Are climate models improving in their ability to simulate monsoon rainfall in east India?

L. Das[1*], J. D. Annan[1], J. C. Hargreaves[1] and S. Emori[2]

- [1]**FRCGC / JAMSTEC, 3173-25 Showamachi, Kanazawa-ku Yokohama City, Kanagawa 236-0001, Japan**
- [2] **National Institutes for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan**

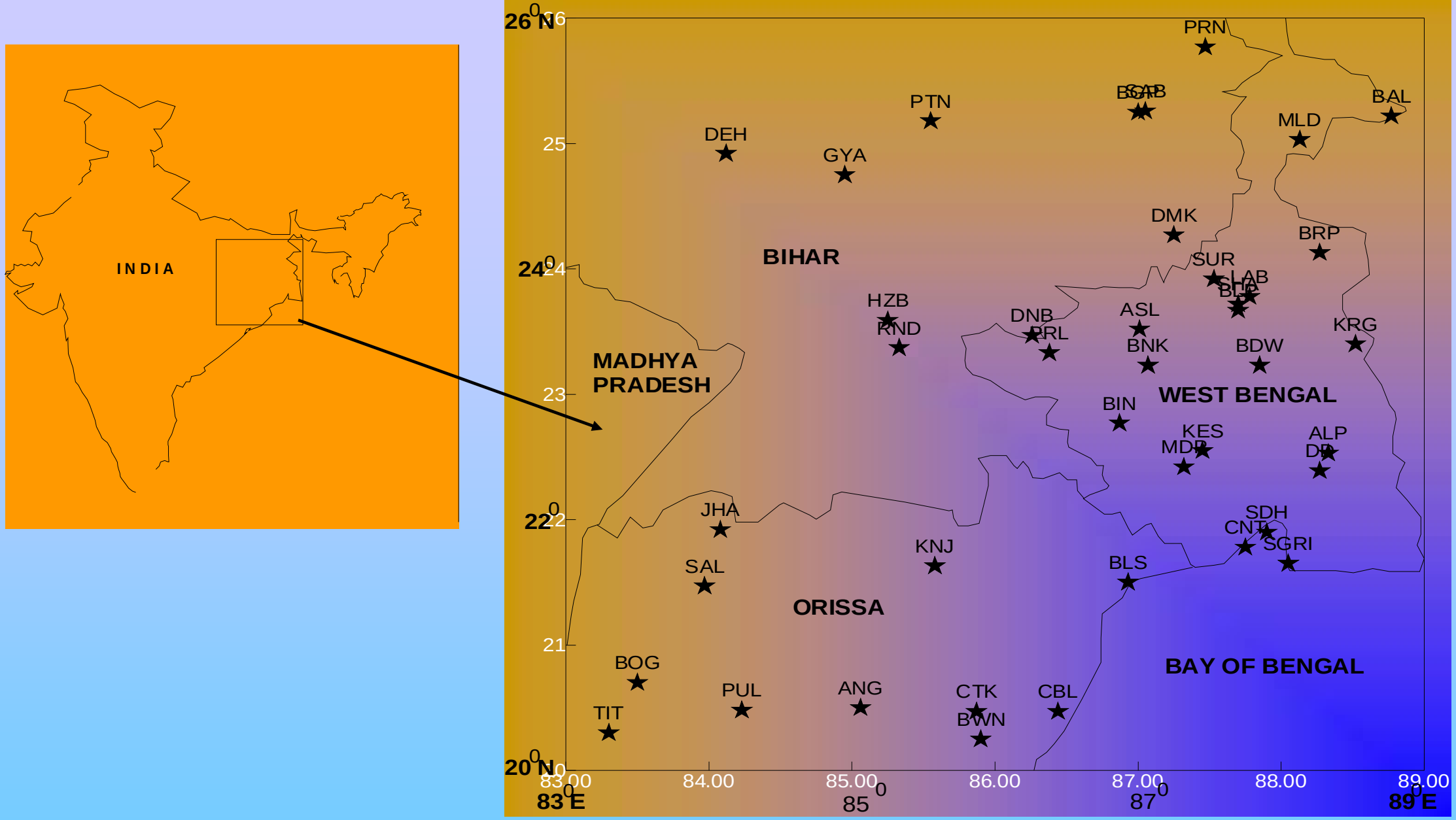
Introduction:

There is widespread competition all over the world to develop coupled GCMs and provide simulation results to the IPCC archives to help policy maker and stakeholders to plan for the future in the context of global warming. The present study was carried out to investigate to what extent the present generation of GCMs (IPCC AR4) is improving their ability to simulate realistic monsoon rainfall over a domain of size 6^o X 6^o in east India compared to their predecessors in the IPCC SAR and TAR.

AIMS OF THIS STUDY:

- To investigate how the performance of GCMs gradually improving from SAR, TAR to AR4 by reducing error and increasing agreement between OBS and simulation monsoon rainfall using visual and statistical methods

- Ranking the models according to gradual improving trends (increasing/decreasing) from SAR to AR4 based on different agreement indices and error statistics of uncertainty measure.



- **Study area showing the distribution of observation stations**

Station information over study area

Latitude	Longitude	Abbreviation	Station Name
22.53	88.33	ALP	Alipore
20.5	85.06	ANG	Angul
21.5	86.93	BLS	Balasore
23.23	87.07	BNK	Bankura
24.13	88.27	BRP	Berhampore
20.25	85.9	BWN	Bhubhaneswar
25.25	87	BGP	Bhagolpur
25.22	88.77	BAL	Balurghat
23.67	87.7	BLP	Bolpur
20.47	86.44	CBL	Chadbali
21.78	87.75	CNT	Contai
20.47	85.87	CTK	Cuttack
22.39	88.27	DD	DumDum
24.27	87.25	DMK	Dumka
21.63	85.58	KNJ	Keonjhar
23.4	88.52	KRG	Krishnagar
23.59	85.25	HZB	Hajaribugh
25.03	88.13	MLD	Malda
22.42	87.32	MDP	Midnapur
23.33	86.38	PRL	Purulia
25.18	85.55	PTN	Patna
21.65	88.05	SGRI	Sagar Island
21.9	87.9	SDH	Sandhead
23.92	87.53	SUR	Suri
23.37	85.33	RND	Ranchi

GCMs Data:

