Understanding the Dynamical Relation of MJO with Indian Summer Monsoon Onset and Progress

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INTRODUCTION

- **The unique location of India with Arabian sea in west, Bay of Bengal in east, great Himalayas in north and western and eastern mountain Ghats generally affects/controls the wind circulation structure and temperature gradient, result into the large scale monsoon dynamics over the continental India and surrounding regions.**
- **Indian Summer Monsoon (SW monsoon in June-September) plays an important role in the weather and climate variability over Indian region.**
- **The south west monsoon onsets around first week of June, over the south-western tip of Indian Peninsula is considered as the onset over Indian subcontinent and its effect lasts for four months (June-September).**

- **The accurate prediction of Indian summer monsoon (ISM) Onset and Monsoon rainfall for India as well as in local scale, in advance is important as the rainfall transition and its progress has direct impact on various sector like agriculture, health and economy over the continent of India.**
- **Large scale processes like ENSO, IOD and MJO has major role in the variation in usual pattern of onset and progress of ISM.**

HOW MJO AFFECTS ISM ?

- **The most important intra-seasonal phenomenon in the tropical atmosphere i.e. Madden-Julian Oscillation (MJO) was discovered by Paul Julian and Roland Madden.**

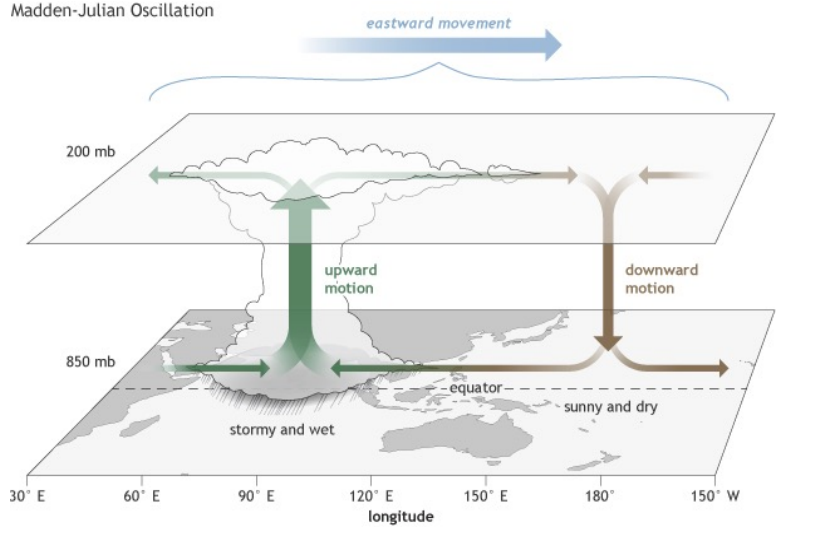
- **MJO is an important climate driver in the tropical weather around the glob, also known as a east ward moving band of rain clouds that travels around the globe spanning 12,000-20,000 km across the tropical oceans.**

- **During its travel period, the band of rain clouds comes in contact with the large pool of warm water and this helps a robust impact on its life cycle.**

MJO is Traversing phenomenon and it is most prominent over the Indian ocean and pacific ocean.

Indian ocean –Low Pressure of MJO –Good rainfall in India

Pacific ocean –Low Pressure of MJO & Indian ocean – High Pressure of MJO - no rain in India



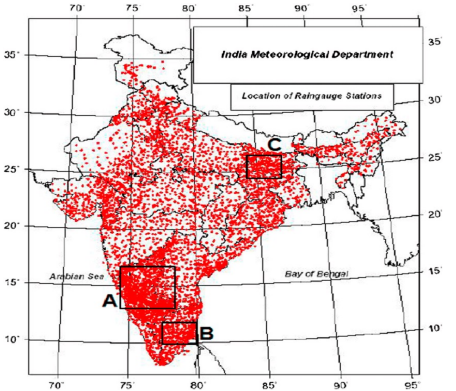
MOTIVATION

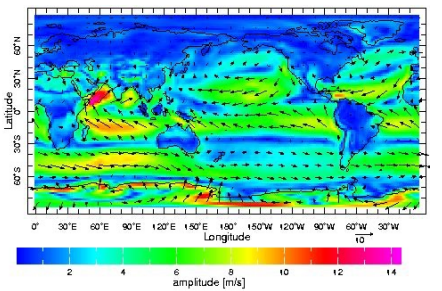
- The Monsoon system is very complex as it is dynamical in nature controlled by the ocean and atmosphere
- There is a need to understand the various physical processes and aspects of the monsoon system at global and regional scale.
- Many studies are being carried out in several countries like Australia, Indonesia, US etc. to find the effect of different LSP like ENSO, IOD and MJO on the monsoon system. Our recent study also emphasized on same (Lenka et al., 2022*)
- **The present proposal is to understand the most important large scale process (LSP) i. e. MJO and its effect on onset of Indian summer monsoon and its progress.**
- There is need to explore more to find the relation between ISM onset and MJO which will be useful in the onset prediction, in turn ISM length and monsoon progress estimation.

