The IPCC Historical Forcing Runs: PCMDI Analyses of an Ensemble of Opportunity

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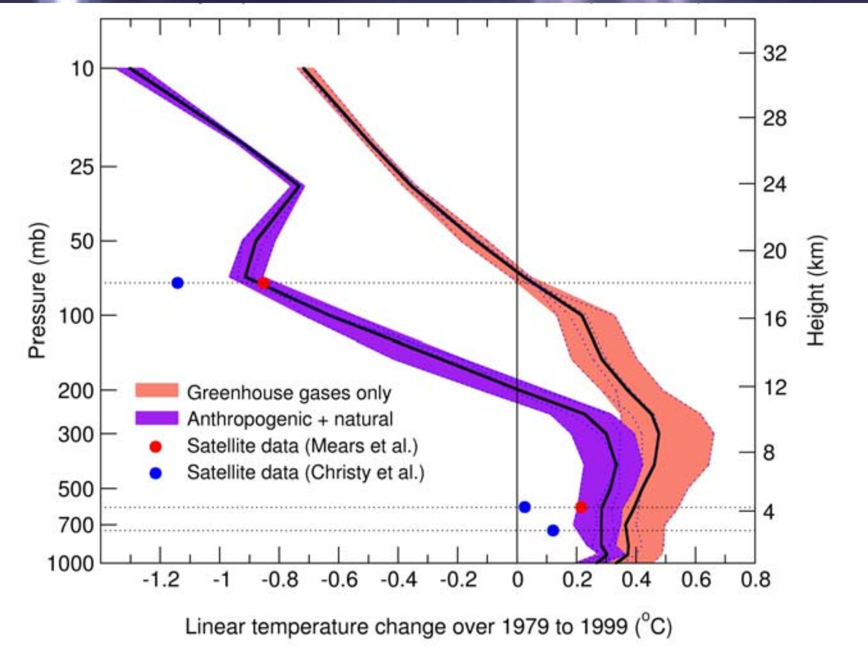

The scientific problem: Do satellite data invalidate "global warming theory"?

"…satellite measurements over 35 years show no significant warming in the lower atmosphere, which is an essential part of the global-warming theory".

James Schlesinger (former U.S. Secretary of Energy, Secretary of Defense, and Director of the CIA), "Cold Facts on Global Warming", L.A. Times, January 22, 2004

