(Abs: Th-1.72)

Dynamics of Monsoonal Orographic Rainfall in the Eastern Himalayas

Pratik Kad & Kyung-Ja Ha

Meghdoot Complex Auditorium, IITM Pune, India

March 18, 2025 (16:00)

| WMO IWM-8 |
| Pune, India |

Dynamics of Monsoonal Orographic Rainfall in the Eastern Himalayas

Pratik Kad[1,2] & Kyung-Ja Ha[3,4,5]

[1]NORCE Norwegian Research Centre, Bergen, Norway
[2]Bjerknes Centre for Climate Research, Bergen, Norway
[3]Department of Climate System, Pusan National University, Busan, South Korea
[4]Center for Climate Physics, Institute for Basic Science (IBS), Busan, South Korea
[5]Institute for Future Earth, Pusan National University, Busan, South Korea

Meghdoot Complex Auditorium, IITM Pune, India

March 18, 2025 (16:00)

Table of Contents

I Background

(Source: CNBC) June 2022

MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV INVESTING CLUB PRO

CLIMATE

Floods in India, Bangladesh leave millions homeless, 18 dead

PUBLISHED SAT, JUN 18 2022•3:19 PM EDT

NDRF personnel rescue residents in Guwahati, a city of India's state of Assam.

Xinhua News Agency | Getty Images

BBC

Warming threatens Himalayan glaciers ...

The Himalayan

World

Floods kill 22 people in India, 170,000 homeless

By REUTERS

Published: 02:11 pm Jul 11, 2016

(Source: The Himalayan Times) July 2016

I Background

(Source: CNBC) June 2022

CNBC MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV INVESTING CLUB PRO

CLIMATE

Floods in India, Bangladesh leave millions homeless, 18 dead

PUBLISHED SAT, JUN 18 2022•3:19 PM EDT

NDRF personnel rescue residents in Guwahati, a city of India's state of Assam.

Xinhua News Agency | Getty Images

Assam flooding: Several rare rhinos die in India's Kaziranga park

19 July 2020

(Source: BBC) July 2020

GETTY IMAGES

The Kaziranga park is home to the world's largest population of one-horned rhinos

More than 100 wild animals, including at least eight rare rhinos, have died in recent flooding at a national park in north-eastern India, officials say.

World

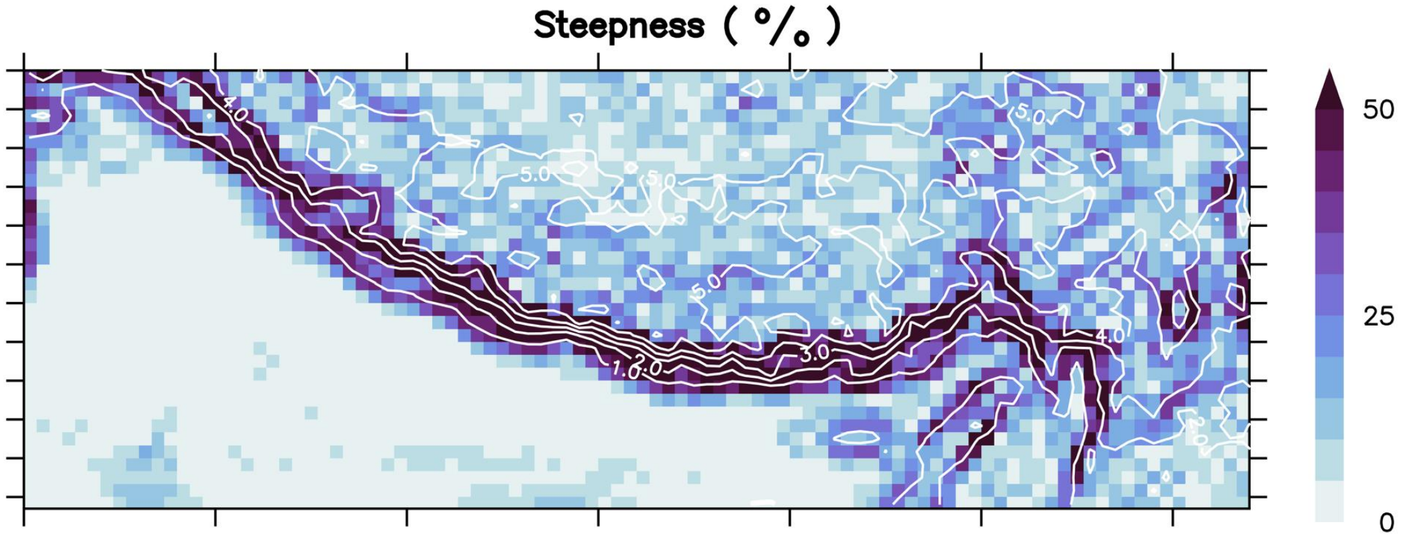
Floods kill 22 people in I

By REUTERS

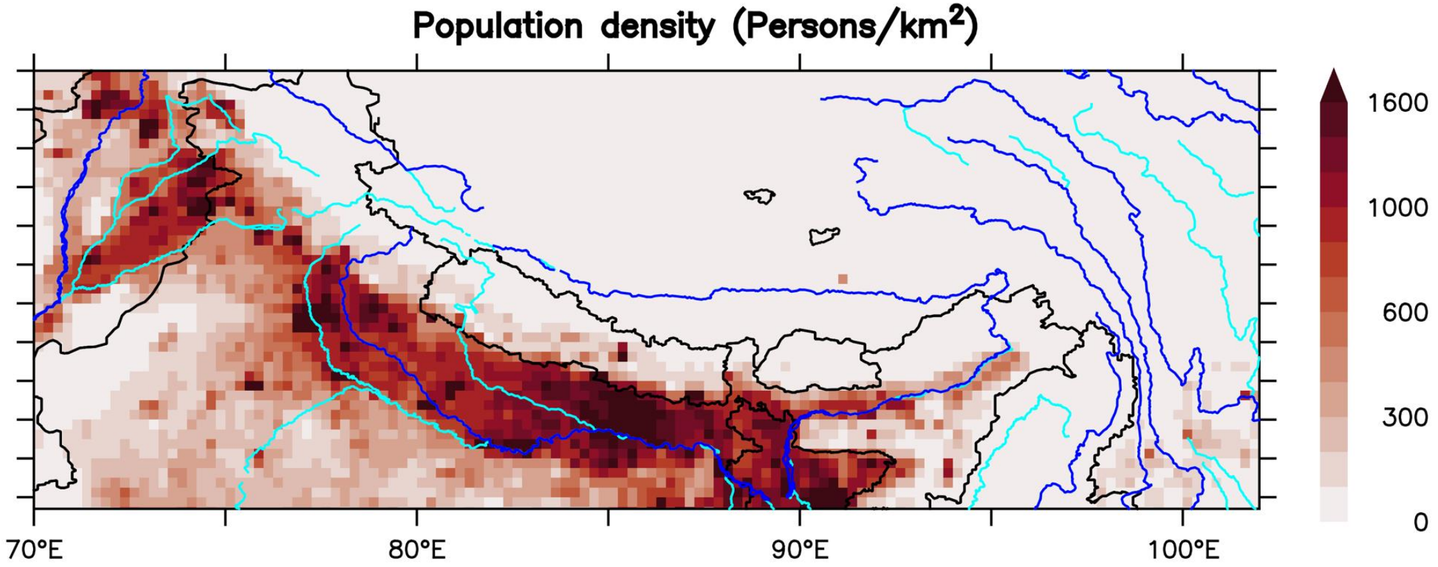
Published: 02:11 pm Jul 11, 2016

(Source: The Himalayan Times) July 2016

I Background



Himalaya is the source of earth's major rivers (the Ganges and Brahmaputra)

