

# *Resolution of Disparities in Tropospheric Temperature Records*

Ben Santer

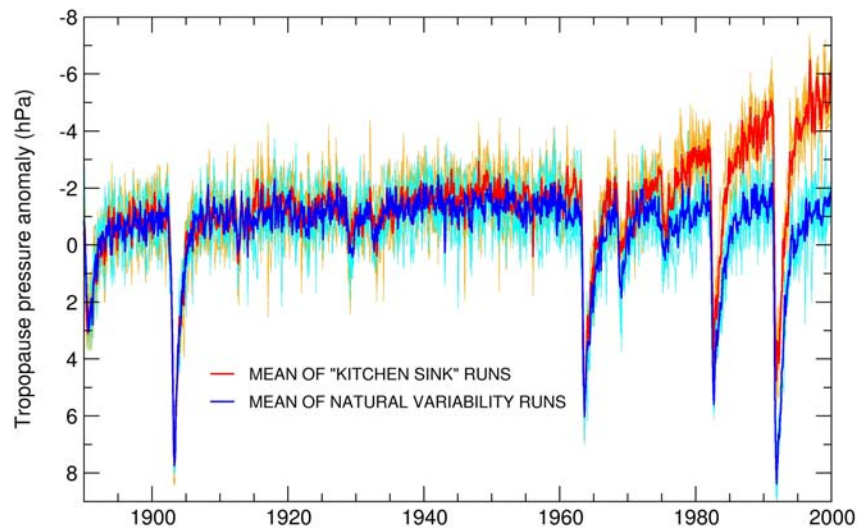
Program for Climate Model Diagnosis and Intercomparison

Lawrence Livermore National Laboratory

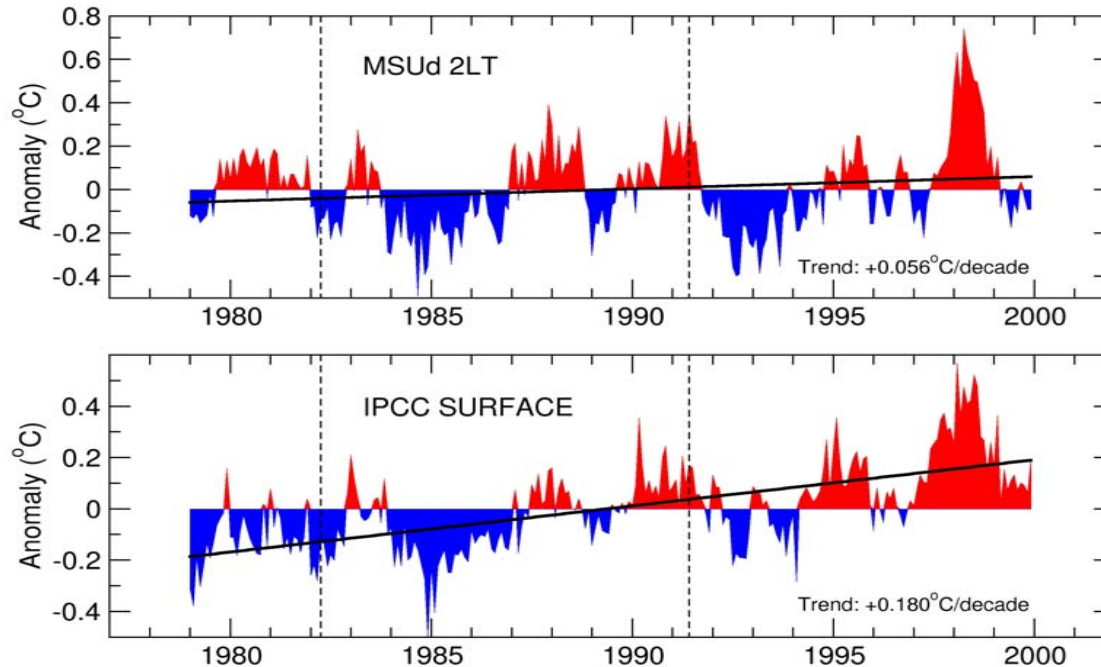
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U.S. Climate Change Science Program Planning Workshop

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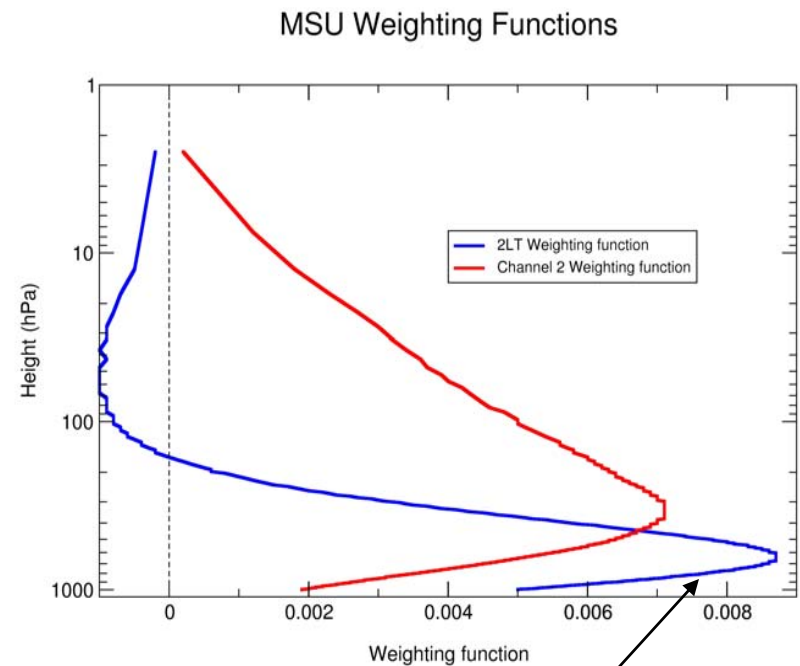
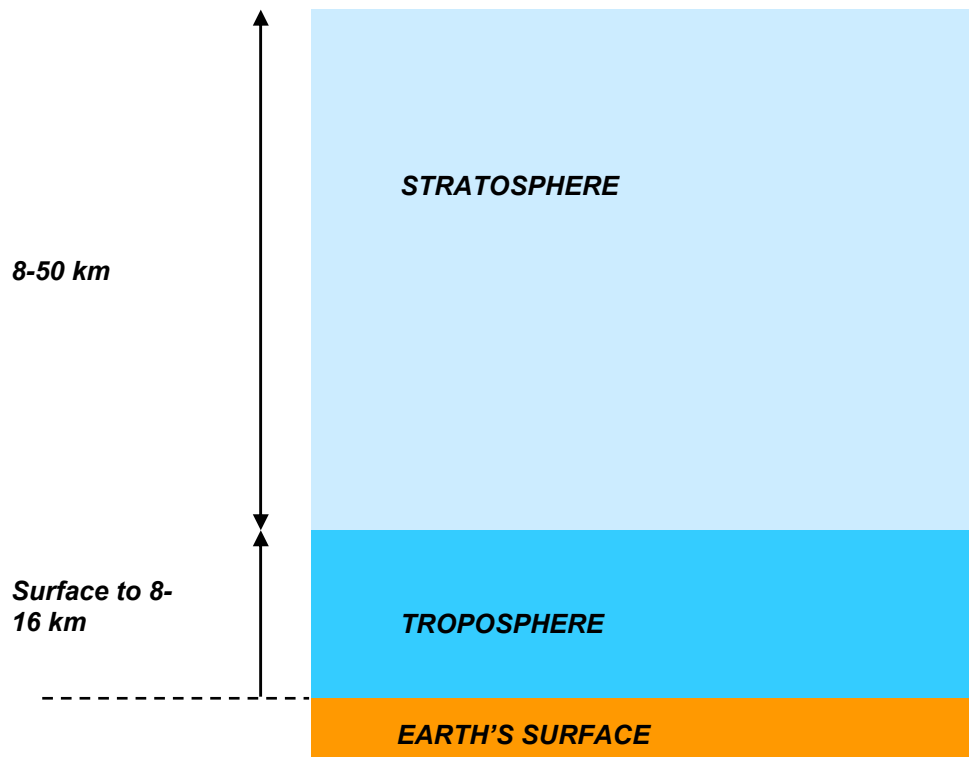
## Why have the surface and troposphere warmed at different rates?



