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Intraseasonal to interannual variability in the temperature structure around the tropical tropopause and its relationship with convective activity

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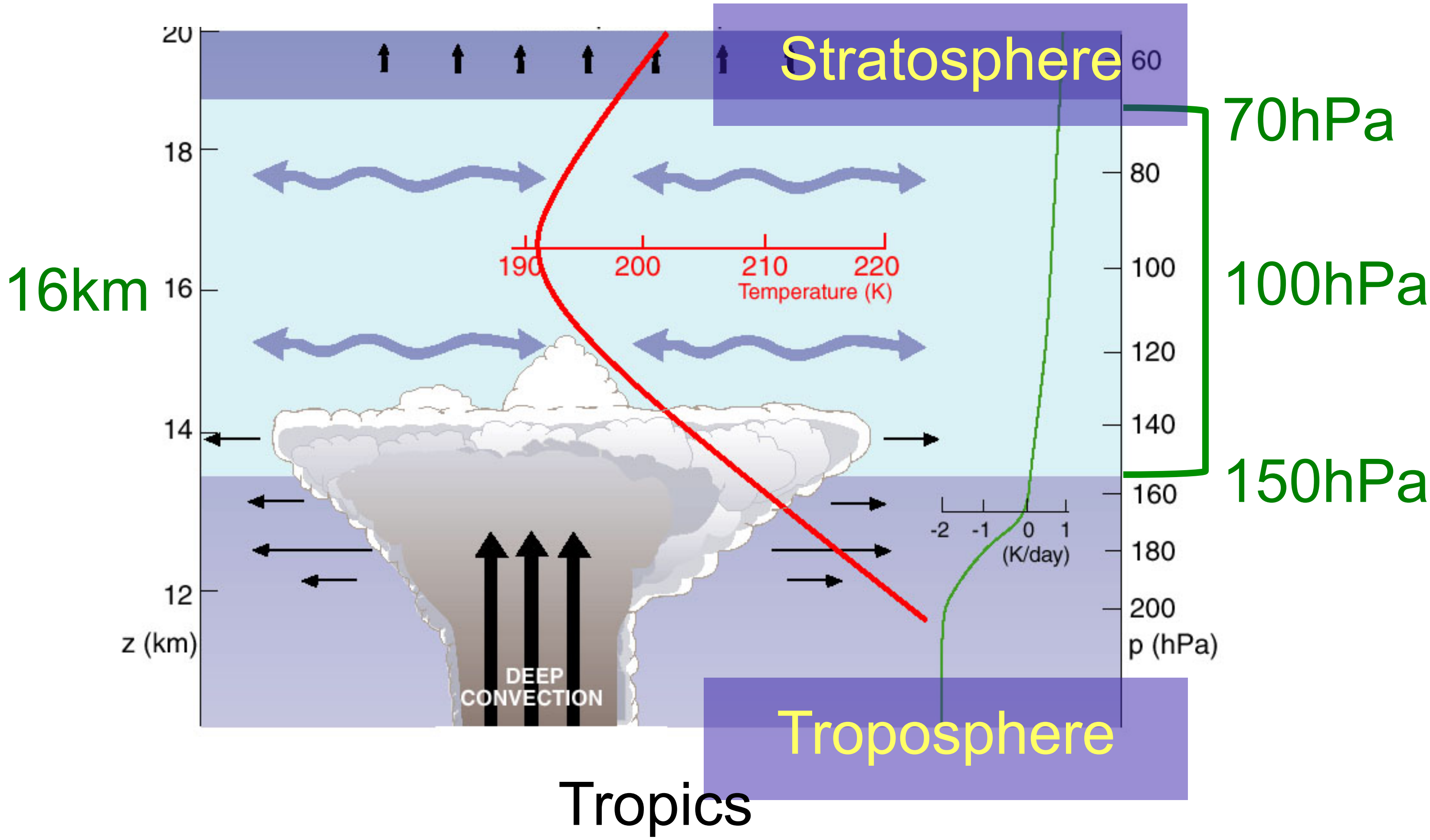
Tropical Tropopause Layer



• Temperature in the TTL in one of the most important factors that control aridity of air in the stratosphere

