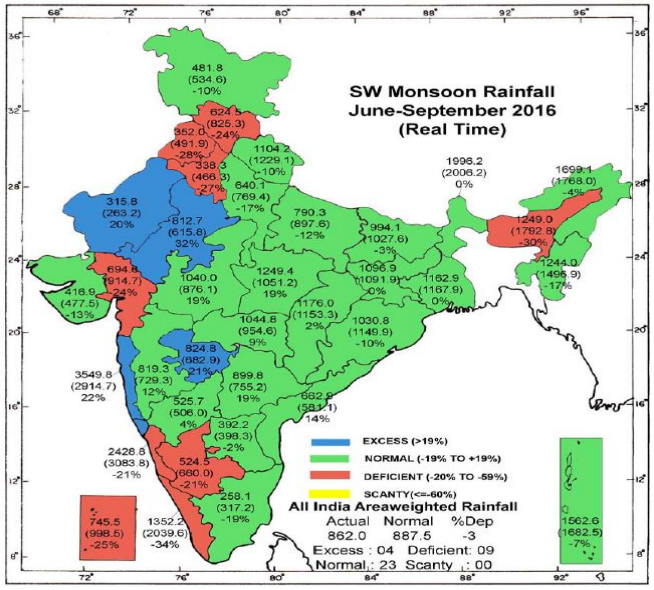
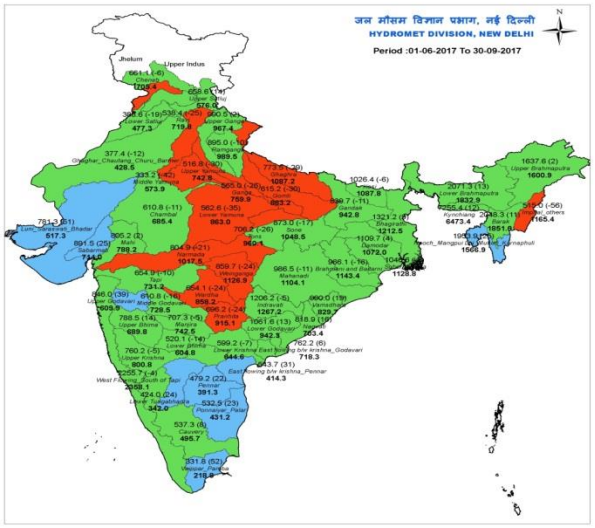
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

RIVER BASIN RAINFALL MAP : INDIA

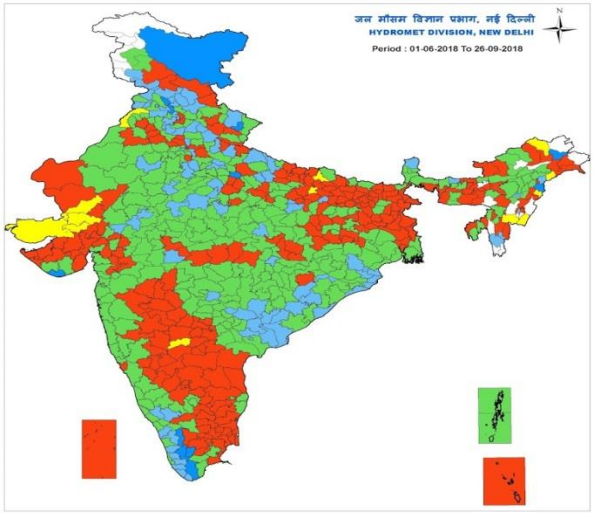


Legend
Large Excess [60% or more] Excess [20% to 59%] Normal [-19% to 19%] Deficient [-59% to -20%] Large Deficient [-99% to -60%] No Rain [-100%] NO DATA

NOTES :
a) RainFall figures are based on operation data.
b) Small figures indicate actual rainfal (mm), while bold figures indicate Normal rainfall (mm).
c) Percentage Departures of rainfall are shown in brackets.

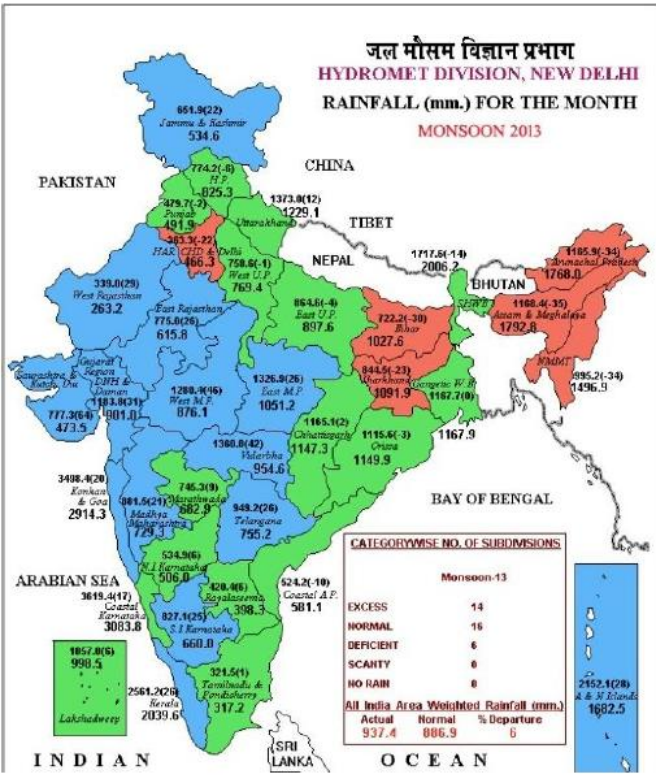
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

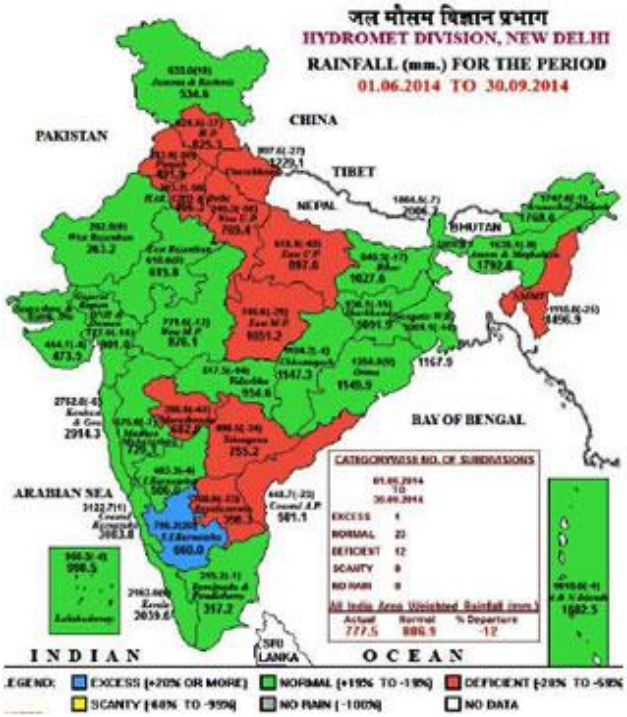
DISTRICT RAINFALL MAP

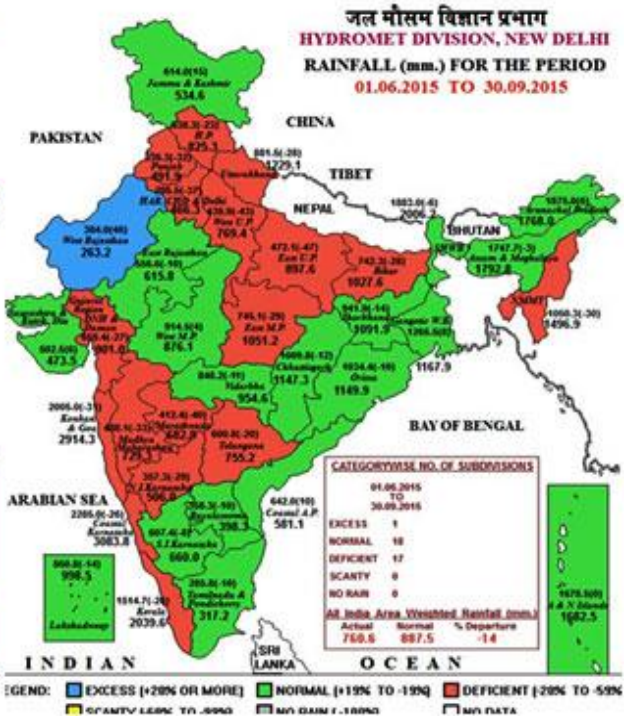


Legend
Large Excess [60% or more] Excess [20% to 59%] Normal [-19% to 19%] Deficient [-59% to -20%] Large Deficient [-99% to -60%] No Rain [-100%] NO DATA

NOTES :
a) RainFall figures are based on operation data.







Large-scale Structures Associated with Onset? Predictable?