- Some have suggested there is a significant discrepancy between:
  - ➔ Strong surface warming of 0.15 - 0.20°C/decade recorded by thermometers
  - ➔ Weak warming of lower troposphere estimated by satellites and radiosondes
- This discrepancy has been used to cast doubt on both climate model predictions and the reality of surface warming



# The Microwave Sounding Unit monitors temperatures over a broad atmospheric layer – not at Earth's surface

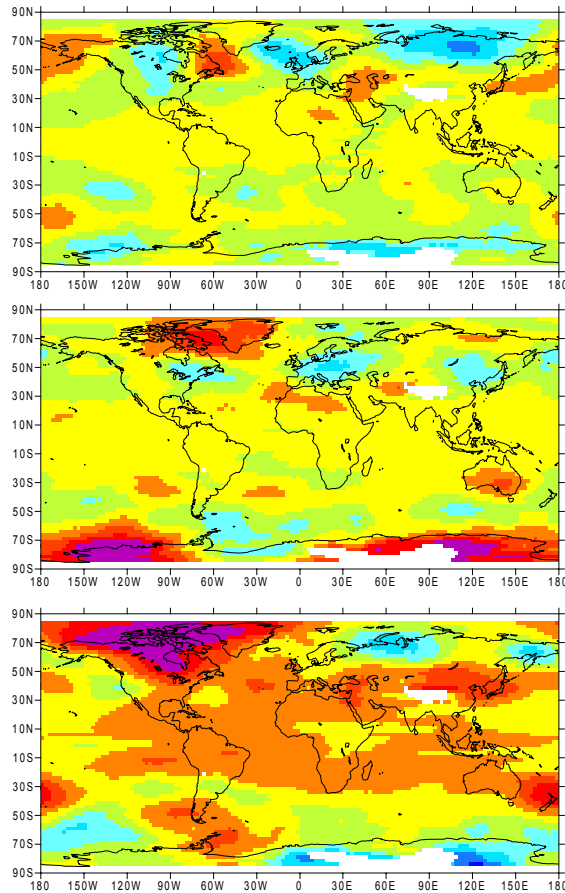


**Weighting function of the MSU lower troposphere temperature retrieval (2LT) peaks at roughly 4 km above Earth's surface**

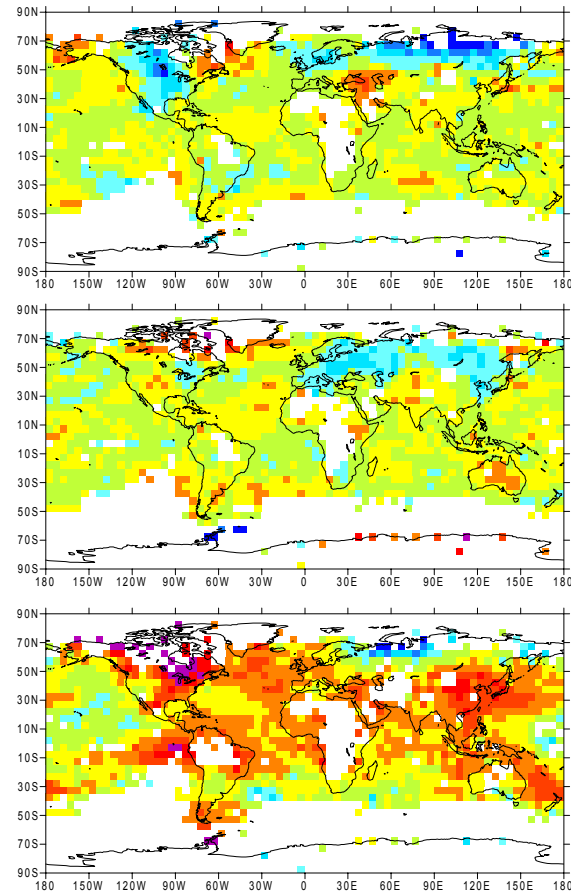


# *There are differences in the spatial coverage of satellite- and thermometer-based temperature measurements*

Lower troposphere (satellite)



Surface (thermometer)



