A stylized graphic featuring three white clouds with black outlines on a light blue background. Below the clouds on the left is a small globe showing the Americas in green and the rest of the world in blue.

Linkages of subtropical stratospheric intra- seasonal intrusions with Indian summer monsoon rainfall

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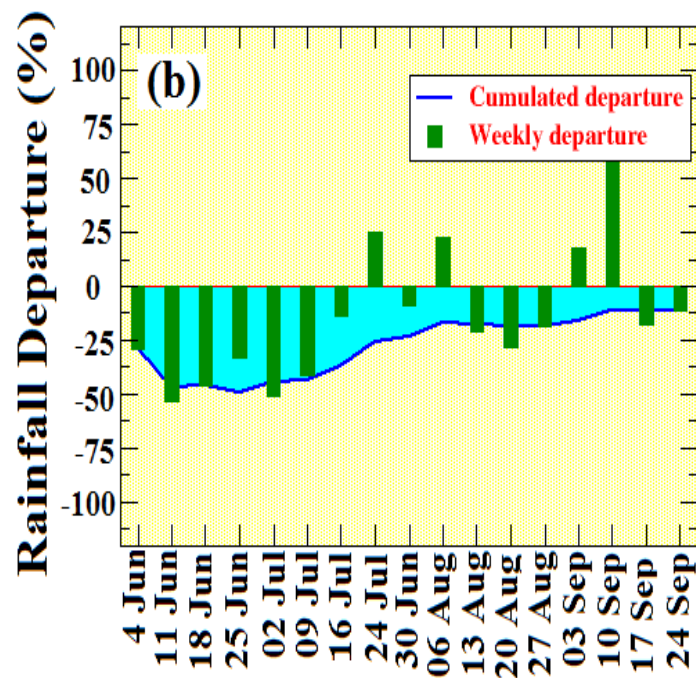
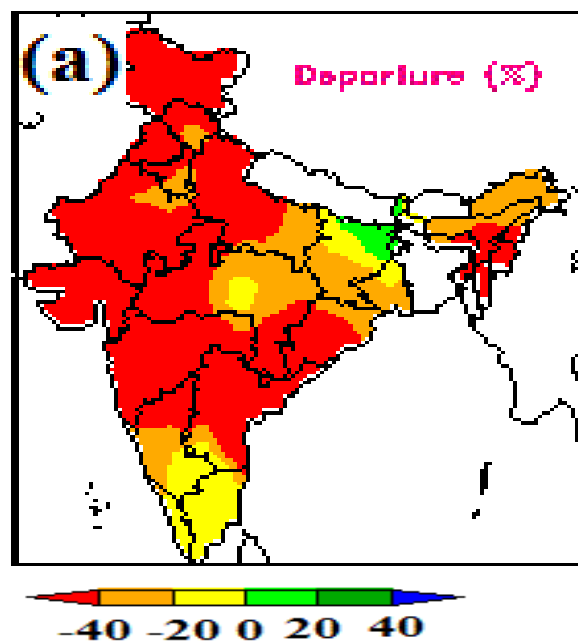
Outline of the talk

- ✓ A life cycle of a strong subtropical *stratospheric intrusion* during June 2014 → influence → reduce the intensity of Indian rainfall after onset.
- ✓ Analysis of all monsoon breaks days during 29 years (1979-2007) (Breaks days from Rajeevan et al., 2010)
- ✓ Propose a hypothesis on “Linkages of Stratospheric Intrusion with deficit Indian rainfall”

Background

- ❖ Ramaswamy (1962) has proposed that the intrusion of the mid latitude trough may trigger monsoon deficit rainfall over the Indian region and lead to development of *break* monsoon condition.
- ❖ Mapes and Zuidema (1996); Allen et al., (2009) delineate invasion of dry air from subtropical upper troposphere with tropical droughts.
- ❖ Krishnan et al., (2000) have attributed monsoon breaks to an abrupt movement of anomalous Rossby waves originating from Bay of Bengal traveling into northwest and central India.