Possible influence of Water Vapor in the Stratosphere

<u>Over the tropics</u>

- Variability of the radiative balance
  - Formation of cirrus cloud

<u>At the polar region</u>

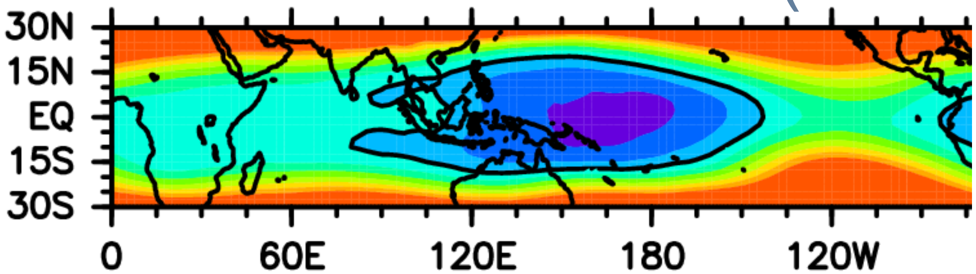
- Variability and recovery of the Ozone layer
  - Source of polar stratospheric cloud (PSC)
  - Chemical reaction

$$H_2O + O(^1D) \rightarrow 2OH$$

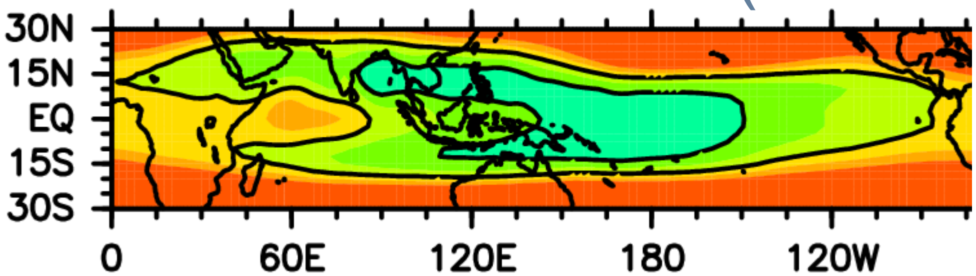
$$\begin{cases} OH + O_3 \rightarrow HO_2 + O_2 \\ HO_2 + O_3 \rightarrow OH + 2O_2 \end{cases}$$

The 100-hPa Temperature

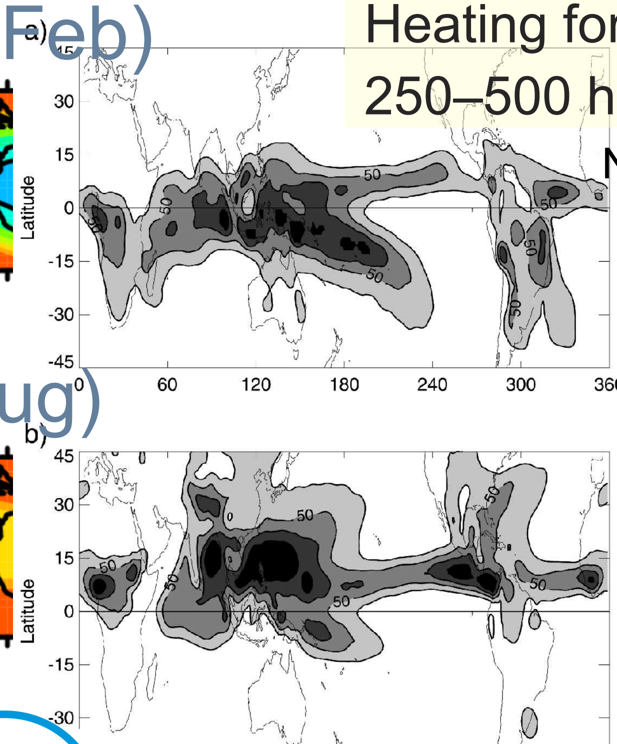
Southern Summer(Dec-Feb)



Northern Summer(Jun-Aug)



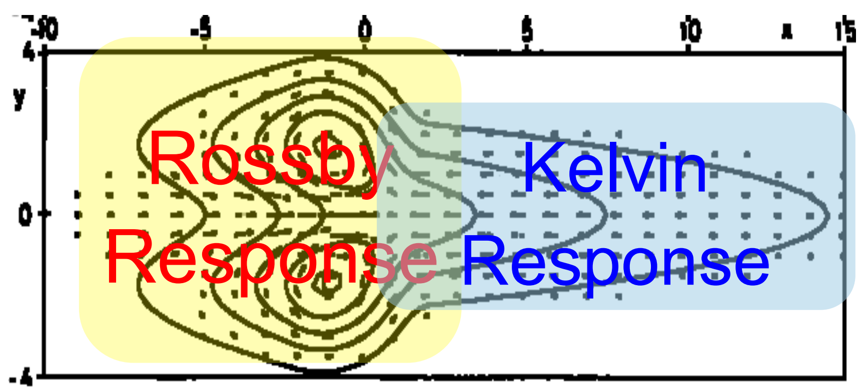
Heating for the layer 250–500 hPa



Norton, 2006

- Low temperatures form a horseshoe-shaped structure, which resembles the Matsuno-Gill pattern
- The seasonal variability is related to the monsoon convections

[Nishimoto and Shiotani, 2012]



Gill, 1980

Topic of this study

Aim

Examine the interannual variability in the horseshoe-shaped temperature structure and its relationship with the convective activity