# Estimating El Niño and volcano effects on tropospheric temperatures

Satellite tropospheric temperature data

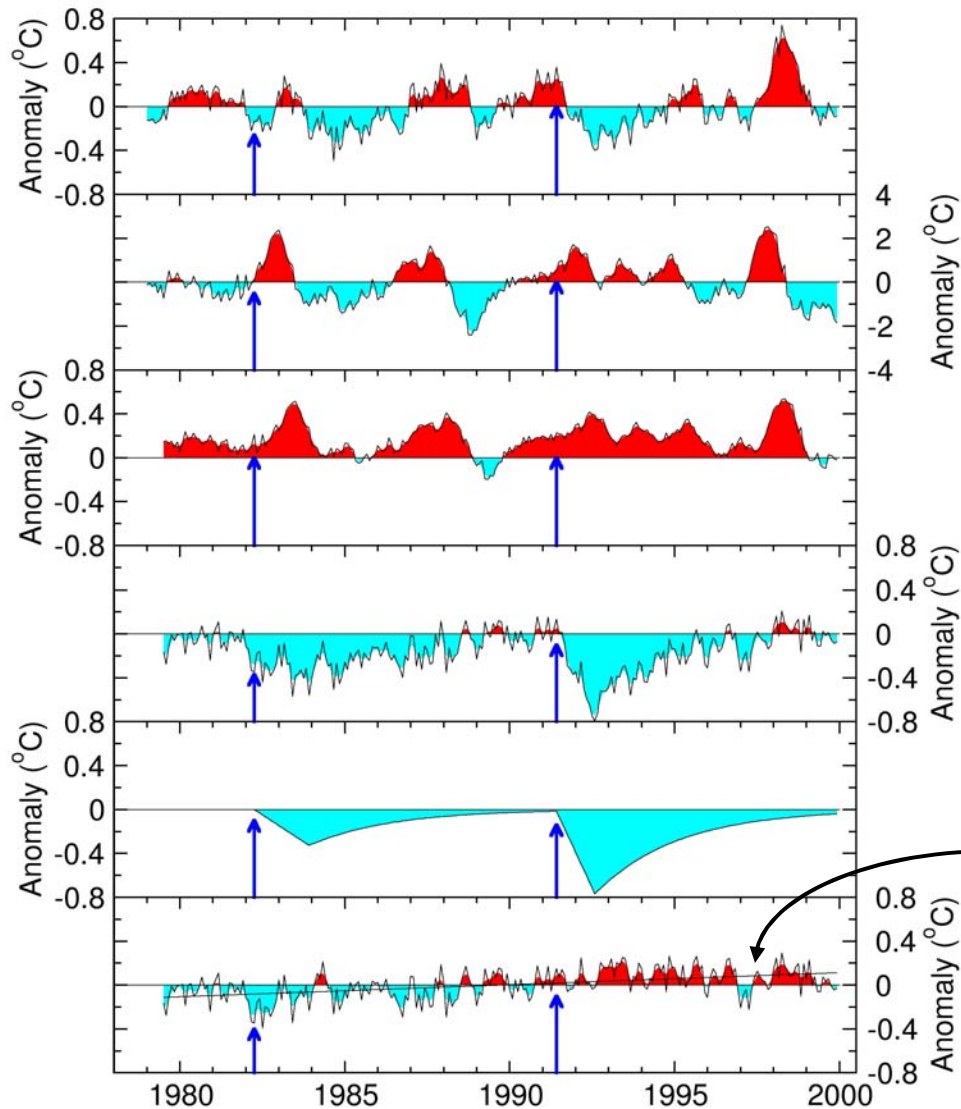
El Niño index

El Niño effect on temperature

Satellite data minus El Niño effect

Volcano effect on temperature

After removing El Niño and volcanoes



# Can we reconcile modeled and observed temperature trends?

**Positive trend difference:  
Surface warms by more  
than troposphere in OBS**

