Understanding El Nino-Monsoon teleconnections

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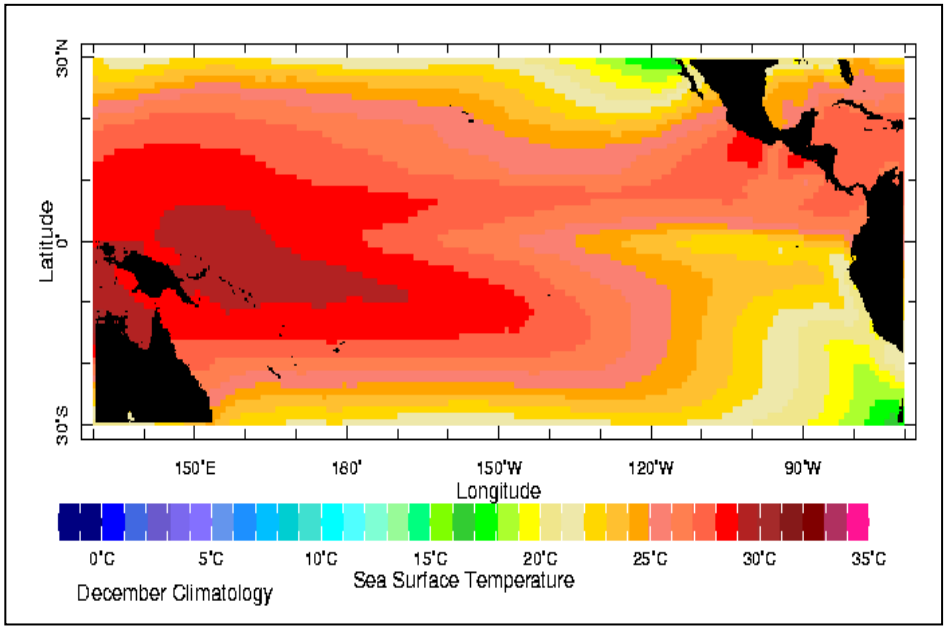
