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The dynamical linkage between the South-Asian monsoon extremes and the large-scale circulation over Indo-Pacific region

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Introduction:

- Southwest summer monsoon rainfall contributes profoundly to India's annual rainfall. So its spatio-temporal variability has larger impact on Indian socio-economic conditions.

- Four prominent stationary wave patterns exist over Indo-Pacific region during boreal summer monsoon season (C. P. Chang, 2004).
  - Tibetan anticyclone
  - West Pacific Subtropical High(WPSH)
  - South-Asian monsoon trough
  - East Asian monsoon trough

- WPSH is a large-scale stationary wave pattern which occupies 1/4th of the northern hemisphere (Akiyama 1989, Zhou et al.2009; Liu and Wu 2004; Chen et al.2001)

- Recent studies highlighted the role of zonal shift of WPSH on the monsoon extremes over North-west Indo-Pakistan region (Zhou et al., 2009, Mujumdar et al., 2012).

- In this study the large-scale stationary wave patterns associated with heavy precipitation over Indo-Pak region, coinciding with strong La Nina events during 1988 and 2010, are presented.

Data and methodology:

- Several data sets are used for this study. It includes gridded rainfall data **2.5 °x 2.5°** from Global precipitation climatology project(GPCP) for period 1980-2012.

- Geopotential height from National Center for Environmental Prediction National Center for Atmospheric Research (NCEP/NCAR) reanalysis datasets at 2.5° **x** 2.5° resolution at different pressure levels is used to represent the stationary wave patterns for 1980-2012.

- To prepare the normalized Southern Oscillation Index, we used mean sea level pressure from NCEP/NCAR reanalysis data sets for the same period.

- The National Oceanic and Atmospheric Administration (NOAA) interpolated out going long wave radiation (OLR) data for the same period is used as a proxy for convection.

