Evaluation of CMIP6 GCMs performance during the *Boro* and *Kharif* seasons over the New Alluvial Zones of West Bengal

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INTRODUCTION

- Climate models are the representatives of the Earth's climate system. Plenty of differentiation equations based on the laws of physics, fluid motion and chemistry are used to develop single climate model. These computer-based simulation models (GCMs) are effective tools for studying the impact of climate change.
- The Coupled Model Intercomparison Project (CMIP) was initiated in 1995 under the influence of the Working Group on Coupled Modeling (WGCM) of the World Climate Research Programme (WCRP). The number of models and their performance is improving across generations from the first assessment report (1995) to the latest sixth assessment report (2014) of IPCC as shown by several published research articles.
- In spite of their continuous improvement of climate model in terms of their physics , regulation and uncertainty , there still remains some questions as to how efficiently the models can reproduce the local climatic information.
- Each model under CMIP6 is not suitable for every location. it is still necessary to test the model performance on regional and local scale because of the inherent bias and uncertainty shown by the CMIP6 GCMs. So evaluation is required to judge the best performing model for a given site.
- To overcome this problem, a study was designed to carry out the latest generations of IPCC CMIP6 model evaluation over the New Alluvial Zone (NAZ) of West Bengal.

OBJECTIVES

1. To evaluate the CMIP6 GCMs performance for two major crop growing seasons (*Boro* and *Kharif*) over Gangetic West Bengal region of India
2. To identify the crop season-wise better performing CMIP6 GCMs for assessing the impact of climate change on agriculture

STUDY AREA

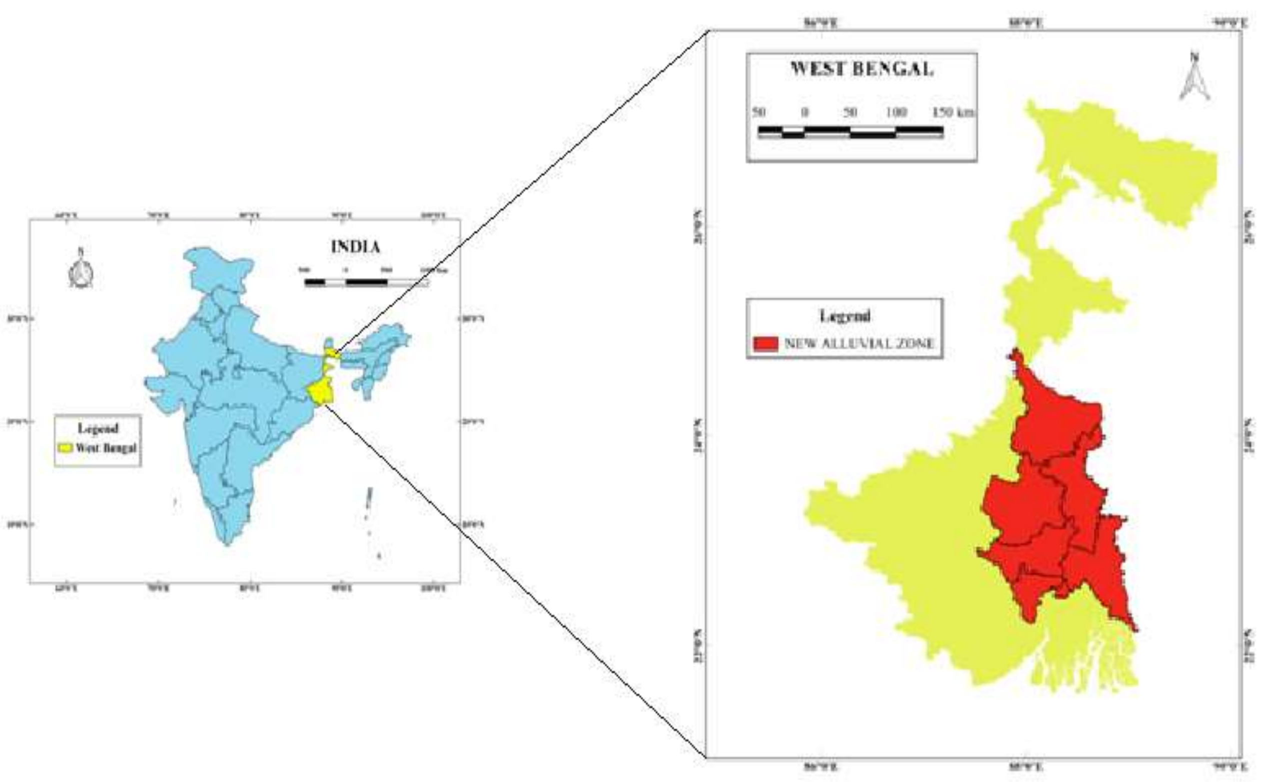


Fig.1: New Alluvial Zone of West Bengal

DATA USED:

