Why Coupled General Circulation Models overestimate the ENSO and Indian Summer Monsoon Rainfall (ISMR) Relationship?

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This study attempt to examine the reasons for stronger ENSO-ISMR relationship in the coupled models.

Introduction

ISMR variability is spread over different time scales viz. interannual, decadal, sub-seasonal, and daily. Predicting the variability of ISMR has remained a challenging problem for quite some. Despite some progress made in recent decades, predicting ISMR by coupled models is difficult and its skill is nowhere close to the potential predictability limit. The aim of this study is to examines the ENSO-ISMR teleconnection on the monthly timescale by analysing the observational data (rainfall and SST) from 1982 to 2017 to explore the ENSO-ISMR relationship.

ISMR correlation with ENSO

Correlation coefficient between ISMR and SST indices	Observations				
	June	July	August	September	JJAS
Niño 1+2	-0.36	-0.21	0.18	-0.16	0.03
Niño 3	-0.3	-0.45	0.01	-0.41	-0.3
Niño 3.4	-0.23	-0.48	-0.03	-0.53	-0.42
Niño 4	-0.2	-0.27	-0.04	-0.54	-0.35
EMI	0.1	-0.11	-0.14	-0.43	-0.34
IOD	0.08	0.05	0.22	-0.19	0.03
East IOD	-0.43	-0.02	-0.3	0.15	0.08
West IOD	-0.28	0.05	-0.04	-0.11	0.13

Table 1: Correlation coefficient of ISMR and SST anomalies for different indexes. Values significant at 90% level are assessed by the means of a two-tailed Student's test (shown in red colour).

- ENSO-ISMR has significant relationship on seasonal scale.
- August ISMR has no association with Niño 3, Niño 3.4, Niño 4, and EMI.
- August has significant correlation between ISMR and East IOD region.

ISMR correlation with East IOD

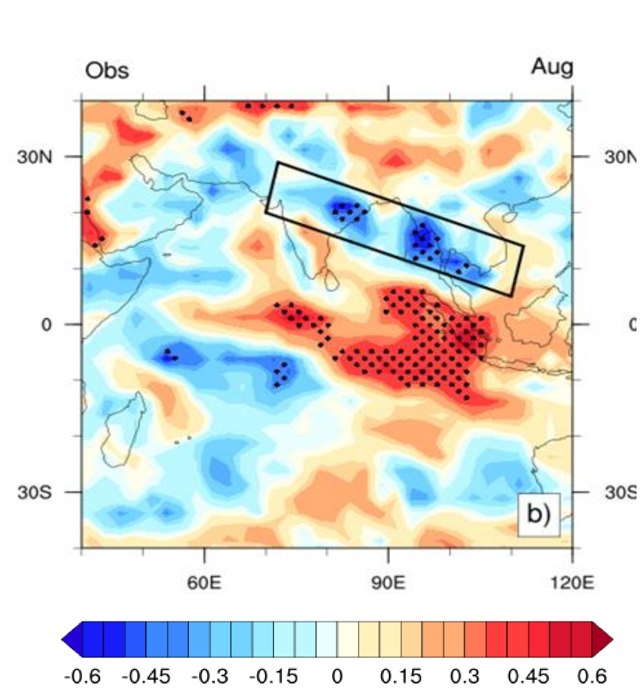

Fig 1: Grid point correlation coefficient between East IOD index and rainfall in and August . A two-tailed Student's test is performed to assess the values significant at 90% level (represented by dots).

- EIOD SST has a significant negative correlation with rainfall (marked by a rectangle) especially in the central India represented by the black box will be called as NW rainfall band.