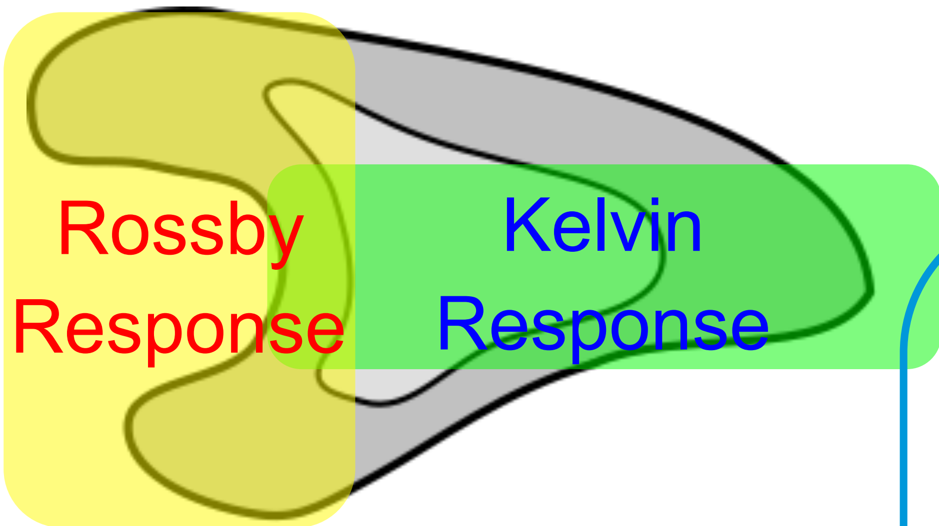
Data

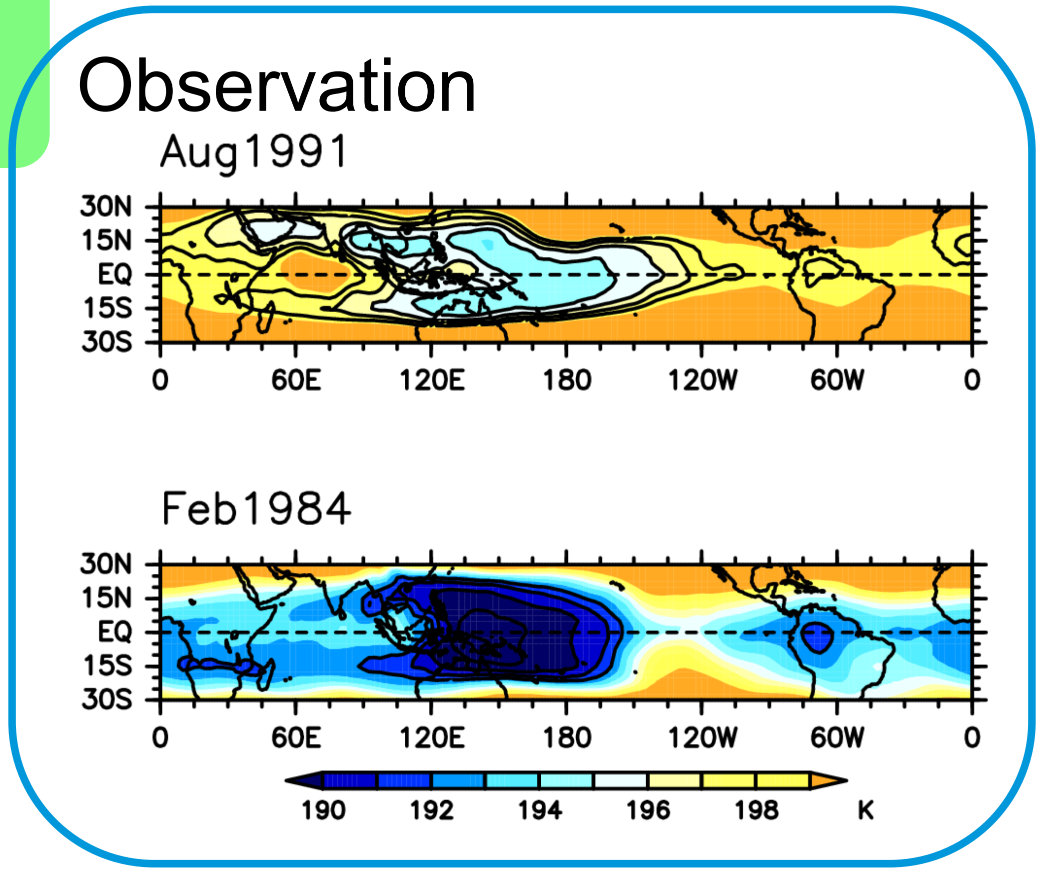
ERA-40 monthly data and NOAA/OLR data (Jan1979 – Aug2002)

