Dynamical Aspects of Heavy Rainfall Events over Southern Peninsular India during Northeast Monsoon Season and association with Indian Ocean Warming and Madden Julian Oscillation

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Introduction

- The Northeast Monsoon is an important season for southern Peninsular India, particularly for Tamil Nadu, which accounts for about 60% of the annual rainfall. It is significant for the agriculture and hydrology of the region.

- The Northeast Monsoon occurs from October to December and is characterized by a shift in wind patterns from southwesterly to northeasterly that brings moisture-laden winds from the Bay of Bengal towards the southeastern coast of India.

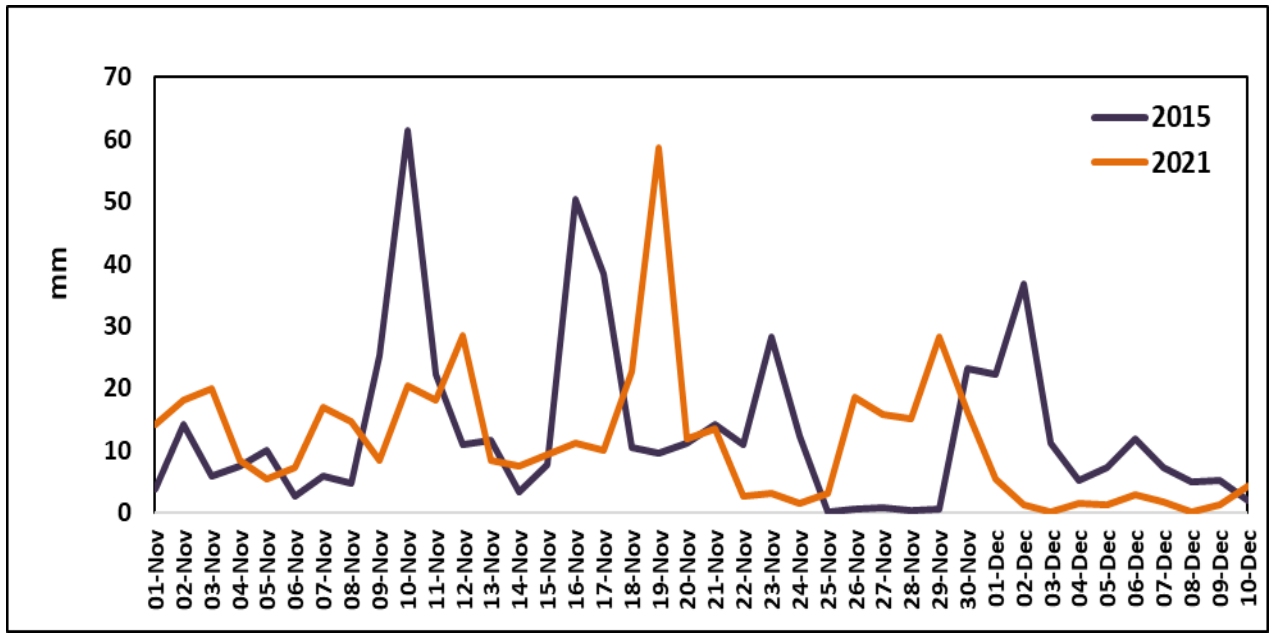
- Southern Peninsular India experienced floods associated with heavy rainfall events during the northeast monsoon in 2015, which was an El Niño year. Several studies have been conducted to understand the November 2015 heavy rainfall event. These studies have emphasized the role of El Niño in the occurrence of heavy rainfall activity over southeastern Peninsular India.

- The southern part of India experienced heavy rainfall activity during November 2021, which was a La Nina year. This study aims to reexamine the relationship between El Niño and heavy rainfall events, as well as their connection with the Madden-Julian Oscillation (MJO). The MJO was in its 4th phase for 15 days in November 2015 and for 17 days in November 2021.

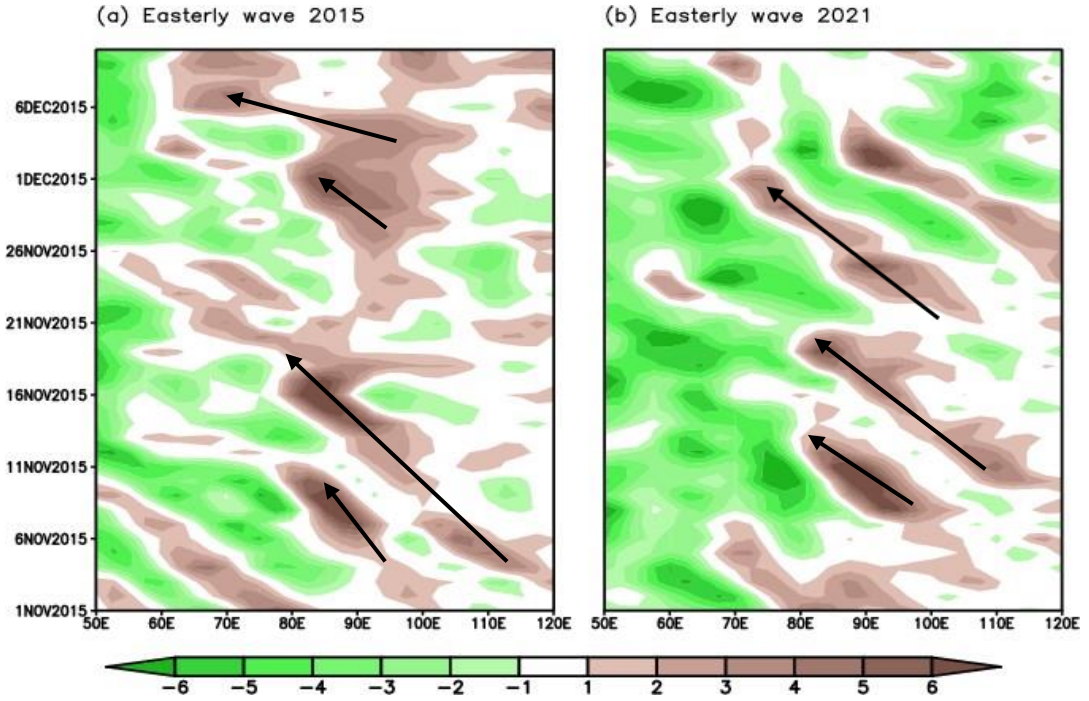
Data and Methods

- Daily gridded rainfall data from IMD (0.25*0.25) is used for the analysis.
- SST data from Hadley Centre Sea Ice and Sea Surface Temperature dataset version 1.1 (HadI-SST 1.1, Rayner (2003))
- All the other datasets are obtained from ERA5 reanalysis, which have a 0.25° by 0.25° horizontal resolution. These datasets include zonal, meridional, and vertical wind at different levels, vertically integrated moisture divergence (VIMD), top net longwave radiation (TTR), which is equal to the negative of outgoing long wave radiation, mean sea level pressure (MSLP), vertically integrated moisture flux (VIMF) data for a period from 1981-2021.
- The Real-time Multivariate MJO indices (RMM1 and RMM2) obtained from http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/RMM/.
- The percentile technique is employed here to detect heavy rainfall events (HRE). When the daily rainfall exceeds 95^{th} percentile threshold, it is considered as one HRE.
- Correlation and composite analysis are employed in the analysis.
- Linear trend analysis of HRE in different phases of MJO was performed.

