Abrupt transition in organized convection during the monsoon onset in central India and climate change effect

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AS1.16: The global monsoons in current, future and palaeoclimates and their role in extreme weather and climate events

Nitin Babu George[1,3], Elena Surovyatkina[1], Raghavan Krishnan[2] and Jürgen Kurths[1,3]

[1]**Potsdam Institute for Climate Impact Research**

[2]**Indian Institute of Tropical Meteorology, Pune, India**

[3]**Humboldt University of Berlin, Germany**

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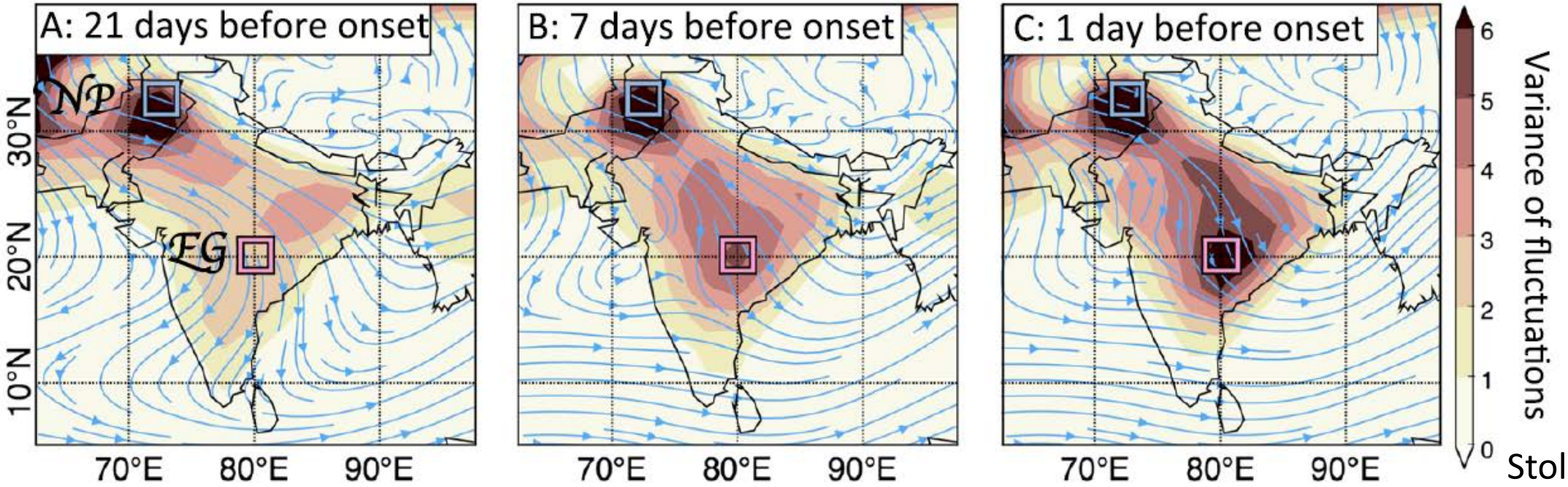
Motivation

The tipping elements approach is a new concept in forecasting monsoon onset and withdrawal (Stolbova et al, 2016). It based on the observations of a critical transition in near surface air temperature and relative humidity and the growth of fluctuations in these atmospheric variables on the eve on Monsoon (Surovyatkina et al, 2005).



Stolbova et al. 2016

There are two Tipping elements in the Indian Summer Monsoon: the Eastern Ghats (EG) and North Pakistan (NP). This finding allows to forecast timing of Indian Summer Monsoon (ISM) in central India, that has proven to be successful for 4 years in a row. The next step is to reveal critical transition in other atmospheric variables.