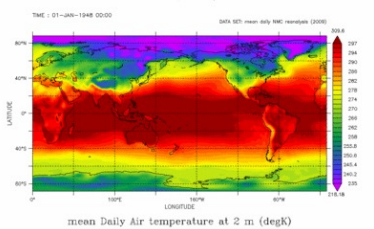
*Lenka, S., Devi, R., Joseph, C.M. *et al.* Effect of large-scale oceanic and atmospheric processes on the Indian summer monsoon. *Theor Appl Climatol* **147,** 1561–1576 (2022). https://doi.org/10.1007/s00704-021-03896-3

DATA SOURCE

- **All the parameters used for the present study is from the period 1980 to 2018.**
- The India Meteorological Department **(IMD)** daily gridded rainfall (mm/day) data at spatial resolution of 0.25°x0.25° over the continental India for 39 year (1980-2018) period is considered.
- The global temperature and wind vector field for this analysis is collected from the National Centres for Environmental Prediction **(NCEP)** reanalysis product available at 1°x1° .
- The daily mean **NOAA** Interpolated Outgoing Longwave Radiation(OLR) data of spatial coverage of 2.5° x 2.5° is used.
- The amplitude and phase of MJO on any given day is found from the RMM1 and RMM2 data of Australia Govt. **Bureau of Meteorology.**







METHODOLOGY

Early/Late onset day calculation:

The onset dates occurring between **27th May to 5th Jun is considered as normal onset** while if the onset occurs **after 5th June it is declared as the Late onset** yeas and similarly onset date before 27th May is considered as early onset.

Pentad Analysis:

P0 includes the date of onset with 2 preceding and 2 following days.

The pentad (P0) analysis of all the fields (rainfall, 850hPa wind vector, OLR, and SST) were computed and the composite analysis for late/early onset years are carried out.

The pentad anomalies of OLR and SST were computed as

Normalised PoAnomaly= $\frac{x(i)-\bar{x}}{\bar{x}}$X100 where, X is the pentad SST/OLR

The pentad average result of Wind and Rainfall also calculated.

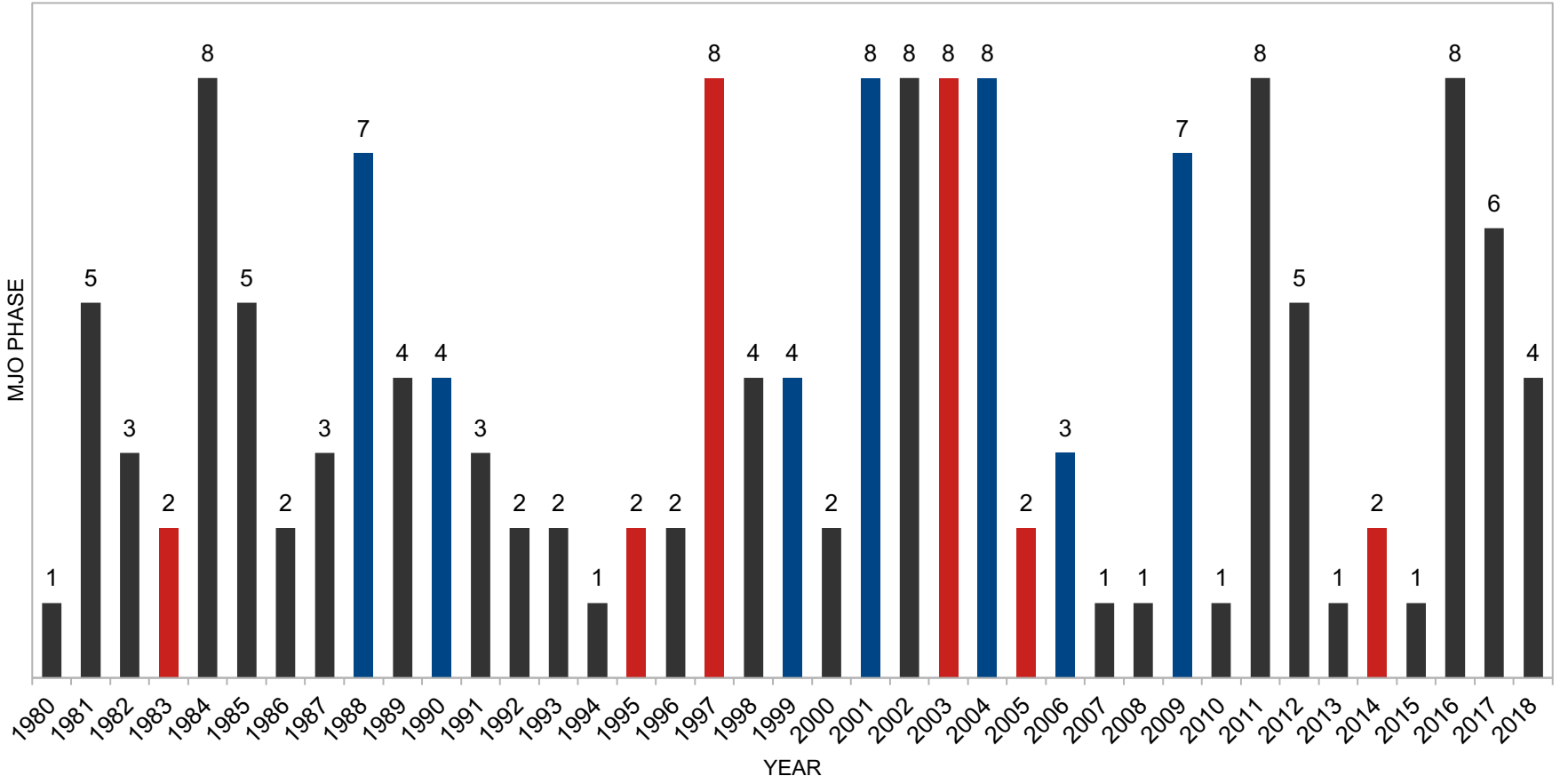
MJO phase analysis:

