Impact of intraseasonal oscillations on local onset and demise of the Indian summer monsoon rainfall

Nirupam Karmakar & Vasubandhu Misra
Department of Earth, Ocean and Atmospheric Science
Florida State University
Tallahassee, FL, USA

A quantitative analysis on the linkage between the *onset/demise* of summer monsoon rainfall over India and *intraseasonal oscillation* observed in it:

- **Defining onset and demise** of the Indian Summer Monsoon (ISM) on a local basis.
- **Extract intraseasonal oscillations** (ISO) using a data adaptive technique.
- Investigate **phases of ISO** modes.
- Associate the occurrences of local onset and demise of the ISM with the phases of ISO and find any **relationship** between them.
- Examine how local onset/demise of the ISM is associated with intraseasonal **large-scale patterns.**

Define local onset and demise:

Use IMD 0.25° gridded rainfall data from 1902–2005 (*Pai et al., 2014; Mausam*).

Daily cumulative anomaly from **daily rainfall every year**

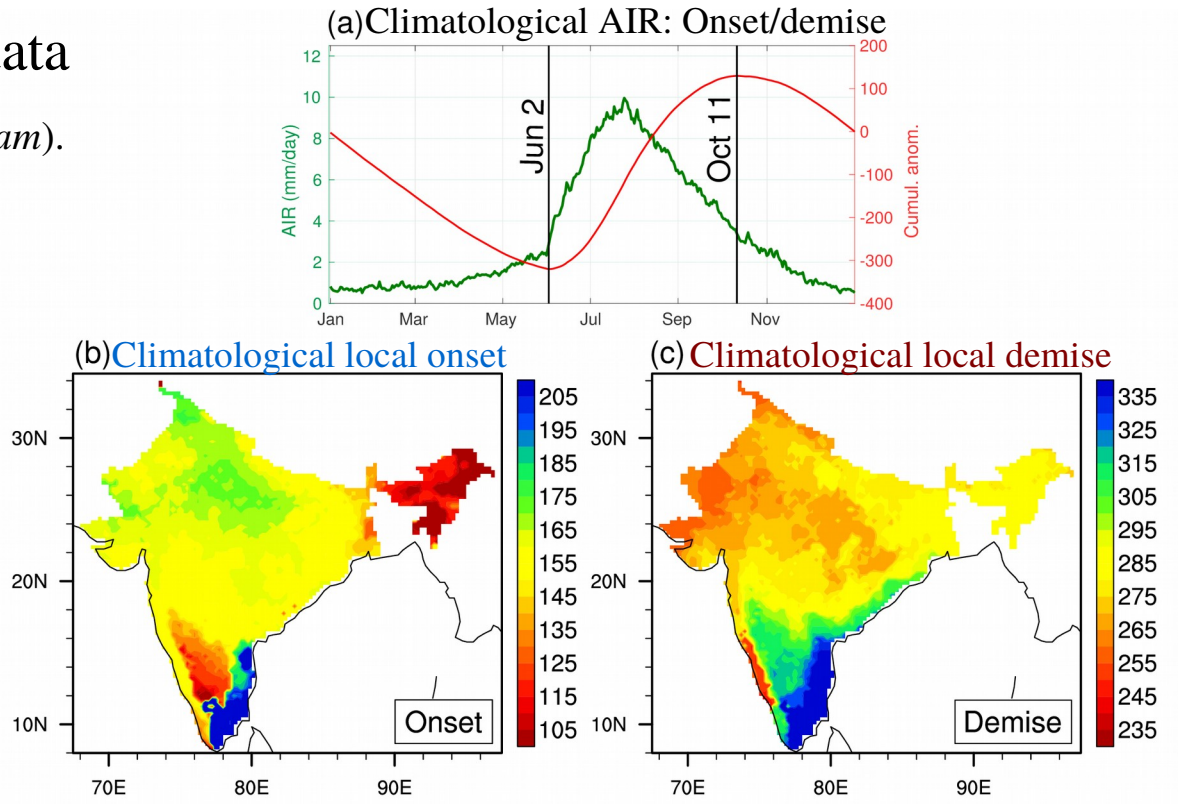
Cumulative anomaly of **All-India rainfall**

Cumulative anomaly of **local climatological rainfall**

Find **minimum** and **maximum** in the curve

Local onset/demise of the ISM

(Misra et al., 2017; Clim. Dyn.)



(a) Daily climatology of the All-India rainfall (AIR; left y-axis in green) and the corresponding cumulative daily anomaly (right y-axis in red) with the onset and demise dates marked in calendar days. The climatological local (b) onset and (c) demise of the Indian summer monsoon (ISM) defined at every grid point. The dates are shown in Julian days.

