

# A Man-made Widening of the "Tropics"

**Jian Lu**

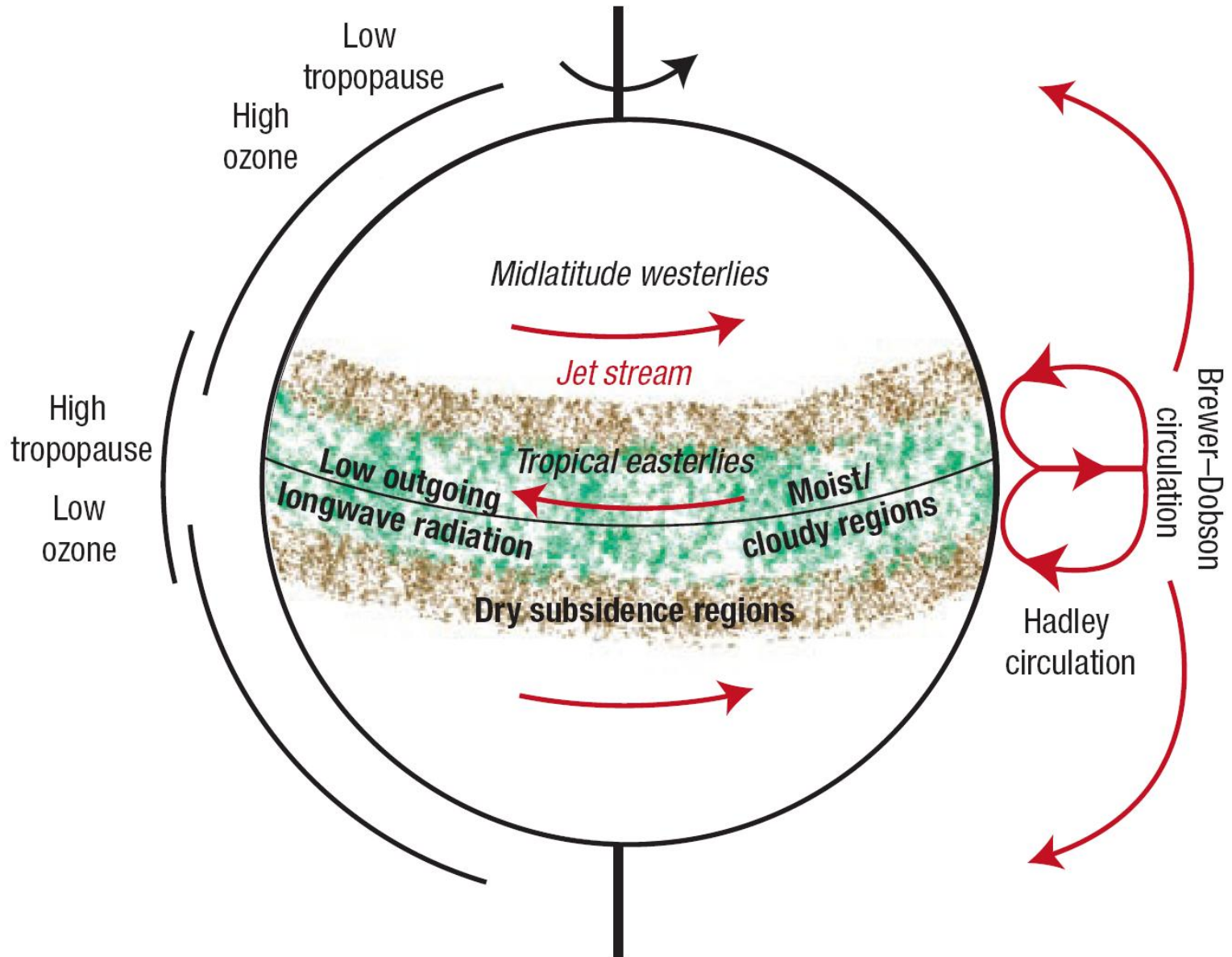
**Collaborators:**

*Clara Deser*

*Tomas Reichler*

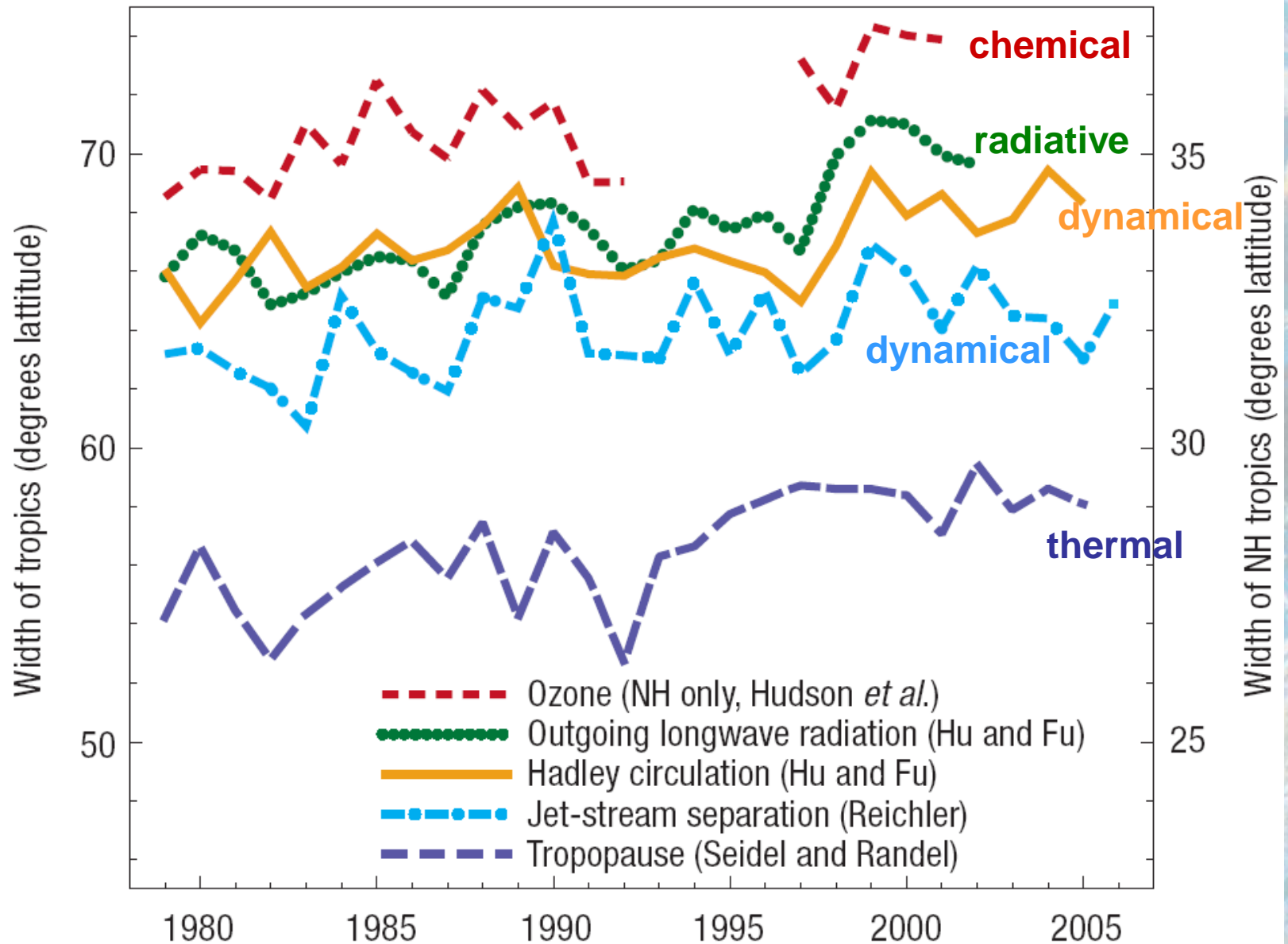
**CCSM Workshop, Breckenridge, June 18, 2008**