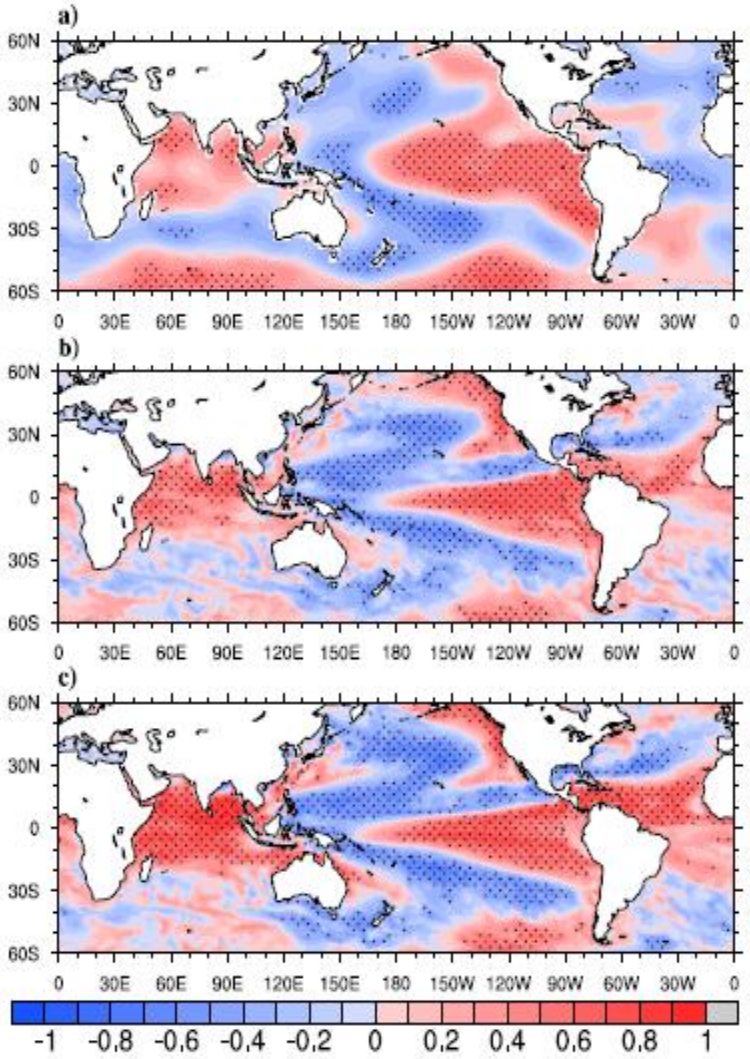


Figure 2. Correlation pattern between onset dates and mean SSTs during May-June (a) NCEP, (b) CFS-T126 (c) CFS-T382 for the period 1982–2008. The regions with correlation significant at 90% confidence level are shaded with black dots. This Figure is created using NCAR Command Language (Version 6.3.0) [Software] (2015). Boulder, Colarado: UCAR/NCAR/CISL/TDD. http://dx.doi.org/10.5065/D6WD3XH5.

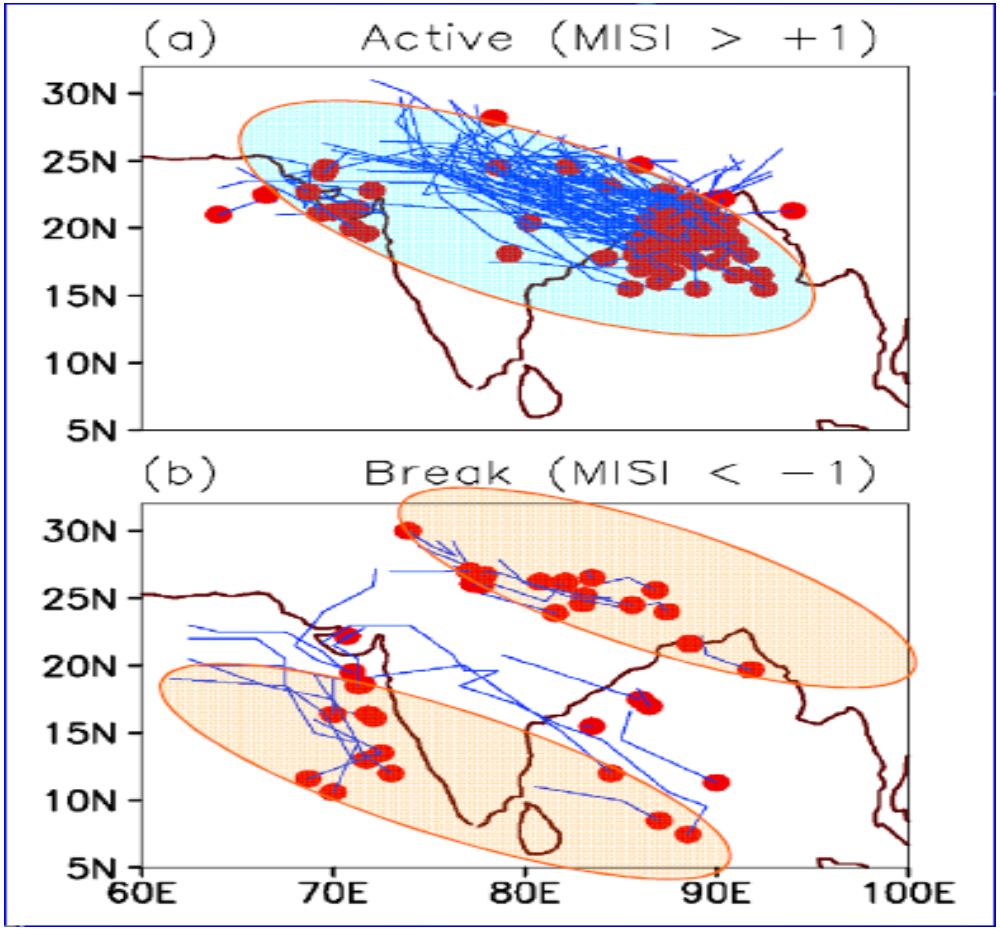
Early onset when MISO activity is stronger

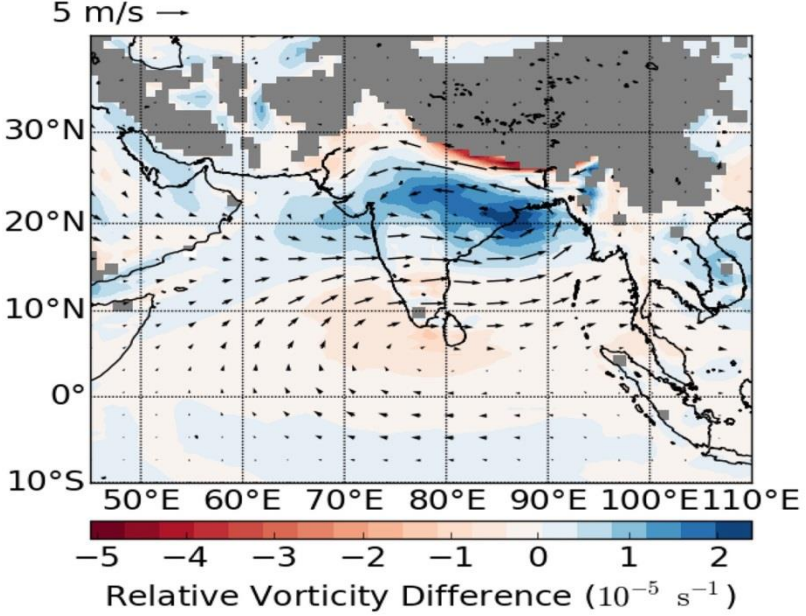
MISO responding to warming

Onset response to warming?

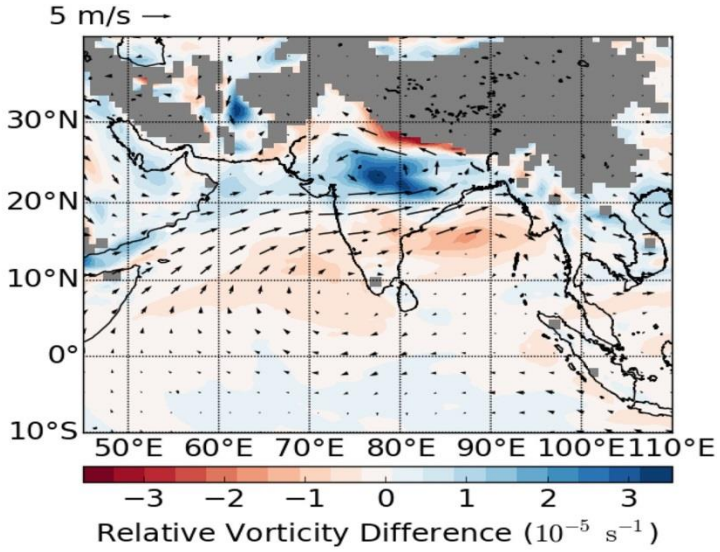
Pradhan et al. 2017, Zhou and Murtugudde 2014

Weather Regimes?