Structure of talk

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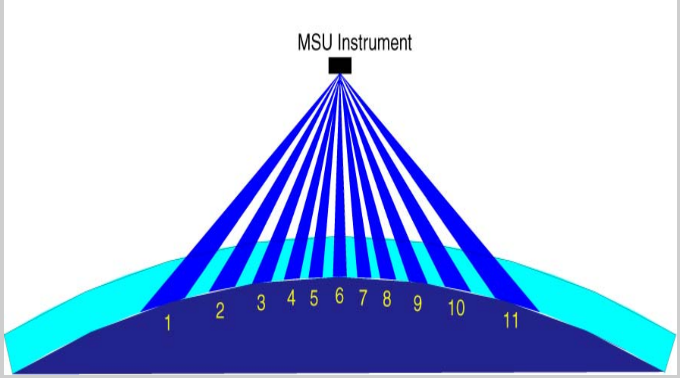
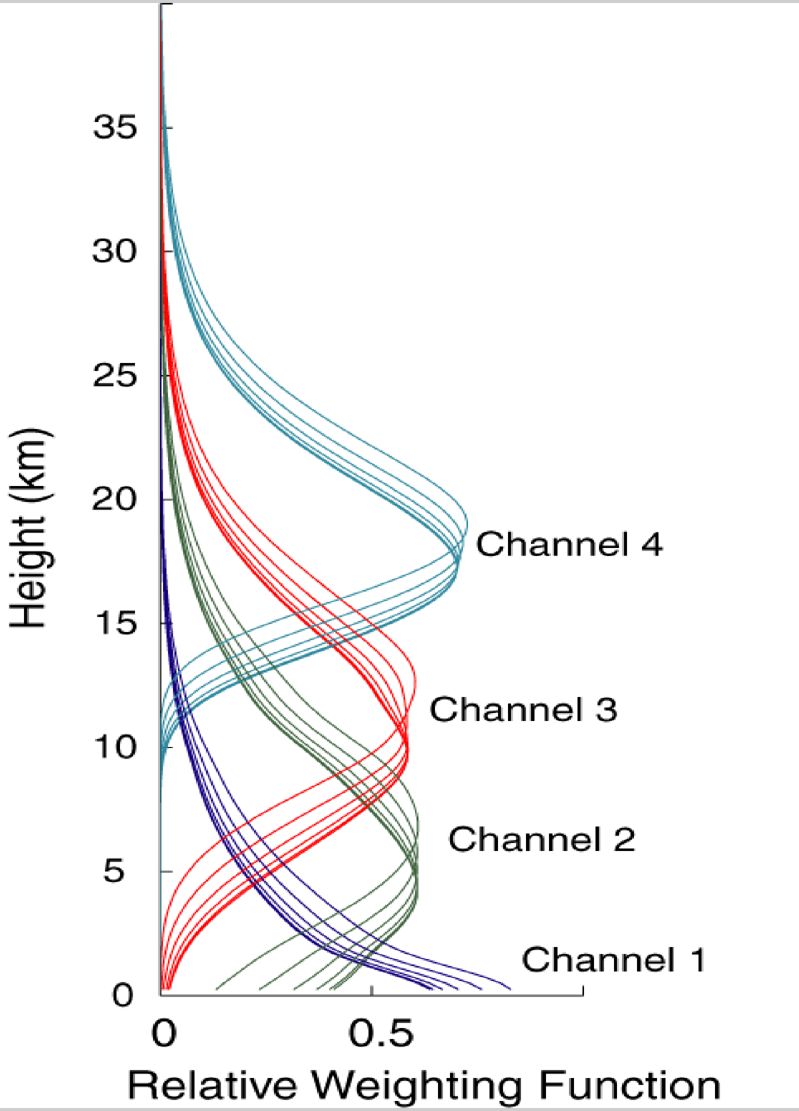
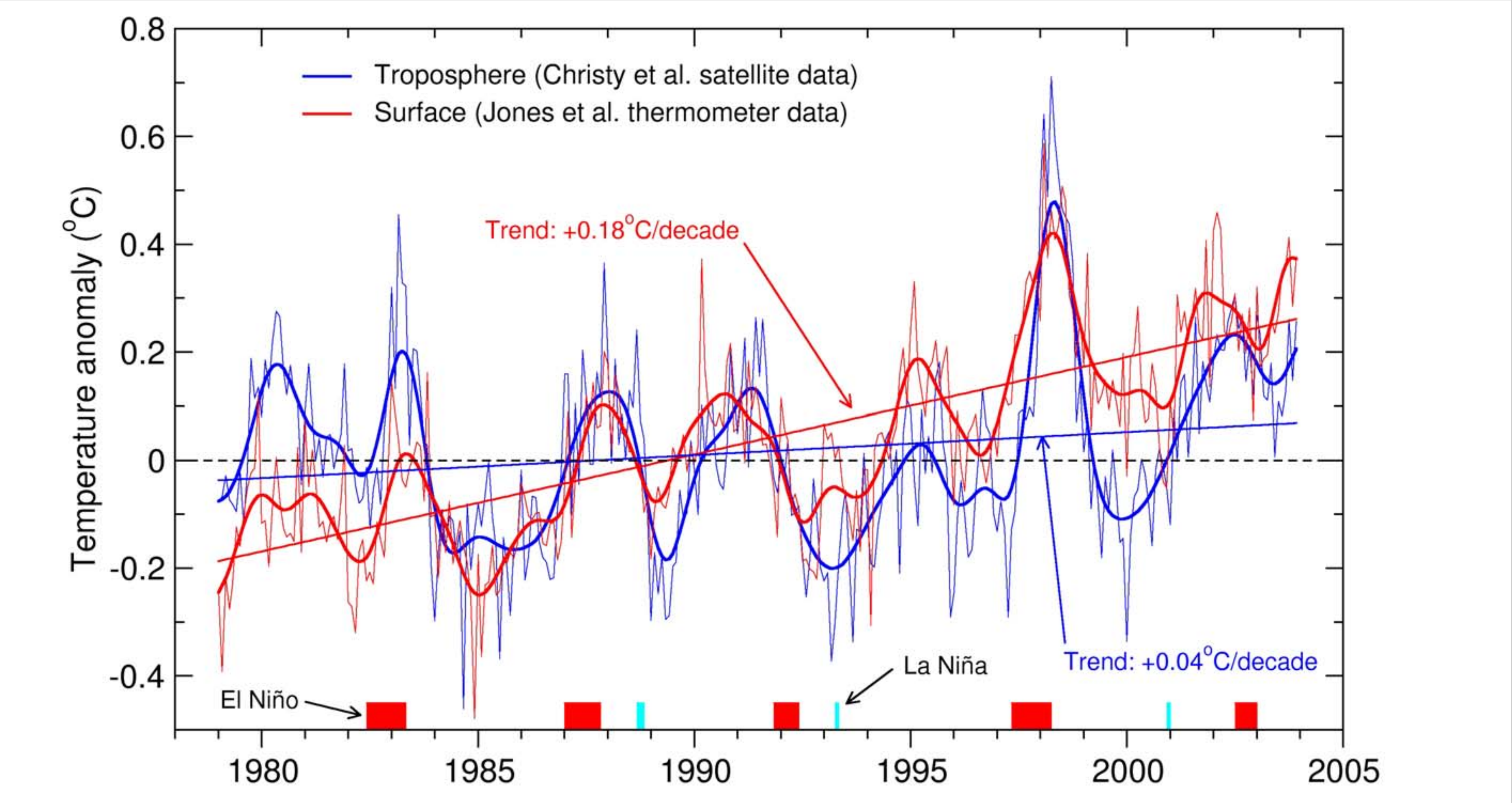
Satellites have been used to measure temperatures of broad atmospheric layers