Method

Define an index characterizing the horseshoe-shaped structure to quantitatively capture its variability

Definition of Indices characterizing the horseshoe-shaped structure





Preliminary indices of the horseshoe-shaped structure

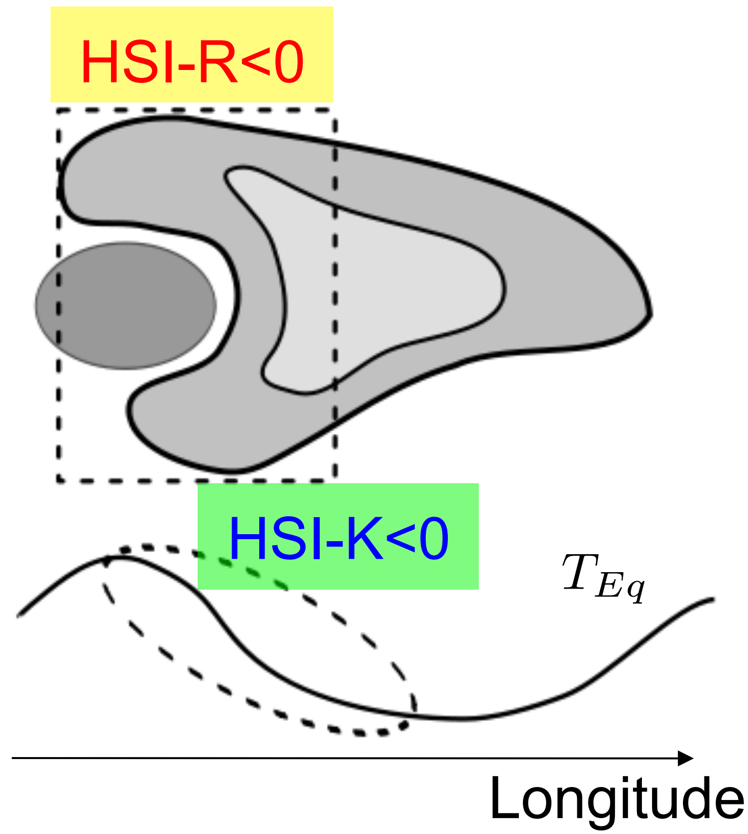
[Nishimoto&Shiotani, 2012, JGR]

$$\text{HSI-R}(x,t) = \frac{T_N(x,t)+T_S(x,t)}{2} - T_{Eq}(x,t)$$

$T_{Eq} = T_{\text{0N}},\ T_N = T_{\text{10N-15N}},\ T_S = T_{\text{10S-15S}}$

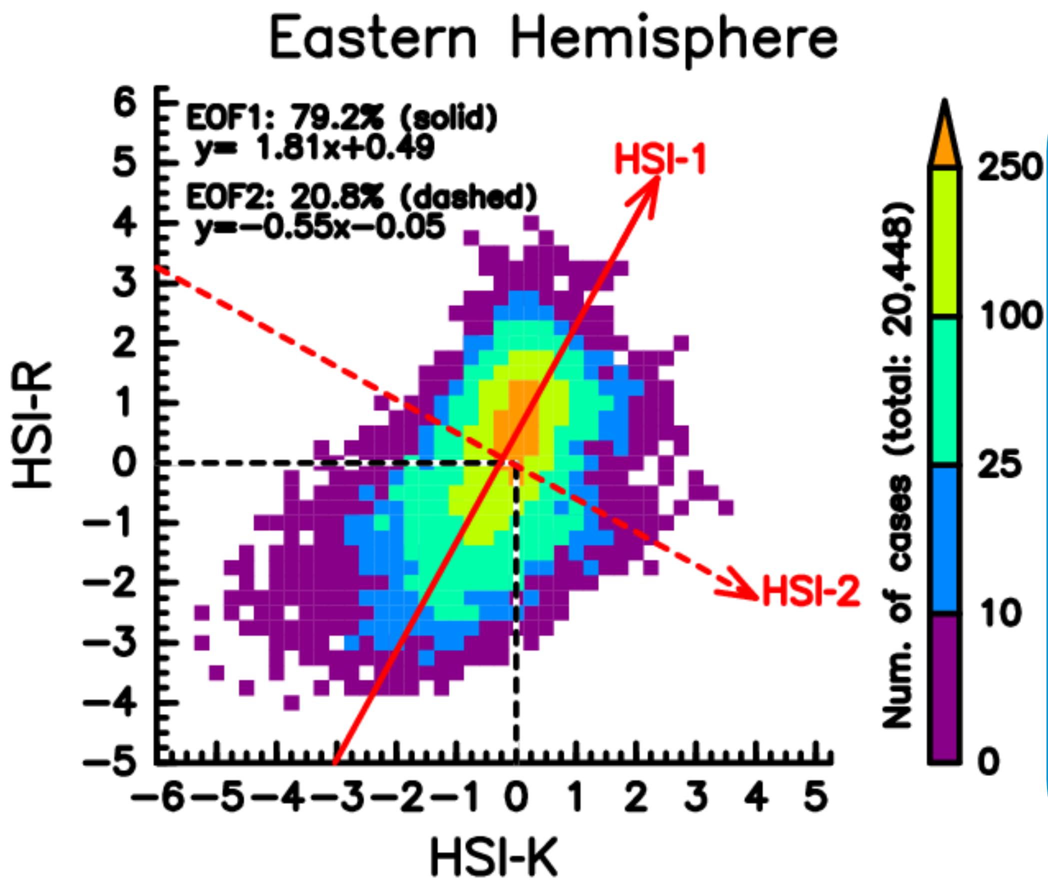
$$\text{HSI-K}(x,t) = T_{Eq}(x+\frac{\Delta x}{2},t) - T_{Eq}(x-\frac{\Delta x}{2},t)$$

