

# *Does Quasi-biennial Oscillation modulate monsoon Hadley Cell?*



**K. Kishore Kumar and Anjana U**

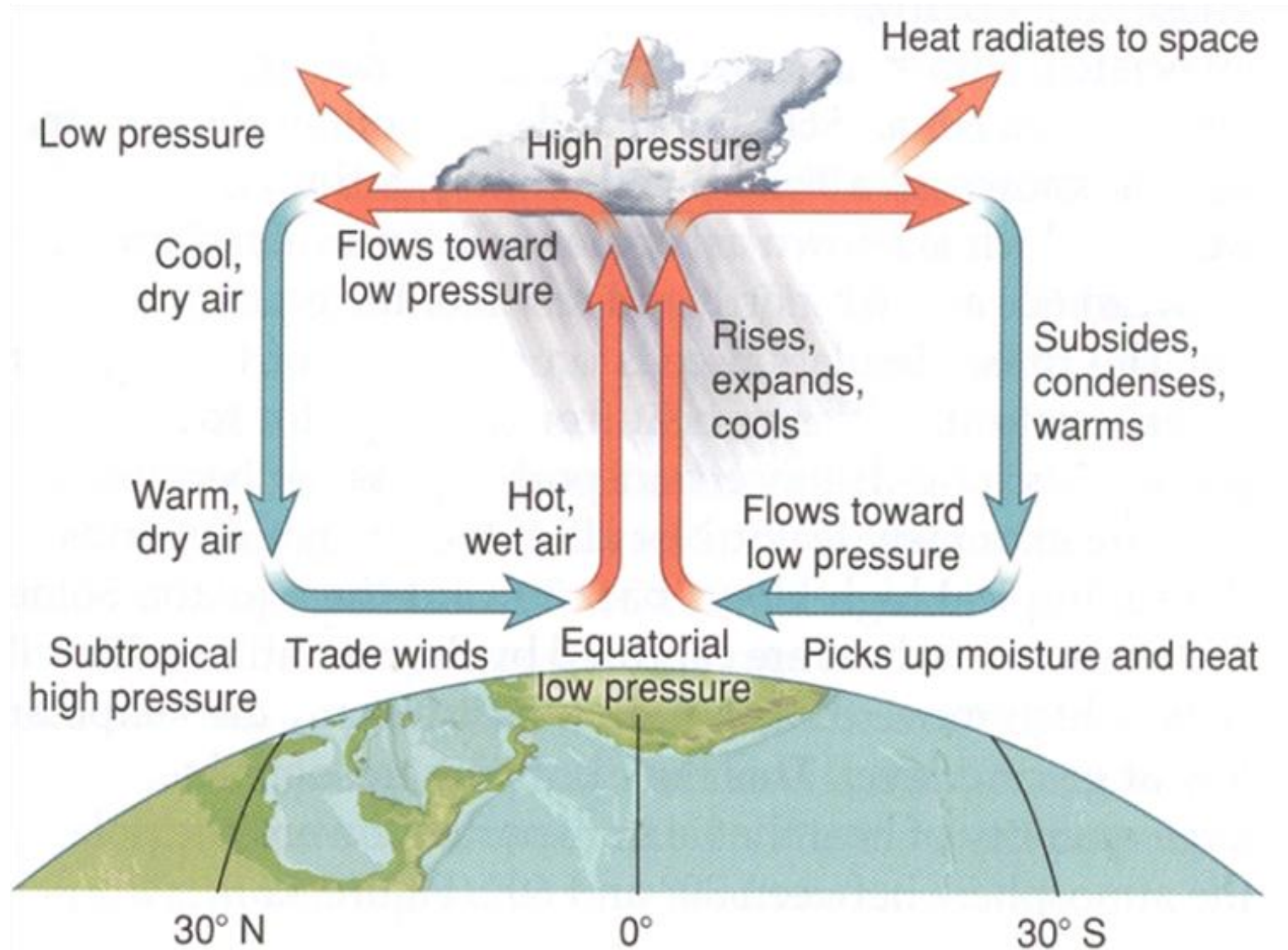
**Space Physics Laboratory**

**Vikram Sarabhai Space Centre, Thiruvananthapuram, India**

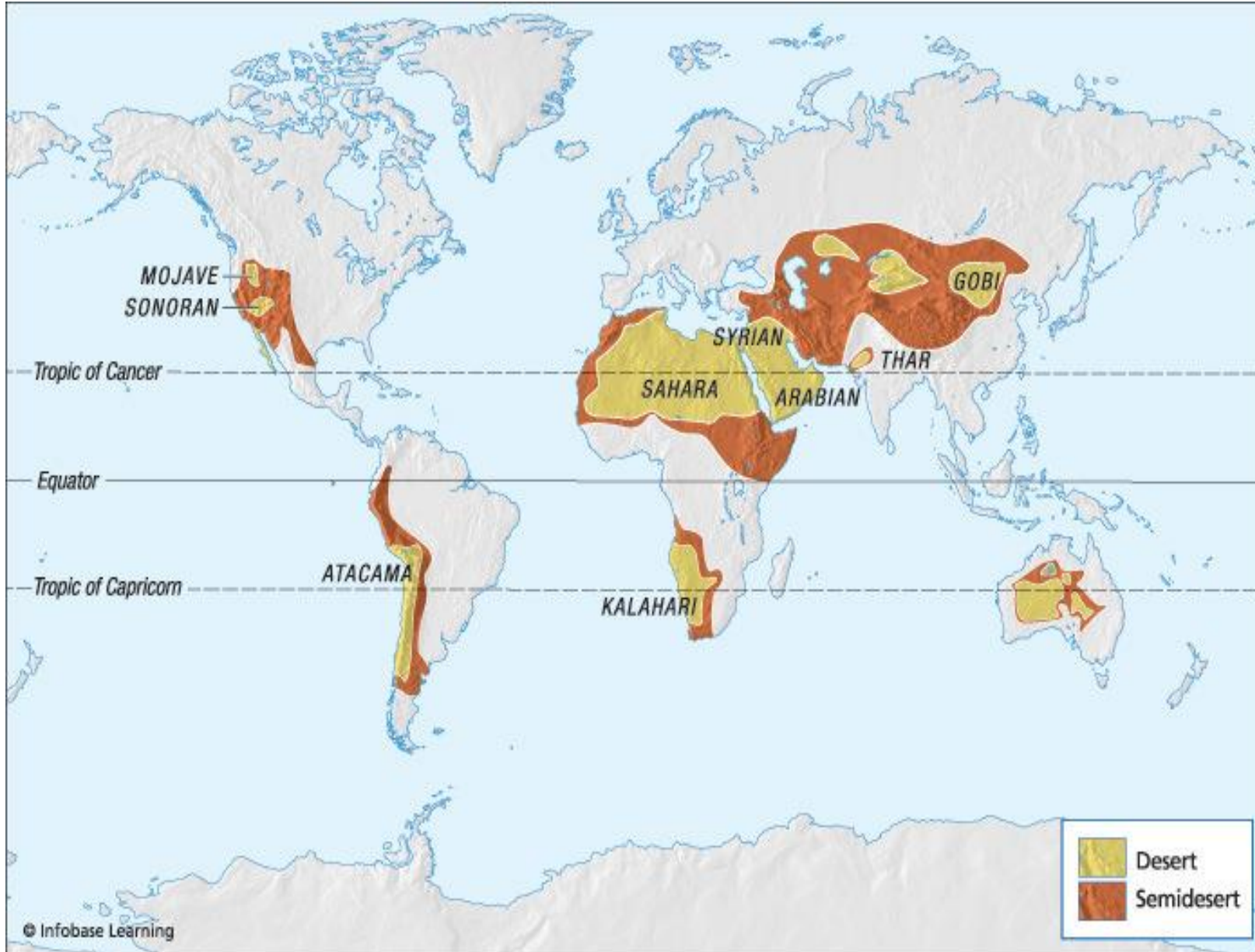
**Sneha Susan Mathew**

**Henry Baker College, Melukavu, Kerala, India**

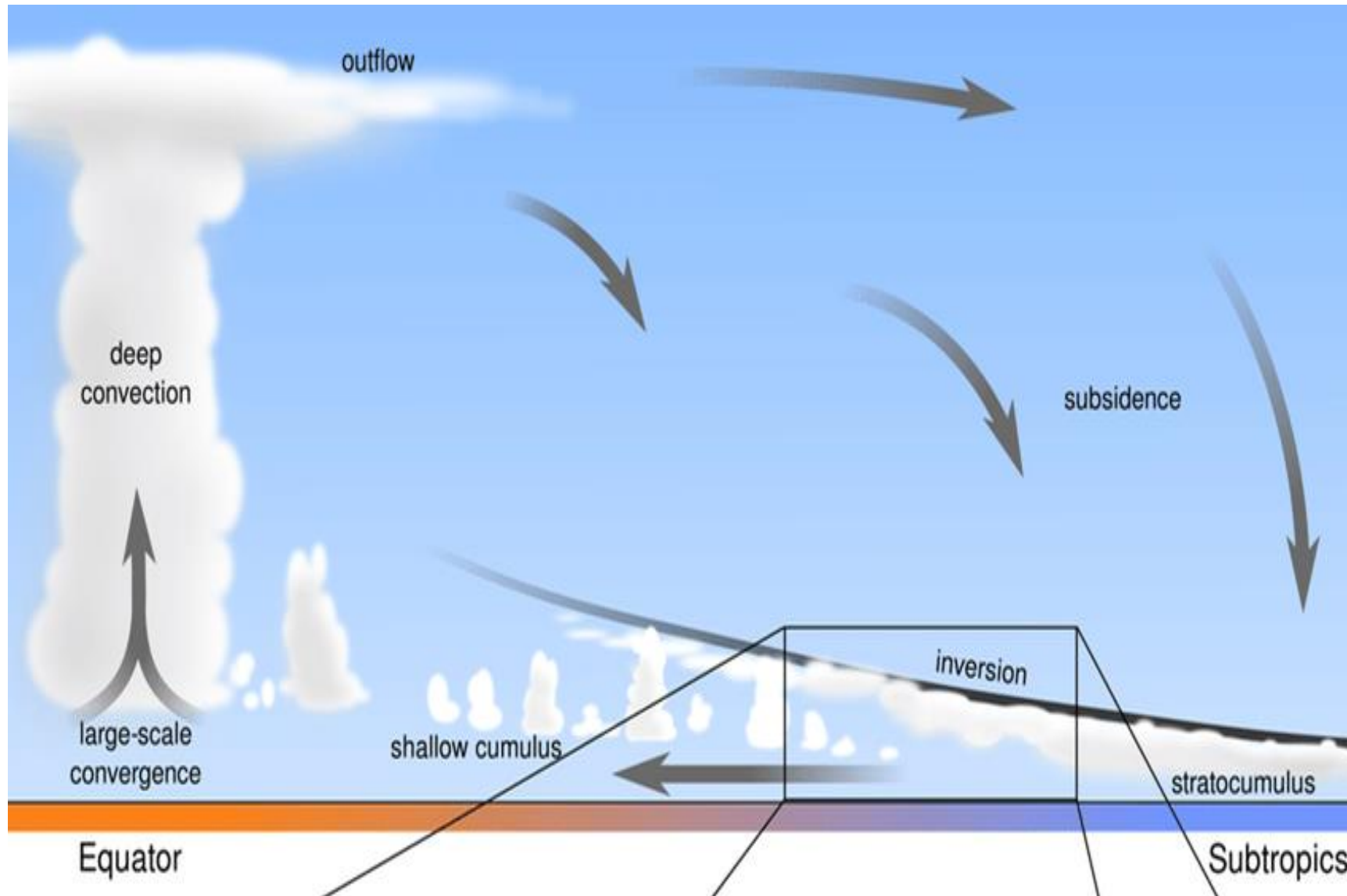
# Hadley Cell : The Atmospheric Juggernaut