- Microwave Sounding Units (MSUs) have been flown on over 12 polar-orbiting satellites since late 1978
- MSUs measure the microwave emissions of oxygen molecules
- Measurements at different frequencies retrieve temperatures of different atmospheric layers
- MSU Channel 4: monitors lower stratosphere
- MSU Channel 2: monitors troposphere



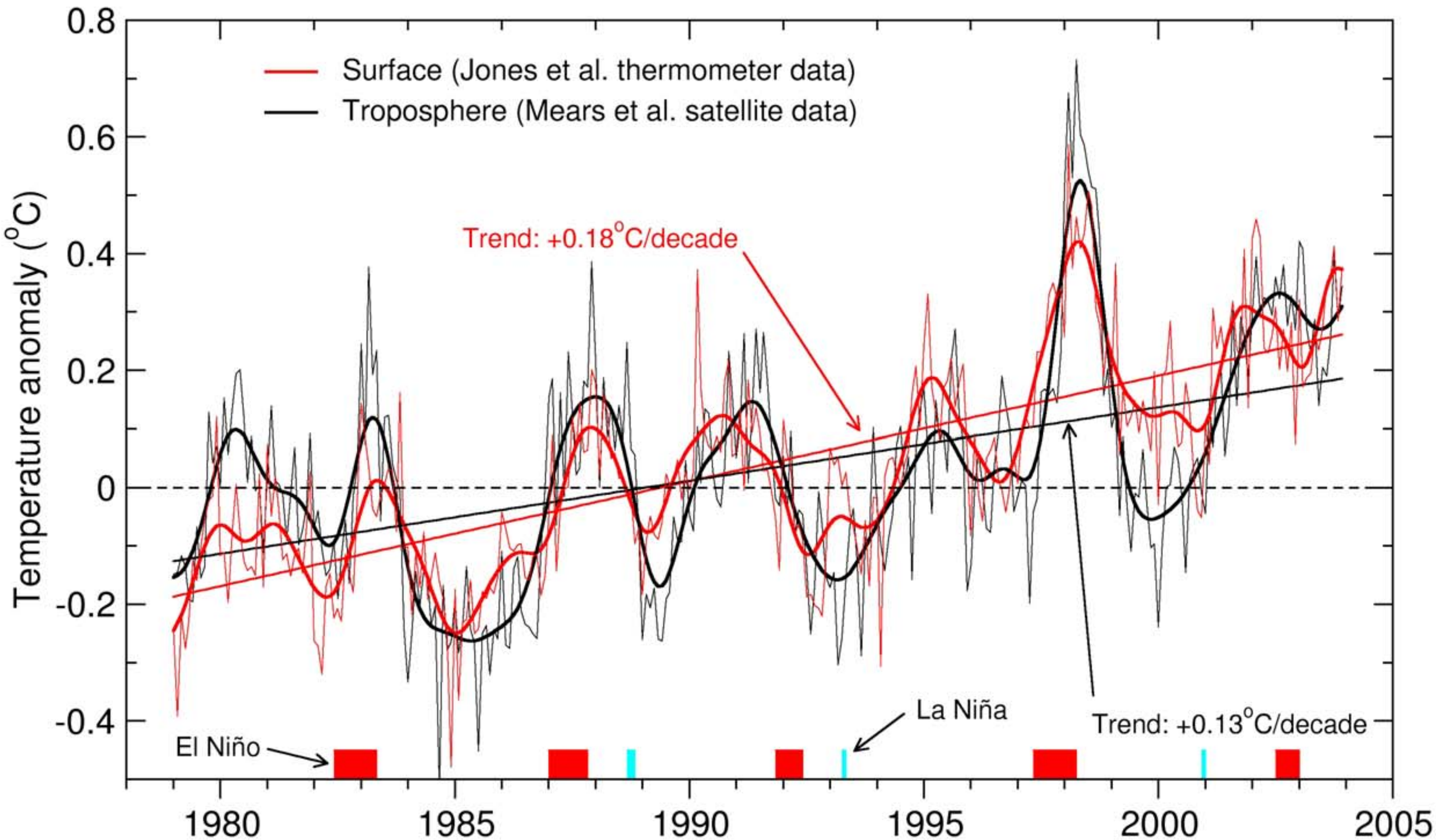


One satellite dataset suggests that the surface and troposphere have warmed at different rates



