Comparison Of "Cloudbursts " In The Nepal And Indian Himalayas: From Tropical-extratropical Interaction Perspectives

Archana Shrestha, Gregory Tripoli and Larissa Back

University of Wisconsin, Madison

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Outline

- Background on Cloudburst
- Case Studies Introduction
- Motivation
- Results: Case studies comparison
  - Synoptic features
  - Pre-condition
  - Energy conversion
- Summary

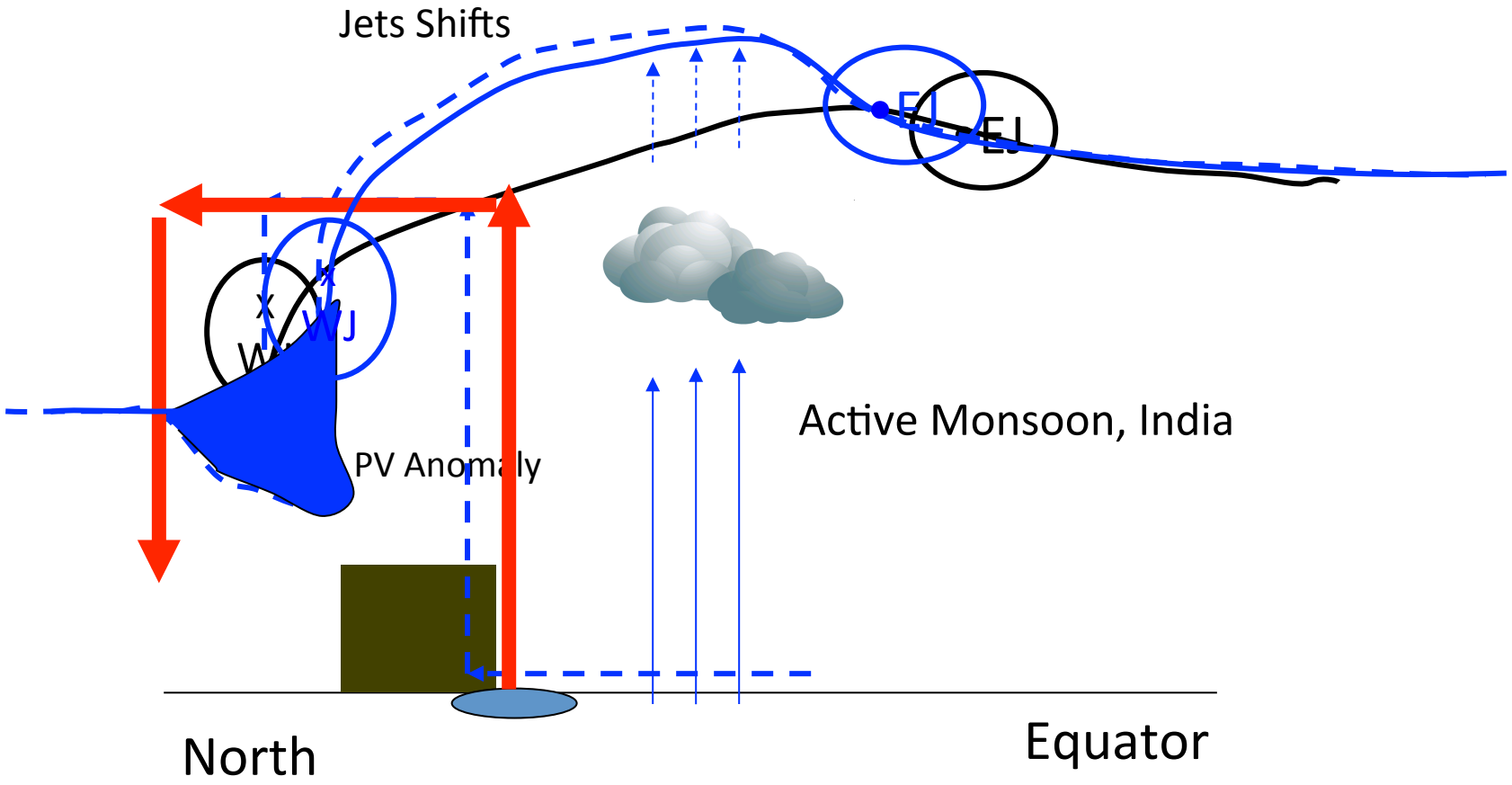
Cloudbursts

- Localized intense rainfall episodes during the monsoon season in the Himalayas leading to devastating flashflood and debris flow

Cloudburst Characteristics: Central Nepal (Results of Composite Analysis)

- Rainfall: more than 220mm/day
- Enhanced rising motion due to the combination of two synoptic factors
  - secondary circulation around the easterly and westerly jet entrances
  - superposition of PV anomaly with elevated topography
- Pre-condition
  - Upper tropospheric theta anomaly over monsoon trough
  - Active monsoon spells in India prior to the event.