- The SAR data sets are basically from this web link (),http://www.ipcc-data.org/gcm_data.html the external forcing are Green House Gas 1% pa (i.e.XGGA1, where X is name of the model) are considered for this studies instead of Greenhouse Gas plus sulphate aerosol available
- The TAR data are taken from the web-link DDC (http://cera.www.dkrz.de) for IPCC_DDC_TAR experiments only and except ECHAM4/OPYC3 that we obtained in the web-link (http://www.ipcc-data.org/sres/echam4_download.html)
- On the other hand AR4 data sets are taken from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) archive through web link (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php). The data are mainly from the “Climate of the Twentieth Century simulation (20C3M) “hereafter simply ‘present day” experiments were used for the period 1961-90

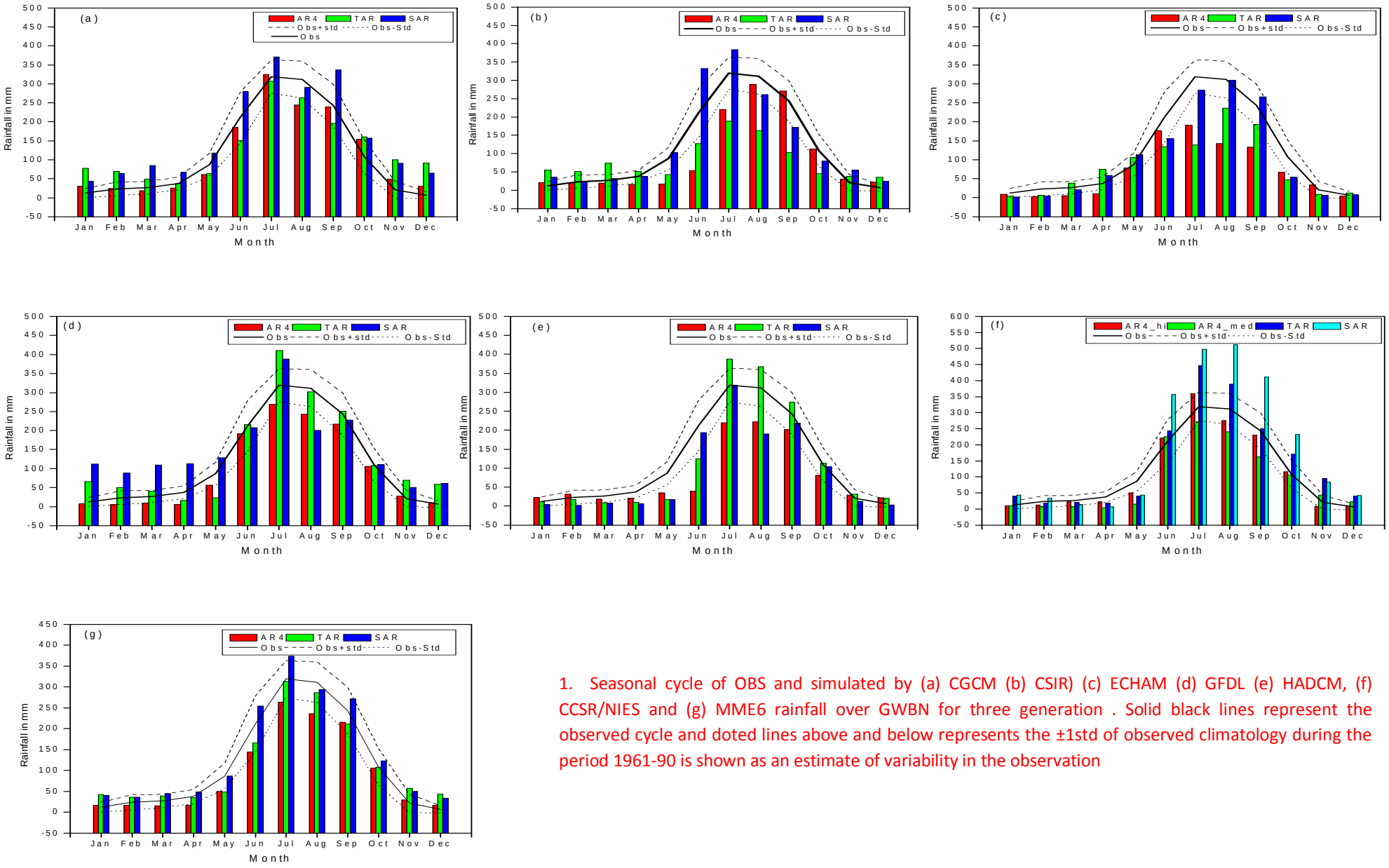
Methodology

1. Comparison of seasonal cycles and spatial patterns between observed and model simulation
2. To measure the accuracy of annual cycles , a relative standard deviation error, annual correlation and annual bias also calculated