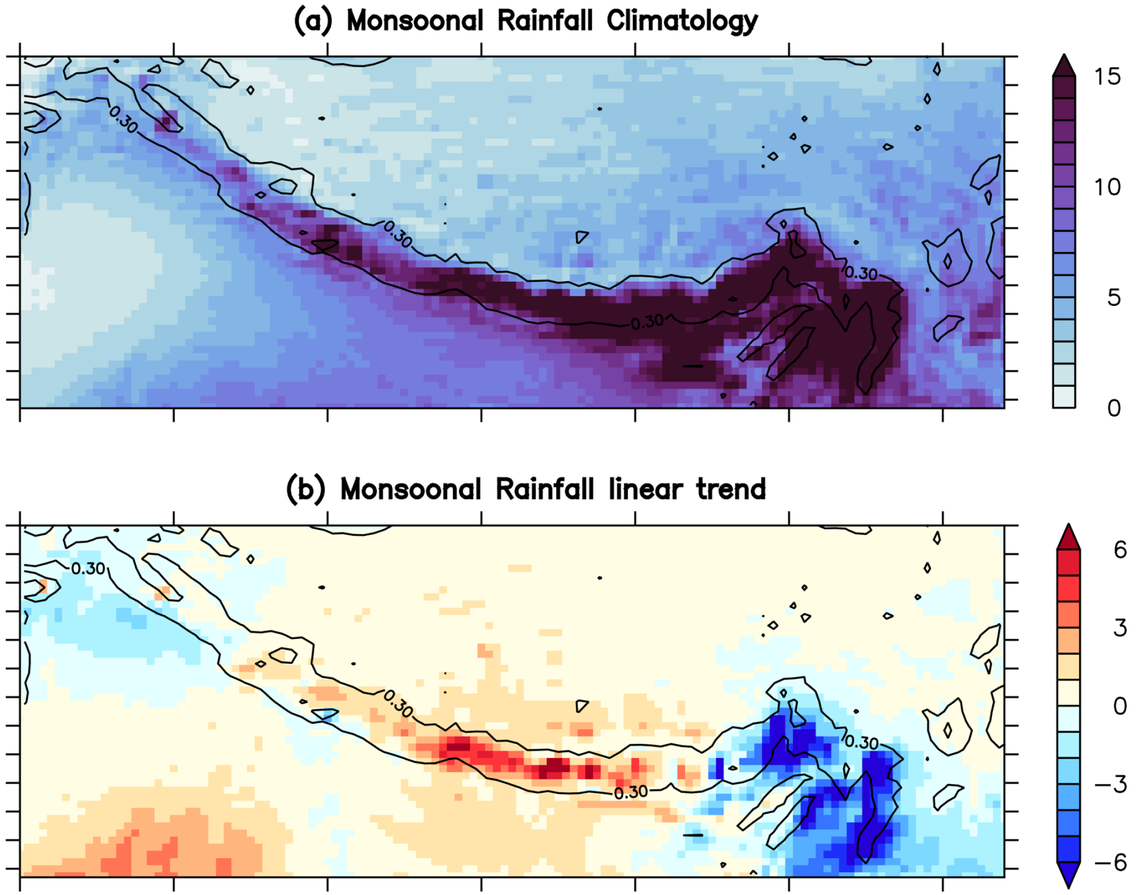


Downstream is a lifeline for the densely populated regions of the world.

II Motivation

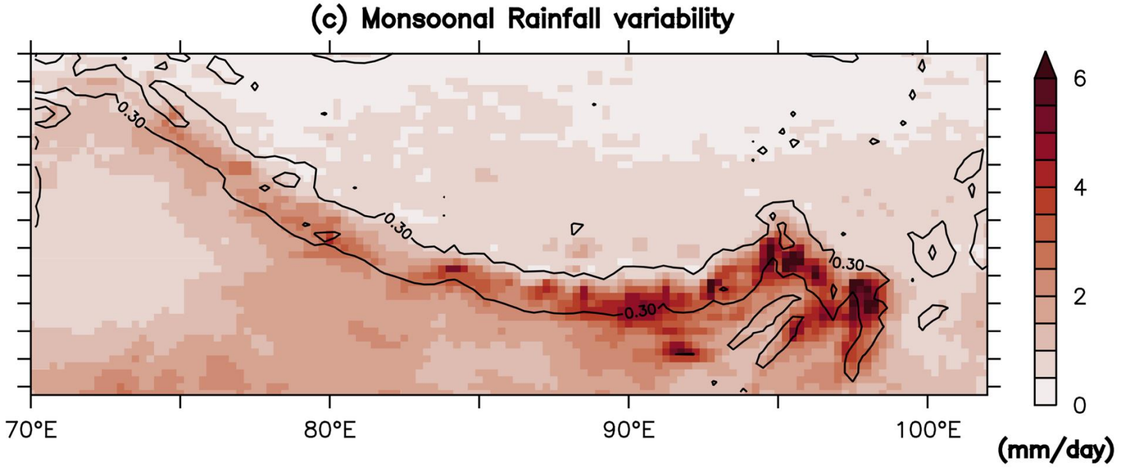
- Warming and extreme events are rising due to climate change.
- Snowmelt/ Flash Flood is causing flooding in the Himalayan river
- The trend shows decline in mean rainfall and Extremes

II Motivation



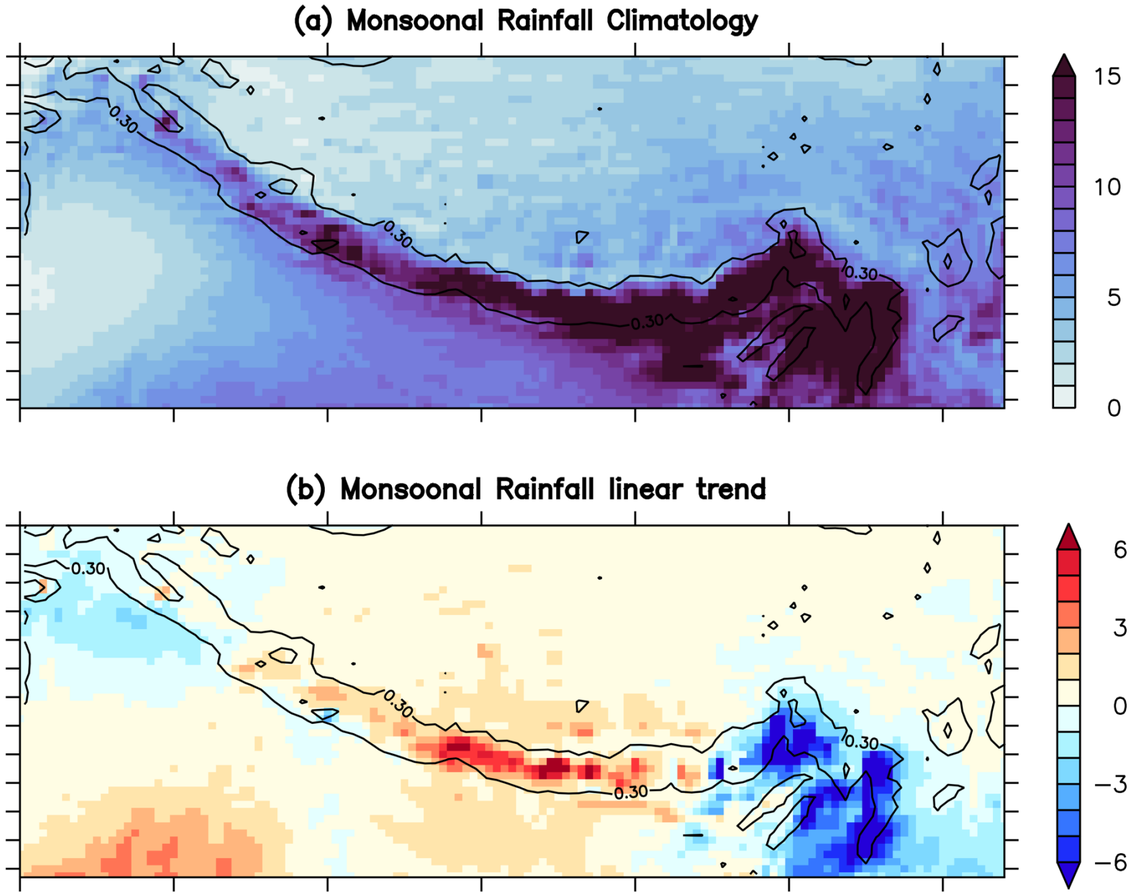
Annual rainfall

- **~11,400 mm (Cherrapunji, Meghalaya)**
- **~800 mm (Pune)**



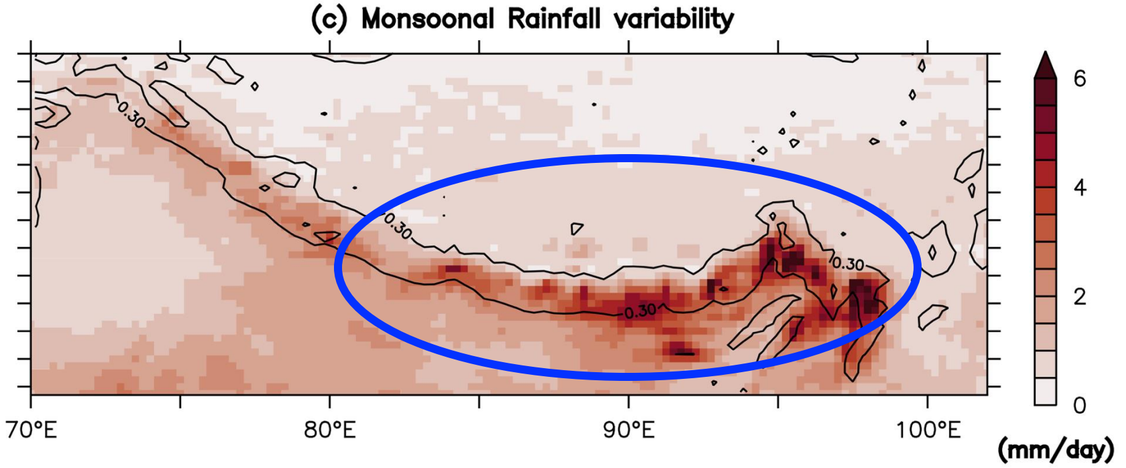
Monsoon variability dominated over steep mountains in the Eastern Himalayas.