- Zonally asymmetric wave component is calculated by formula,

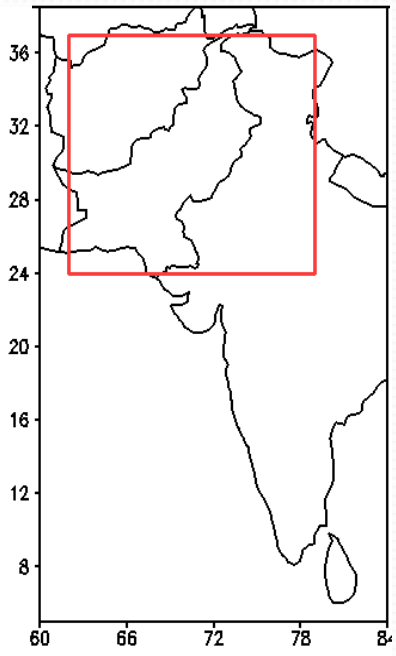
$$Z' = Z - [Z]$$

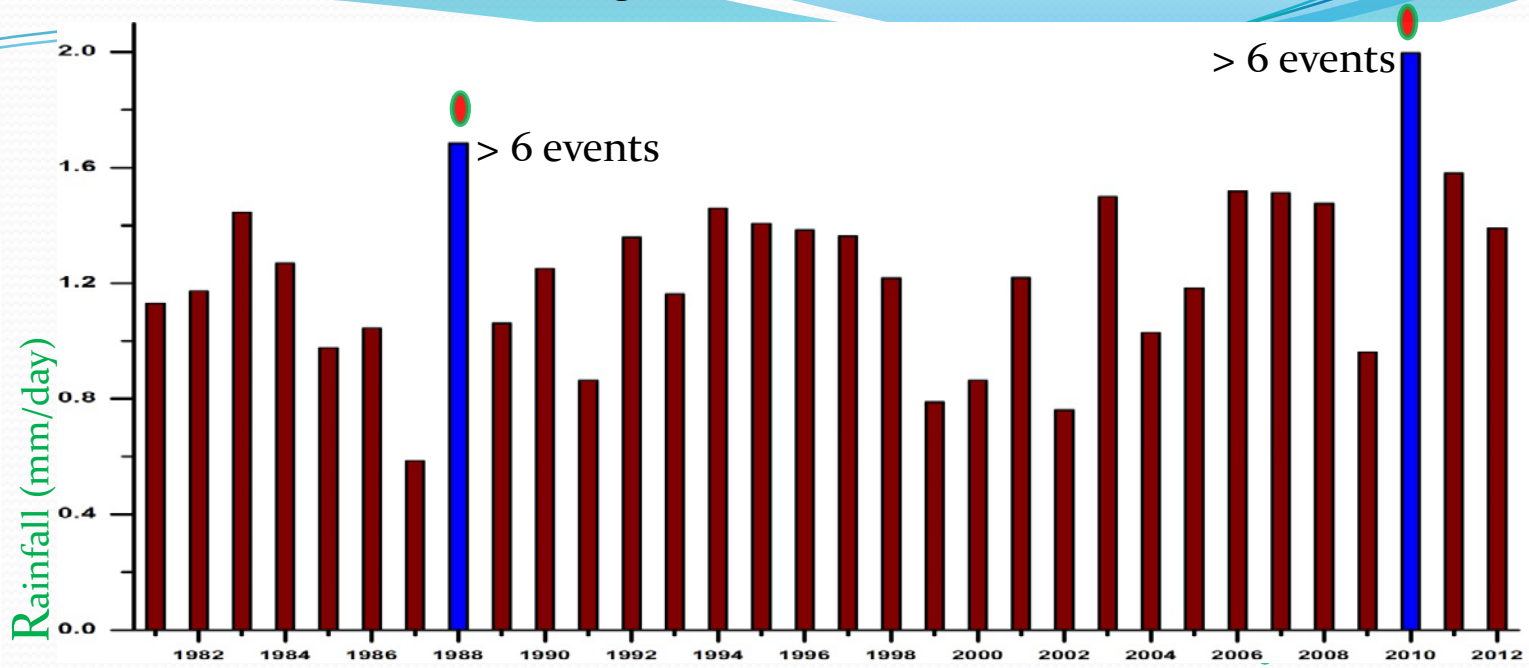
Here, Z' = Zonally asymmetric component

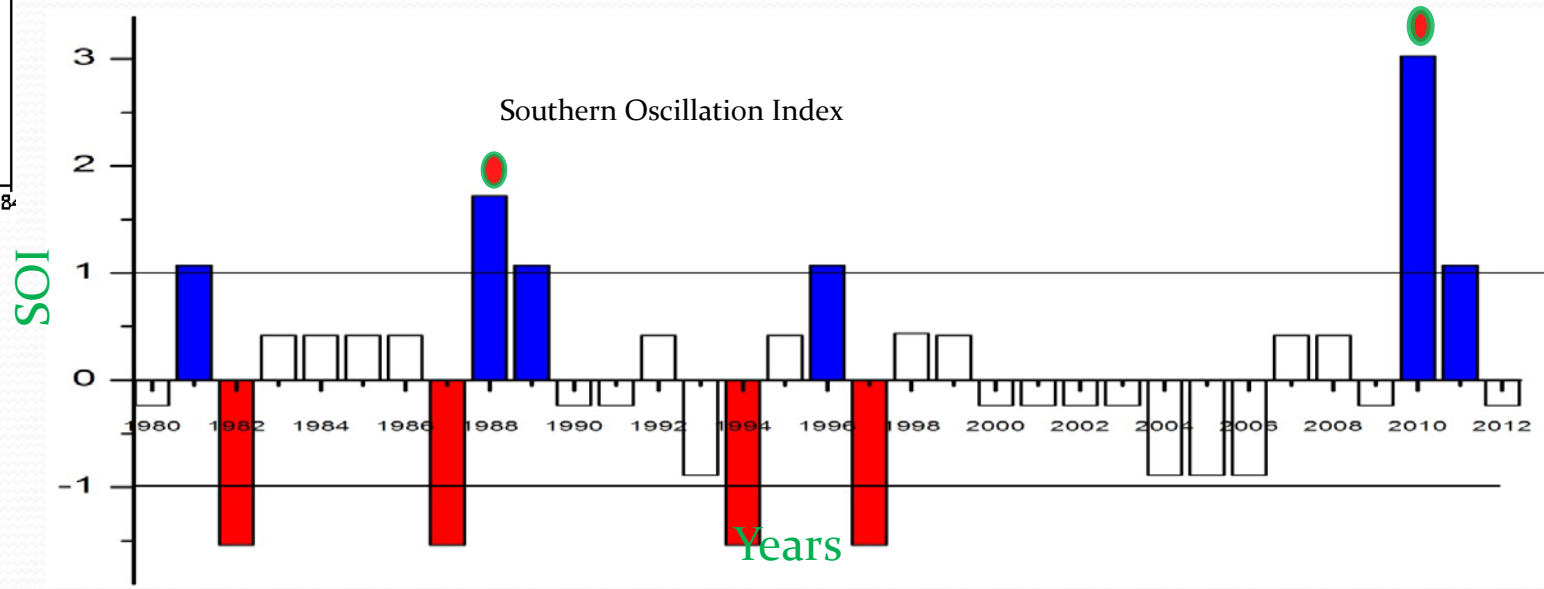
Z = mean of geopotential field