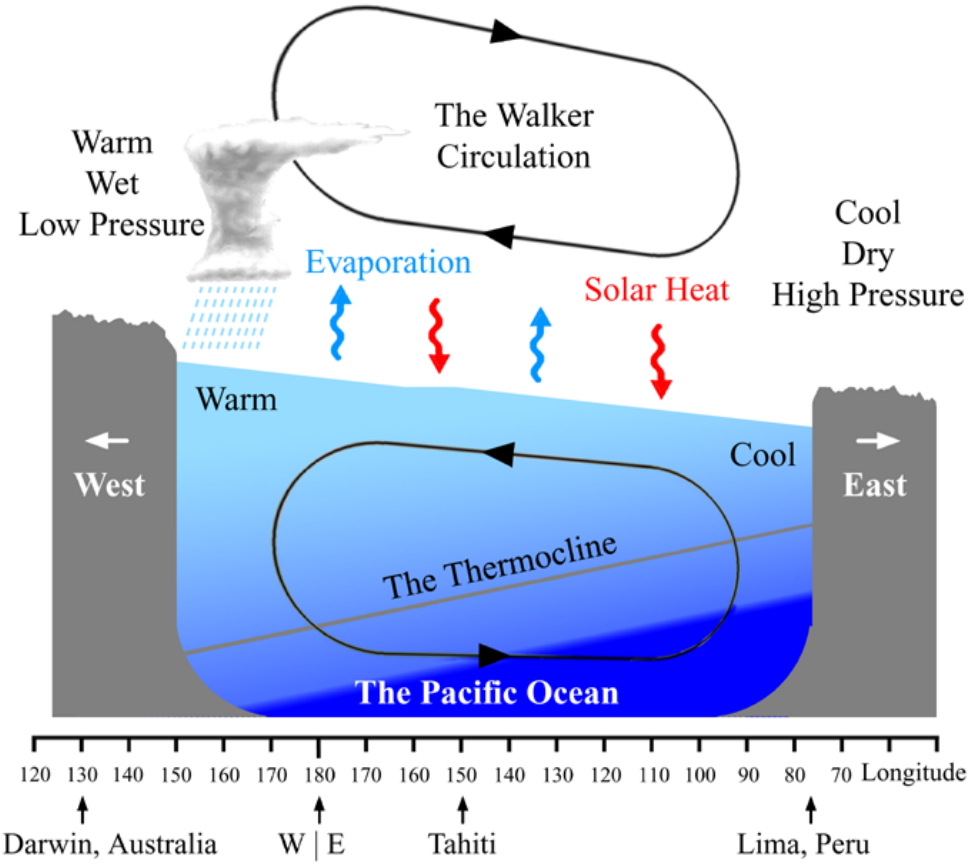
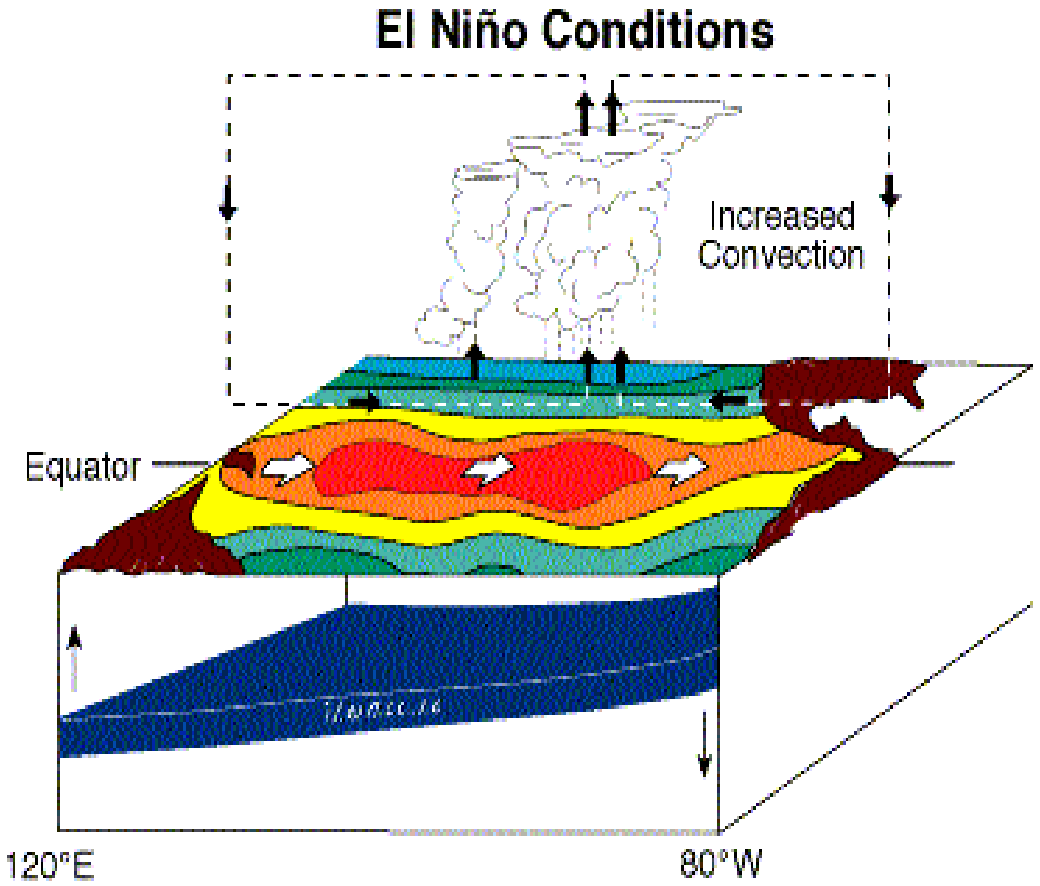
Mean State of the equatorial Pacific coupled Ocean-Atmosphere System