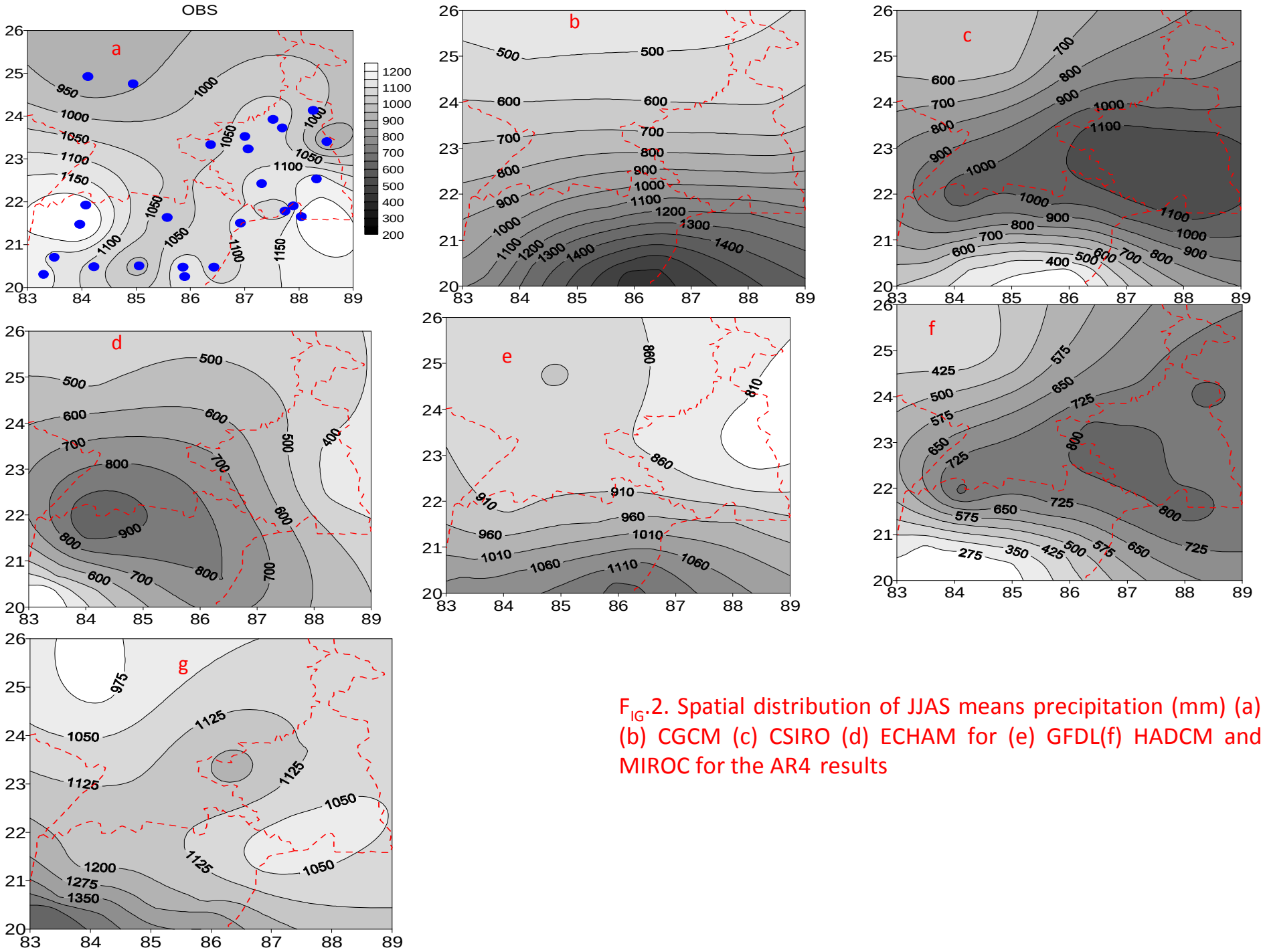
Conventional statistical measures

- Agreement Index (d-Index)
- Coefficient of efficiency
- Error estimators

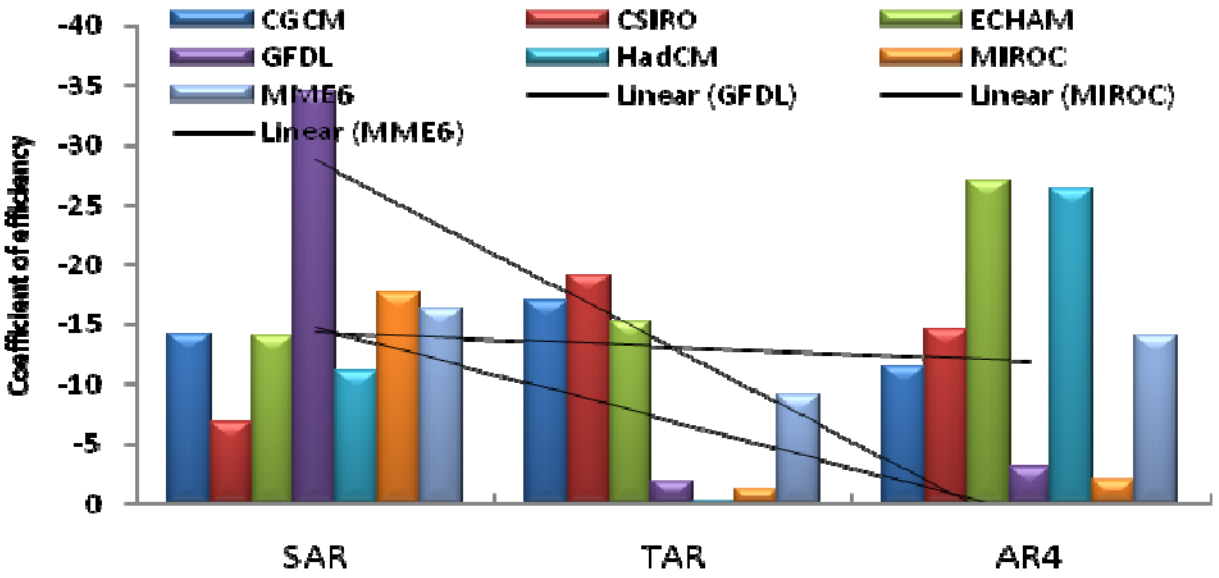
I. Normalized total RMS Error (NTRMSE)
II. Normalized centered RMS Error (NCRMSE)
III. Normalized Mean Absolute Error (NMAE)
Iv. Normalized Error Variance (NEV)
v. Grand Mean Error (GME)