When amplitude ($\sqrt{RMM1^2 + RMM2^2}$) is ≥ 1 then the MJO phases are categorized as strong MJO phases.

In case ($\sqrt{RMM1^2 + RMM2^2}$) < 1, The MJO phase is considered as weak

Exploring the MJO Phase and Onset of Indian Monsoon

Onset of Monsoon	MJO Phases							
	P1	P2	P3	P4	P5	P6	P7	P8
EARLY Before 27 May			2006	1990 1999			1988 2009	2001 2004
LATE After 5 June		1983 1995 2005 2014						1997 2003
NORMAL	1980 1994 2007 2008 2010 2013 2015	1986 1992 1993 1996 2000	1982 1987 1991	1989 1998 2018	1981 1985 2012	2017		1984 2002 2011 2016

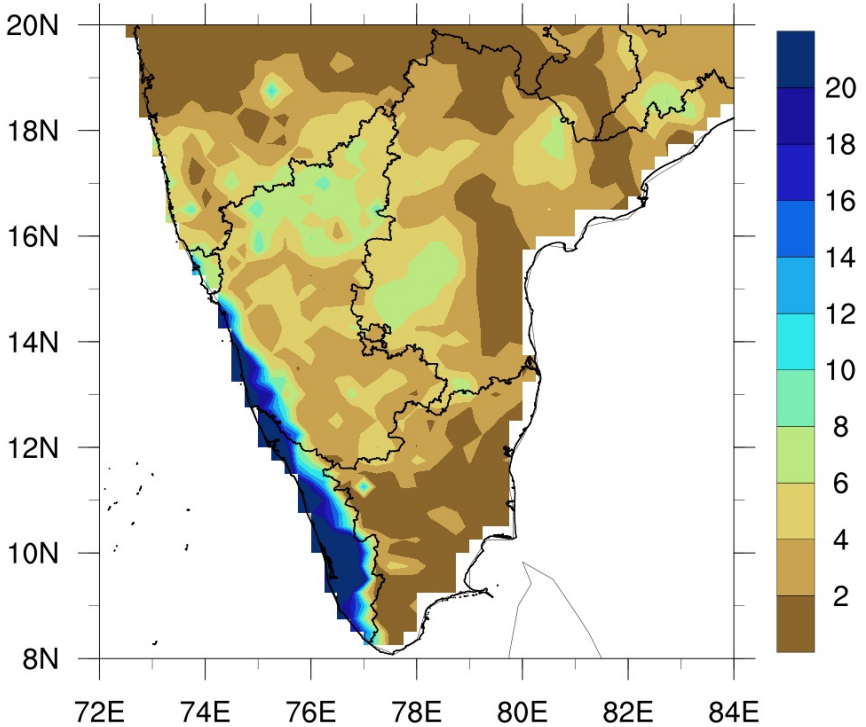


Interannual variability in the Phases of MJO during onset of monsoon over India

