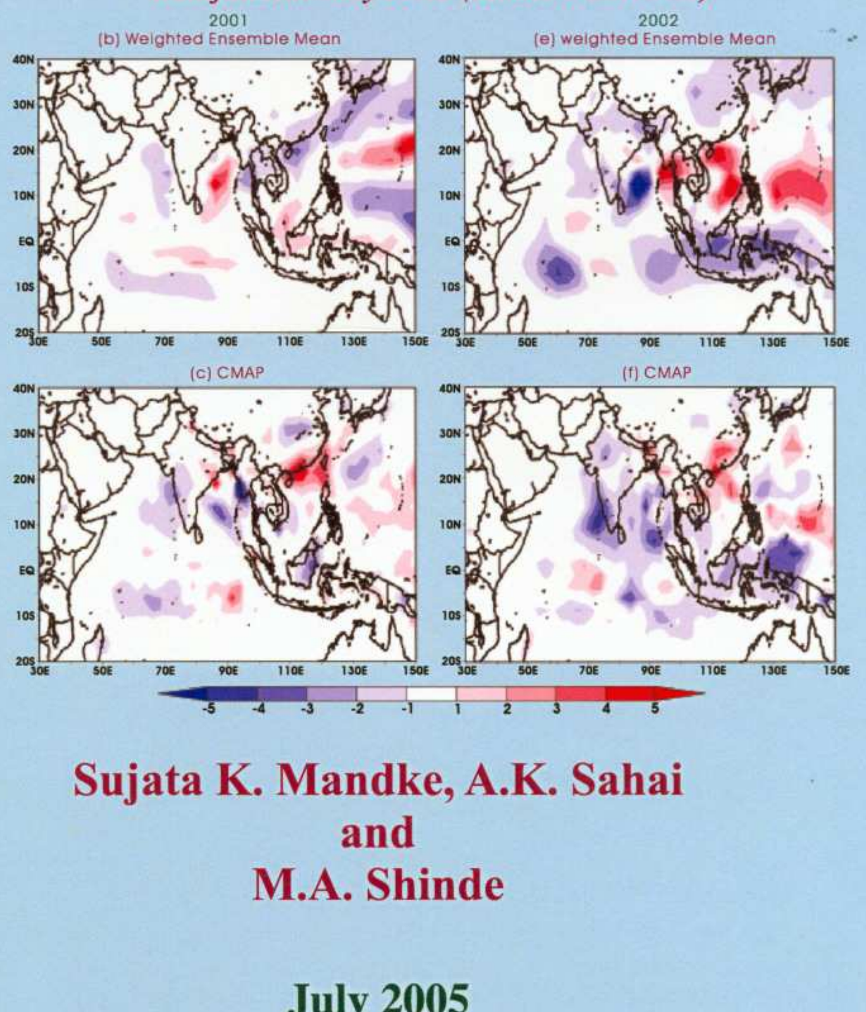
Rainfall Anomaly JJAS (Model-PUMvn4.5)



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CONTENTS

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Abstract

The first key topic of this study is the examination of experimental dynamical ensemble seasonal prediction of recent Indian summer monsoons. Twelve-member ensemble integrations for six-monsoon seasons (1999-2004) are made with Portable Unified Model (PUM) version 4.5 AGCM specified with May SST anomaly persistent as boundary forcing. The Indian summer monsoon precipitation simulation by models is sensitive to small changes in initial conditions causing large intraensemble spread. Thus the multiple realizations of the model are required. The second key topic is the examination of the use of weighted ensemble mean (WEM) method that gives more (less) weight to ensemble members for which the sum of the distance between daily anomalies from rest of the ensemble members is less (more). The WEM may capture the signal resulting from boundary forcing of SST by reducing the noise from unpredictable internal dynamics.

Comparison of percentage departure of precipitation averaged over two regions viz. Indian land region and a broader region between 65^0E-95^0E; 10^0N-30^0N, simulated by the model in twelve-member ensemble mean (EM) and WEM method has been made with corresponding CMAP observations. Spatial distribution of precipitation anomalies over 30^0E-150^0E; 20^0S-40^0N in EM and WEM have also been compared with corresponding CMAP anomalies for all six monsoons. Results have shown that the precipitation from WEM is closer to observations than EM and thus improves the prediction in majority of monsoons.

The percentage departure of precipitation over India in 2003 (2004) in majority of ensemble members is positive(negative) in spite of presence of La Nina in the month of May of both years, implying that the SST's of ocean basins other than Nino3, play a role in the interannual variability of these two monsoons.

1. INTRODUCTION

Monsoon varies on various time and space scales. Understanding the causes of variability eventually leading to prediction is one of the significant challenges for meteorologists. However the complexity of the phenomenon makes the monsoon prediction difficult. In recent years considerable efforts and interest in simulating and predicting the interannual fluctuations of climate is demonstrated by many international programs such as AMIP (Atmospheric model intercomparison program) (www.lmd.jussieu.fr/pcmdi-mirror/projects/amip) (Gates et.al. 1992), WCRP/CLIVAR AAMIP (Asian/Australian Monsoon intercomparison program) (http://climate.snu.ac.kr/clivar) (Kang et.al. 2002a, Kang et.al. 2002b, Waliser et.al. 2003) and PROVOST (Prediction Of climate Variations On Seasonal to interannual Time-scales) (QJRMS, July2000, part B). These programs aim to assess the skill of Atmospheric General Circulation Models (AGCMs) in simulating atmosphere and its variability. Despite differences in models, results have shown that the AGCMs have skill in simulating large-scale features in agreement with observations, leading to better understanding. However, AGCMs have difficulty in properly simulating the small scale features.

Seasonal mean fluctuations of the atmosphere are governed by the low frequency planetary scale flow patterns. The predictability of planetary scale flow is partly determined by "internal dynamics" and partly by "Slowly varying boundary forcing" (Shukla, 1984). Numerical simulation indicated that the seasonal mean fluctuations of the atmosphere and ocean in middle latitudes is directly associated with short-period flow instabilities or internal dynamics and nonlinearity. In contrast, large part of seasonal mean fluctuations in the tropics is due to slowly varying lower boundary forcing such as Sea Surface Temperature (SST), albedo, soil moisture, sea ice and snow cover at earth's surface. These forcings evolve on a slower time scale than that of weather; can impart significant predictability on atmospheric phenomena (Charney and Shukla, 1981). This leads to the conclusion that the seasonal mean fluctuations of atmosphere in tropics are potentially more predictable than that in the middle latitude. The prospect for atmospheric prediction on seasonal-time scales in tropics is based on this premise.

Attempts to stimulate climate prescribed with specified observed boundary forcing of SST have an extensive history (Shukla and Wallace, 1983, Lau, 1985, WCRP-1992, 1993, 1995, Brankovic et.al.1994, Dix and Hunt, 1995, Sperber and Palmer, 1996, Brankovic and Palmer, 1997, 2000, Rowell, 1998, Rowell, 2001, Folland et. al., 2001). SST is one of the particularly important slowly varying boundary forcing as it is coherent over large spatial scales. Studies indicated that climate in large parts of tropics is mainly governed by SST boundary forcing. However, simultaneously there is growing evidence provided by observational and modeling studies (Sugi et.al. 1997, Brankovic and Palmer, 1997, Goswami, 1998, Soman et.al.2001, Goswami and Ajaymohan, 2001) that there are regions within the tropics such as Indian monsoon region, where the contribution from internal dynamics is also important. The potential predictability of Indian summer monsoon precipitation is due to slowly varying sea surface temperature and is limited by internal chaotic dynamics.

The simulation of mean Asian Summer Monsoon (ASM) and its variability (Martin and Soman, 2000) by the Hadley centre model (version same as used in the present study) shows that the strength of the monsoon is rather overestimated and the onset of monsoon is early compared with observations. The interannual variability of the monsoon circulation is well represented by the model. The active/break cycles in the simulated monsoon are in good agreement with observations. This version of the model is used in the AMIPII. The model is also being used in series of coupled ocean/atmosphere climate simulations, HadCM3 (Gordon et.al. 2000), as well as for seasonal predictions.

2. Objective

The following objectives have been addressed in the report:

(1) Study of dynamical ensemble seasonal prediction estimates of recent six Indian summer monsoons (ISM) made with Portable Unified Model (PUM) version 4.5 specified with May SST anomaly persistent as boundary forcing.