A comparative study between the rainfall events during 2015 and 2021

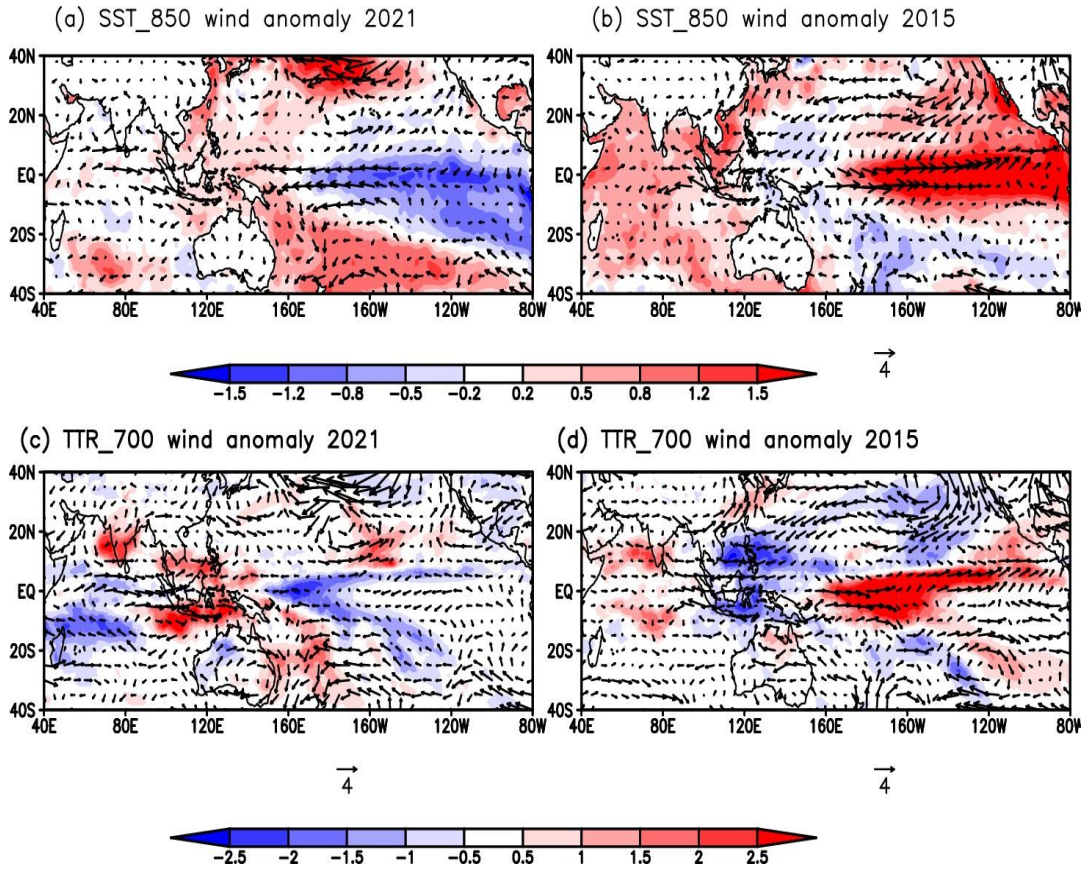


The daily rainfall averaged over southern Peninsular India (6-15, 65-85E) for 2015 and 2021



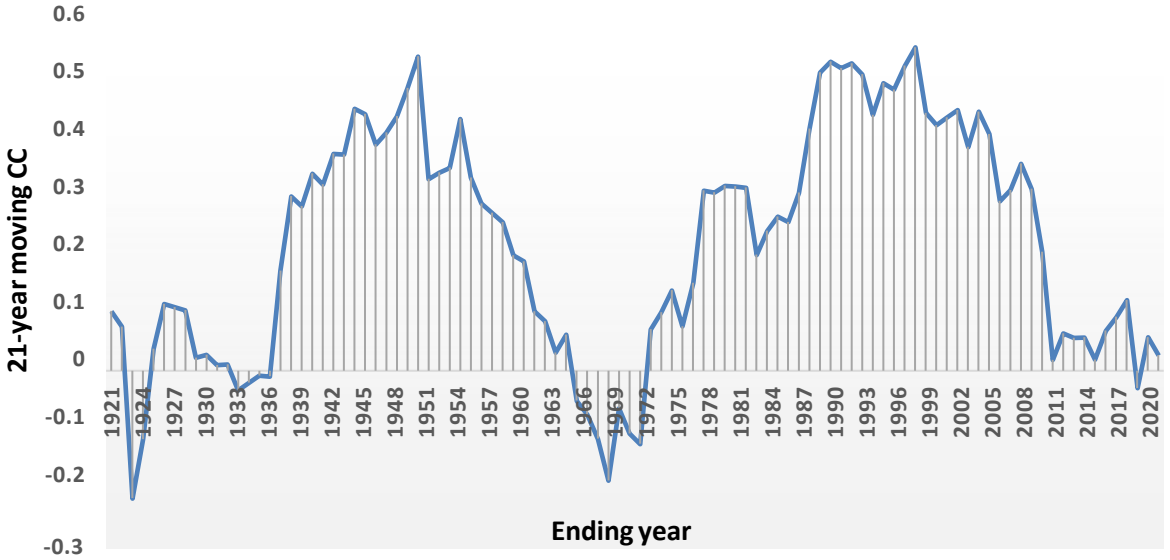
Hovmöller (time-longitude) diagram for meridional wind anomaly averaged over 5°-20°N.

Synoptic conditions during 2015 and 2021



SST and 850hPa wind anomaly in (a)2021 and (b)2015 and TTR (negative OLR) anomaly and 700hPa wind in ()2021 and (b) 2015.