ISMR correlation with LPS

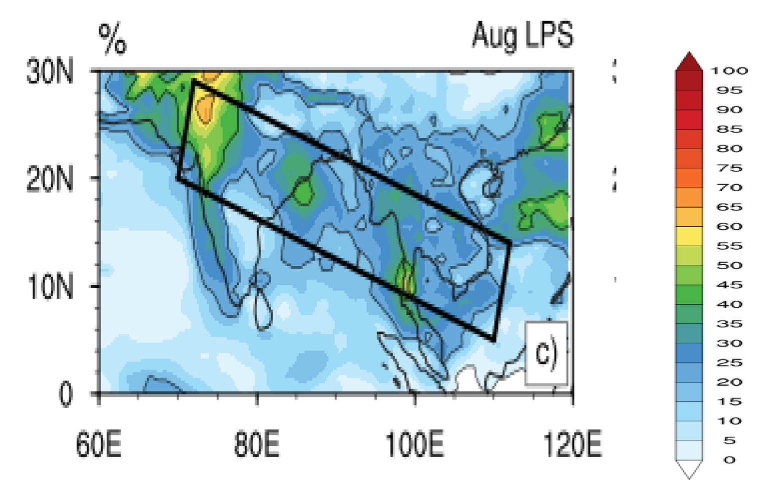

Fig 2: Percentage contribution of LPS days rainfall to seasonal mean rainfall during August from GPCP rainfall.

- Low Pressure System (LPS) contribution to seasonal mean monsoon rainfall during August over central India is more than 20% for most regions and upto 70 %.
- **Thus, LPS is mostly contributing to the ISMR variability during August.**

ENSO-ISMR correlation in the Coupled model

Correlation coefficient between ISMR and SST indices	a) MMCFS				
	June	July	Aug	Sep	JJAS
Niño 1+2	-0.39	-0.7	-0.77	-0.69	-0.81
Niño 3	-0.25	-0.69	-0.72	-0.67	-0.74
Niño 3.4	-0.2	-0.64	-0.66	-0.64	-0.68
Niño 4	-0.23	-0.61	-0.64	-0.61	-0.68
EMI	0.21	-0.13	-0.49	-0.54	-0.34
IOD	-0.5	-0.42	-0.63	-0.6	-0.63
East IOD	0.28	0.12	0.43	0.51	0.34
West IOD	-0.19	-0.33	-0.39	-0.38	-0.34

Correlation coefficient between ISMR and SST indices	b) CCSM4				
	June	July	Aug	Sep	JJAS
Niño 1+2	-0.42	-0.15	-0.56	-0.65	-0.59
Niño 3	-0.32	-0.2	-0.6	-0.72	-0.62
Niño 3.4	-0.28	-0.17	-0.58	-0.74	-0.6
Niño 4	-0.09	0.05	-0.45	-0.71	-0.45
EMI	0.29	0.17	0.06	-0.6	0.11
IOD	-0.59	-0.03	-0.25	-0.28	-0.36
East IOD	0.22	0.26	0.25	0.24	0.37
West IOD	-0.4	0.31	-0.09	-0.17	-0.08

Correlation coefficient between ISMR and SST indices	c) FLORB				
	June	July	Aug	Sep	JJAS
Niño 1+2	-0.71	-0.46	0.0	0.38	-0.55
Niño 3	-0.75	-0.54	-0.06	0.4	-0.63
Niño 3.4	-0.78	-0.57	-0.06	0.4	-0.65
Niño 4	-0.8	-0.58	-0.06	0.41	-0.65
EMI	-0.49	-0.62	-0.22	0.36	-0.65
IOD	-0.72	-0.54	-0.06	0.29	-0.65
East IOD	0.76	0.6	0.18	-0.26	0.75
West IOD	-0.19	-0.21	0.23	0.23	-0.18

Table 2: Correlation coefficient of ISMR and SST anomalies for different indexes of (a) MMCFS, (b) CCSM4 and (c) FLORB model.

- Coupled model over estimate the ENSO-ISMR relationship during August (except FLORB).