(a) All depression days minus JJAS climatology

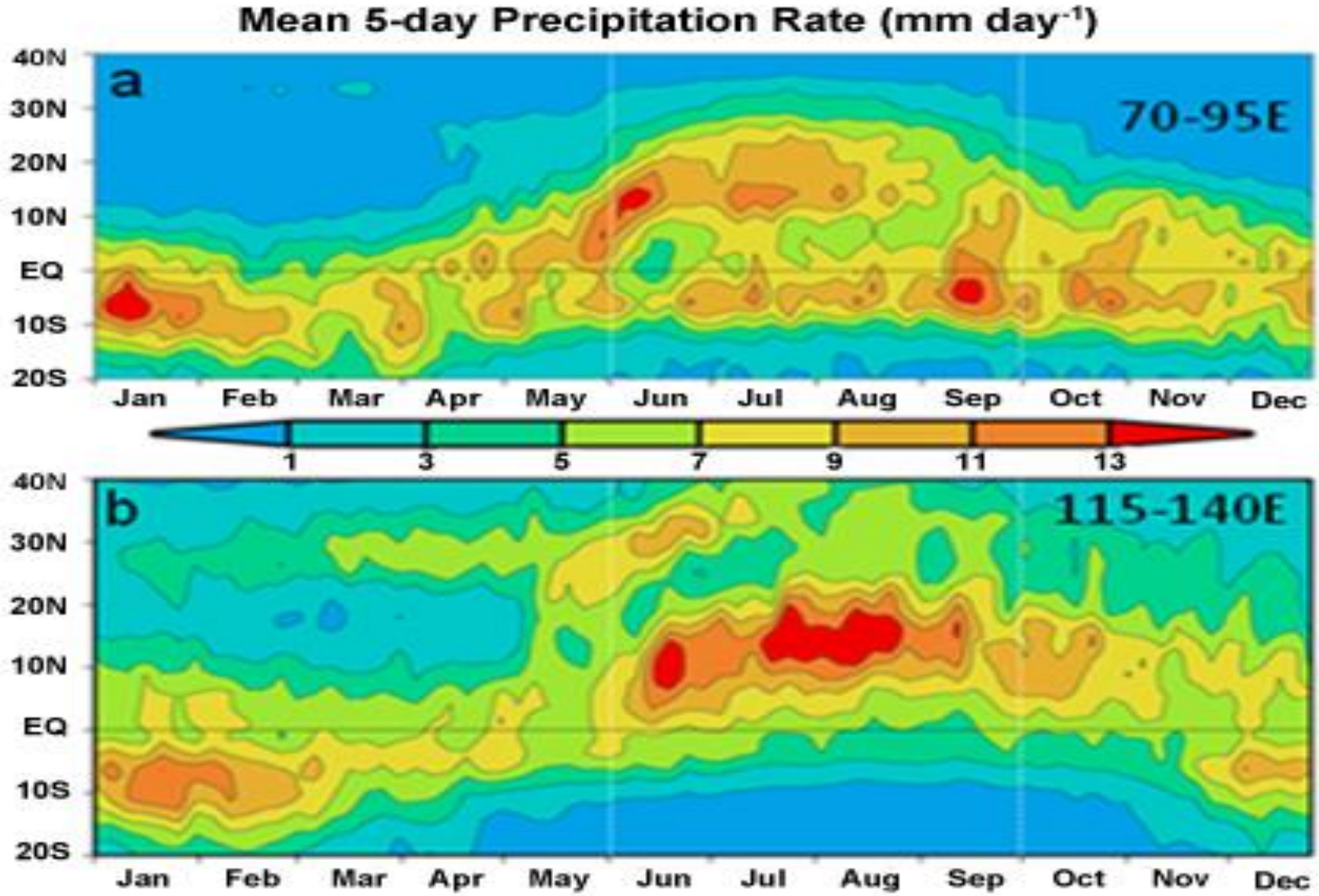


(b) Active-minus-neutral depression days

FIG. 25. Relative vorticity (colored contours, 10^{-5} s^{-1}) and wind (m s^{-1}) for (a) all depression days as an anomaly to the boreal summer mean and (b) active-minus-neutral depression days. The colored contours are grayed out where the orography rises above the 850-hPa level. Hunt et al. 2016

Vortex stretching and Diabatic PV generation vs PV Advection

Standing and Oscillatory Modes?



WMO

Signal-to-Noise Must be Increased as much as possible to focus the Theoretical Approaches

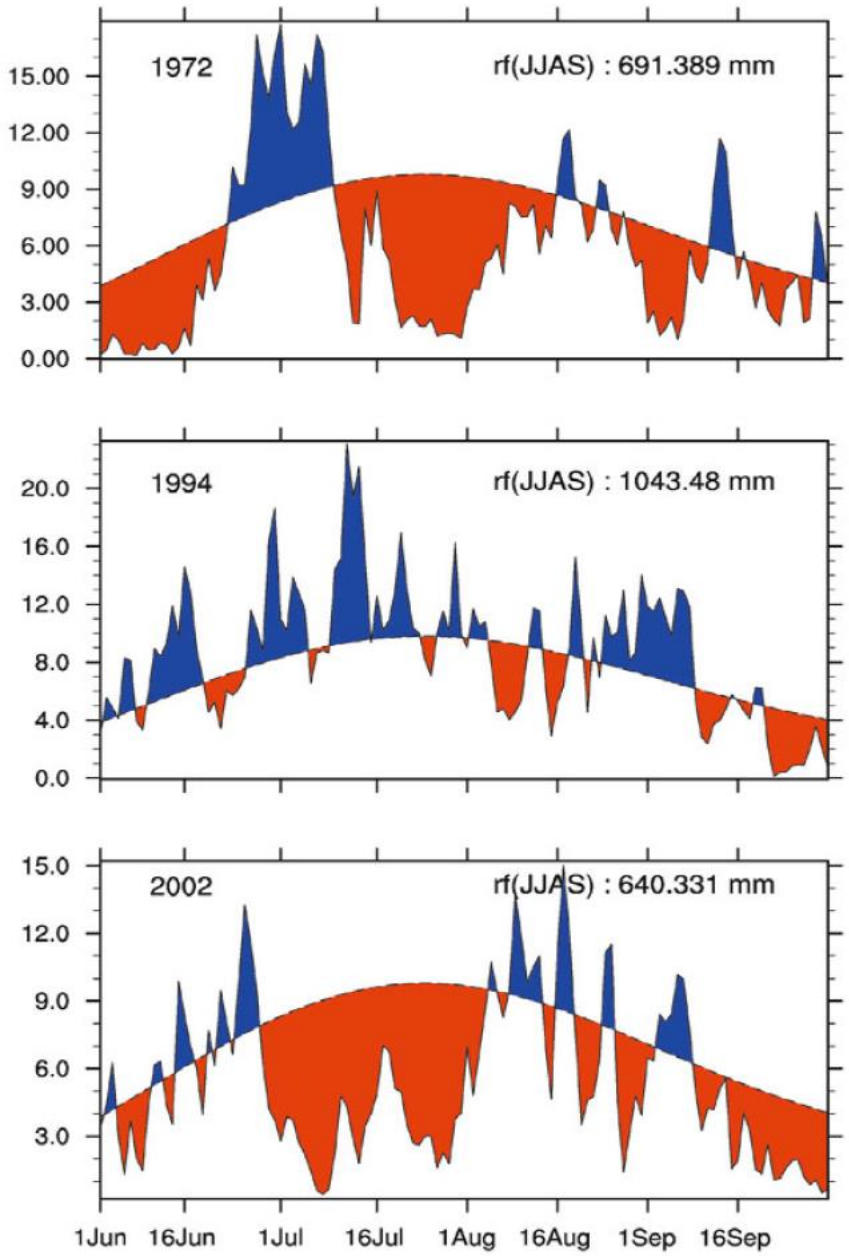
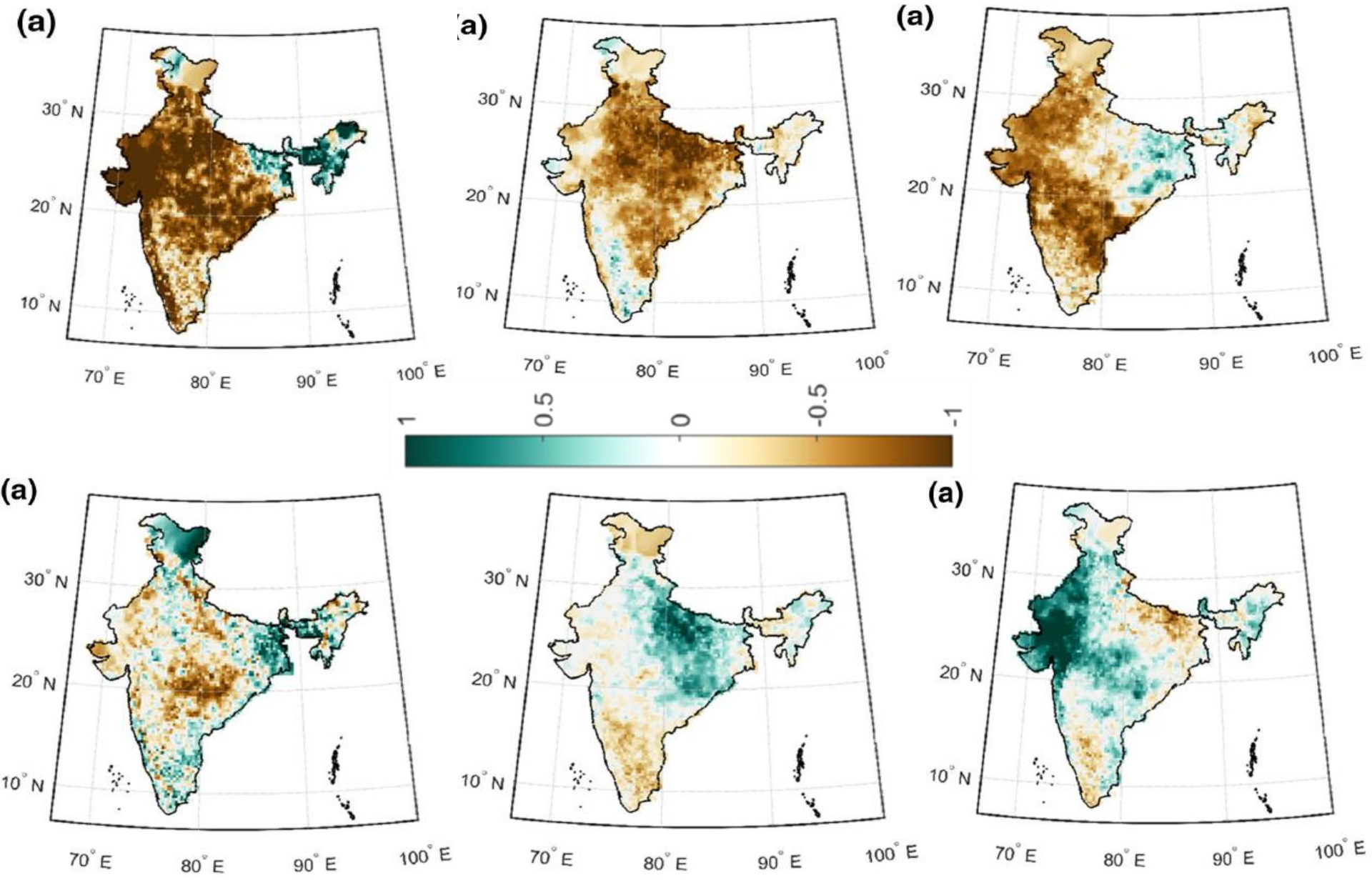