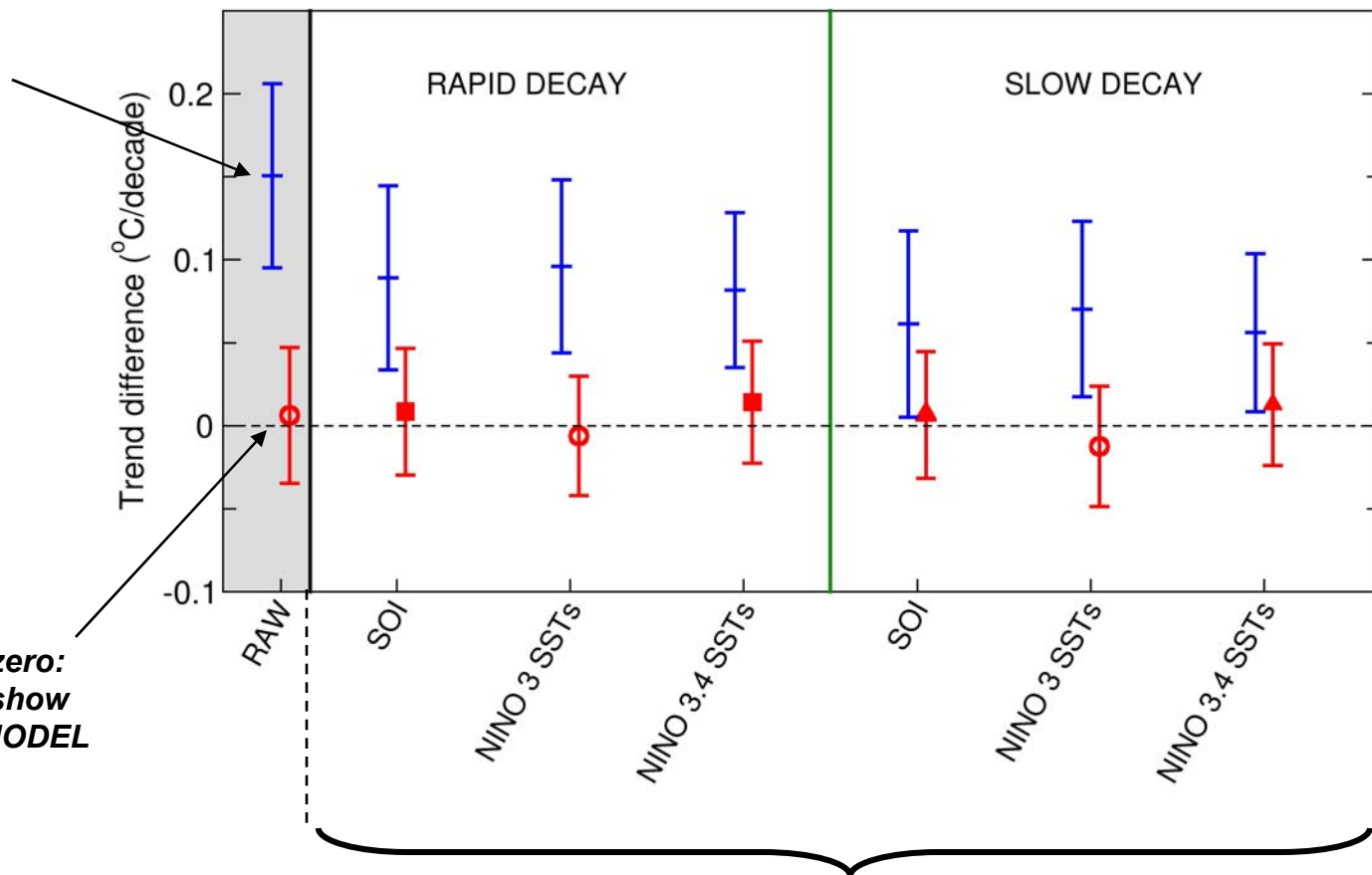
## SIGNIFICANCE OF TREND DIFFERENCES

- 1% level
- 5% level
- 10% level
- ▲ Not sig. diff. at 10% level

**BLUE: OBSERVED**

**RED: MODEL**

**Trend difference close to zero:  
Surface and troposphere show  
similar warming rates in MODEL**



**Time period for trend comparisons  
is 1979-1997**

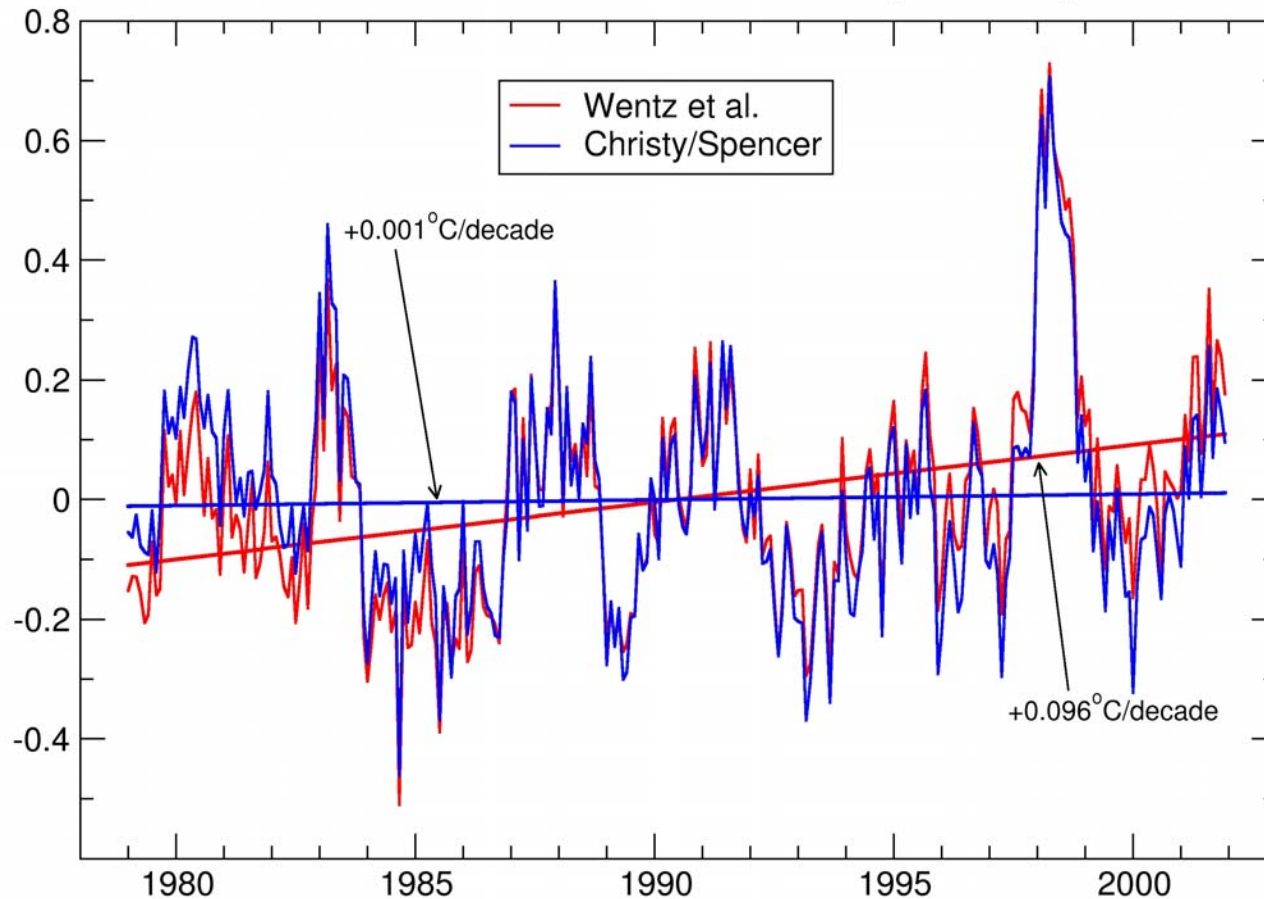
*Different ways of removing volcano and El Niño effects*