The trade winds moves surface water towards west. Land surfaces restrict its further movement and water "piles up" in the W. Pacific.

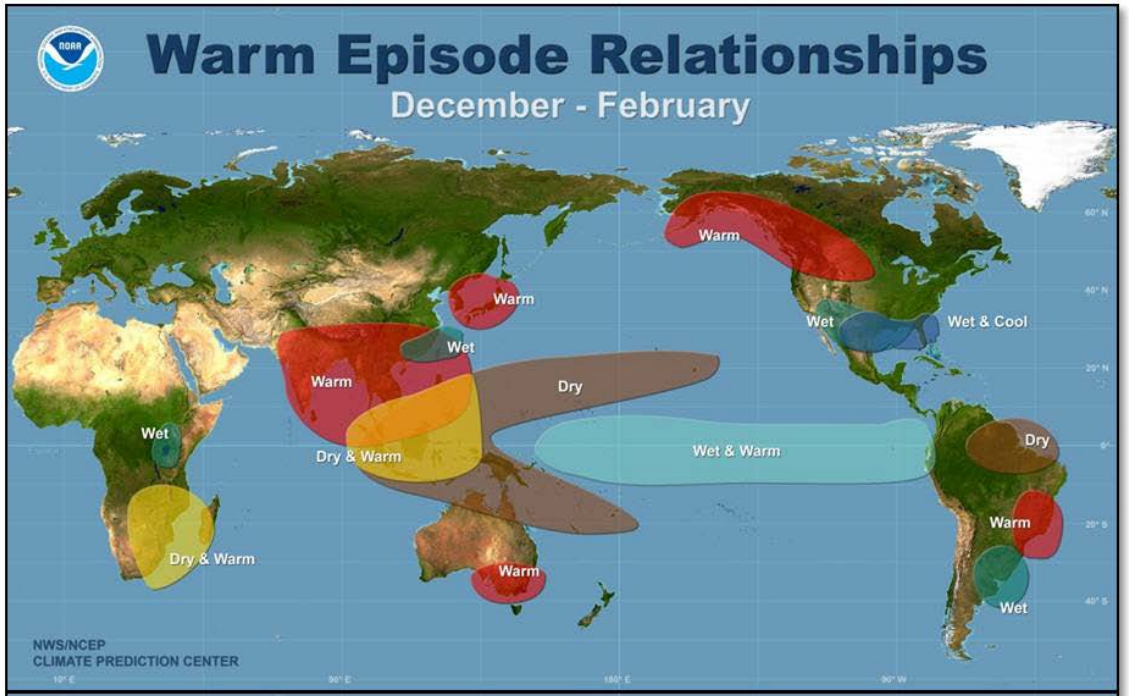
Warm SST, high sea surface, Low pressure, convection, clouds and rain over western Pacific and opposite conditions over Eastern Pacific.