# How wide is the Tropics?



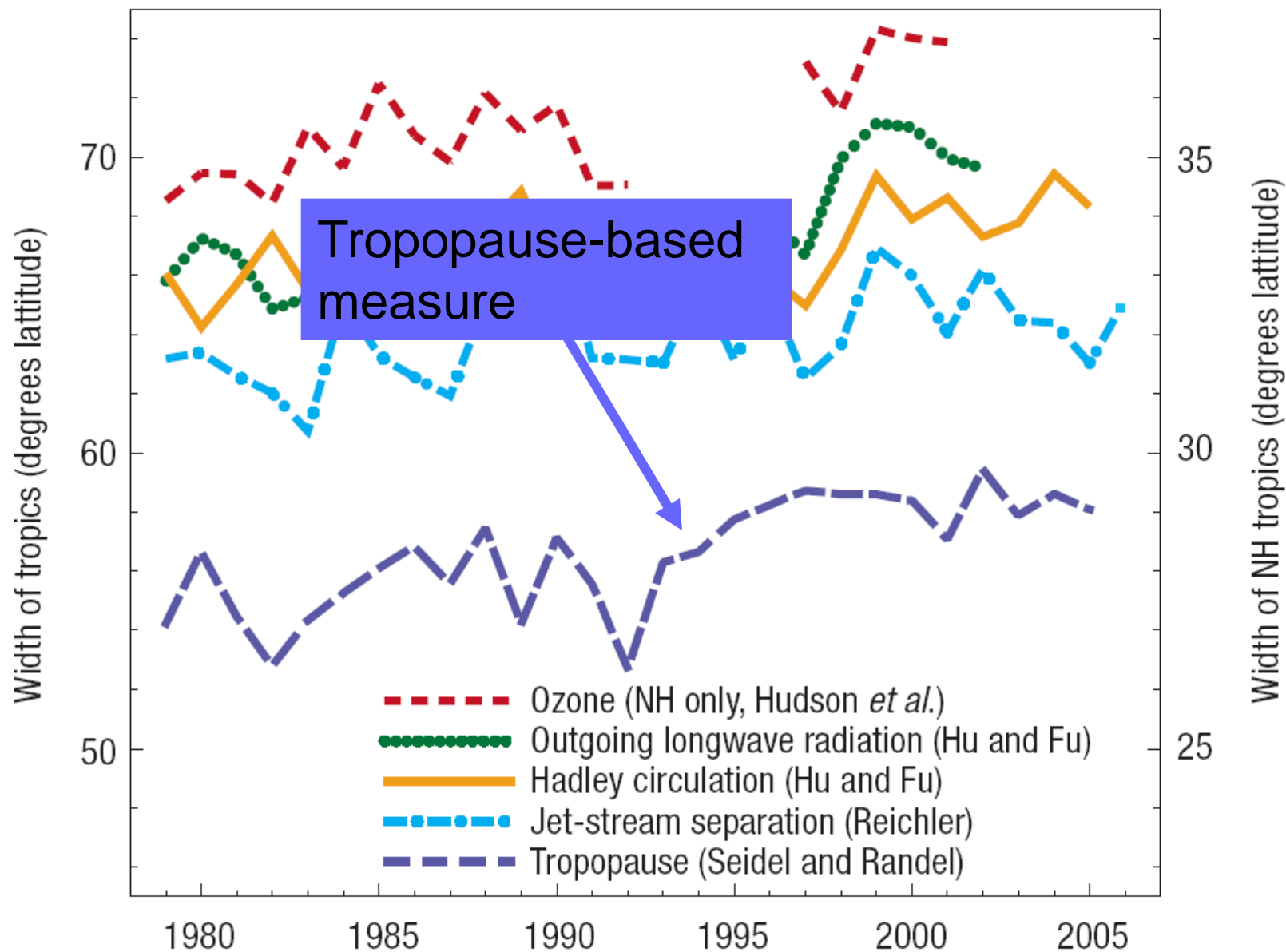
# Expansion from different measures

Seidel et al. 2008, *Nature Geoscience*



# Expansion from different measures

Seidel et al. 2008, *Nature Geoscience*



# Objective

- **What causes the tropopause-based expansion of the “Tropics”?**
  - SST changes or radiative effects (GHG, ozone, volcanic and sulphate aerosols, solar output)?
- **Tools: GFDL AM2.1 (NCAR CAM3.0)**
- **1958-2000**