Deficit rainfall over India during June 2014



Data and Analysis

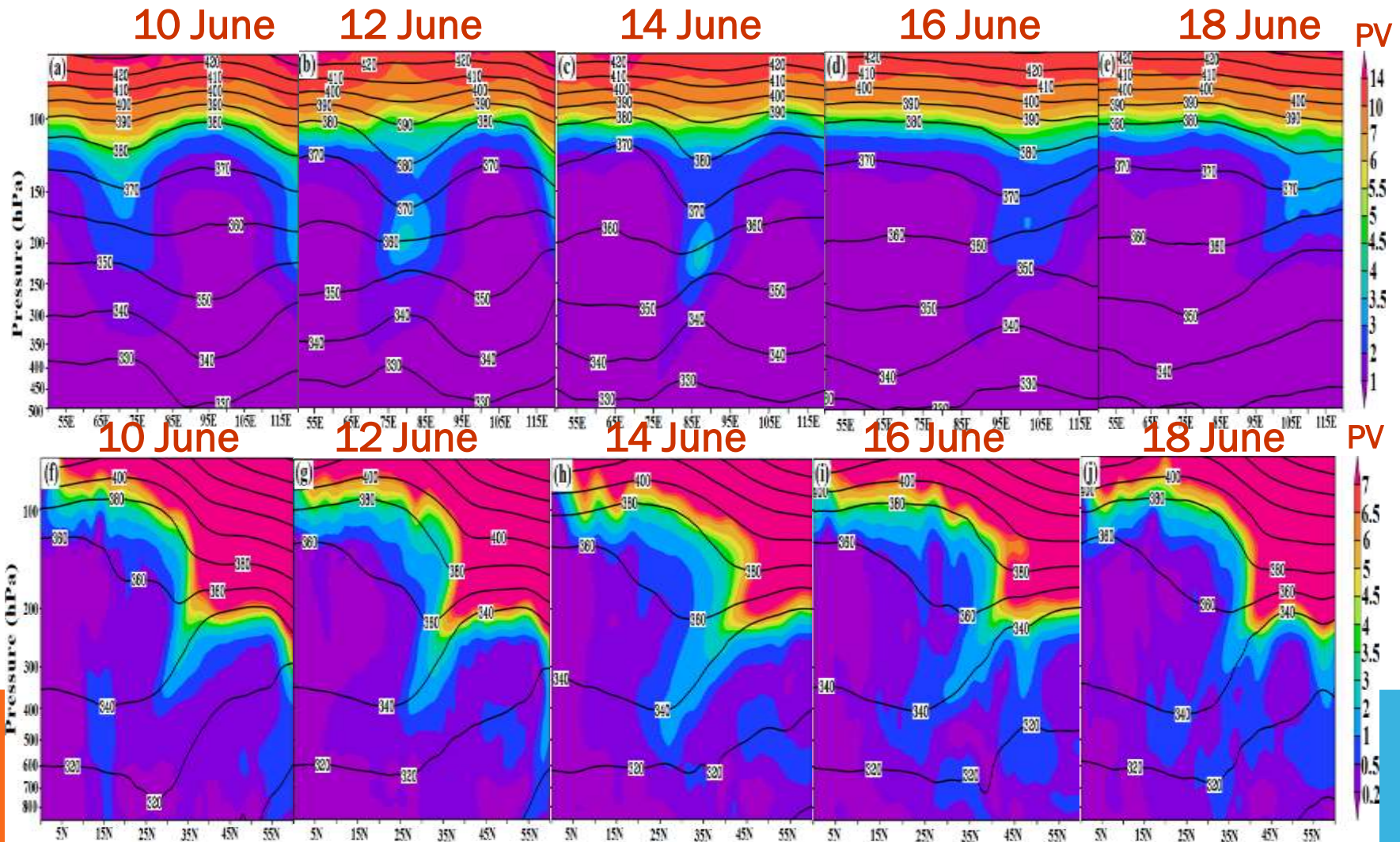
ERA-Interim Reanalysis data:

- Potential Vorticity (PV)
- temperature
- winds
- ozone
- relative humidity (RH)
- Indian summer monsoon rainfall (ISMR) from India Meteorological Department

✓ Diagnostic Analysis:

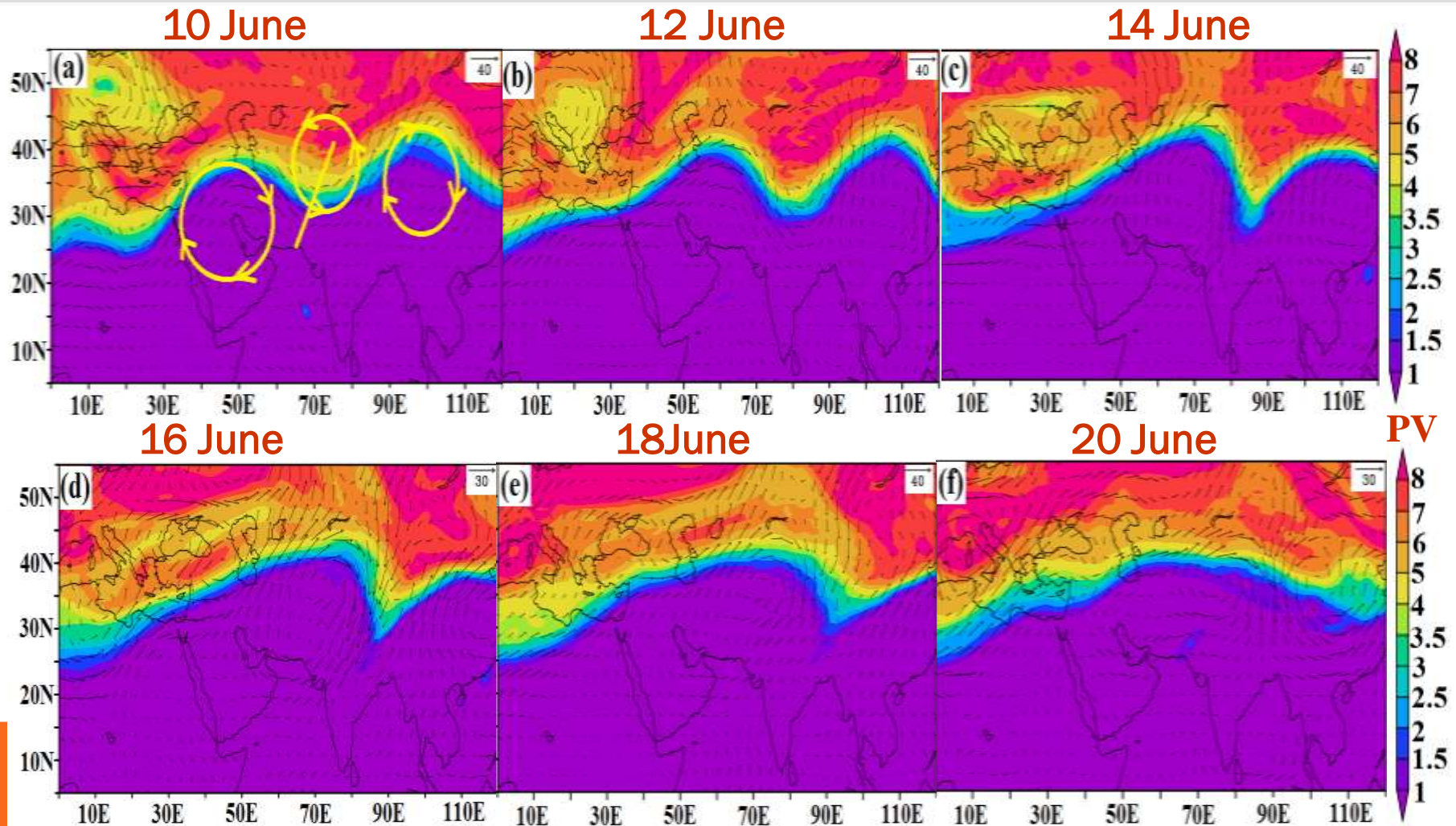
- ✓ Bivariate Probability Distribution Function (BPDF) of the two variables (PV and rainfall)
- ✓ Specific humidity (q) (vertically averaged between 400hPa-200hPa)
- ✓ Vertical wind shear (i.e. difference in zonal winds (U) at 200hPa minus 850 hPa)
- ✓ Temperature anomaly (departure from climatology) index (Tanom_diff_index), (i.e. temperature anomaly at 200 hPa minus 850 hPa)
- ✓ Kinetic energy at 200 hPa (ke200 i.e. $U*U$)