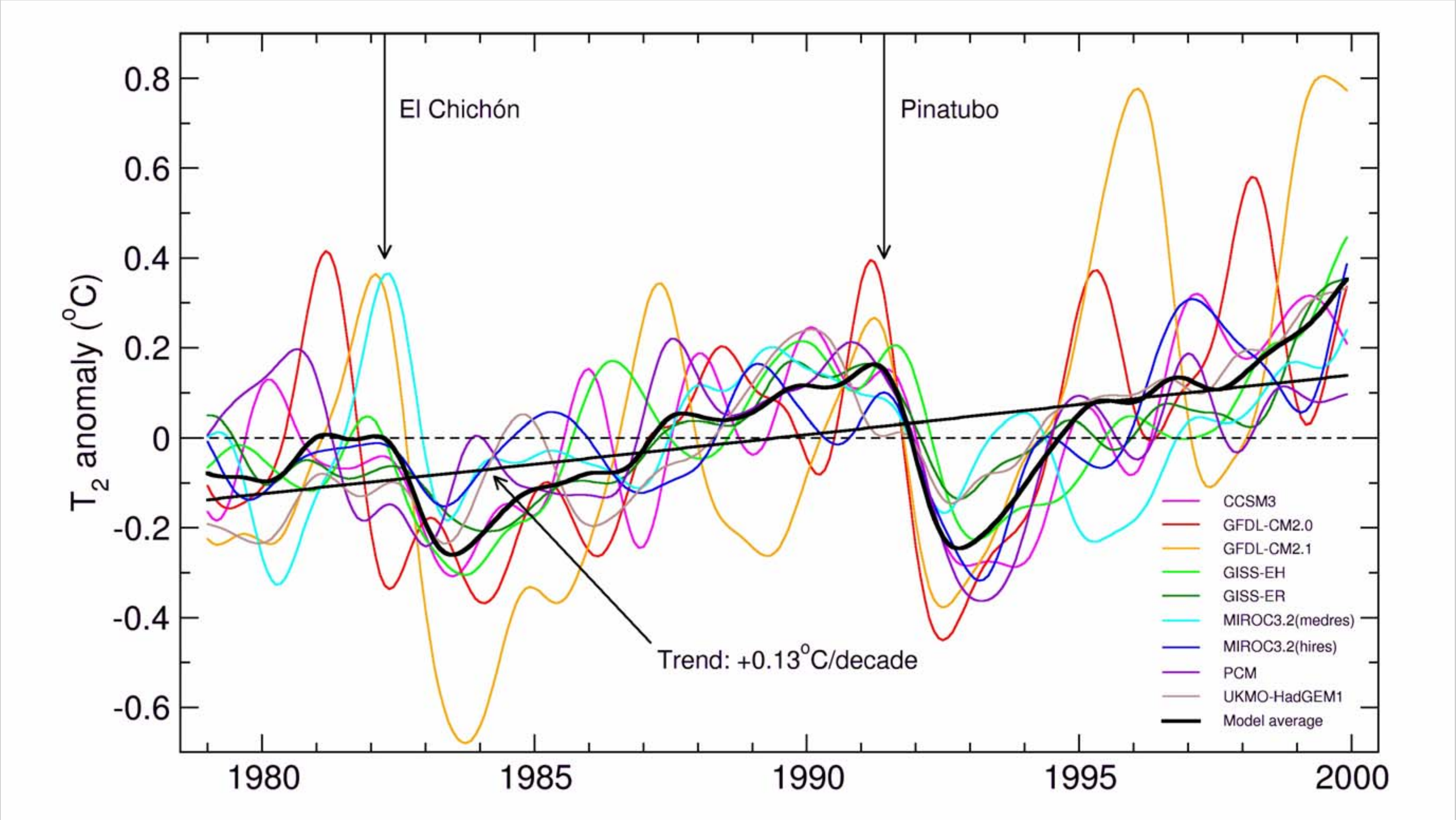
Satellite data: MSU channel 2

Surface and tropospheric warming rates are more similar using a second satellite dataset



Satellite data: MSU channel 2

Climate models indicate that the troposphere should have warmed over the last 26 years



Global means. Individual realizations. "IPCC class" climate models, MSU channel 2

There are two separate "discrepancies"

1. **Between different observational datasets:**

   - Surface thermometer data show strong warming of Earth's surface, while one satellite dataset and weather balloons show muted warming of troposphere
   - Casts doubt on reality of surface warming

2. **Between modeled and observed tropospheric temperature changes:**

   - Models show pronounced tropospheric warming should be occurring; such warming is absent in one satellite dataset and in weather balloons
   - Casts doubts on climate models and on "global warming theory"

Possible explanations for first “discrepancy” (differential warming in observations)

1: Inhomogeneities in surface temperature data

2: Inhomogeneities in satellite and radiosonde data

3: Differences in coverage of satellite and surface data

4: Natural internal climate variability

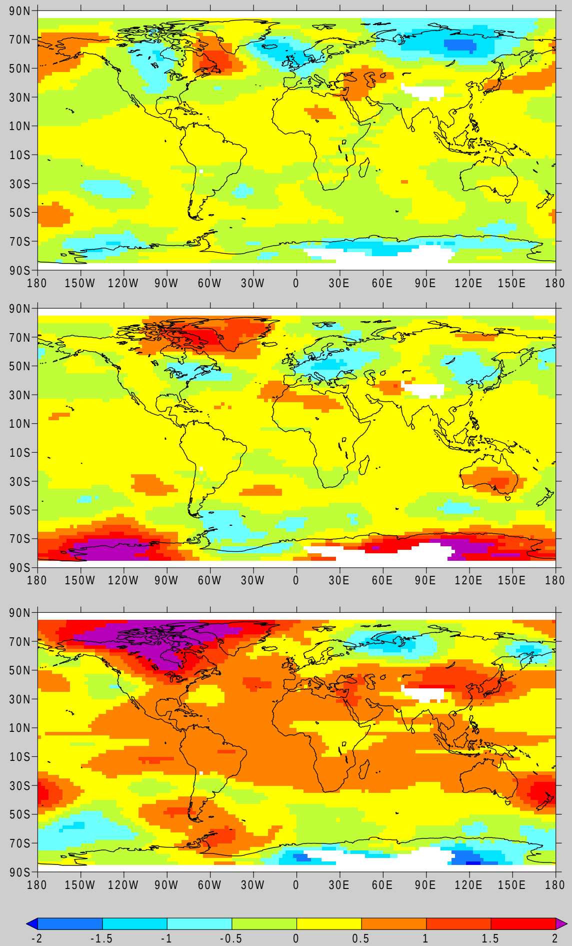
- Physical processes with different temperature effects at the surface and aloft (e.g., North Atlantic Oscillation, El Niño)