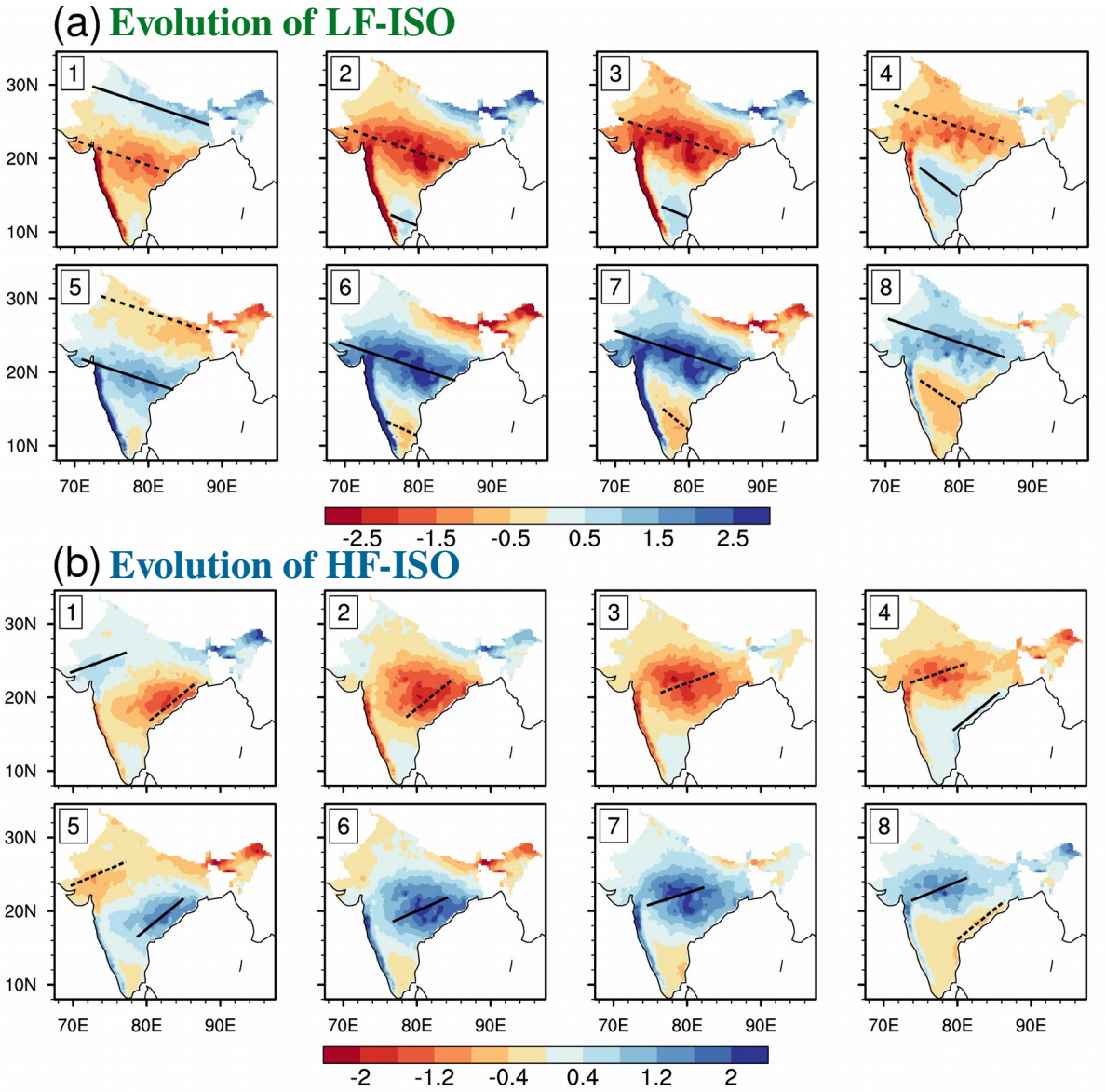
ISO modes in the ISM:

Extracted ISO modes using **multichannel singular spectrum analysis**.(Ghil et al., 2002; Rev. Geophys.)

Identifies oscillatory components in the data in a **data-adaptive way** (diagonalizes a lag-covariance matrix).

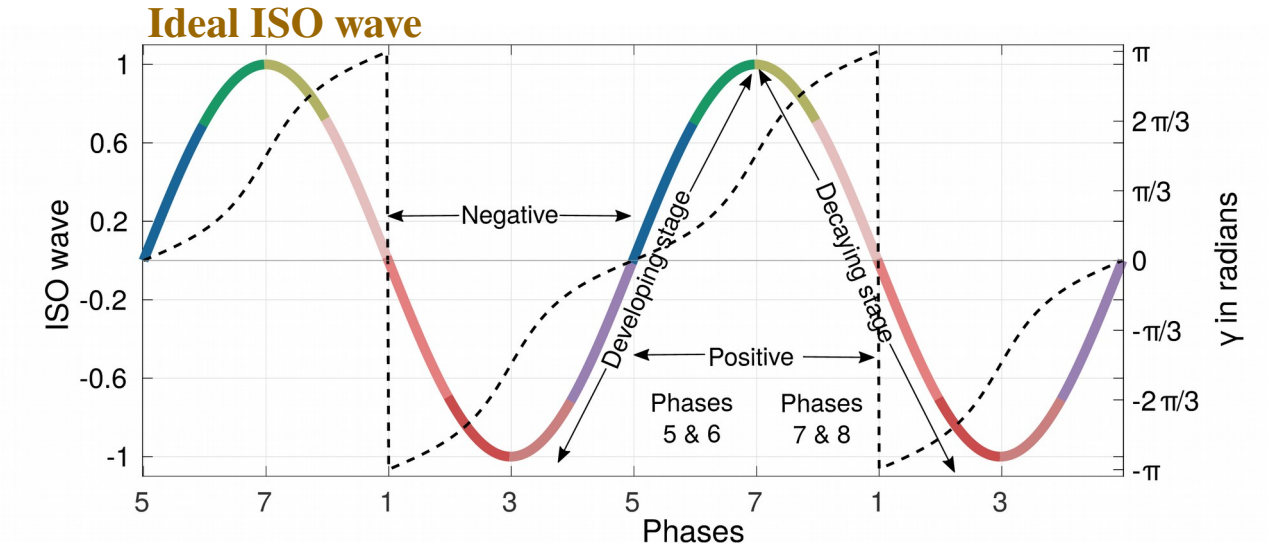
Two types of ISOs:
1. 20–60-day periodic northward propagating ***low-frequency ISO (LF-ISO)***
2. 10–20-day periodic northwestward propagating ***high-frequency ISO (HF-ISO)***