Vertical distribution of Potential Vorticity (PV)



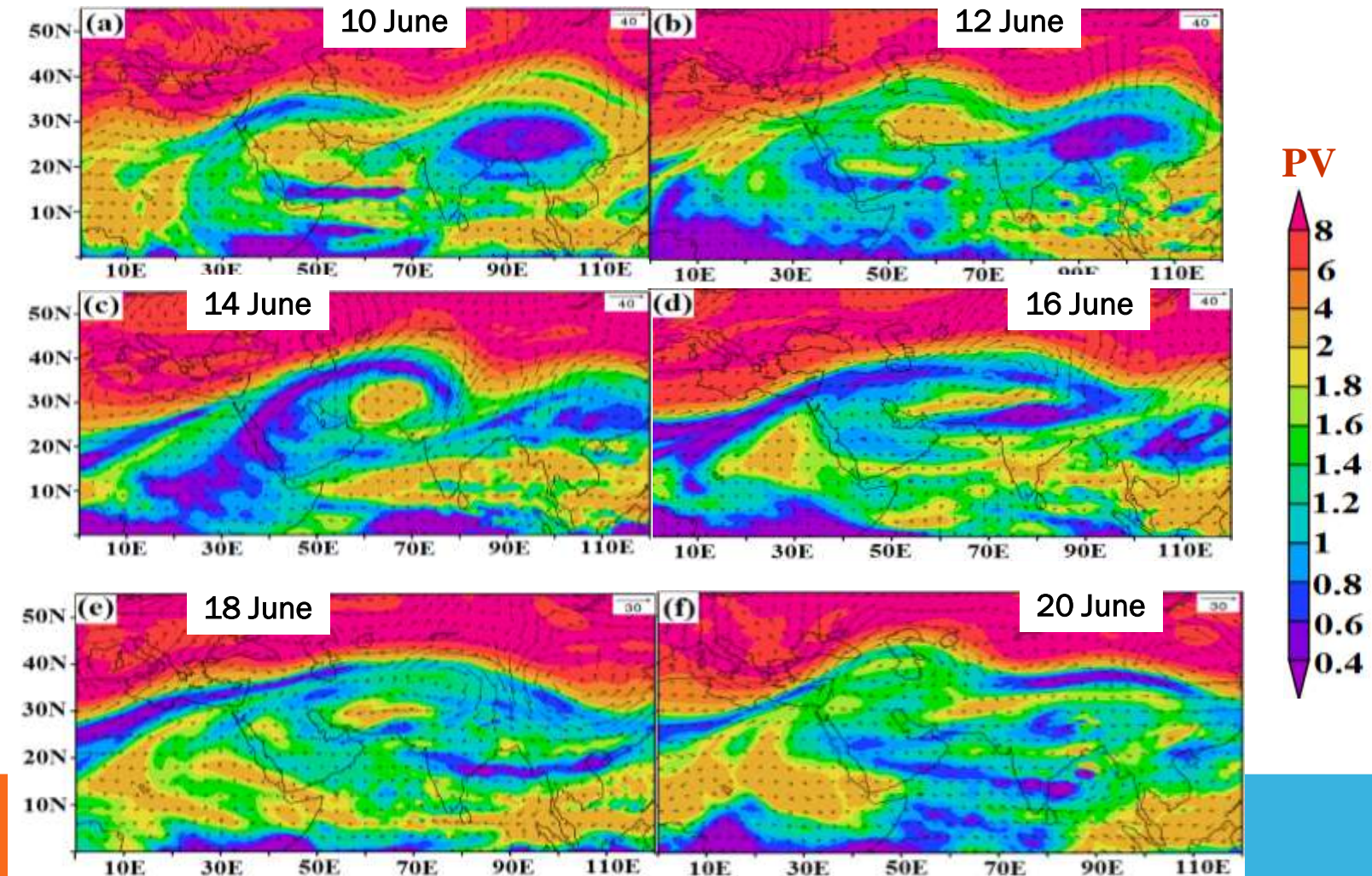
Eddy shading from the RWB over the Tibetan Plateau

Rossby wave breaking in the subtropical Jet (PV-350K)