Conceptual Diagram of the Initiation of Cloudburst

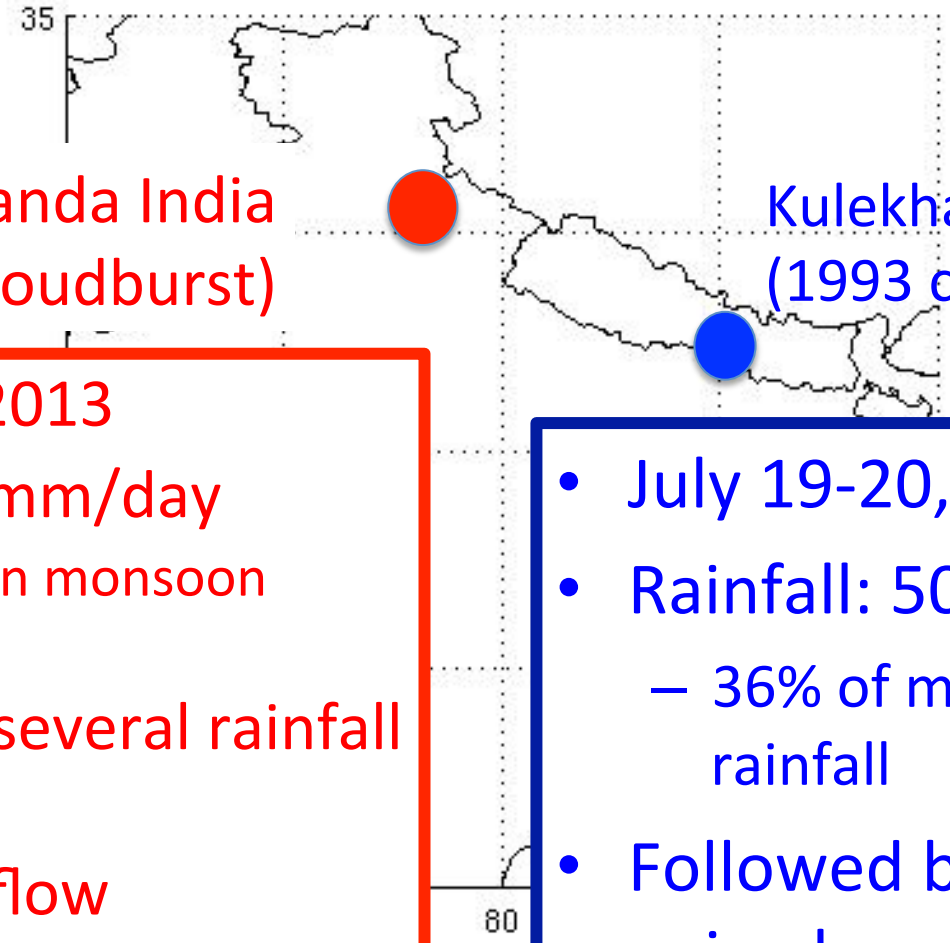


Energy converted from Available Potential Energy (APE)

Anomaly is represented by Positive Work Term

$$\frac{\partial KE}{\partial t} = -V.\nabla_\theta M = Work\ Term$$

Two Case Studies: Introduction



Uttarakhanda India
(2013 cloudburst)

Kulekhani, Nepal
(1993 cloudburst)

- June 15-16, 2013
- Rainfall: 325mm/day
  - 25% of mean monsoon rainfall
- Followed by several rainfall episodes
- Huge debris flow
- Glacier Lake Outburst

(Dohbal et al 2013)

- July 19-20, 1993
- Rainfall: 500mm/day
  - 36% of mean monsoon rainfall
- Followed by a rainfall episode
- Huge debris flow

Motivation

- Nepal event occurred: mid-monsoon (July)
- Indian event occurred: monsoon onset (June)

1. First Question…

– Does monsoon onset cloudburst have similar synoptic characteristics as the mid-monsoon case?