[Z] = Zonally symmetric mean geopotential

Seasonal monsoon rainfall over Indo-Pak region & Southern Oscillation Index

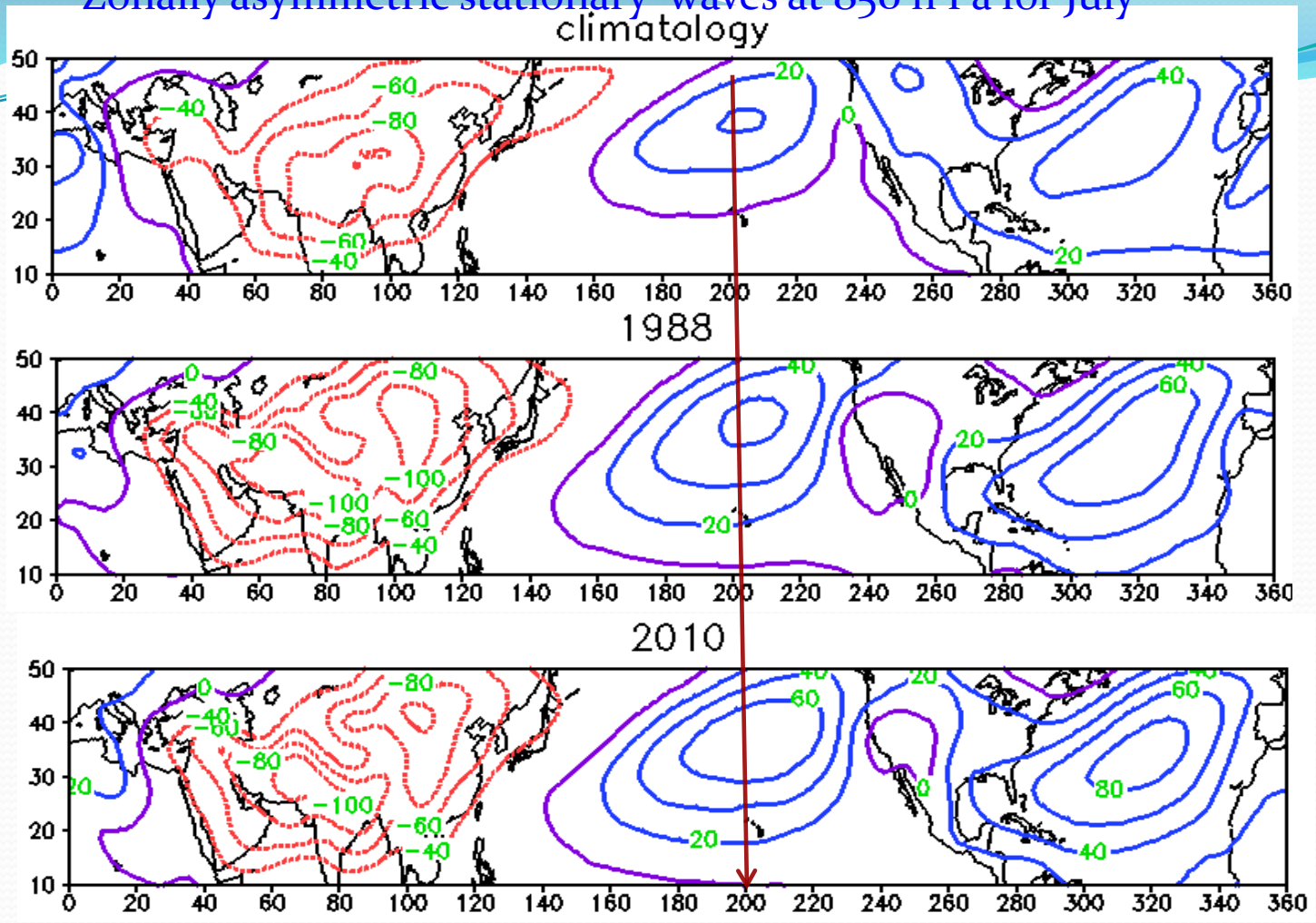