# Observational uncertainties: A missing piece of the puzzle?

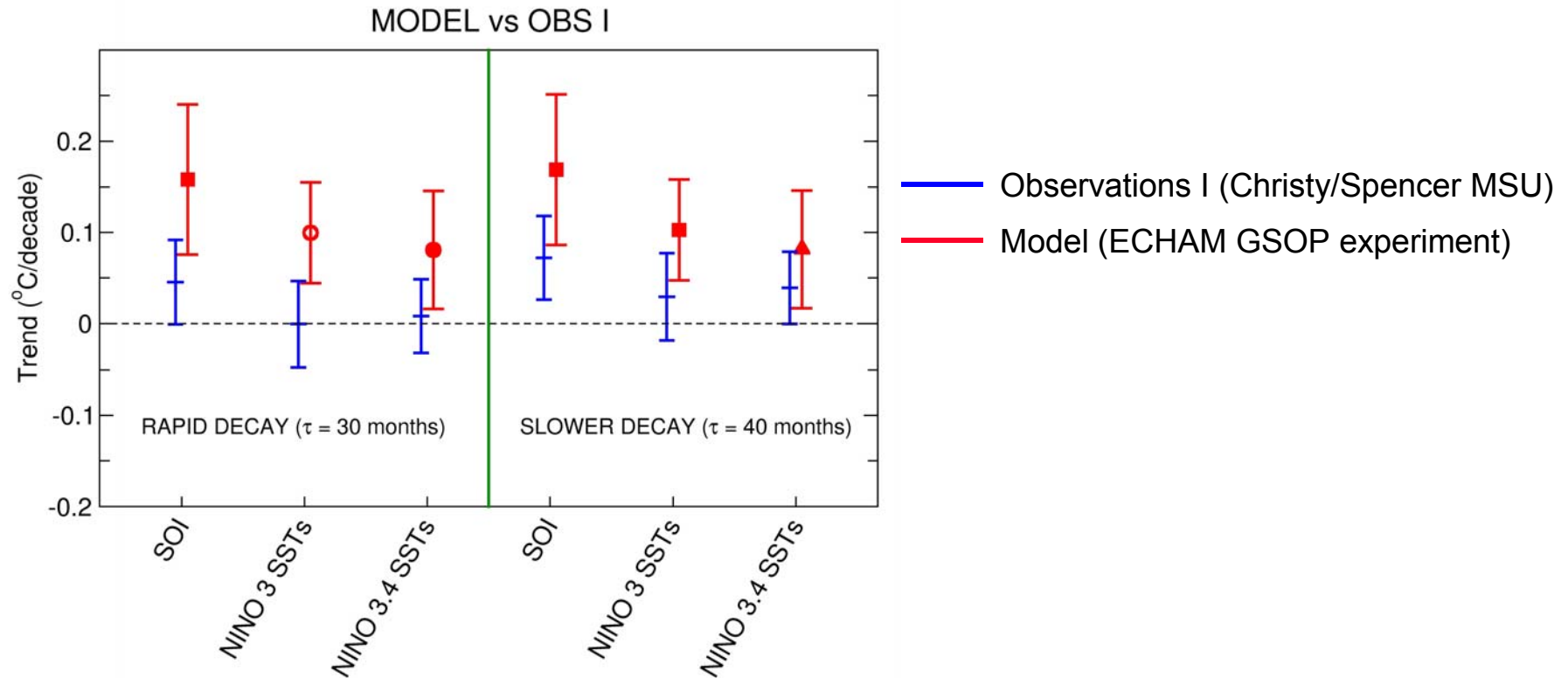
## Tropospheric temperature anomalies in two observational datasets

Channel 2. Anomalies w.r.t. 1979-2001 climatological monthly means





# Modeled tropospheric temperature trends are significantly different from one set of MSU observations...



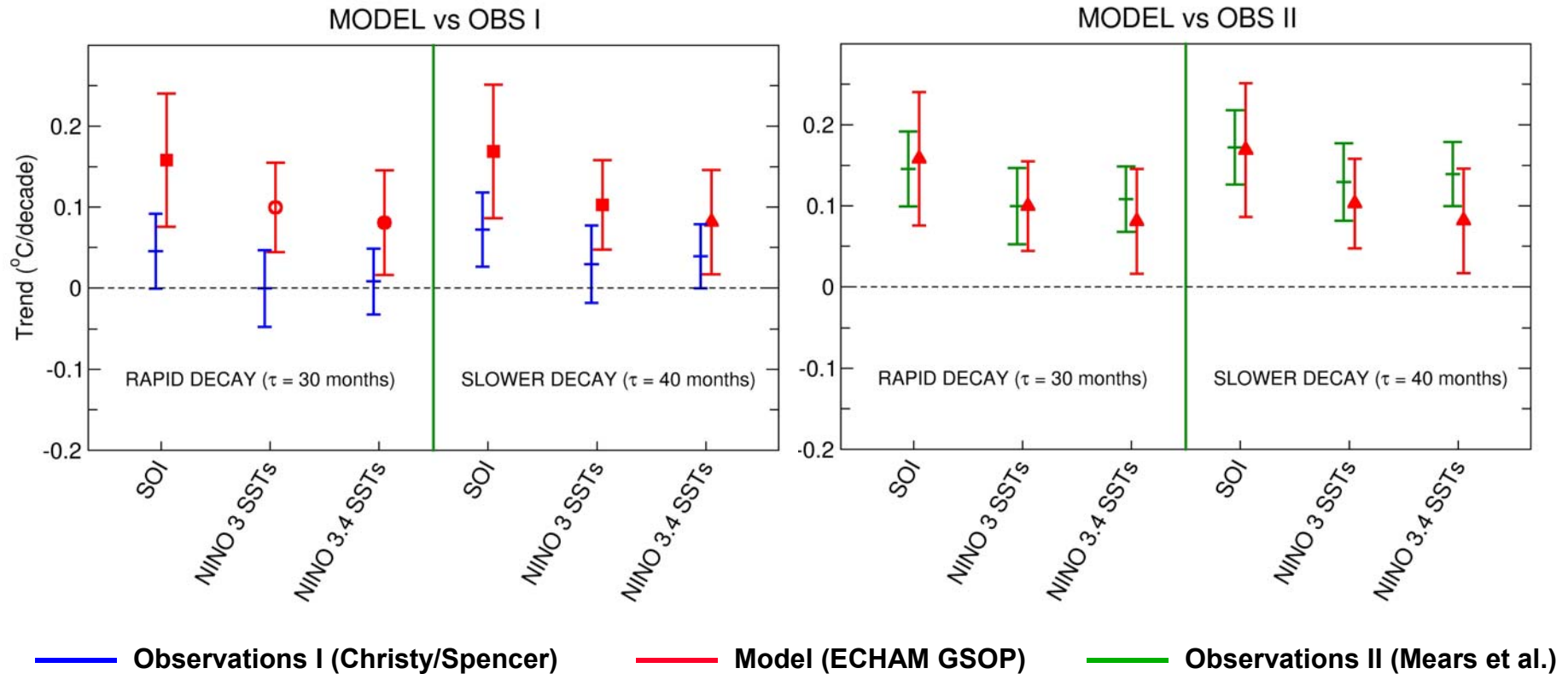
Significance of differences between modeled and observed Channel 2 trends (1979-1997)