(2) To test the performance of dynamical seasonal prediction estimates from weighted ensemble mean method versus conventional ensemble mean.

The various sections in the report are arranged as follows:-

The details concerning the model (PUM version 4.5) are given in section 3a and data sets used are described in section 3b. Design of model experiments is presented in section 4. Weighted ensemble mean method is discussed in section 5. Attention is focused on discussion of results in Section 6. Summary of the report is provided in section 7.

3a. Description of Portable Unified Model (PUM) version 4.5:

The Portable Unified Model version 4.5(PUMvn4.5) is obtained from Hadley Centre for Climate prediction and Research, U.K. The model along with user interface is installed on the Silicon Graphics ORIGIN-350 computer. The origin 350 is a 4-CPU machine with IRIX6.5 operating system.

PUMvn4.5 is a global atmospheric grid point model with horizontal resolution of 3.75^0 long. x 2.5^0 lat. This version of the model is the atmospheric component of the coupled ocean-atmosphere climate model HadCM3 (Gordon et. al. 2000). There are 19 levels in vertical in hybrid coordinate system. Basic formulation of the first unified forecast/climate model is described in Cullen (1993).

Model uses Conservative split-explicit integration scheme (Cullen and Davies, 1991). The parameterizations of convection (Gregory et.al.1997), radiation (Edwards and Slingo, 1996), boundary layer (Smith, 1993) but representation of non-local mixing of thermodynamic quantities are removed; land surface processes (MOSES- Met Office Surface Exchange Scheme) etc. are incorporated in the model. MOSES includes coupled soil hydrology and thermodynamics (four-layer model) and an interactive canopy resistance model (Cox et.al., 1999). The time step used in the model is 30-minutes. The details of the model are described in Pope et.al. 2000.

3b. Data sets used

The boundary forcing of SST and sea-ice used for integrations of 1999-2004 is monthly mean Optimum Interpolated SST (OISST) data downloaded from NCEP website (ftp.ncep.noaa.gov). OISST is available over whole globe on 1^{0} long x 1^{0} lat. resolutions. Reynolds et.al. (2002) describes the details of OISST (version v2) analysis.

We have used global grid point monthly mean precipitation analysis based mainly on observation from CMAP (Climate Diagnostic Centre (CDC) Merged Analysis of Precipitation) for validating model precipitation forecast. The CMAP precipitation data is downloaded from www.cdc.noaa.gov. This is described in Xie and Arkin (1997). (Hereafter referred to as CMAP).

4. Design of model experiments

The model integrations for six recent monsoon seasons from 1999-2004 have been made in ensemble mode. An experimental set consists of twelve-member ensemble integrations for each of the six monsoon seasons.

The length of integrations for all ensemble members is 183-days from 1st April-30th September. Difference between twelve-members of ensemble runs for a monsoon season is only in initial condition but uses same SST. The observed monthly SST is used as boundary forcing till May, thereafter May SST anomaly is persisted on climatology of rest of the months. The details of the model experiments are shown in table-1.

In absence of availability of SST for the summer monsoon season from June-September in advance, persistence of May SST anomaly on the rest of the season's climatological SST is used as boundary forcing. The use of persisted SST anomalies in the dynamical seasonal prediction of Indian summer monsoon has been reported by other authors (Harrison et.al.1997, Mandke et.al.2000, Soman et.al. 2000, Graham et.al.2000, Mujumdar et.al. 2003). Tests carried by Graham et.al. (2000) indicate that a substantial proportion of the skill achieved using observed SSTs is retained using persisted SST anomalies from the month preceding the initial date of the integration, indicating that the use of persisted SSTA is a viable method for real-time seasonal prediction, at least up to one season ahead. The performance of the recent six monsoons is evaluated with respect to the model climatology.

Indian Summer Monsoon Rainfall (ISMR) was on the negative side of long period Average (LPA) for five out of six years ,1999 (-4.5%), 2000 (-8%), 2001 (-8%), 2002 (-19%) and 2004 (-13.0%). ISMR of 2003 is normal (+2%) (IMD, reports).

The time required for one day integration of this model on the origin-350 machine is 6 minutes. Thus the total time required for 12-member ensemble integrations from April- September of 1999-2004 is 1317hours (~ 55days).

5. Weighted ensemble mean method

The Indian summer monsoon precipitation exhibits chaotic behavior associated with nonlinear atmospheric dynamics resulting in ensemble dispersion or spread (Palmer 1994, Sperber and Palmer, 1996, Sugi et.al., 1997, Brankovic and Palmer, 2000). Thus there is requirement of multiple ensemble integrations. For the same reason, the ensemble mean considered in conventional seasonal prediction methods average precipitation from entirely different individual ensemble members. The problem with ensemble mean is intense particularly when anomalies are large and of opposite sign as is the case with Indian summer monsoon precipitation.

The large spread of ISM precipitation among twelve members of ensemble has also been noticed in six monsoon seasons in the present study. This point is illustrated in figure 1 showing normalized ensemble spread for six monsoons. Spread of ensemble members (σ_n^2) for a monsoon season is calculated as sum of the squares of the difference between summer monsoon precipitation averaged over India for each of the 12-member ensemble and the corresponding 12-member ensemble mean (EM).

$$\sigma_n^2 = \frac{1}{N}\sum_{j=1}^{N}(p_{ji} - p_{EMi})^2$$

Where j = 1, 2, 3.....12 are ensemble members
N = 12
p_{EMi} is average of precipitation over 12-ensemble members for year i.
p_{ji} is precipitation for j[th] ensemble member for year i.

The ensemble spread is normalized by model's (climatological) seasonal variance (σ_c^2). Model's climatological seasonal variance is calculated as variance of all ensemble members for all years.

$$\sigma_c^2 = \frac{1}{N.K}\sum_{i=1}^{K}\sum_{j=1}^{N} p_{ji}^{'2}$$

N = 12 ensemble members, K=6 years
Where p'_{ji} anomalies are defined as

$$p'_{ji} = p_{ji} - \overline{p}$$

Where p_{ji} is precipitation from j[th] ensemble member and i[th] year and

$\overline{p}$ is average of precipitation over all ensemble members and all years. Normalized spread shown in figure 1 is calculated as ratio

$R = \sigma_n / \sigma_c$

Above variances and ratio R are similar to that defined by Stern and Miyakoda (1995). The ratio R is also referred as reproducibility. Smaller values of R indicate less spread among members of ensemble and thus larger reproducibility. It is seen that the ensemble spread varies among six monsoon seasons with minimum (maximum) in monsoon 2000 (2003).

To reduce the problem of spread among the ensemble members, method is devised in which different weights are given to members depending on the inverse distance among daily anomalies of members. The daily anomaly for any parameter say 'x' at a grid point is calculated for all twelve members from model climatology and the distance between anomalies of all twelve members is calculated as follows

$$\text{Dist (j)} = \sum_{\substack{i=1 \\ i \neq j}}^{i=12} (x_i - x_j)^2 \qquad \text{where } j = 1, 2, 3 \ldots\ldots 12 \tag{1}$$

Where x_i and x_j are anomalies of i^{th} and j^{th} ensemble member respectively. x can be any model parameter, for example precipitation.
Weights are assigned to different members as follows

$$\text{Wt (j)} = \frac{\left(1/dist(j)\right)}{\sum_{i=1}^{i=12} (1/dist(i))} \tag{2}$$

Where Wt (j) is the weight for j^{th} ensemble member. Weights are calculated for all 12-member ensembles from equation (2) at all model grid points and for 122-days during summer monsoon season. Based on these weights, the twelve-member mean anomaly is calculated (hereafter referred as weighted ensemble mean).

The schematic of weighted ensemble mean (WEM) method is shown in figure 2. The schematic shows variation of anomaly from EM and WEM for 12 idealized cases. EM and WEM are same when the anomaly is of same sign (either positive or negative) in all 12-members of ensemble (first and last point). Similarly when anomaly is of opposite sign in equal number of ensemble members then again the EM and WEM are same (midpoint in the figure 2). In between these cases, EM and WEM varies as shown (figure 2) such that WEM is toward majority of ensemble members while EM is just the average of anomaly of all ensemble members.