# Hadley Cell : The Atmospheric Juggernaut



# Clouds and Circulations



## Objectives

- ❑ To Characterize the regional monsoon HC using zonally resolved meridional mass stream function by employing Helmholtz decomposition of horizontal winds
- ❑ To discuss the impact of Quasi-biennial Oscillation on the monsoon Hadley Circulation over the Indian region

## Data and Methodology

- ❑ ERA5 reanalysis Meridional Wind dataset during 1979-2021
- ❑ Rain fall datasets from Global Precipitation Climatology Project (GPCP)
- ❑ Radiosonde observations over Singapore
- ❑ Zonally resolved Meridional Mass Stream function (ZR-MSF) is estimated using Helmholtz transformation of horizontal winds.

# Meridional Mass Stream Function

$$\psi = \frac{2\pi a \cos \phi}{g} \int_0^p [\bar{v}] dp$$

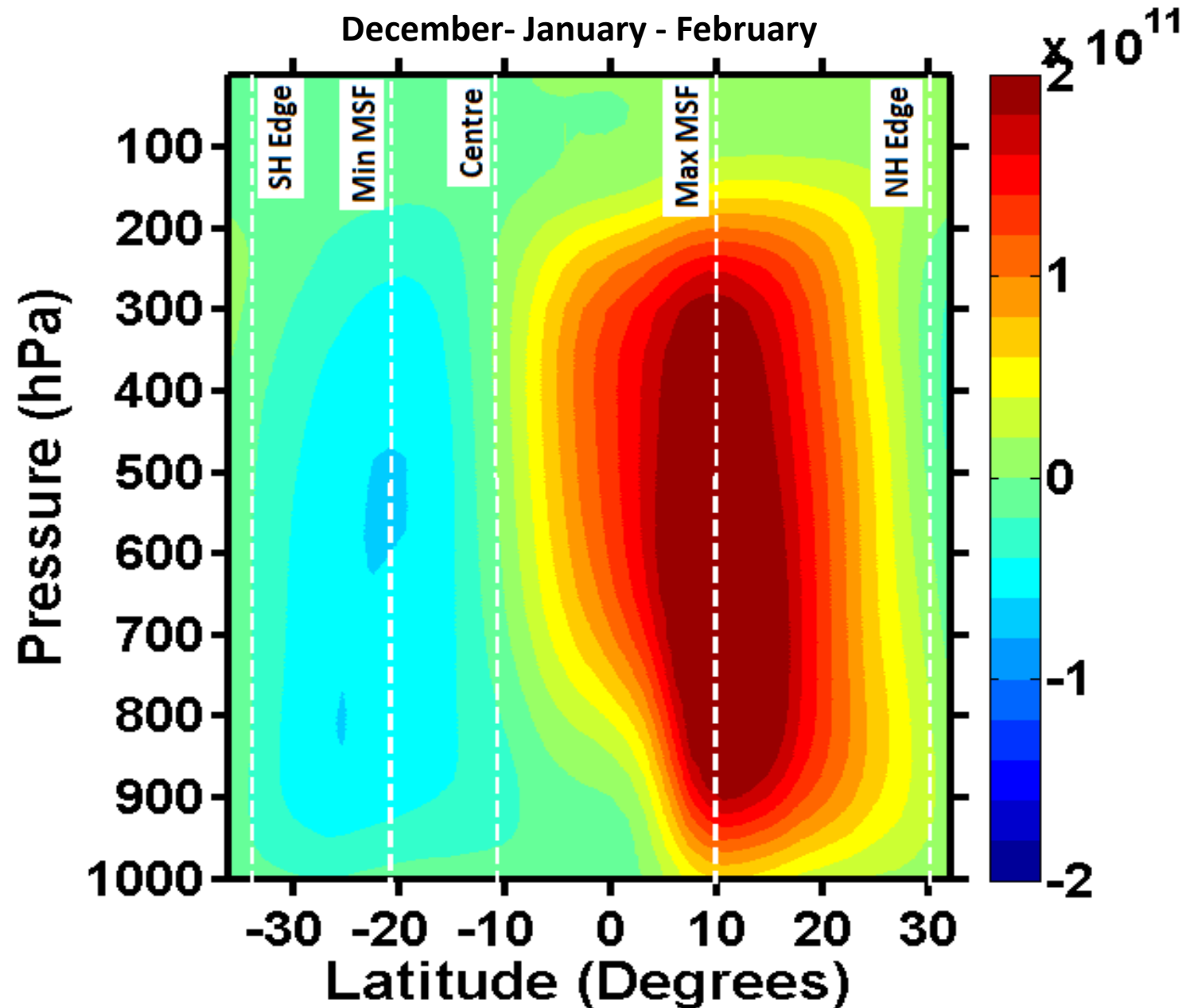
a radius of Earth

g acceleration due to gravity

v meridional winds

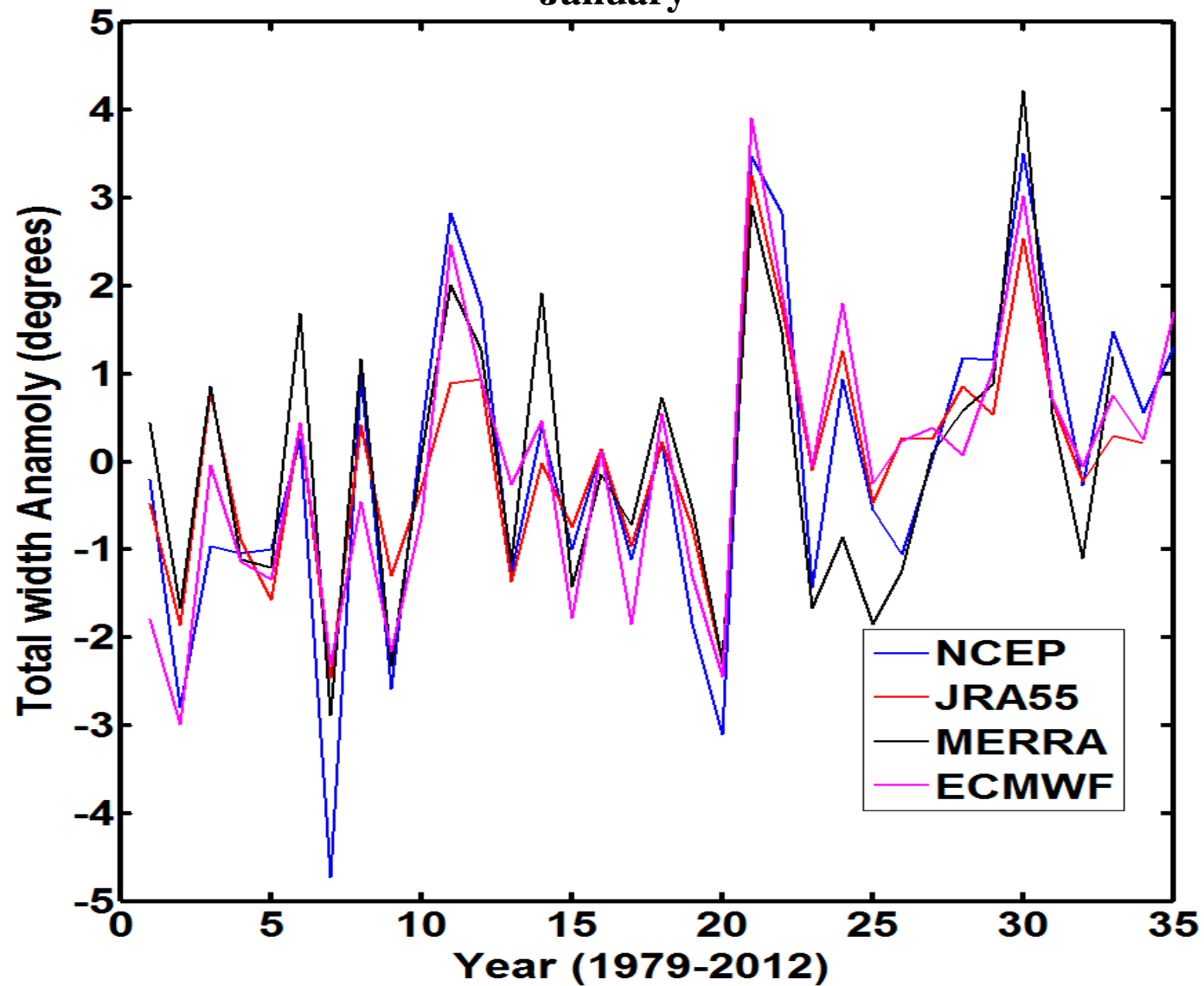
p pressure

$\phi$  latitude

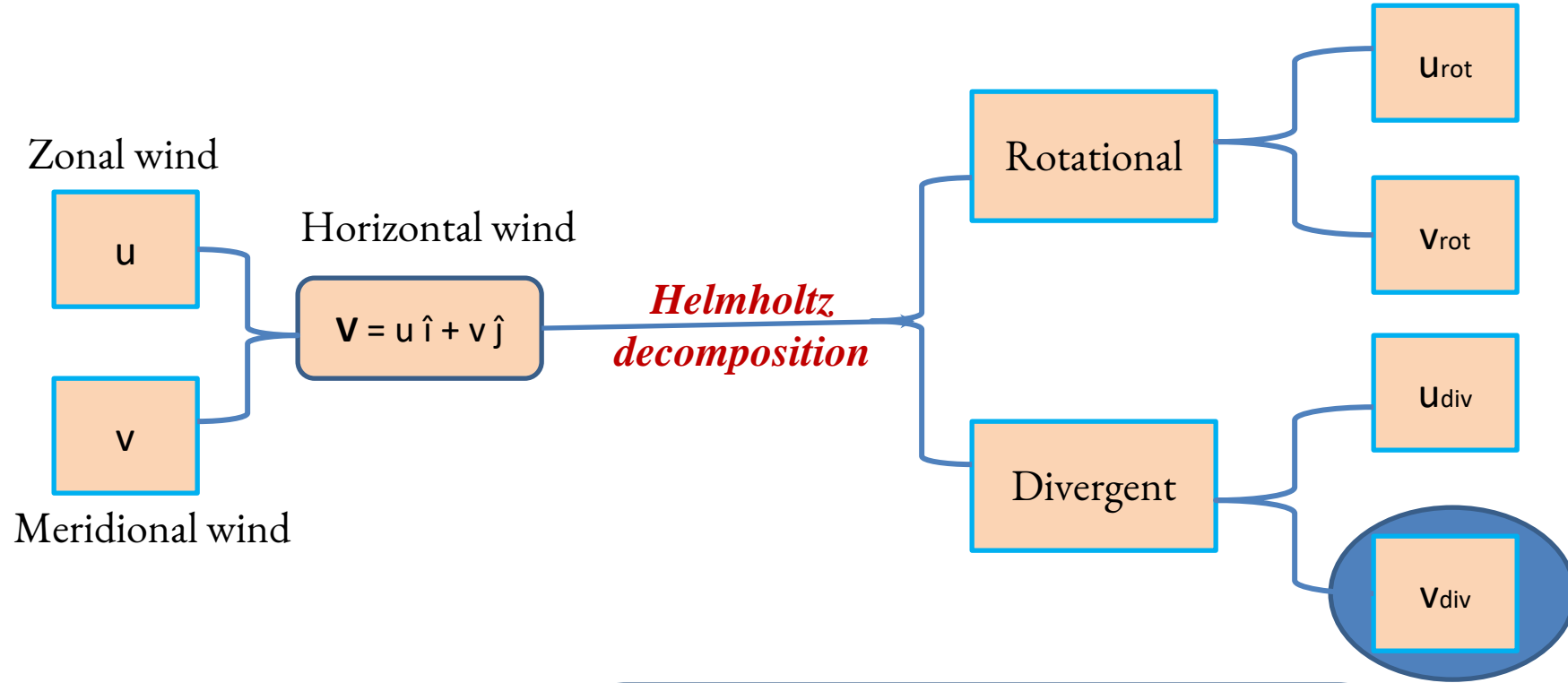


# Anomaly in Hadley cell total width

January



# Zonally Resolved HC Boundaries



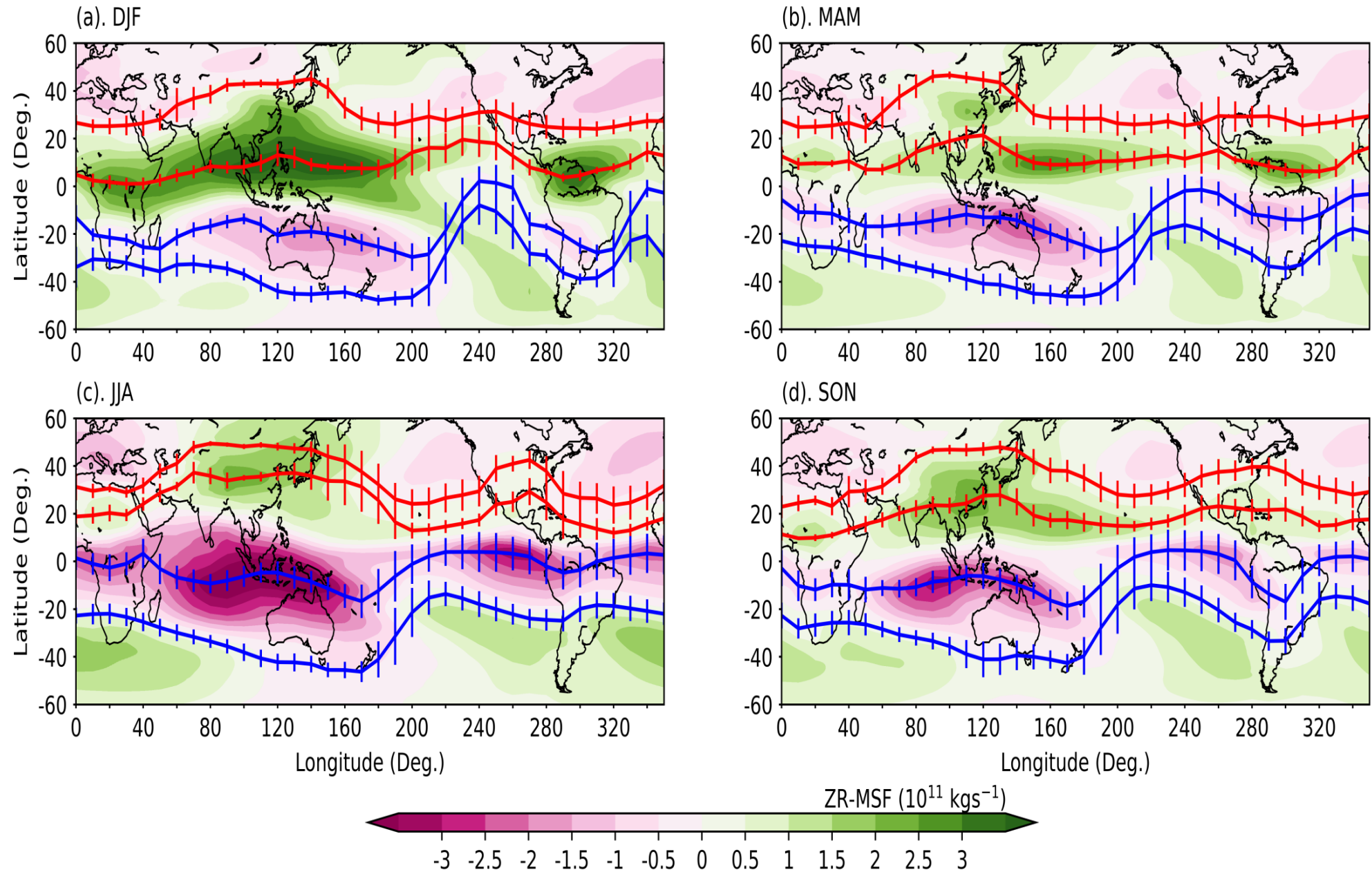
A blue oval containing the label  $V_{div}$  has an arrow pointing to a large pink rounded rectangle containing the following equation:

$$\psi(\theta, \Phi, p) = \frac{2\pi a \cos \theta}{g} \int_0^p v(\theta, \Phi, p) dp$$