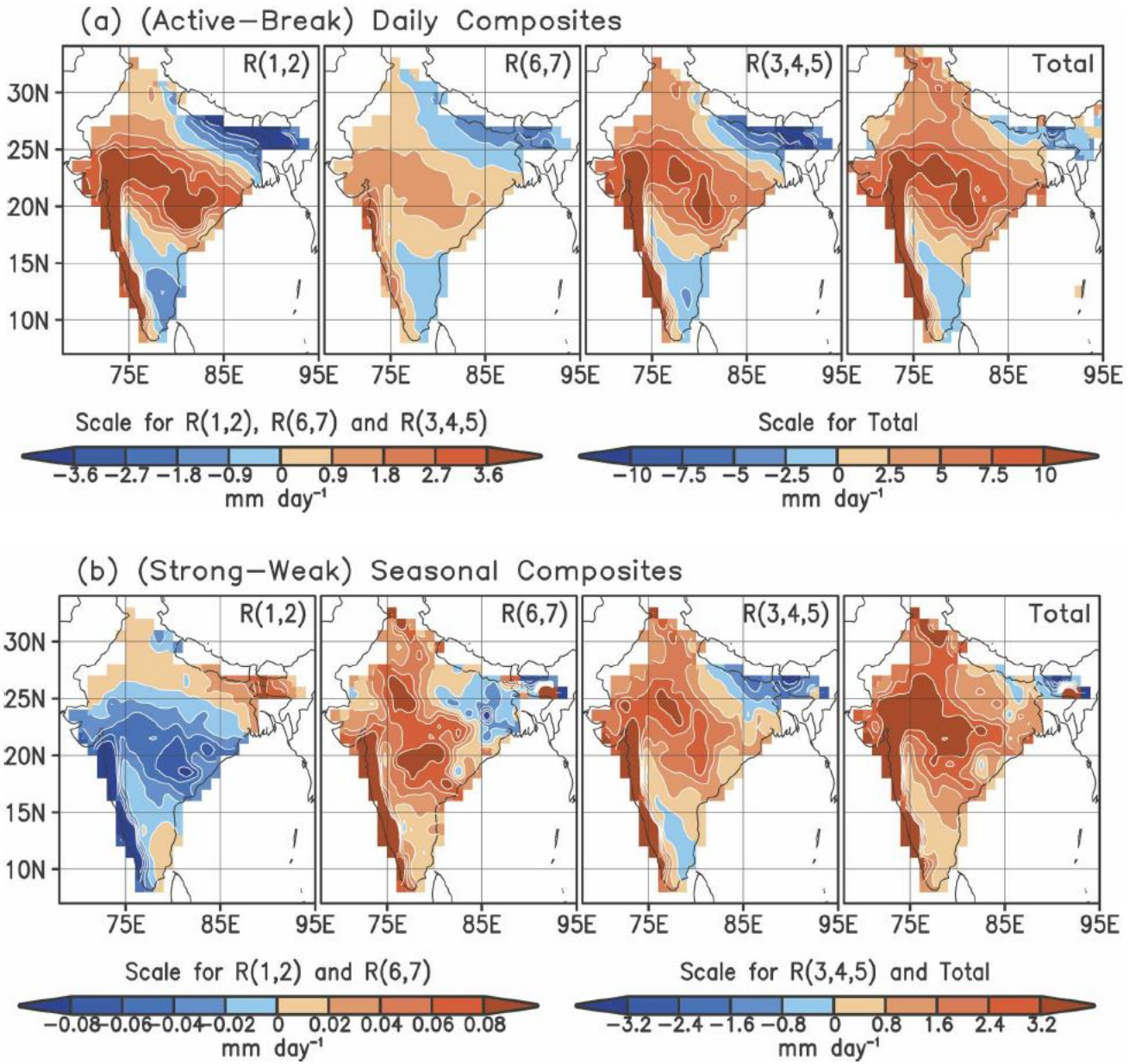
Figure 2.2. Daily rainfall (mm day^{-1}) averaged over 72.5°E–85.5°E and 10.5°N–25.5°N based on high-resolution daily gridded rainfall data (IMD) over the Indian subcontinent during the summer monsoon season for 3 years: 1972, 1994, and 2002. Departures from the mean annual cycle (shown as the envelope) are shaded. Seasonal mean rainfall for each year is also shown in the top-right corners.

Goswami 2012

Weather and Climate Regimes: Who Determines them?