The daily precipitation anomaly simulated by the model for June-September 2002 at 79°E; 23°N calculated from both 12-member ensemble mean and weighted ensemble mean is shown in figure 3b as an example. For the same grid point, the daily variation of maximum and minimum precipitation anomaly is shown in figure 3a. For each day, maximum anomaly among all 12-members of ensemble is considered as maximum for that day and similarly minimum anomaly is calculated. Thus the maximum and minimum anomaly shown in figure 3a corresponds to the different members of ensemble for different days. The difference between ensemble mean and weighted ensemble mean precipitation anomaly varies daily at the grid point shown depending on the distance between anomalies of various ensemble members for that particular day and for that grid point.

6. Results

The comparison of May SST anomalies with that of average summer monsoon season SST anomalies is shown in figure 4(a-d) for 1999-2000 respectively. Similar SST anomalies for 2001-2002 and 2003-2004 are shown in figures 5(a-d) and 6(a-d) respectively. The assumption that May SST anomalies persist throughout the summer monsoon season is reasonable as the difference between May and season average SST anomalies is small. However it is clearly seen from figure 6a and 6c that La Nina developed in May 2003 and 2004 that reduced to a large extent in its magnitude and extent subsequently during the summer monsoon season (fig.6 b and 6d). The differences between May and season average SST anomalies are small over global oceans except for East Pacific ocean in 2003 & 2004.

The model daily precipitation climatology and estimates of ensemble dynamical seasonal prediction of precipitation over Indian land region from six recent monsoon season experiments with May SST persistence as boundary forcing are discussed in section 6.1. The comparison of model simulated precipitation anomalies with corresponding observations is made. The spatial distribution of precipitation anomalies in EM and WEM over broader region from 30°E - 150°E; 20°S - 40°N are discussed in section 6.2.

6.1 Model climatology and precipitation forecast over Indian region

The daily precipitation anomalies at each grid point are used to calculate weights in WEM discussed in section 5. The daily model precipitation climatology at each grid point is used for calculation of daily anomalies. As it is not feasible to show model climatology at each grid point, variation of precipitation rate (mm/day) climatology averaged over Indian land region for the period 1June-30September calculated as 5-day moving average for smoothing is shown in figure 7. The model precipitation climatology from June-September is simulated reasonably well. The precipitation increases steadily from 1June till mid-July. Thereafter it decreases but not as smoothly as observed ISMR climatology possibly because model climatology is based on limited monsoon seasons and also due to the systematic errors of the model.

The percentage departure of summer monsoon precipitation averaged over Indian land region for ensemble integrations of model for six monsoons are shown in Table - 2. Though spread among twelve-members for six monsoons considered for the present study is large, the sign of percentage departure is same in majority of members. In 2003 and 2001, majority of ensemble members (10-11) shows percentage departure of ISM precipitation on the positive side of normal. In contrast, for monsoon seasons of 1999, 2002 and 2004, percentage departure of ISM precipitation in majority of ensemble members (8-11) is below normal. The percentage departure is below normal in all 12-members of 2000 (normalized spread is minimum in 2000 as shown in figure 1). This result suggests that the role of SST boundary forcing in the interannual variability of the monsoons considered in the present study is significant compared to internal dynamics. The corresponding observations from CMAP are given for comparison at the bottom. The WEM is in better agreement with observations than EM except for monsoon 2000. The presence of La Nina is clearly seen from figure 6a and 6c in the month of May 2003 and 2004. However the model simulated above normal precipitation in 2003 in all ensemble members (except 1) and below normal precipitation in majority of ensemble members (except 3) of 2004 suggesting that SST over oceans other than Nino3, might have influenced the monsoons of 2003 and 2004.

The percentage departure of summer monsoon precipitation averaged over region 65^{o}-95^{o}E, 10^{o}-30^{o}N for ensemble integrations of model (EM and WEM) and CMAP observations for six monsoons are shown in Table-3. Percentage departure with WEM is closer to observations than EM in 2001-2003.

The validation of model precipitation forecast with corresponding CMAP observations in EM and WEM is represented as bar diagram in figure 8. Figure 8a shows percentage departure of summer monsoon precipitation over India and figure 8b over 65^{0}-95^{0}E, 10^{0}-30^{0}N. The observed value for 2004 shown in figure 8a is from IMD reports. Figure 8a suggests that there is better agreement of WEM with observations than EM over Indian region in majority of monsoons.

6.2 Precipitation over Asian region

We now describe the spatial distribution of summer monsoon precipitation anomalies over region spanning 30^{0}E-150^{0}E; 20^{0}S-40^{0}N. The spatial distribution of 12-member ensemble mean precipitation anomaly for 1999 is shown in figure 9a. Spatial distribution provide further insight in the geographical variation. The precipitation anomaly from WEM for monsoon 1999 is shown in figure 9b and the corresponding observed (CMAP) anomaly is shown in bottom panel in figure 9c. Precipitation anomalies of monsoon 2000 in EM, WEM and CMAP are shown in figure 9d, 9e and 9f respectively. Similarly precipitation anomalies for summer monsoons of 2001 and 2002 are shown in figures 10(a-f) respectively. Figure 11(a-f) respectively shows precipitation anomalies with EM, WEM and CMAP of monsoon 2003 and 2004.

Observations show negative anomalies over Indian peninsula and North India in 1999. The observed precipitation anomalies are positive over central and east India. Neighboring oceans of Arabian Sea and Bay of Bengal (BB) are also characterized by weak negative anomalies. Model EM precipitation anomalies are small positive over North India and strong negative over Bay of Bengal, relatively weaker negative over peninsular India and Arabian Sea. WEM reduces the extent of positive anomalies over North India, restricting it over Eastern part of North India. However positive anomalies in WEM over Northeast India are weaker and spread over larger region than observations. Model underestimates precipitation over BB. Over Equatorial central Indian Ocean positive anomalies are noticed in EM, WEM and observations. However, there are minor differences in location and strength of these anomalies simulated by the model and observations.

Model EM simulates strong positive anomalies during summer monsoon 2000 over Northeast India and Equatorial Indian Ocean and weak positive anomalies over extreme North India. Peninsular India, Arabian Sea and BB are marked by very strong negative anomalies (stronger than in 1999). The main features of observed anomalies of 2000 are weak positive anomalies over Northeast India and part of East coast. Central Equatorial Indian ocean precipitation anomaly is weak positive with near normal anomalies over rest of the Indian Ocean. WEM reduces extent of positive anomalies over extreme north India and increases the extent of negative anomalies over BB. The positive anomalies over East peninsula have not been correctly simulated by the model even in WEM. BB anomalies are strongly underestimated in 2000 alike 1999.

The observed precipitation anomalies for 2001 monsoon are weak negative over peninsular and part of central India and positive over North and Northeast India. Stronger negative anomalies of the order of -2mm/day are noticed off the West coast of India and BB. Model EM simulated precipitation anomalies are small positive throughout Indian land region. The strong positive anomalies are located over BB. WEM Precipitation anomalies for 2001 monsoon are near normal over peninsula India and negative over Arabian Sea. Thus the WEM method indicates improvement in precipitation compared to EM over Indian land region and Arabian Sea except off the West coast of India. The model simulated above normal precipitation over BB contrasting to observations (below normal) that is unaltered in WEM method.

The summer monsoon 2002 attracted the attention of meteorologist due to long break conditions during July, resulting in ISMR much below normal (-19%). An observation (fig. 10f) revealed negative anomalies throughout Indian land region, neighboring oceans except extreme Eastern India. Model precipitation anomalies resemble observations over majority of Indian region (most of the peninsula, neighboring oceans) except small part over Northeast peninsula, part of West coast and Eastern India. WEM reduces positive anomalies and strengthens negative anomalies over peninsular India and neighboring oceans resulting in much closer agreement with observations than EM.

The precipitation anomalies during monsoon 2003 simulated by the model in both EM and WEM are similar over majority of regions except over Bay of Bengal and small portion over Northeast India. Observed anomalies indicate below normal precipitation over peninsula and above normal over rest of the Indian region. Thus little improvement in precipitation simulation during 2003 is noticed in WEM method. Model failed to simulate below normal precipitation anomalies over peninsular India.

The precipitation anomalies are near normal over majority of Indian land region in 2004 in EM and WEM except peninsula. The precipitation anomalies over equatorial Indian Ocean simulated by model resembles observations. Observed positive anomalies over parts of Northeast India are simulated by model. However, observed positive anomalies over extreme East India are not simulated by model in both EM and WEM. WEM strengthen and extends spatially negative anomalies over Peninsular India and reduces positive anomalies over North India.