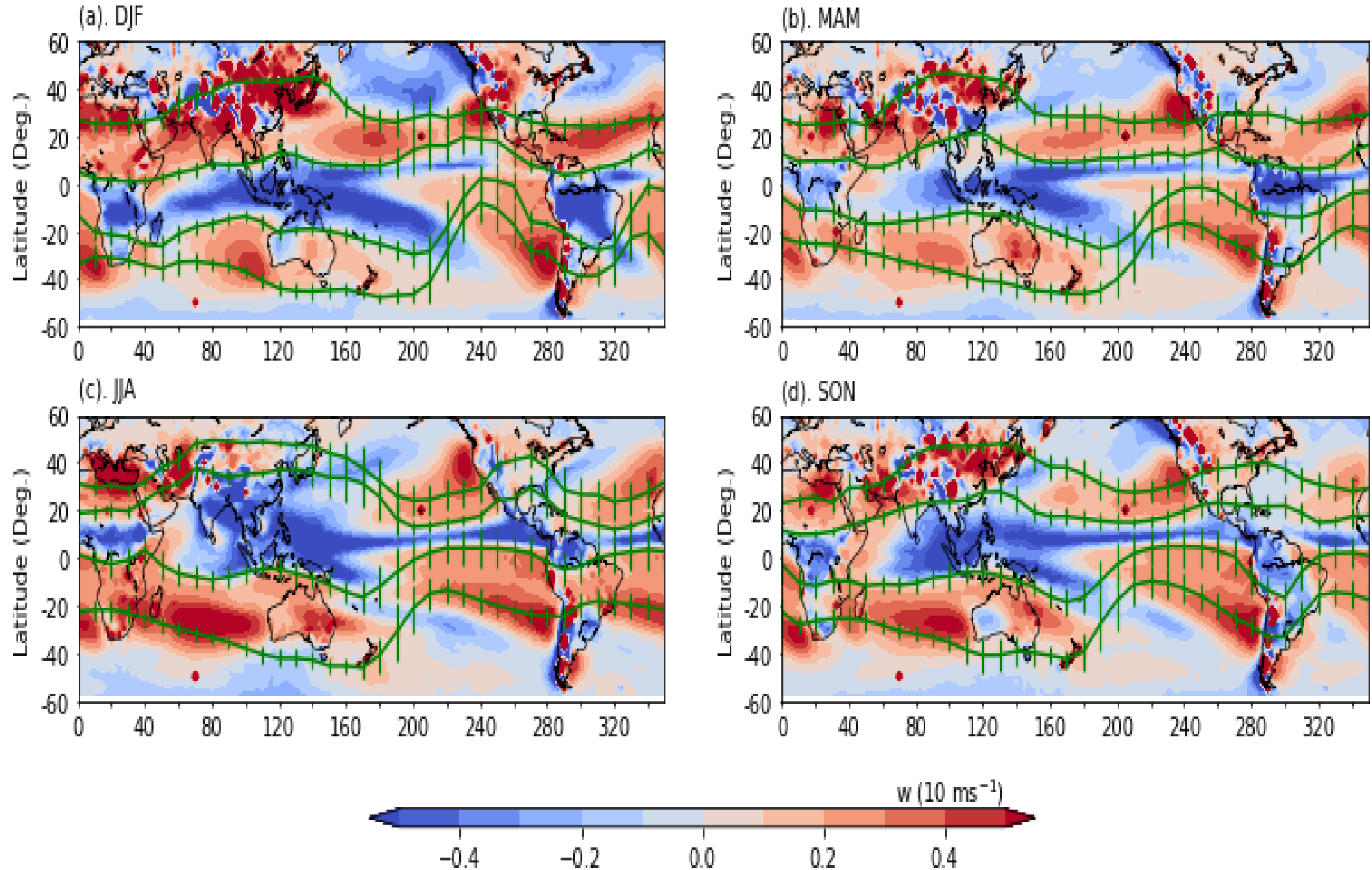




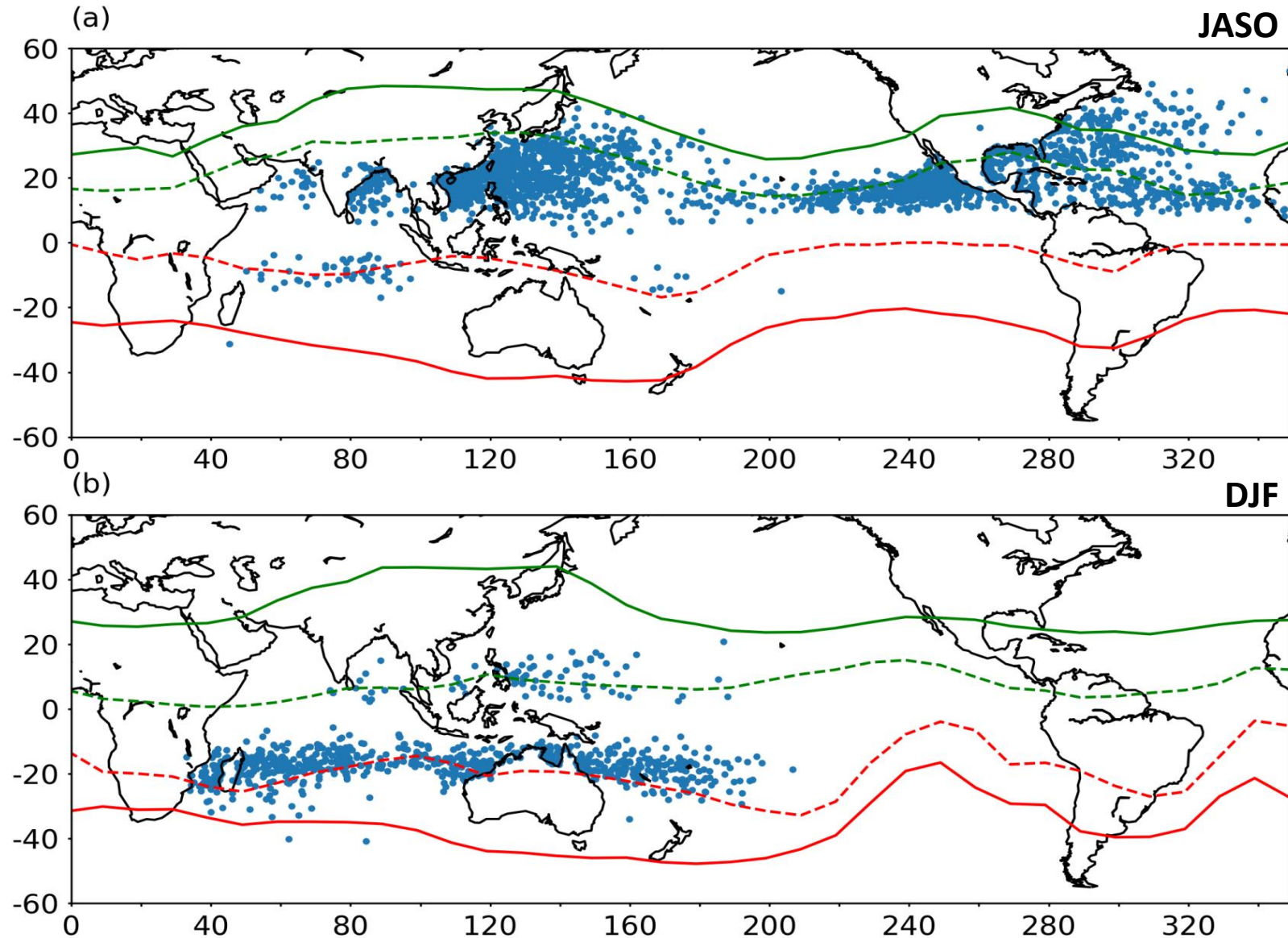
# Climatology of ZR-MSF and HC Boundaries



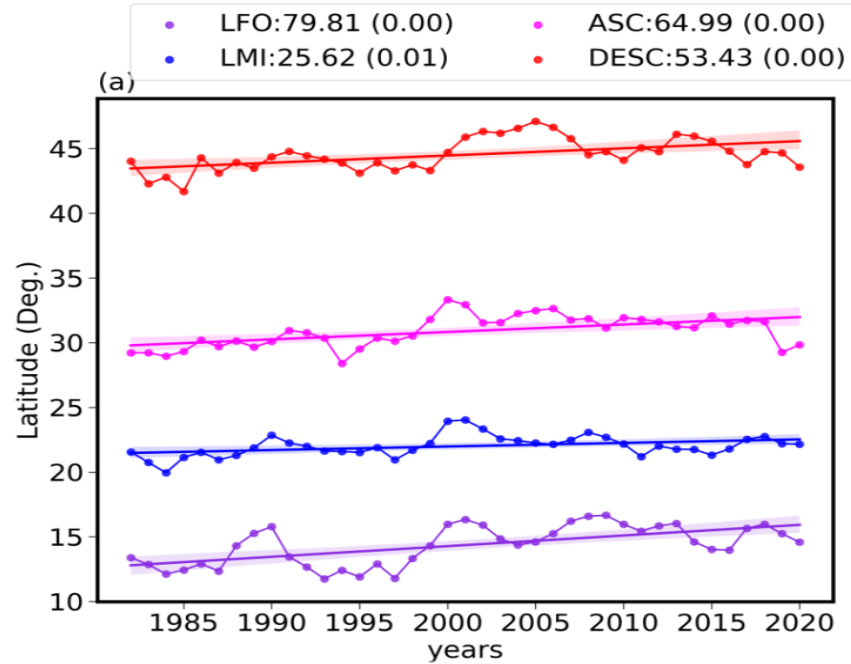
# Climatology of Vertical Velocity and HC Boundaries



# Distribution of LMI locations with respect to HC boundaries during peak TC season of NH and SH

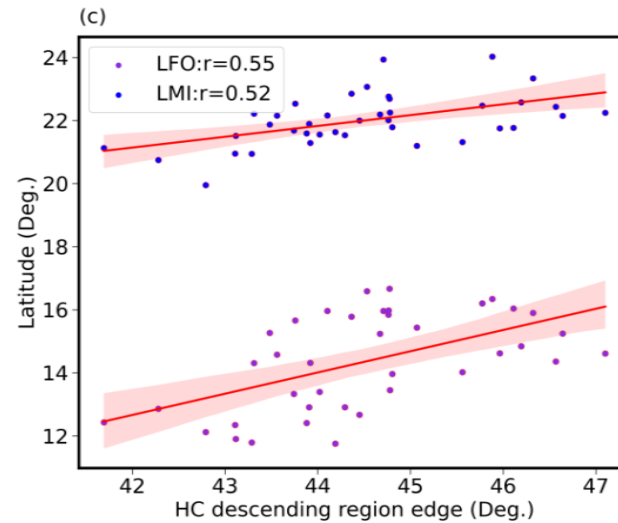
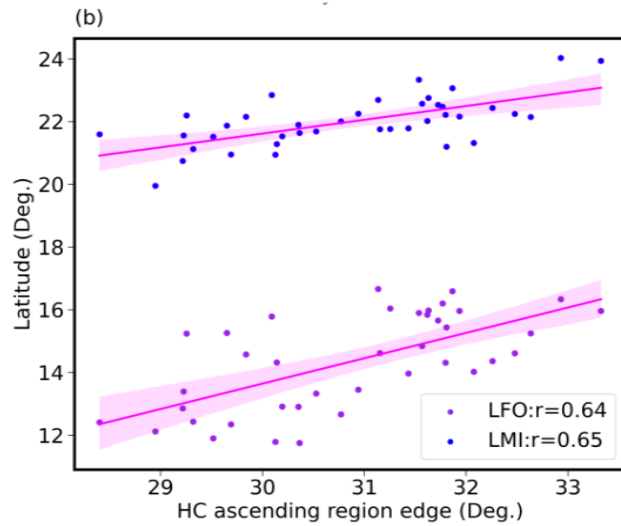