5: External forcing

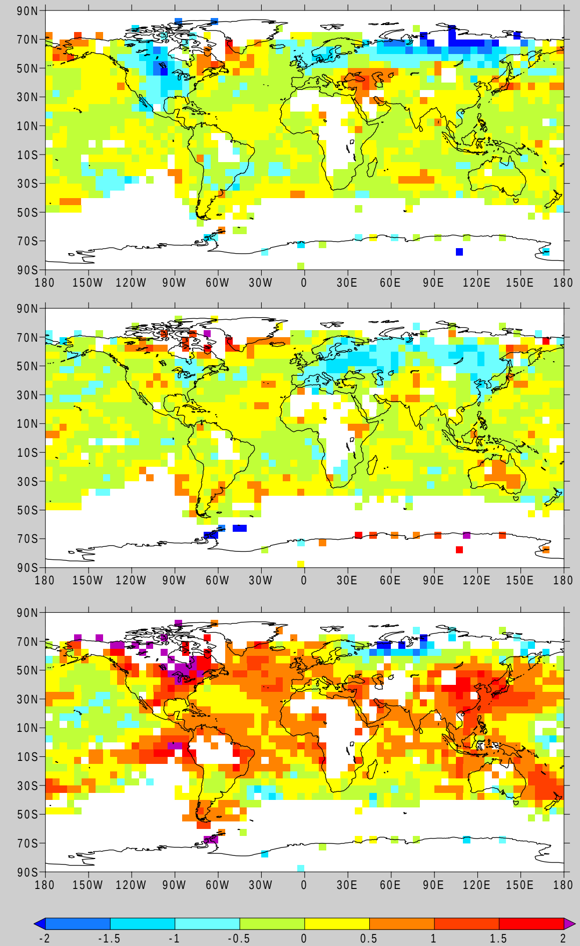
- Changes in greenhouse gases, anthropogenic sulfate aerosols, stratospheric ozone depletion, volcanic aerosols