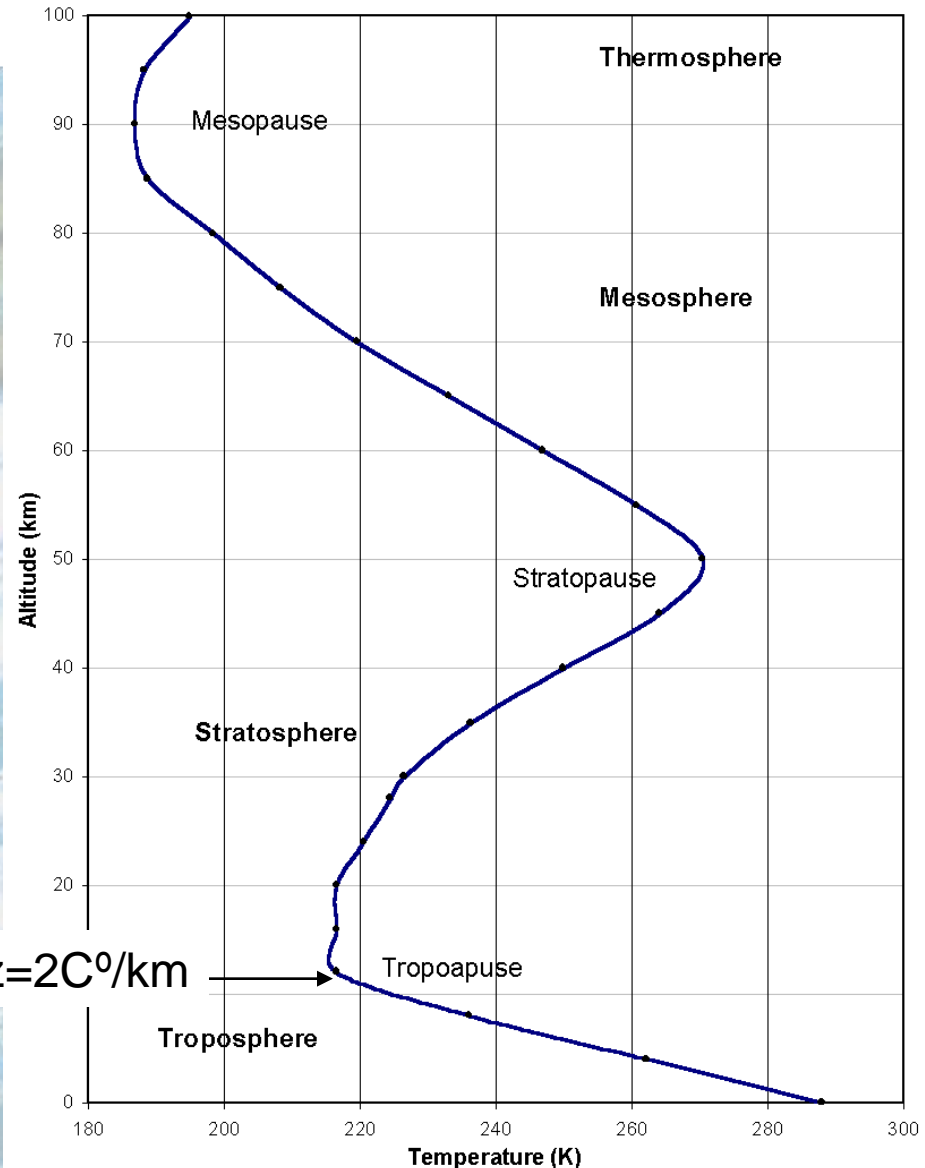
# Data

- **Radiosondes:** HadRT V2.1 (1957-2001) (Parker et al., 1997)
- **Reanalysis:** ERA40 (1957/10—2001/09) (Uppala et al. 2005)  
NCAR/NCEP
- **GFDL AM2.1 simulations**
  - “SST”: Obs SST/SIC 1950-2000
  - “SST+RAD”: Obs SST/SIC + radiative forcings including: GHG, O<sub>3</sub>, solar and sulphate and volcanic aerosols
  - “SST+RAD” – “SST”: Effects of radiative forcings

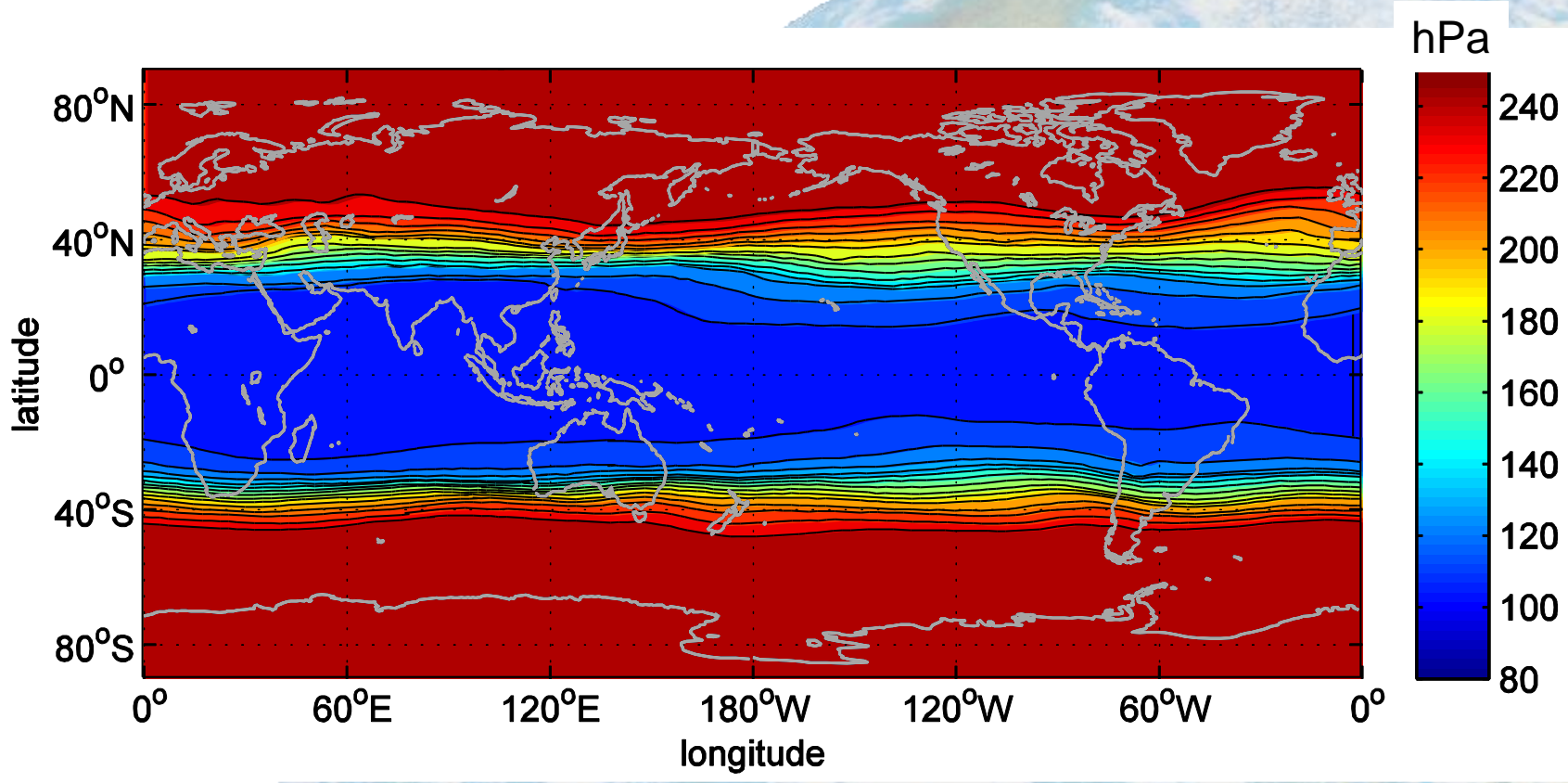
# Method

## Tropopause-based metric

- WMO criterion:  
the lowest level at which the lapse rate decreases to  $2\text{C}/\text{km}$ , provided also the average lapse rate between this level and higher levels within  $2\text{km}$  does not exceed  $2\text{C}/\text{km}$ .
- Reichler (2003) algorithm