7. Summary

An assessment of experimental dynamical seasonal prediction of recent Indian summer monsoons of 1999-2004 with May SST anomaly persisting on climatology of June-September has been carried out. Comparison of percentage departure of summer monsoon precipitation forecast by model over Indian region and larger region (65°E-95°E; 10°N-30°N) with corresponding observations for six monsoons suggests improvement with WEM compared to EM in majority of monsoons. Spatial distribution of precipitation anomalies simulated by model and their comparison with CMAP observations shows that BB is characterized by negative anomalies in all six monsoon seasons. WEM improves the simulation of precipitation over BB in all monsoons except in 1999 which still show strong positive anomalies in WEM though magnitude and extent reduces than EM.

Investigation of the model simulation of monsoon prescribed with observed SST for complete summer monsoon season compared to May SST persistence is required to conclude about the performance of May SST persistence method. Integrations with observed SST also will be carried out for all monsoon seasons. Results presented in the report are based on only six monsoon season integrations which is limited, so the integrations with may SST persistence for more number of monsoon seasons are being carried out.

It is likely that WEM may show even better improvement in precipitation forecast of multiple-model ensembles comprising of combination of ensemble members with different AGCMs.

SST anomalies of May 2003 and 2004 indicate presence of La Nina. The experiments carried out in the present study uses May SST persistence for a season; model sees La Nina conditions throughout the summer monsoon season. In spite of similar SST conditions in the East Pacific, the monsoon of 2003 (2004) is above (below) normal in majority of ensemble members. This result indicates that SST in regions other than Nino3 might have influenced the interannual variability of these two monsoons.

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Table 1 : Experimental design

Year	No. of ensemble members	Initial condition	Boundary forcing of SST
1999	12	Model states corresponding to 1st April of different years from long control integration of the model.	May 1999 SST anomaly persisting on the climatology of June-September
2000	"	"	May 2000 SST anomaly persisting on the climatology of June-September
2001	"	"	May 2001 SST anomaly persisting on the climatology of June-September
2002	"	"	May 2002 SST anomaly persisting on the climatology of June-September
2003	"	"	May 2003 SST anomaly persisting on the climatology of June-September
2004	"	"	May 2004 SST anomaly persisting on the climatology of June-September

Table 2 : % departure of JJAS precipitation over Indian Region

Member	1999	2000	2001	2002	2003	2004
1	-7.94	-8.83	0.39	-13.31	2.05	-9.67
2	-2.06	-12.48	9.92	-6.80	17.28	10.52
3	-11.53	-2.26	6.49	-12.55	11.73	5.55
4	1.58	-17.57	10.51	-13.85	-2.89	1.11
5	6.88	-16.16	-3.50	-3.86	9.76	-4.87
6	2.96	-8.34	10.14	-1.33	20.41	-1.33
7	-2.86	-12.83	8.76	-11.37	11.65	-9.39
8	-1.59	-6.61	10.16	4.87	4.78	-14.31
9	-11.82	-5.75	5.96	-8.55	23.61	-2.54
10	-1.52	-4.85	0.09	-0.87	13.29	-5.45
11	-6.57	-12.37	0.35	3.63	16.18	-5.45
12	0.23	-8.19	-0.69	-5.15	10.55	-1.79
EM	-2.85	-9.69	4.88	-5.76	11.56	-3.13
WEM	-9.10	-15.09	-0.58	-11.90	5.65	-8.79
Observed (CMAP)	-6.41	-7.09	-0.92	-14.03	4.40	-13.0 (IMD)

Table 3 : % departure of JJAS precipitation over Region (65-95°E, 10-30°N)

Member	1999	2000	2001	2002	2003	2004
1	-16.95	-24.17	5.78	-14.58	-4.29	-10.17
2	-9.27	-21.85	9.38	-5.76	17.67	7.69
3	-16.25	-13.76	9.84	-12.10	10.54	2.32
4	-11.34	-31.78	13.86	-13.59	-6.40	-8.04
5	-3.01	-29.45	-0.77	0.94	6.70	-2.39
6	-1.93	-22.37	2.58	-0.76	14.21	-4.84
7	-16.34	-19.58	9.28	-13.54	8.44	-3.42
8	-9.99	-20.65	8.96	2.94	0.88	-14.23
9	-23.18	-18.65	3.32	-6.45	14.67	-5.10
10	-6.96	-15.39	0.34	-3.37	3.56	-11.18
11	-10.89	-22.62	2.99	6.54	13.38	-11.18
12	-8.74	-23.60	-2.63	-4.02	13.82	-3.21
EM	-11.24	-21.99	5.24	-5.31	7.76	-5.31
WEM	-17.27	-27.06	-0.72	-11.50	1.61	-11.70
Observed (CMAP)	-5.32	-7.33	-3.43	-14.95	3.44	0.11