Data used:

1. Observed Weather data:
The observed values of selected weather parameters namely, maximum temperature, minimum temperature and rainfall for the period of 1998-2014 were collected from the Meteorological Observatory situated at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia. The geographical coordinates of the observatory are 23.6565 N and 88.2254 E.

2. CMIP6 data:
After scrutinizing the GCMs outputs through visual inspection, it was noted that many CMIP6 GCMs simulation have missing data and may not have future outputs for all SSPs, So present study was carried out by consideringalmost 13 Numbers of GCMs which was available through available athttps://esgf-node.llnl.gov/search/cmip6).

MATERIALS AND METHOD

The model performance is analyzed by two ways:

1. Calculation of some agreement index

Correlation coefficient (r):

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y^2)]}}$$

Index of agreement (d):

$$d = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(|P_i - \bar{O}| + |O_i - \bar{O}|)^2}, \quad 0 \le d \le 1$$

Nash-Sutcliffe efficiency (NSE):

$$NSE = 1 - \frac{\sum_{i=1}^{n}(OBS_i - SIM_i)^2}{\sum_{i=1}^{n}(OBS_i - \overline{OBS})^2}$$

2. Calculation of some error index

Error index (NRMSE):

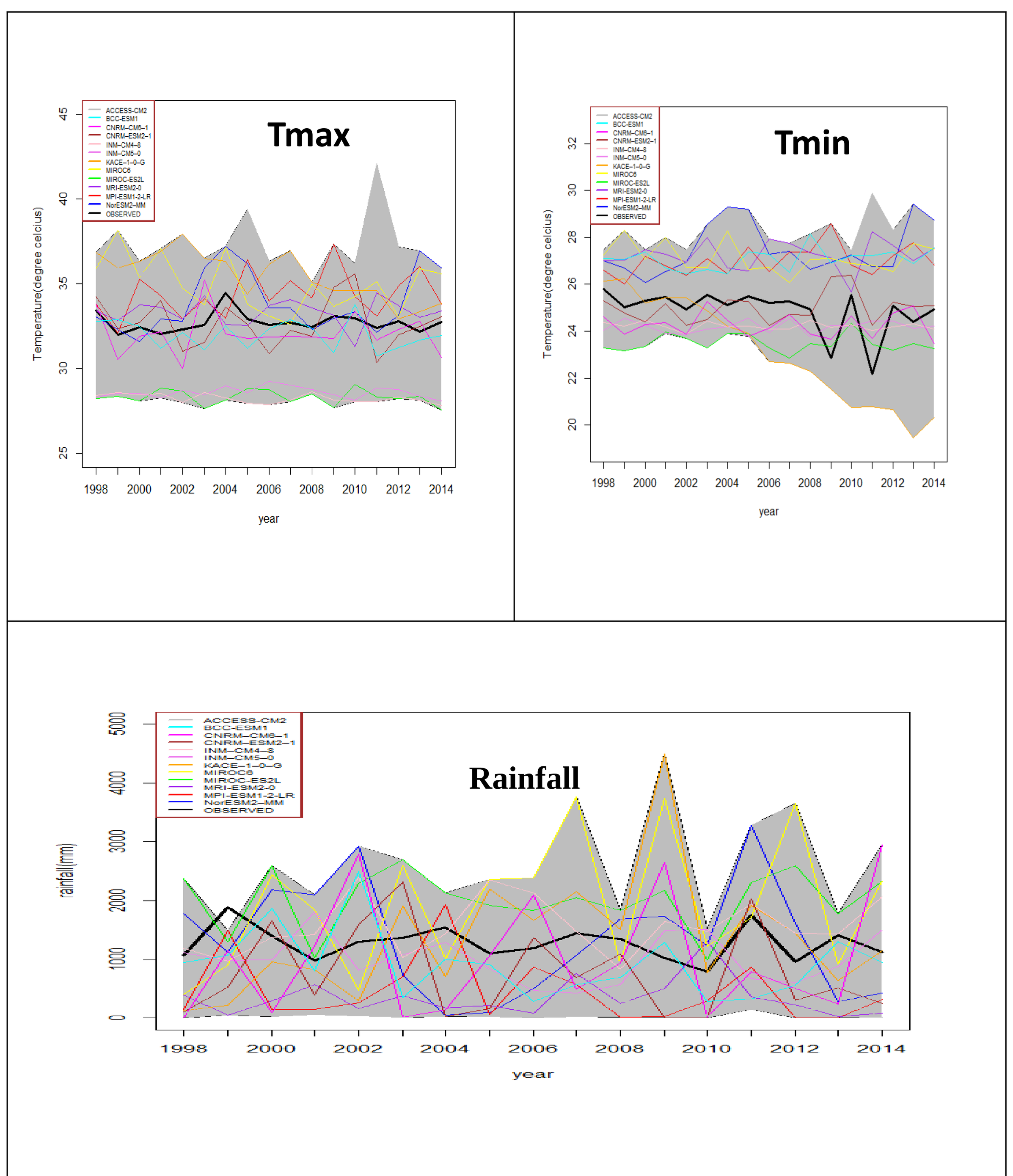
$$NRMSE = \frac{\sum (S_i - O_i)^2}{\sum O_i^2}$$