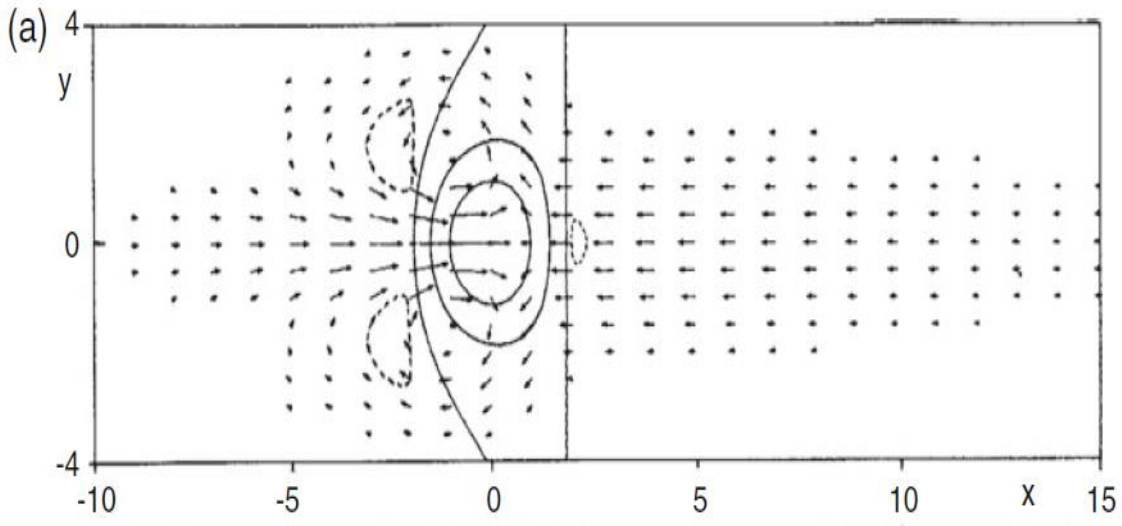


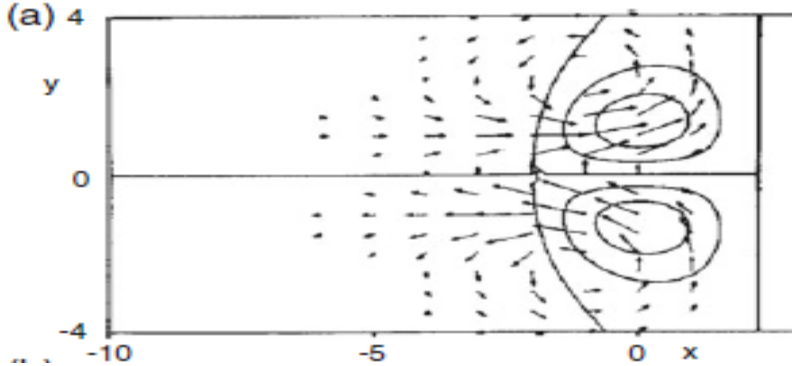
Sahastrabuddhe et al. 2017

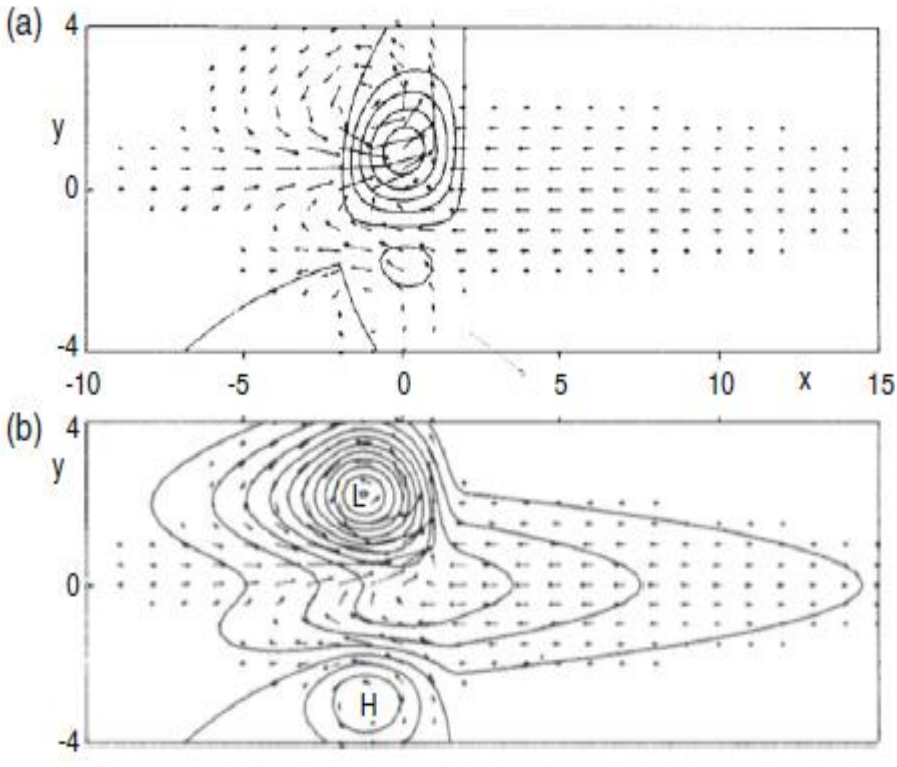


Seasonally Persistent and Propagating Patterns

Krishnamurthy and Shukla 2007







Heat-Induced Circulations Gill 1980

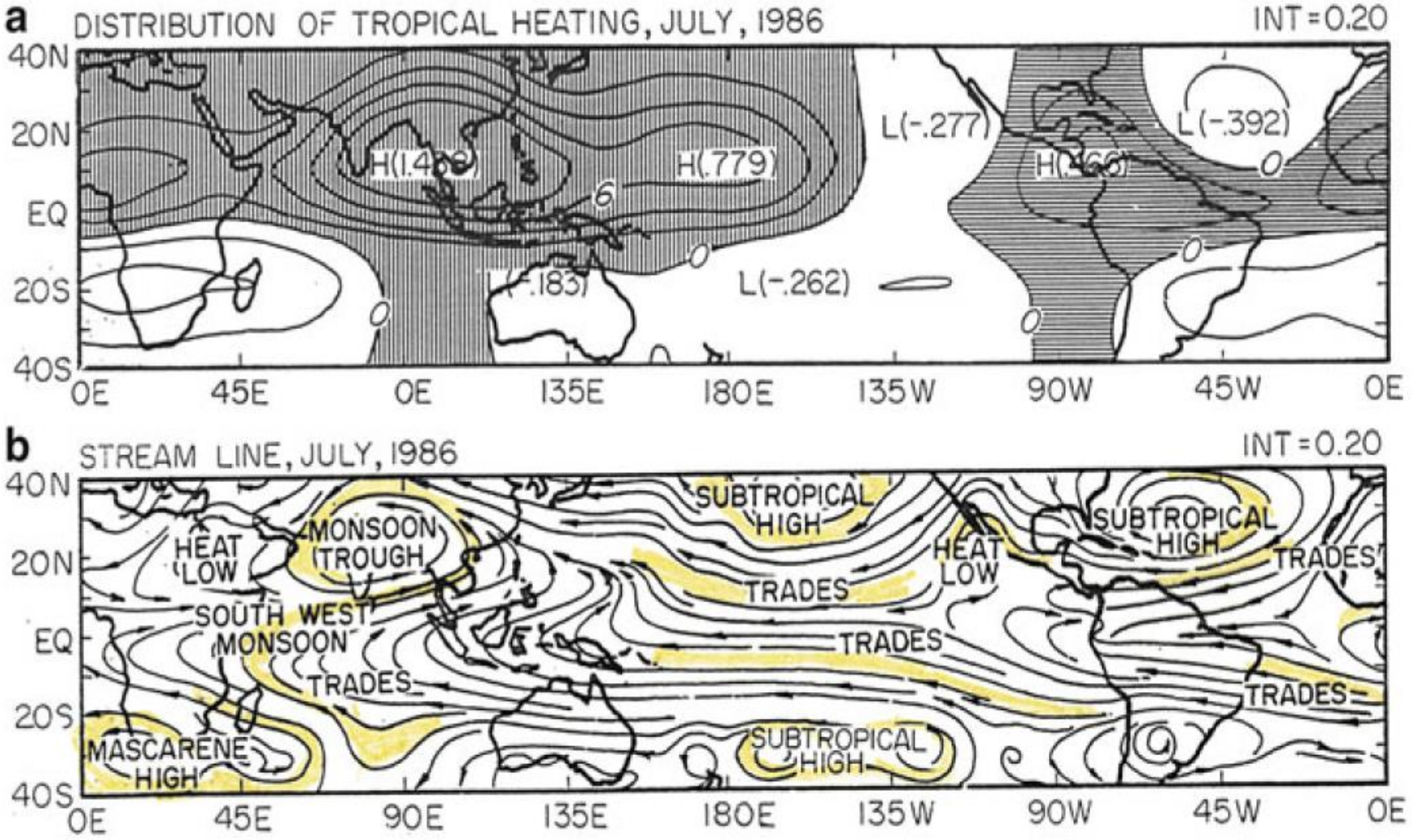
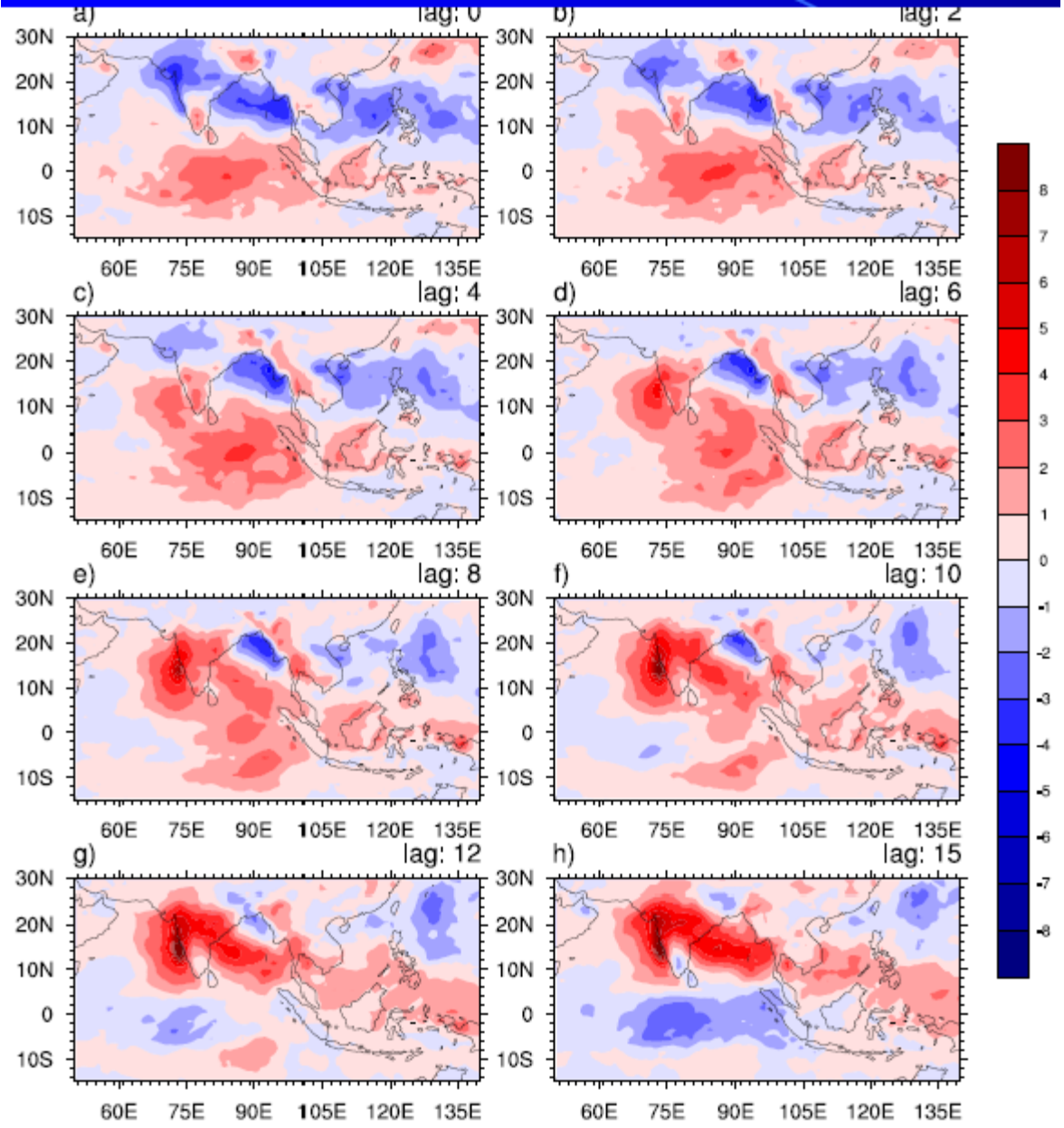
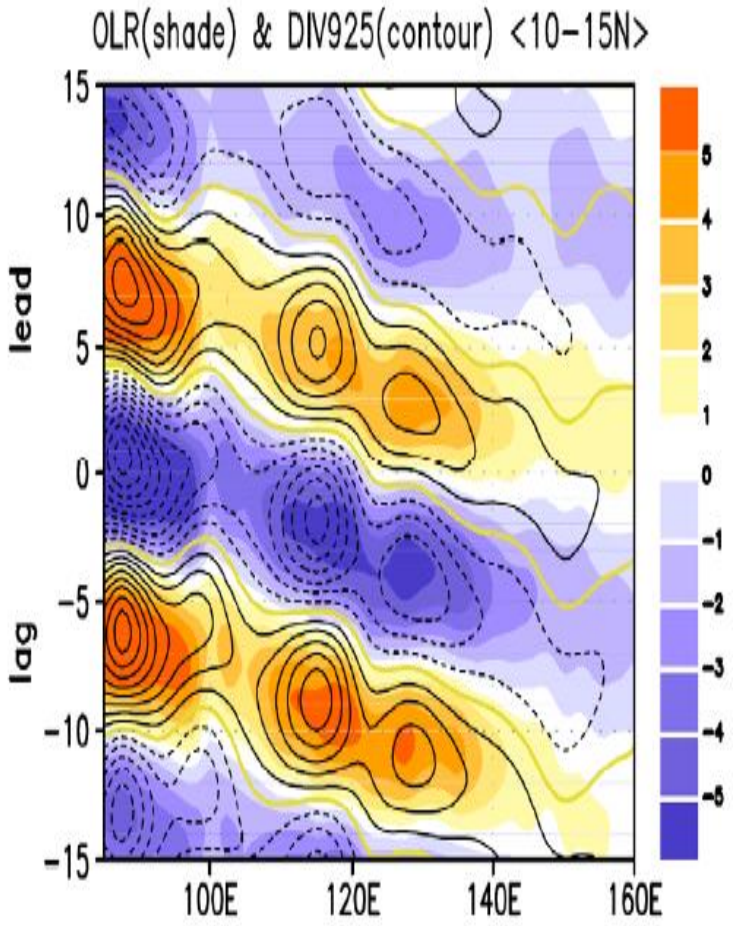