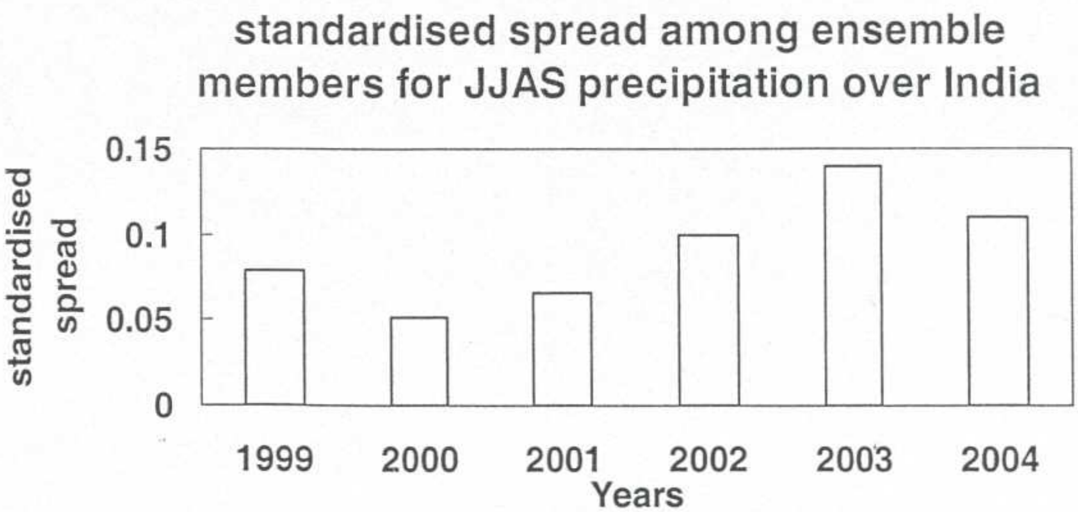


Fig: 1

Schematic representation of weighted ensemble mean

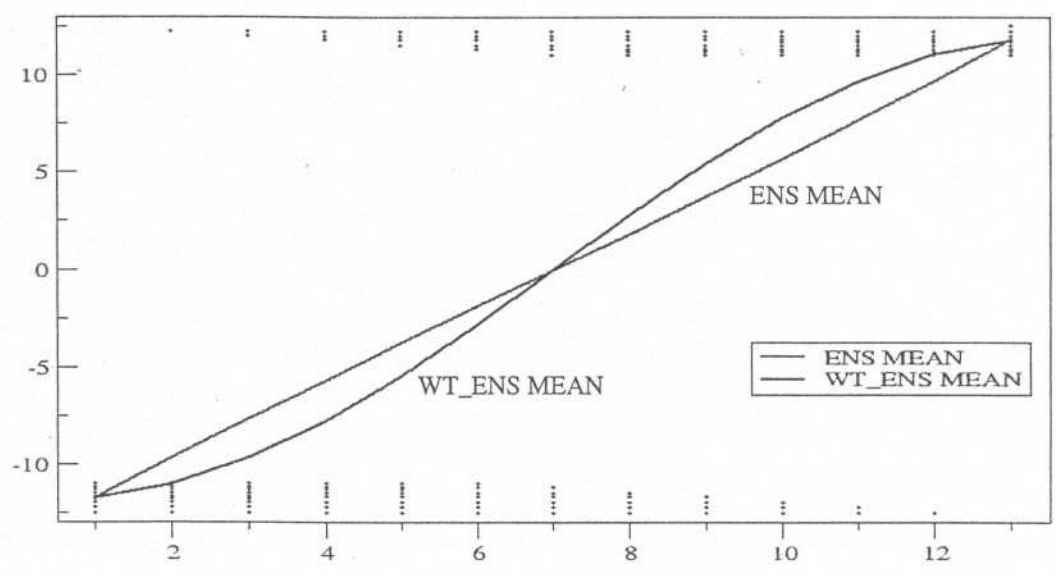


Fig: 2

Standardised daily precipitation anomaly at 79°E 23°N for 2002

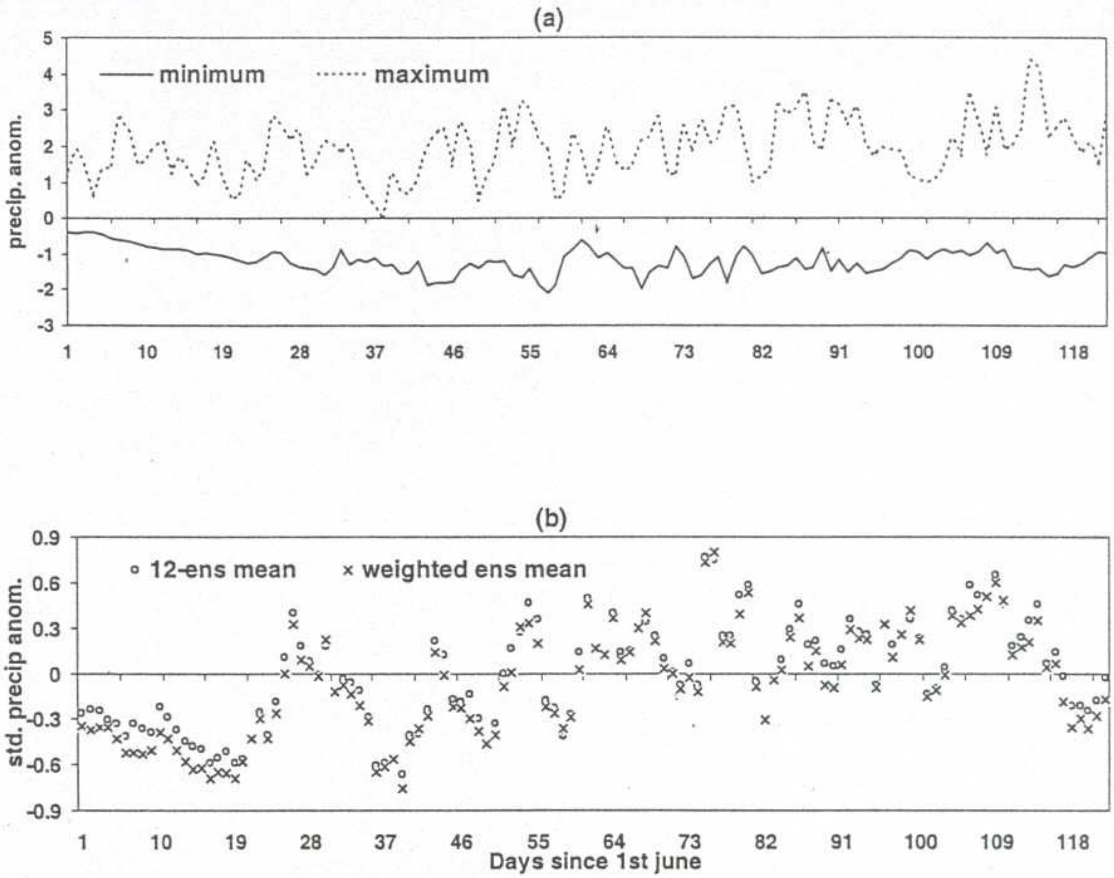


Fig: 3

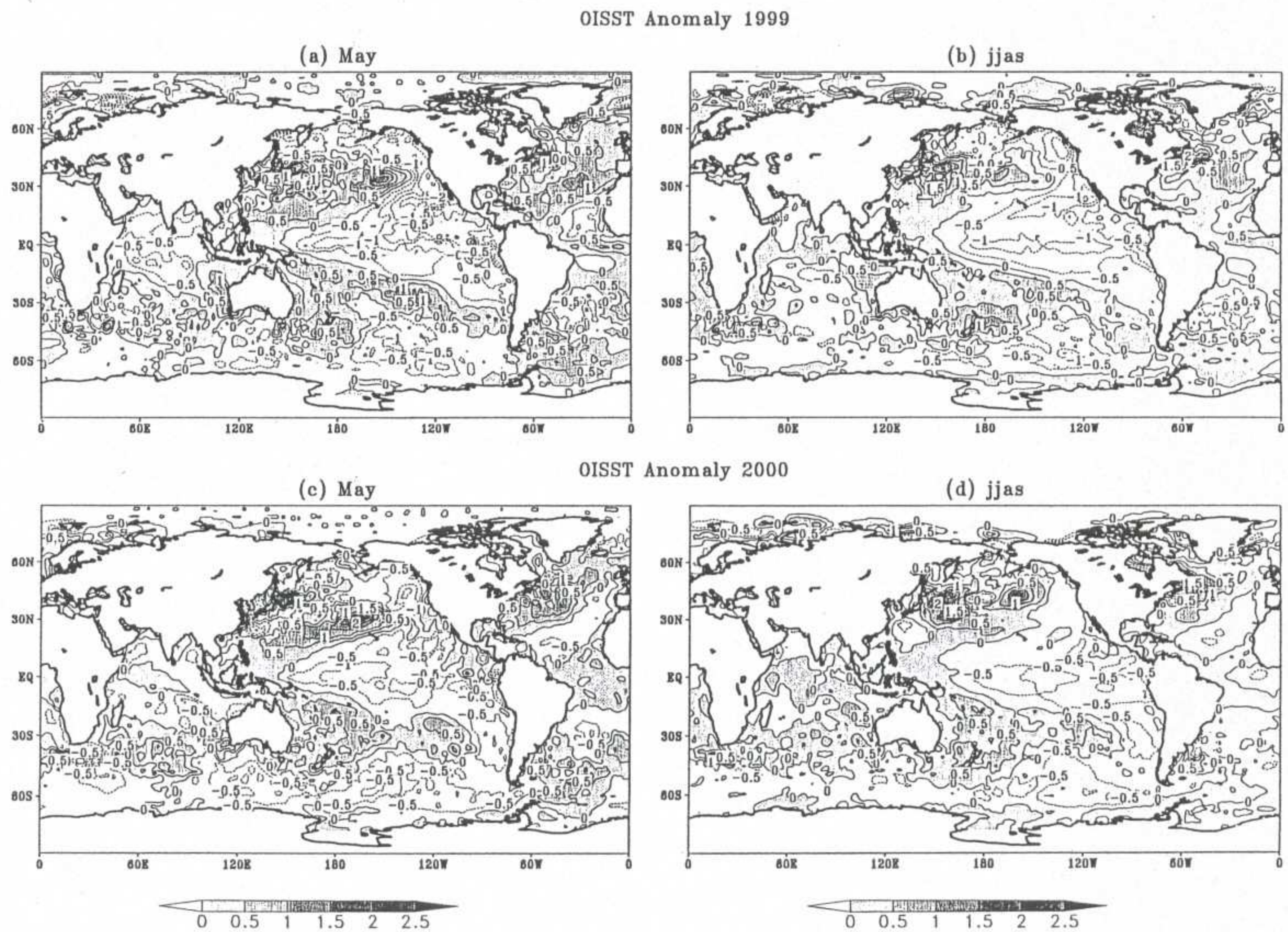

OISST Anomaly 1999
(a) May
(b) jjas
OISST Anomaly 2000
(c) May
(d) jjas
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
0 0.5 1 1.5 2 2.5