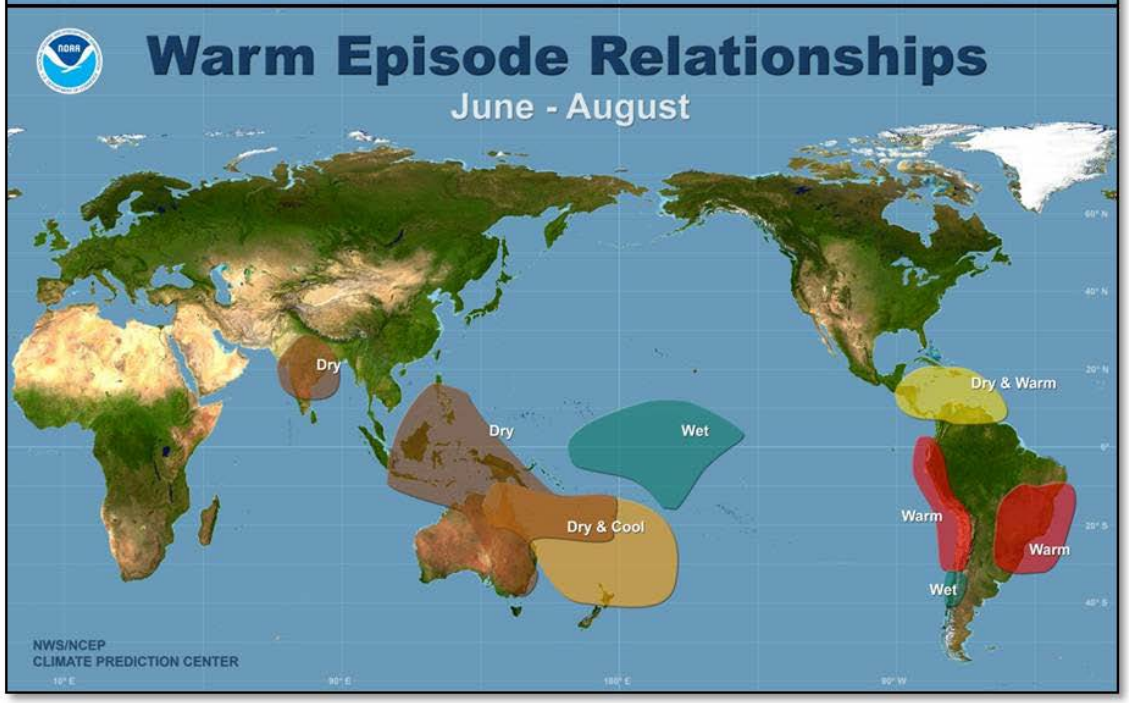




- El Niño events are departures from mean state in the Pacific which results from weakening of easterly trade winds, and are associated with changes in Walker circulation.

- The El Niño-Southern Oscillation (ENSO) describes the natural year-to-year (interannual) variations in the ocean and atmosphere in the equatorial Pacific.

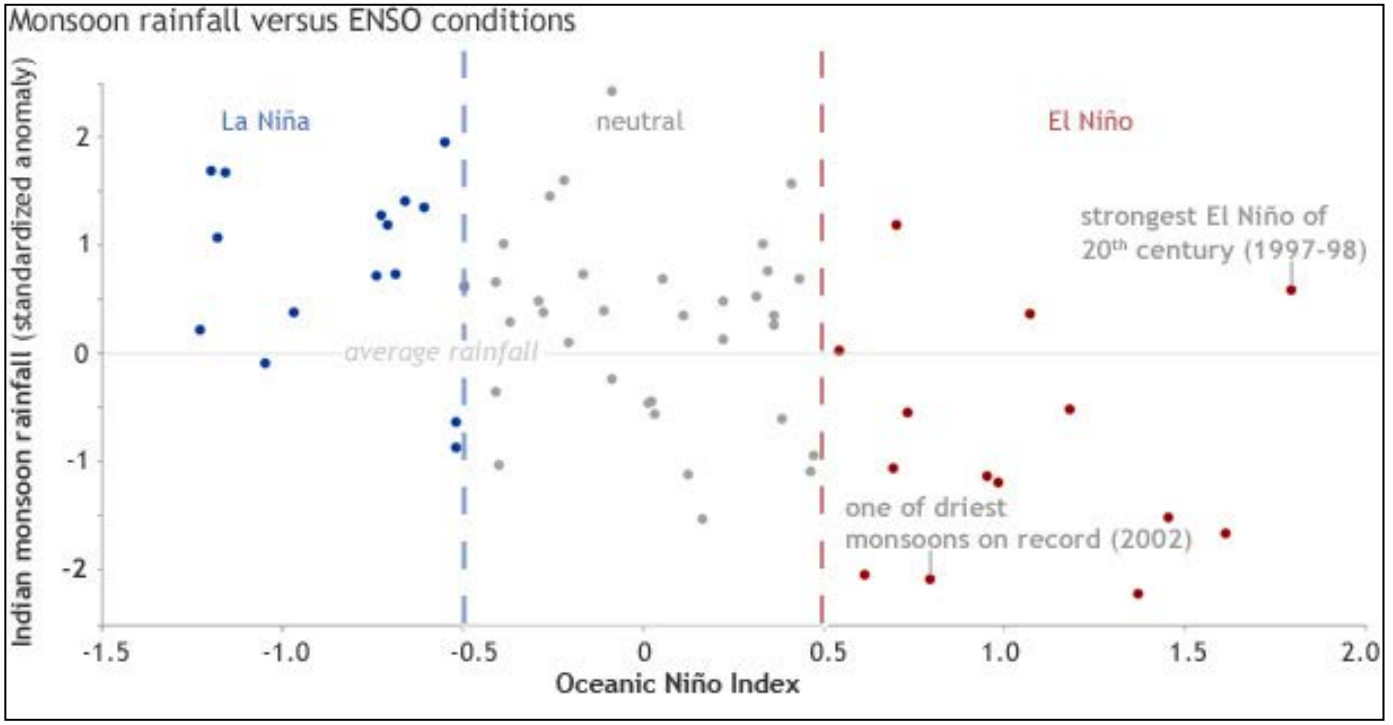




- One of the most important climate phenomena.
- It can lead to large-scale changes in pressure, SST, precipitation and winds not only in the tropics but across many other regions of the world.