ENSO-ISMR correlation in the Coupled model

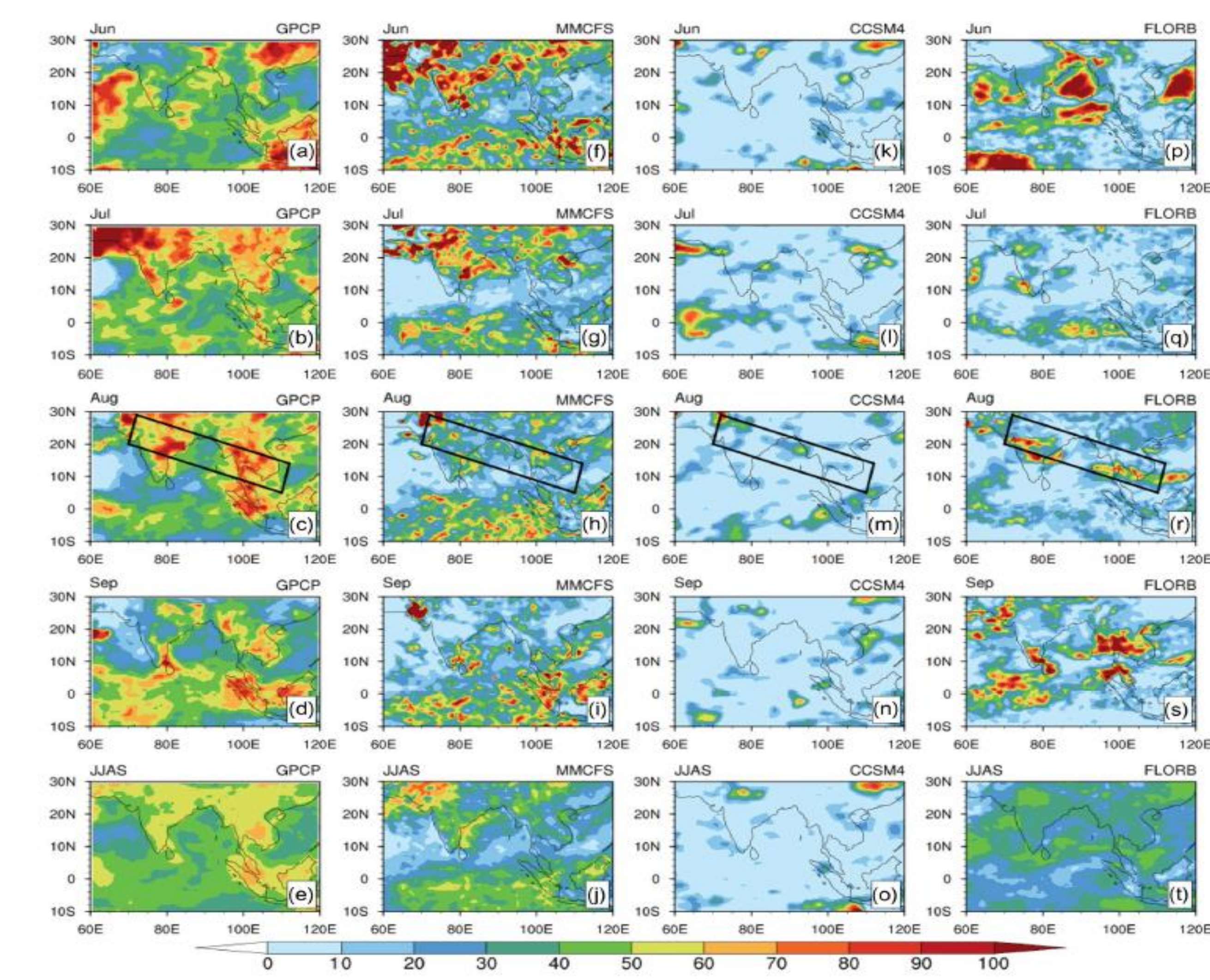

Fig 3: Ratio of synoptic scale (2–10 days band pass filter) variance to total variance in GPCP for June (**a**), July (**b**), August (**c**), September (**d**), and JJAS (**e**). **f–j** is similar to (**a–e**) but for MMCFS, **k–o** is similar as (**a–e**) but for CCSM4 and (p–t) is similar as (**a–e**).

- GFDL-FLORB simulates a better synoptic variance as compared to other models.
- Thus, GFDL-FLORB can simulate weak ENSO-ISMR relationship for August.