$\frac{\Delta x}{2} = 10$ degrees east



The HSI-R and HSI-K values may change accordingly with a positive correlation in response to heating generated by convective activities.

Definition of the horseshoe-shaped structure index



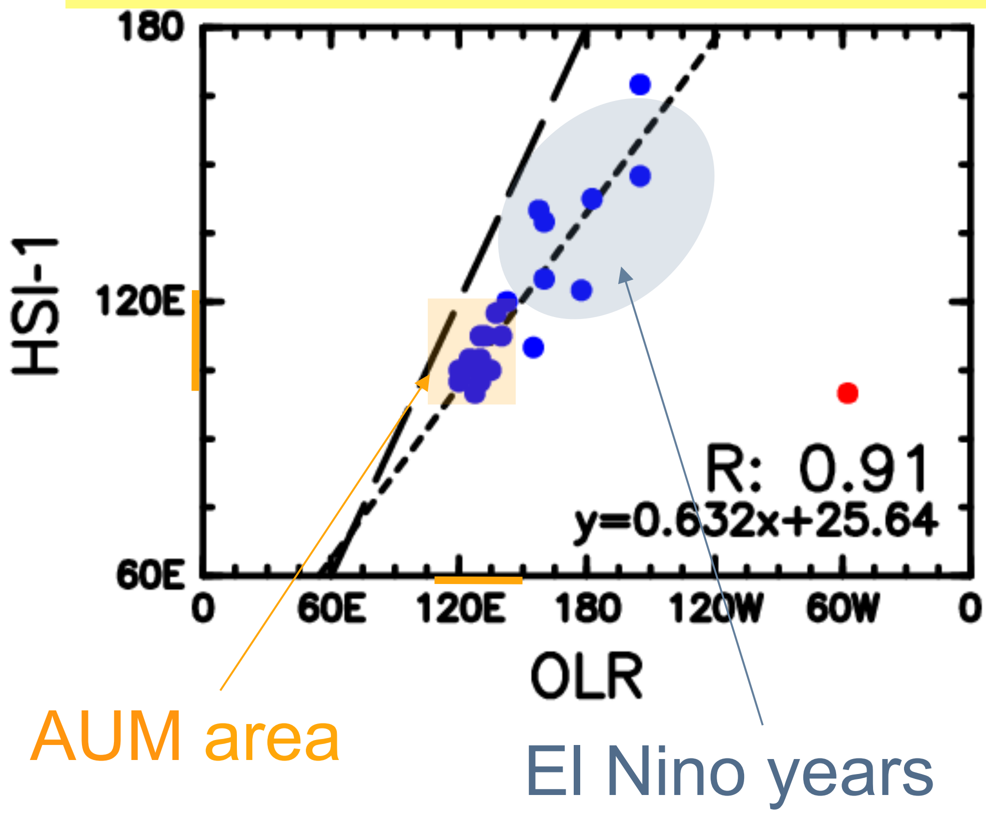
Negative HSI-K values located 15 degrees to the east of the negative HSI-R values

- The index HSI-1 is derived by results of EOF analysis applied to HSI-R and HSI-K values and projects a positive linear relationship between them
- The HSI-1 is calculated over the all longitudes.

Interannual variability in the Southern Summer

- The convective area shifts eastward in the El Nino years, accompanying the horseshoe-shaped temperature structure.