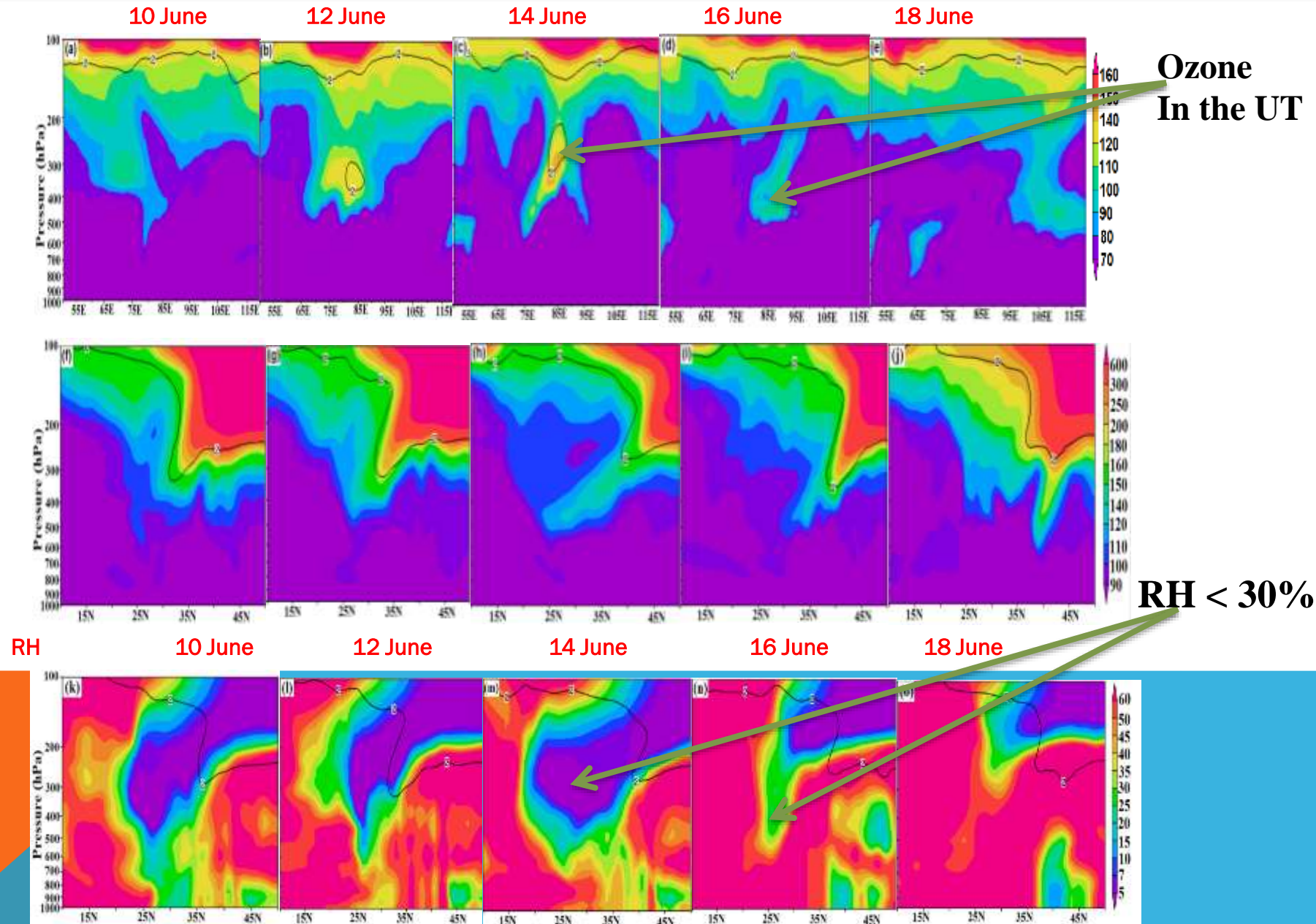
Rossby wave breaking in the jet → migration of extra-tropical stratospheric PV (>2) over the Tibetan Plateau