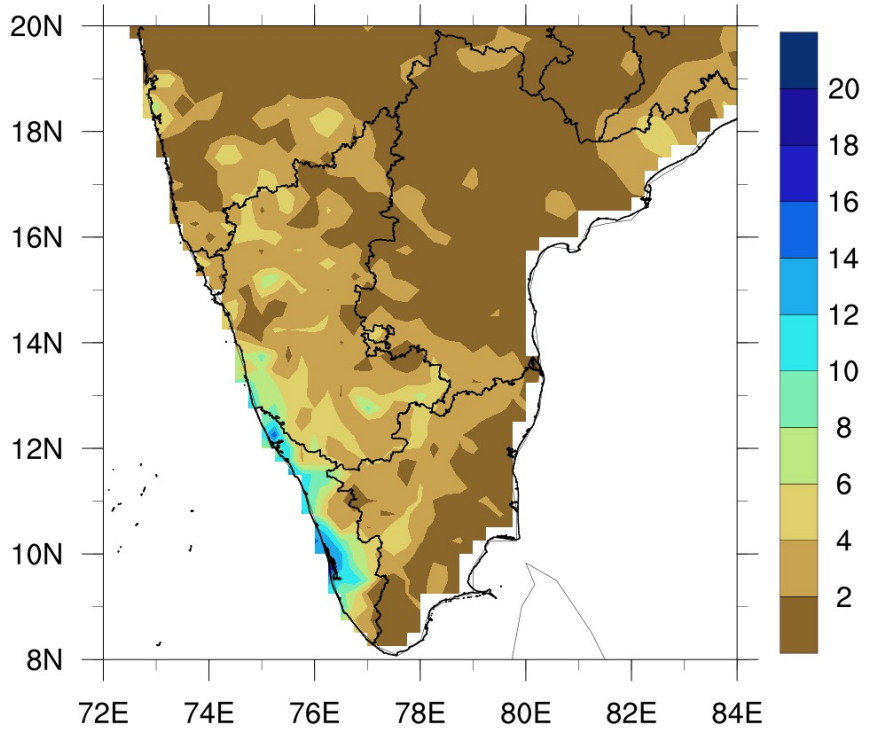
Red (late onset), blue (early onset) & black(normal onset)

Composite Pentad Rainfall during Onset of Monsoon in South Peninsular India

Early onset year



Late onset year



Composite Pentad climatology of rainfall during onset over Kerala

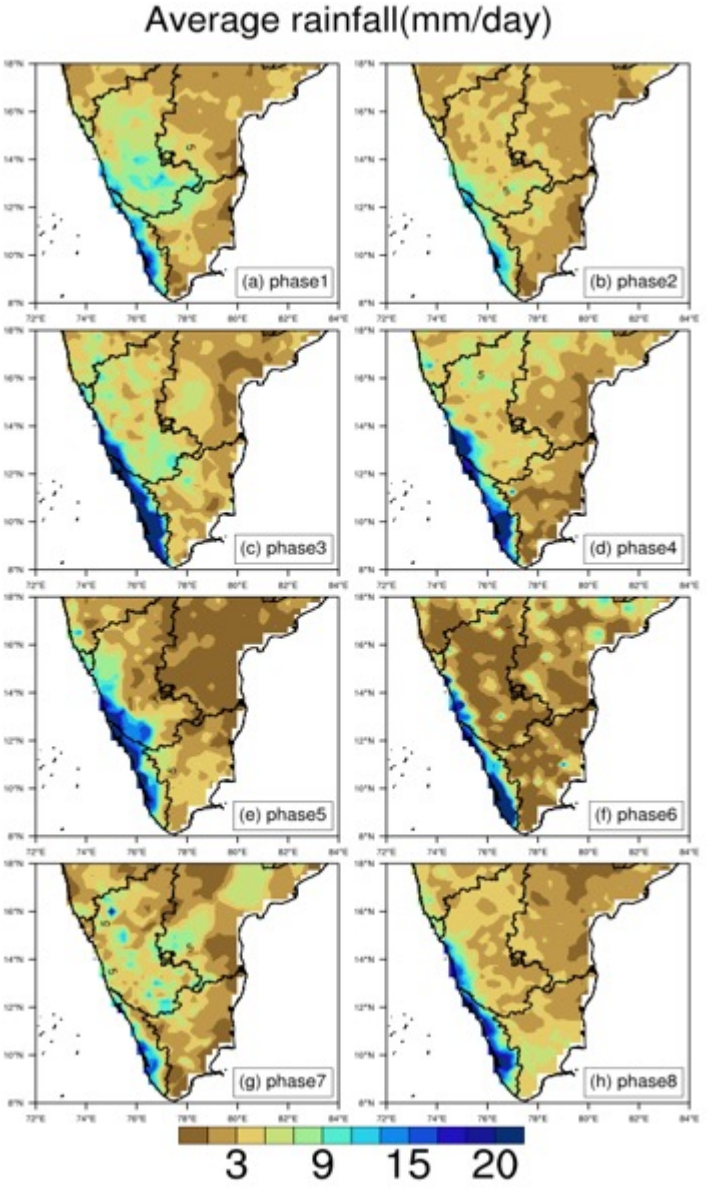
High intense Rain and high spatial spreading over Kerala observed during Early monsoon onset years unlike the Late onset year.

ISM RAINFALL DURING ONSET(P0) IN DIFFERENT MJO PHASES OVER KERALA

Here we analyzed the monsoon onset pentad rainfall (mm/day) over Kerala for each composite MJO phases.