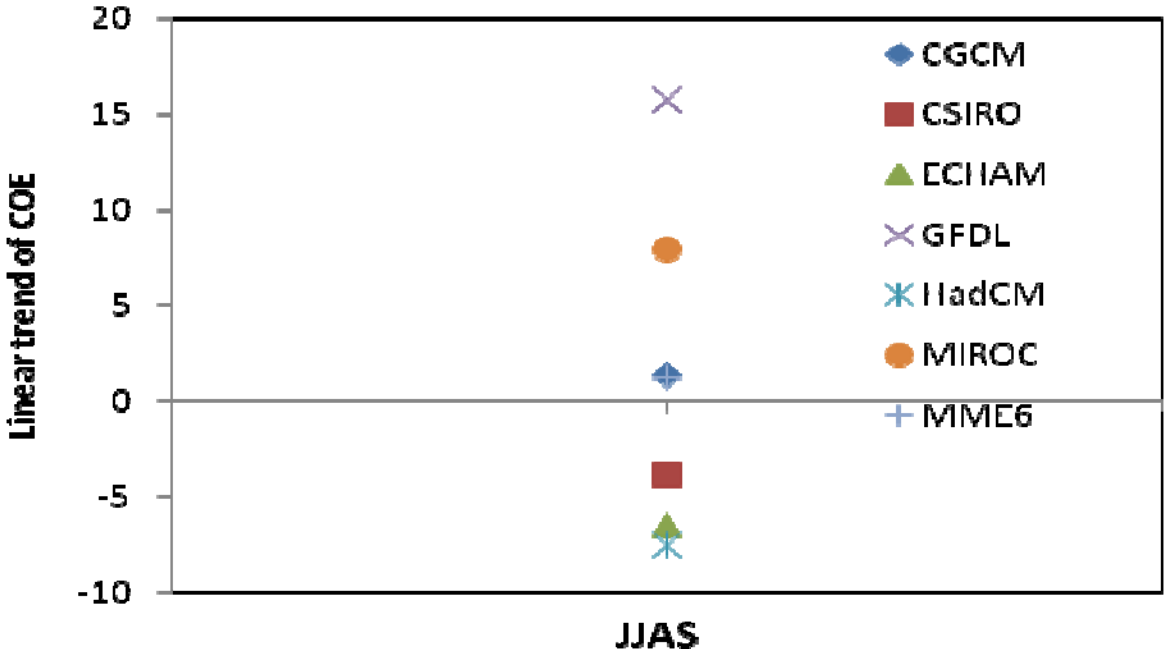


1. Seasonal cycle of OBS and simulated by (a) CGCM (b) CSIR) (c) ECHAM (d) GFDL (e) HADCM, (f) CCSR/NIES and (g) MME6 rainfall over GWBN for three generation . Solid black lines represent the observed cycle and doted lines above and below represents the ±1std of observed climatology during the period 1961-90 is shown as an estimate of variability in the observation

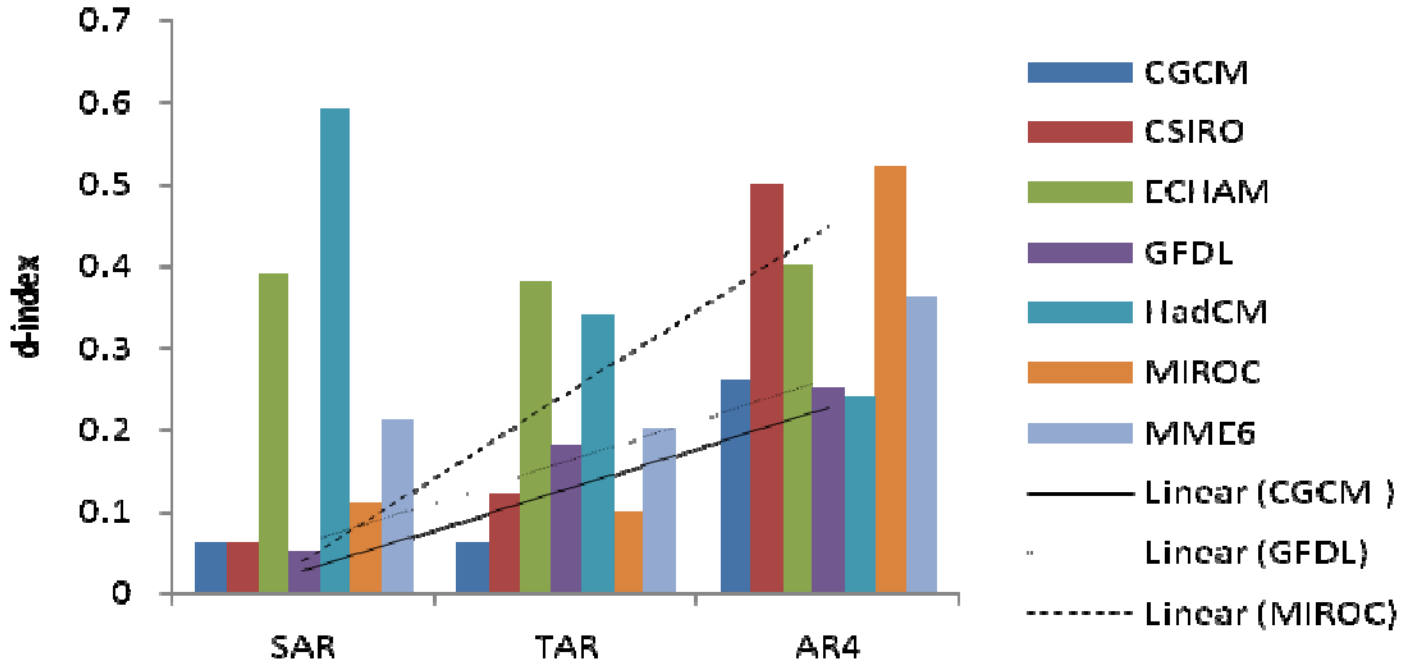


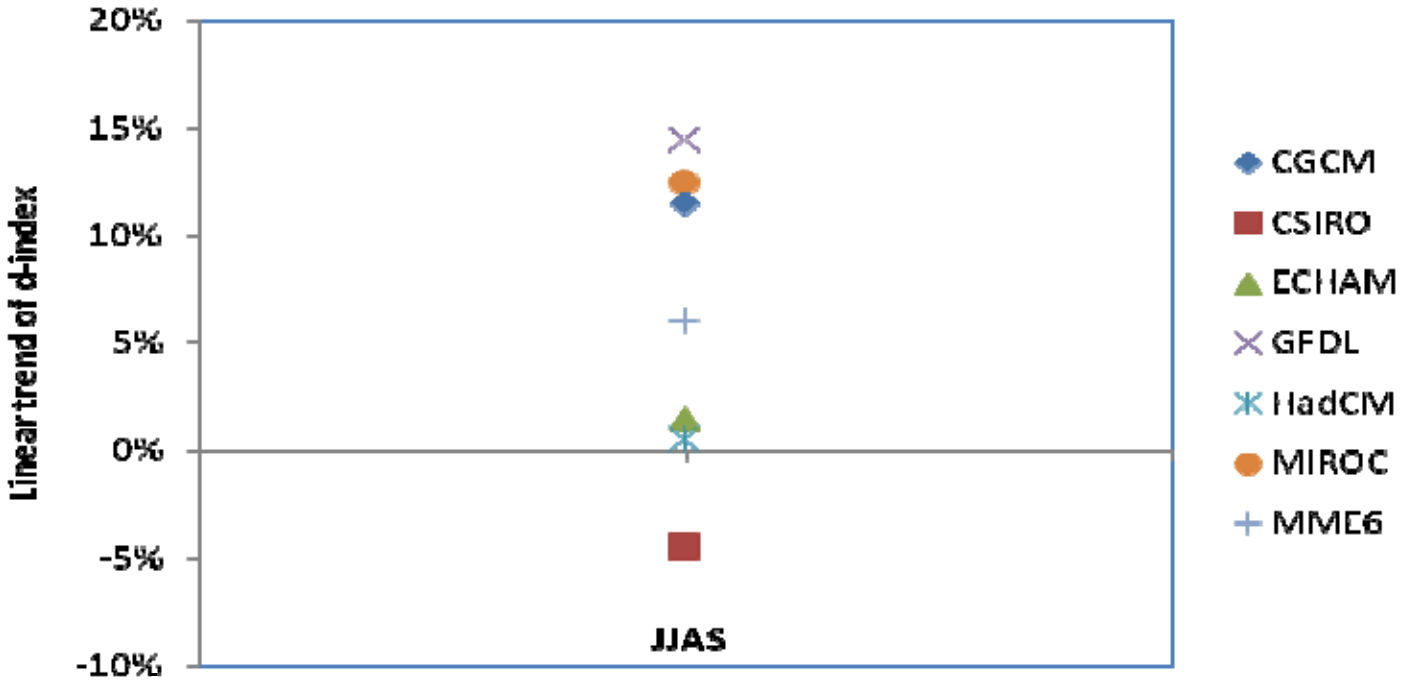
F_{IG}.2. Spatial distribution of JJAS means precipitation (mm) (a) OBS (b) CGCM (c) CSIRO (d) ECHAM for (e) GFDL(f) HADCM and (g) MIROC for the AR4 results