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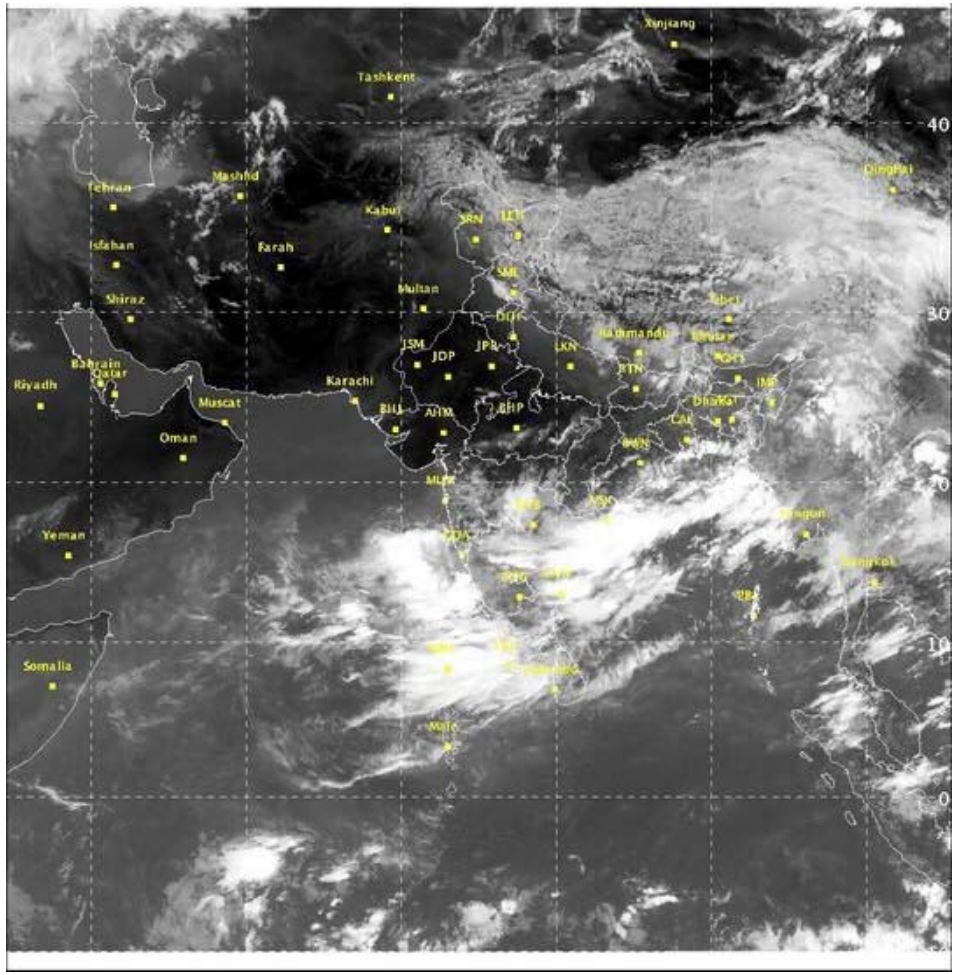
Does Outgoing Longwave Radiation exhibit critical transition?



Monsoon clouds before onset over Kerala 2019
http://www.imd.gov.in/pages/monsoon_main.php

The Outgoing Longwave Radiation is a measure of the amount of energy radiated back to space from the earth.

- High OLR indicates lack of cloud cover
- Low values of OLR correspond to thick cloud cover – more rain
- OLR is used by IMD to declare monsoon onset over the southern state of Kerala (Pai & Nair 2009).
- OLR has been used for prediction of monsoon onset over Kerala. (Ghanekar et al. 2010)
- We observe that the Outgoing Longwave Radiation exhibit critical transition on the eve of monsoon.