Rossby Wave Breaking (RWB) at 370 K

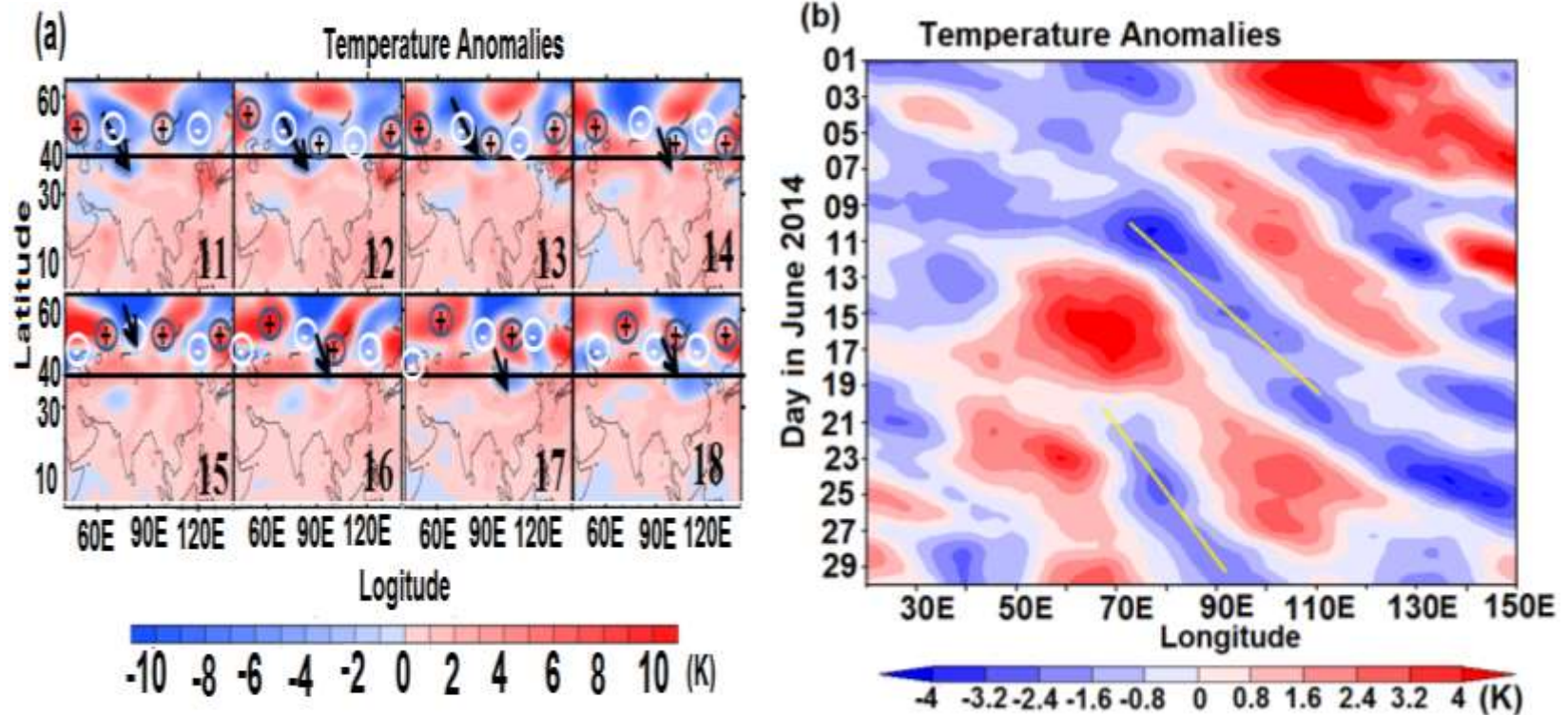


Westward eddy shedding associated with RWB

Intrusion of dry and ozone-rich air

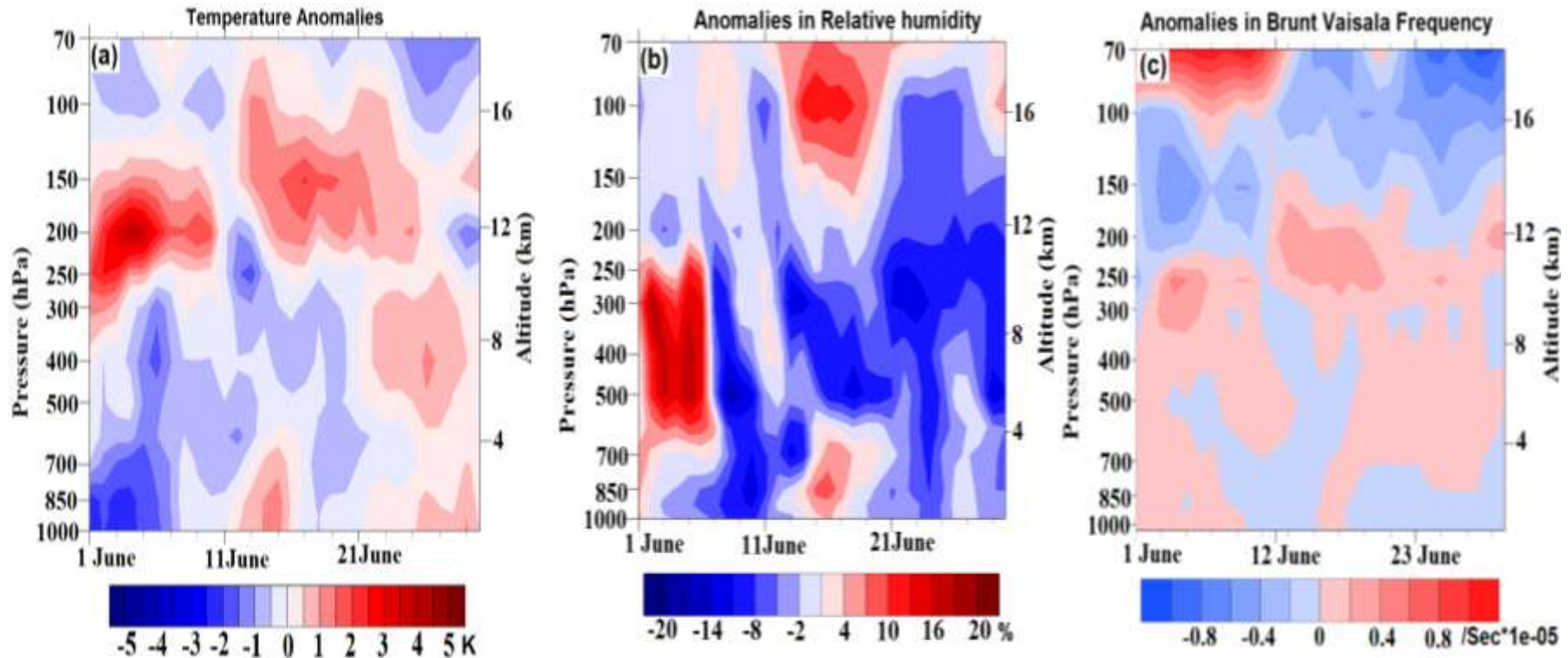


Cold air intrusion over the Tibetan Plateau



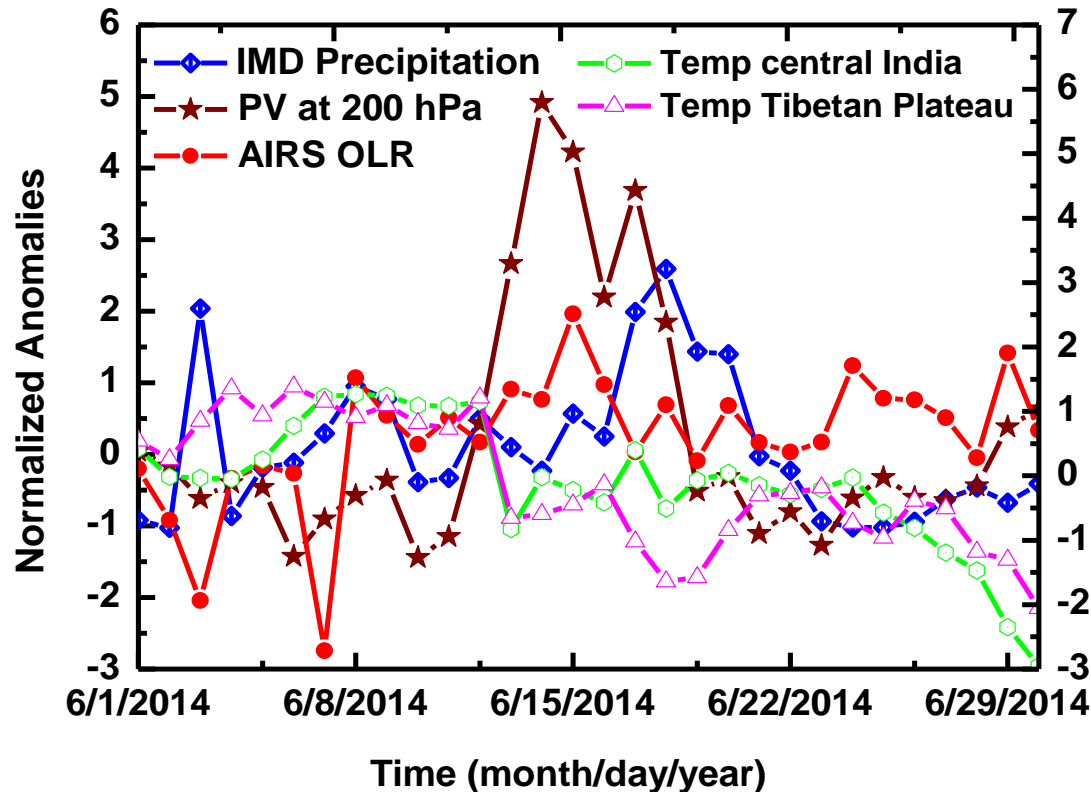
RWB event associated with cold intrusion over the Tibetan Plateau from extra-tropics. Cold