# Co-variation of HC Boundaries with TC latitudes for WNP



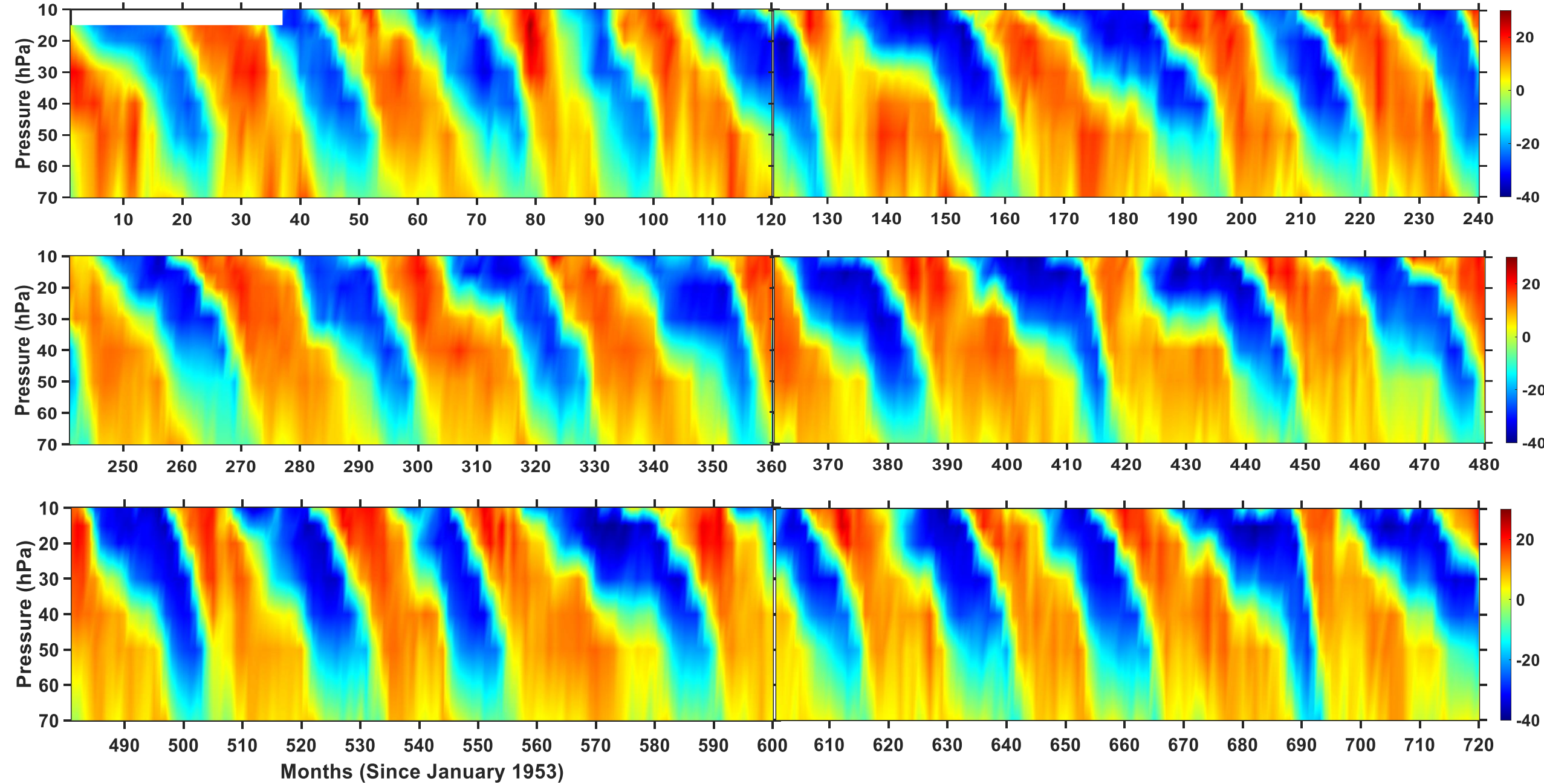
**LFO**-Latitude of first occurrence

**LMI**-Latitude of Maximum Intensity

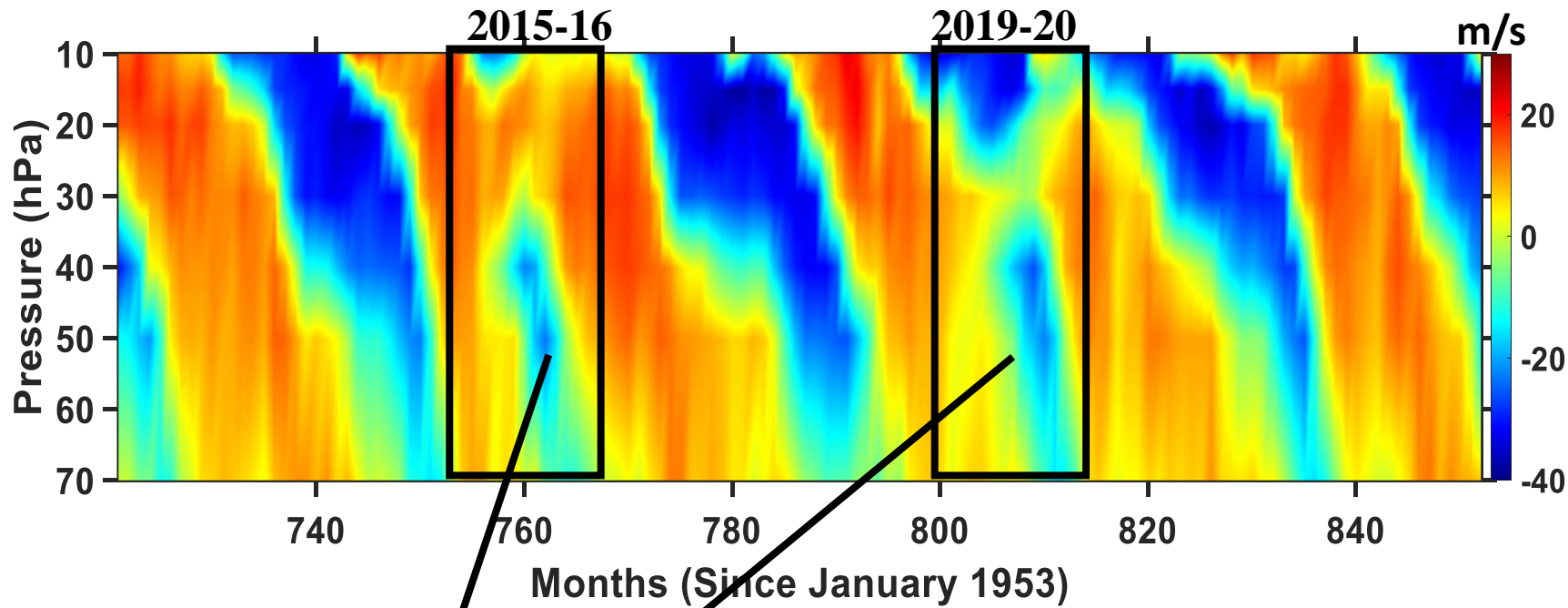


# Stratospheric Zonal Winds over Singapore (1953-2013)

m/s



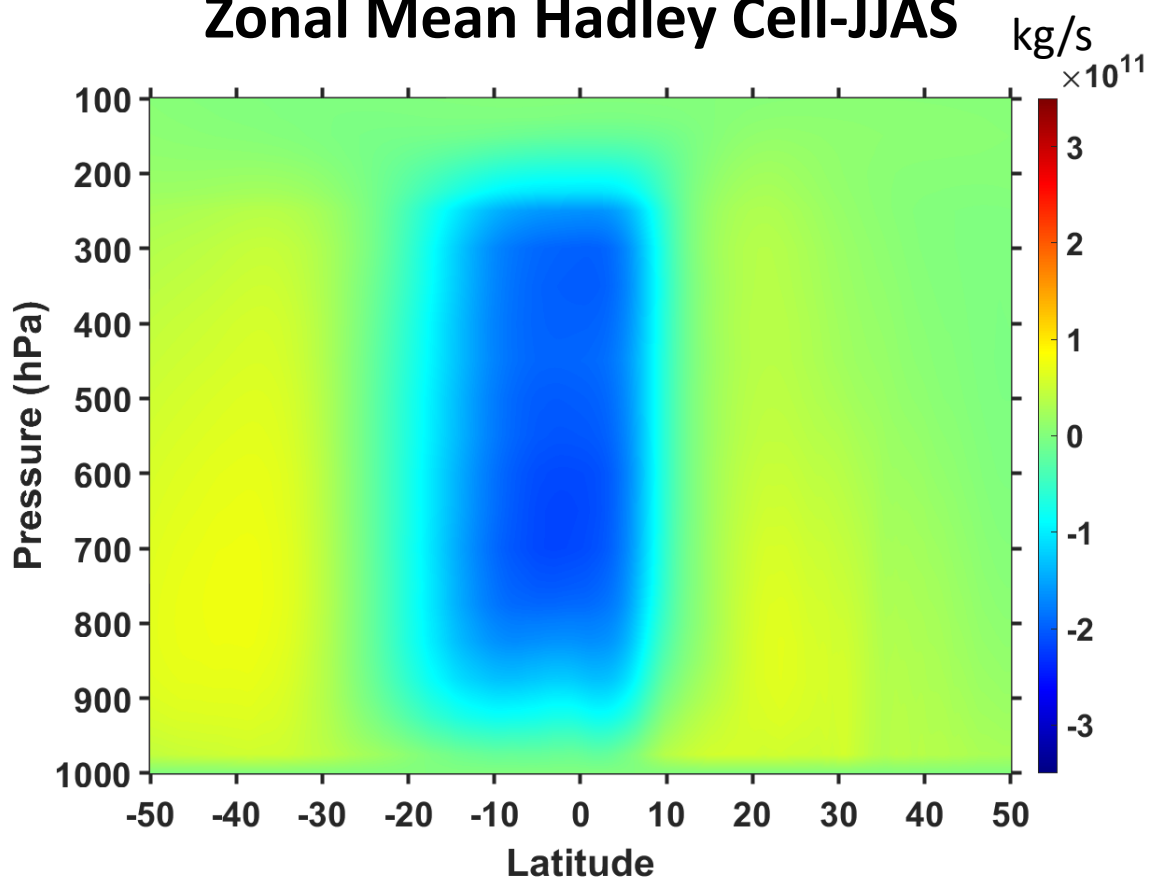
# Stratospheric Zonal Winds over Singapore (2014-2023)



