A Dynamical Framework to Understand and Predict the Indian Summer Monsoon Low Pressure Systems

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Background and Objective

- The Indian summer monsoon low-pressure systems (LPS) are broadly classified into in situ and downstream amplification based on their genesis mechanisms.
- Earlier studies suggested that Tropical Cyclones (TCs) making landfall over the east China coast trigger westward propagating waves and might be responsible for the downstream amplification of LPSs over the Bay of Bengal (BoB). However, the nature of TCs responsible for the triggering of downstream amplification is not fully investigated.
- **The main objective of the current study is to establish a cause-effect relationship (and thereby the existence of predictability) between West North Pacific (WNP) TCs activity and the downstream genesis of LPSs over the BoB.**

Material and Methodology

- The LPS activity in the models is tracked using the algorithm developed by Praveen et al. (2015) from the Sea Level Pressure (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 storm centers identified from consecutive time intervals of gridded SLP data are connected to get the track.
- The identified LPSs are broadly classified into in situ and downstream using the algorithm proposed by Srujan et al. (2021) which is an automation of the classification technique used by Meera et al. (2019) based on the westward relative vorticity propagation from the WNP prior to the initiation of LPS
- The WNP TCs are divided into six clusters using the mixture polynomial regression model to fit the trajectories of TCs following the Camargo et al. (2007). The number of clusters is selected on the basis of a threshold log-likelihood (Δl) value of 0.05. The termination of clusters happens when the Δl value falls below the threshold value for two consecutive times. The Δl values between clusters 6,7 and clusters 7,8 are less than 0.05, and therefore a total of six clusters are considered.
- The transfer entropy (TE), which is a measure to quantify the information transferred from one variable to another variable, is calculated between the PC1 and the SLP over the domain 90˚E - 120˚E, 15˚ N – 25˚N.

Methodology

- Three experiments have been conducted including a control run in the Community Atmospheric Model (CAM5) by modifying SST over the Pacific.
- In the experiment 2, the SST over the region of TC genesis density over the West to central Pacific (From clusters A to D) has been raised; designated as Expt. CAD.
- In the experiment 3, the SST over the region of TC genesis density over the West Pacific (West of 120E, cluster B alone) has been raised; designated as Expt. CB.
- The model runs were carried out for of 15 years.