II Motivation



Annual rainfall

- **~11,400 mm (Cherrapunji, Meghalaya)**
- **~800 mm (Pune)**



Monsoon variability dominated over steep mountains in the Eastern Himalayas.

Vulnerability to floods due to monsoon variability?

III DATA (1979–2021)

- The GloFAS-ERA5 river discharge (Harrigan et al., 2020) reanalysis product is publicly available on the CDS, https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-historical?tab=overview.

- ERA5 reanalysis data is publicly available from the ECMWF on their Climate Data Store (CDS), https://cds.climate.copernicus.eu/cdsapp#!/home (Hersbach et al., 2020)

- HadSST data are available at the Met Office Hadley Centre website, https://www.metoffice.gov.uk/hadobs/hadisst/

10

- Earth topography five-minute grid (etopo5) is publicly available at National Geophysical Data Center, https://www.ngdc.noaa.gov/mgg/global/etopo5.HTML

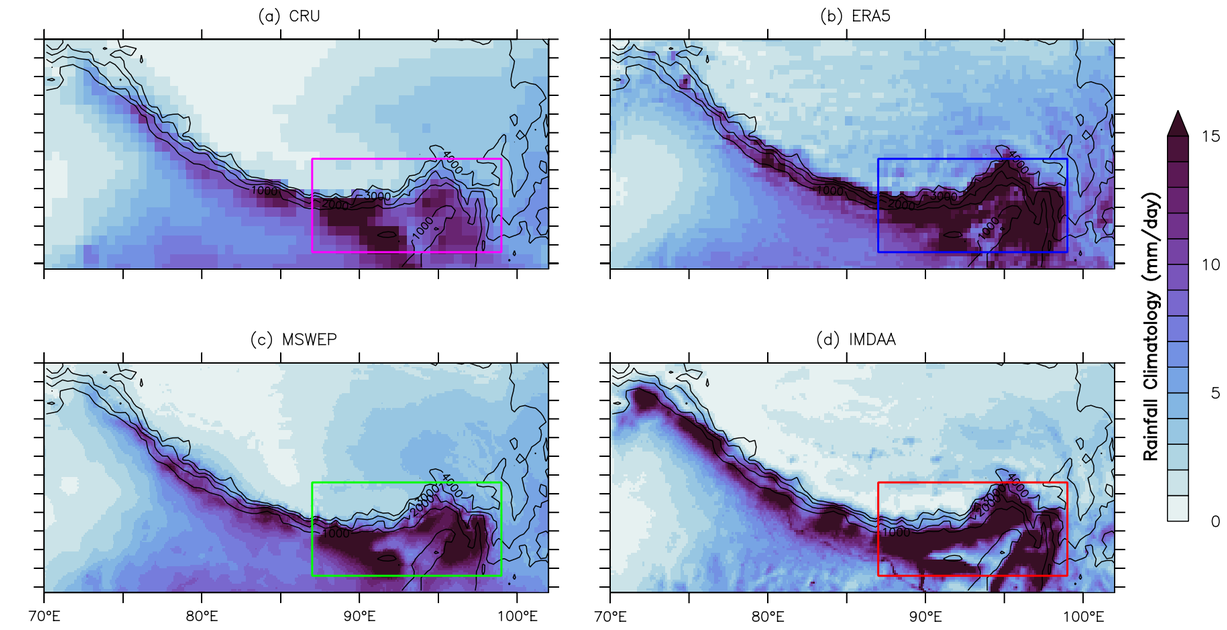
- Multi-Source Weighted-Ensemble Precipitation (MSWEP) rainfall product data from GloH2O is publicly available, http://www.gloh2o.org/mswep/

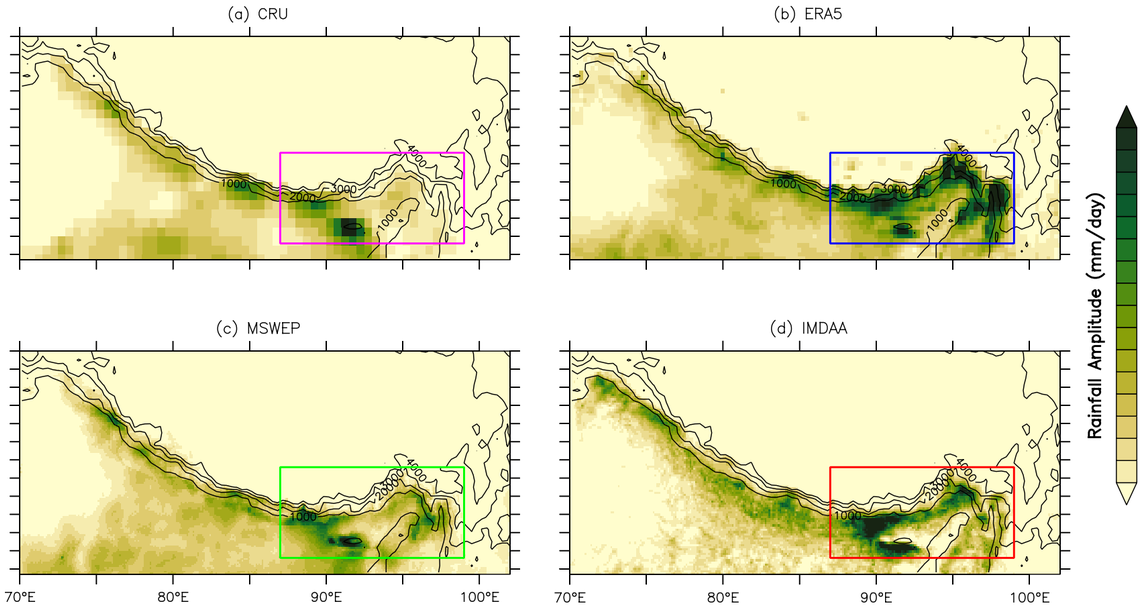
Data Validation

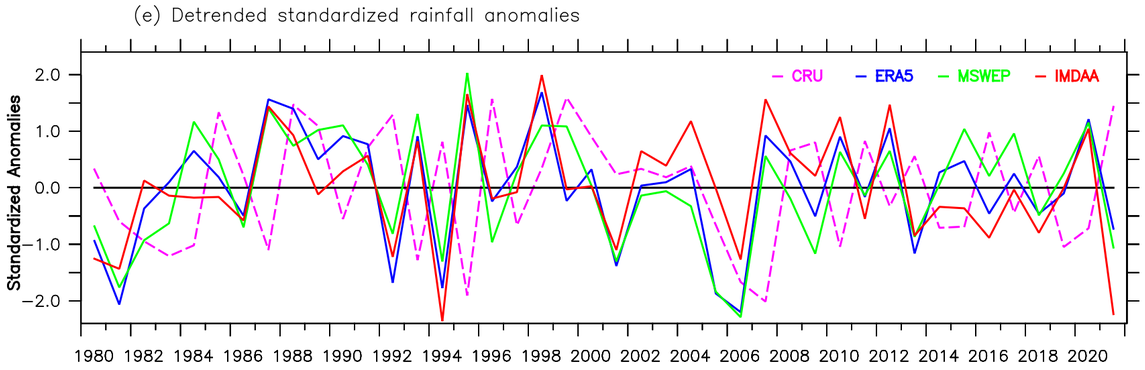
III Monsoonal variability dominated over steep mountains in the Eastern Himalayas