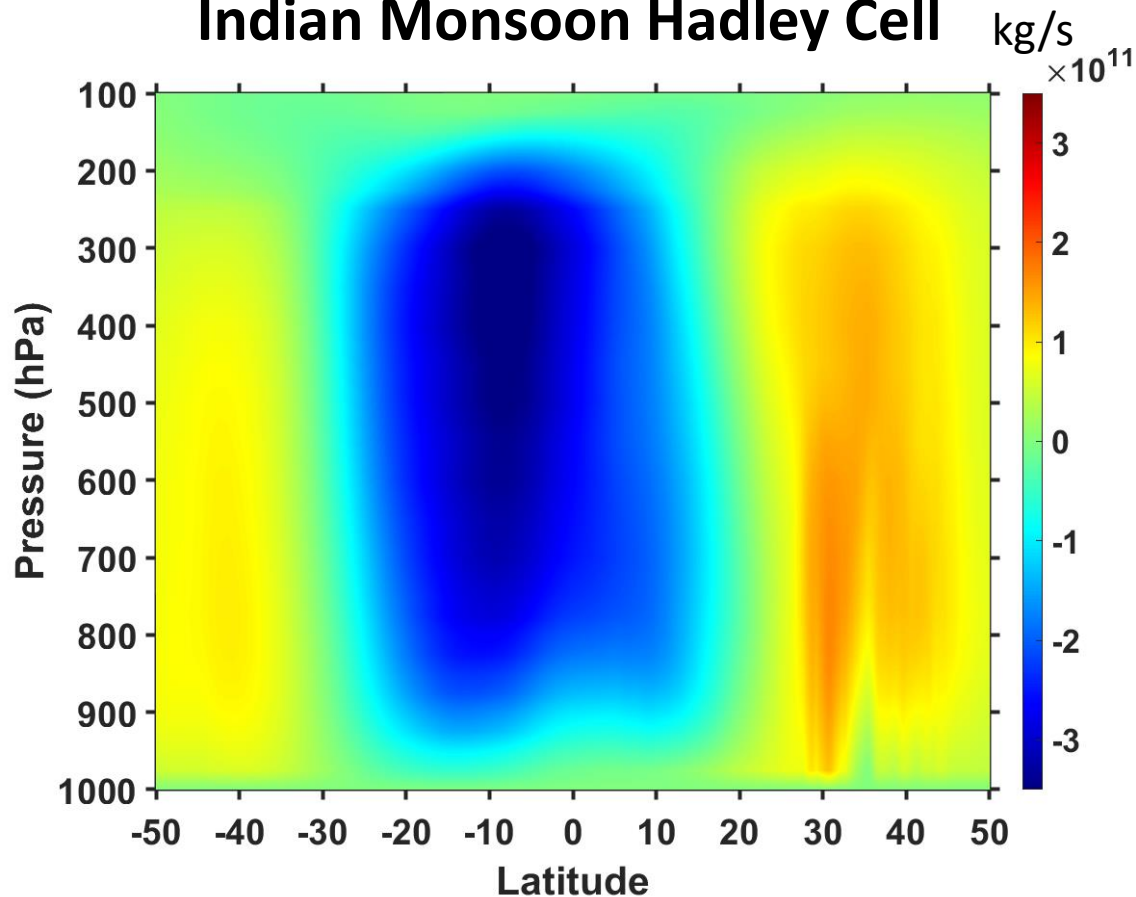
**QBO Disruption**



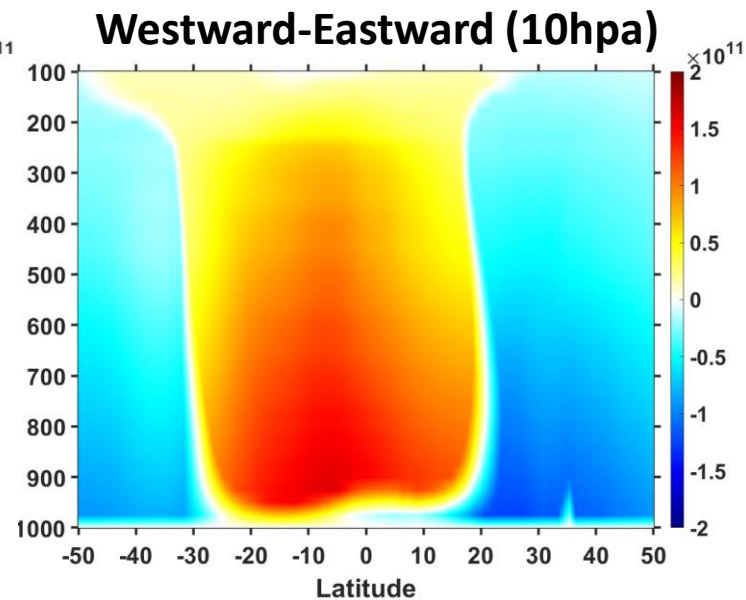
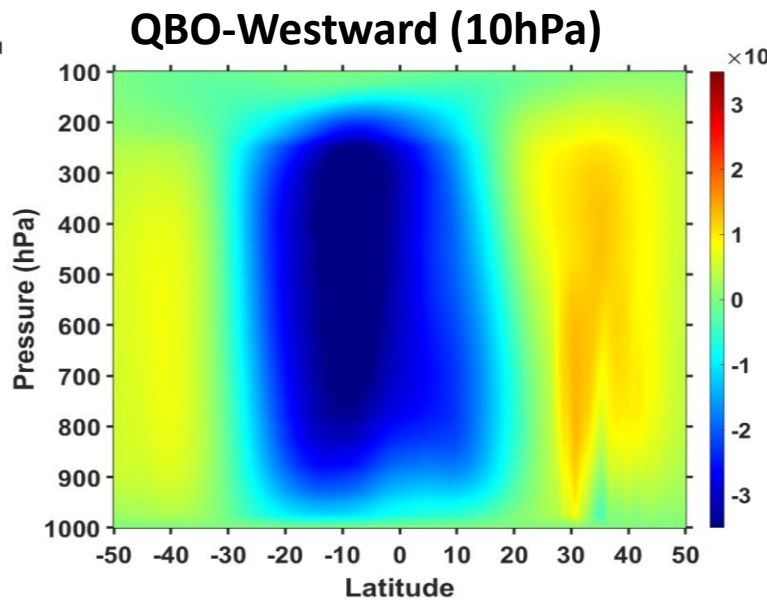
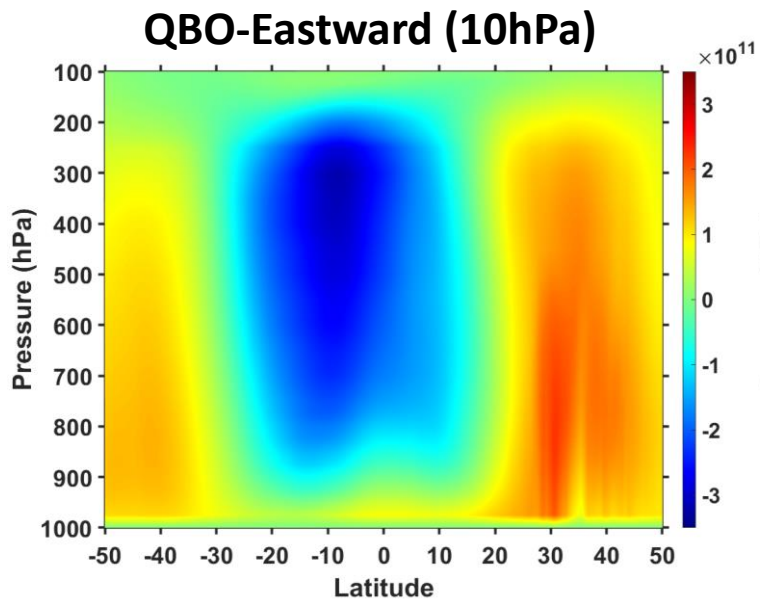
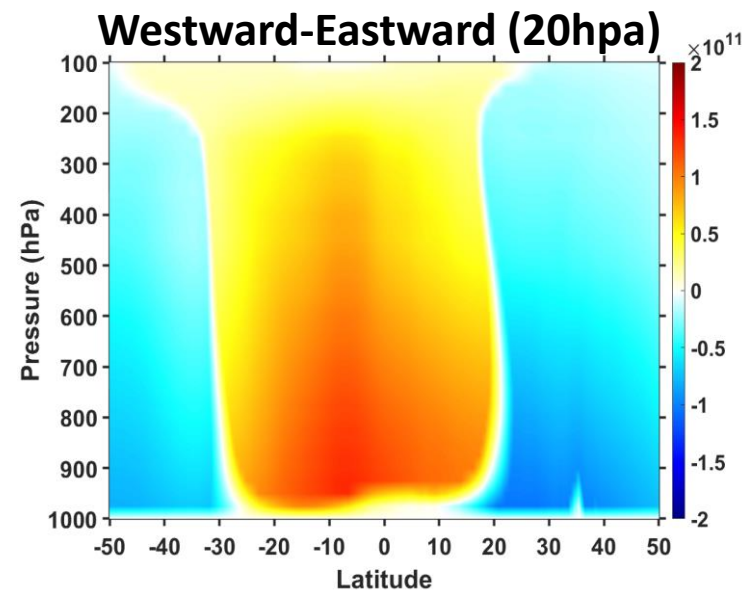
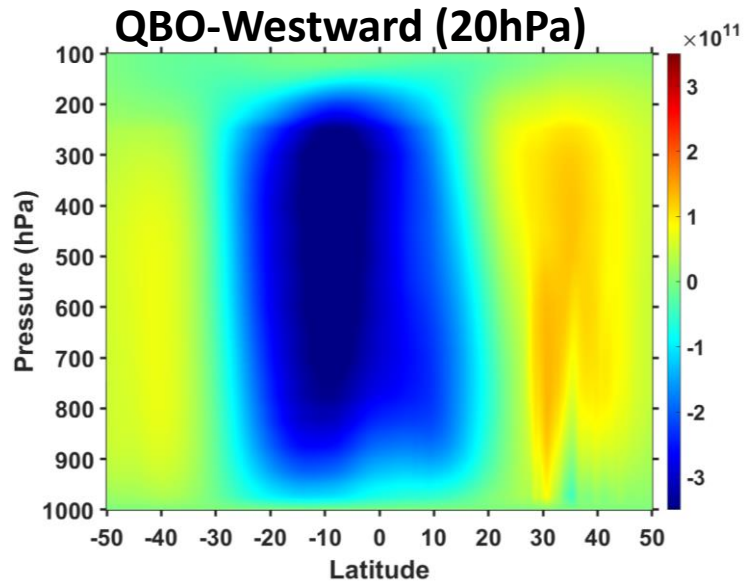
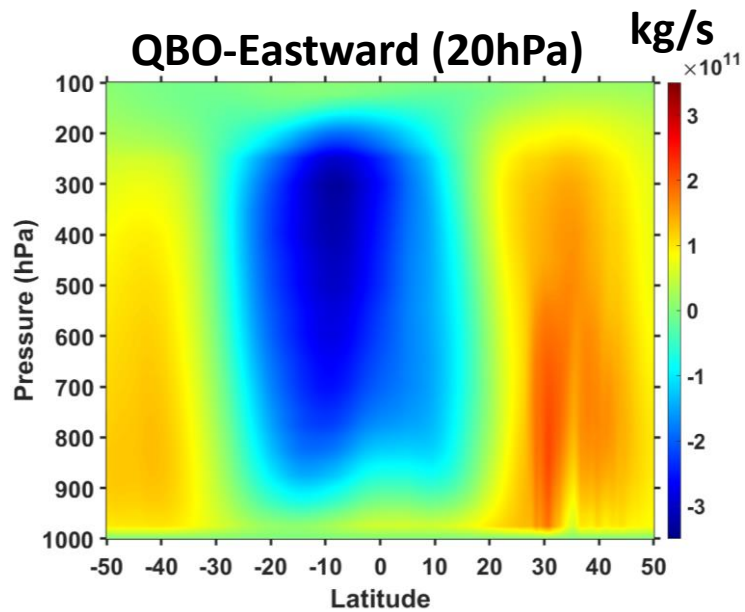
### Zonal Mean Hadley Cell-JJAS