Results

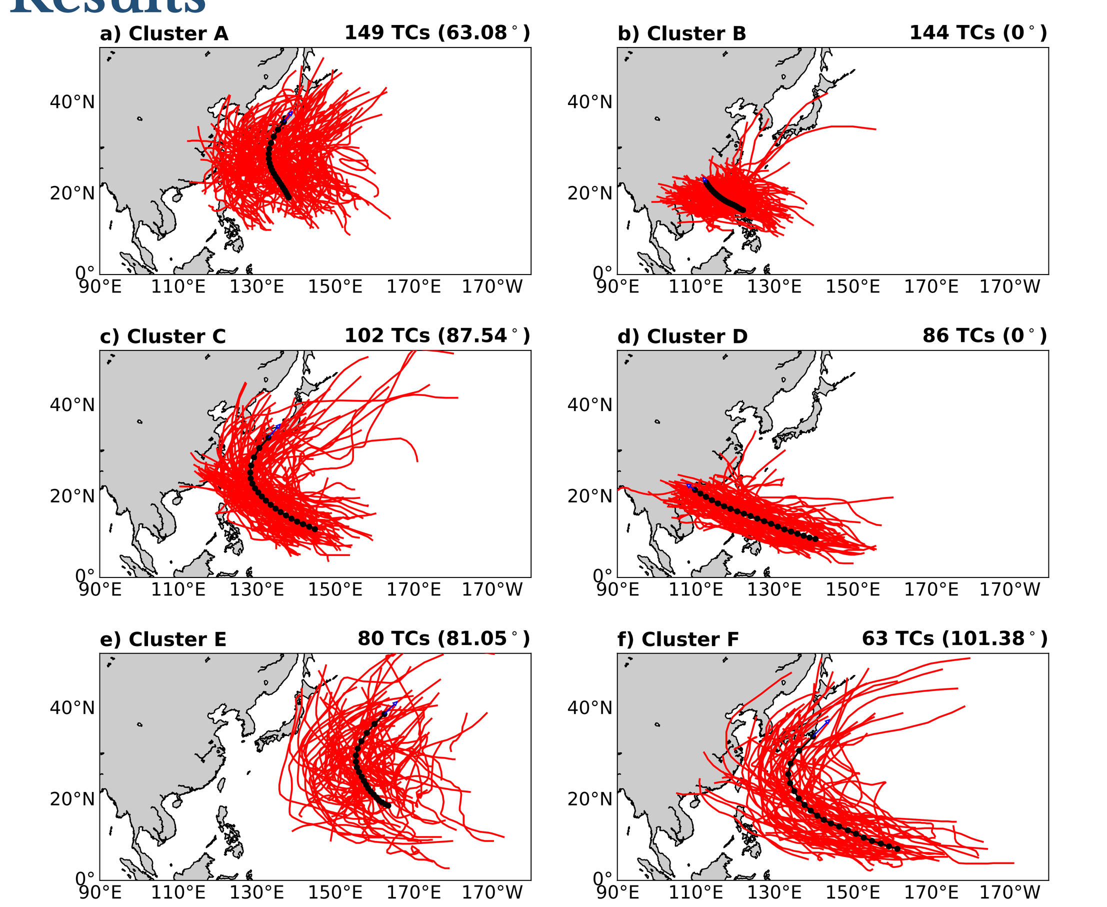

Fig. 1 The tracks of TCs over WNP from 1979-2017 during JJAS divided into six clusters from A-F with the mean track (Black line) of TCs interpolated to a length of 5 days in each cluster. The number of TCs in each cluster is indicated on top right side of the panels. The blue arrows in the mean track indicates the direction of the track. The values in brackets in each subplot title represents the angle of recurvature (in degrees) of mean TC track of each cluster.

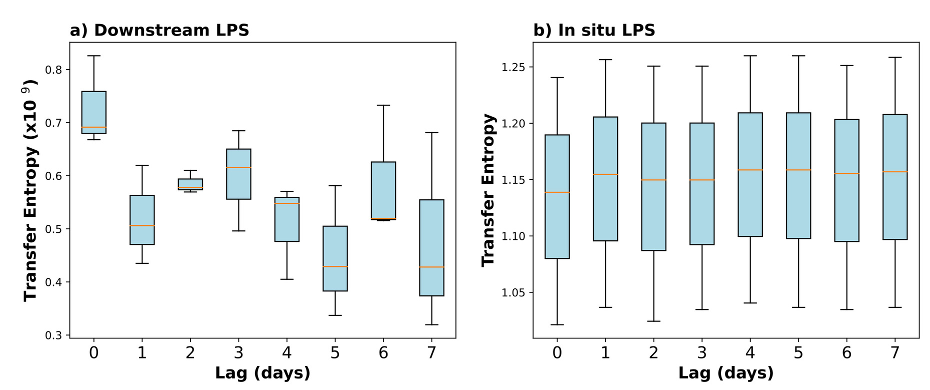

Fig. 2 Transfer entropy (TE) between PC1 of Rossby filtered OLR over the WNP and SLP over the BoB computed for (a) downstream and (b) in situ LPS at different lags. The box plot indicates the 25th and 75th percentile, and the orange bar represents the median. Lag-0 indicates that both the time series have the same start and end dates and with increasing lags, the PC1 time series is shifted ahead of a fixed SLP time series. At each lag, the TE is computed three times by varying the length of the time series.