(*Karmakar et al., 2017; MWR*)



Evolution of (a) northward propagating LF-ISO and (b) northwestward propagating HF-ISO using phase composite diagram.

Calculate the phases of ISO modes:



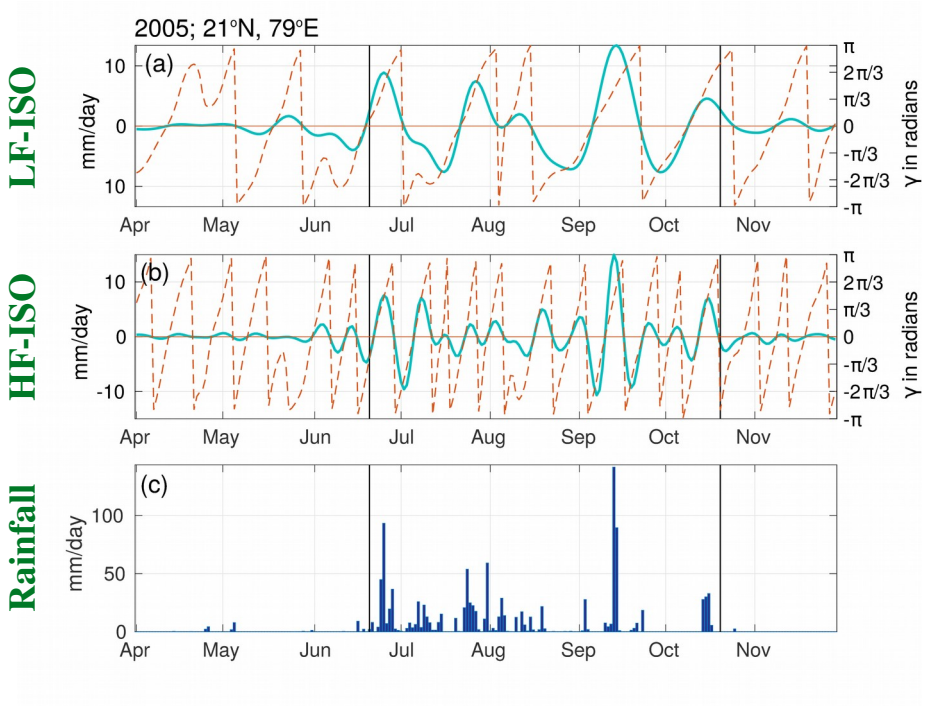
An ideal ISO wave represented by a sine function (solid line; left *y-axis*) and associated phase angles (dotted line; right y-axis). Phase numbers are noted in the *x-axis*. Different colors in the ISO wave indicate 8 different phases of ISO.

Done at each grid point

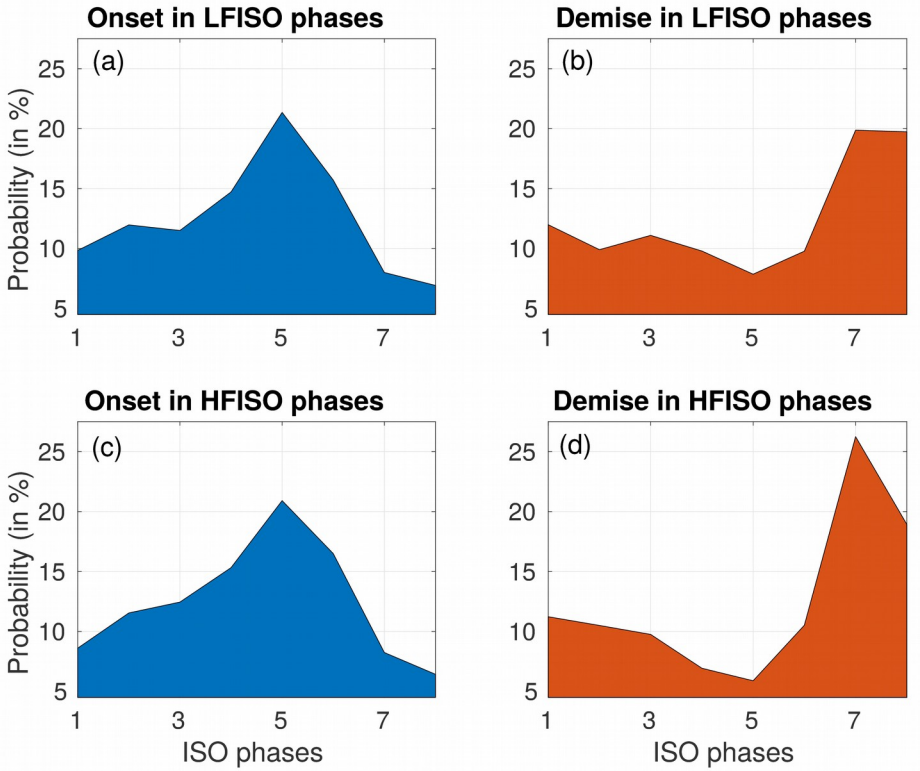
Divided the entire phase plane for ISO at into **eight** equally spaced intervals.