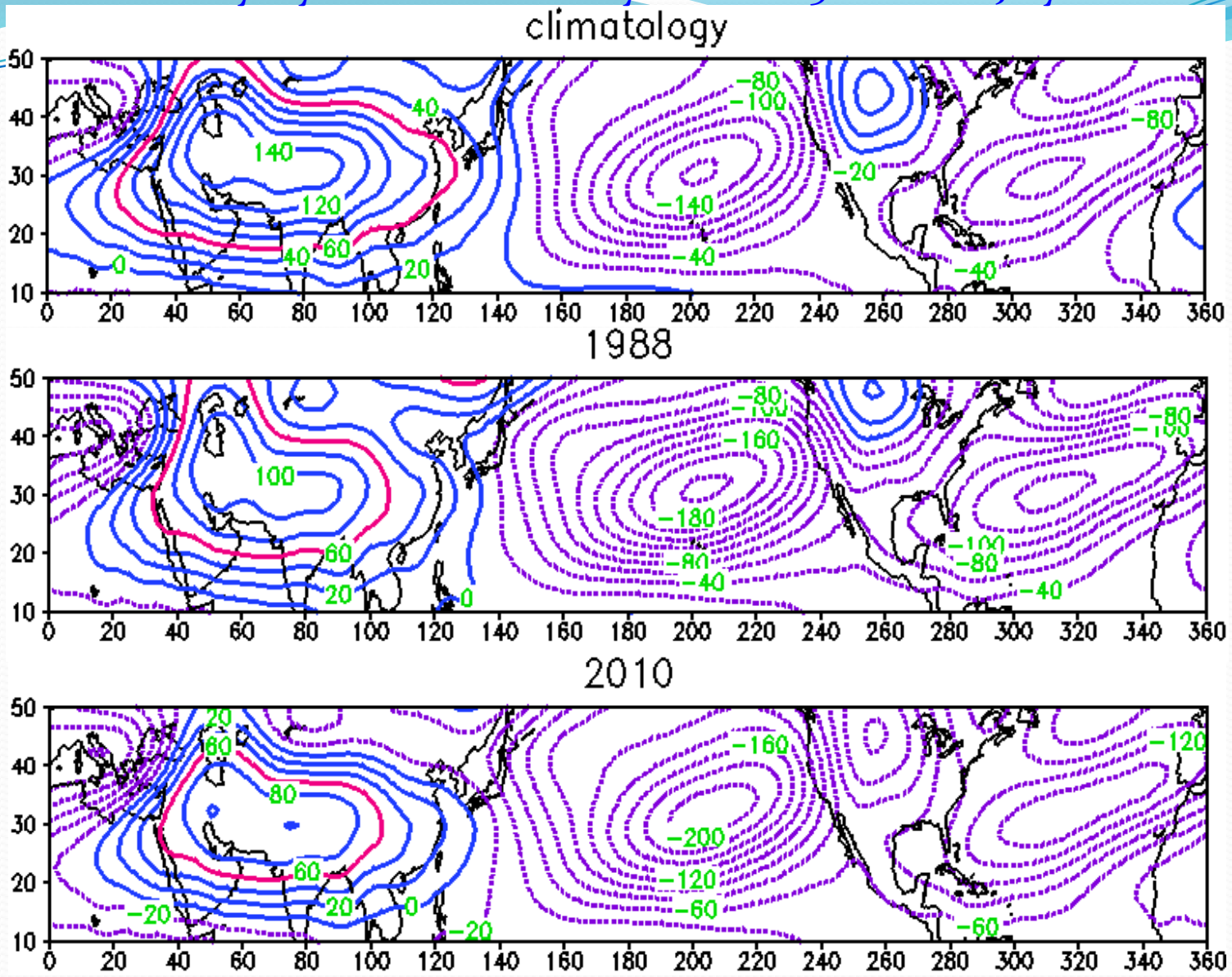
Extreme La Nina events are associated with strong monsoon over Indo-Pakistan region