Results

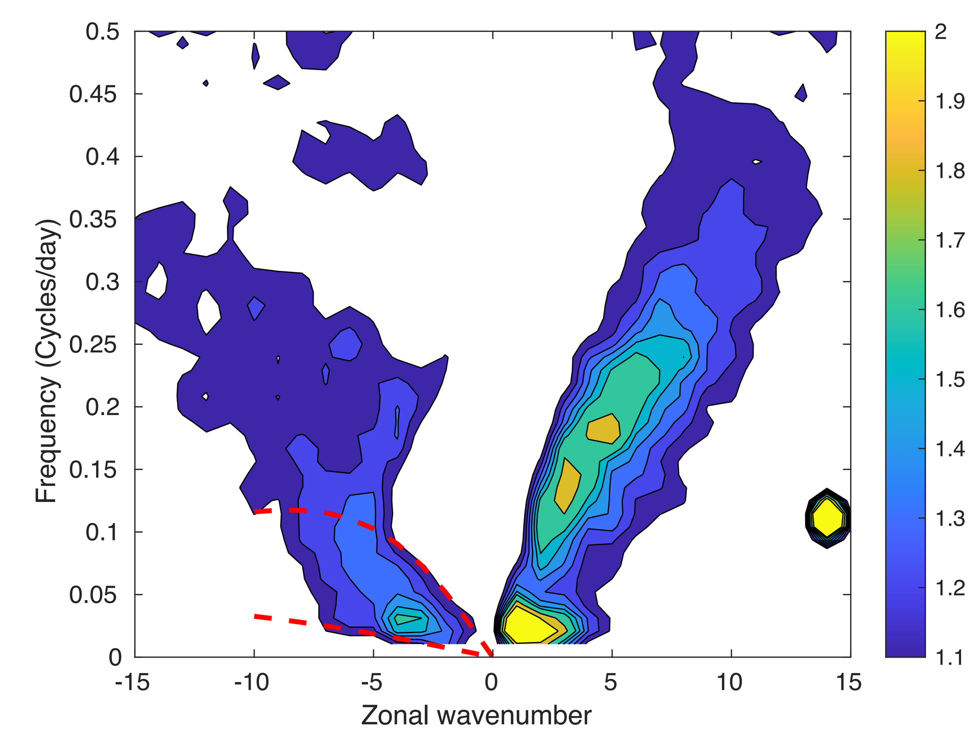

Fig. 3 The Wheeler Kiladis symmetric/background wavenumber-frequency spectra of daily outgoing longwave radiation anomaly from 1979 to 2017 (June-September). Red lines represent theoretical dispersion for n=1 Rossby waves for an equivalent depth equal to 10 m and 100 m, respectively.