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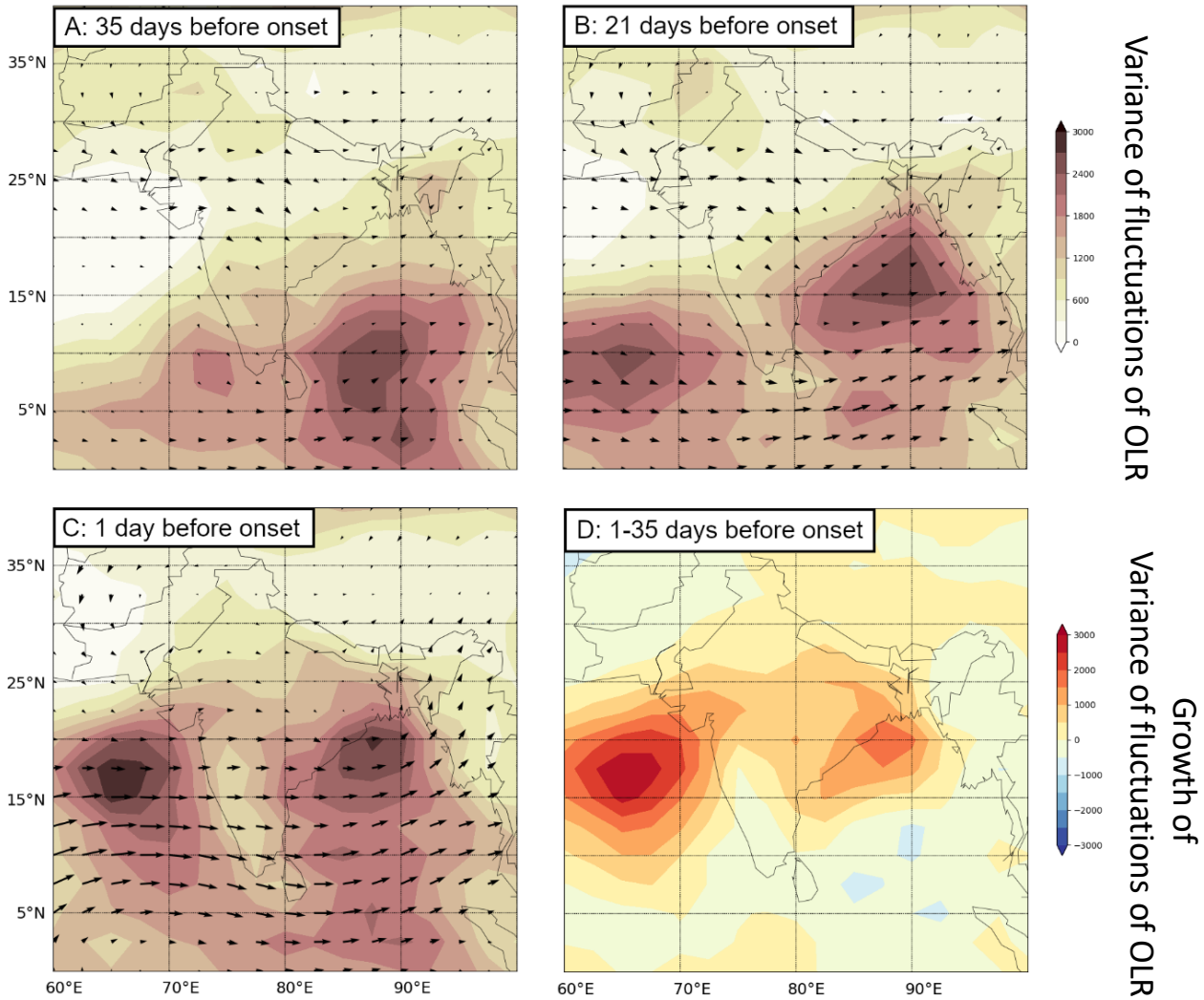
Tipping elements in organized convection during monsoon onset



Critical fluctuations indicate an upcoming critical transition. Maximum variance of fluctuations of OLR shows locations of tipping elements in the Arabian Sea and the Bay of Bengal. Thus, it allows us to reveal tipping elements in organized convection during monsoon onset.

Figure shows the Pre-monsoon growth of the variance of fluctuations of the weekly mean values of OLR prior to the monsoon onset at the Eastern Ghats: A,B and C. Figure D shows difference between C and A. Wind at the level 850 hPa is shown by black arrows.

Data: NOAA interpolated OLR, 2.5° x 2.5° grids, years: 1975-2018, Wind: NCEP/NCAR reanalyzes