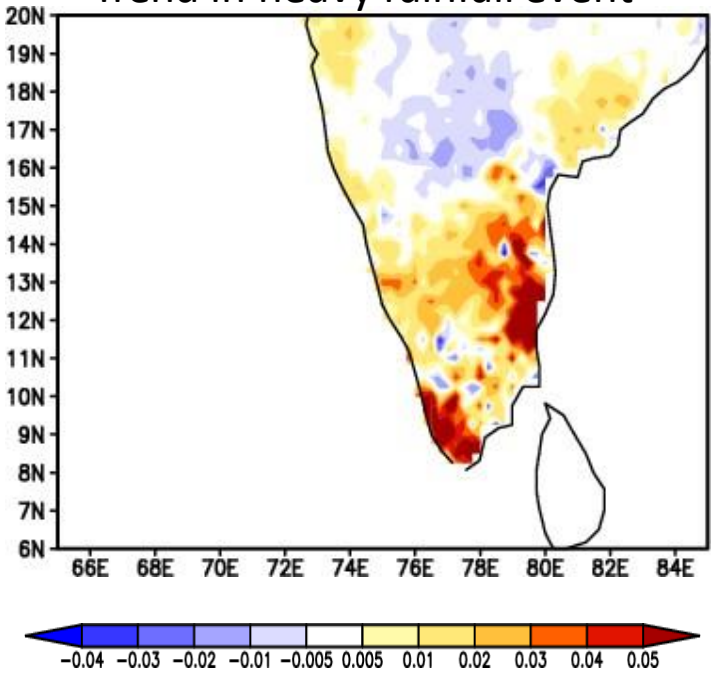
Relation between HRE (NEM) and Nino 3.4 SST(OND)

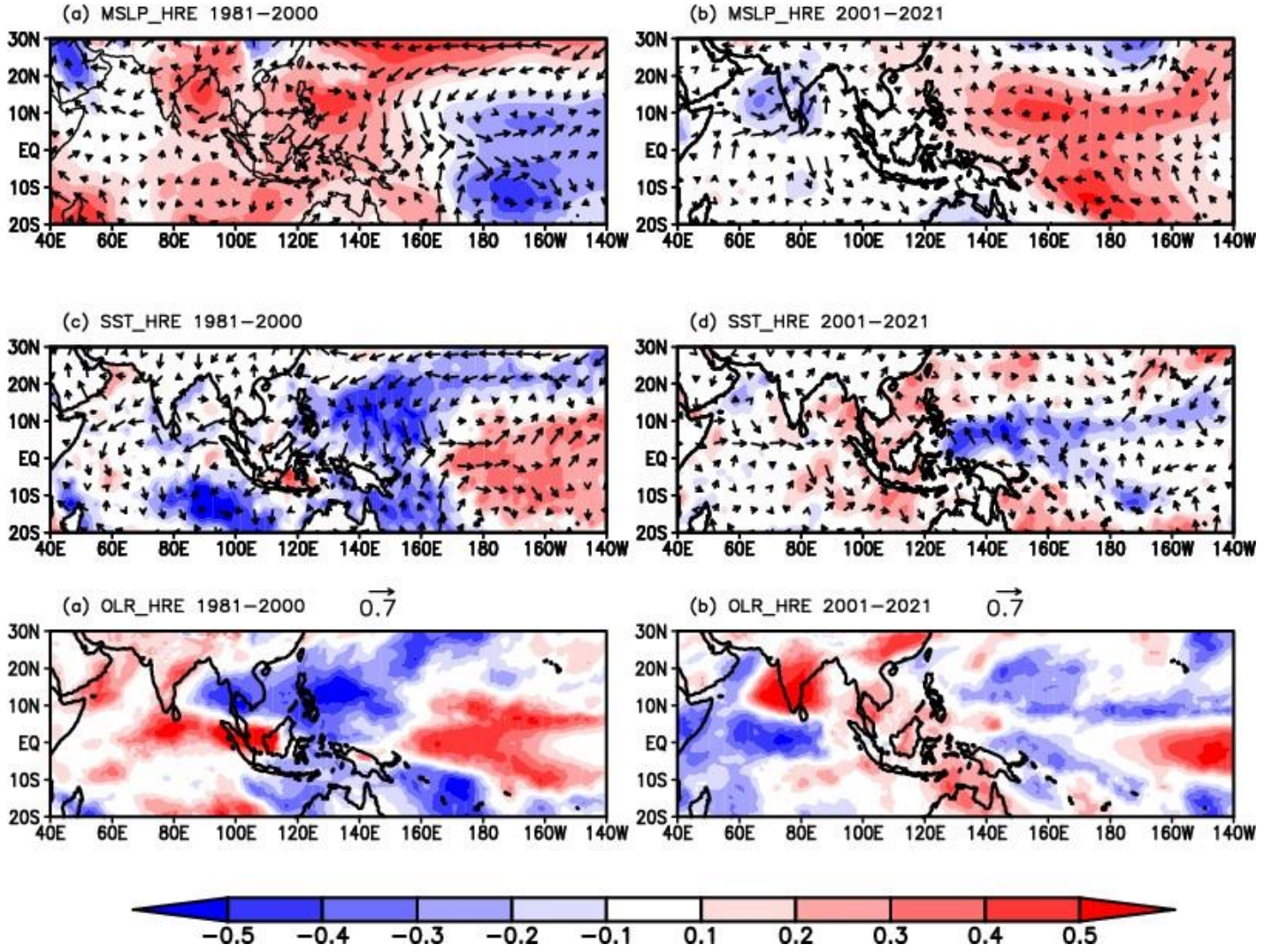


- The relationship between El Nino and northeast monsoon rainfall is weakening in recent years (Rajeevan et. al,2012 ; Yadav et al., 2011).

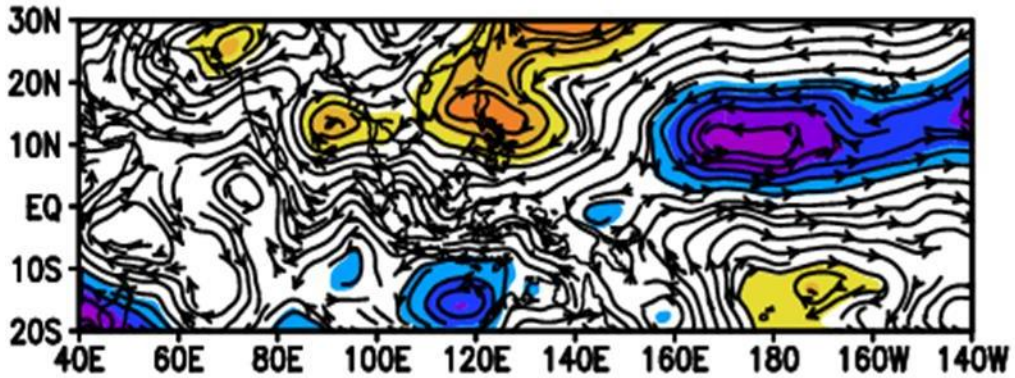
Trend and epochal variation in heavy rainfall events