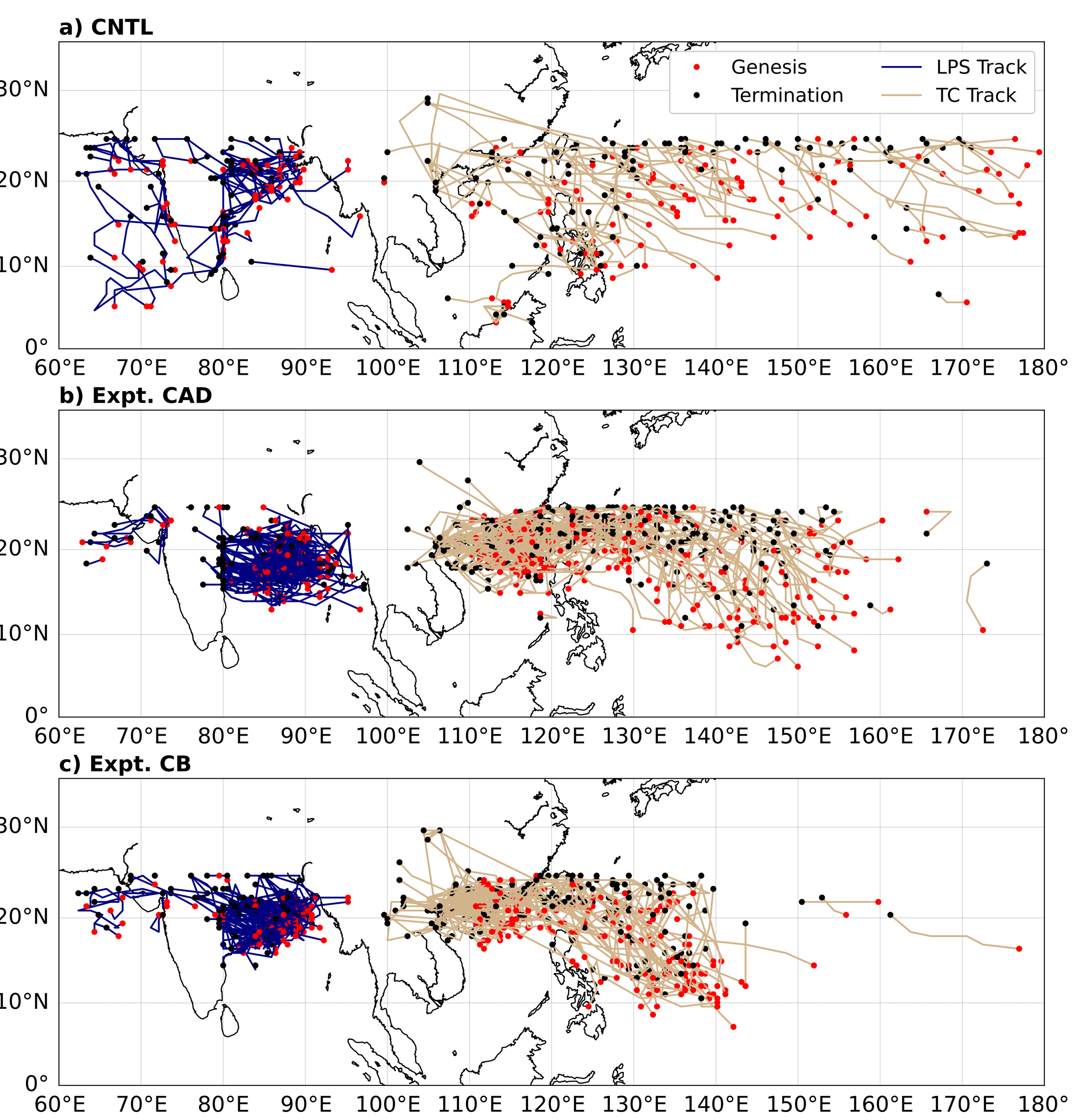

Fig. 4 The tracks of low-pressure systems (LPS) and tropical cyclones (TC) simulated in a) Control run (CNTL), b) Experiment CAD (Expt. CAD), and c) Experiment CB (Expt. CB). The blue and orange lines are the tracks of LPS and TC, respectively. The red and black points indicate the genesis and lysis of the storm, respectively.

	Downstream LPS	In situ LPS	#TCs simulated over WNP
Control run (CNTL)	*42*	*44*	*118*
Experiment 2 (Expt. CAD)	*40*	*74*	*284*
Experiment 3 (Expt. CB)	*71*	*73*	*200*

Table 1 Statistics of LPS and TCs simulated in the sensitivity experiment.

Conclusions and Way forward....

- A causal relationship is found between Rossby waves originating from the TCs of the WNP and SLP variation over the Bay of Bengal.
- Landfalling TCs over the South China Sea are associated with LPS genesis over the BoB.
- 83% of the downstream LPS associated with top 4 clusters (A to D).
- The SST warming over the WNP ocean induces more TCs over WNP and further increases the synoptic activity of BoB. Clustering of synoptic activity over the BoB is also observed.
- The prediction of monsoon LPS activity is highly desirable as these systems account for the synoptic-scale variability that contributes more than half of the seasonal rainfall over the plains of continental India.
- Such a relationship can be useful for selecting parameters for deep learning models. With the recent claims of synoptic-scale predictability by deep learning models (Sinha et al., 2021). A reliable prediction of downstream LPS genesis over the BoB based on WNP TC genesis might be possible.

References

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Acknowledgements and contact

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