2. Secondly:

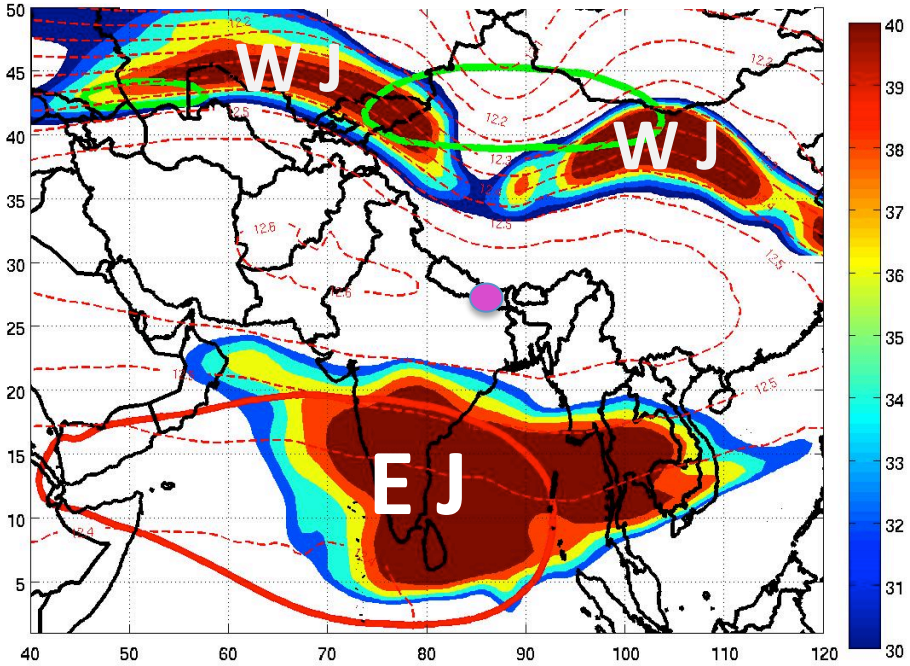
– Composite Analysis Hypothesis: latent heat release prior to the cloudburst stimulates the favorable synoptic condition for the cloudburst.

– What stimulates the cloudburst during the onset period?

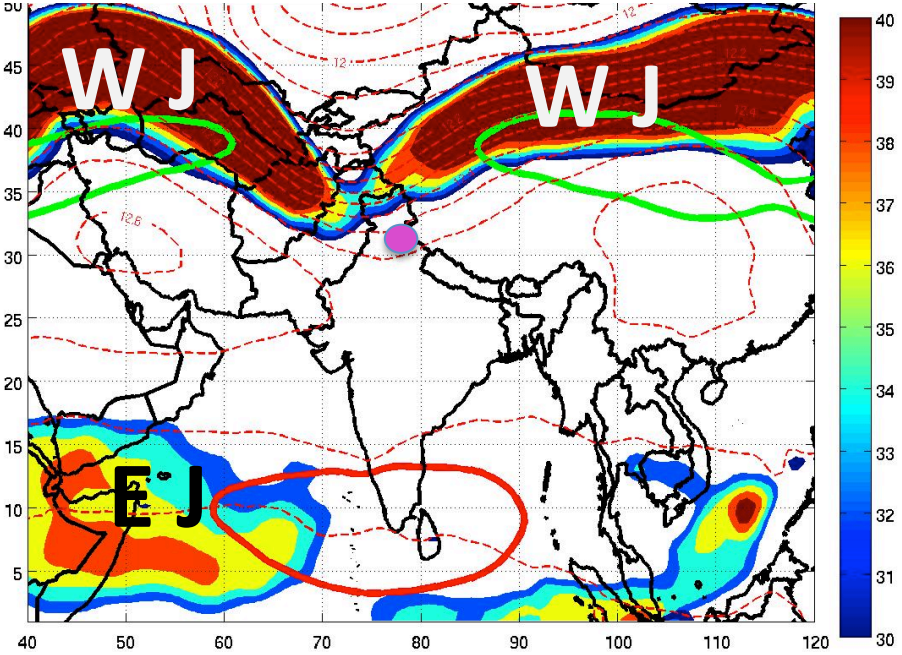
Results:
Comparison of Synoptic Features two Case Studies