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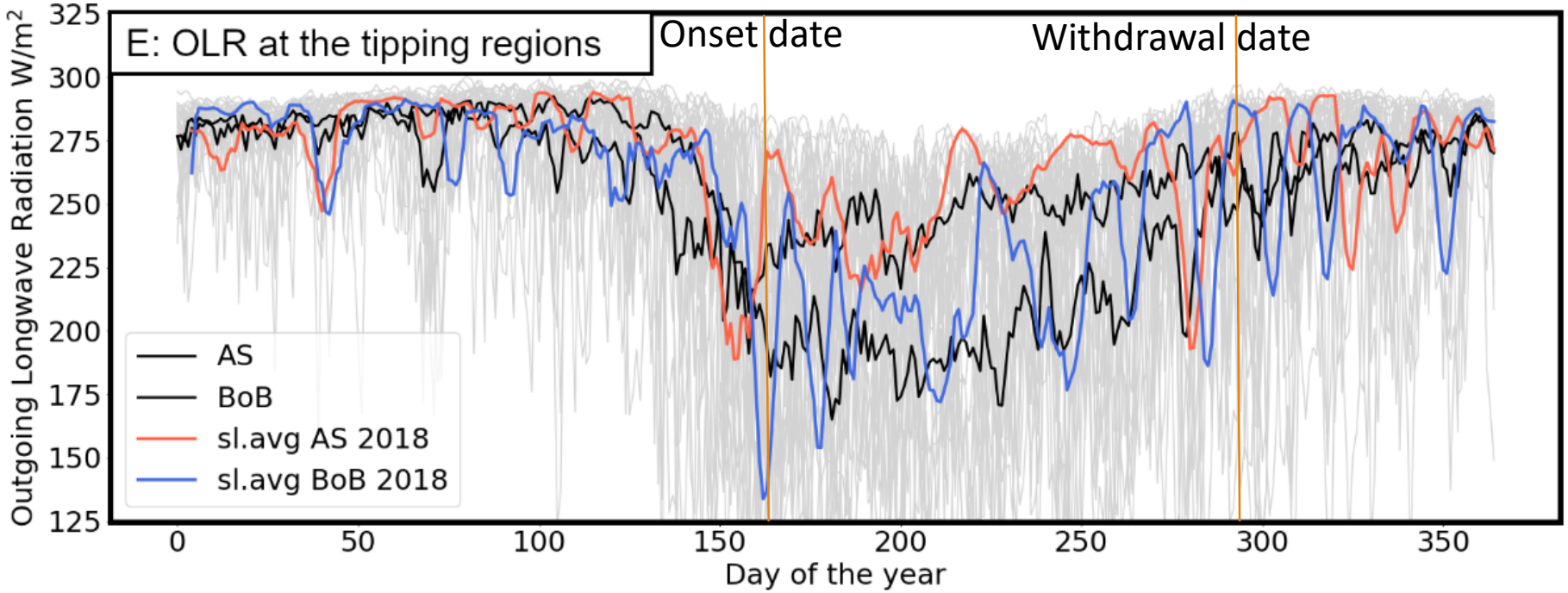
Abrupt critical transition in the OLR on the eve of monsoon onset over central India

We observe that the time-series of the OLR at the tipping elements diverge from each other prior to the onset. They intersect close to withdrawal of monsoon from central India. Thus, the OLR at the tipping elements signal the timing of the monsoon in central India.



E: Average values of OLR for the years 2005-2017 at the tipping regions are indicated in black. The daily values of OLR for the same period at the two tipping regions are shown in light gray. Sliding window average (window size=5 days) of OLR for the year 2018 at AS (red) and BoB (blue).