air persisted for the rest of month - June 2014.

Intrusion of cold and dry air : Implications on static stability



Stratospheric intrusion 10 June 2014 → cold air and dry in the UT for rest of the month → Increase in static stability → may lead to monsoon break.

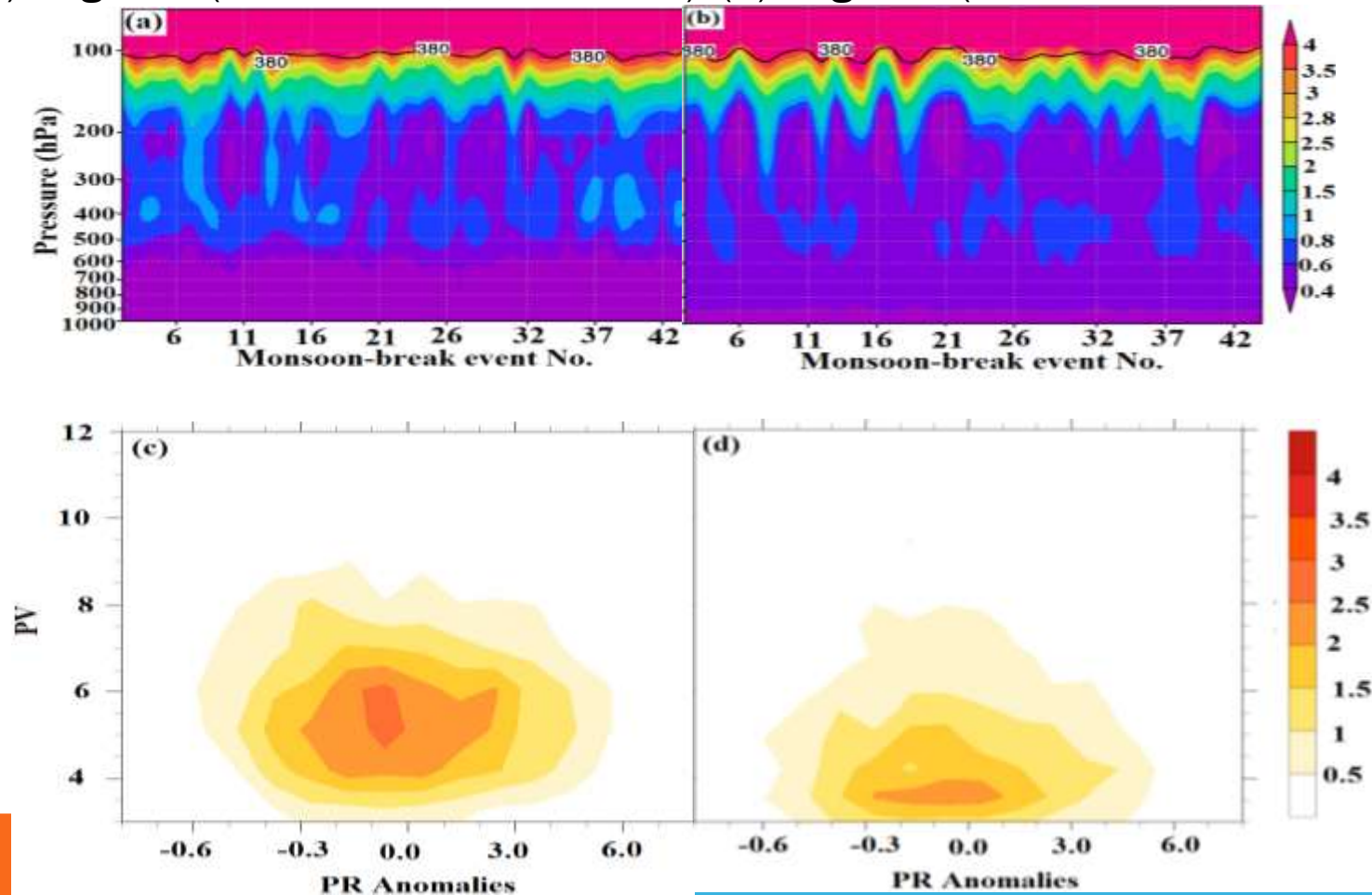
Linkages of stratospheric intrusion with Indian rainfall