Trend in heavy rainfall event

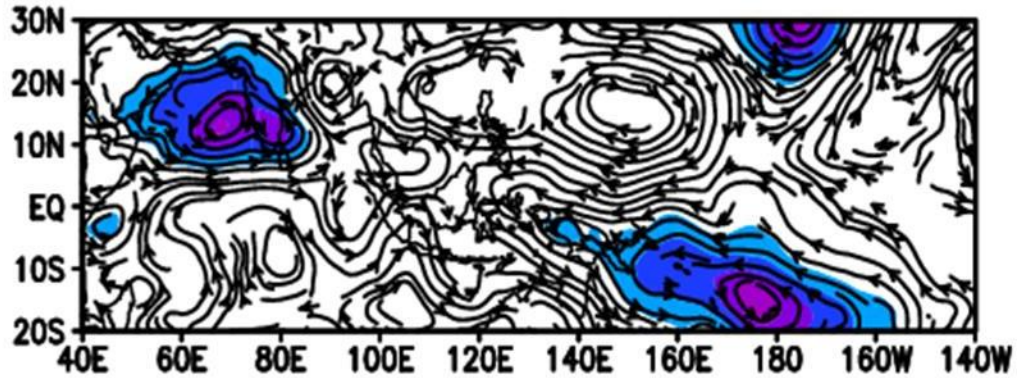




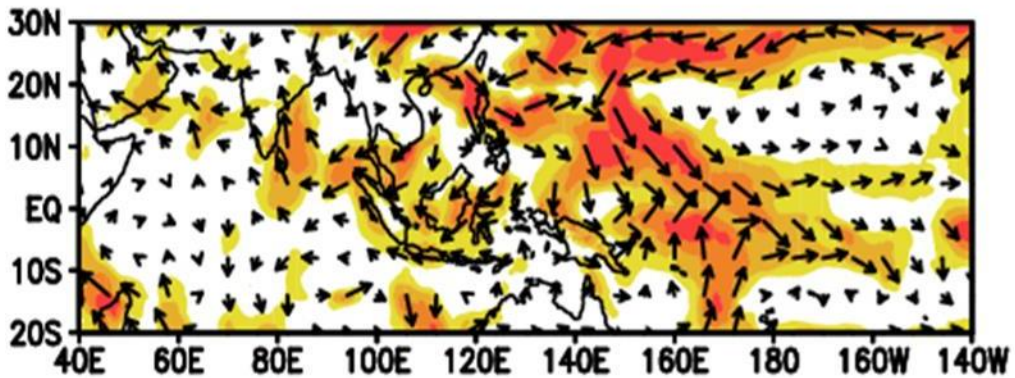
Stream- HRE 1981-2000



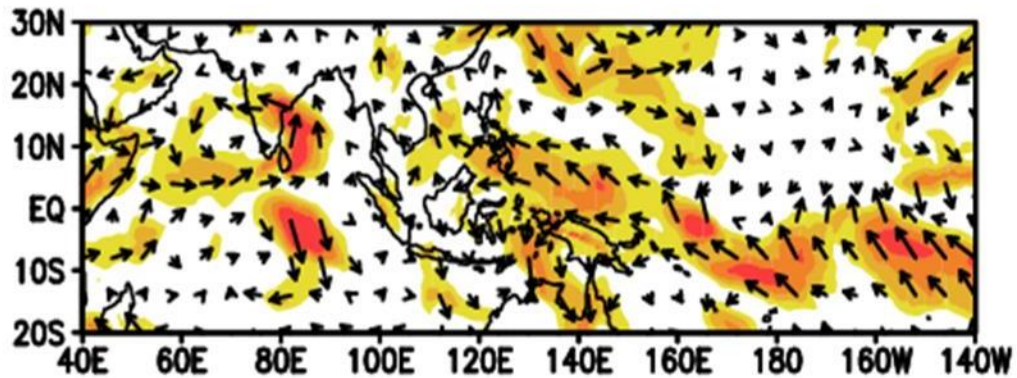
Stream- HRE 2001-2021

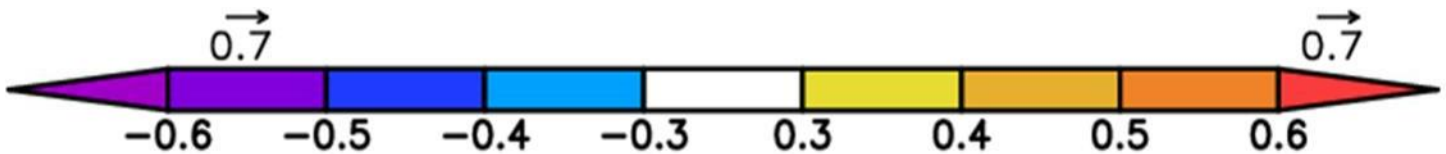


VIMF-HRE 1981-2000

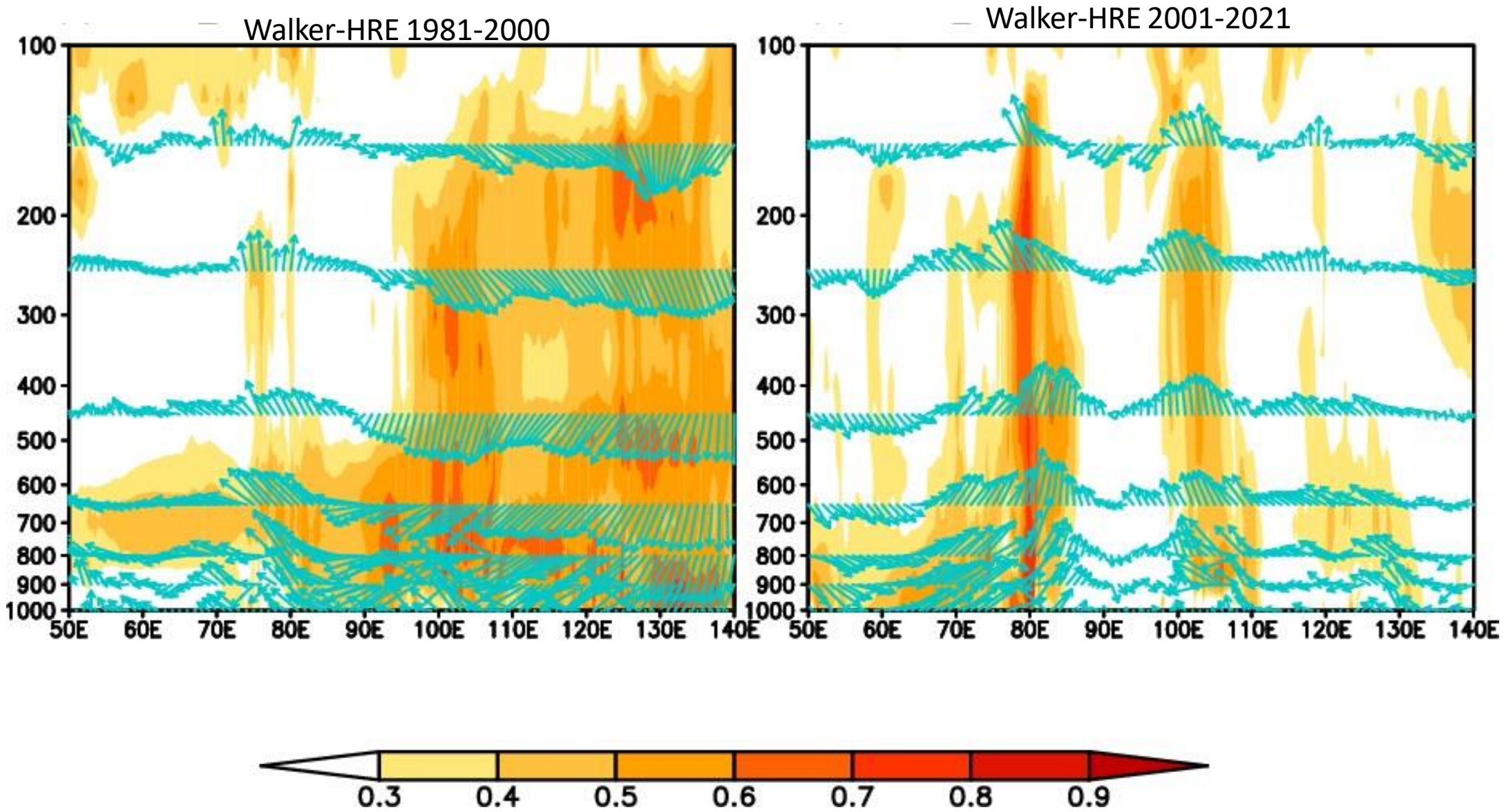


VIMF-HRE 2001-2021



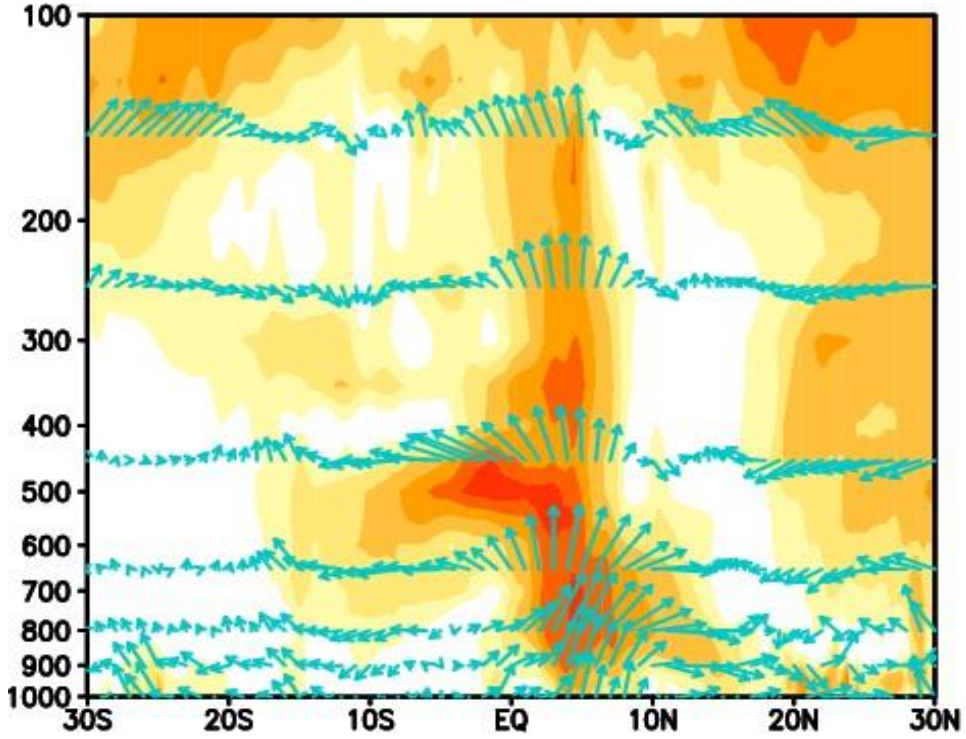


Relation of HRE with Walker circulations

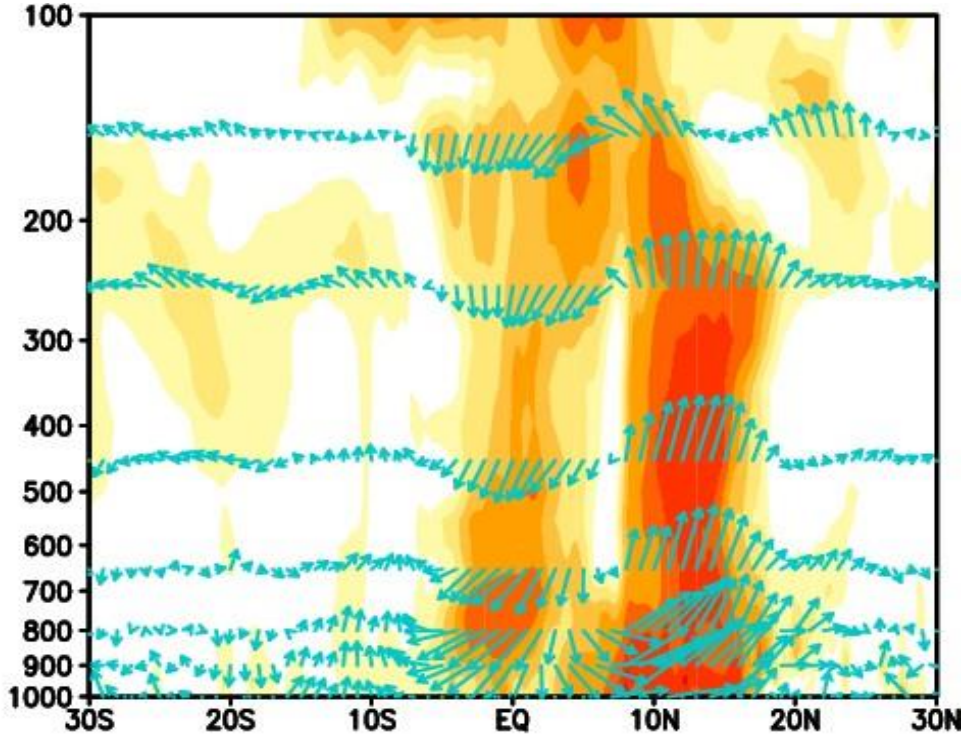


Relation of HRE with Hadly circulations

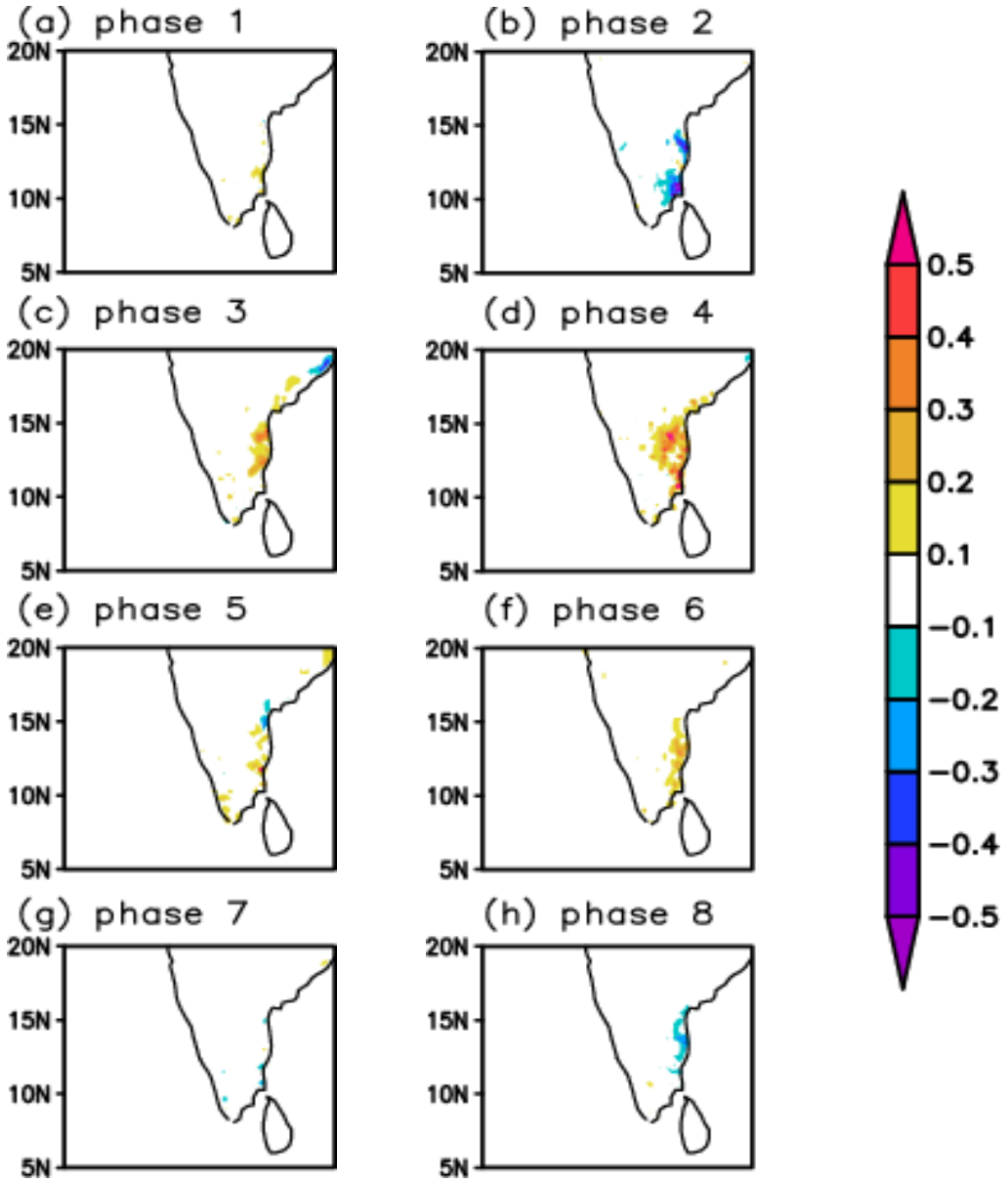
Hadly-HRE 1981-2000

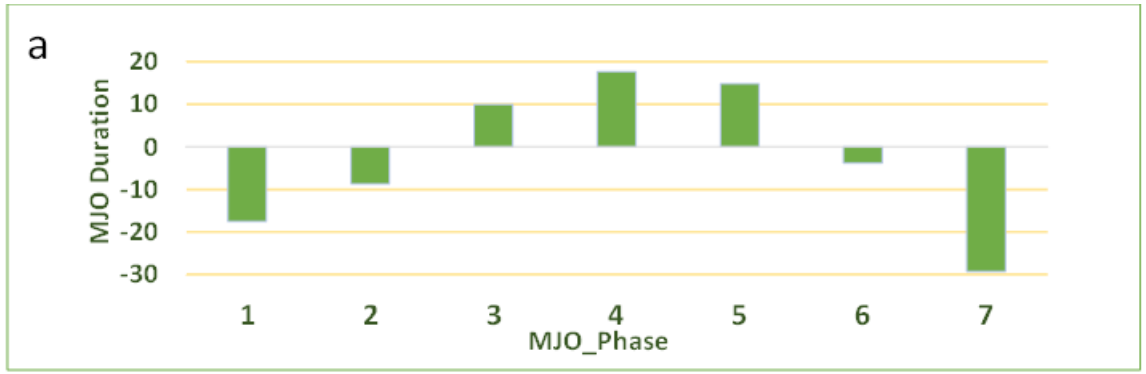


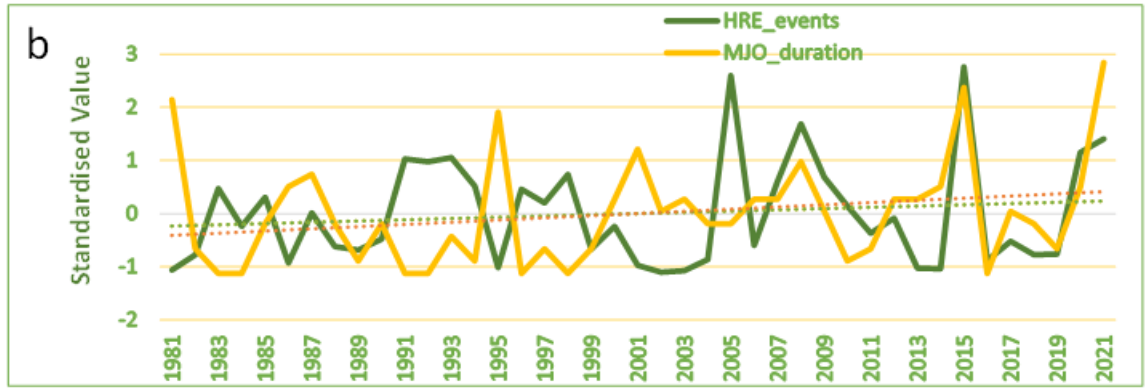
Hadly-HRE 2001-2021

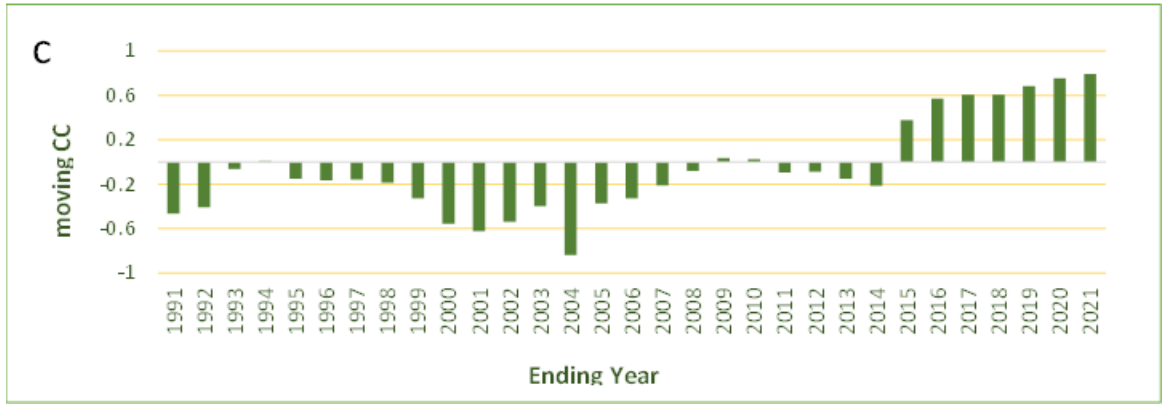


Association of MJO and HRE

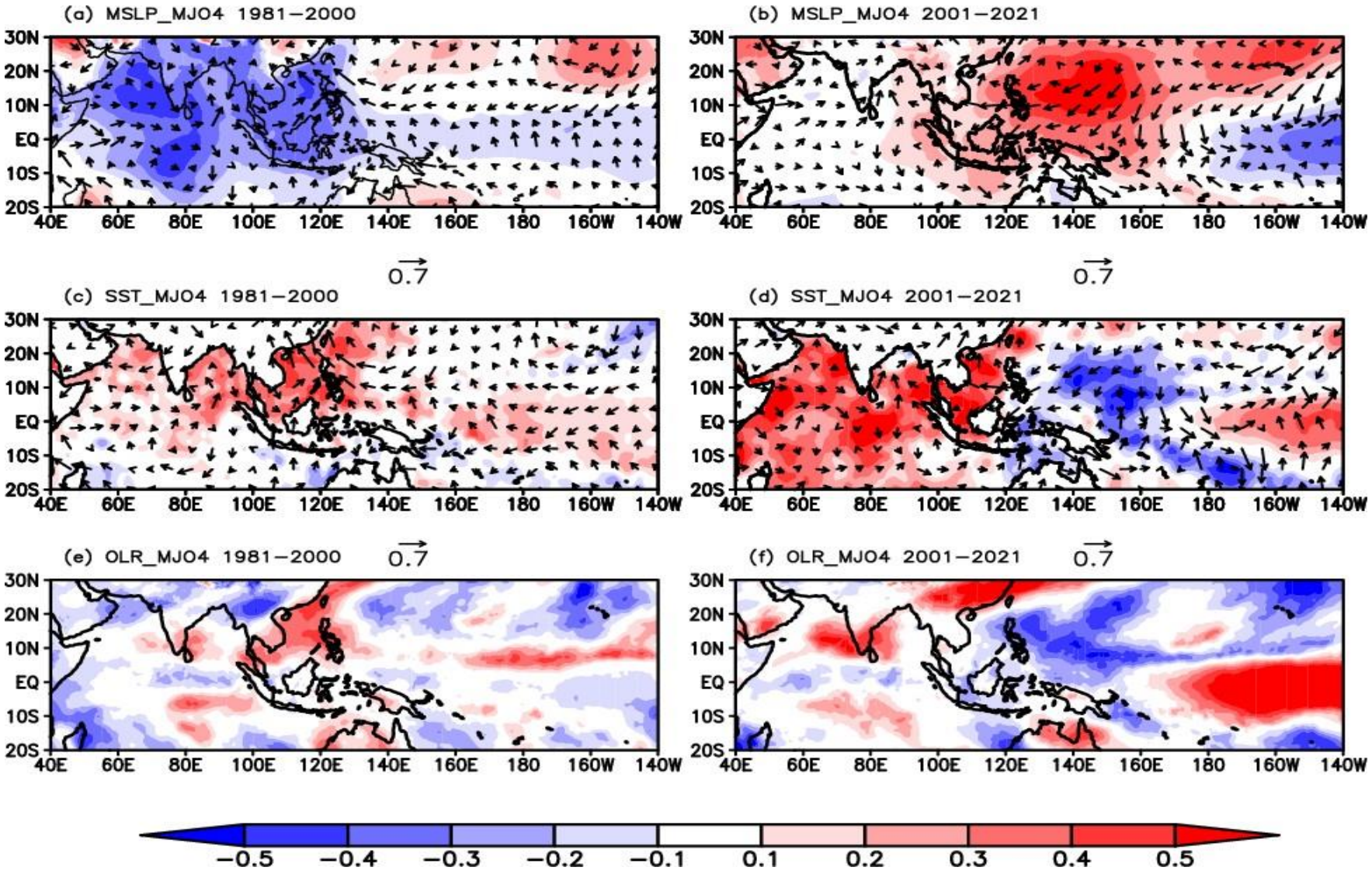




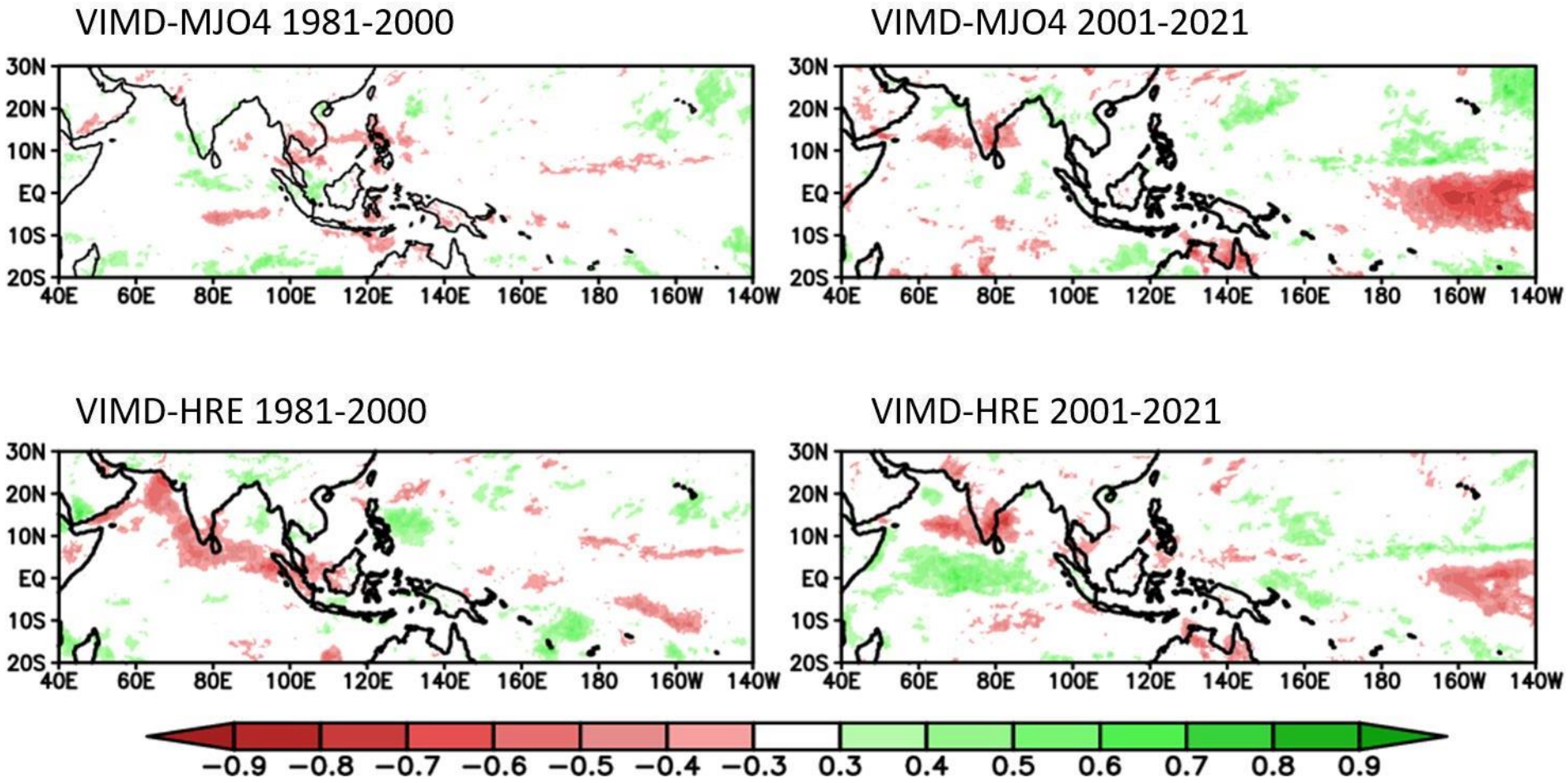