Zonally asymmetric stationary waves at 850 h Pa for July



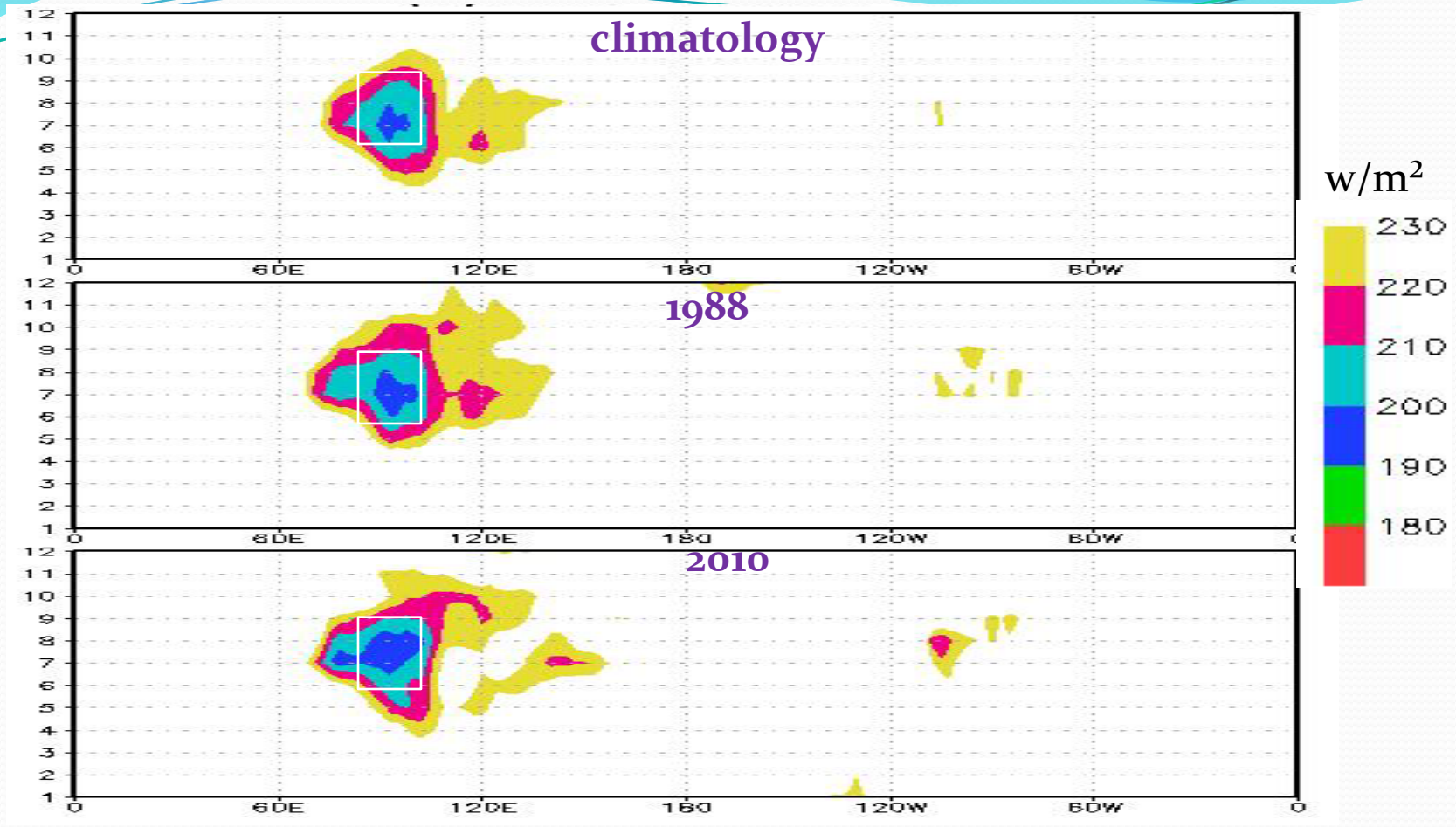
- **The stationary wave patterns (Atlantic high, WPSH and continental lows over South Asian monsoon regions) shows an intensification during 1988 and 2010.**
- WPSH is shifted westward during 1988 and 2010 as compared to its climatological position at 850 hPa.
- **The large-scale expansion of the WPSH from the center to western outer periphery is 6° in 1988 and 10° in 2010 as compared to the climatology.**

Zonally asymmetric stationary waves at 150 h Pa for July



- An meridional shrinking is observed over eastern flank of Tibetan anticyclone.
- The lows over the Pacific and Atlantic oceans shows an intensification during 1988 and 2010.

Longitude-time cross section of observed OLR (W/m²) averaged over 10-35° N



❖**The deep convective areas during extreme La Nina events shows longitudinal expansion as compared its to climatological pattern.**

Time	extent of Stationary wave pattern (in degrees)		longitudinal extent of deep convection over South-Asian monsoon region (OLR<210 w/m^2) in degree Climatological extent is 28°
	WPSH (850 hPa)	Tibetan High (150 hPa)	
1988	6	-2.7	3
2010	10	-3.5	8

Climatological position of WPSH is **160** E and Tibetan high is **20** N

- WPSH shows an enhanced westward extension during 1988 and 2010.
- A latitudinal shrinking of Tibetan anticyclone is noted during 1988 and 2010.
- Deep convective areas over South- Asian monsoon regions is increased during 1988 and 2010.

Conclusions:

- **Westward shift of West Pacific Subtropical High is more prominent during 2010 compared to 1988 which in turn consistent with the intensity of rainfall activity over Indo-Pakistan region.**

- **The existence and maintenance of the subtropical anticyclone is ultimately related to zonally asymmetric stationary waves.**

- **Our analysis shows that there a strong interplay between West Pacific Subtropical High and large scale heat source over South-Asian monsoon region.**

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