- 1% level
- 5% level
- 10% level
- ▲ Not sig. diff. at 10% level





# But modeled tropospheric temperature trends are in good agreement with a second set of MSU observations



**Significance of differences between modeled and observed Channel 2 trends (1979-1997)**

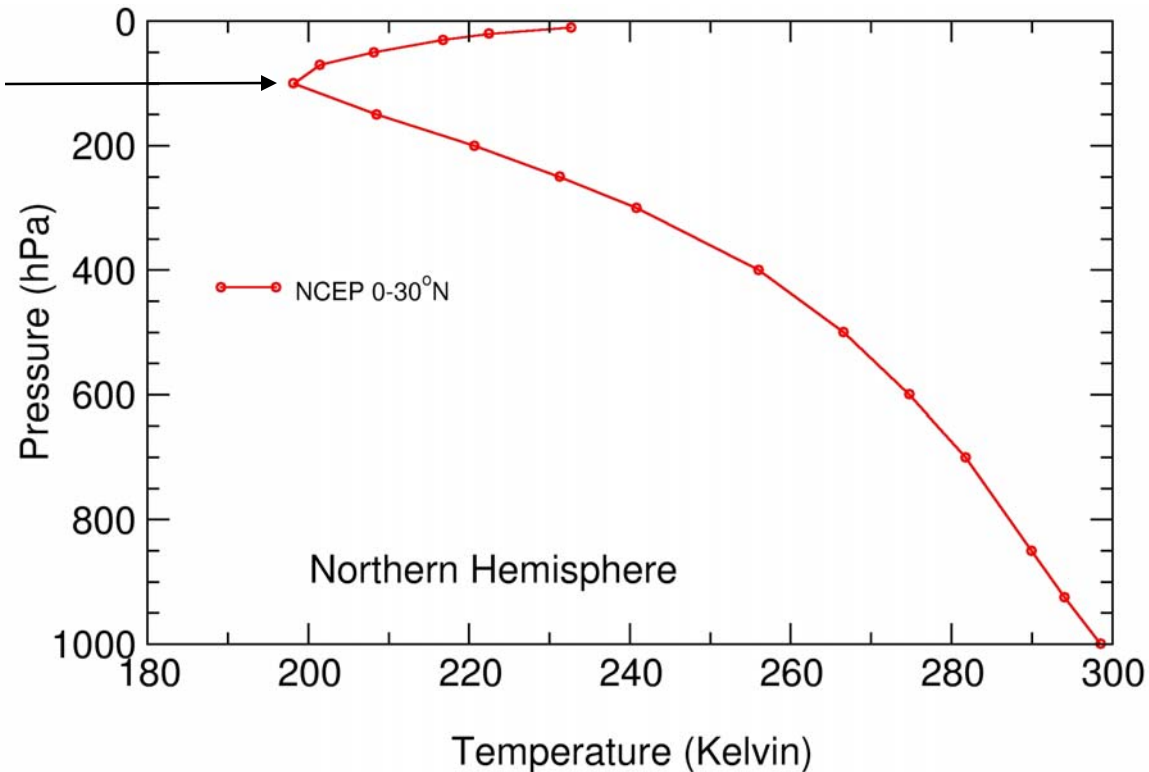
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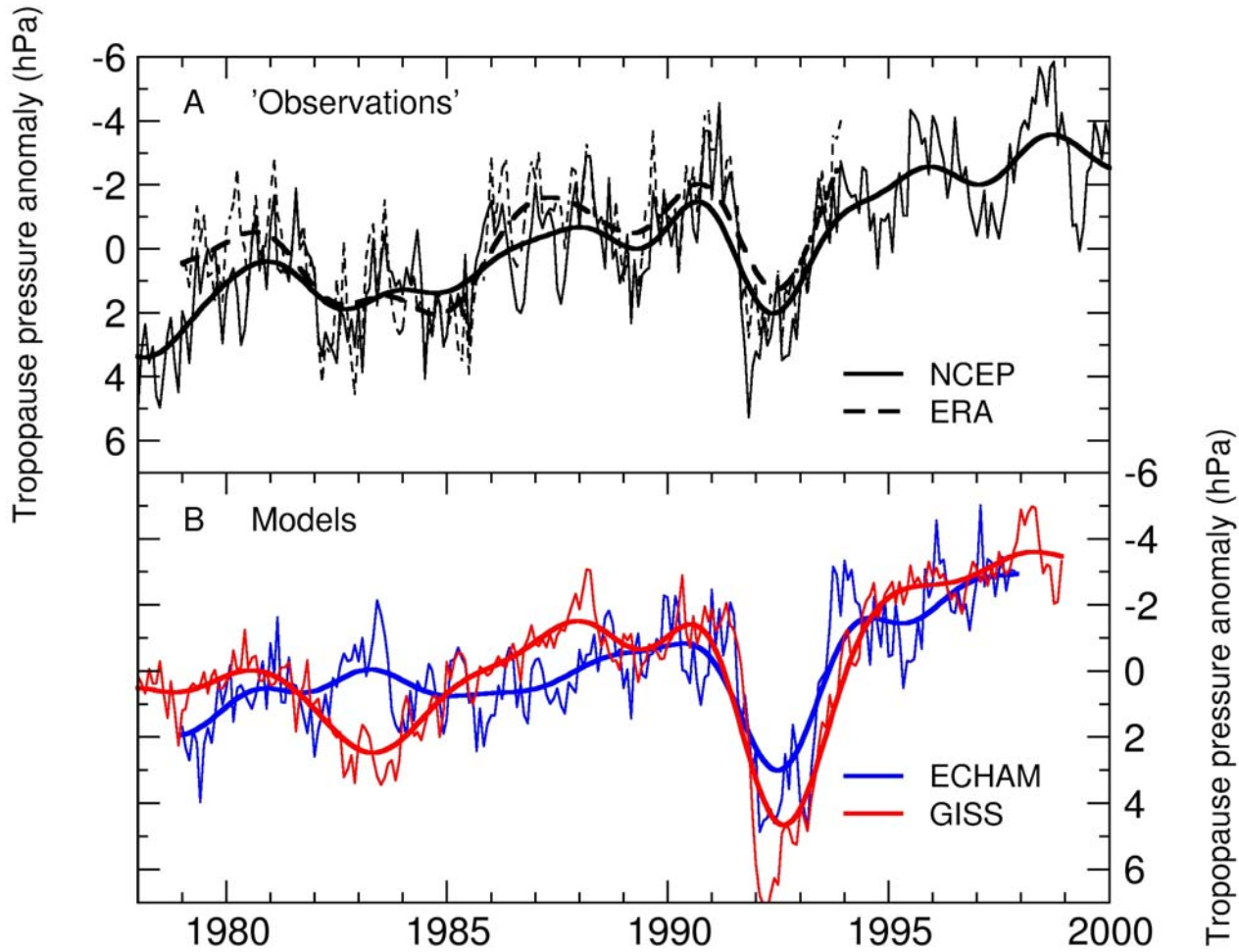
## *Does other evidence support recent warming of the troposphere?*