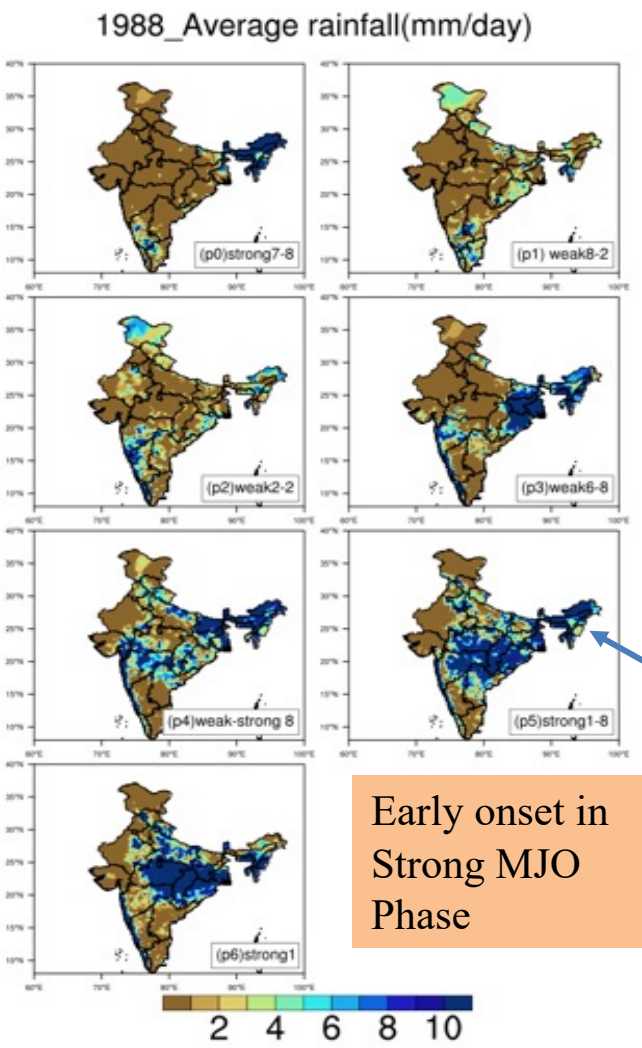
Analysis shows there is significant high intense rainfall in phase 3 ,4 and 8 where as very less intense rainfall during onset pentad in phase 6 and 7

as in phase 2 and 3 corresponds to the period when MJO's convective envelope is in the Indian ocean, unlike 6 and 7 corresponds to equatorial pacific ocean



Pentad Rainfall analysis during Onset of Monsoon in India composite over different phases of MJO (1980-2018)

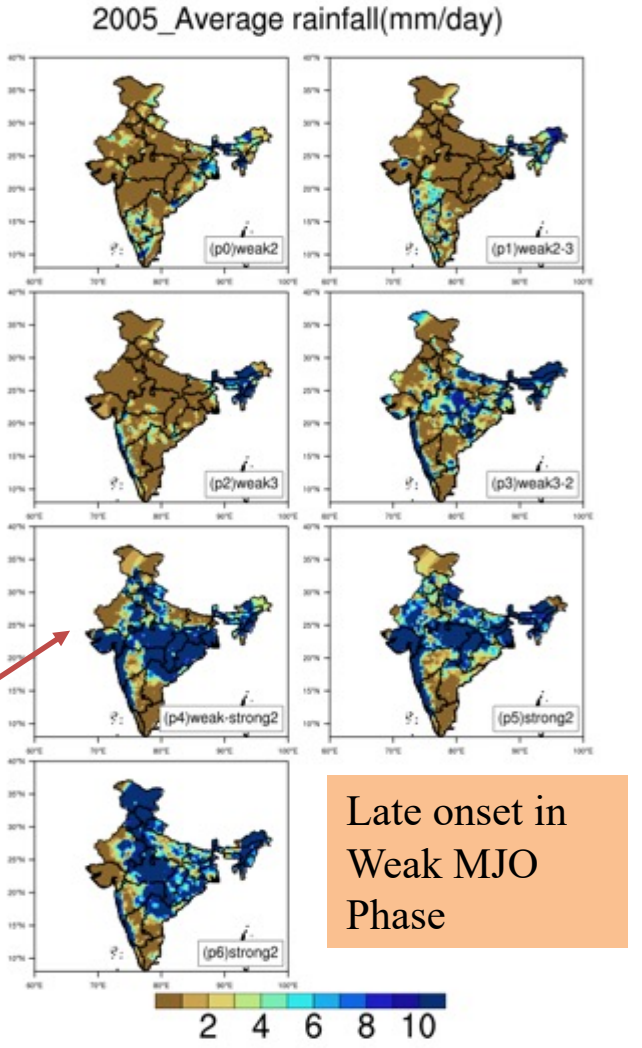
SPATIAL SPREADING OF RAINFALL DUE TO MJO PHASE SHIFT



There is a significant change in spatial spreading of ISM rainfall when MJO changes its phase from weak to strong, whether it is early/late onset year