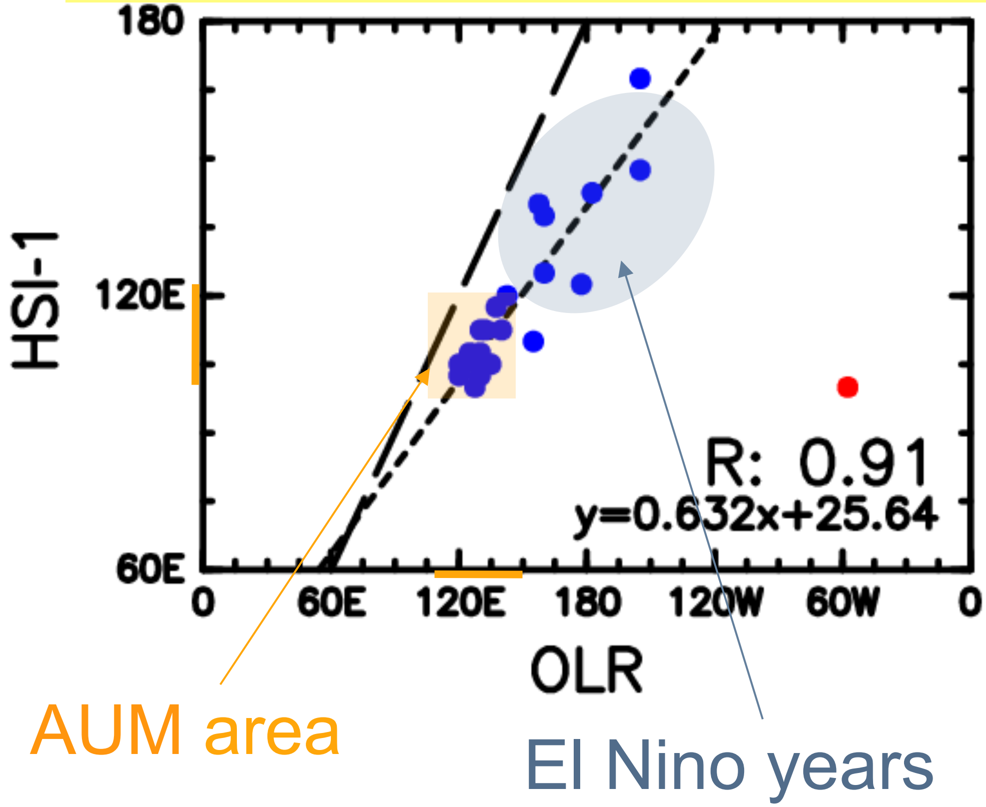
Longitudes of OLR and HSI-1



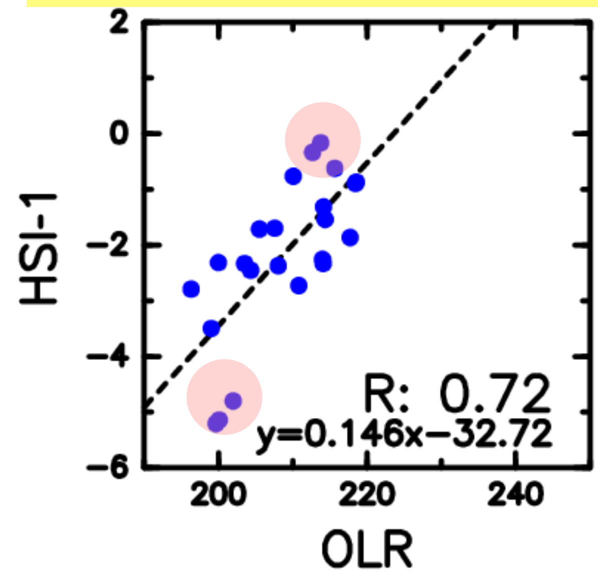
Interannual variability in the Southern Summer

- The convective area shifts eastward in the El Nino years, accompanying the horseshoe-shaped temperature structure.
- The strength of these OLR and HSI-1 is significantly related.