Percent bias (PBIAS):

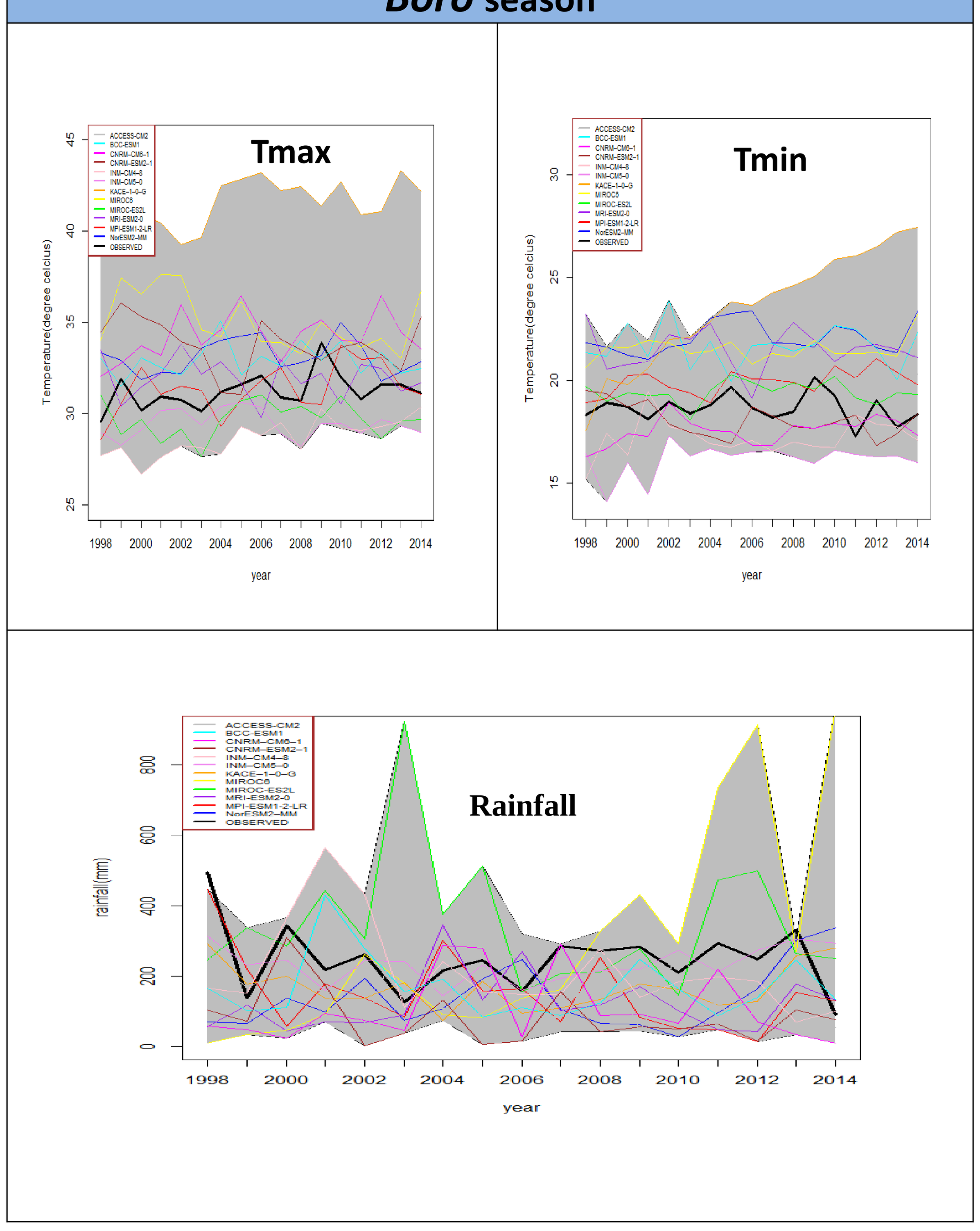
$$PBIAS = \frac{\sum_{i=1}^{n}(Y_i^{obs} - Y_i^{sim})}{\sum_{i=1}^{n}(Y_i^{obs})}$$