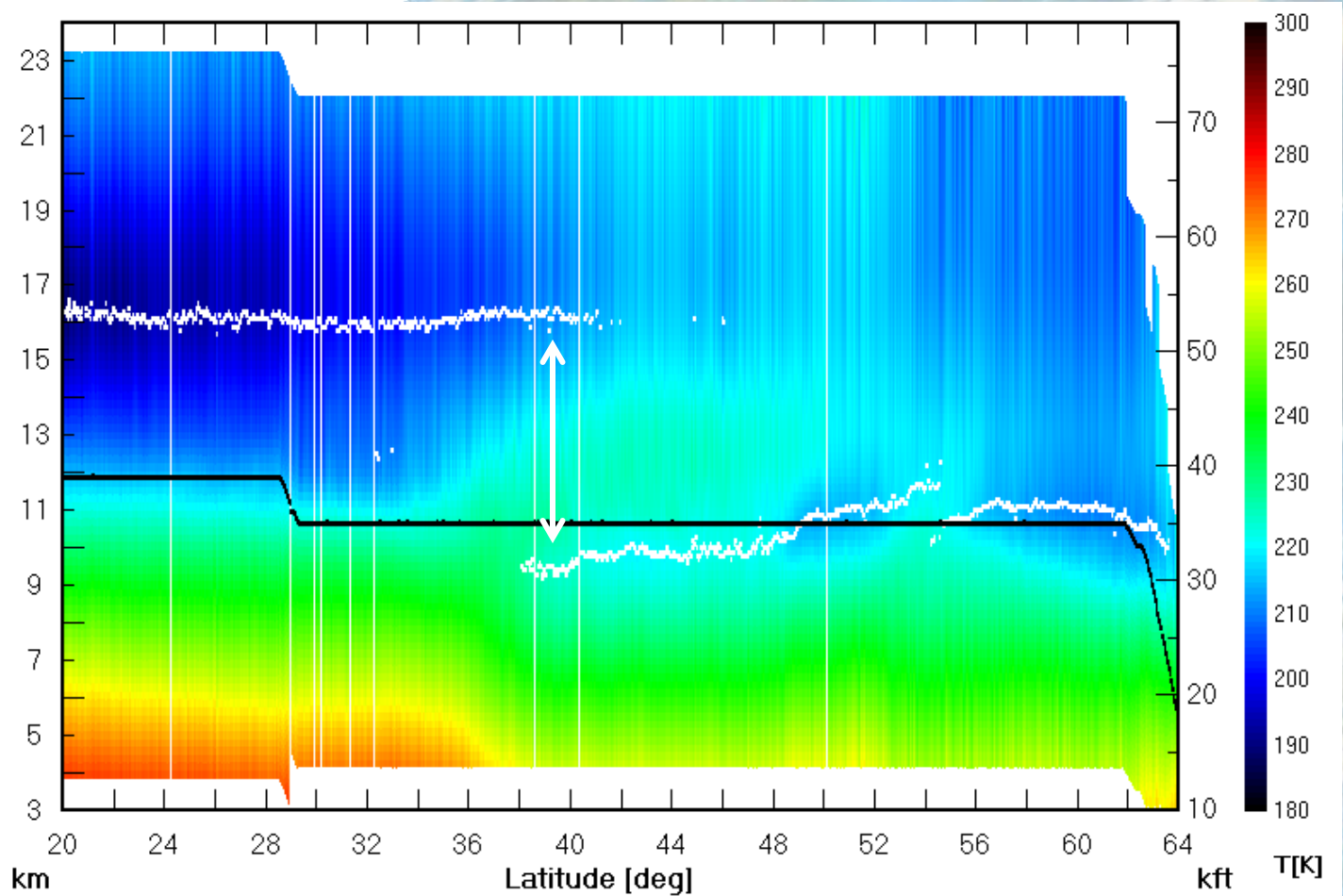
# Annual mean tropopause





# A snap shot of tropopause

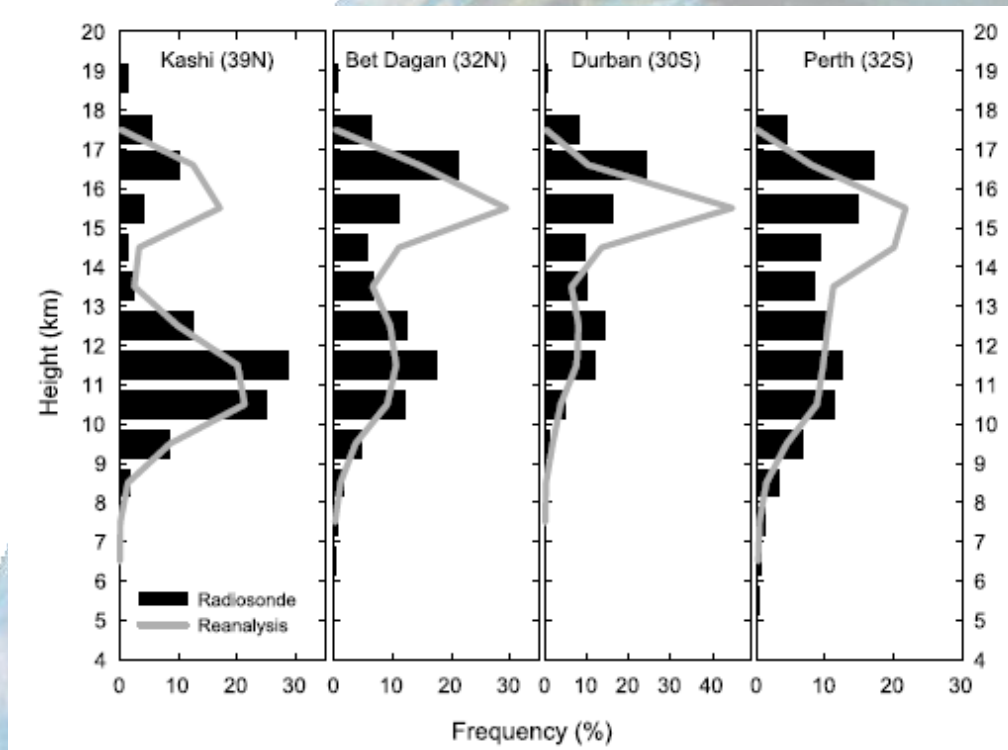
- Shape of the tropopause



# PDFs of tropopause

---metric of Seidel and Randel

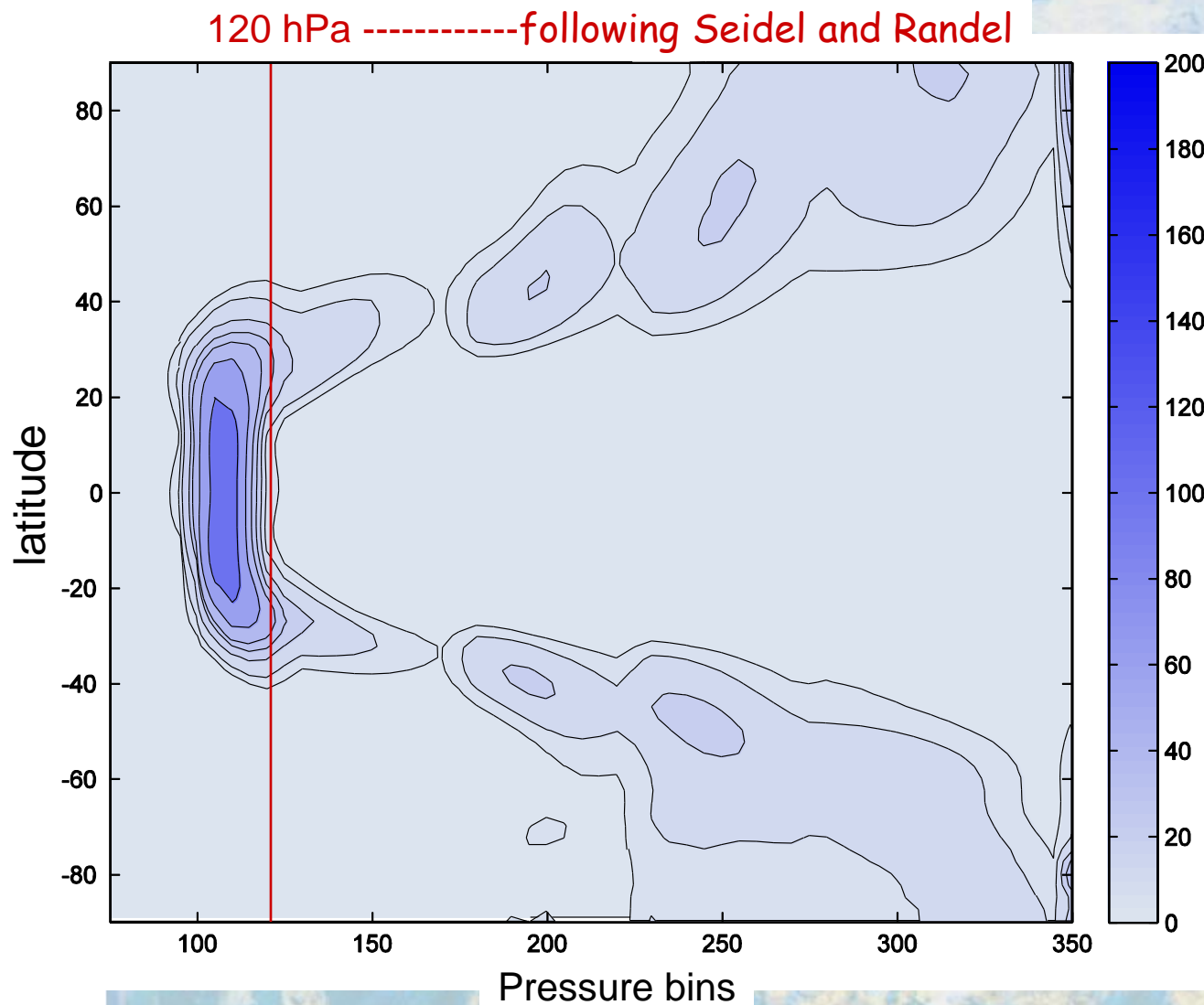
- Compute tropopause for each day using Reichler algorithm  $\Rightarrow H(x,y)$ ; for a year:  $H(\text{days},x,y)$
- For each year, compute the probability density function of  $H(d,x,y)$  in to [75:5:350] pressure(hPa) bins  $\Rightarrow P(\text{bins},x,y)$