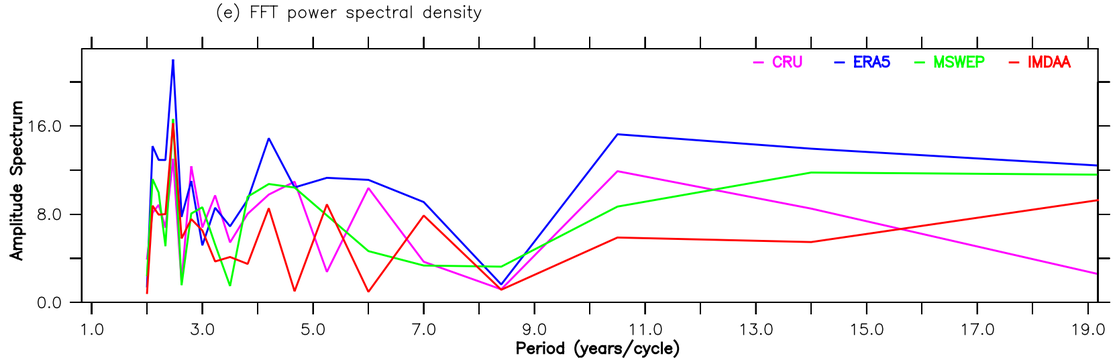
Reanalysis data (ERA5, IMDAA)

Observation data (CRU4, MSWEP)





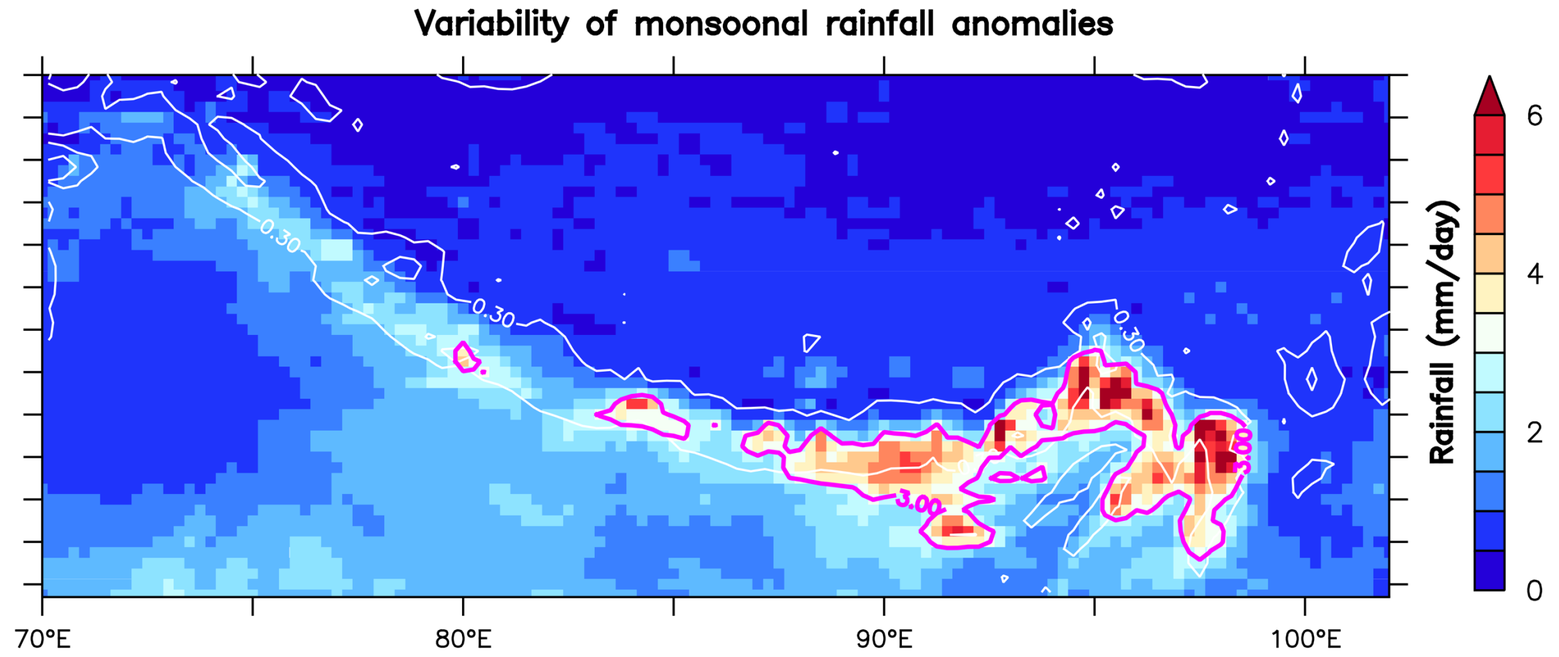


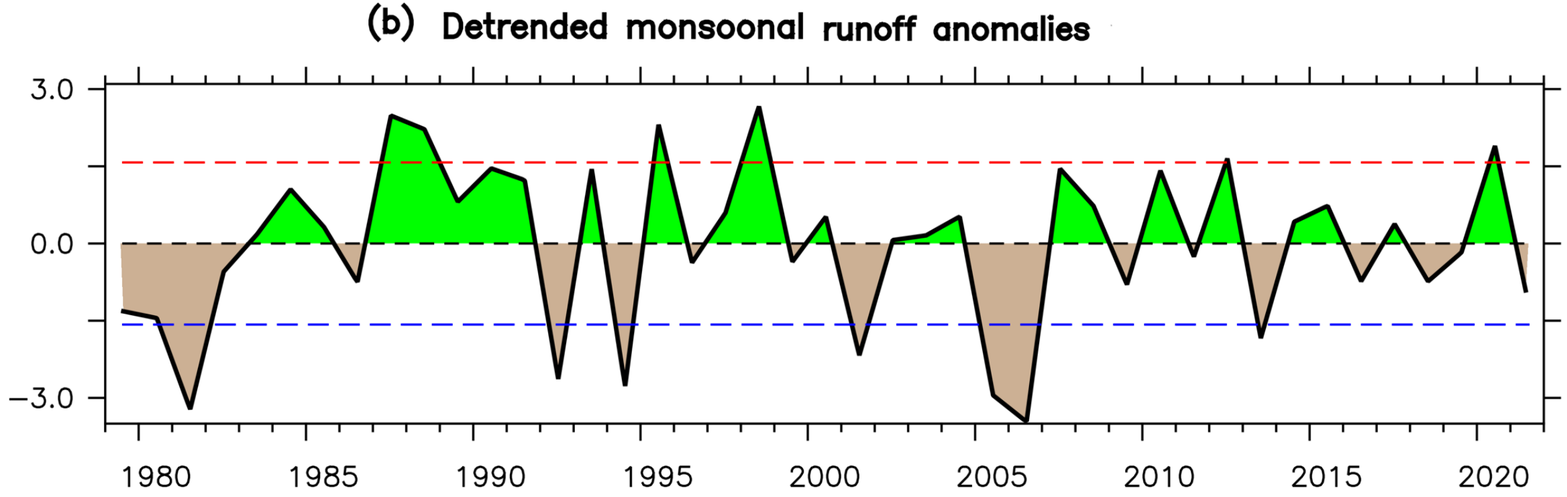


III

1. Extreme Monsoon Years

Why is monsoonal runoff variability dominated over steep mountains in the Eastern Himalayas?