Fig. 4.3 (**a**) The vertically integrated heating distribution retrieved from OLR observations for July 1986 and (**b**) Gill's solution of motion field at low level for the prescribed heating (shown in a) (From authors unpublished work based on Zhang and Krishnamurti 1996)

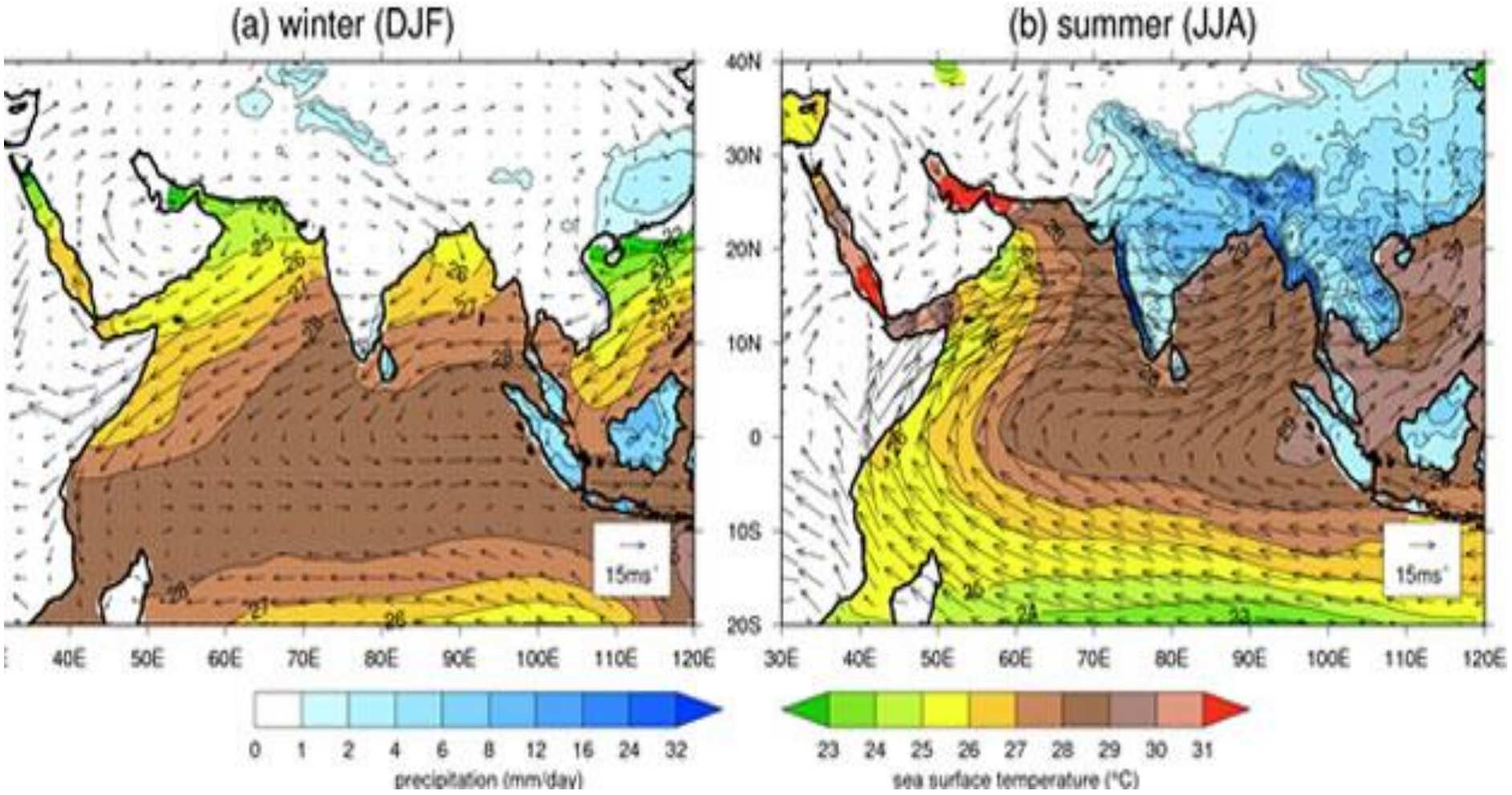
MISOs - Coupled





25-90 day GPCP lag composite and 10-20 day Goswami (2012)

Energy Source: Baroclinic or Barotropic Instability?



Can both seasons be explained by one or the other?

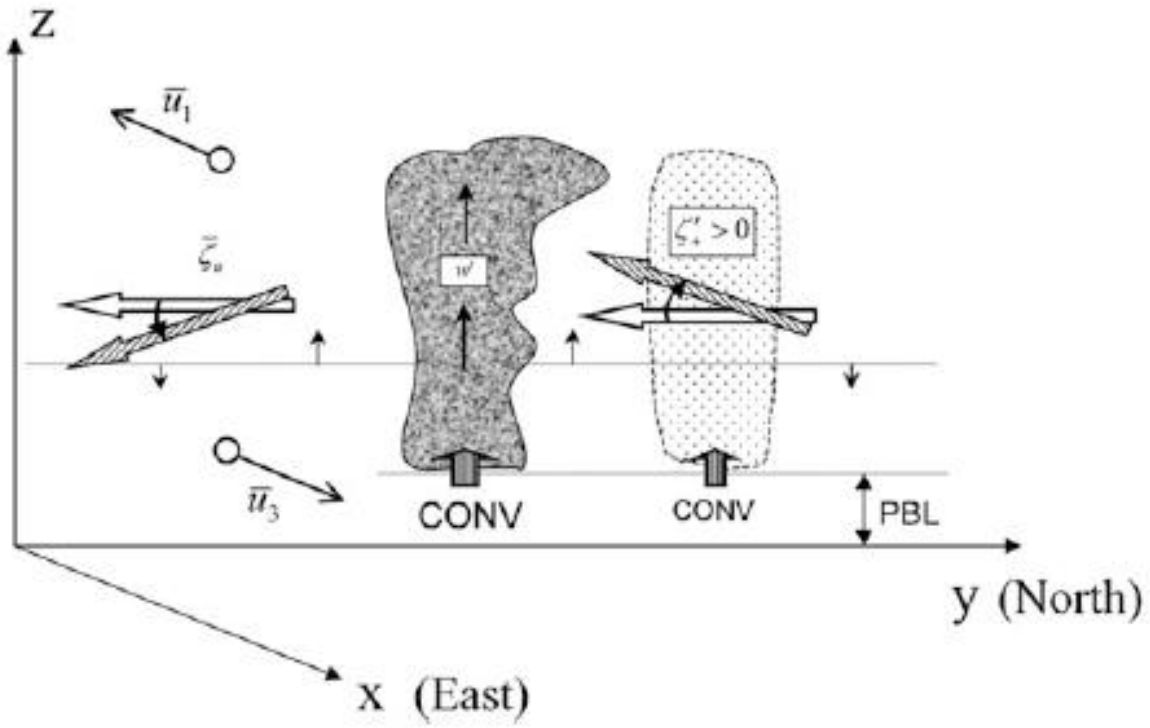


Fig. 3.25 Schematic diagram for the generation of the barotropic vorticity due to the twisting of the background southward vorticity (*hollow double arrow*) associated with the easterly shear by BSISO perturbation vertical motion (From Wang (2006). Copyright © 2006, Praxis. Springer Berlin Heidelberg)