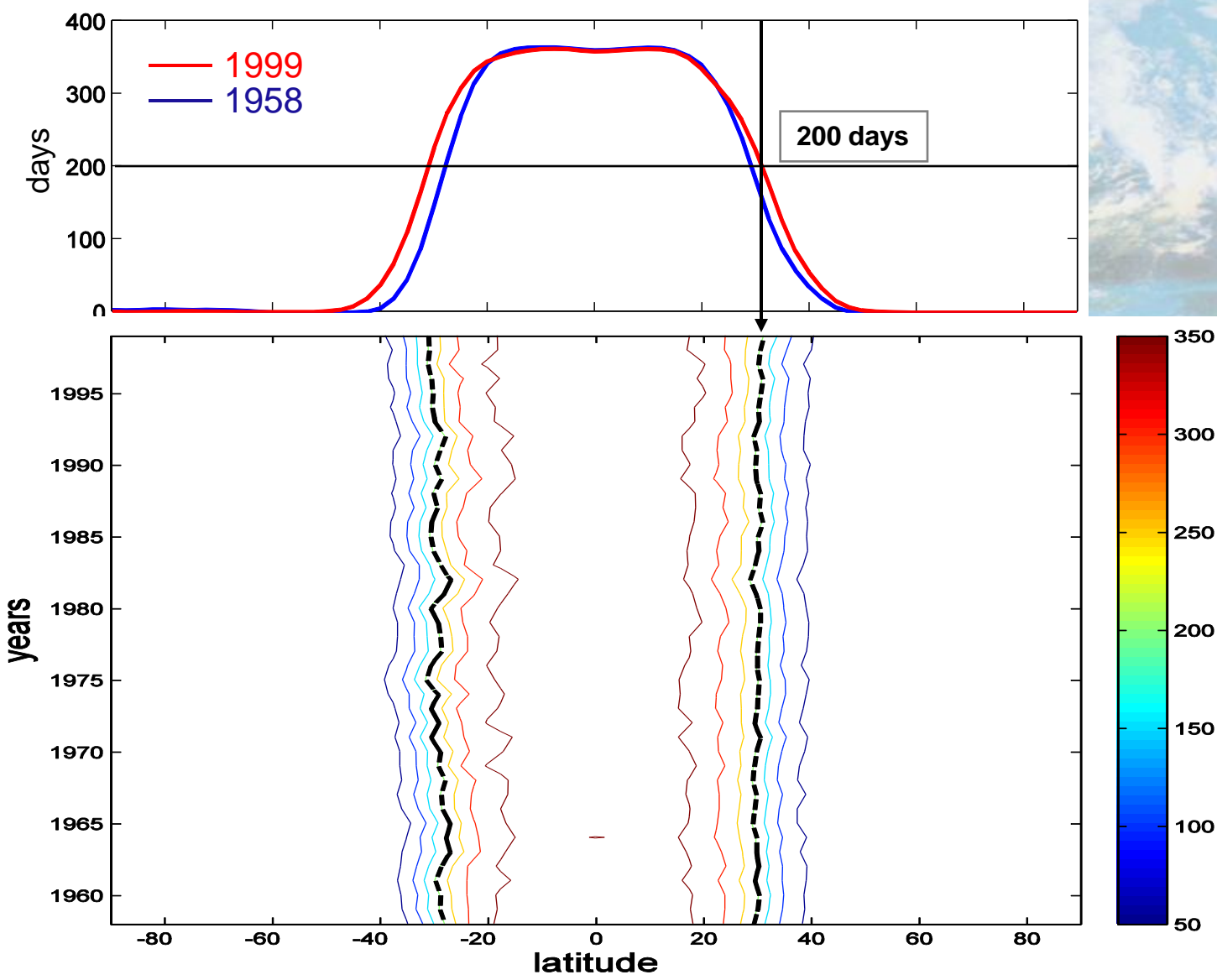
Seidel and Randel, 2007

- Zonal average of  $P(\text{bin},x,y) \Rightarrow P(\text{bin},y)$

# PDFs of daily tropopause $P(\text{bin}, y)$