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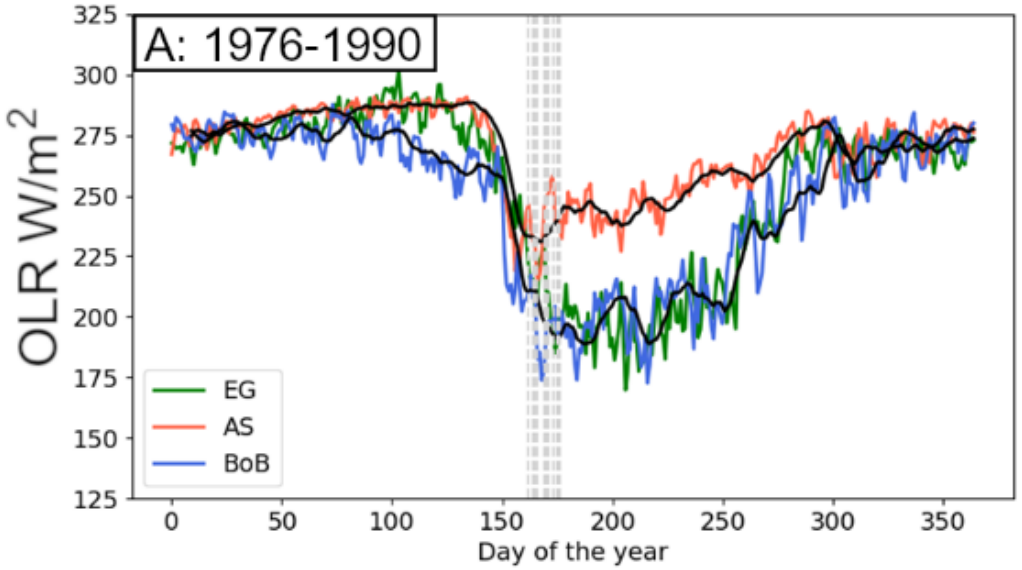
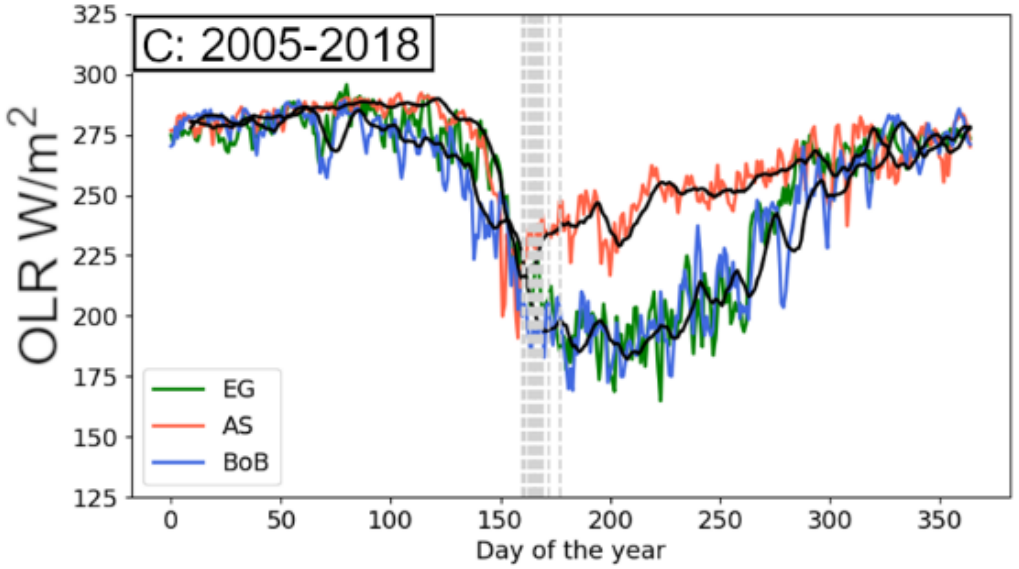
The tipping elements reveal climate change effects





- The transition of OLR prior to onset at Bay of Bengal has shifted from an abrupt transition to a gradual transition
- The fall of OLR at Arabian sea is earlier in recent years.

Figures show 14-year time averaged plots of OLR - for A: 1976-1990, C: 2005-2018 at Eastern Ghats (green), Arabian sea (red) and Bay of Bengal (blue). Dashed gray lines depict the onset dates of monsoon at EG for the respective years. Black curves indicate sliding window average values.