Early onset in Strong MJO Phase

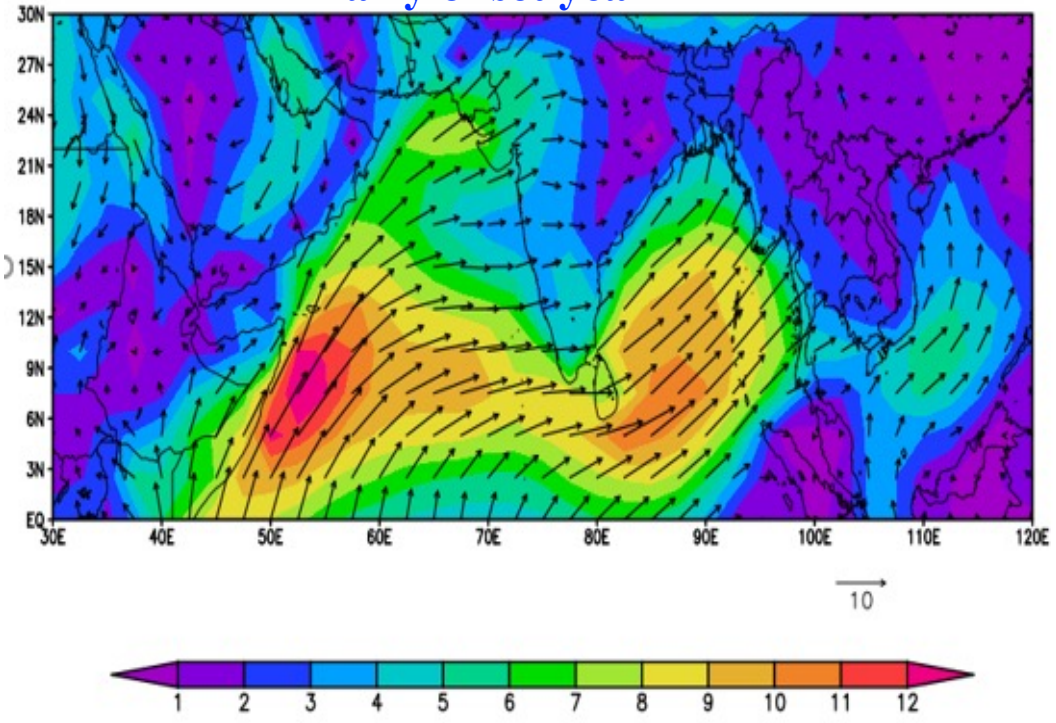
Phase shift of MJO from weak to strong



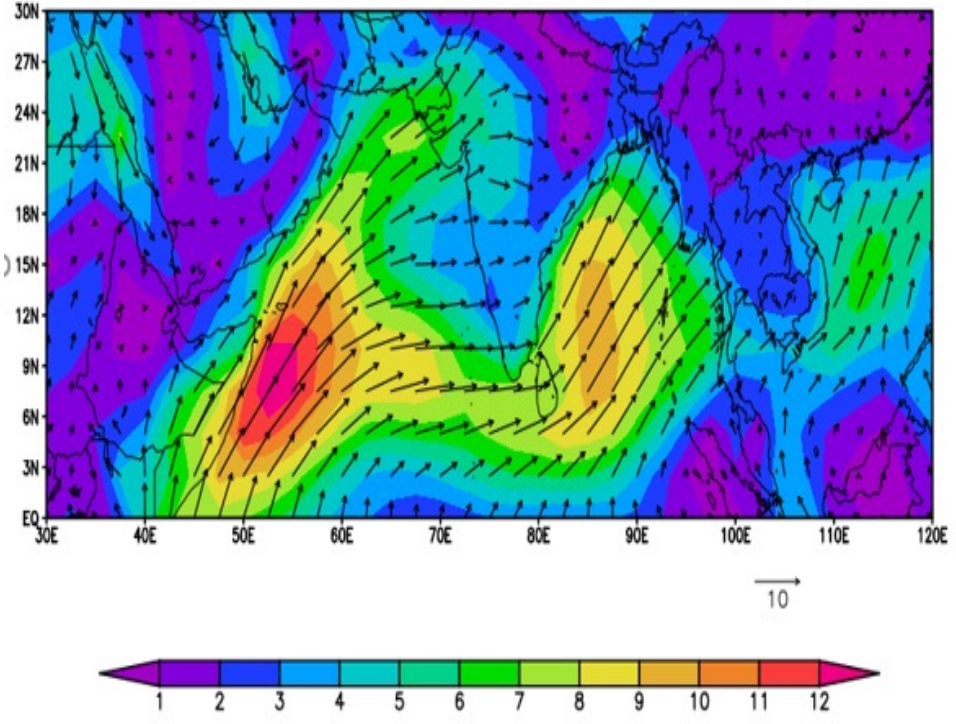
Late onset in Weak MJO Phase

WIND ANALYSIS DURING ISM ONSET (P0 analysis)