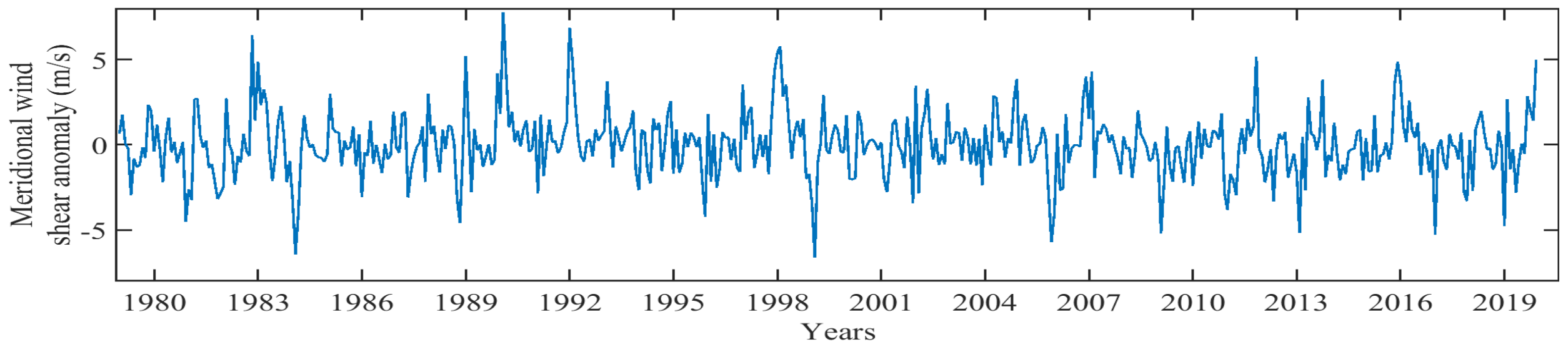
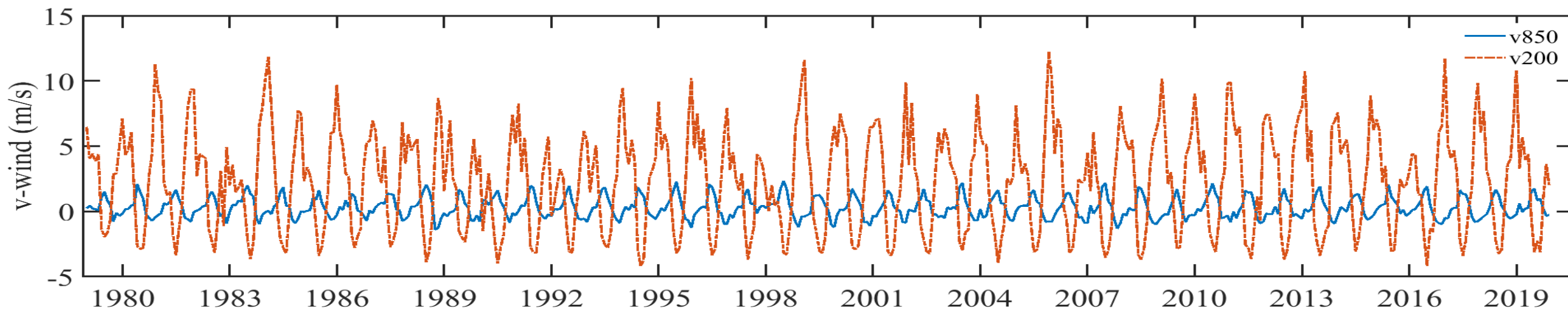
### Indian Monsoon Hadley Cell