Association of MJO-4 with oceanic-atmospheric variables



The duration of MJO-4 in the recent epoch (2001-2021) is influenced by the El Nino.



- The MJO initiation over the maritime continent during the El Nino year can be due to the moistening of the eastern Pacific Ocean and weakened easterly wind (T.Wang and T. Li, 2021).
- In recent years the influence of El Nino on MJO duration over the maritime continent has increased.
- The enhanced moisture convergence over southern Peninsular Indian region and surrounding Indian Ocean region due the enhanced MJO convection over maritime continent.

Summary and conclusion

- The changes in synoptic conditions favorable for the heavy rainfall events over southern Peninsular India during the post-monsoon months of November and December in recent years (2001-2021) are analysed in this study. The warming of the eastern Indian Ocean and western Pacific Ocean (Indo-Pacific Ocean) and the cooling of the western-central Pacific Ocean i.e. the SST gradient in the Indo-Pacific Ocean, the MJO in the fourth Phase, presence of cyclonic circulation over south peninsular India and Arabian sea are found to be a crucial factor in the formation of Heavy rainfall events.

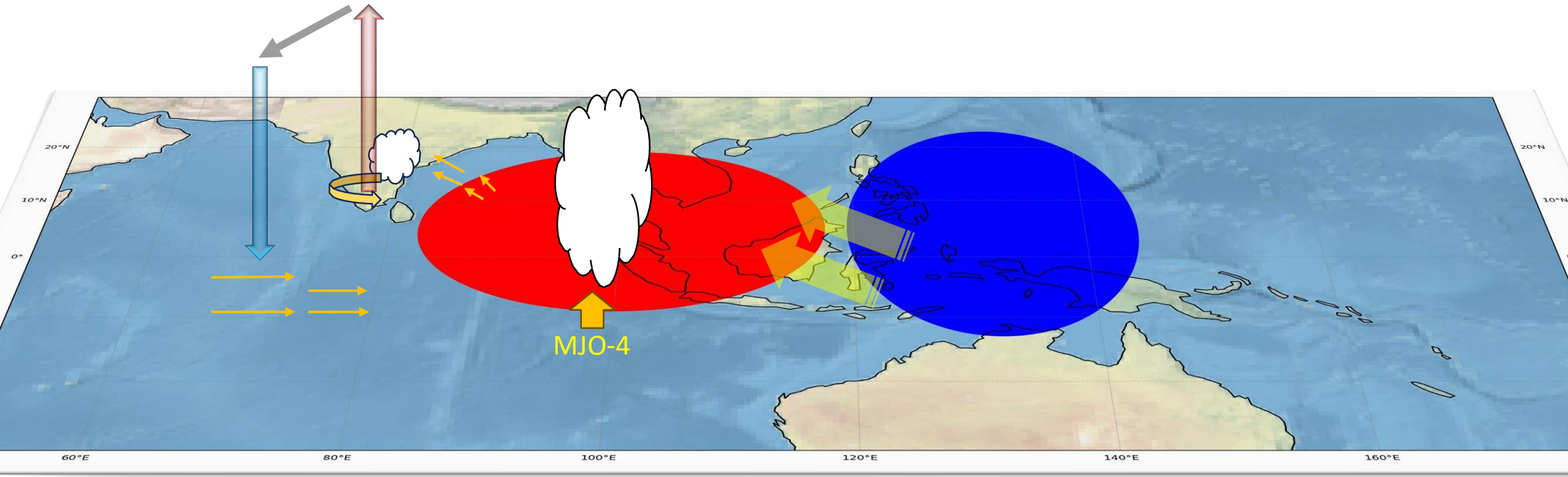
- The sea surface temperature (SST) gradient within the Indo-Pacific Ocean facilitates moisture transport towards the maritime continent region from the West Pacific Ocean which supports the active phase of the MJO during its fourth phase. Additionally, the easterlies developed due to this SST gradient play a role in limiting the eastward propagation of MJO, thereby prolonging its duration in the fourth phase.