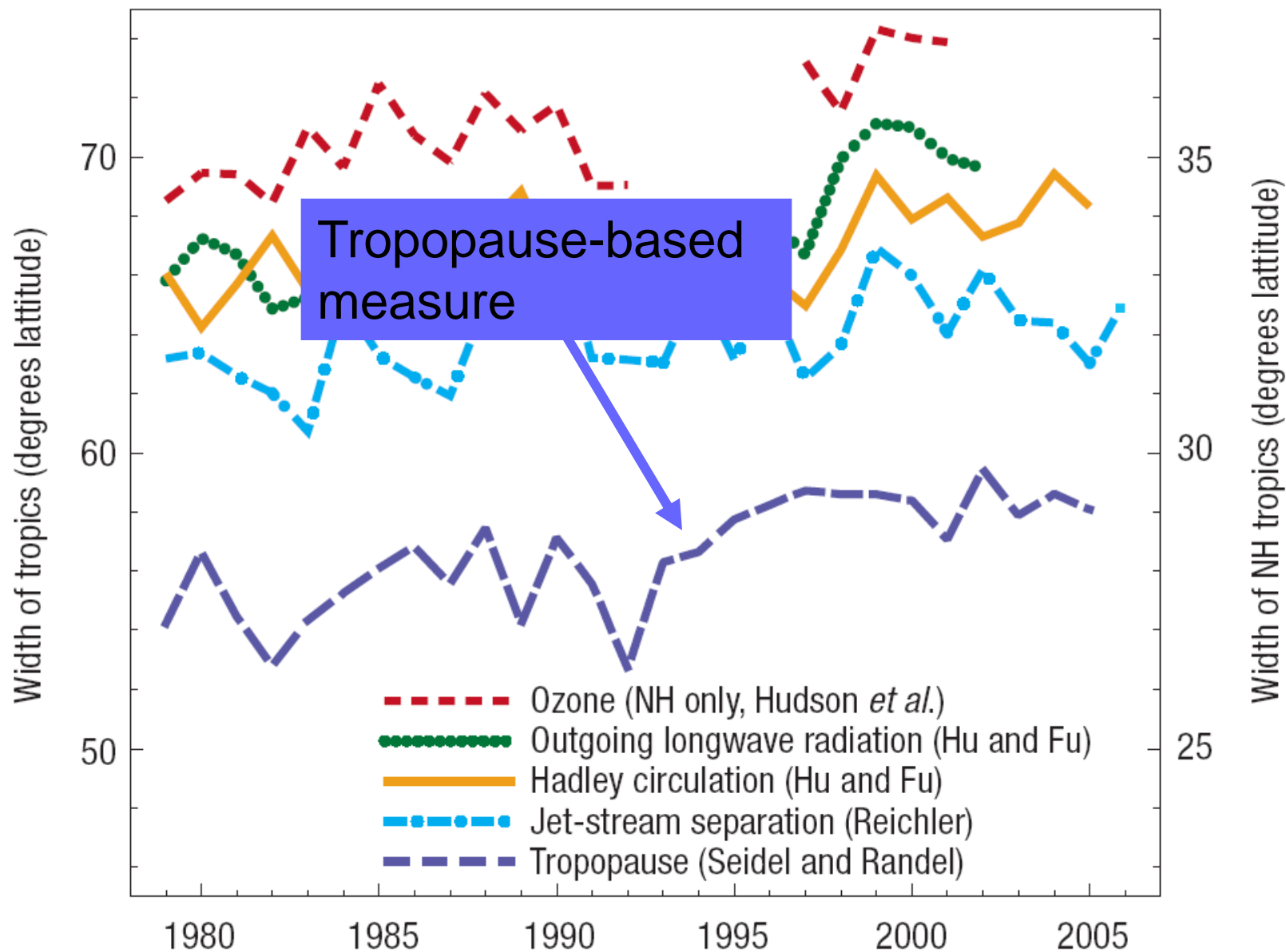


$$\Sigma P(\text{bin} \leq 120 \text{hPa}, y)$$

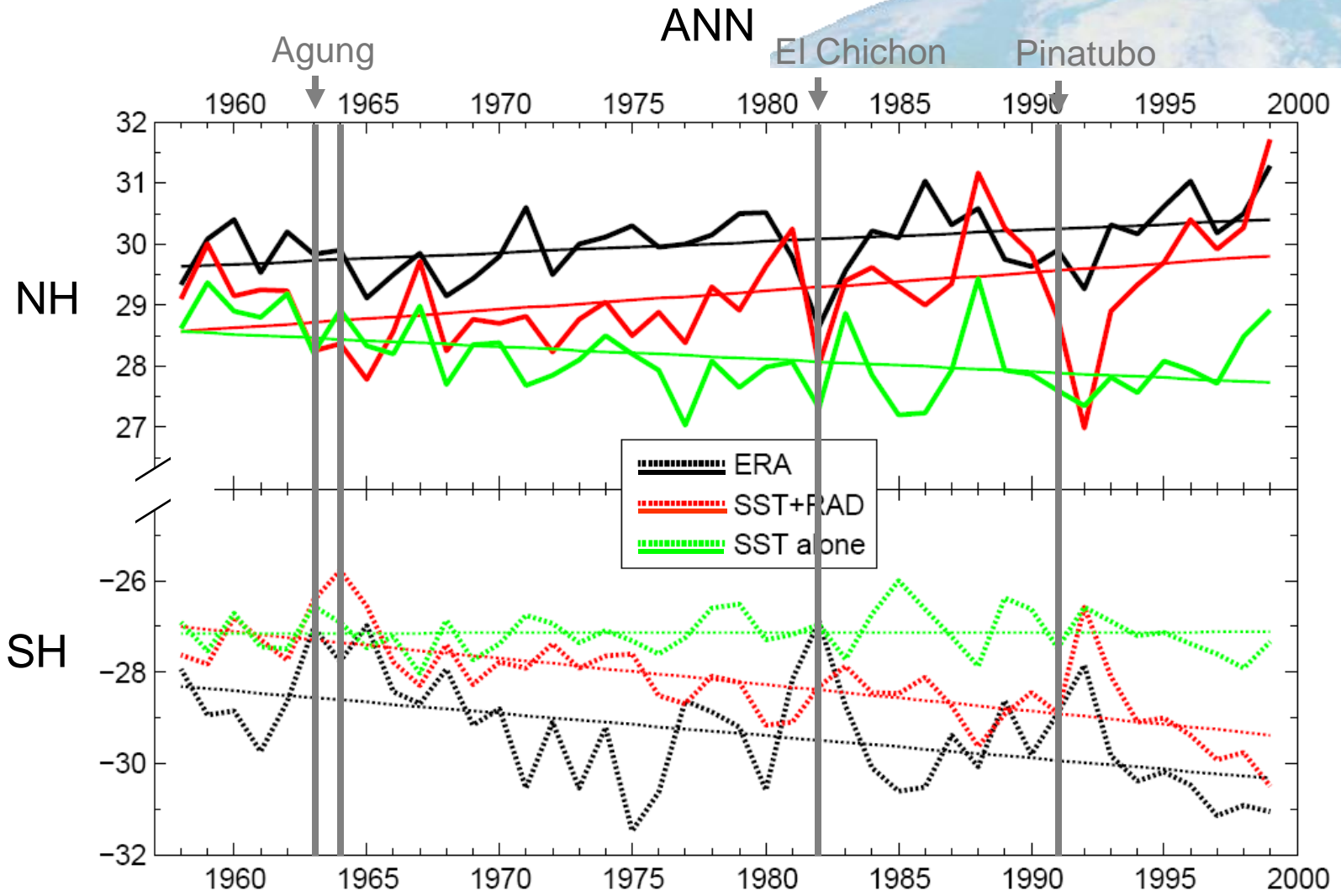


# Expansion from different measures

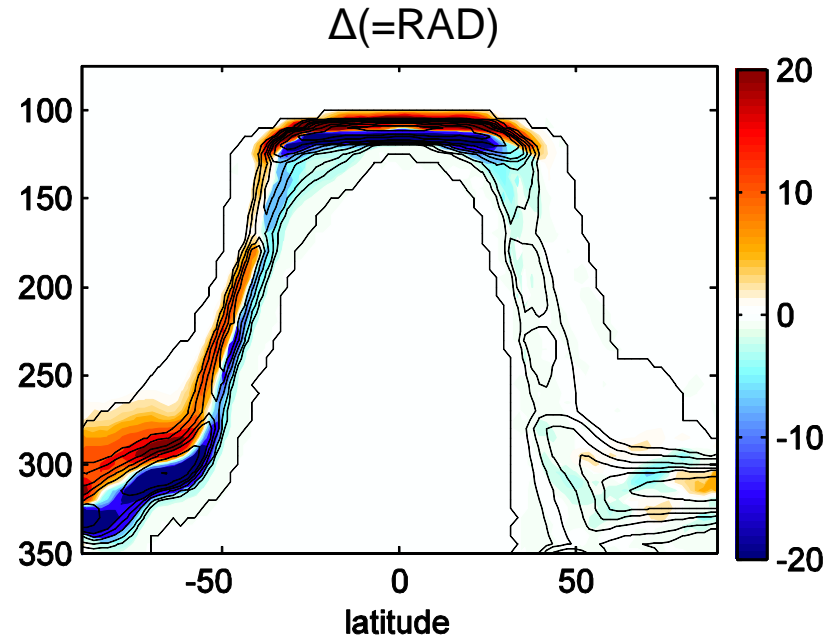