Differences in coverage of satellite and surface data

MSUd lower troposphere



IPCC near-surface



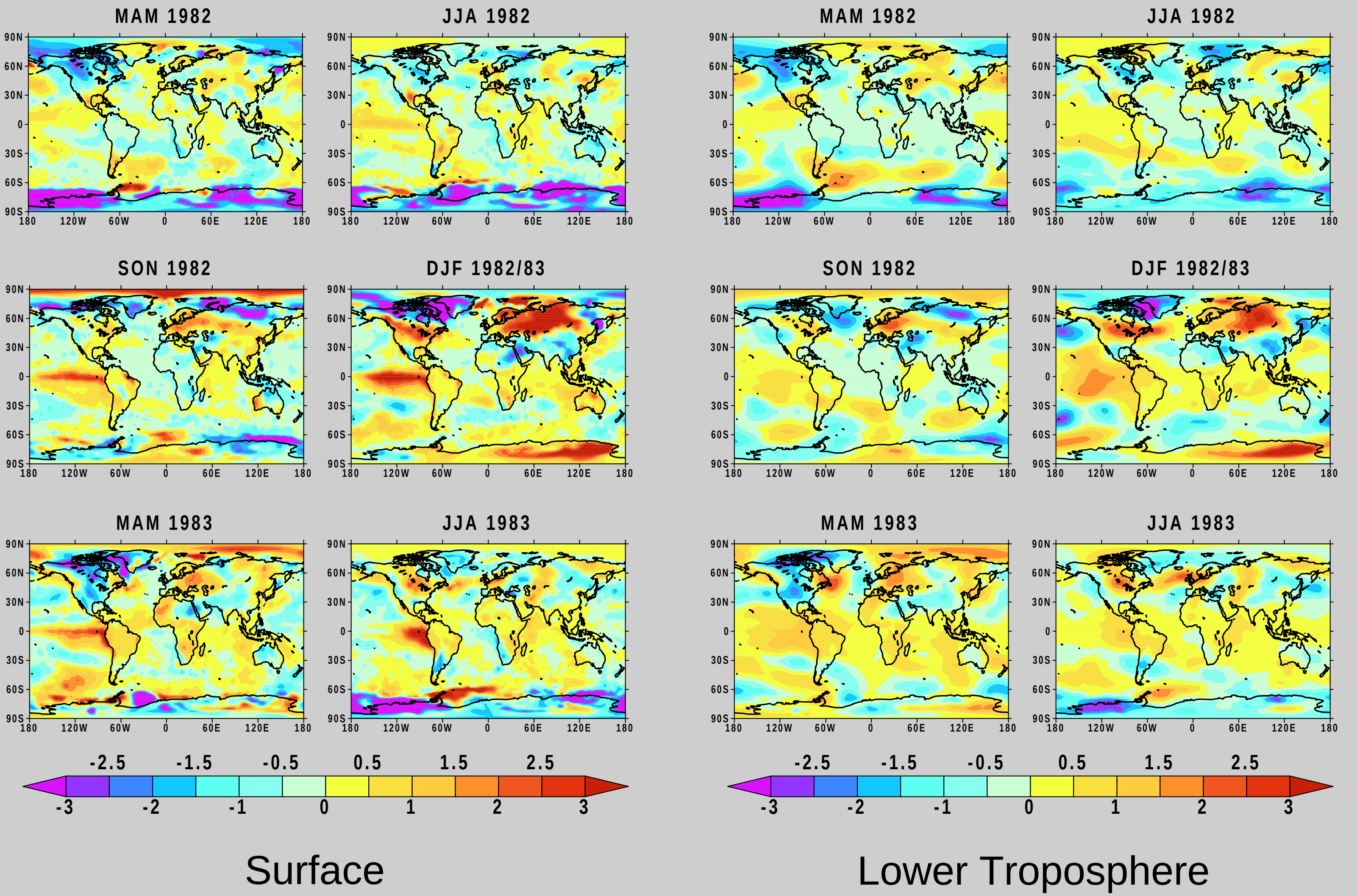
1979

1980

1998

Annual-mean temperature anomalies (^oC) w.r.t. 1979-93

Natural internal climate variability



Temperature anomalies at the surface and in the lower troposphere during the 1982/83 El Niño