LF-ISO or HF-ISO time series is in phase ***m*** if the associated phase angle belongs to the ***m***-th interval.

Onset/demise and ISO phases: Phase association



(a) LF-ISO, (b) HF-ISO and (c) Actual rainfall over a grid point over central India (21^{O}N, 79^{O}E) during April–November, 2005.



Histogram of local onset/demise dates of the ISM (presented as a percentage of the total) in different LF-ISO/HF-ISO phases.

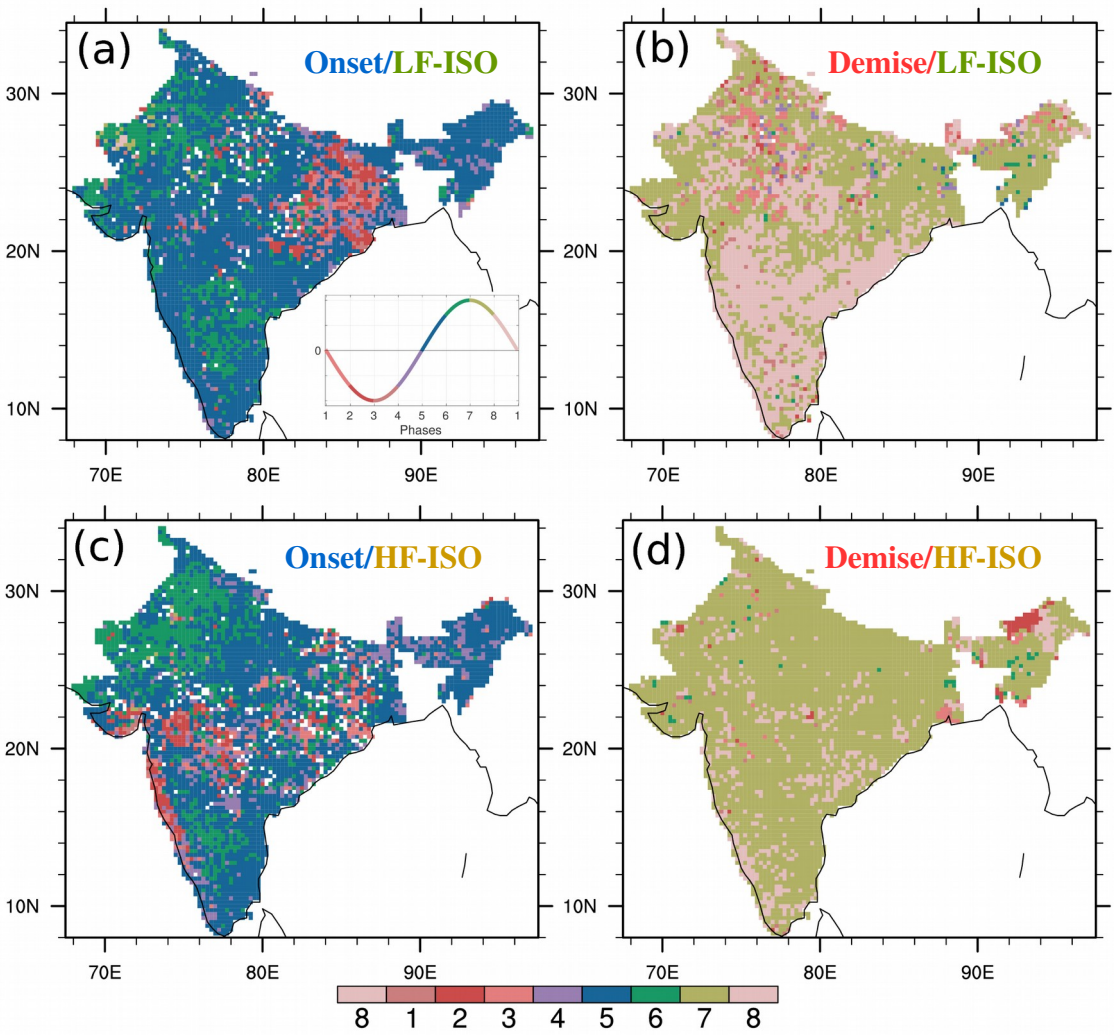
~37% of local onset of the ISM occurs when LF-ISO is in phases 5–6.

~37% of local onset of the ISM occurs when HF-ISO is in phases 5–6.

~40% of local demise of the ISM occurs when LF-ISO is in phases 7–8.

~45% of local demise of the ISM occurs when HF-ISO is in phases 7–8.