RESULTS AND DISCUSSIONS

CMIP6 Model evaluation through visual inspection for *Kharif* season



CMIP6 Model evaluation through visual inspection for *Boro* season



Model evaluation through conventional statistics:

Table 1 Variation of computed values of different indices between observed and CMIP6 GCMs simulated maximum temperature (T_{max}) , minimum temperature (T_{min})and Rainfall and their ranks and final accumulated ranks during *Kharif* season

Tmax	VALUES					RANKS						
MODELS	CO	D	NRMSE	PBIAS	NSE	CO	D	NRMSE	PBIAS	NSE	SUM	RANK
ACCESS-CM2	-0.10	0.13	228.50	-10.30	-52.59	9	11	9	9	10	48	10
BCC-ESM1	0.19	0.37	133.70	2.10	-2.93	4	4	4	4	1	17	3
CNRM-CM6–1	0.23	0.39	109.30	1.90	-4.43	3	2	2	3	4	14	2
CNRM-ESM2–1	0.44	0.52	87.10	0.10	-3.54	1	1	1	1	2	6	1
INM-CM4–8	-0.14	0.15	1743.80	15.80	-59.96	10	10	12	12	12	56	12
INM-CM5–0	0.15	0.17	1279.60	14.40	-50.84	5	8	11	10	9	43	9
KACE–1–0–G	0.01	0.21	221.10	-7.80	-28.80	7	6	8	8	8	37	8
MIROC-6	-0.03	0.26	177.70	-6.40	-22.24	8	5	7	7	7	34	7
MIROC-ES2L	-0.21	0.15	1033.50	15.50	-58.37	11	9	10	11	11	52	11
MPI-ESM1-2-LR	-0.31	0.12	161.60	-1.80	-3.55	12	12	5	2	3	34	7
MRI-ESM2-0	0.04	0.20	162.10	-4.90	-13.42	6	7	6	6	6	31	5
nORESM2–MM	0.43	0.38	109.70	-3.50	-10.72	2	3	3	5	5	18	4

Tmin	VALUES					RANKS						
MODELS	CO	D	NRMSE	PBIAS	NSE	CO	D	NRMSE	PBIAS	NSE	SUM	RANK
ACCESS-CM2	-0.36	0.27	376.60	-9.50	-9.34	12	12	5	12	12	53	12
BCC-ESM1	-0.04	0.31	535.20	-8.10	-5.86	8	7	11	8	6	40	9
CNRM-CM6–1	0.44	0.56	196.60	2.50	-0.26	2	1	3	2	1	9	1
CNRM-ESM2–1	-0.01	0.40	175.80	-0.40	-0.49	7	4	2	1	3	17	2
INM-CM4–8	0.37	0.44	683.40	2.80	-0.43	3	2	12	4	2	23	4
INM-CM5–0	-0.18	0.31	475.60	2.80	-0.72	9	6	10	4	4	33	6
KACE–1–0–G	0.47	0.43	117.30	7.80	-7.12	1	3	1	7	9	21	3
MIROC-6	0.02	0.30	399.50	-8.30	-6.35	6	8	7	9	8	38	7
MIROC-ES2L	0.14	0.39	454.80	6.00	-2.33	4	5	9	5	5	28	5
MPI-ESM1-2-LR	-0.32	0.28	435.00	-8.70	-7.36	11	10	8	10	10	49	11
MRI-ESM2-0	-0.24	0.30	388.80	-7.80	-5.99	10	9	6	7	7	39	8
NORESM2–MM	0.14	0.27	268.40	-9.50	-8.97	5	11	4	12	11	43	10