Stratospheric PV → negative anomalies in temperature over TP and CI → high OLR → negative anomalies in rainfall

Stratospheric Intrusions during monsoon break days (1979-2007)

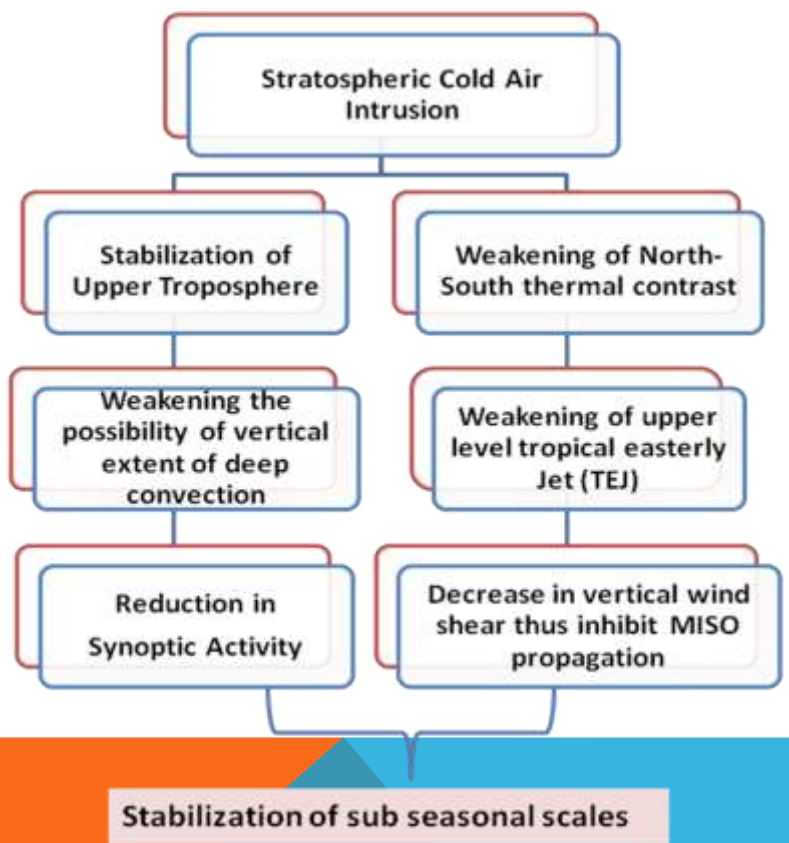
(a) Region-1 (27°N - 35°N , 60°E - 78°E) (b) Region-2 (27°N - 35°N , 78°E - 110°E).