Phase association:



The **spatial distribution** of the ISO phase numbers at which the distribution of local onset/demise dates in different LF-ISO phases during 1902–2005 attains maxima.

Spatially coherent patterns across entire India, except

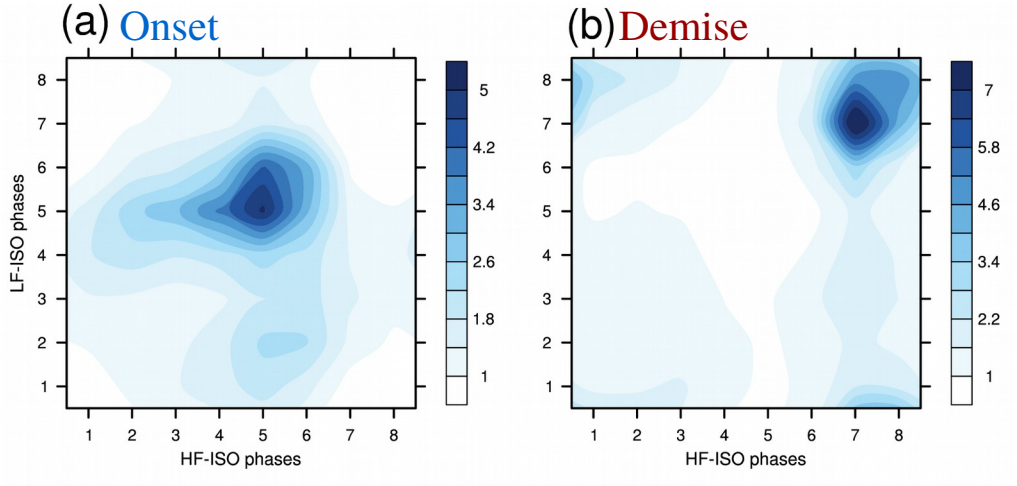
Onset/LF-ISO association is weaker over east-central India.

Onset/HF-ISO association is weaker over western Ghats & central India.

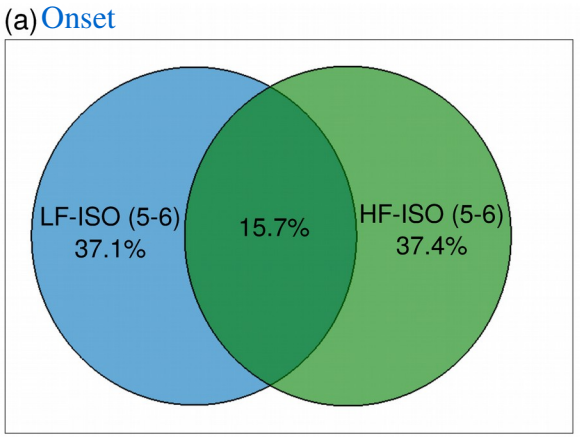
Demise/LF-ISO association is weaker over some parts of northern India.

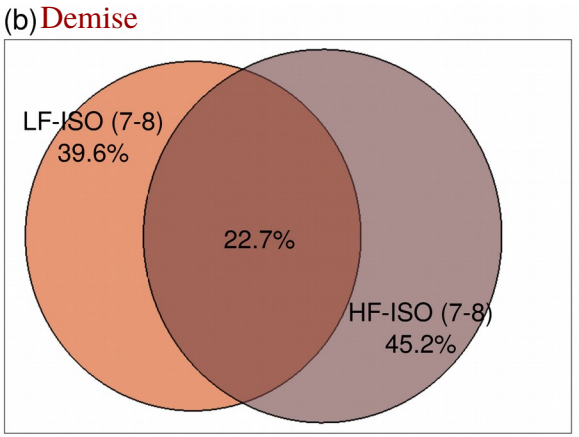
Demise/HF-ISO association is weaker only over some parts in northeast India.

Phase association:



Joint probability distribution (represented as percentage of total occurrences) of onset/demise dates in ISO phases.





Simple **Venn diagrams** representing the percentage of occurrence of (a) local onset and (b) local demise over the entire domain in favorable LF-ISO and HF-ISO phases (phases 5–6 for local onset and phases 7–8 for local demise of the ISM).

Positive developing stages of ISOs are favorable for onset to occur (59%), positive decaying stages are favorable for demise events (62%).

Phase-locking between the two ISO modes is important for the occurrence of onset/demise!

Large-scale association:

Consider a box over **central India**.

Calculate **onset/demise and the ISO phases** based on area-averaged rainfall in a similar way.

Investigate large-scale patterns for **two** contrasting cases: Onset in **LF-ISO** phases A) 5–6 (favorable), B) 1–2 (non-favorable).