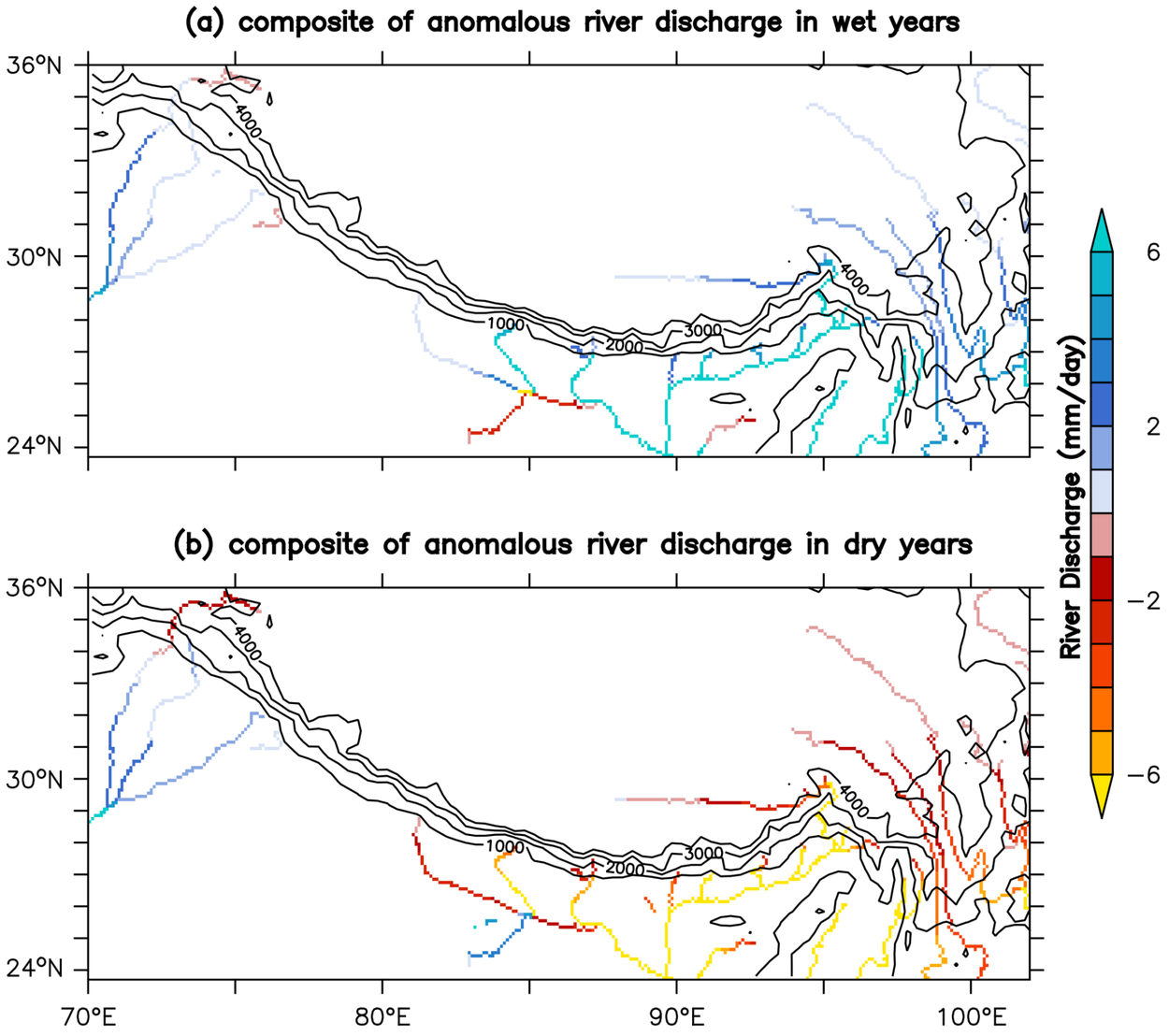


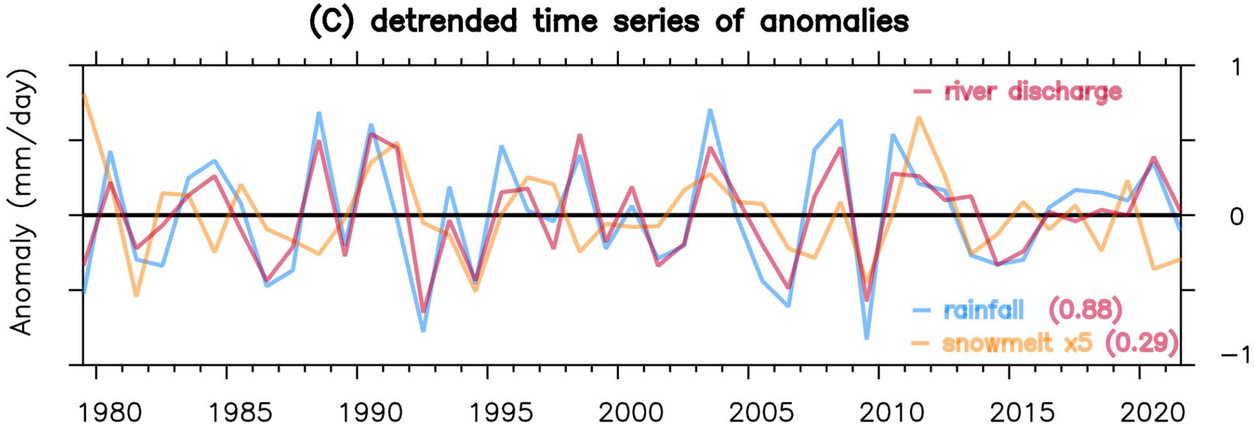
composite analysis

III

2. Role of Melting Snow

findings ruling out the role of melting snow in extreme monsoonal years





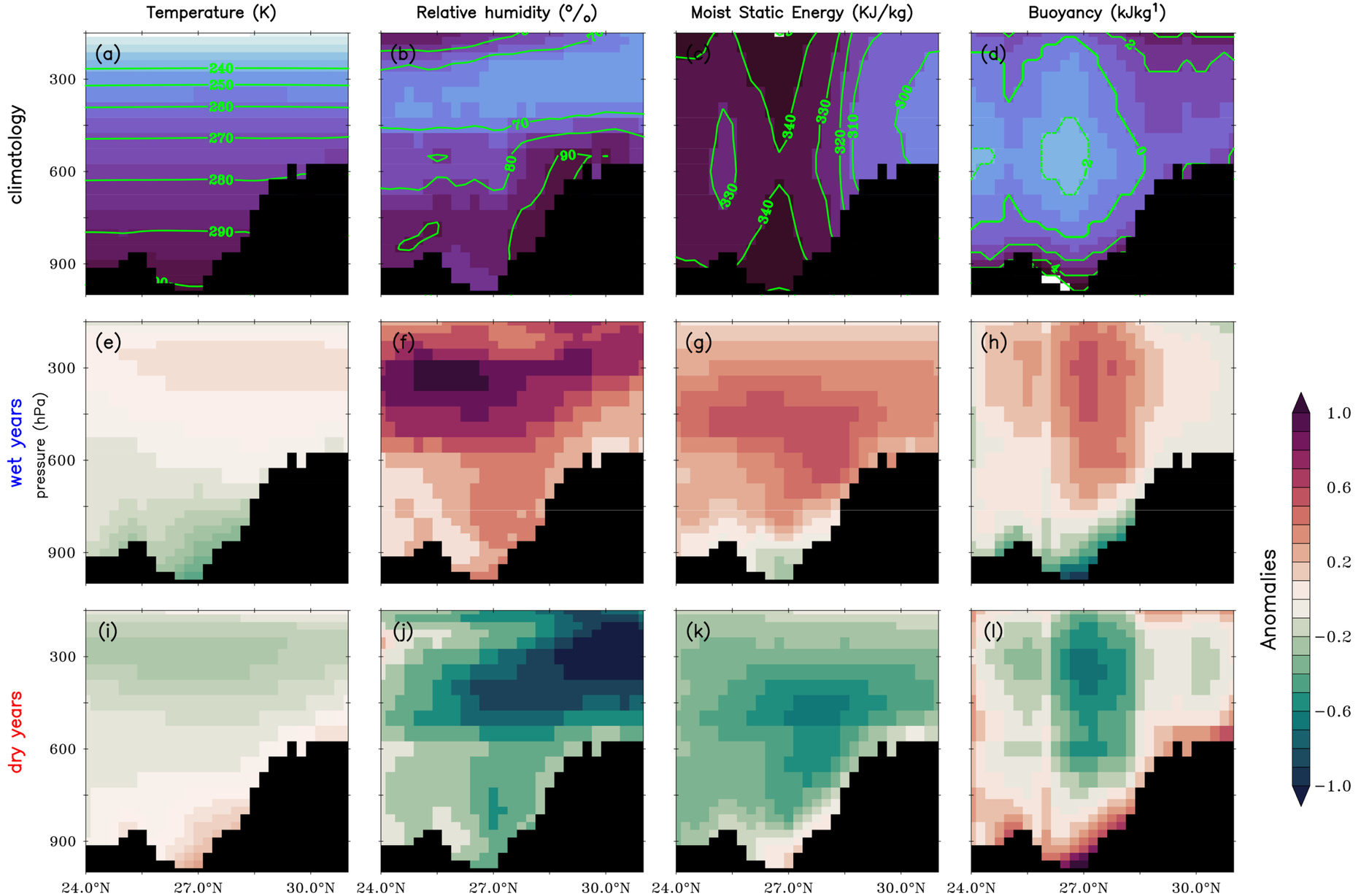
Monsoon rainfall is a major contributor to river discharge.