Early onset year



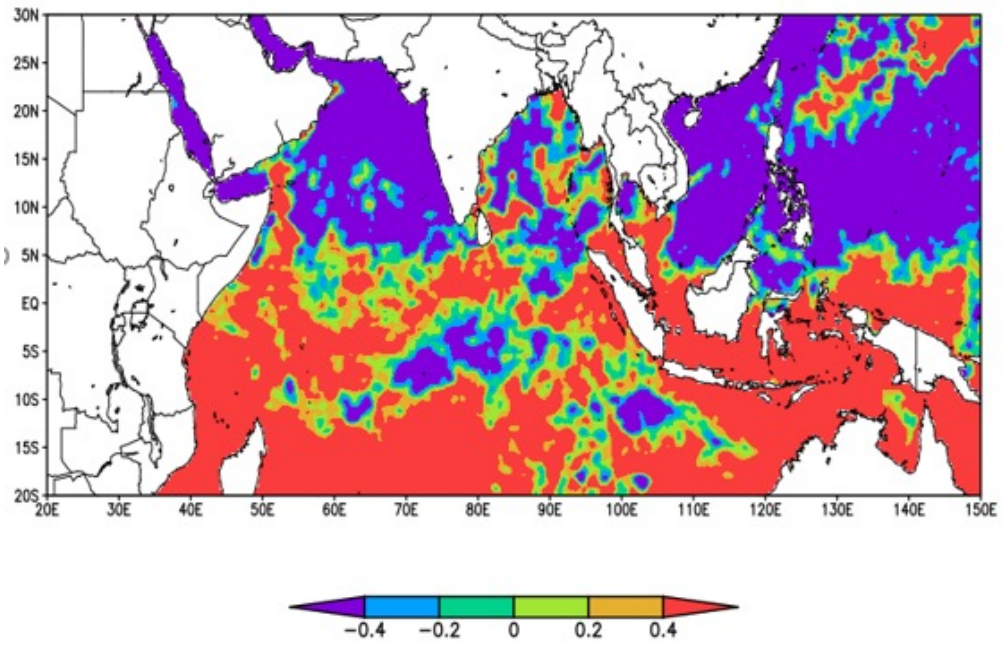
Late onset year



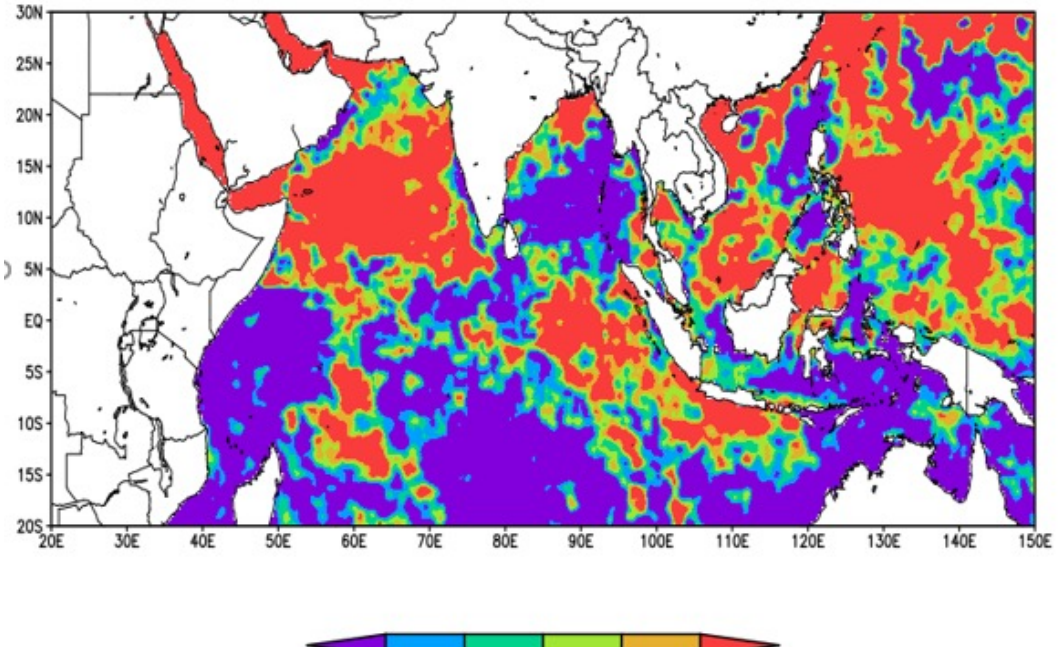
Pentad average wind speed and direction during monsoon onset

ANALYSIS OF SST ANOMALY(% of mean) DURING ISM ONSET (P0 analysis)