- It is the transition zone between the turbulently-mixed troposphere and more stably-stratified stratosphere

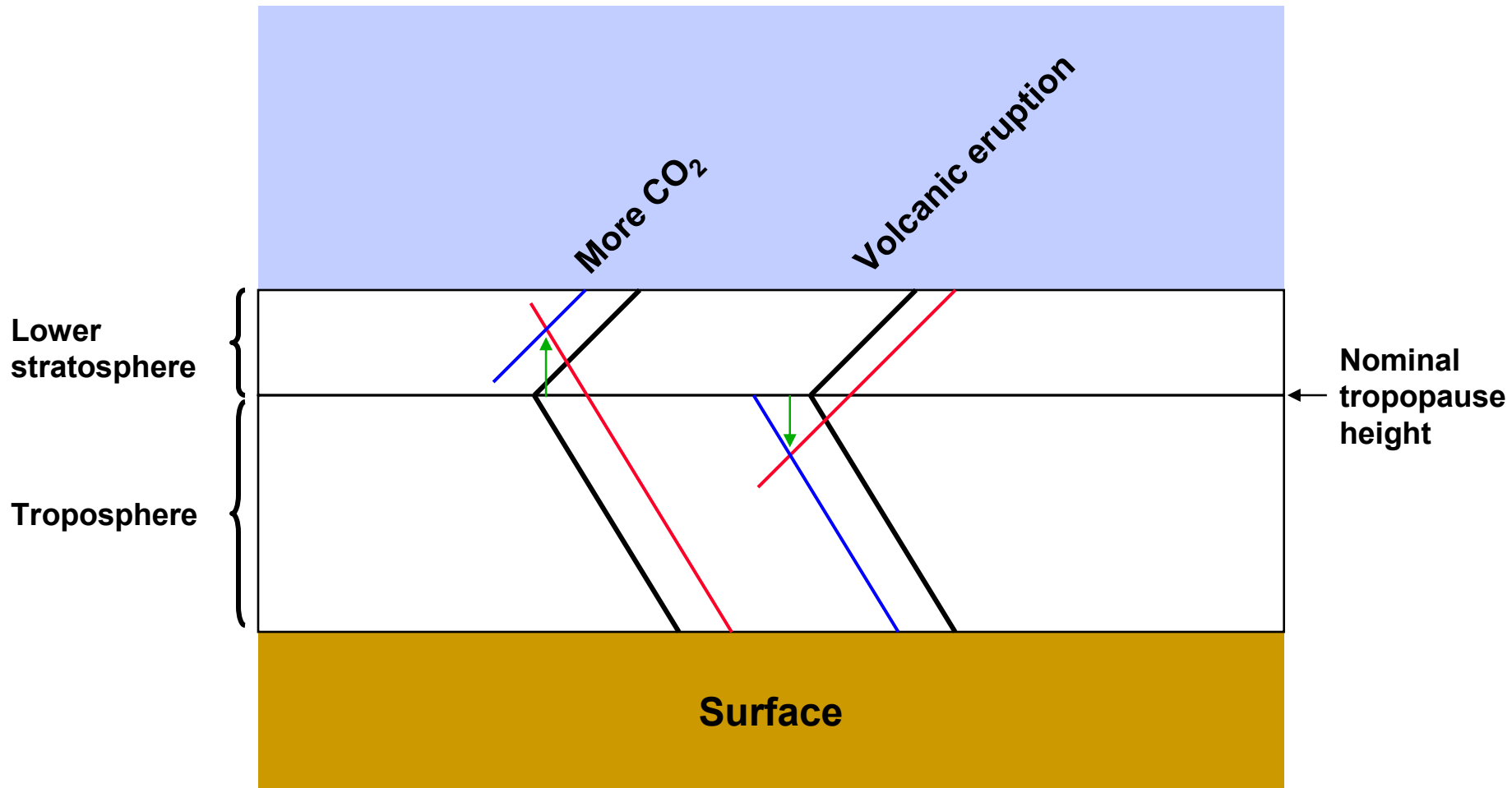
Tropopause



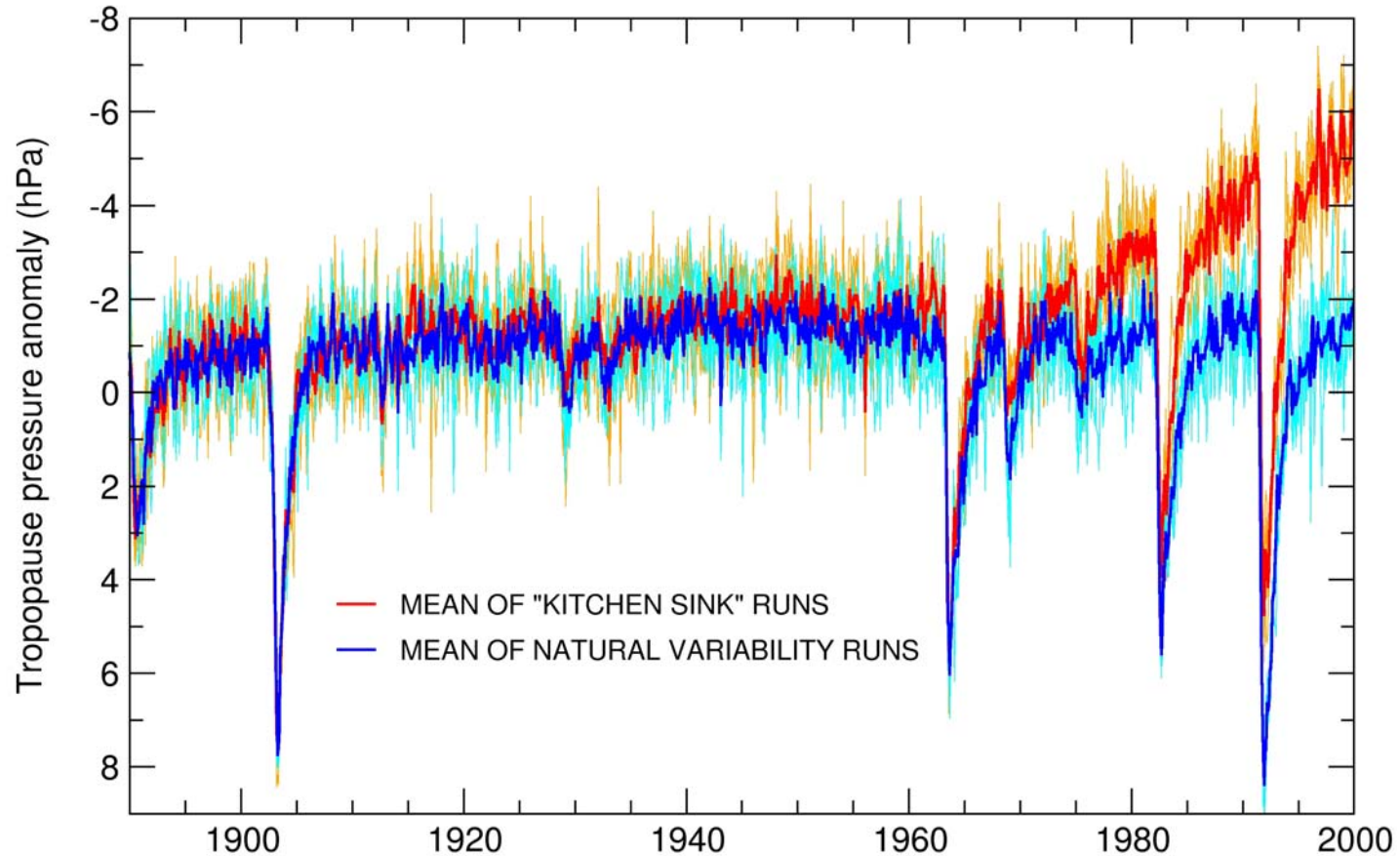
# Are recent tropopause height changes similar in models and 'observations'?