3. Thermal structure of climatology, anomalous wet and dry monsoon

III

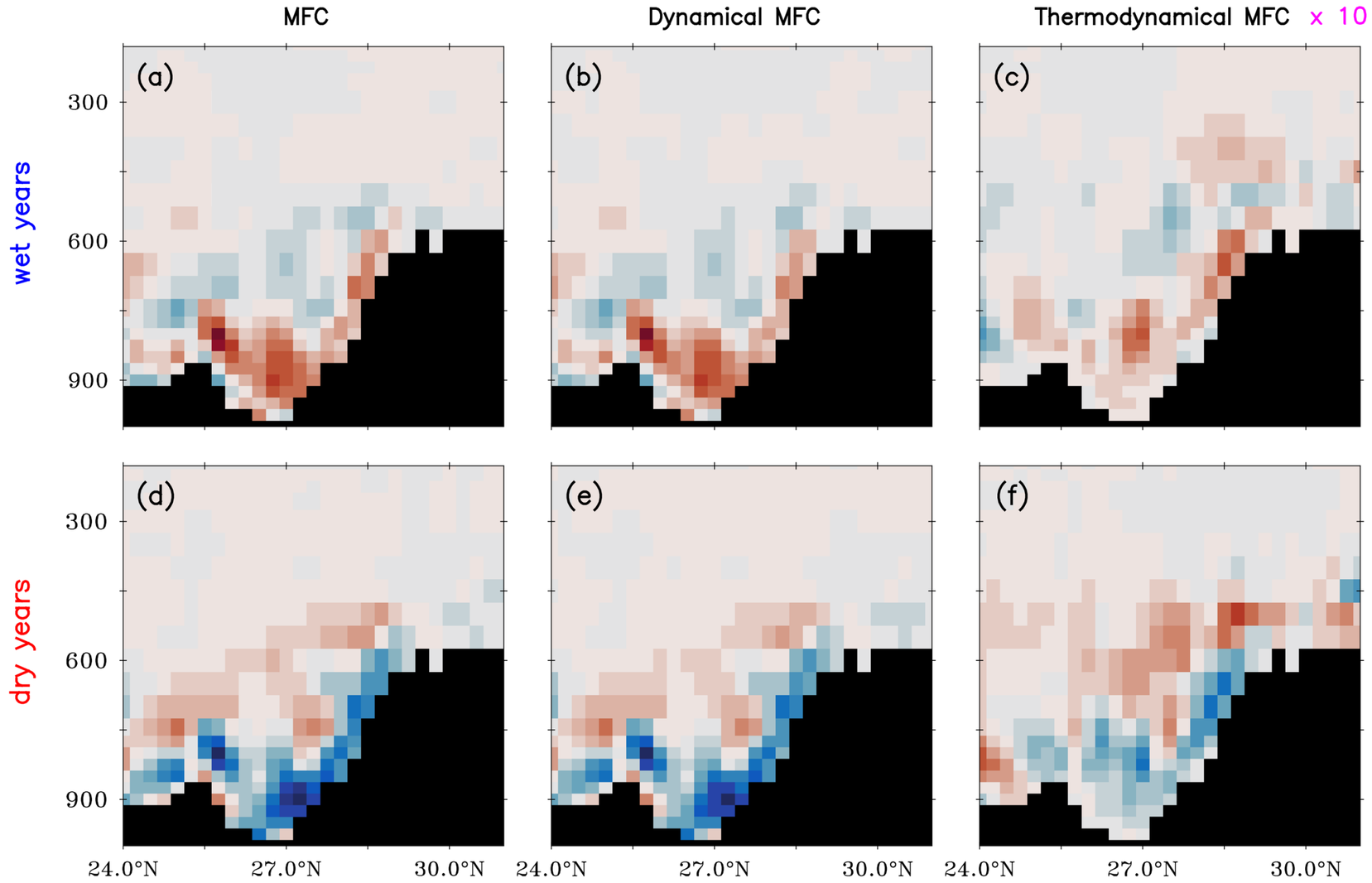
positive anomalies

negative anomalies



III 4. Dominant Influence of Atmospheric Dynamics

Composite analysis reveals orography modulates MFC.



The horizontal MFC can be expressed as follow:

$$MFC = -\nabla.(qV_h)$$

Furthermore, Anomalous MFC can be decomposed into dynamical and thermodynamical MFC.

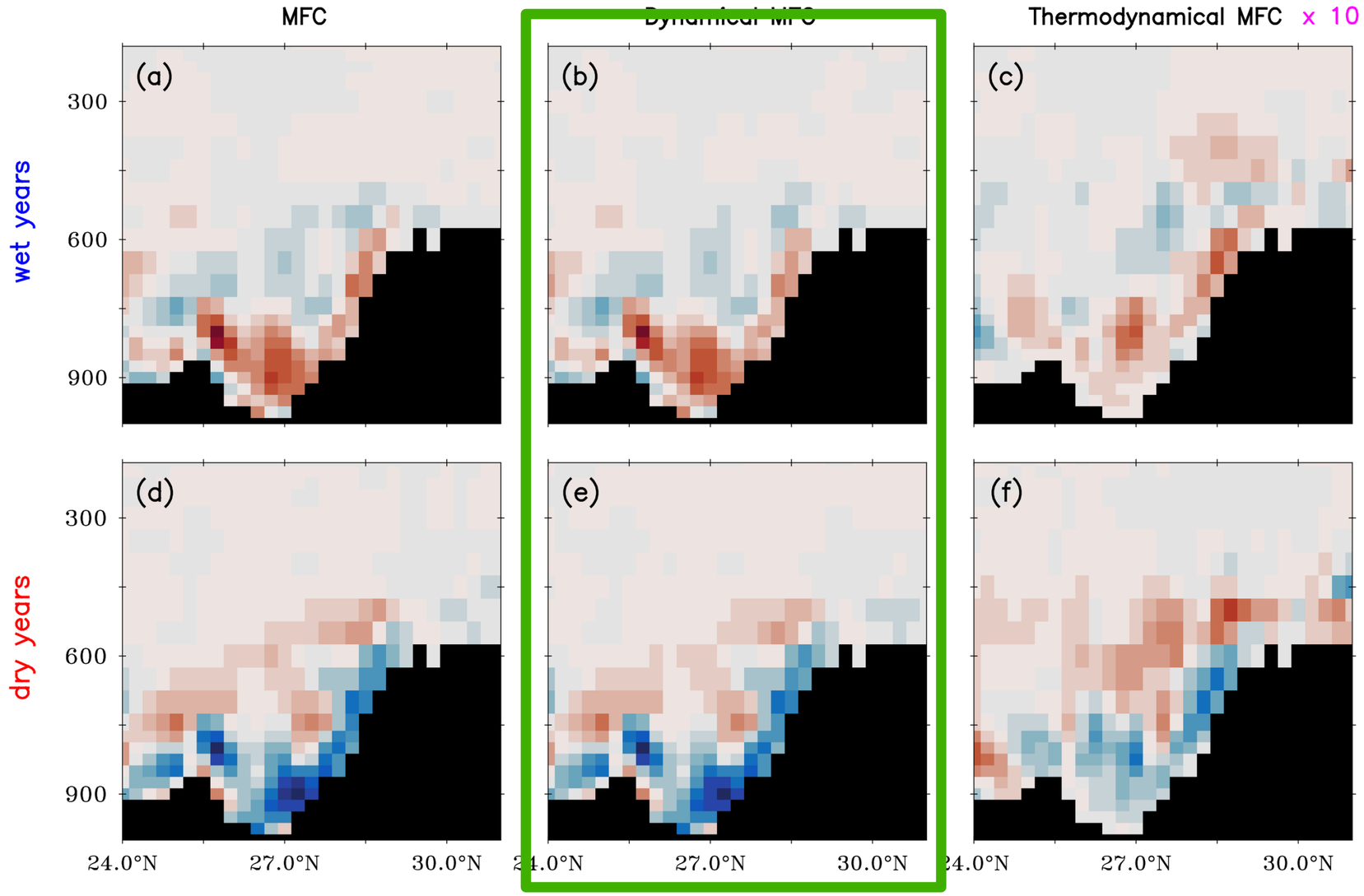
Delta indicates the anomaly with reference to mean state climatology.

$$\Delta\left(-\nabla.(qV_h)\right) = -\nabla.(\overline{q}\Delta V_h) - \nabla.\left(\Delta q\overline{V_h}\right)$$

distinctive anomalous MFC pattern in a cross-section at 94°E

III 5. Dominant Influence of Atmospheric Dynamics

Composite analysis reveals orography modulates MFC.