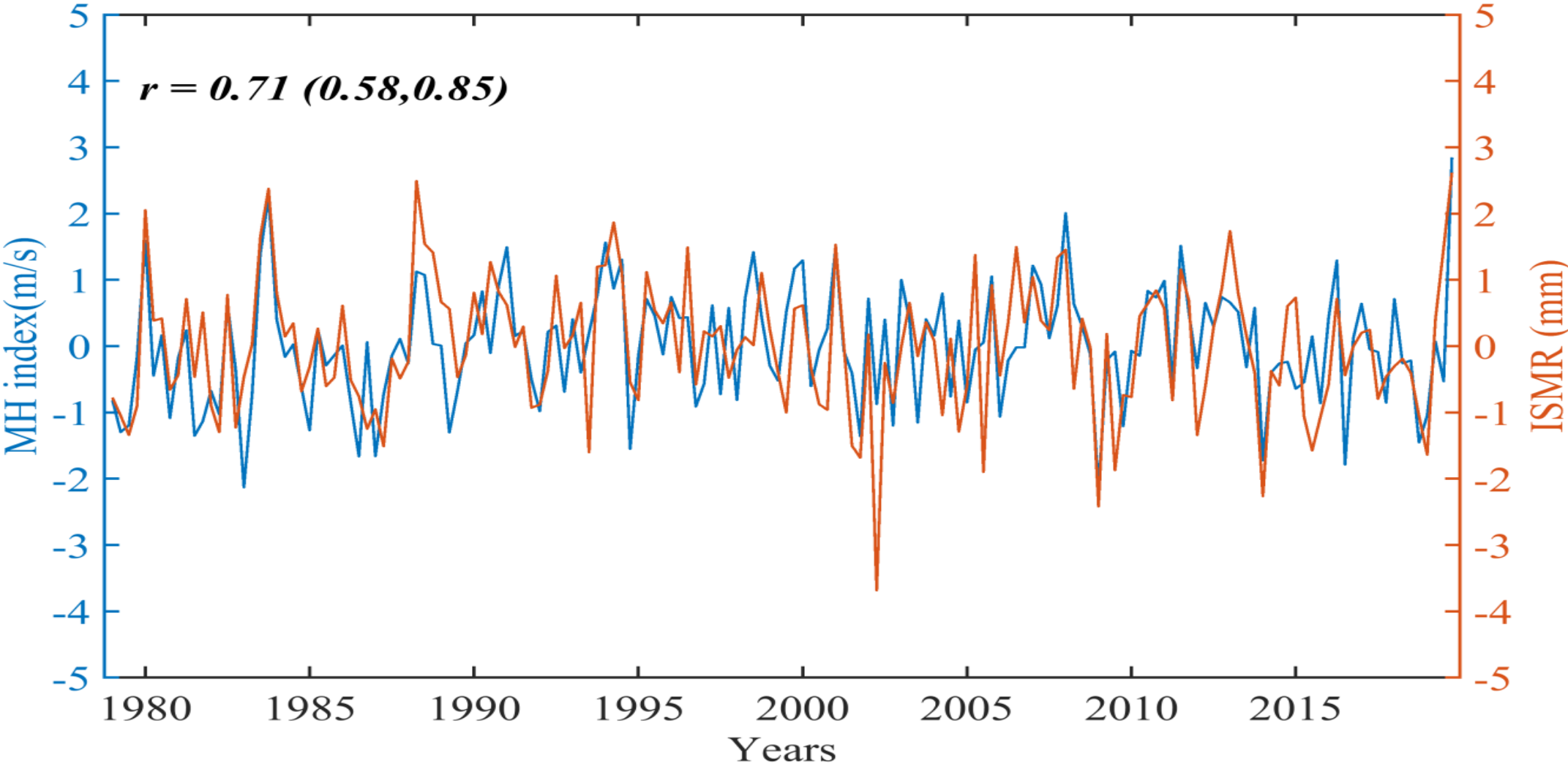




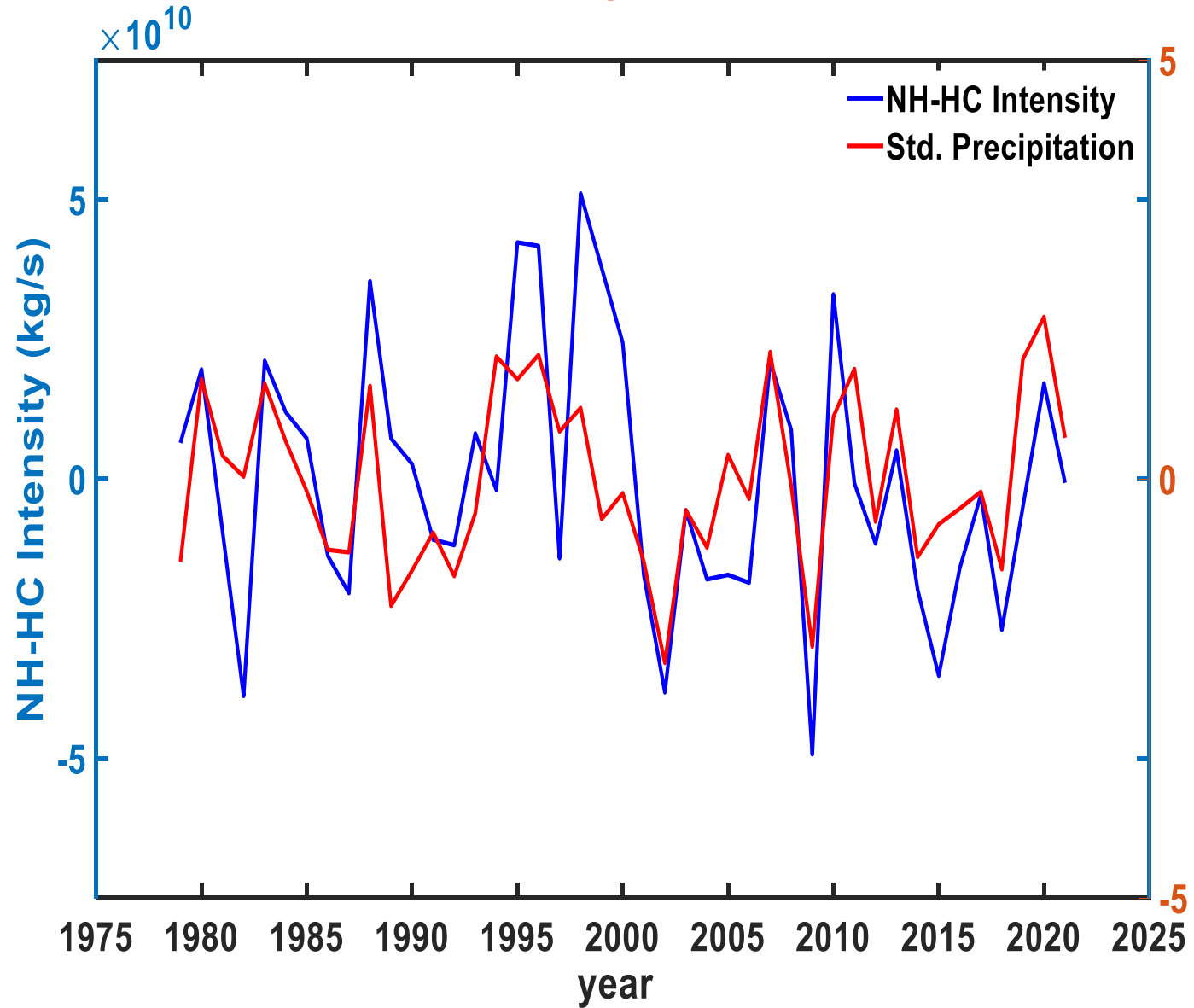
# Monsoon HC Index



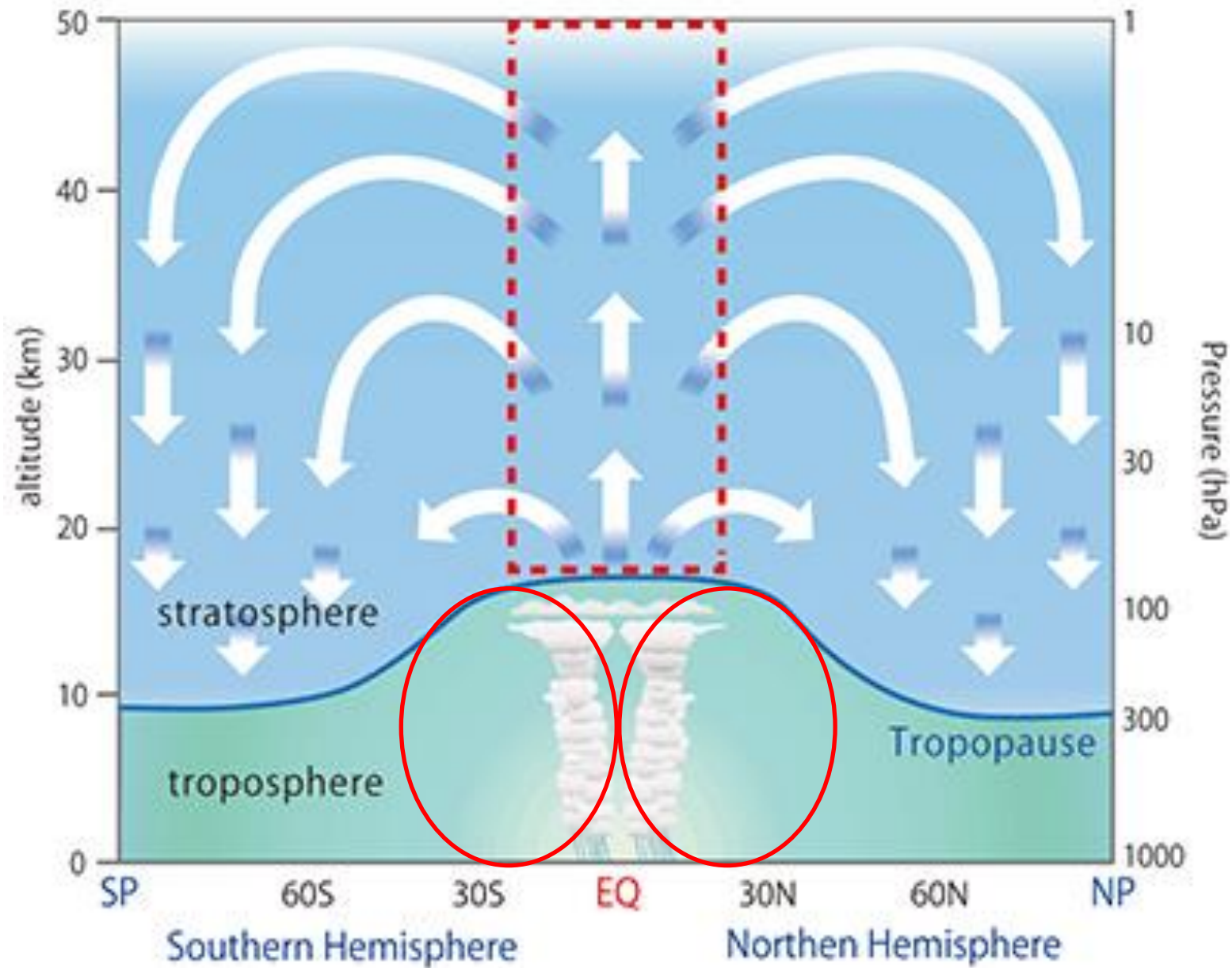
# Association between MH index and ISMR (1979-2019)



# NH-HC Intensity and ISMR Rainfall

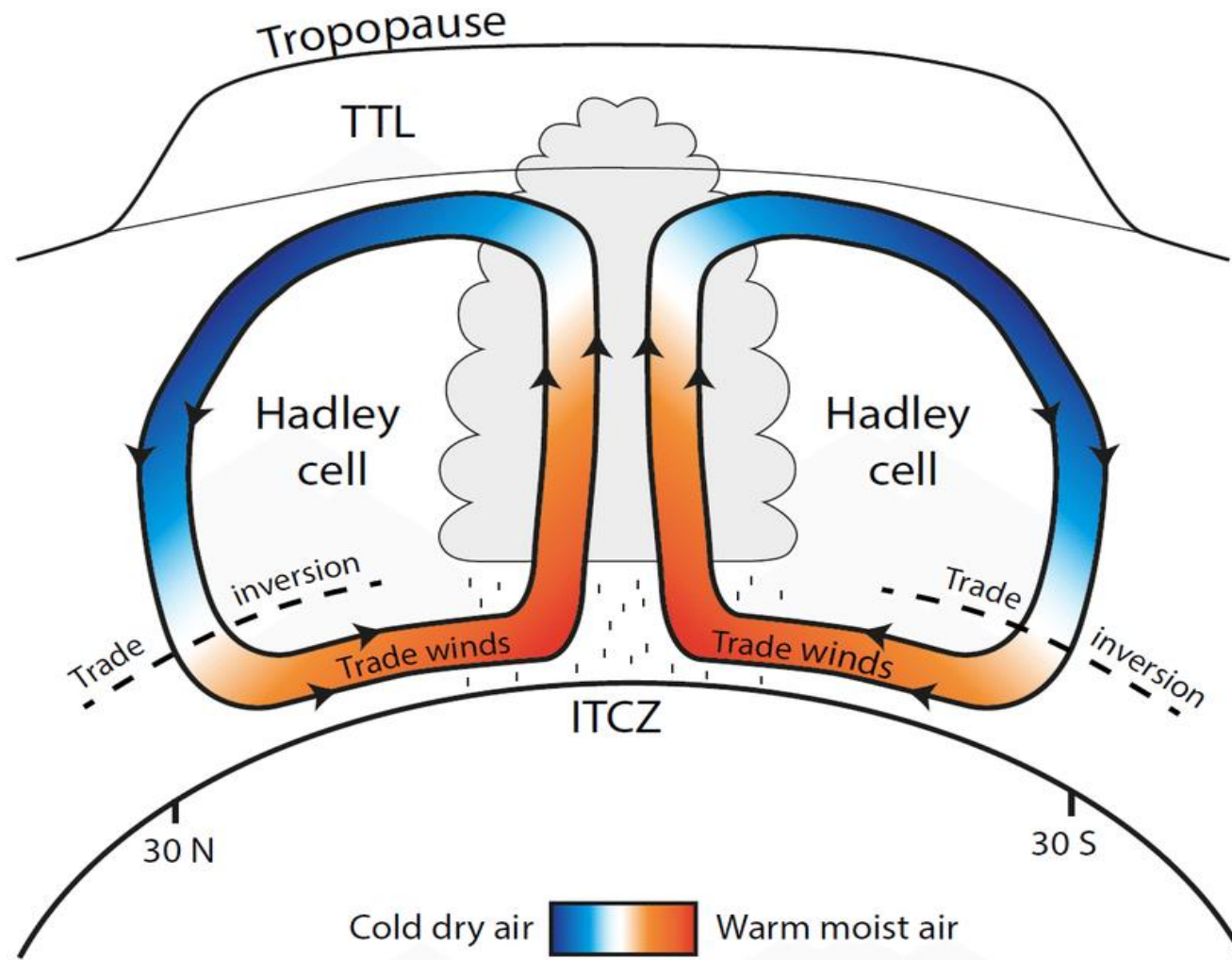


# Pathways: QBO vs Monsoon HC



# Summary

- ❑ The zonally resolved mass stream function is estimated using *Helmholtz decomposition* technique for deriving divergent and non-divergent meridional winds
- ❑ The Hadley circulation is characterised in terms its ascending and descending region boundaries as a function of longitude. The regional circulations are identified, which are consistent with the present understanding thus validating the method
- ❑ The stratospheric quasi-biennial oscillation is characterised using zonal winds over Singapore. A composite mass stream function is constructed for eastward and westward phases of QBO. The results show that HC is relatively intense during the westward phase of the QBO.
- ❑ It is noted that the intensity of the summer hemispheric HC during the Indian summer monsoon varies in tandem with the ISMR.
- ❑ The significance of the present study lies in investigating the impact of QBO on the Indian monsoon HC and discussing the potential physical processes involved in the interaction of tropical stratosphere and troposphere in the context of Indian summer monsoon.



THANK YOU