Courtesy: NOAA CPC

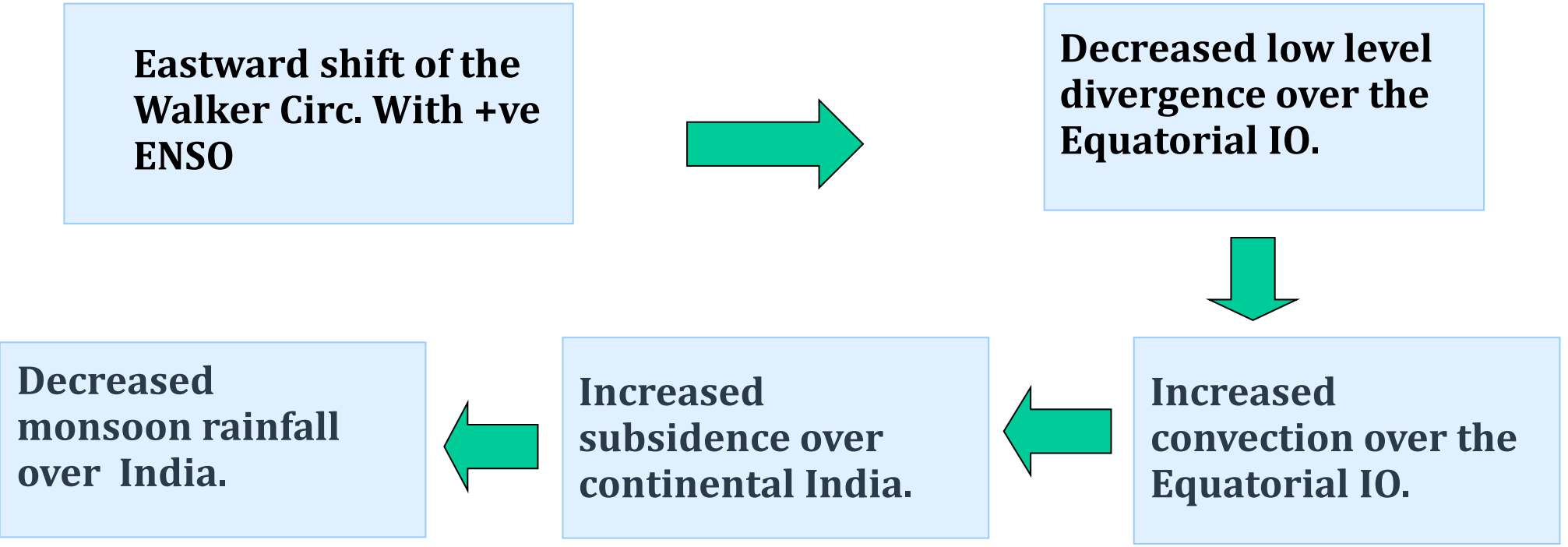
El Nino – Monsoon relationship



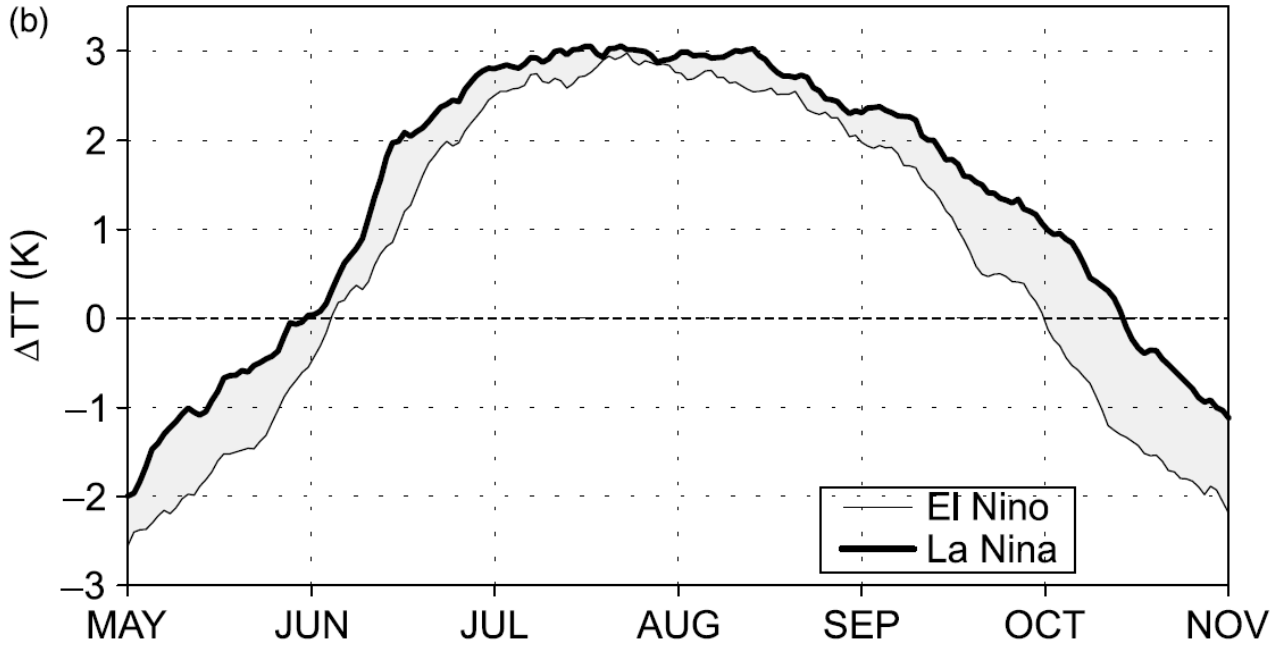
La Niña years (blue), neutral years (gray), and El Niño years (red) compared with the monsoon strength (1950-2012).
(Kumar et al. 2006)

How does ENSO induce decreased Indian summer monsoon precipitation?

Large scale circulation changes associated with ENSO inhibits organized convection over Indian region.



ENSO influences the monsoon by affecting the meridional tropospheric temperature gradient over the Indian monsoon domain which in turn modulate the strength and duration of the monsoon (Goswami and Xavier 2005).



The missing link in the understanding of the El-Nino-monsoon teleconnection is an explanation for the time scales and pathways through which the warming perturbations over the Pacific reach the monsoon domain.

Remote influence of El Nino on monsoon through wave responses induced by atmospheric diabatic heating.

El Nino SST anomalies and associated convection can directly modulate the free tropospheric temperature over the region locally and remotely through atmospheric waves.

Heating associated with El Nino can setup stationary waves in the atmosphere which can determine the teleconnection pathways across the globe. The teleconnection pathways between ENSO and monsoon can be identified by adopting the principles of atmospheric energy dispersion and wave dynamics.