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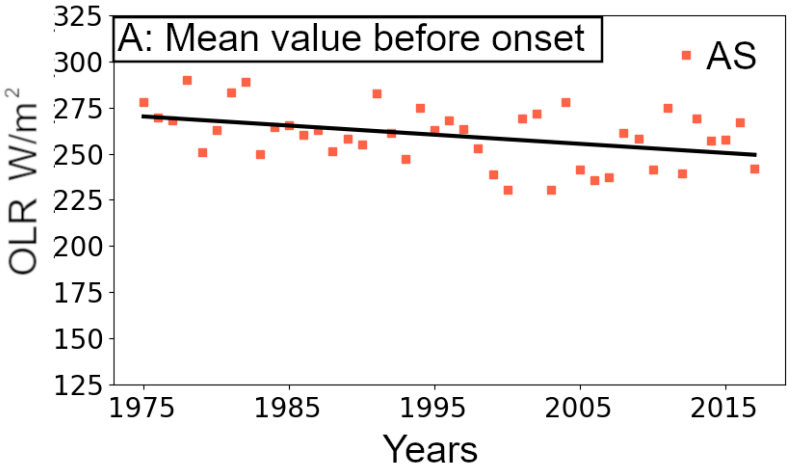
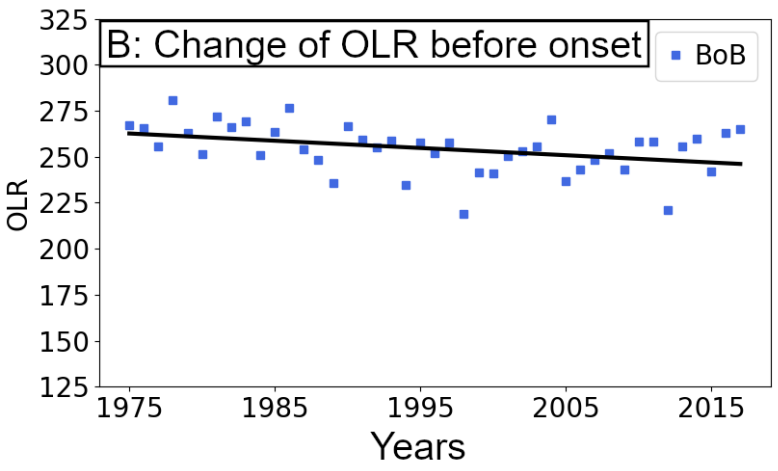
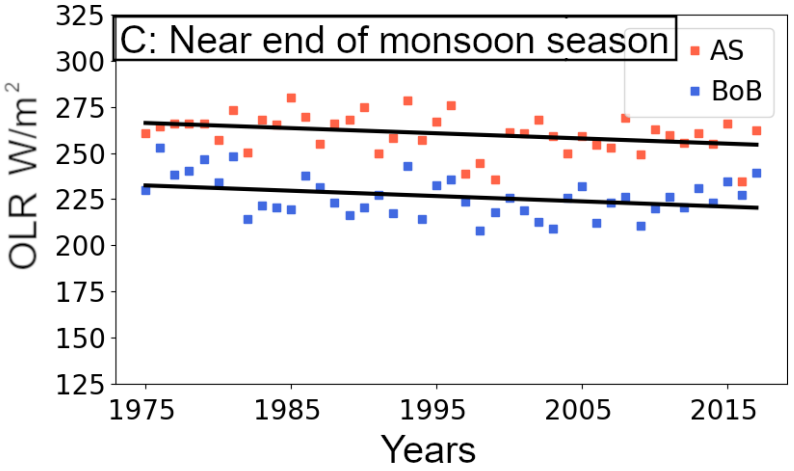
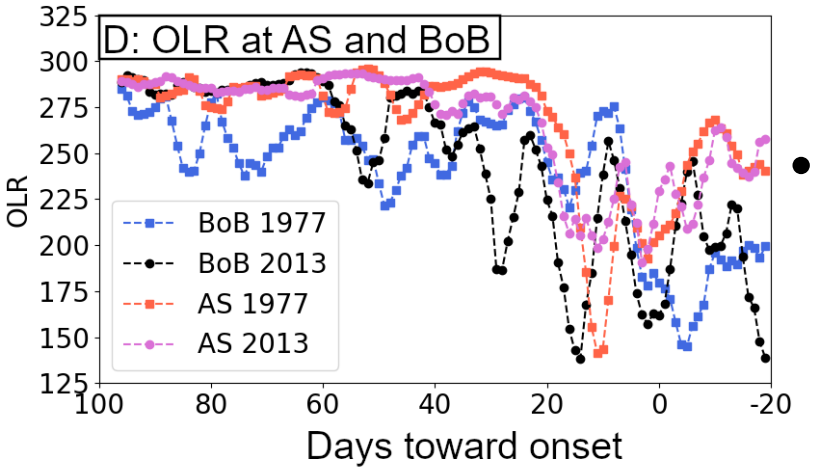
The Tipping elements reveal earlier transition in Arabian Sea and enhanced pre-monsoon convective activity in Bay of Bengal









- The OLR at Arabian sea reveals a trend towards earlier transition
- The OLR at Bay of Bengal before onset indicates pre-monsoon convective activity in recent years resulting in a gradual transition
- The OLR at the tipping elements reveal higher convective activity in the recent years near the end of the monsoon season

A: Mean value of OLR at AS before onset in central. B: OLR at BoB prior to monsoon onset. C: OLR at the tipping elements near the end of the monsoon season. D: OLR at the tipping elements for year 1977 and 2013.

Conclusion

We reveal a critical transition in the organized convection during the monsoon onset in central India. We find three key features in the spatial-temproral organization of the Outgoing Longwave Radiation (OLR):

- There are two tipping elements of OLR appearing in the Arabian sea and Bay of Bengal on the eve of the monsoon onset in central India.
- The OLR at the tipping elements indicate the timing of the monsoon season in central India
- The OLR at the tipping elements exhibits climate change effects: earlier transition in Arabian Sea and enhanced pre-monsoon convective activity in Bay of Bengal.

The methodology opens new possibilities for identifying critical regions around the globe signaling monsoon timing.

References

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