- Analyzing mean sea level pressure (MSLP) and 850 hPa wind, positive anomalies of MSLP and anticyclonic circulation were observed over the Bay of Bengal (BOB) in the early epoch. However, in the recent epoch, a cyclonic vorticity with negative MSLP anomalies over southern Peninsular India has been observed. The low-pressure systems formed over the eastern Indian Ocean region during the MJO-4 phase move westwards and get strengthened due to the presence of the westerly wind in equatorial Indian ocean.

- The moisture from the western Indian Ocean is found to be contributing in the recent epoch while the moisture for HRE was from the eastern Indian Ocean in the early epoch.

- In recent years, there is a weakening in the relationship between Nino3.4 SST and NEM rainfall was observed.

- The present study proposes a mechanism, the SST gradient present in the Indo-Pacific Ocean (warm eastern Indian Ocean and cool western Pacific Ocean) enhances the active MJO in the maritime continent and strong easterly wave activity in the eastern Indian Ocean. These synoptic conditions along with the strong equatorial westerlies towards the eastern Indian Ocean are favorable for the strengthening of cyclonic circulation with strong ascending wind anomalies over Southern Peninsular India and descending wind anomalies over the equatorial Central Indian Ocean, which leads to the heavy rainfall activity over the southern Peninsular India.



THANK YOU

References

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- Wang, T., & Li, T. (2022). Diversity of MJO initiation regions and processes. *Journal of Climate*, *35*(20), 6721-6740.