# A simplified interpretation of tropopause height changes....



# Climate model simulations of changes in tropopause height

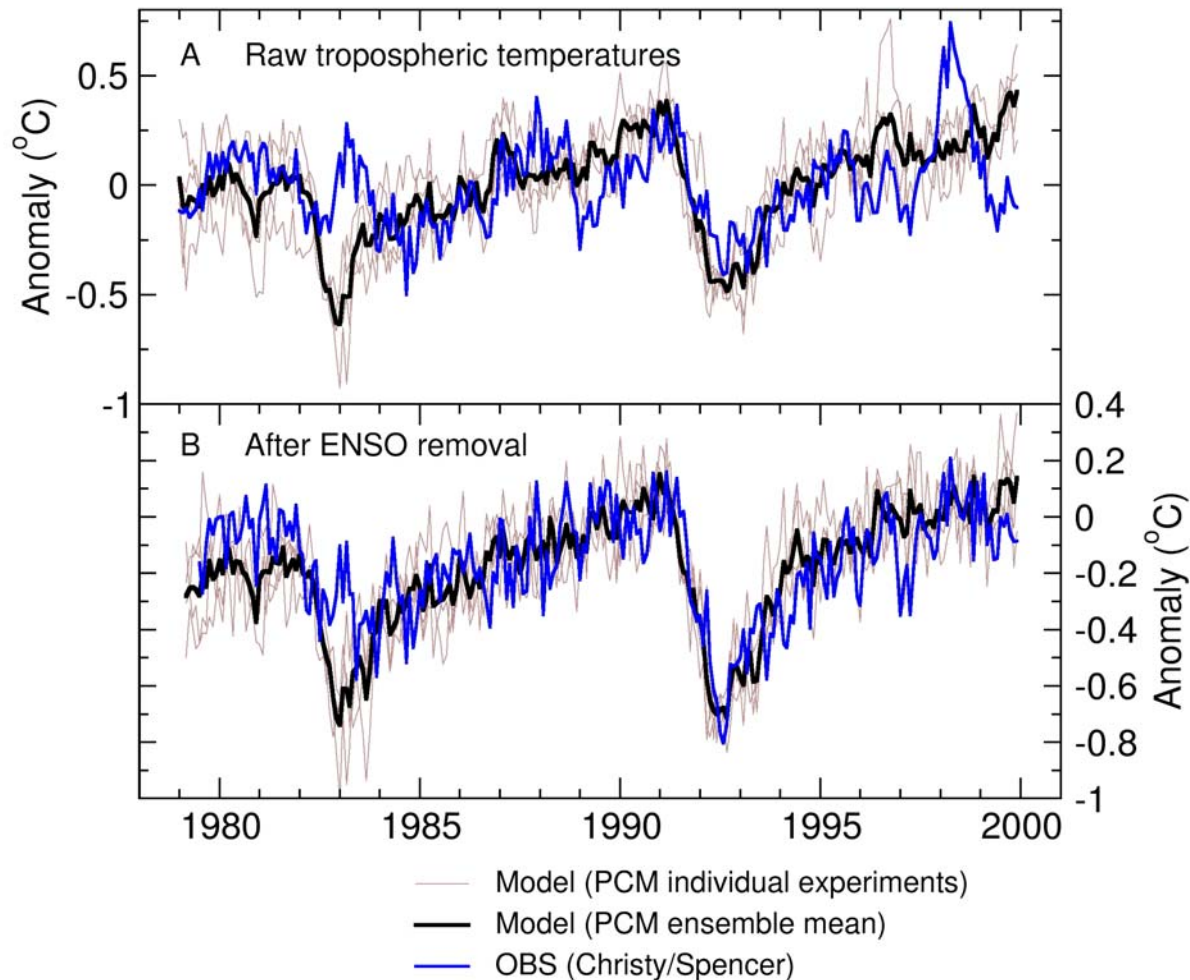


*All model results are from the Parallel Climate Model (PCM) of the National Center for Atmospheric Research*



# Is PCM useful for studying tropopause height changes?

Tropospheric Temperatures Before and After ENSO Removal  
MSU Channel 2



# ***Conclusions***

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- **Without the Pinatubo and El Chichón volcanic eruptions, the troposphere would have warmed over 1979 to present**
- **These eruptions cooled the troposphere more than the surface**
- **Modeled and observed surface temperature trends are in good agreement**
- **We still need to reconcile differences between modeled and observed tropospheric warming trends**
- **Observational uncertainty may help to explain some of these remaining differences**
- **Recent tropopause height changes are consistent with a warming troposphere**