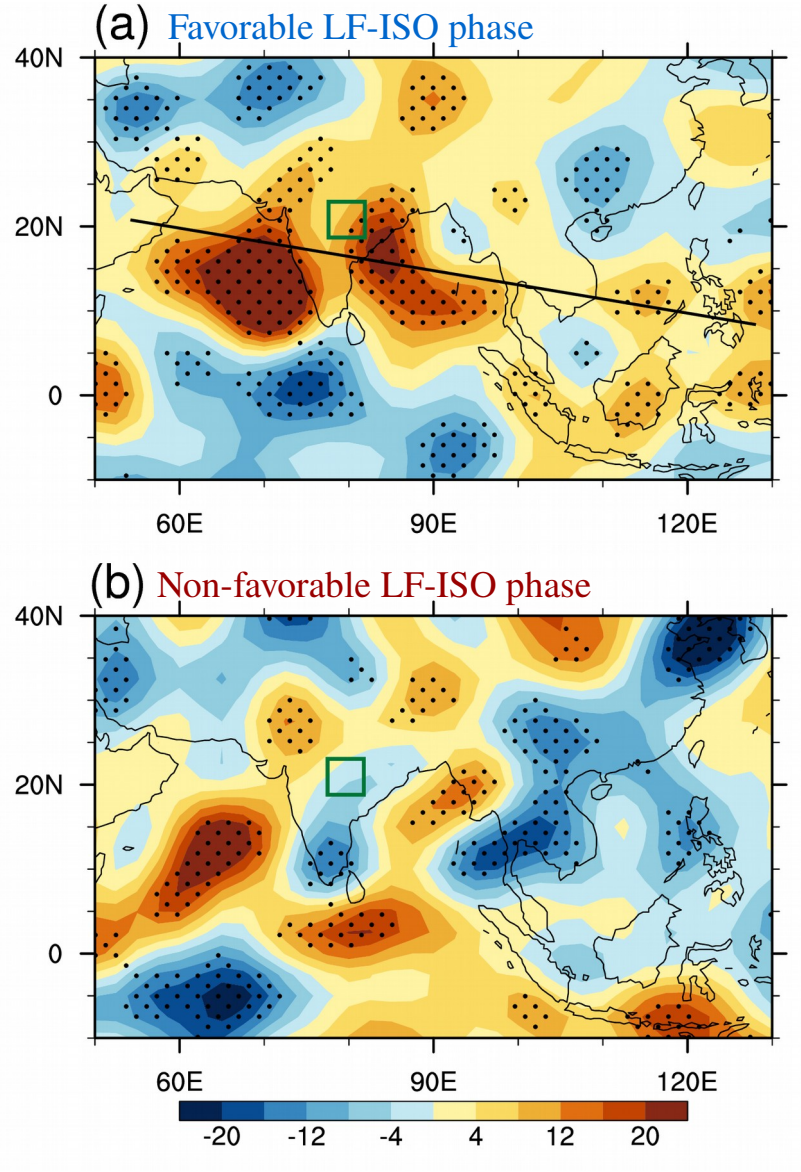
NCEP/NCAR Reanalysis 1 data used (1948–2005).

28 cases in (a), 11 cases in (b)

Upper-level divergence

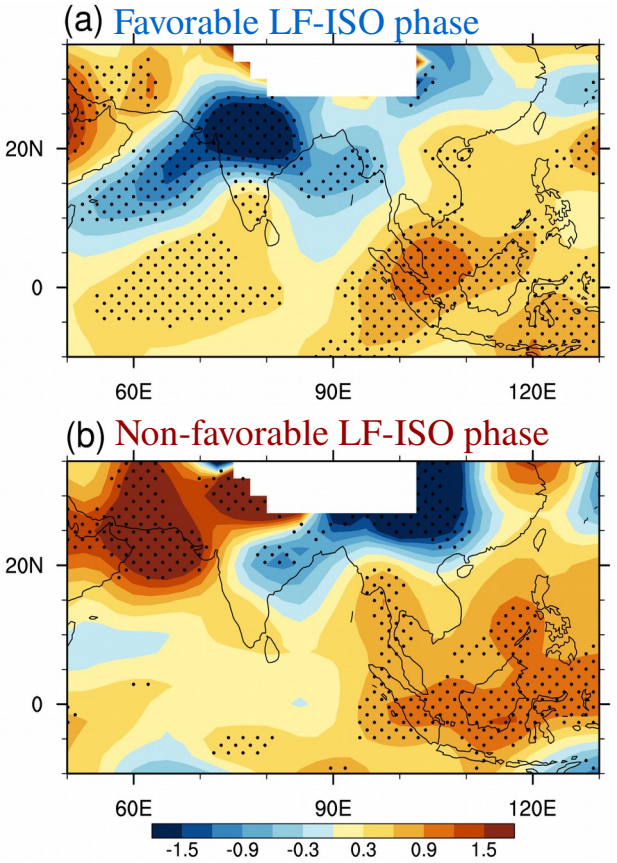
(a) shows large-scale northwest-southeast tilted structure.