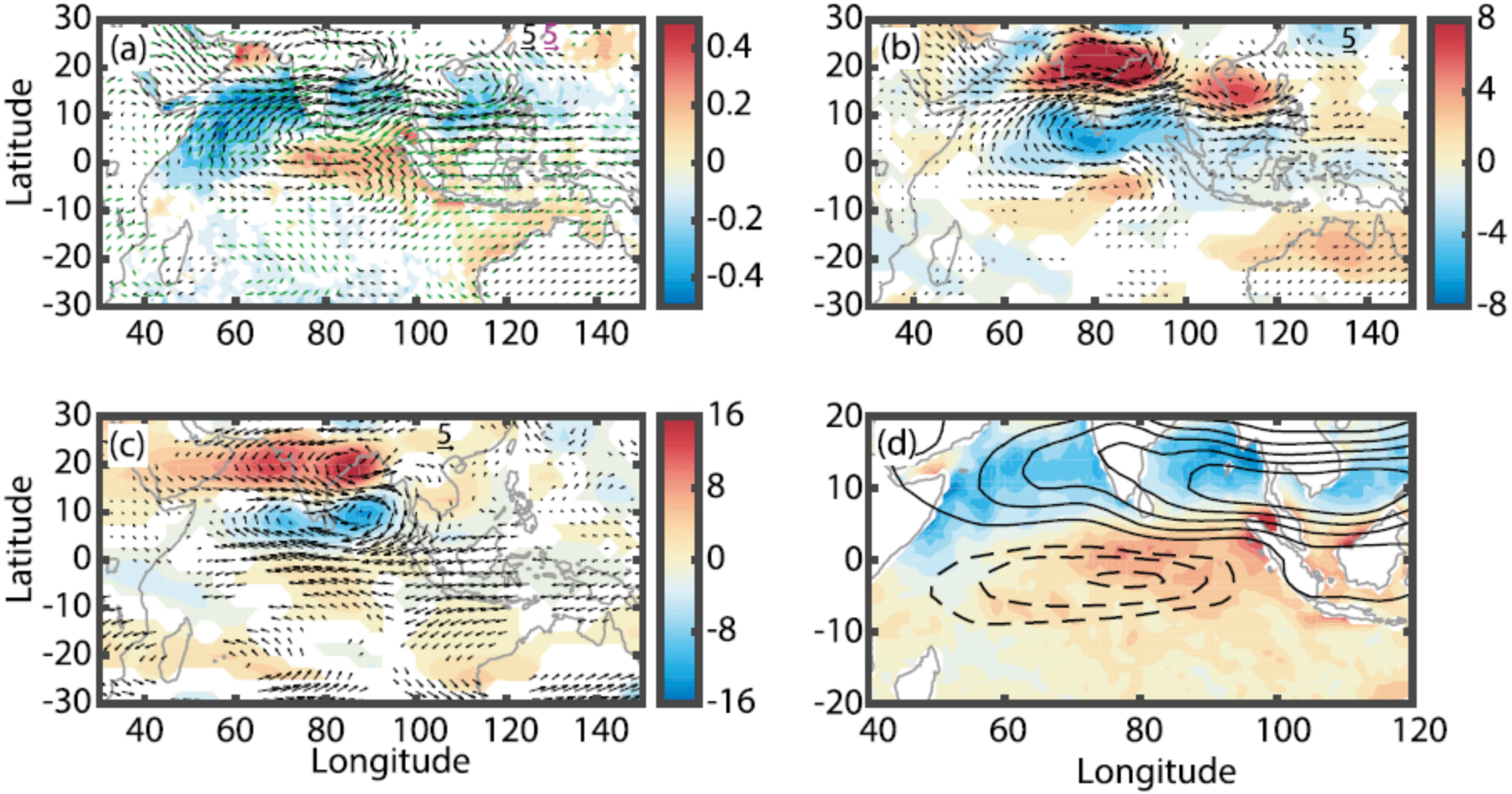


FIG. 3. (a) The differences between the large- and small-rainfall groups in intraseasonal SST anomalies (color shading; °C), intraseasonal wind anomalies at 850 hPa (black vectors; $m\,s^{-1}$), and vertical wind shear (green vectors; $kg\,m^{-2}\,s^{-1}$). (b) The differences in intraseasonal PV anomalies at 850 hPa (color shading; 10^{-2} PVU; 1 PVU = $10^{-6}\,m^2\,K\,s^{-1}\,kg^{-1}$) and intraseasonal wind anomalies at 850 hPa (black vectors; $m\,s^{-1}$). (c) As in (b), but for the upper troposphere at 300 hPa. (d) The pattern of the positive CIO mode. Reddish (bluish) color denotes the positive (negative) node of the SST mode. Solid (dashed) contours denote the positive (negative) node of the zonal wind mode. All color shading and vectors shown in (a)–(c) are significant at a 95% confidence level.