Early onset year



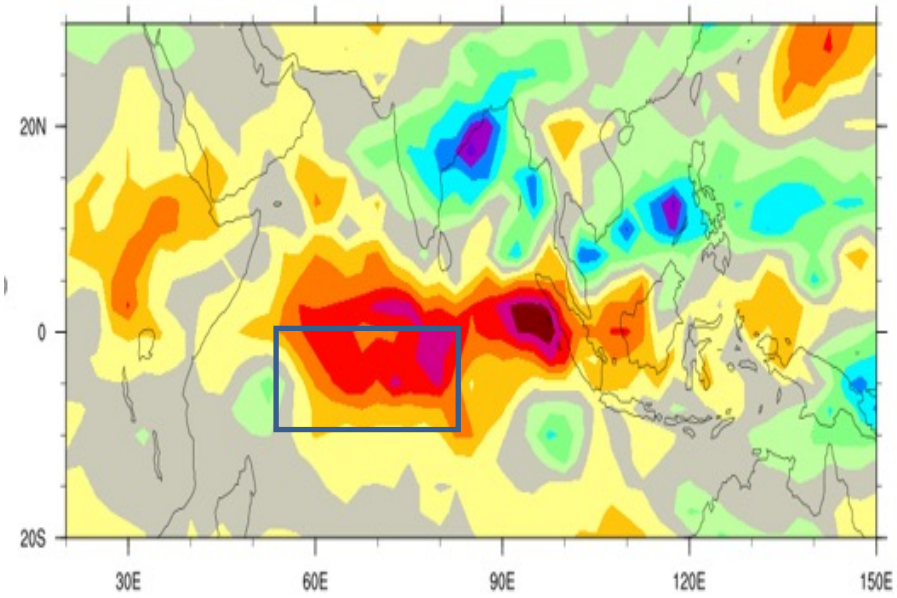
Late onset year



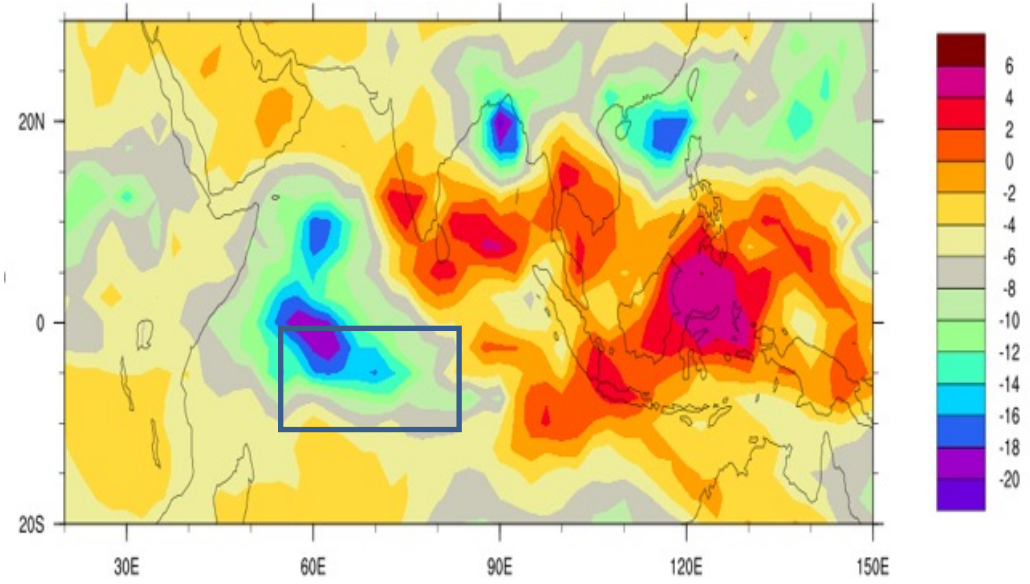
Pentad average SST anomaly (% of mean) during monsoon onset

ANALYSIS OF OLR ANOMALY(% of mean) DURING ISM ONSET (P0 analysis)

Early onset year



Late onset year



Pentad average out going long wave radiation(OLR) anomaly (% of mean) during monsoon onset

CONCLUSION

- Different MJO phases has significant effect on ISM onset, monsoon rainfall and its progress.
- Unlike late onset year, in early onset year the state Kerala receives high intense rainfall during onset and with in 3 to 4 days the monsoon spreads very fast towards the north direction.
- **When MJO changes its phase from weak to strong, it provides more energy and helps the progress of monsoon all over the country.**
- Early onset year shows high wind speed during ISM onset and it helps the monsoon to reach Indian subcontinent soon.
- Positive OLR helps the monsoon to reach Indian subcontinent soon.

FUTURE PERSPECTIVE

❖ **Implementation of the MJO impact on the onset in the dynamical modelling framework will surely help in accurate prediction of the onset of ISM.**

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