Jet Streams during Cloudbursts

Nepal Himalayas

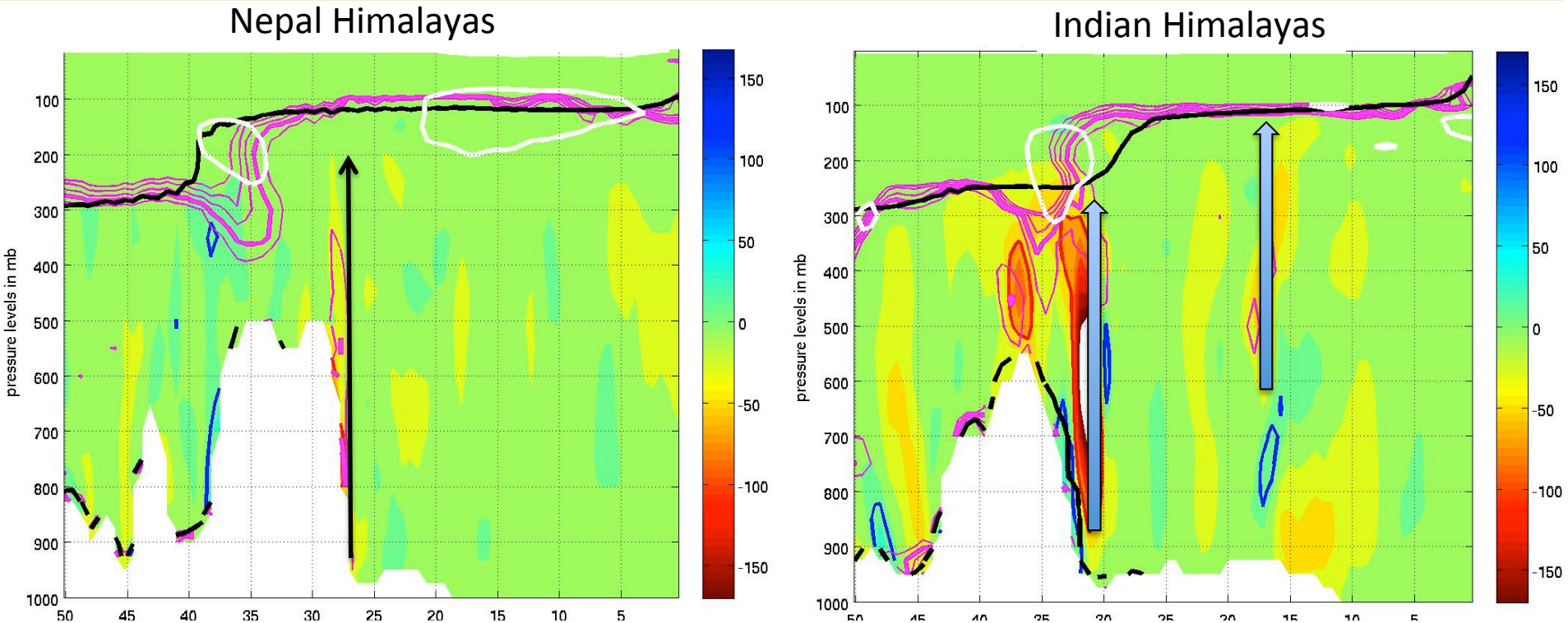


Indian Himalayas



- In both cases, both the Jets are stronger than climatology
- In both cases, easterly and westerly Jet entrances shifts and relocate relative to the cloudburst regions.
- But in Indian case easterly jet entrance remained over the normal latitude

Tropopause Fold over Elevated Topography

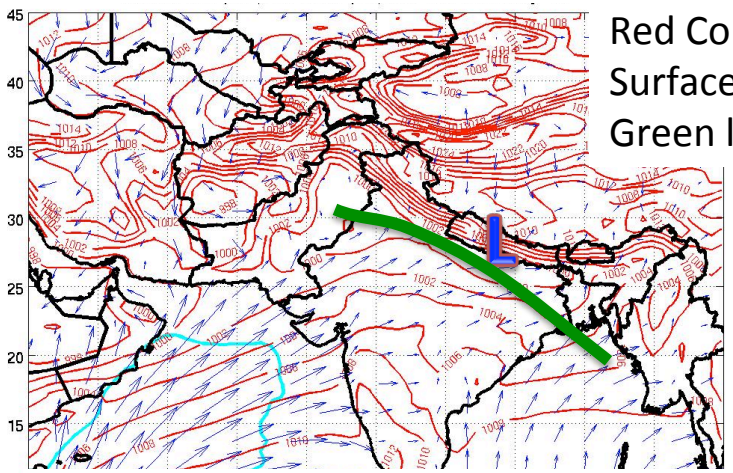


Latitudinal Cross Section across cloudburst Shading: vertical velocity in Pa/s
Contours: Climate PV =1.5 PVU; **Magenta: cloudburst PV > 1 PVU**

- Strong tropopause fold (TF) and Upper level PV anomaly over Elevated Topography in both cases
- Single rising branch in Nepal Case
- Double rising branches in Indian Case

