DOWNSTREAM AND IN SITU GENESIS OF MONSOON LOW-PRESSURE SYSTEMS IN COUPLED MODELS

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Introduction

The monsoon low-pressure systems (LPSs) are synoptic scale cyclonic vortices of ~1000km in diameter embedded in the large-scale Indian summer monsoon circulation. A dozen of such synoptic-scale precipitating vortices originate over the Bay of Bengal (BoB) and adjacent land region, propagate north-westward across continental India, and produce as much as 60% of the total rainfall over Central India. Despite its importance in the hydrological cycle of South Asia, the fundamental genesis mechanisms of LPS are still not fully understood. LPS genesis mechanisms over the BoB are broadly classified into in situ (due to the local processes) and downstream amplification (in which the westward propagating atmospheric disturbances from the Pacific amplify over the BoB), which account for 68% and 32% of total LPS genesis, respectively.

Objectives

The objective of the paper is to propose an automated algorithm to classify LPS genesis over the BoB, broadly into in situ and downstream amplification. Despite its importance to the water security of the country, the fundamental genesis mechanisms of LPS are still not fully understood. In addition, although the current generation of general circulation models simulate LPS, they have relatively low skill in capturing LPS activity. Furthermore, in situ and downstream LPS genesis are not quantified in coupled models yet. The aim of this study is to quantify and understand the spatial and temporal distribution of both the LPS genesis mechanisms in the coupled models. Using this algorithm, we tracked the LPS activity in 11 models from the Coupled Model Intercomparison Project Phase 5 (CMIP5).

Data & Methodology

Daily mean sea level pressure (SLP), relative vorticity (ζ) and winds at 850 hPa, potential vorticity (PV) and temperature at 500 hPa from the European center interim reanalysis (ERAI) and 11 CMIP5 (as listed in Table 1) historical all forcing experiment ensemble r1i1p1 during 1979–2005 are considered for this study.

✓The LPS activity in the models is tracked using the algorithm developed by Praveen et al. (2015) from the SLP, which searches for closed isobars at a 1 hPa interval at every time step. The storm center is considered the centroid of the innermost closed isobar.

✓The LPS genesis is classified broadly into in situ and downstream based on the propagation of ζ anomaly from the Pacific by defining criteria and thresholds (based on the LPS genesis dates of Meera et al. (2019) from ERAI). This algorithm is an automation of the manual classification done by Meera et al. (2019), but with a slight modification to define an additional category named *"uncertain events"*. Uncertain events are LPS genesis where both in situ and downstream mechanisms are present.

✓This algorithm is generalised and applied to CMIP5 models by multiplying defined thresholds with a weighting factor defined as the ratio of the JJAS mean ζ of the model to that of ERAI.

More information regarding the classification criteria is mentioned in Srujan et al. (2021).