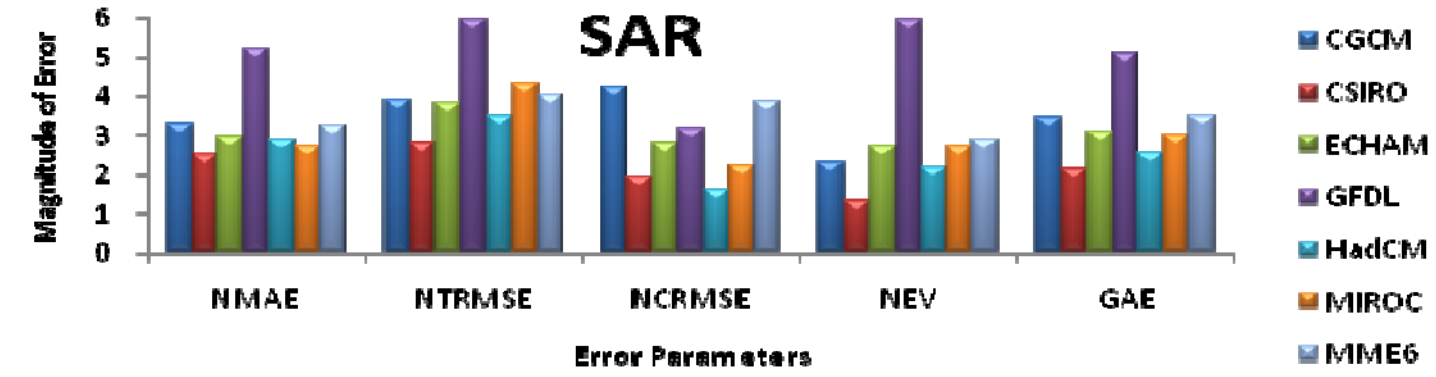


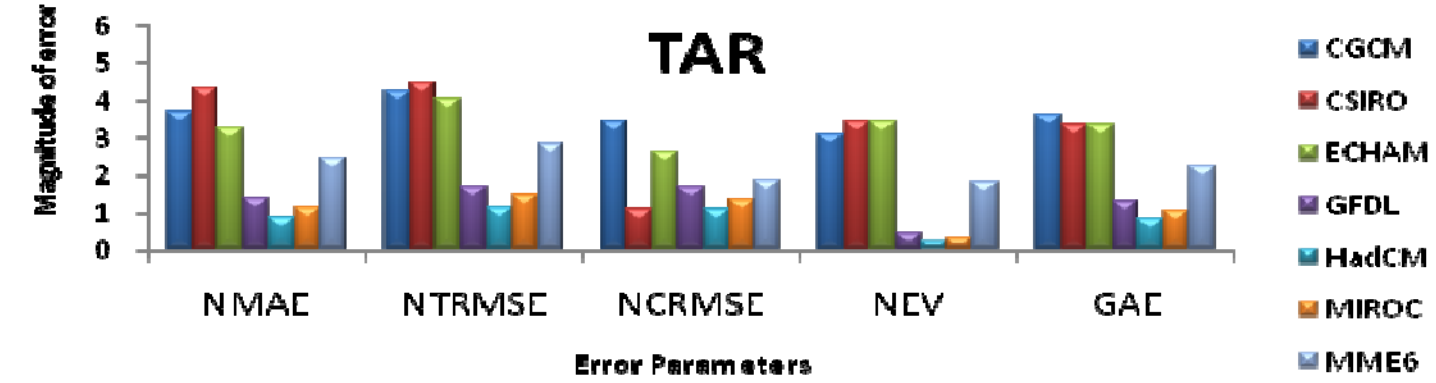
Model	Rank
GFDL	1
MIROC	2
CGCM	3
MME6	4
CSIRO	5
ECHAM	6
HADCM	7