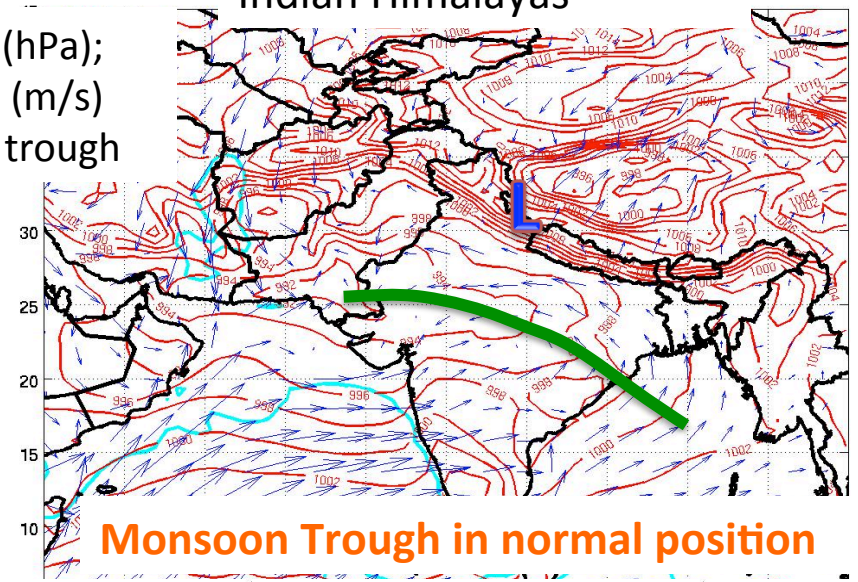
Monsoon Trough During Cloudburst

Nepal Himalayas



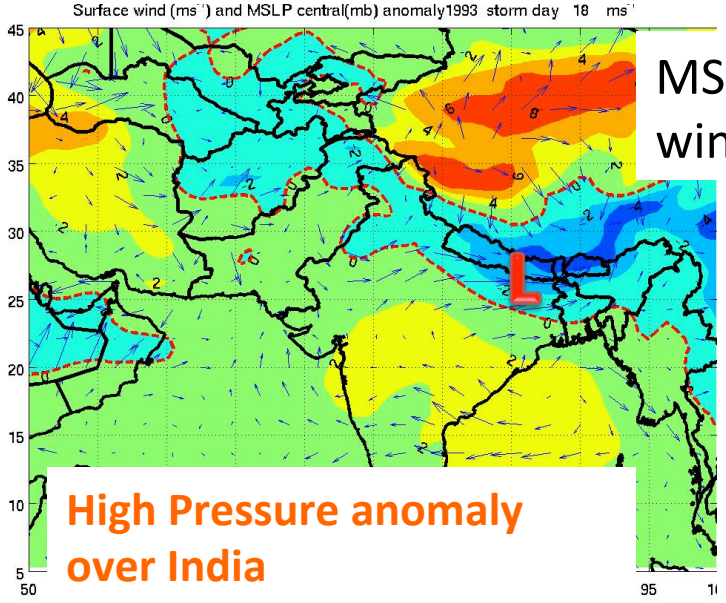
Red Contours: MSLP (hPa);
Surface wind vectors (m/s)
Green line Monsoon trough