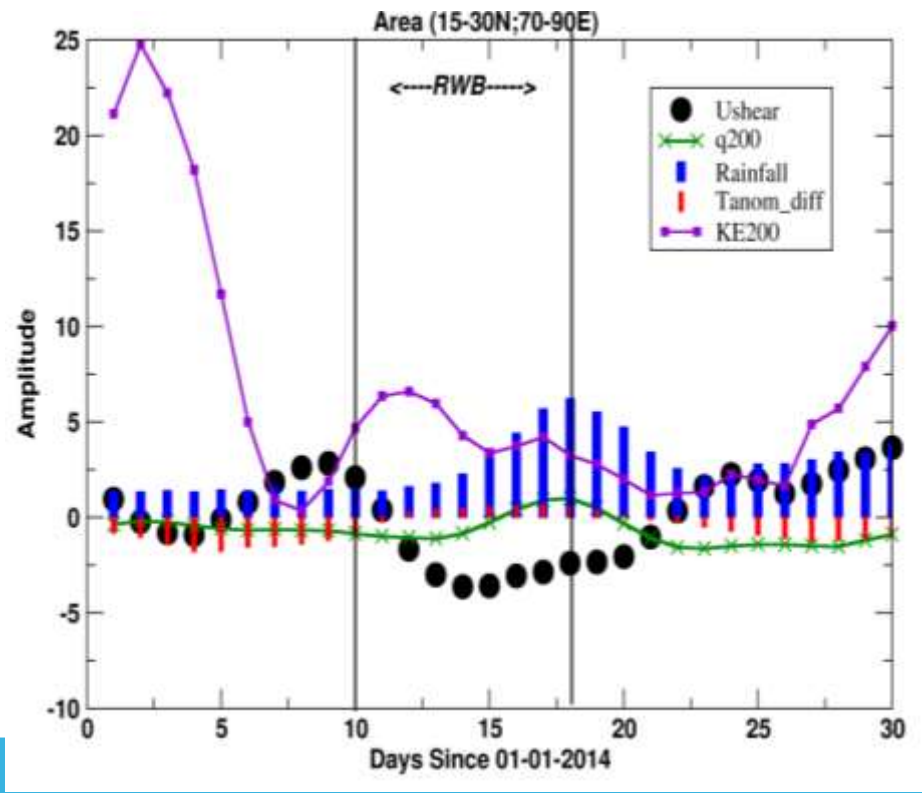
- ❖ Bivariate Probability Distribution Function (BPDF) is negatively skewed, indicating a likelihood of deficit monsoon during stratospheric intrusions ($PV > 2$).
- ❖ It indicates that subtropical stratospheric intrusions near the Indian region may be one of the factors influencing ISMR deficit.

Hypothesis: Linkages of stratospheric intrusion with Indian rainfall deficit

(a)

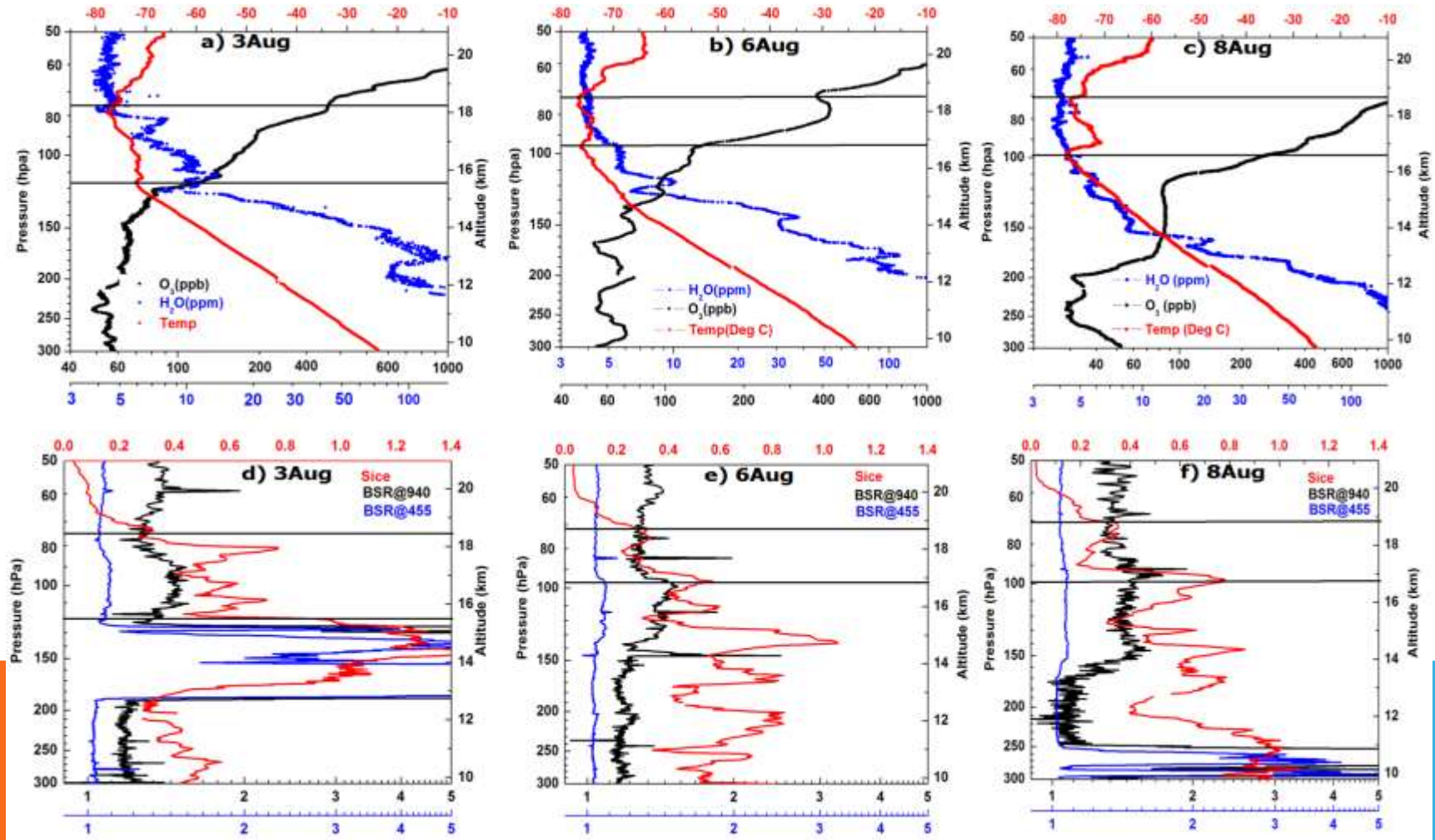


(b)



Balloonsonde measurements at Nainital, India (August 2016)

Collaboration: IITM, Pune, ETH, Zurich, DWD Germany, ARIES, Nainital



Thank you !

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