Results & Discussion

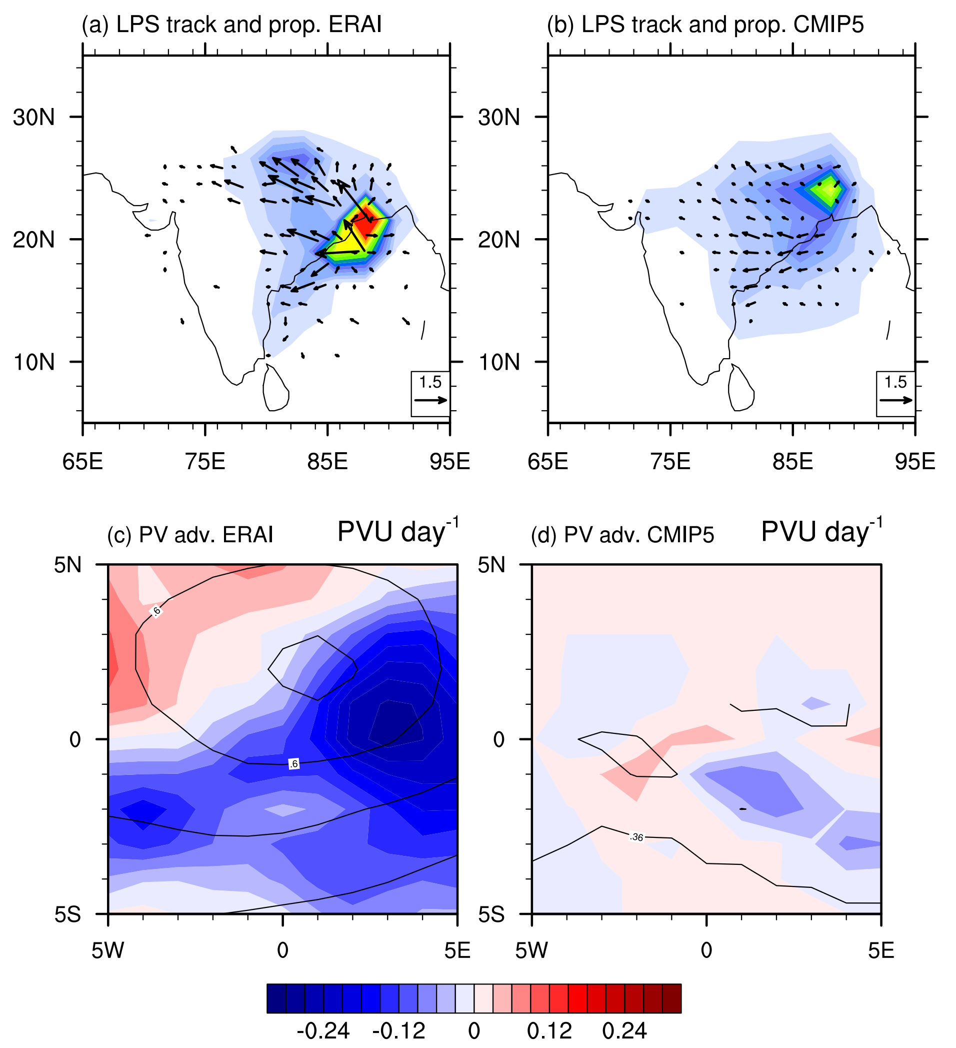

Fig. 1 June to September climatology of track density (units: no. of LPS per grid per season) and LPS propagation vectors (units: m s−1) for (a) ERAI and (b) multi-model ensemble of CMIP5; storm centered composites of 500 hPa–300 hPa average PV (contours; units: PVU) and PV advection (shading; units: PVU day−1) for (c) ERAI, and (d) multi-model ensemble mean of CMIP5.The latitudes and longitudes in (c) and (d) are relative latitudes and longitudes with respect to the LPS center. The calculations are done for the period 1979–2005.