Bias in the model

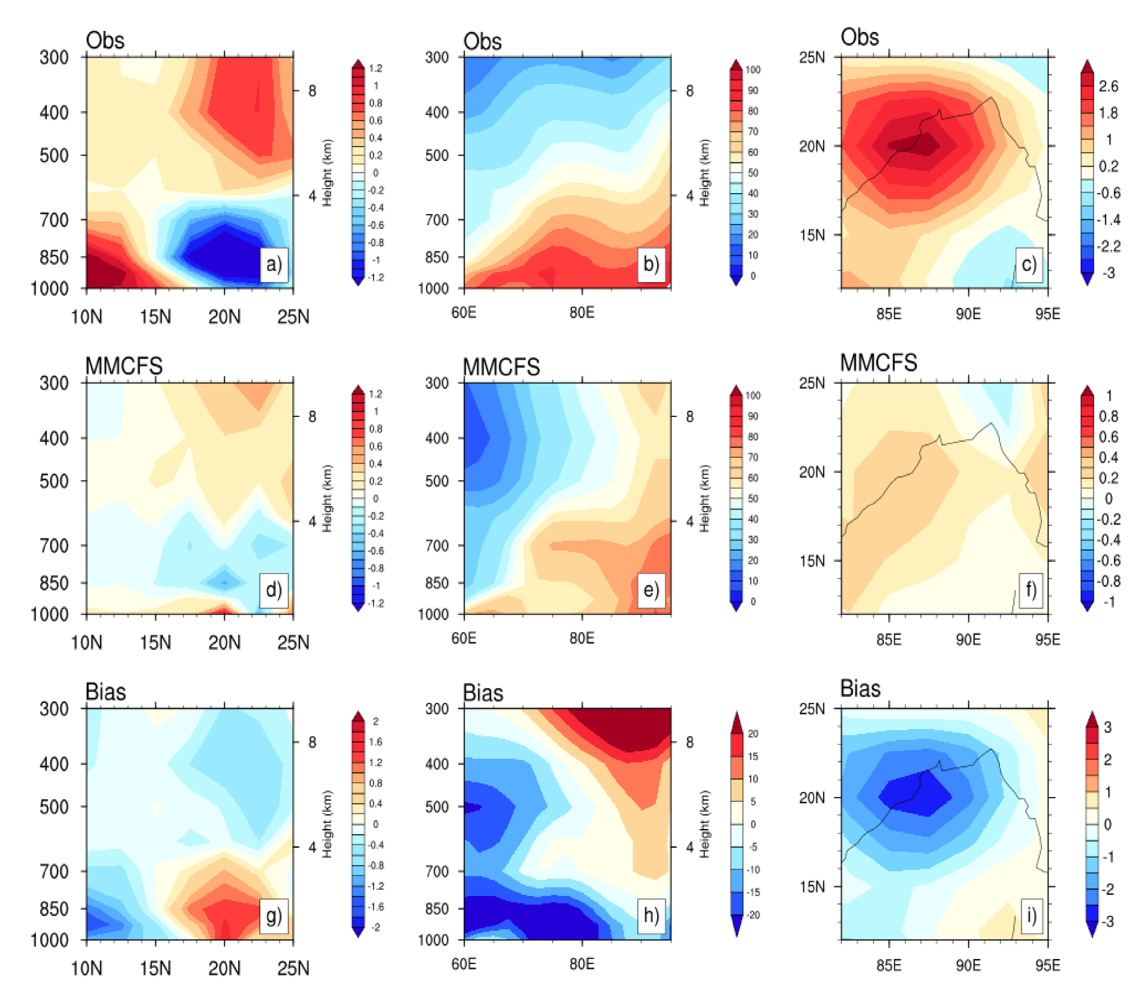

Fig 4: August mean meridional gradient in potential vorticity ($\times 10^{-7}$ K m^2 kg^{-1} s^{-1}) on isobaric levels at 85°E (a), relative humidity (%) averaged over 15°N-25°N (b), and relative vorticity ($\times 10^{-5}$ s^{-1}) at 850 hPa (c) for NCEP reanalysis 2. Similarly, MMCFS is plotted

- MMCFS simulates a weak meridional gradient of potential vorticity and dry bias at the low level.
- Weak cyclonic circulation is simulated over the head BoB.
- These condition represents the unfavourable condition for the growth of LPS.

CONCLUSIONS

- **Predictability of the ISMR is limited by the underestimation of synoptic variability in models.**
- **To improve the predictability of ISMR we need to improve synoptic variance in present-day coupled models.**

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