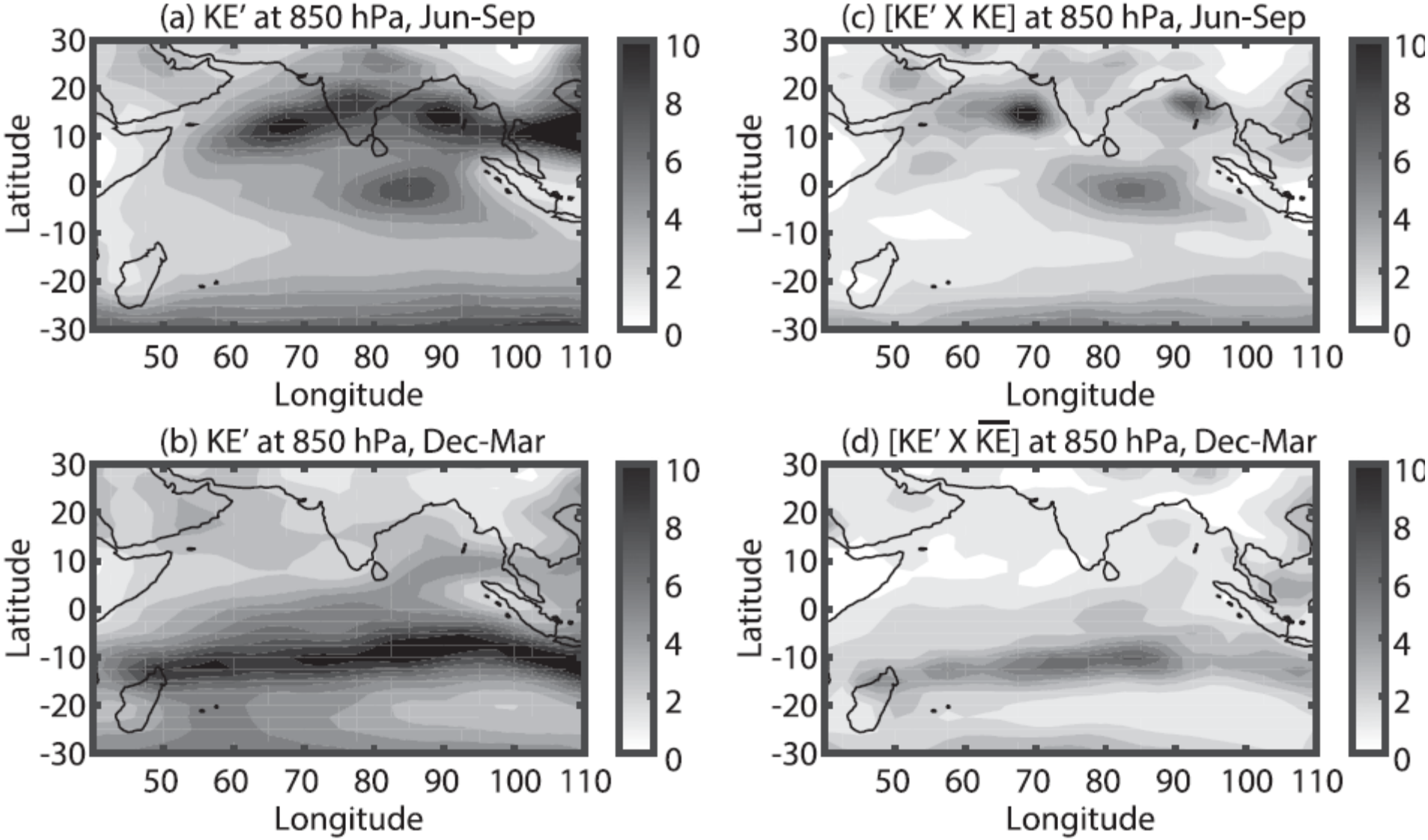
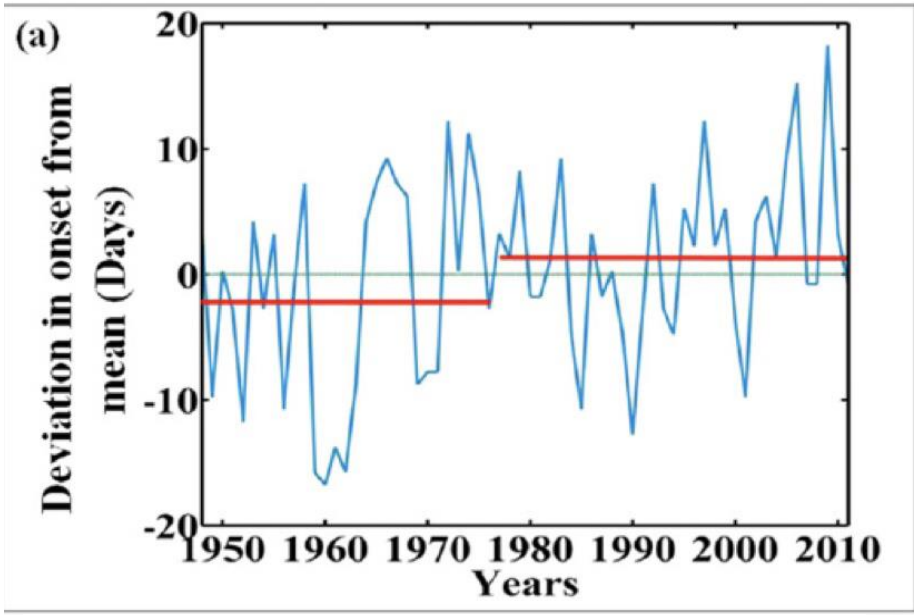
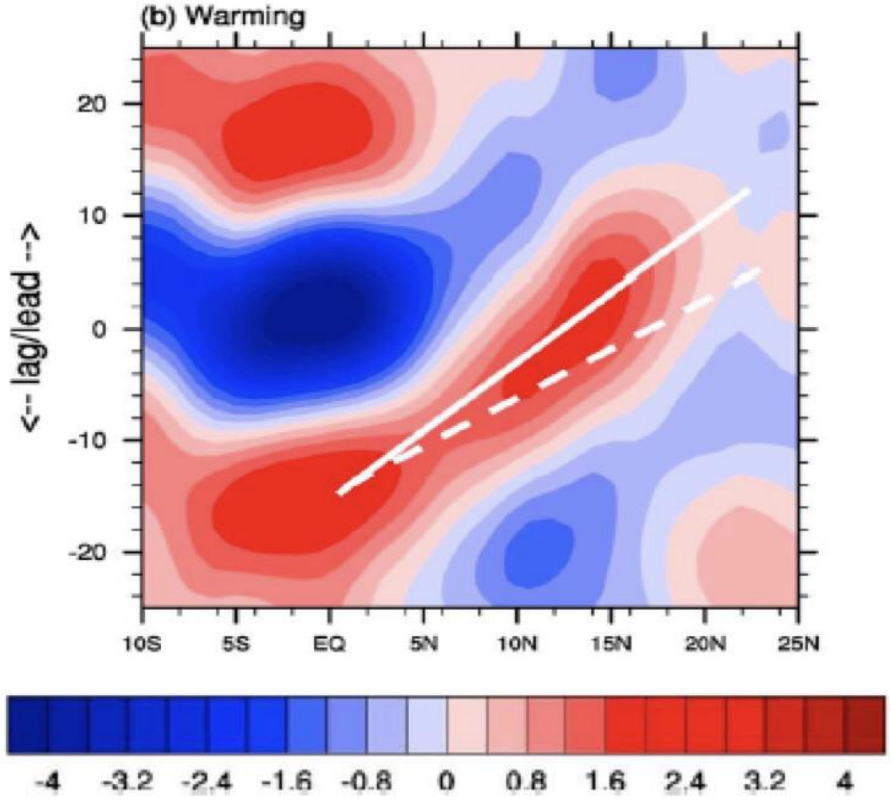


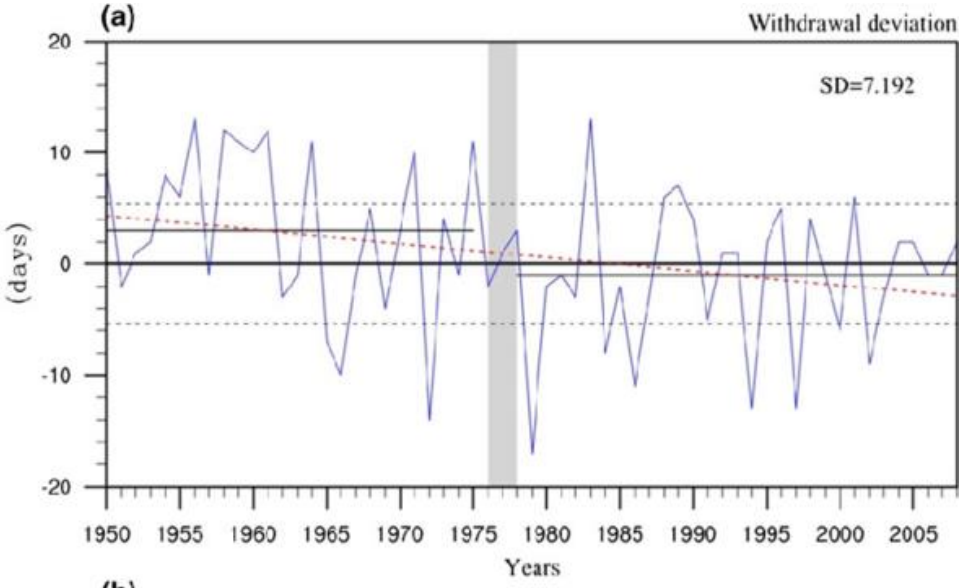
FIG. 3. (a) KE′ at 850 hPa (J kg^{-1}) averaged over boreal summer from June to September. (b) As in (a), but averaged over boreal winter from December to March. (c),(d) As in (a),(b), but for [KE′ × $\overline{KE}$] (J day^{-1} kg^{-1}).

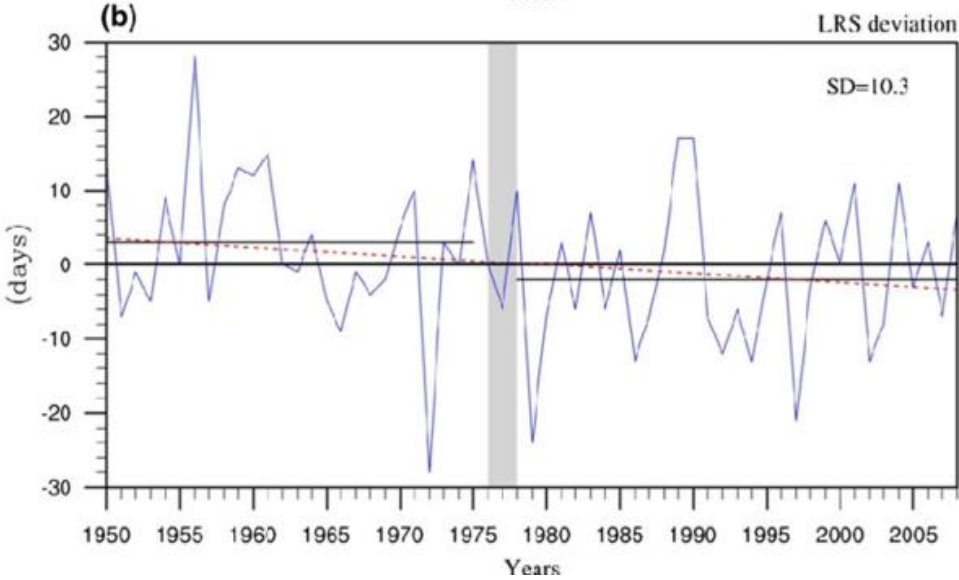
Monsoon Onset/Withdrawal; Length of the Rainy Season

Sahana et al. 2015; Sabeerali et al. 2013









Theoretical Approaches to the Summer Monsoon

- **Better to Split the Problem into the Standing Mode and Propagating Modes**
- **Can Heat-Induced Circulations capture the Standing Mode?**
- **Are there wave solutions to the Propagating Modes?**
- **Energy Source: Barotropic vs Baroclinic Instabilities**