The horizontal MFC can be expressed as follow:

$$MFC = -\nabla.(qV_h)$$

Furthermore, Anomalous MFC can be decomposed into dynamical and thermodynamical MFC.

Delta indicates the anomaly with reference to mean state climatology.

$$\Delta\left(-\nabla.(qV_h)\right) = -\nabla.(\overline{q}\Delta V_h) - \nabla.\left(\Delta q\overline{V_h}\right)$$

- A dynamical MFC has a leading role in the Himalayan monsoon variability resulting in wet and arid events

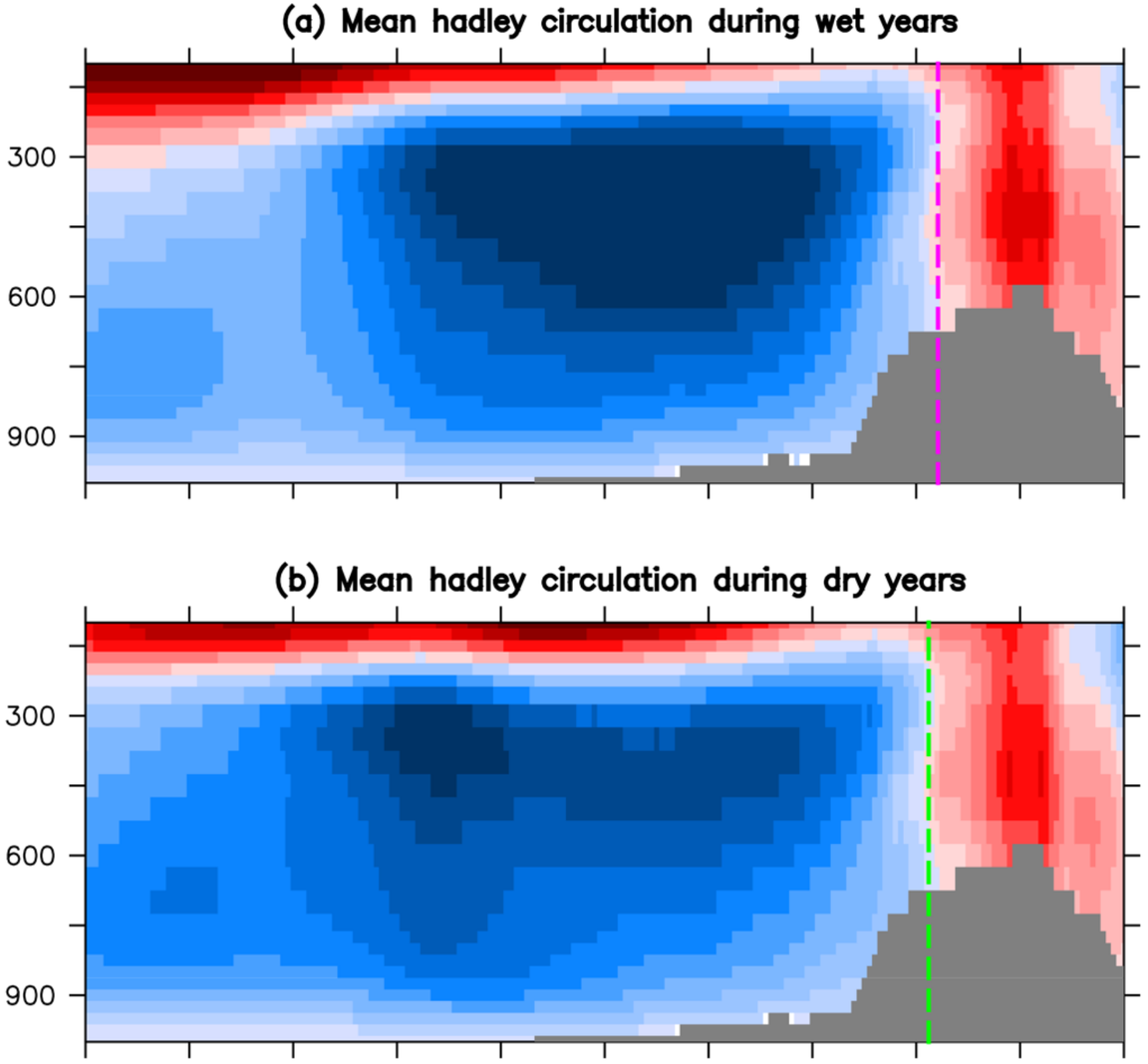
distinctive anomalous MFC pattern in a cross-section at 94°E

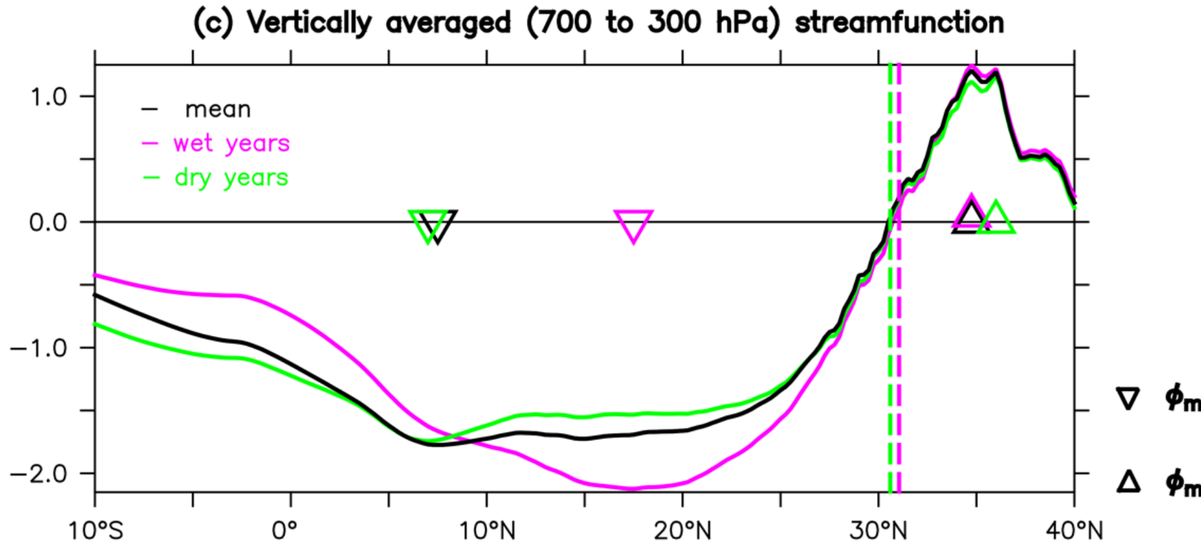
III 6. Monsoonal Hadley Cell

narrow during wet phase and extends wider during dry phase

meridional mass stream function (kg day^{-1})	$\Psi = \frac{2\pi\, a \cos\phi}{g} \int_{p}^{p_s} \vec{V}\, dp$

(Byrne and Schneider, 2016)





Narrowing of ITCZ width

Widening of ITCZ width

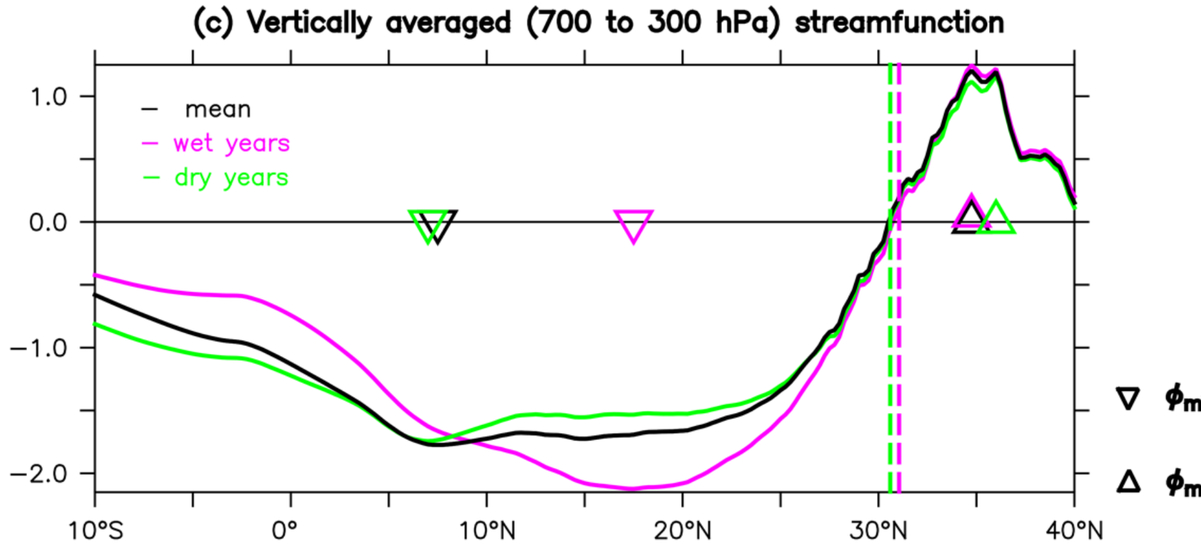
III 6. Monsoonal Hadley Cell

narrow during wet phase and extends wider during dry phase

meridional mass stream function (kg day^{-1})	$\Psi = \frac{2\pi\, a \cos\phi}{g} \int_{p}^{p_s} \vec{V}\, dp$