Indian Himalayas

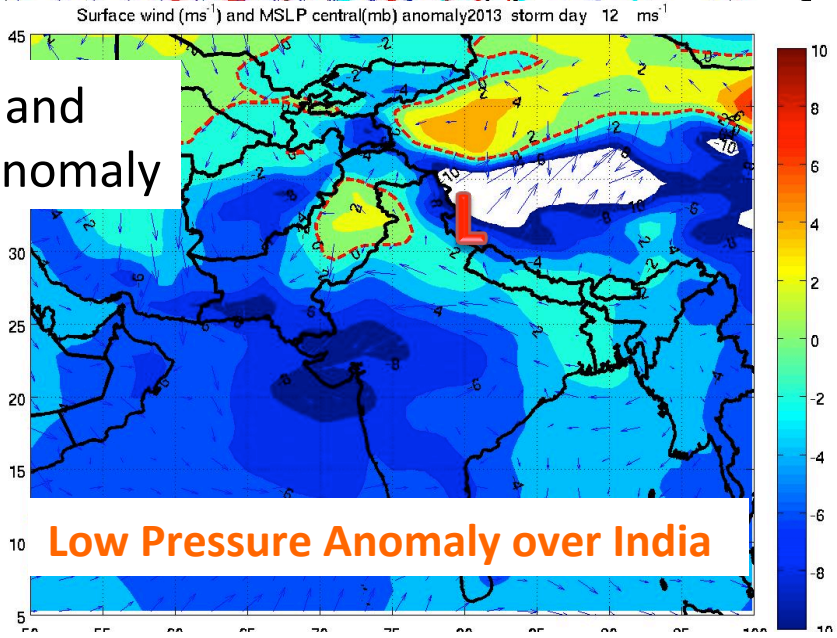


Monsoon Trough shifts to the Himalayas

Monsoon Trough in normal position



MSLP (shading) and
wind (vectors) Anomaly

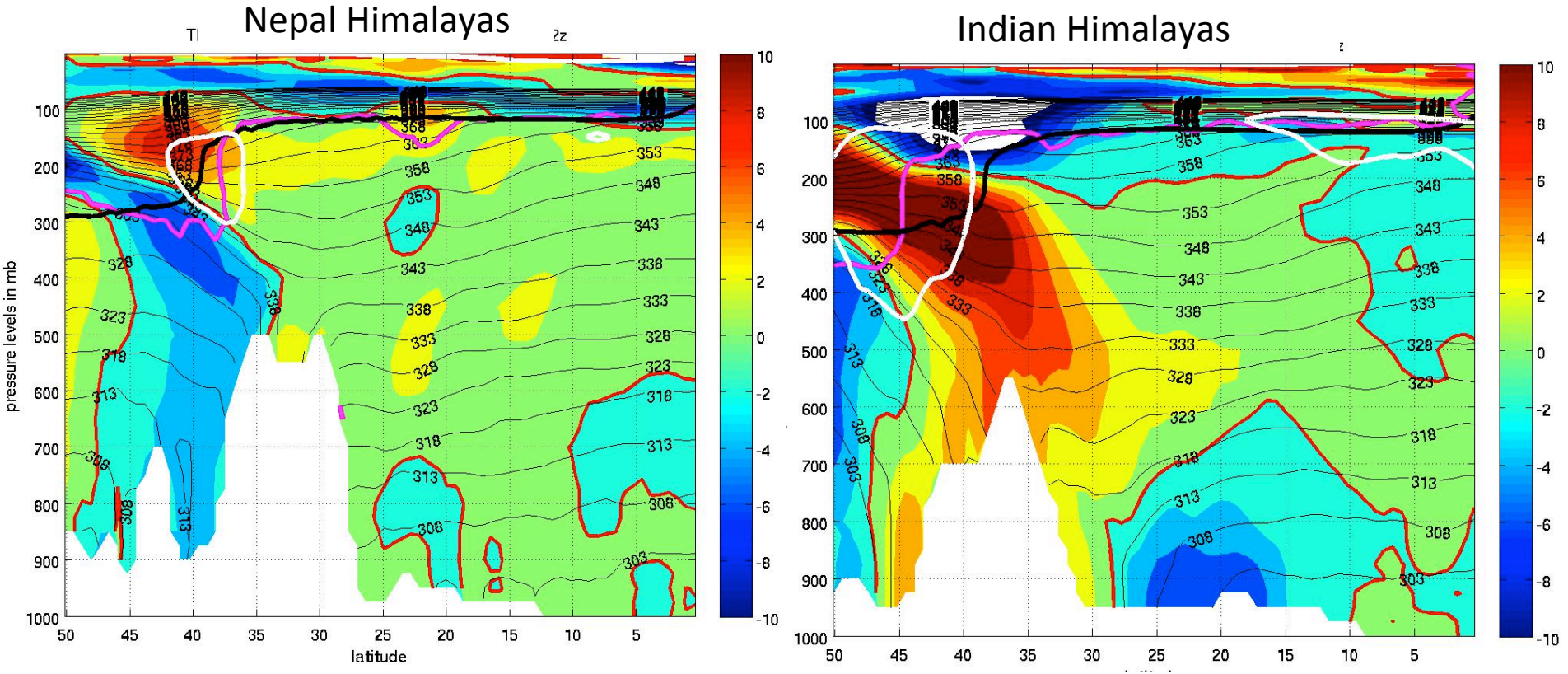


High Pressure anomaly over India

Low Pressure Anomaly over India

Results:
Precursor Theta Anomaly

5 pre-day Theta Anomaly
Cross-section along the cloudburst region



Latitudinal Cross Section across cloudburst. Shading: Theta Anomaly (oK) Contours: Theta (K). Thick Black contour: Climate PV =1.5 PVU; **Magenta: cloudburst PV > 1 PVU**