Rainfalll	VALUES					RANKS						
MODELS	CO	D	NRMSE	PBIAS	NSE	CO	D	NRMSE	PBIAS	NSE	SUM	RANK
ACCESS-CM2	0.34	0.28	888.50	1035.20	-17.22	3	6	12	12	11	44	10
BCC-ESM1	0.12	0.37	119.40	38.60	-5.25	5	3	8	8	3	27	4
CNRM-CM6–1	-0.13	0.19	107.50	26.60	-14.36	7	10	4	4	9	34	9
CNRM-ESM2–1	0.45	0.47	109.80	66.50	-7.84	2	1	9	9	4	25	3
INM-CM4–8	-0.20	0.21	138.70	-18.50	-4.31	9	8	3	3	2	25	3
INM-CM5–0	-0.39	0.19	154.40	27.40	-4.07	11	9	5	5	1	31	7
KACE–1–0–G	-0.17	0.18	105.20	-5.60	-14.63	8	11	2	2	10	33	8
MIROC-6	-0.25	0.12	121.00	-33.70	-22.26	10	12	6	6	12	46	11
MIROC-ES2L	0.13	0.30	177.50	-36.60	-9.69	4	4	7	7	6	28	6
MPI-ESM1-2LR	-0.45	0.23	331.90	270.10	-13.32	12	7	11	11	8	49	12
MRI-ESM2-0	0.65	0.41	164.30	175.50	-9.69	1	2	10	10	5	28	6
NORESM2–MM	0.08	0.29	99.40	-4.90	-10.48	6	5	1	1	7	20	1

Table 2. Variation of ranks of each model according to different meteorological parameters but irrespective method of analysis (indices) for *Kharif* season

MODELS	TMAX	TMIN	RF	SUM	RANK
ACCESS-CM2	10	12	10	32	12
BCC-ESM1	3	9	4	16	4
CNRM-CM6–1	2	1	9	12	2
CNRM-ESM2–1	1	2	3	6	1
INM-CM4–8	12	4	3	19	7
INM-CM5–0	9	6	7	22	9
KACE–1–0–G	8	3	8	19	7
MIROC-6	7	7	11	25	10
MIROC-ES2L	11	5	6	22	9
MPI-ESM1-2-LR	7	11	12	30	11
MRI-ESM2-0	5	8	6	19	7
NORESM2–MM	4	10	1	15	5

Table 3.Variation of ranks of each model according to different meteorological parameters but irrespective method of analysis (indices) for *Boro* season

MODELS	TMAX	TMIN	RF	SUM	RANK
ACCESS-CM2	7	5	6	18	5
BCC-ESM1	8	10	5	23	7
CNRM-CM6–1	9	2	8	19	6
CNRM-ESM2–1	10	3	11	24	8
INM-CM4–8	7	7	3	17	4
INM-CM5–0	5	8	1	14	3
KACE–1–0–G	11	12	4	27	12
MIROC-6	12	7	7	26	10
MIROC-ES2L	2	1	9	12	2
MPI-ESM1-2-LR	5	10	12	27	12
MRI-ESM2-0	1	4	3	8	1
NORESM2–MM	3	11	11	25	9

Summary &Conclusion

✓The present study showed that CNRM–ESM2–1of France to be the best fit model for *Kharif* season and MRI-ESM2-0 of Japan for *Boro* season whereas ACCESS-CM2of Australia for *Kharif* season andMPI-ESM1-2-LR of Germany for *Boro* season were the worst performing models over that above mentioned location

✓it can be concluded that whenever users consider the climate output for their impact assessment study it is necessary to evaluate the model simulation for the study region for a particular temporal scale.
So, the present study will be very much beneficial for the researchers interested in any kind of climate related impact study over the NAZ of west Bengal.