Fig: 4

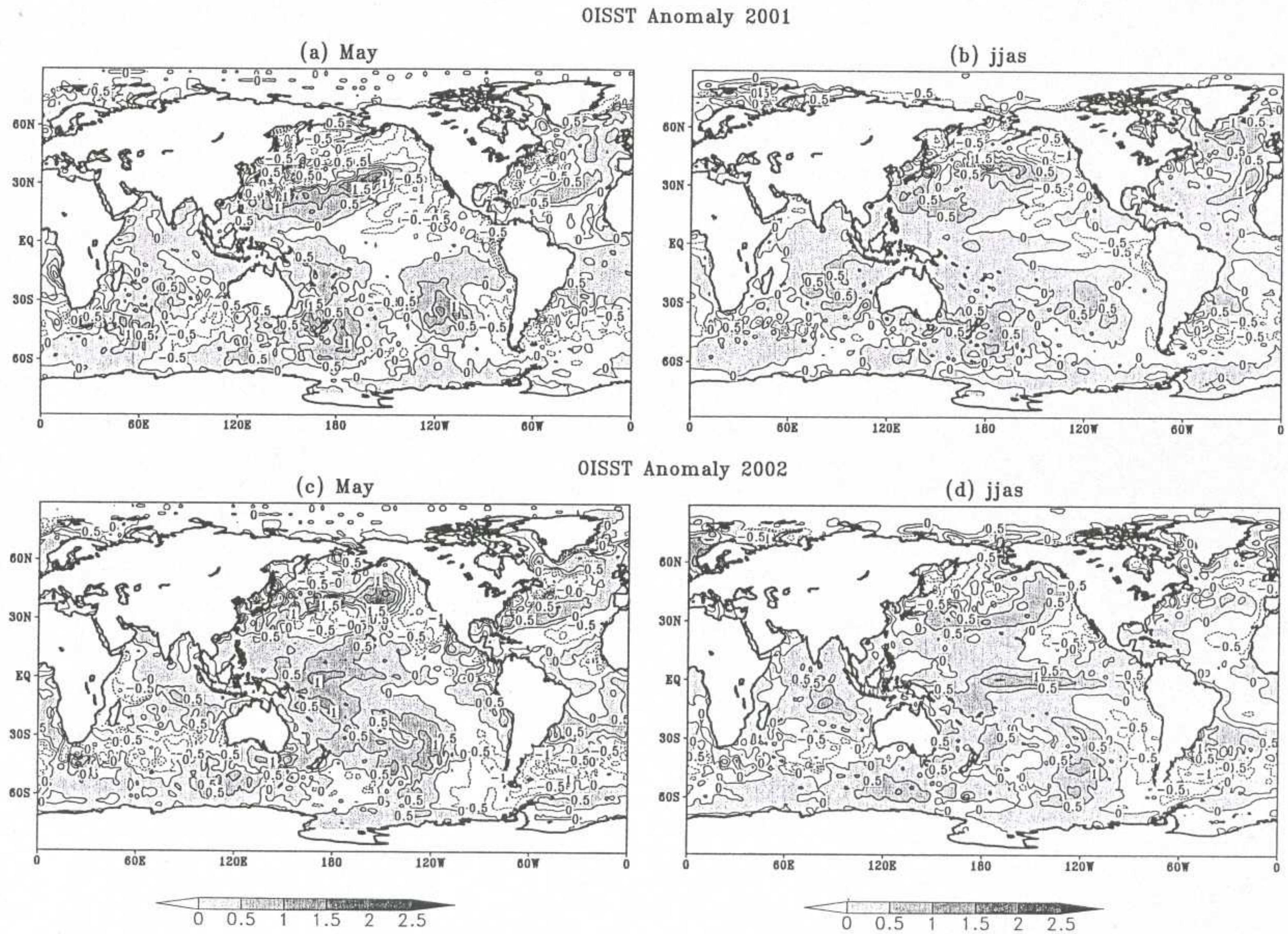

OISST Anomaly 2001
(a) May
(b) jjas
OISST Anomaly 2002
(c) May
(d) jjas
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0 0.5 1 1.5 2 2.5

Fig: 5

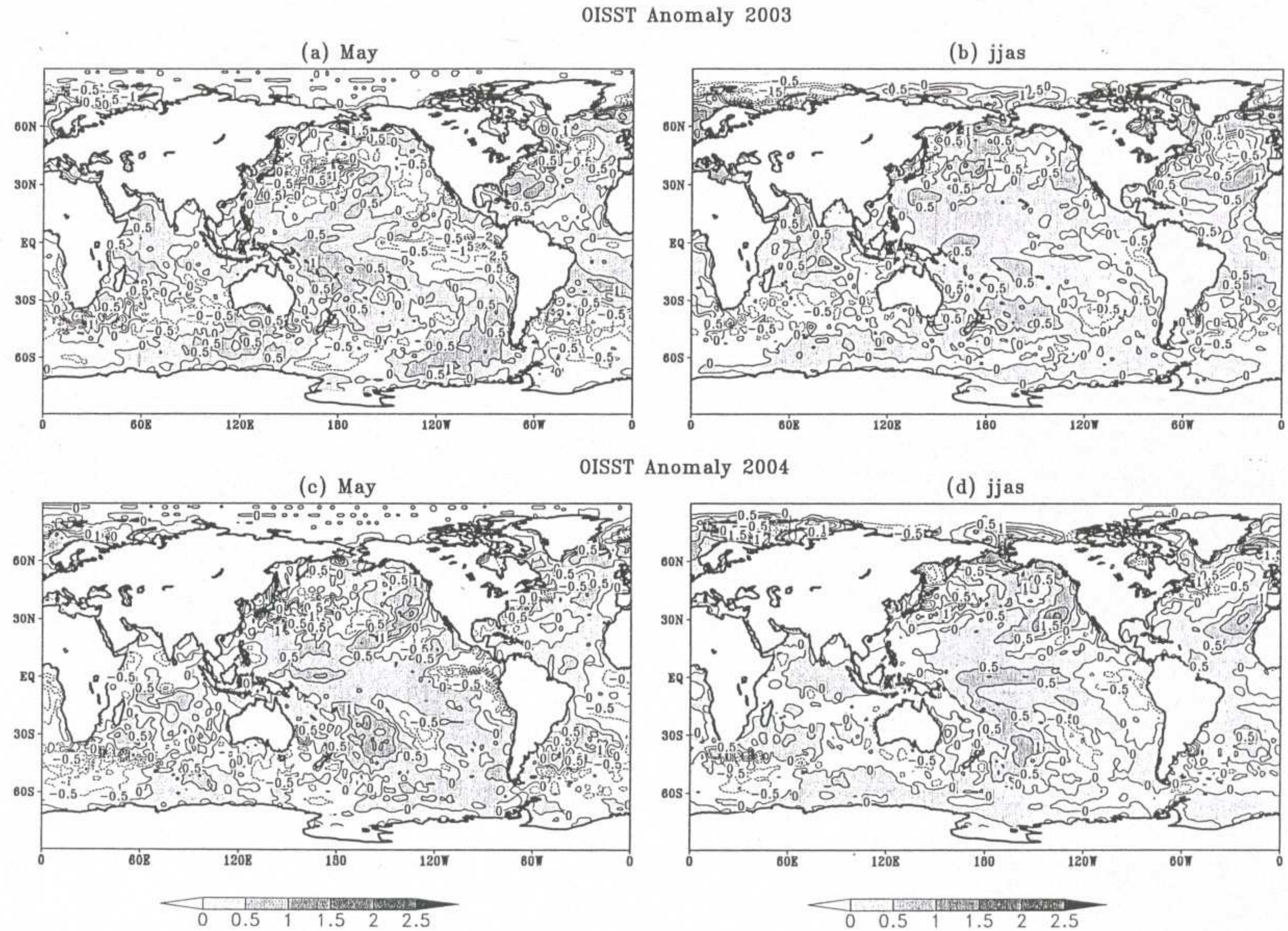
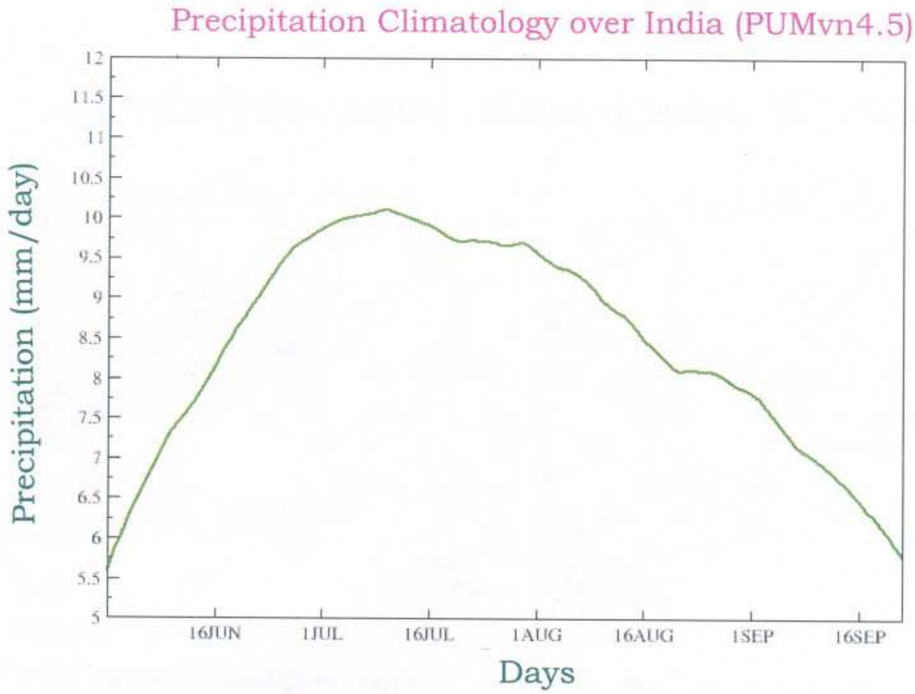
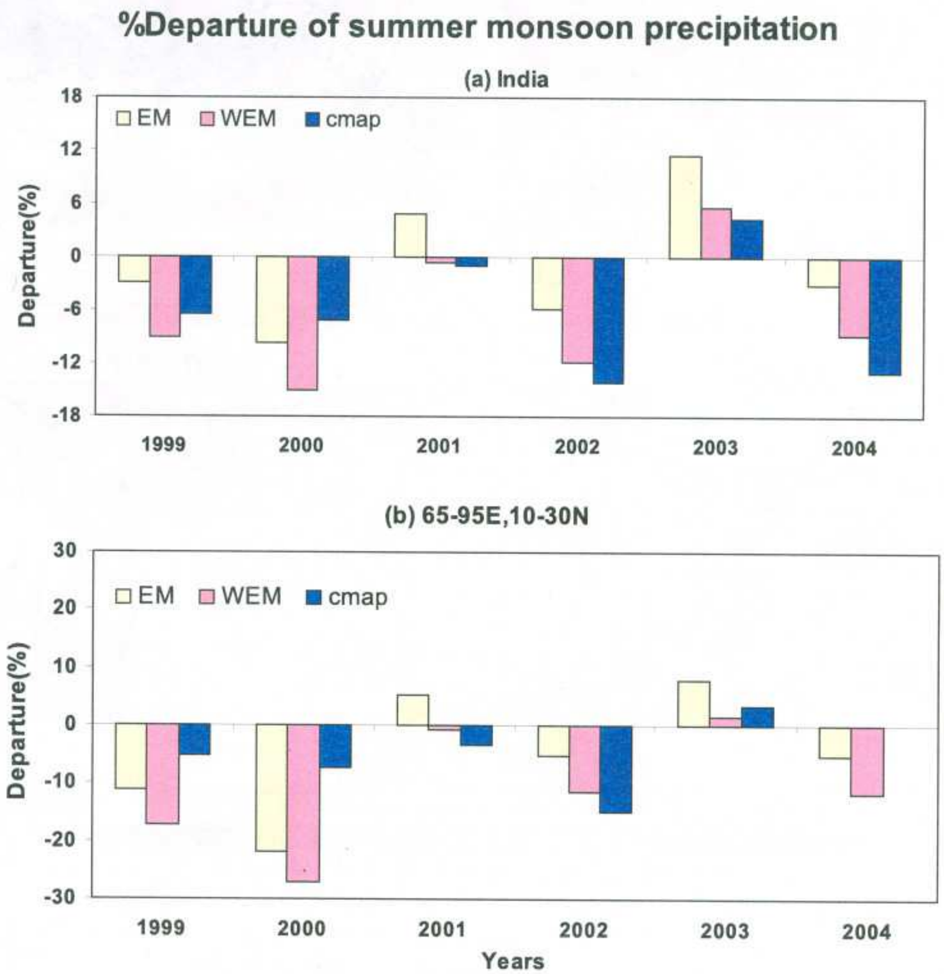