Tropical theta anomaly in the upper level centered over 20N

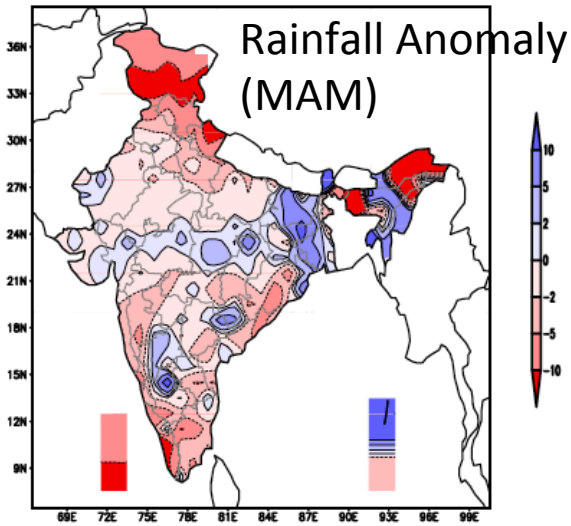
Tropical theta anomaly in the mid troposphere centered over 35N

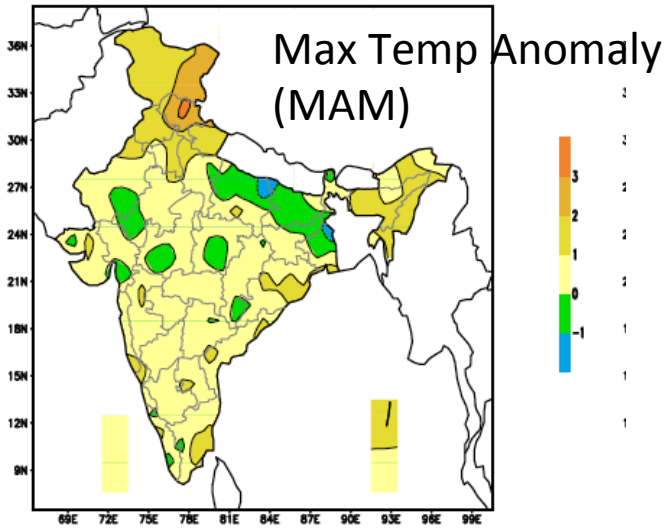
Pre-cloudburst Theta anomaly: Nepal Case

- Preceded by two active monsoon spells in India (Rajeevan et al 2010) and weak easterly jet
  - Active monsoon in India is associated with condensational heating
  - Weak easterly jet might have led to less southward transport of energy
  - Resulting in positive theta anomaly

Pre-cloudburst Theta Anomaly: India Case

- The event was preceded by long period rainfall deficit and heat wave condition in the northwest India