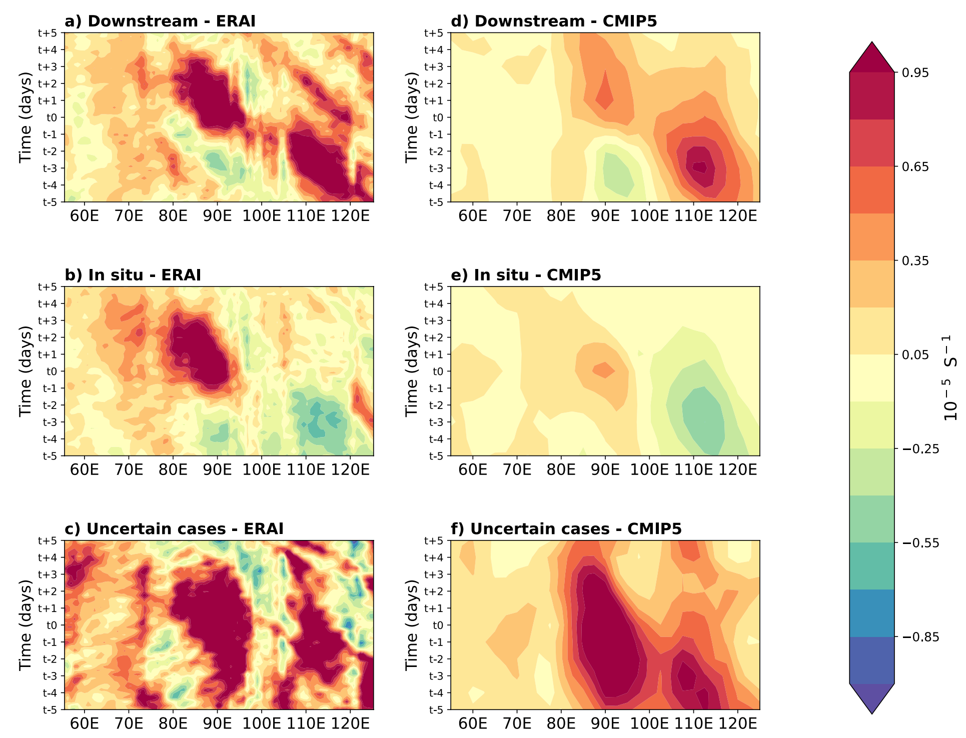

Fig. 2 Lead lag composite of relative vorticity for (a) downstream, (b) in situ, and (c) uncertain LPSs genesis days during 1979–2017 tracked from ERAI reanalysis; (d–f) same as (a–c) but for the ensemble mean relative vorticity composites for the LPS tracked from 11 CMIP5 models during 1979–2005.

Table 1 No. of LPS in ERAI and 11CMIP5 models during 1979-2005.

Sl.no.	Model/ reanalysis	In situ	Downstream	Uncertain
1	BCC-CSM1-1m	149	107	38
2	CNRM-CM5	128	82	41
3	GFDL-ESM2G	116	84	26
4	GFDL-ESM2M	113	53	21
5	IPSL-CM5A-MR	29	10	4
6	IPSL-CM5B-LR	14	7	2
7	MIROC-ESM	46	33	17
8	MIROC-ESM-CHEM	59	30	9
9	MIROC5	120	61	18
10	MRI-ESM1	102	50	18
11	MRI-CGCM3	97	42	21
12	ERAI	105	52	11

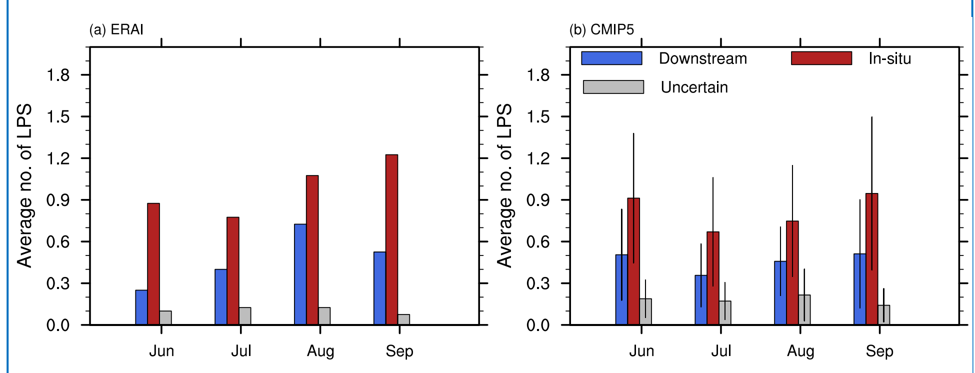

Fig. 3 Average monthly frequency of the downstream, in situ, and uncertain LPS for (a) ERAI reanalysis for the period 1979–2017 and (b) ensemble mean of 11 CMIP5 models for the period 1979–2005. The error bars in (b) indicate the inter-model spread (±1 standard deviation) in the LPS frequency for each month.

Summary/Conclusion

✓A simple objective algorithm has been developed to evaluate the synoptic activity in coupled models. This algorithm was found to have a robust skill in classifying the LPS based on their genesis when tested on the reanalysis dataset.

✓The propagation vectors of LPS in CMIP5 models show a westward propagation instead of the observed north-northwestward trajectory.

✓It is found that a weaker PV advection causes a weaker and incoherent propagation of LPS in CMIP5 models.

✓The core region of LPS genesis is shifted northward, with the majority of them forming over land in CMIP5 models.

✓Substantial inter-model variability has been observed in the frequency of in situ and downstream LPS genesis, ranging from 47% to 67% and 23% to 37%, respectively. About 12% of the LPS genesis in CMIP5 models is attributed to the "uncertain category". It is observed that all models have predominantly in situ LPS genesis mechanisms that are consistent with the observations.

✓The genesis of downstream LPS happens too early in the monsoon season (June and July), whereas it peaks in August and September in observations. The stronger Rossby wave activity in June and July in the models qualitatively explains the higher downstream LPS genesis.

Acknowledgements & References

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