- **Explore upper tropospheric pathways of energy transfer**
- **How fast does the communication of tropospheric heating perturbation happen between the Pacific and monsoon domain such that they can influence the monsoon variability?**

Wave tracing approach (Karoly, 1983)

The dispersion relation for atmospheric barotropic Rossby wave is given by

$$\omega = \bar{u}k + \bar{v}l + \left(\frac{\frac{\partial \bar{q}}{\partial x} l - \frac{\partial \bar{q}}{\partial y} k}{K^2} \right)$$

Where $\bar{u}$ is the time mean state of zonal wind, $\bar{v}$ the time mean state of meridional wind, $\bar{q}$ is the absolute vorticity, k is the zonal and l the meridional wavenumbers, ω is the frequency of barotropic Rossby wave, and $K = \sqrt{k^2 + l^2}$.

Horizontal and meridional component of group velocity of barotropic Rossby wave is given by

$$u_g = \bar{u} + \left(\frac{\frac{\partial \bar{q}}{\partial y}(k^2 - l^2) - 2kl\frac{\partial \bar{q}}{\partial x}}{K^4} \right)$$

$$v_g = \bar{v} + \left(\frac{\frac{\partial \bar{q}}{\partial y} 2kl - (k^2 - l^2)\frac{\partial \bar{q}}{\partial x}}{K^4} \right)$$

The allowed path (x,y) of barotropic Rossby waves for a given mean state can be traced by solving the above set of equations for different horizontal wavenumbers.