Longitudes of OLR and HSI-1



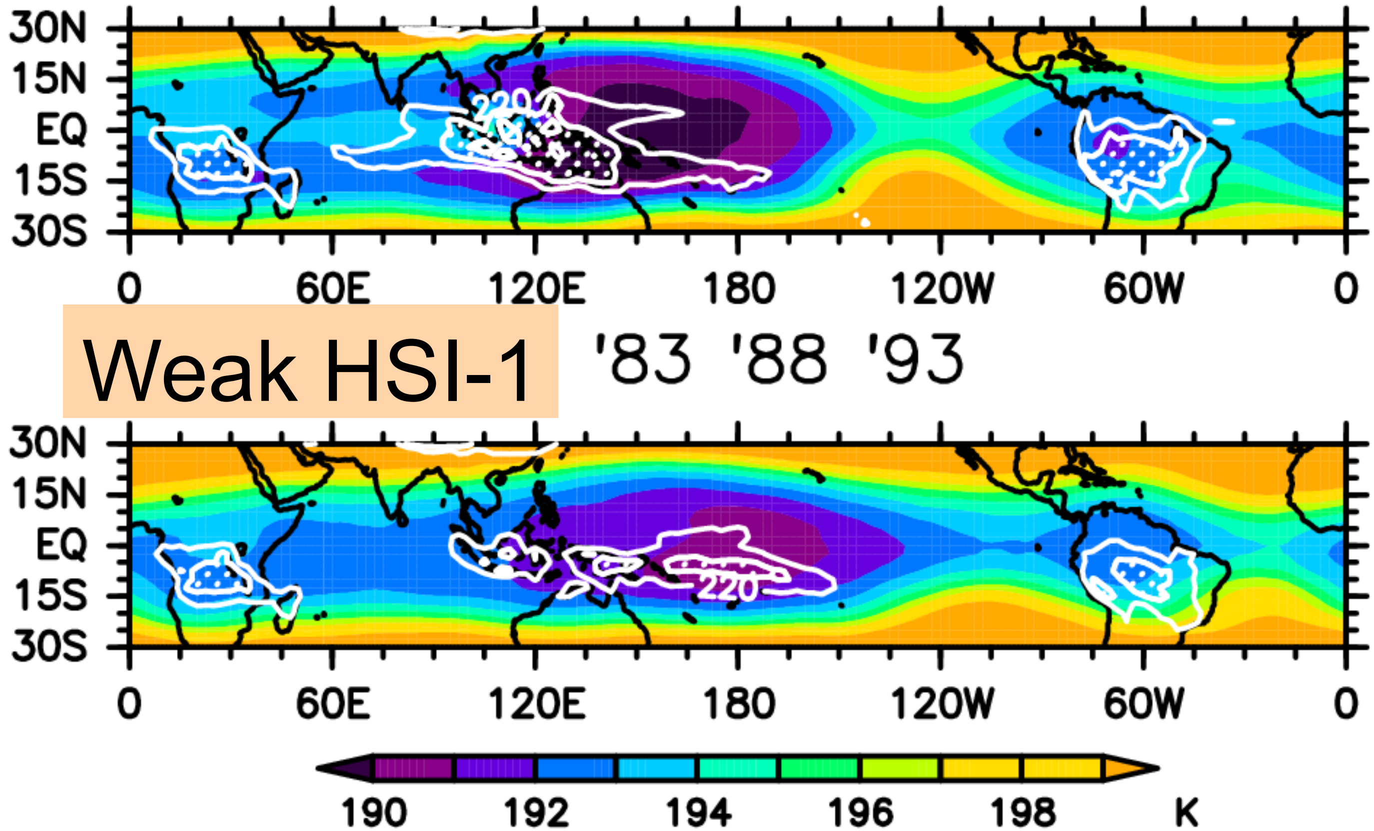
Strength of OLR/HSI



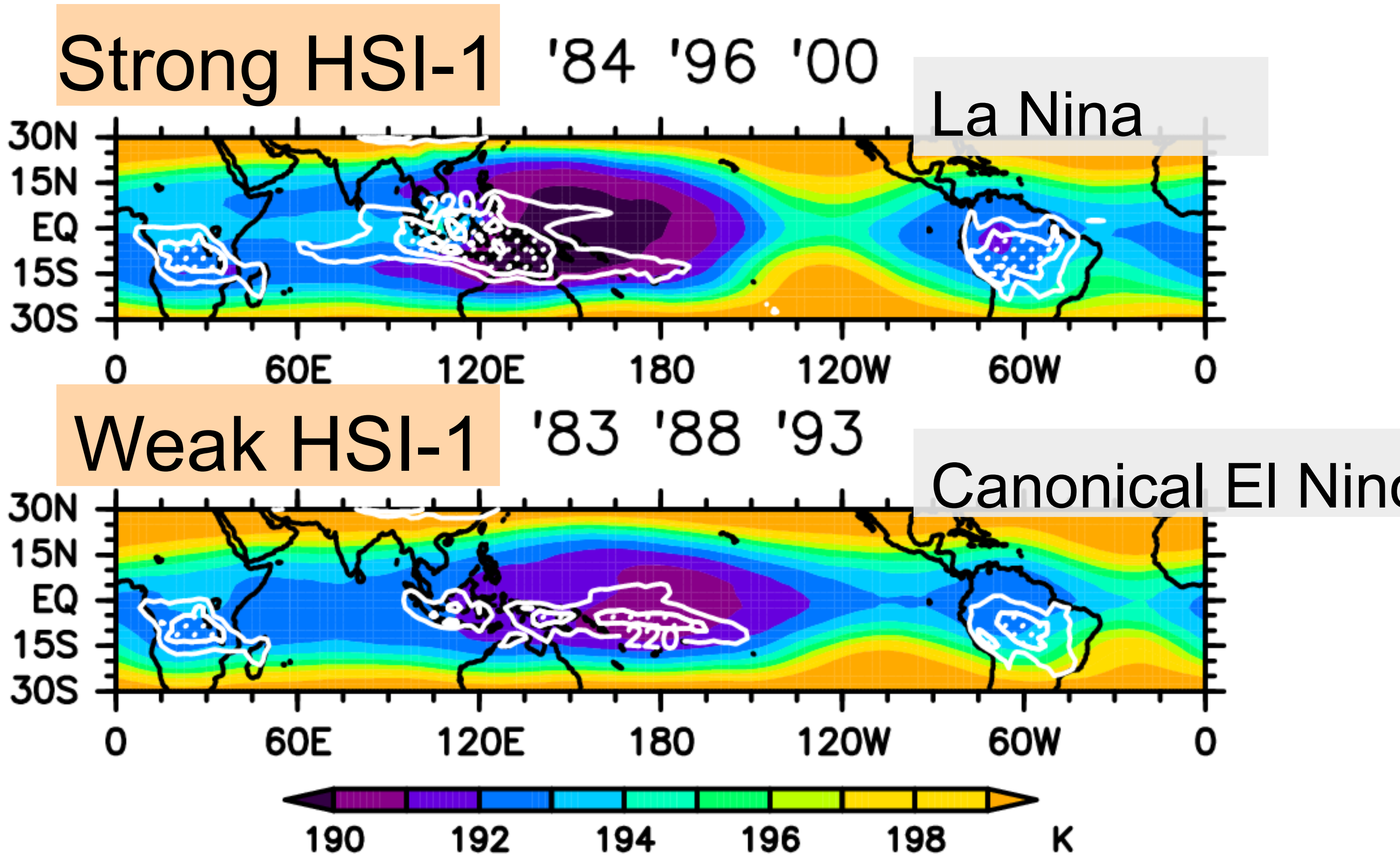
ENSO-related variability in the Southern Summer