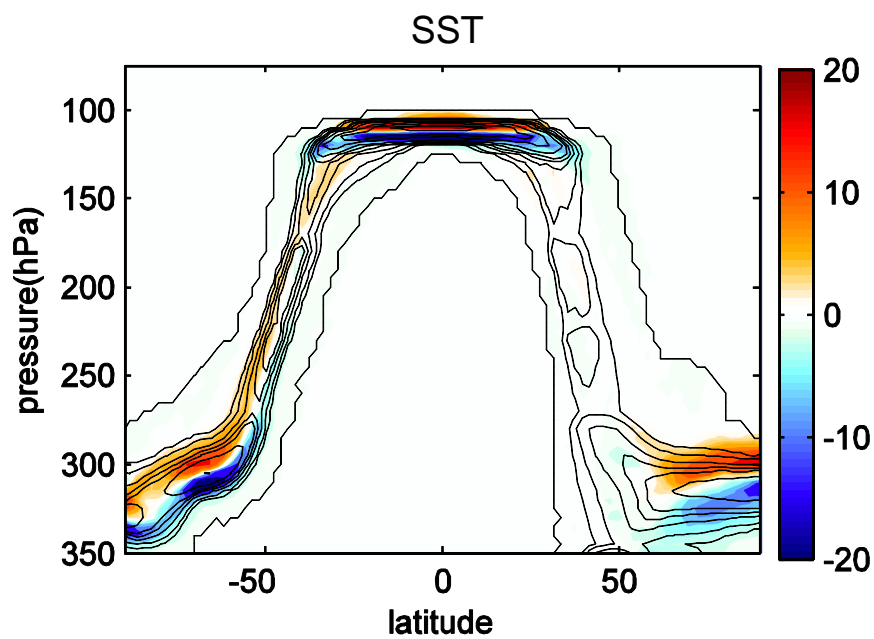
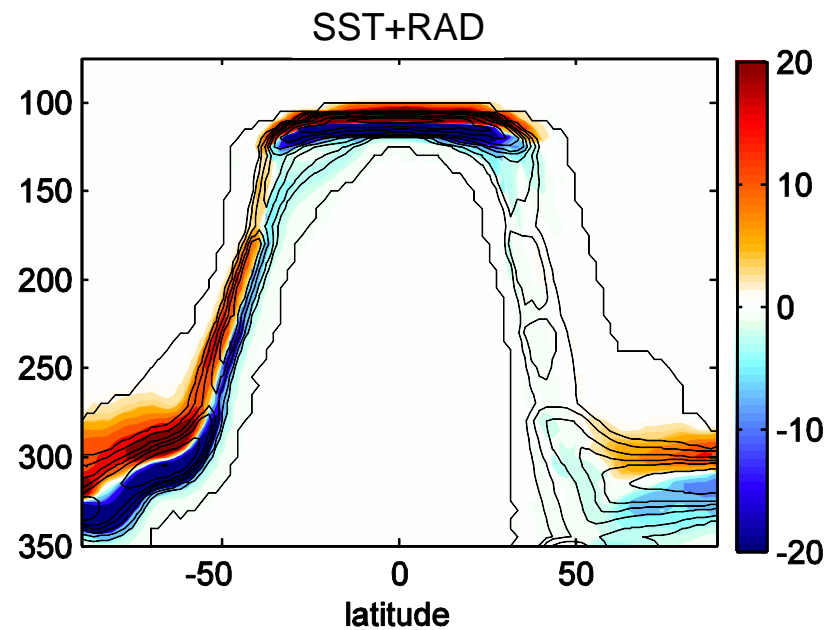
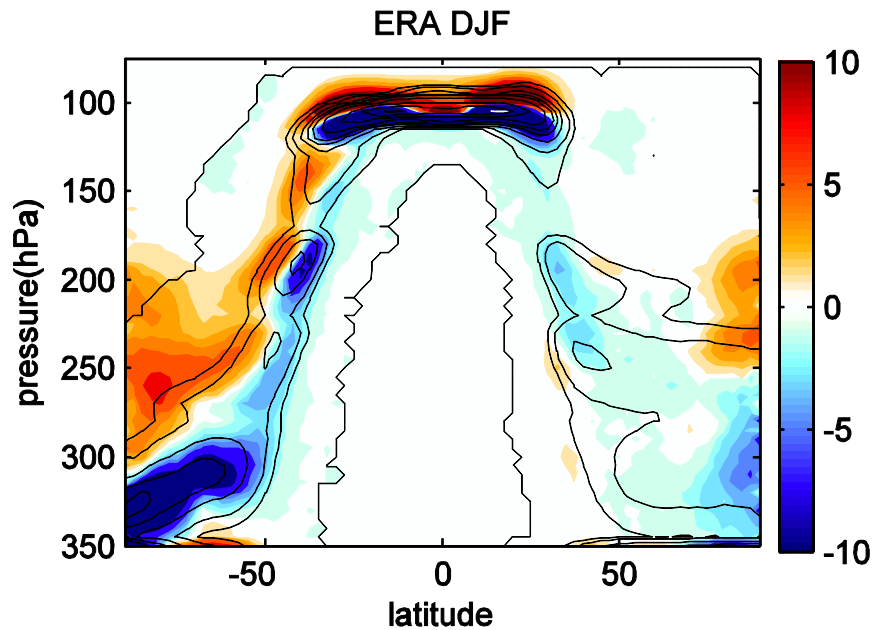
Seidel et al. 2008, *Nature Geoscience*