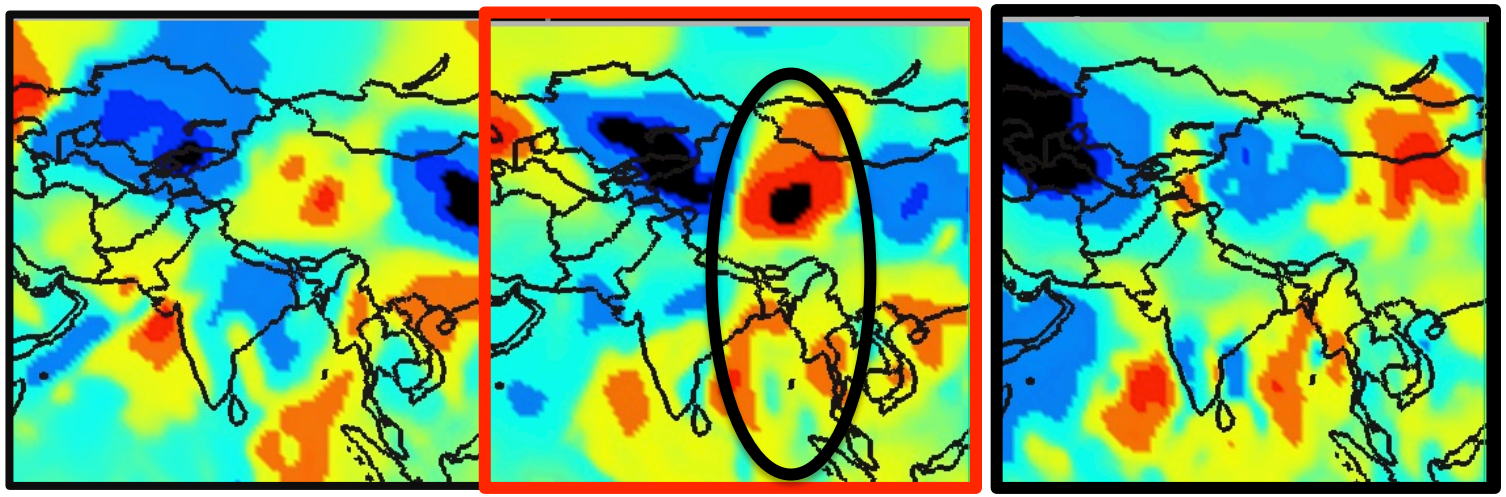




IMD, 2013

  - Positive theta anomaly in the Indian Case

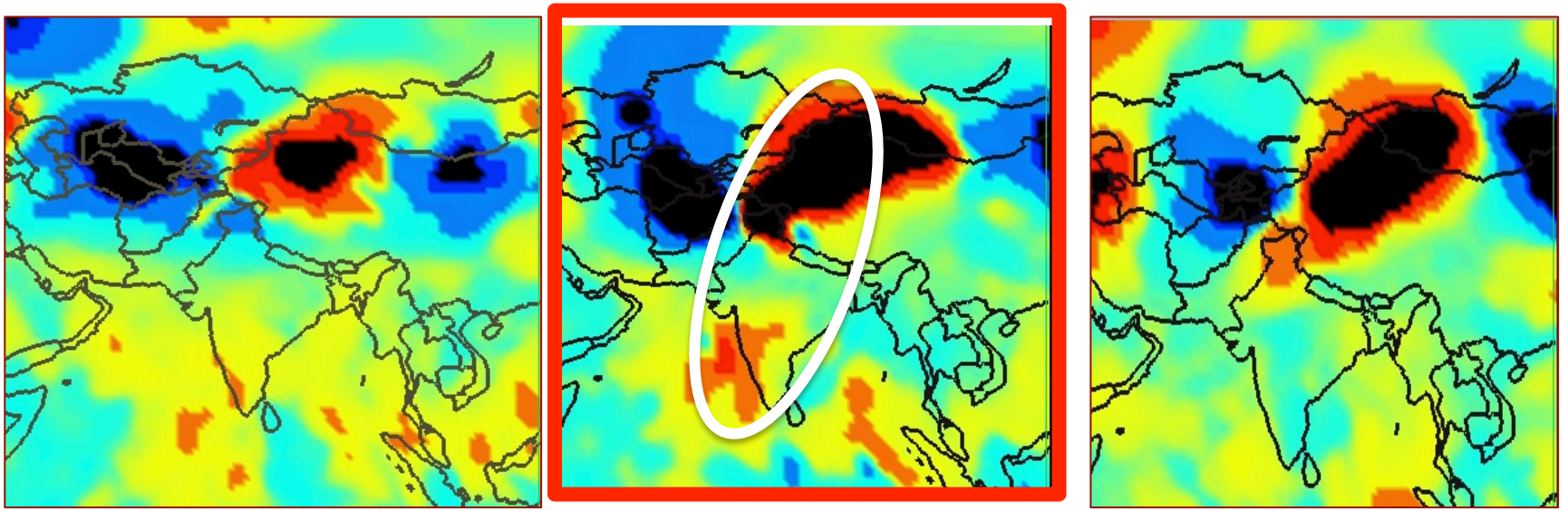
Work Term Nepal Case



Shading work term at 13km (oK/day). Warm colors: positive; cold color: negative

- Positive work: energy conversion at upper levels associated with two direct circulations: 1) easterly jet entrance and 2) westerly jet entrance
- Energy conversion from APE anomaly to jet strength during the event

Work Term India Case



Pre-Cloudburst **Cloudburst** **Post-Cloudburst**

Shading work term at 13km (oK/day). Warm colors: positive; cold color: negative

- Energy conversion from APE anomaly to jet strength during the event
- Northward work term is stronger than in Nepal Case

Summary

- Similarities:
  - superposition of Upper level PV-Anomaly with the elevated terrain
  - superposition of the up-branch of easterly and westerly direct circulations produces enhanced lifting
  - the direct circulations are enhanced by conversion of from locally generated APE anomalies

- Differences:
  - Influence of easterly Jet is stronger in Nepal Case than in Indian case
  - APE anomaly in Nepal case is associated with monsoon activity
  - APE anomaly in Indian case is associated with the strong pre-monsoon elevated landmass heating

Thank You!