OISST Anomaly 2003
(a) May
(b) jjas
OISST Anomaly 2004
(c) May
(d) jjas
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
0 0.5 1 1.5 2 2.5

Fig: 6



Precipitation Climatology over India (PUMvn4.5)
Precipitation (mm/day)
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
16JUN
1JUL
16JUL
1AUG
16AUG
1SEP
16SEP
Days

Fig : 7



%Departure of summer monsoon precipitation
(a) India
EM
WEM
cmap
Departure(%)
18
12
6
0
-6
-12
-18
1999
2000
2001
2002
2003
2004
(b) 65-95E,10-30N
30
20
10
0
-10
-20
-30
Years

Fig : 8

Rainfall Anomaly JJAS (Model-PUMvn4.5)

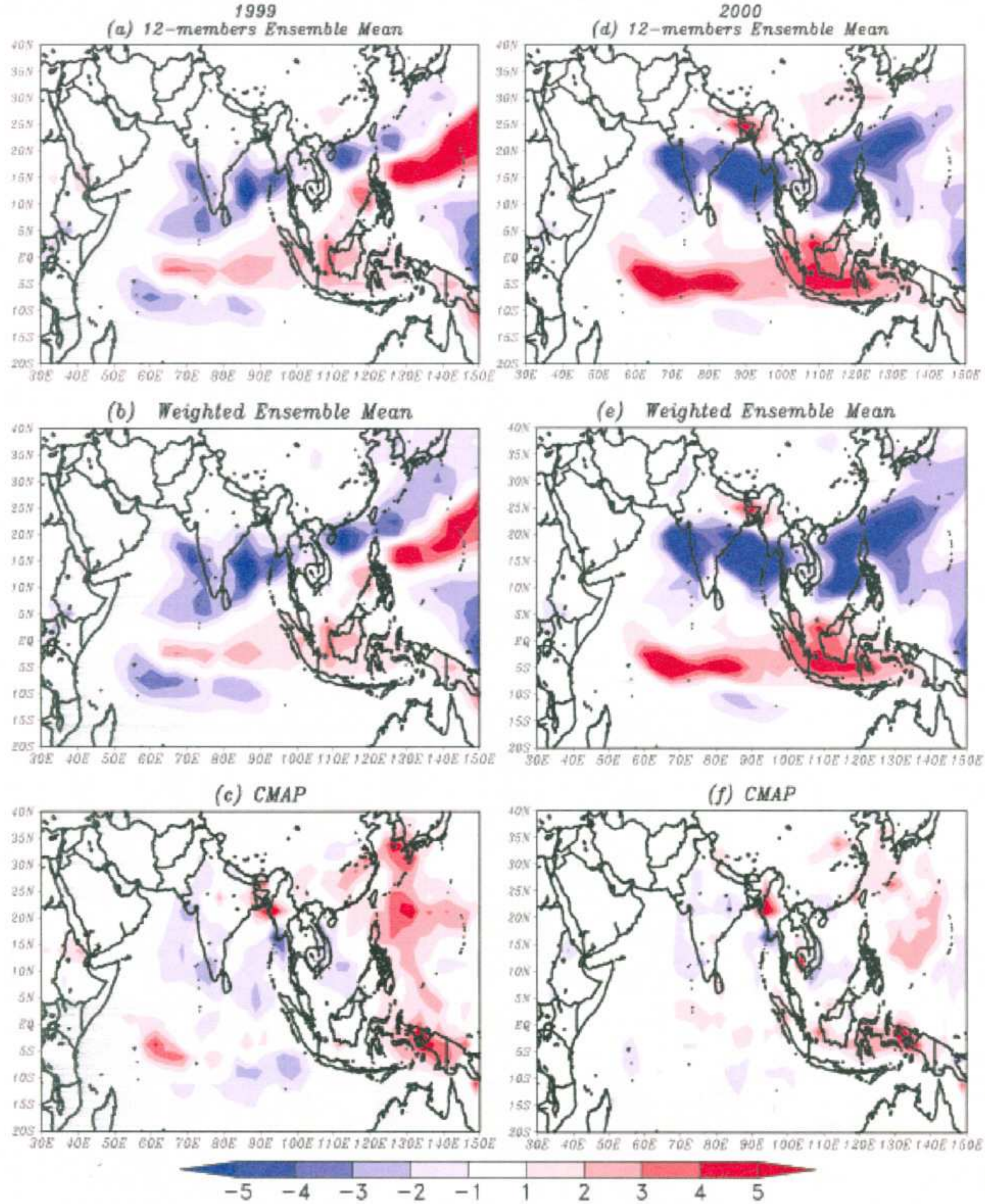


Fig : 9

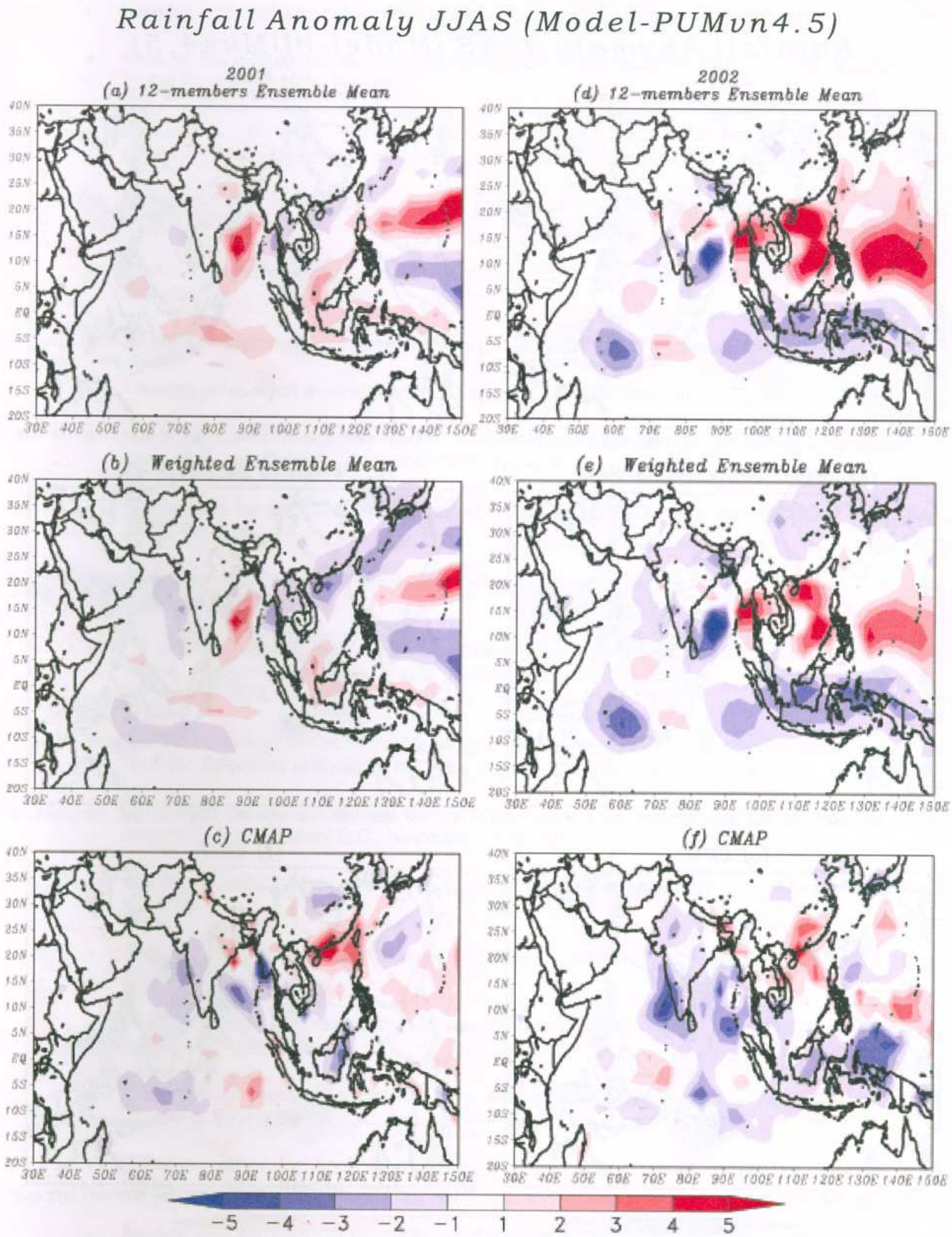