(Byrne and Schneider, 2016)

Temporal scale	ITCZ location (°N) ϕ_{ITCZ}
Climatological mean	30.51
Extreme Wet Monsoon (Δ)	31.00 (0.49)
Extreme Dry Monsoon (Δ)	30.71 (0.2)



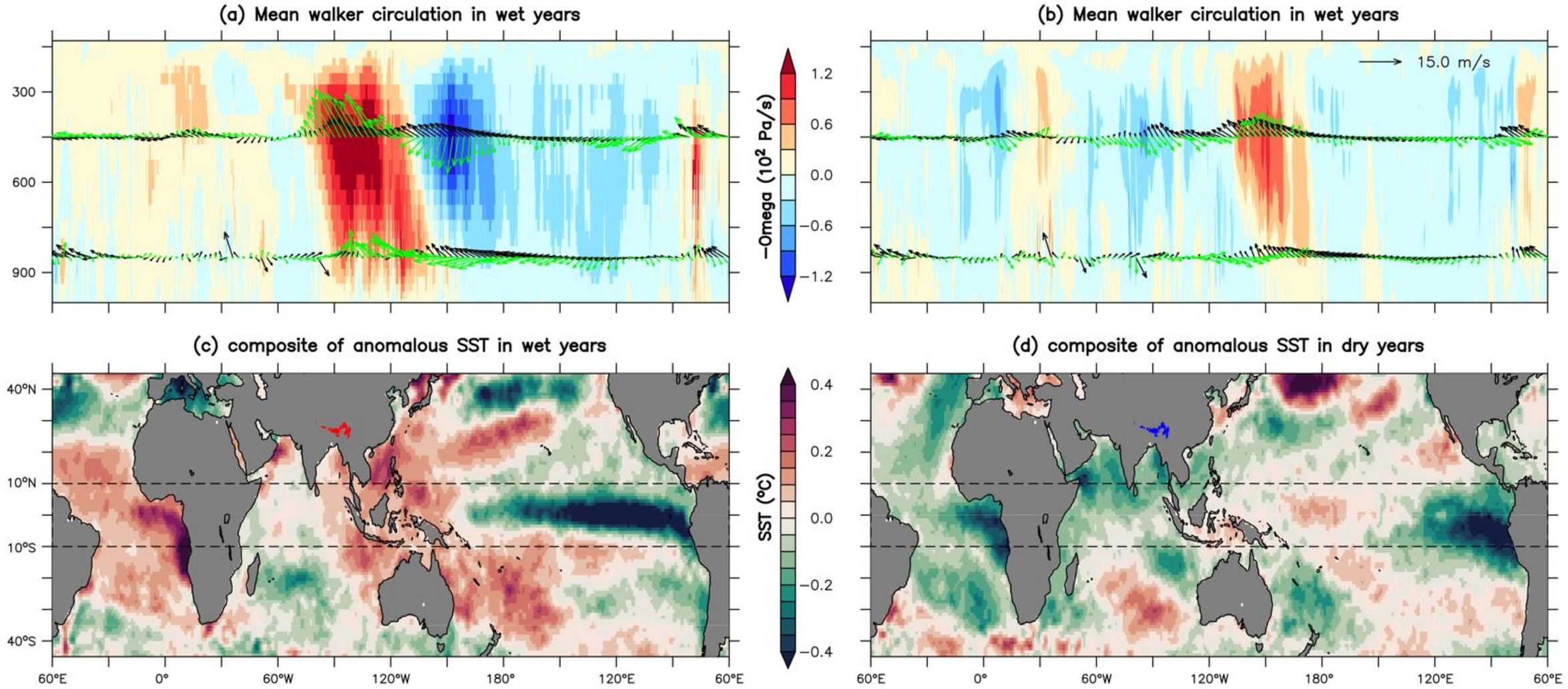
Narrowing of ITCZ width

Widening of ITCZ width

III

7. Tropical zonal circulation in summer monsoon

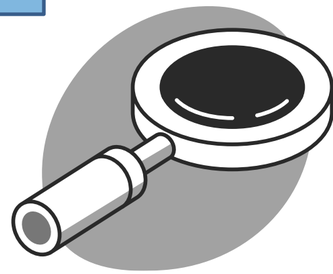
seesaw over eastern IO and western PO



Amplified ascending convection over the Eastern Indian Ocean

Reduced convection over the Indian Ocean

IV Summary



Convection over Indo-Pacific warm pool

Walker Circulation

Local Hadley Cell

Meridional overturning circulation and ITCZ shift

Wind-driven moisture flux convergence

Locality

Himalayan Monsoon

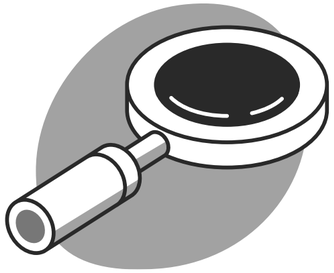
Rainfall overstep Eastern Himalayas

IV Summary

1. A study found a strong natural variability in the Eastern Himalayas over steep topography.

2. A dynamical MFC plays a leading role in the Himalayan monsoon, driven by moist process and shift in ITCZ

3. Importance of monsoon dynamics in shaping the variability of these rivers



I sincerely thank you all for your kind attention.

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2023JD038759

Recent Tangible Natural Variability of Monsoonal Orographic Rainfall in the Eastern Himalayas

Pratik Kad[1] and **Kyung-Ja Ha**[1,2,3]

[1]Department of Climate System, Pusan National University, Busan, South Korea, [2]Center for Climate Physics, Institute for Basic Science, Busan, South Korea, [3]BK21 School of Earth and Environmental Systems, Pusan National University, Busan, South Korea

Key Points:

- The study highlights the natural variability in the eastern Himalayan hydroclimate over the past 43 years, emphasizing its significance as a recurring natural hazard that affects the region
- The research identifies extreme monsoonal rainy years, with monsoon rainfall as a major contributor to river discharge. Notably, the study rules out the role of melting snow in these extreme events
- This research underscores the dominant influence of atmospheric dynamics as the primary modulating factor in the Eastern Himalayan monsoon

Supporting Information:

Supporting Information may be found in the online version of this article.

Abstract Himalayas hydroclimate is a lifeline for South Asia's most densely populated region. Every year, flooding in the Himalayan rivers is usual during summer monsoon, which impacts millions of inhabitants of the Himalayas and downstream regions. Recent studies demonstrate the role of melting glaciers and snow in the context of global warming, along with monsoonal rain causing recurrent floods. Here, we highlight the natural variability in the eastern Himalayan hydroclimate over the last 43 years (1979–2021). We found extreme monsoonal rainy years with six dry years and seven wet years after removing the climate change signal. Monsoon rainfall is a significant contributor, and melting snow is not a potential contributor to these anomalous extreme years. The variability of Himalayan monsoonal rainfall is strongly regulated by local monsoonal Hadley circulation associated with tropical sea surface temperature. Our findings demonstrate mechanisms associated with Himalayan wet and dry monsoon. Atmospheric dynamics are attributed as the primary modulating factor, influencing local thermodynamics through moist processes. The insights provided in this study underscore the impact of natural variability-driven challenging events that could be predictable. Thus, this mechanism could improve the predictability of the Himalayas floods.

get in touch

Email
prka@norceresearch.no

LinkedIn
/In/pratikkadpatil/

ORCID
0000-0002-0010-0891

ResearchGate