Defining El Nino using convective heating metric (OLR)

Studies points to the importance of adopting atmospheric heating based metric to study El-Nino induced teleconnections (Chiodi and Harrison 2012)

El-Nino SST based index: Area averaged monthly mean SST data over the Nino3.4 region of equatorial Pacific (5S-5N, 120W-170W) (red)

El Nino OLR based index: Area averaged monthly mean OLR data over the domain 5S-5N, 170E-100W) (blue)

Seasonality of El Nino events

Most number of El Nino events occur in winter and spring.

The observed relationship between ElNino heating anomaly and free tropospheric temperature anomaly peaks when ElNino leads by three month. Hence we base our wave tracing approach using the spring mean state.

Tracing the tele-connection pathway

We carried out Rossby wave tracing analysis for the 200 hPa level using boreal spring ElNino background state

The pathways long waves take to travel from the central Pacific to south Asian monsoon domain is not arbitrary as it is constrained by the background atmosphere.

Point correlation map of 200hPa meridional wind anomalies w.r.t. a reference time series from the region of peak El Nino activity, overlaid with the theoretical Rossby wave pathway

Tracing the tele-connection pathway

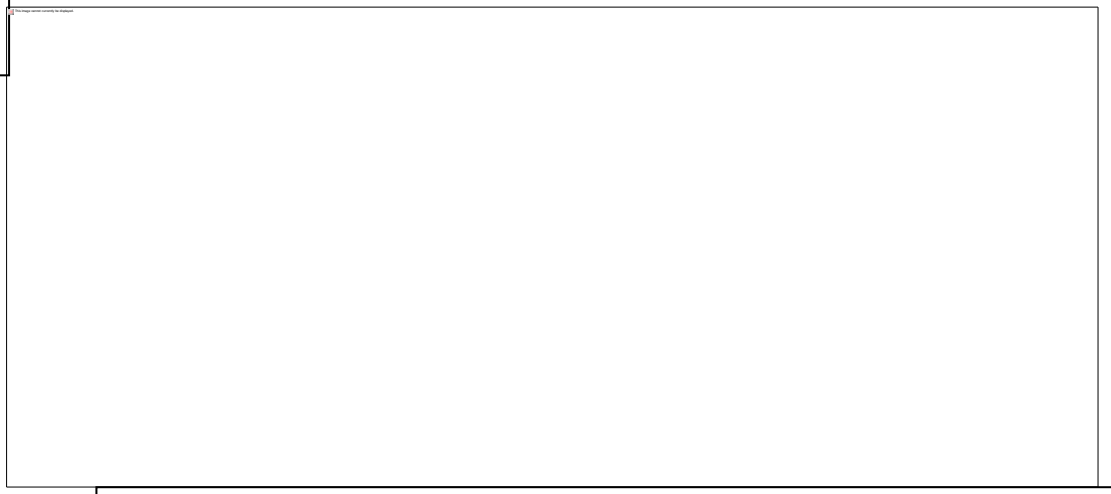
Zonal wavenumbers 3 to 7 are the allowed waves which can connect the two domains.

Two Rossby tracks are observed:

- First wave guide supports Rossby wave traveling from northern hemispheric off equatorial region of central Pacific to north Indian region, roughly along the latitude circle. The path is traced in 15 days.
- The second path crosses to southern hemisphere over eastern Pacific and travel up to south Indian Ocean region. The path is traced in 38 days.

Point correlation map of 200hPa meridional wind anomalies w.r.t. a reference time series from the region of peak El Nino activity, overlaid with the theoretical Rossby wave track for zonal wavenumber 4

The analysis results suggest that the *stationary Rossby waves induced by the boreal spring El Nino state can alter free troposphere temperature over north India and south Indian ocean*, modulate the tropospheric temperature gradient and also generate dynamical responses over monsoon domain



But the correlation between OLR El Nino index and free TT anomaly over north India is not only weak but also it reaches maxima only when free TT anomaly leads OLR El Nino index and is *unlikely that the central Pacific atmospheric heating anomaly cause perturbations in free TT over north Indian domain*.

Summary

- **Examined the El Nino-Monsoon teleconnection using a wave-dynamic framework.**
- **Identified an inter-hemispheric waveguide from central Pacific to South Asian monsoon domain.**
- **One month lead shown by El Nino heating and TT anomaly over the monsoon domain suggest the untapped potential for developing a forecast scheme for predicting the monsoon onset and evolution.**

Thank You!