Rainfall Anomaly JJAS (Model-PUMvn4.5)
2001
(a) 12-members Ensemble Mean
2002
(d) 12-members Ensemble Mean
(b) Weighted Ensemble Mean
(e) Weighted Ensemble Mean
(c) CMAP
(f) CMAP
40N 35N 30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S
30E 40E 50E 60E 70E 80E 90E 100E 110E 120E 130E 140E 150E
-5 -4 -3 -2 -1 1 2 3 4 5

Fig : 10

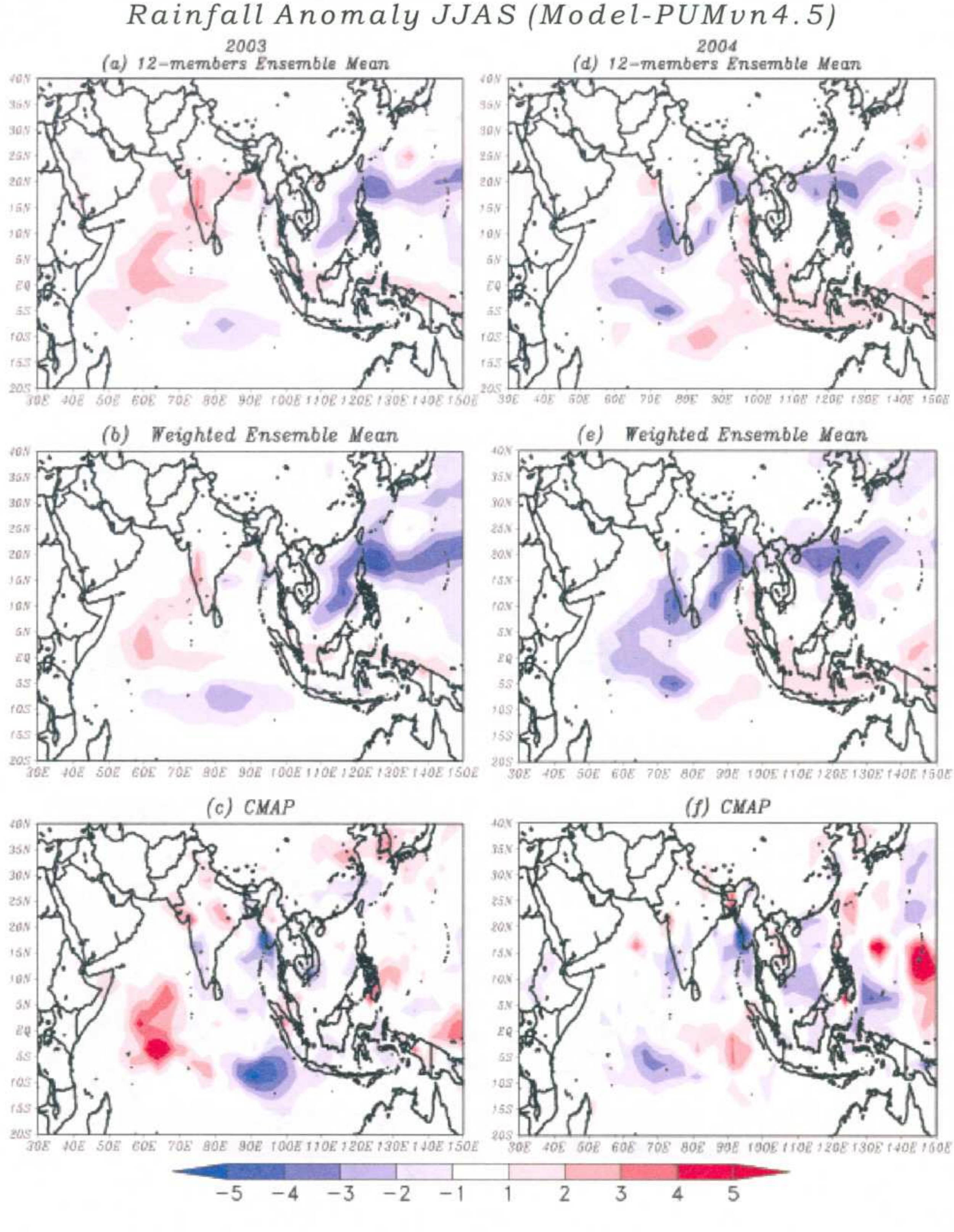

Rainfall Anomaly JJAS (Model-PUMvn4.5)
2003
(a) 12-members Ensemble Mean
2004
(d) 12-members Ensemble Mean
(b) Weighted Ensemble Mean
(e) Weighted Ensemble Mean
(c) CMAP
(f) CMAP
-5 -4 -3 -2 -1 1 2 3 4 5

Fig : 11

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