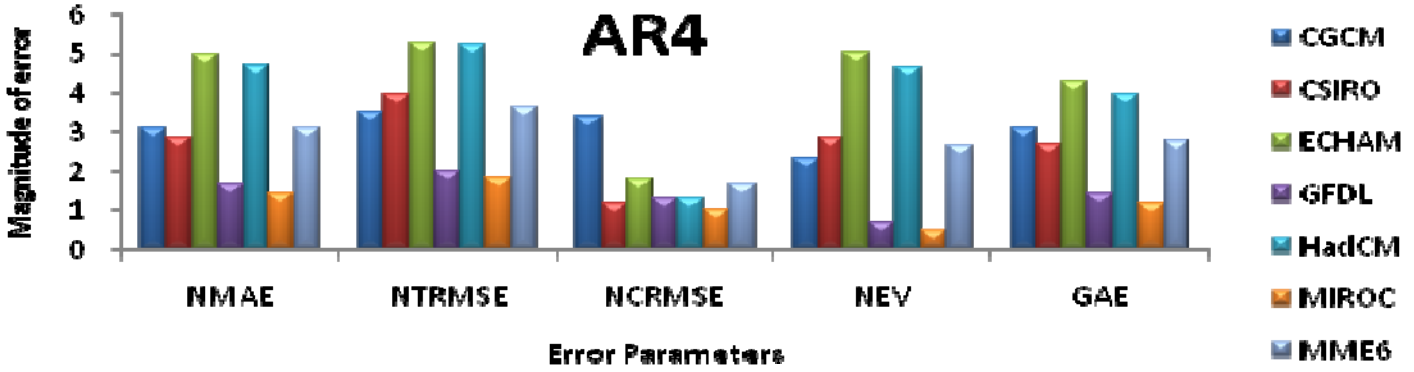


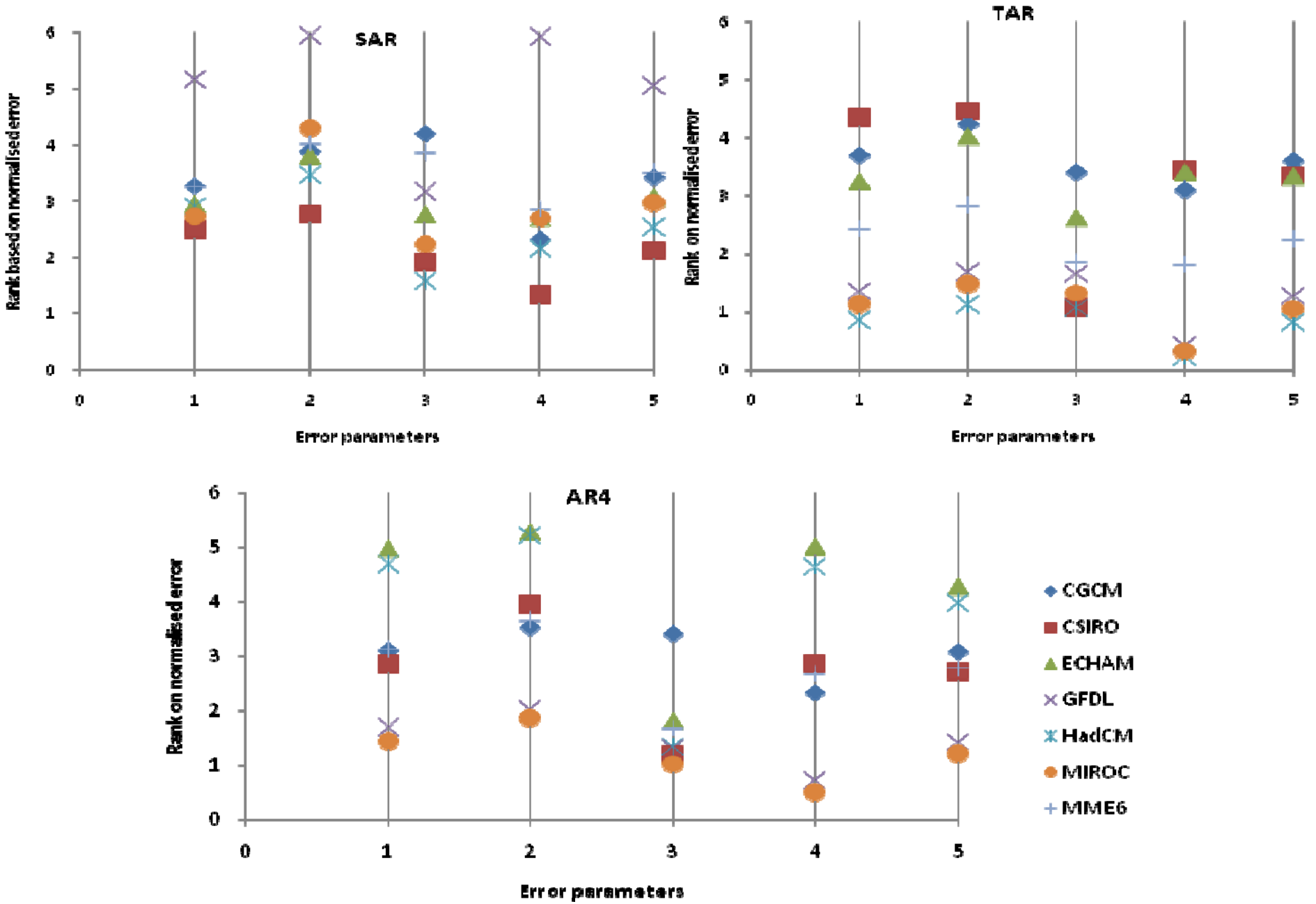


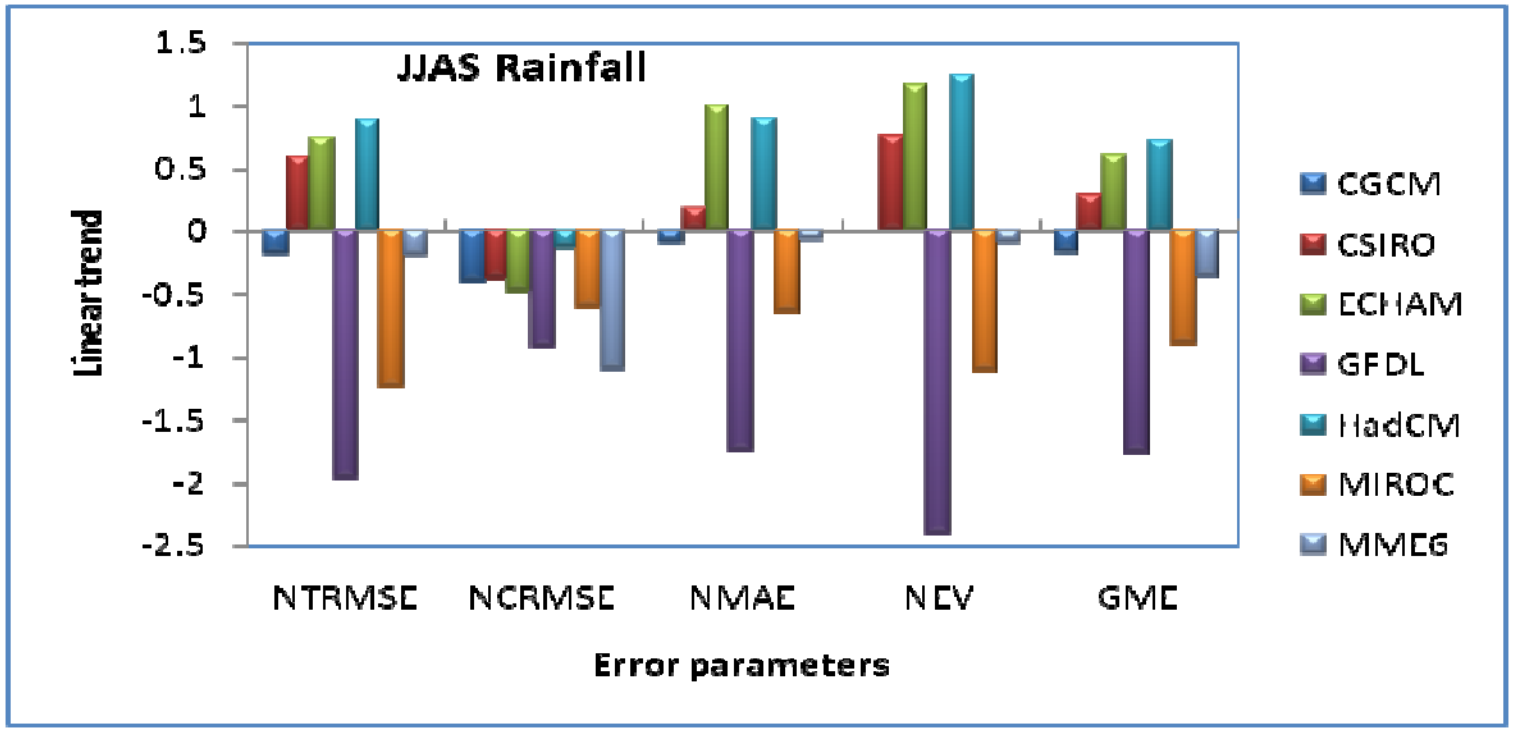
Models	Rank
GFDL	1
MIROC	2
CGCM	3
MME6	4
ECHAM	5
HADCM	6
CSIRO	7

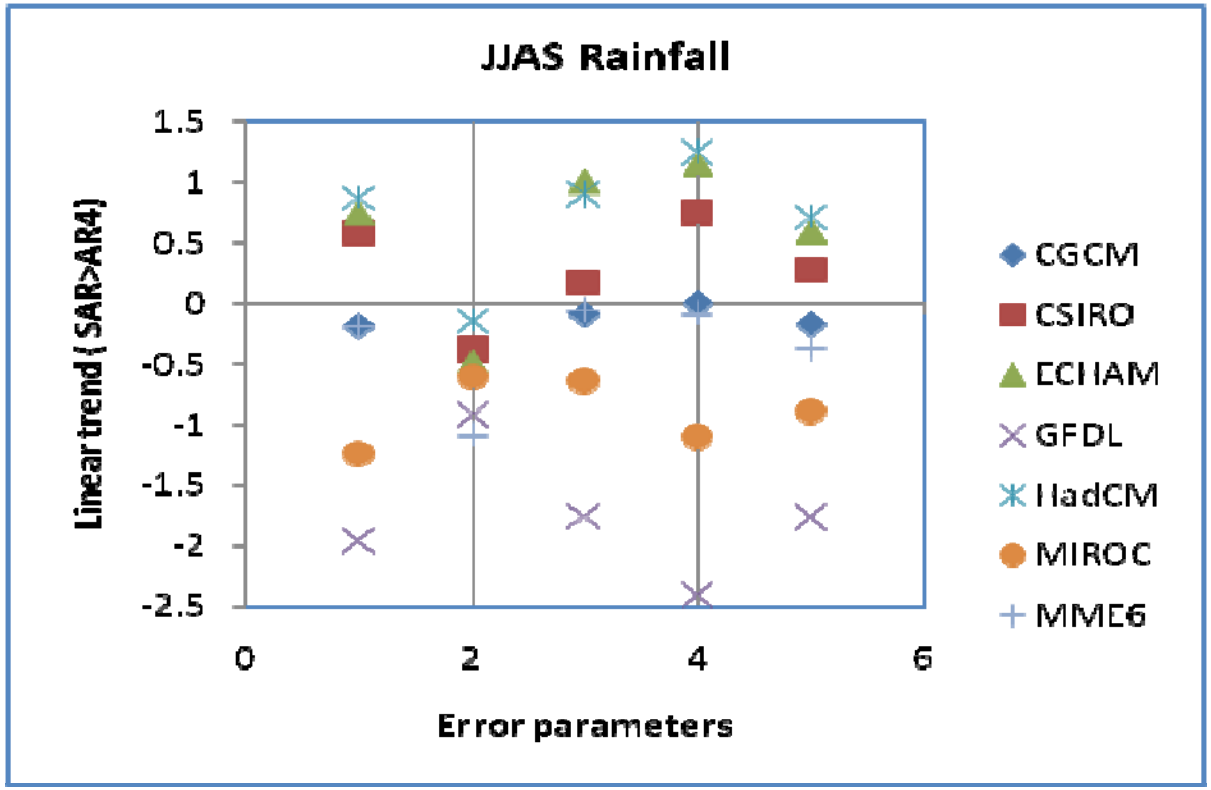

SAR
Magnitude of Error
0
1
2
3
4
5
6
NMAE
NTRMSE
NCRMSE
NEV
GAE
Error Parameters
CGCM
CSIRO
ECHAM
GFDL
HadCM
MIROC
MME6


TAR
Magnitude of error
0
1
2
3
4
5
6
NMAE
NTRMSE
NCRMSE
NEV
GAE
Error Parameters
CGCM
CSIRO
ECHAM
GFDL
HadCM
MIROC
MME6


AR4
Magnitude of error
0
1
2
3
4
5
6
NMAE
NTRMSE
NCRMSE
NEV
GAE
Error Parameters
CGCM
CSIRO
ECHAM
GFDL
HadCM
MIROC
MME6


SAR
TAR
AR4
Rank based on normalised error
Rank on normalised error
Error parameters
0
1
2
3
4
5
6
CGCM
CSIRO
ECHAM
GFDL
HadCM
MIROC
MME6