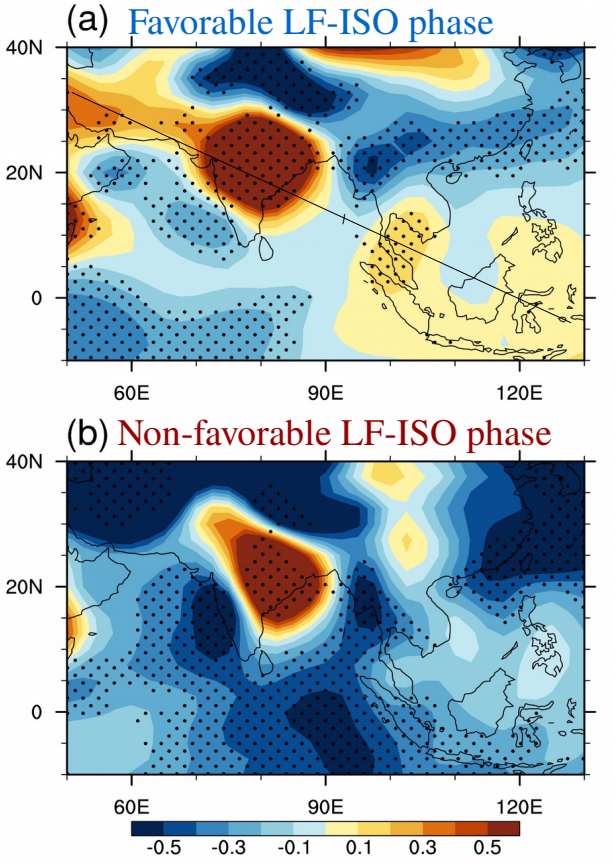
(b) shows Rossby wave-like pattern (association with HF-ISO).



200hPa divergence anomalies during onset of the ISM over CI

Large-scale association:





Vertically integrated Vertical Moist Stability (VMS = $MSE_{top} - MSE_{bot}$) anomalies during onset over CI.

VMS is a necessary condition for convection to occur.

Large-scale instability is seen during onset which occurs in LF-ISO phases 5–6.

Surface temperature anomalies during 9–11 days before onset over CI.

Increase in surface temperature leads convection by about 10 days.

Large-scale development in positive surface temperature anomalies are seen during onset which occurs in LF-ISO phases 5–6.

Conclusions:

- **Positive developing** stages of ISOs are favorable for **onset** to occur (59%).
- **Positive decaying** stages are favorable for **demise** events (62%).
- **Phase-locking** between the two ISO modes plays major role in determining onset/demise dates.
- If onset of monsoon over central India is *favored by LF-ISO* phases, large-scale ***northwest-southeast tilted*** patterns are seen.
- Westward propagating ***Rossby wave-like*** structures could also trigger onset of monsoon rainfall.

Discussion and future work:

- Capturing onset, demise and the seasonal mean rainfall in a model **largely depends upon how it simulates ISO modes**.
- Examine the relationship using a **regional coupled model** (RSM-ROMS).
- Can we do a **probabilistic estimation** of the local onset/demise events in the ISM using the information about the phases of LF-ISO and HF-ISO?
- Examine if this **relationship changes** in a warming scenario, with more number of small-scale systems getting generated over the Indian region.

Karmakar, N., Misra, V. “The relation of intraseasonal variations with local onset and demise of the Indian summer monsoon”, Submitted to *J. Geophys. Res.- Atmos.*

Acknowledgments:

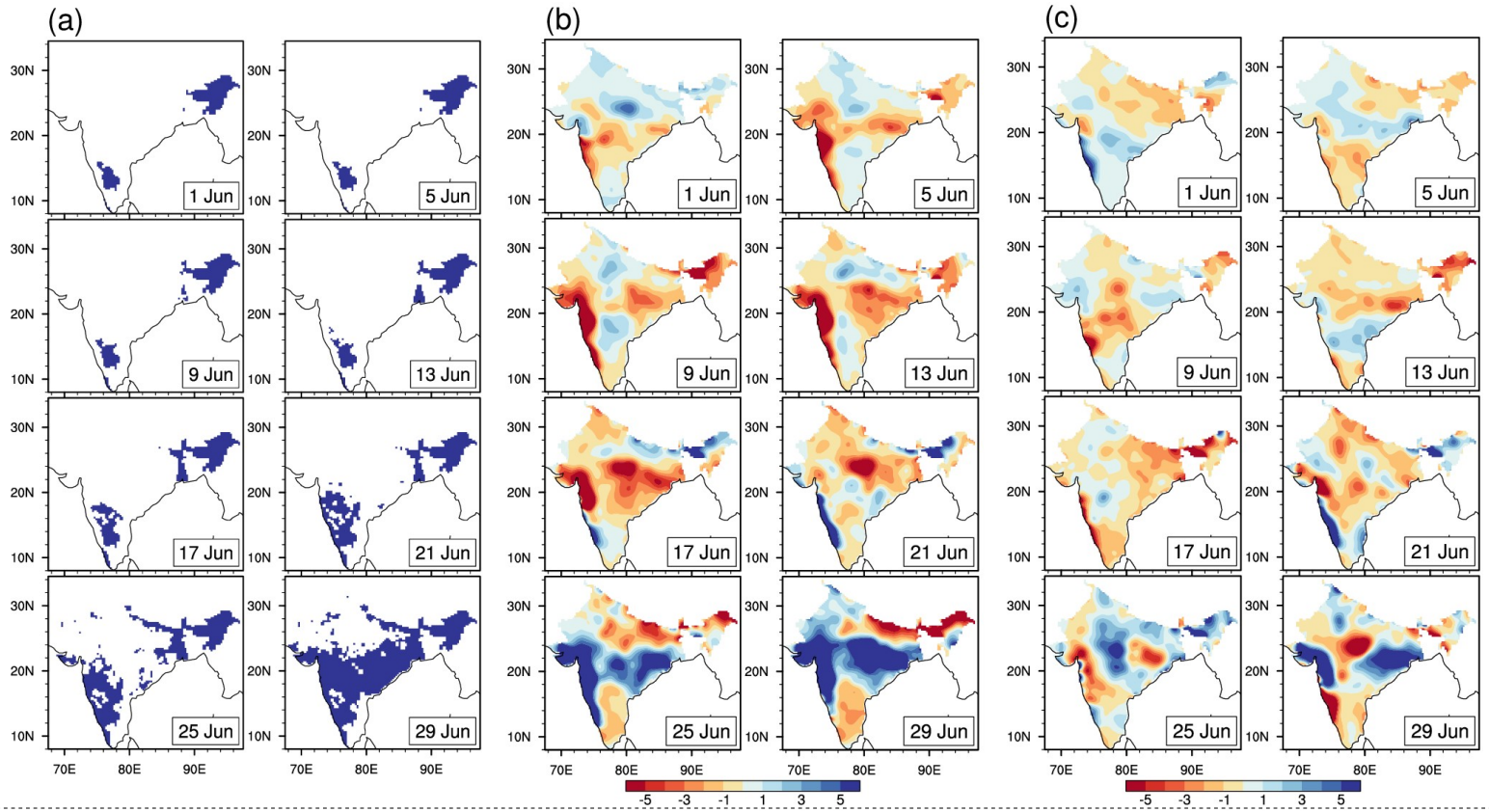
This work was funded by NASA grants NNX17AG72G, NNX16AD83G, NSF award number 1606296, and the Earth System Science Organization, Ministry of Earth Sciences, Government of India (Grant number MM/SERP/FSU/2014/SSC-02/002).