Strong HSI-1 '84 '96 '00

Weak HSI-1 '83 '88 '93

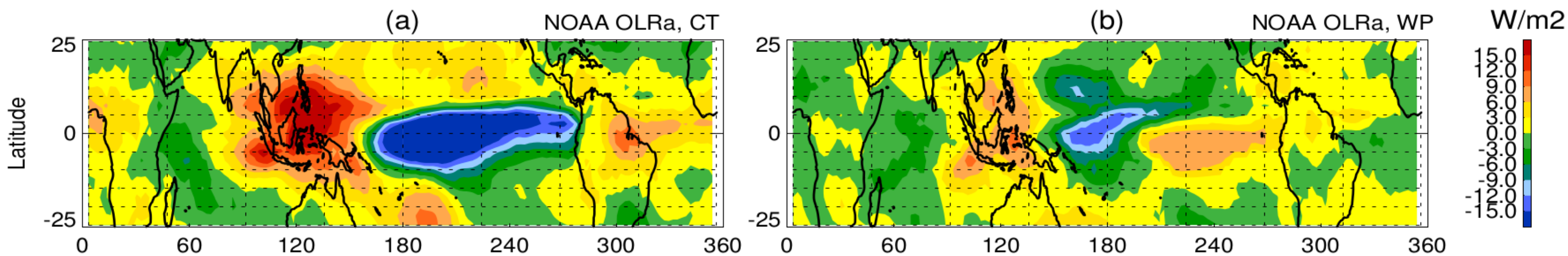


ENSO-related variability in the Southern Summer



- Strong and weak HSI-1 years are equivalent to La Nina and El years, respectively.
- The El Nino conditions have a moistening impact on the water vapor mixing ratio of the air entering the stratosphere [e.g., Gettelman et al., 2001]

How ENSO modoki impacts on the TTL temperature ?



Canonical El Niño	El Niño Modoki
JUL1982–AUG1983	SEP1990–DEC1991
DEC1986–JAN1988	APR1994–JUN1995
MAY1997–MAY1998	JUN2002–APR2003
AGU2006–JAN2007	JUN2004–DEC2004

Xie et al. [2012]

- The convective activities are considerably weak in the El Nino modoki years.
- Consequently, the horseshoe-shaped temperature structure should be weak.

Summary

- The horseshoe-shaped temperature structure around the tropical tropopause is induced by the heating generated by the convective activities.
- Its interannual variability is significantly related to the ENSO cycle.
- The different flavour of ENSO could also affect its variation.
    - The ENSO modoki conditions could have a moistening impact on the stratospheric water vapor
    - However the strength of the upwelling etc.. may change as well.

Questions

1. Do atmospheric teleconnections significantly differ among various ENSO flavors/extremes? If so, what dynamical processes are responsible?

2. What ENSO flavors/extremes have the greatest impacts on various stakeholders?

Convective variability in the canonical ENSO cycle has strong impact on the tropopause temperature variability.

3. How are these ENSO teleconnections and impacts influenced by changing radiative forcings, natural or anthropogenic?

Seasonal Cycle

- Significant relationship between OLR and HSI-1 over the three monsoon regions.