# Broadening of tropics

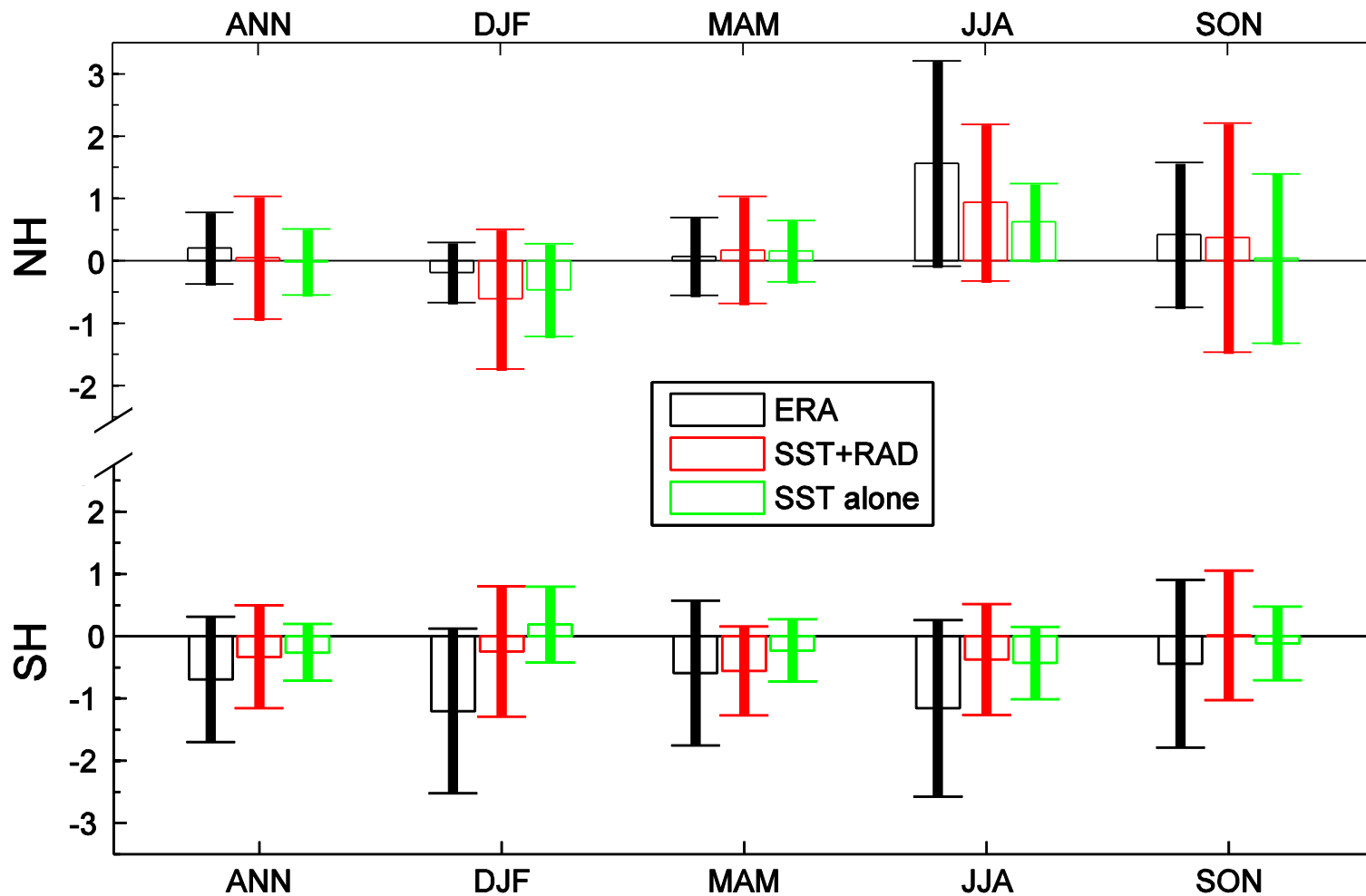


# Trend in PDFs of daily tropopause $P(\text{bin}, y)$ , DJF



# Significance of the Widening

Trend 1978-99

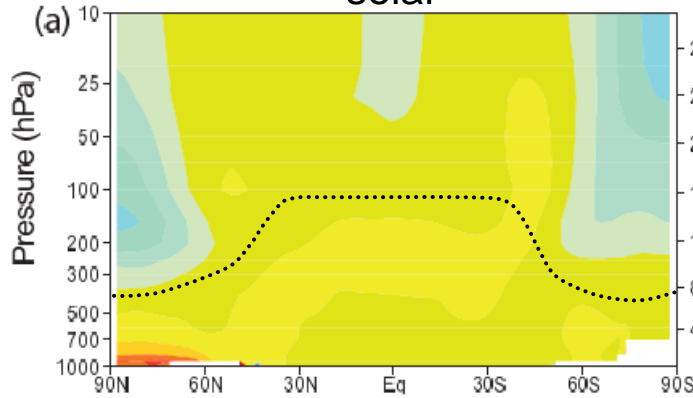




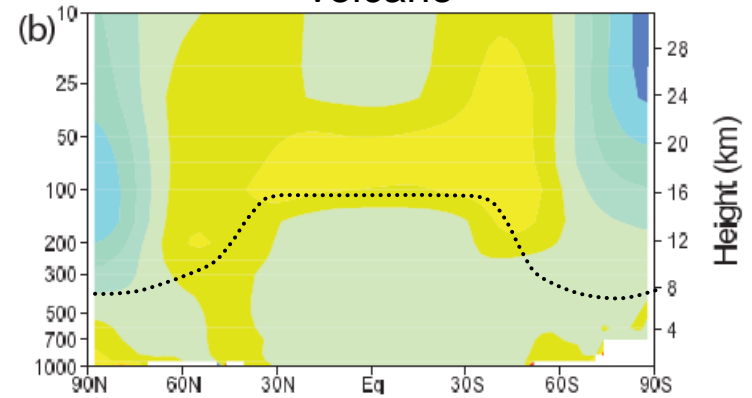
# Fingerprints of radiative forcings

natural

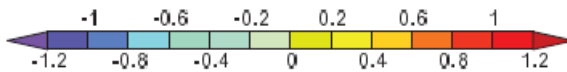
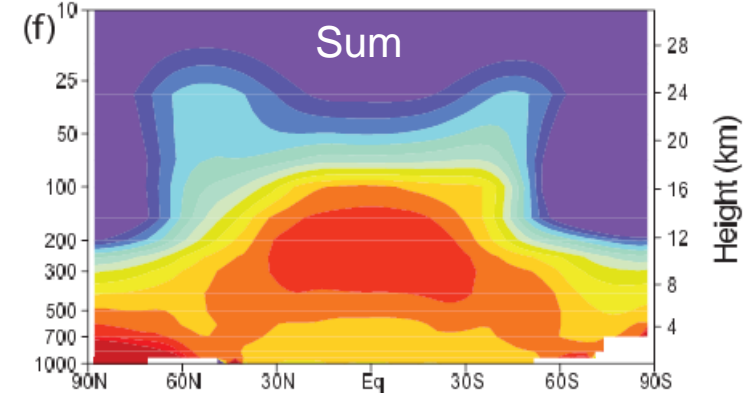
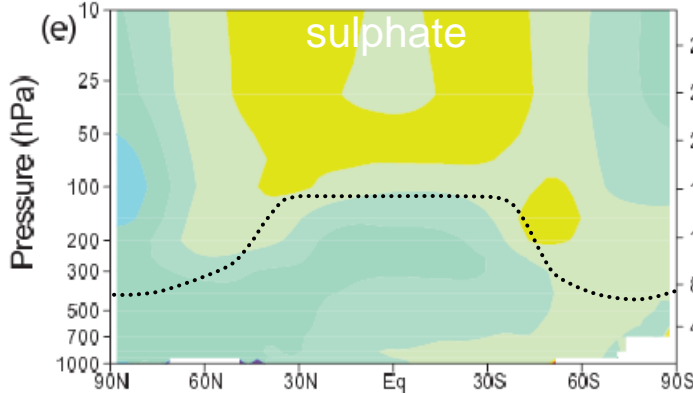
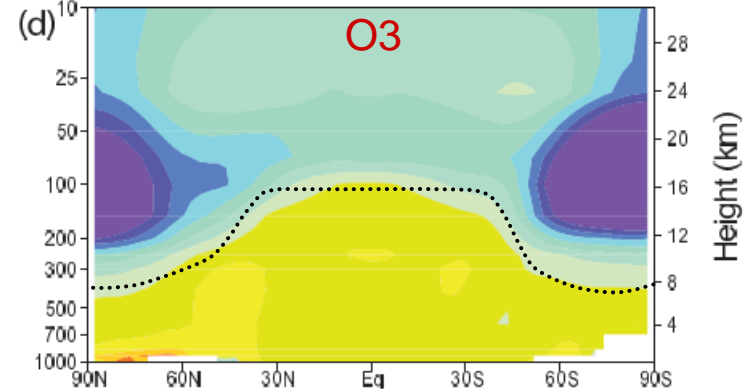
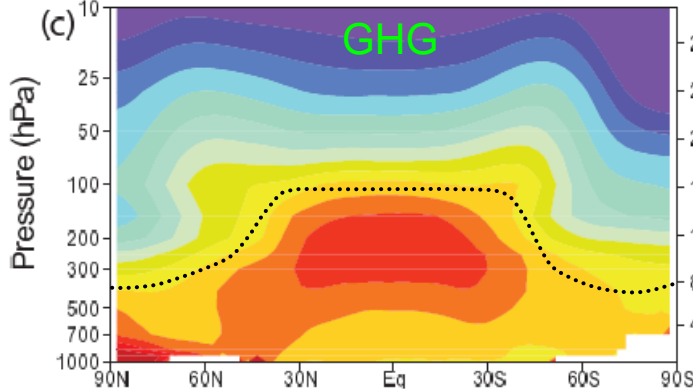
solar



volcano



anthropogenic



# Conclusion and outlook

- The agreement between ERA40 and the GFDL AM2.1 simulations corroborates the reality of an expansion of the tropics since the 1950s.
- SSTs alone drive no trend (or even a slightly shrinking trend) in tropical width. Only under the radiative forcing, especially GHG and O<sub>3</sub>, can AM2.1 reproduce the expansion of the tropics, a result that points to anthropogenic sources for the expansion.
- Further attribution is underway to investigate the respective roles of GHG and O<sub>3</sub> forcing using AM2.1.
- The tropical expansion in SH summer (DJF) varies hand-in-hand with the expansion of the Hadley cell and the associated change in subtropical rain (P-E) pattern. Puzzles remain for NH and other seasons.