Thank you!

Thank you!

Extras

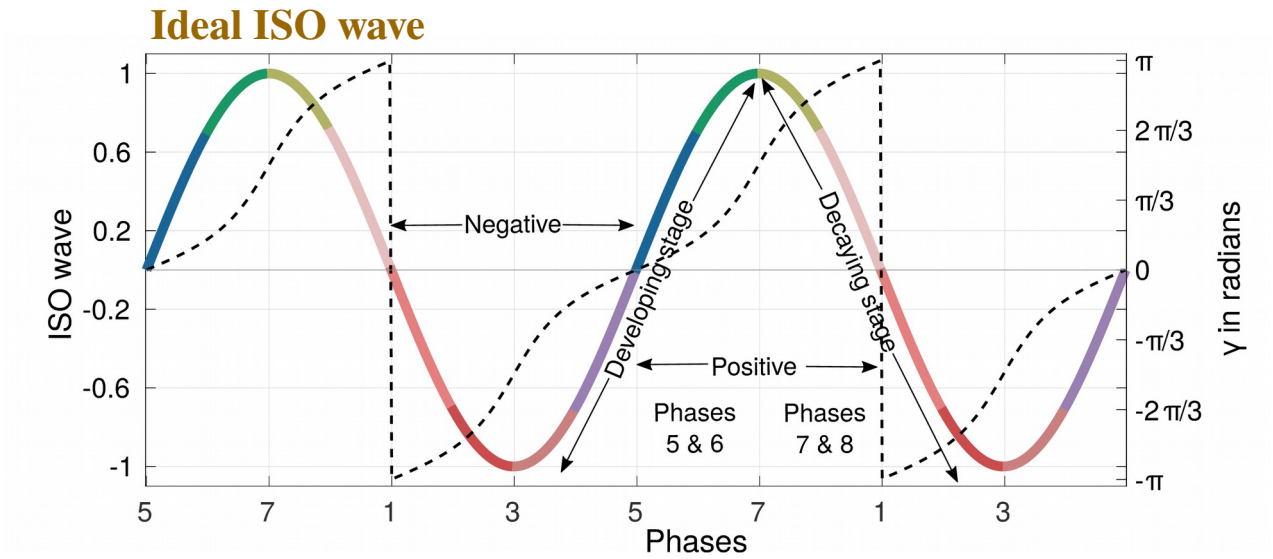
Progression of onset dates with ISO: Example



(a) The progression of local onset after June 1, 2005. The shaded area denotes the grid points where onset has already occurred by the indicated day of the panel. The corresponding rainfall anomalies (mm/day) associated with (b) LF-ISO and (c) HF-ISO. Dates are written in bottom right of each panel.

Progression of onset occurs along with propagation of ISO modes.

Calculate the phases of ISO modes:



An ideal ISO wave represented by a sine function (solid line; left *y-axis*) and associated phase angles (dotted line; right y-axis). Phase numbers are noted in the *x-axis*. Different colors in the ISO wave indicate 8 different phases of ISO.

Phase angle $\gamma(t) = Arg(Y'(t) + iY(t))$

Y(t) is ISO time series over a grid point or over a an area. *Y' (t)* is derivative of *Y(t)*.

$\gamma(t)$ lies between -π and π.

Divided the entire phase plane for ISO at each point into 8 equally spaced intervals such that $-\pi + (m-1)\frac{\pi}{4} \leq \gamma(t) < -\pi + m\frac{\pi}{4}$, $m = 1, \ldots, 8$.

LF-ISO or HF-ISO time series is in phase ***m*** if the associated phase angle belongs to the ***m***-th interval.