Rank of models based on linear error

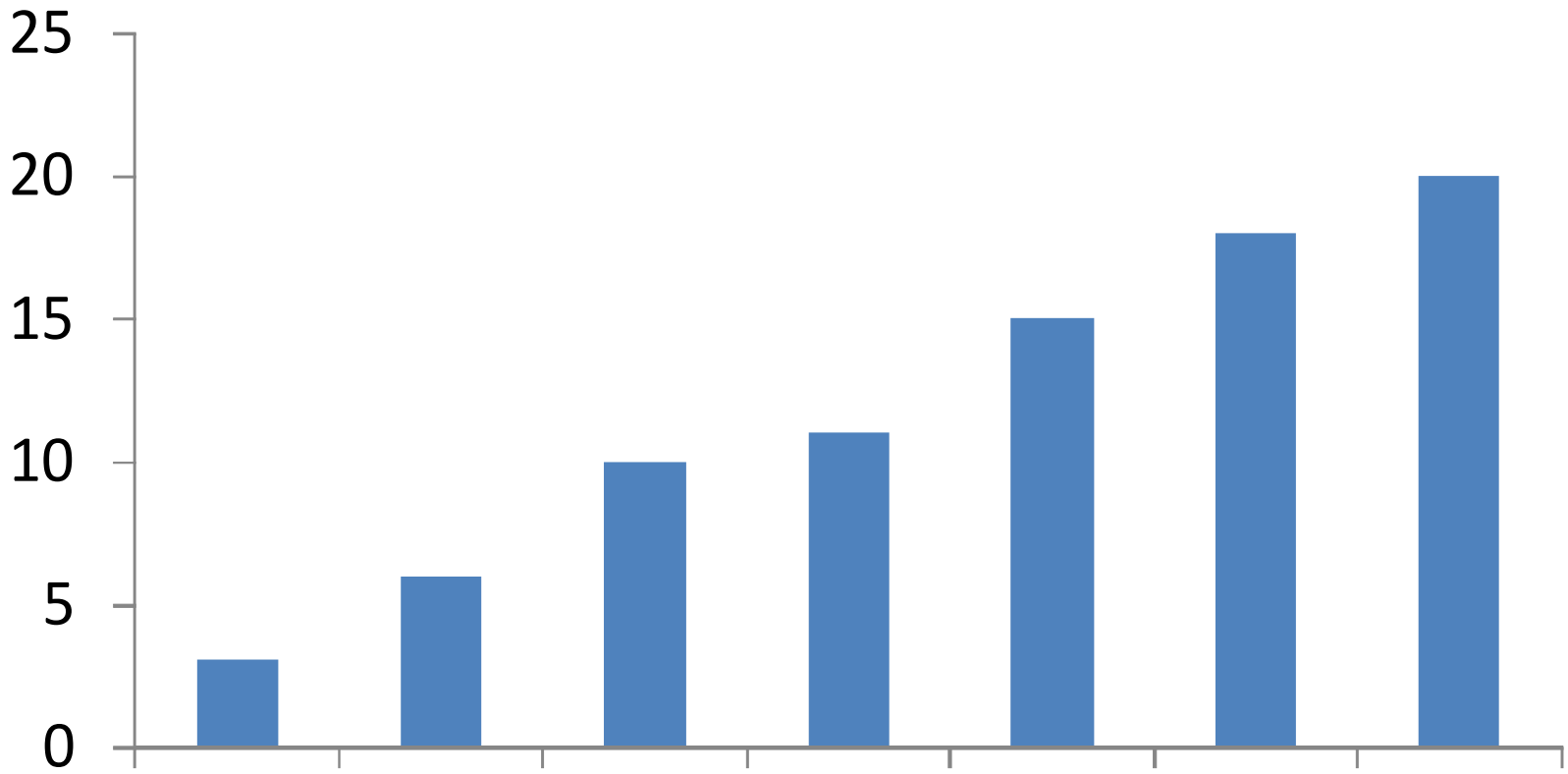
	NTRMSE	NCRMSE	NMAE	NEV	GME
CGCM	4	5	3	4	4
CSIRO	5	6	5	5	5
ECHAM	6	4	7	6	6
GFDL	1	2	1	1	1
HADCM	7	7	6	7	7
MIROC	2	3	2	2	2
MME6	3	1	4	3	3

Ranking of GCMs based on linear trend

Models	Rank							
	Linear trend on error parameters					Agreement of		Final rank
	NTRMSE	NCRMSE	NMAE	NEV	GME	d-index	COE	
CGCM	4	5	3	4	4	3	3	10 (3)
CSIRO	5	6	5	5	5	5	5	15 (5)
ECHAM	6	4	7	6	6	6	6	18 (6)
GFDL	1	2	1	1	1	1	1	3 (1)
HADCM	7	7	6	7	7	6	7	20 (7)
MIROC	2	3	2	2	2	2	2	6 (2)
MME6	3	1	4	3	3	4	4	11(4)

Ranking of GCMs based on linear trend

Models	Rank							
	Linear trend on error parameters					Agreement of		Final rank
	NTRMSE	NCRMSE	NMAE	NEV	GME	d-index	COE	
CGCM	4	5	3	4	4	3	3	10 (3)
CSIRO	5	6	5	5	5	5	5	15 (5)
ECHAM	6	4	7	6	6	6	6	18 (6)
GFDL	1	2	1	1	1	1	1	3 (1)
HADCM	7	7	6	7	7	6	7	20 (7)
MIROC	2	3	2	2	2	2	2	6 (2)
MME6	3	1	4	3	3	4	4	11(4)


25
20
15
10
5
0

Conclusion:

(1) Visual intercomparison shows gradual improvement of models performance from SAR to AR4 to simulate mean monsoon rainfall over east Indian region with a considerable 1std of observed rainfall variability.

(2) Linear trends drawn on different error parameters indicates more than 70% models reducing errors from SAR to AR4

(3) The relative ranking based on linear trend varies considerably from method to method therefore final ranking made on aggregated rank based on the rank of d-index, coe and grand mean errors which indicates GFDL, MIROC, CGCM, MME6, CSIRO, ECHAM and HADCM is secured rank 1, 2, 3, 4, 5, 6, and 7 respectively on the basis of overall improving performance from SAR to AR4