External forcing: Effects of volcanic eruptions

Satellite tropospheric temperature data

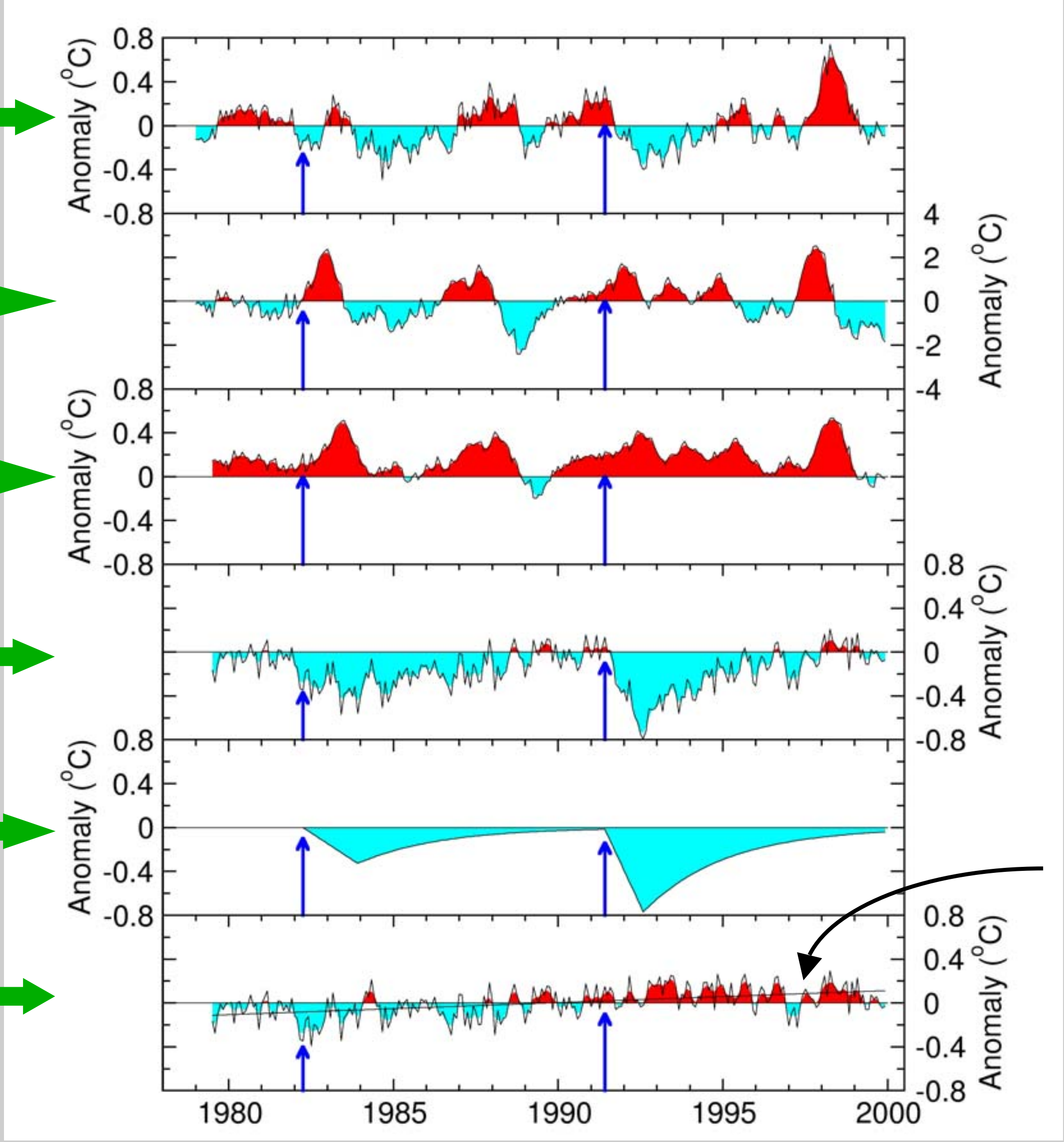
El Niño index

El Niño effect on temperature

Satellite data minus El Niño effect

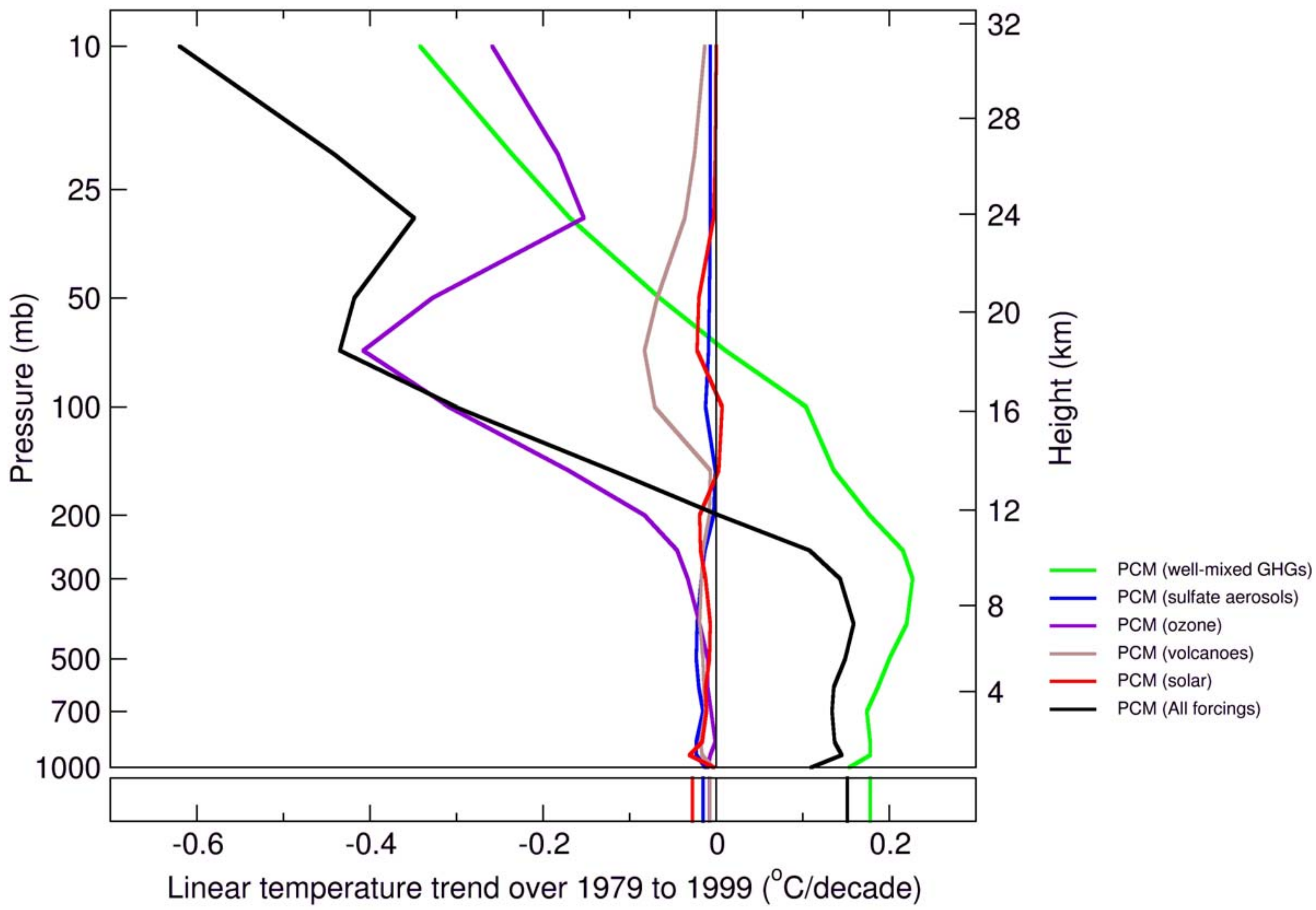
Volcano effect on temperature

After removing El Niño and volcanoes



Trend in residuals: 0.11°C/decade

Different external forcings can have different effects on atmospheric temperature profiles



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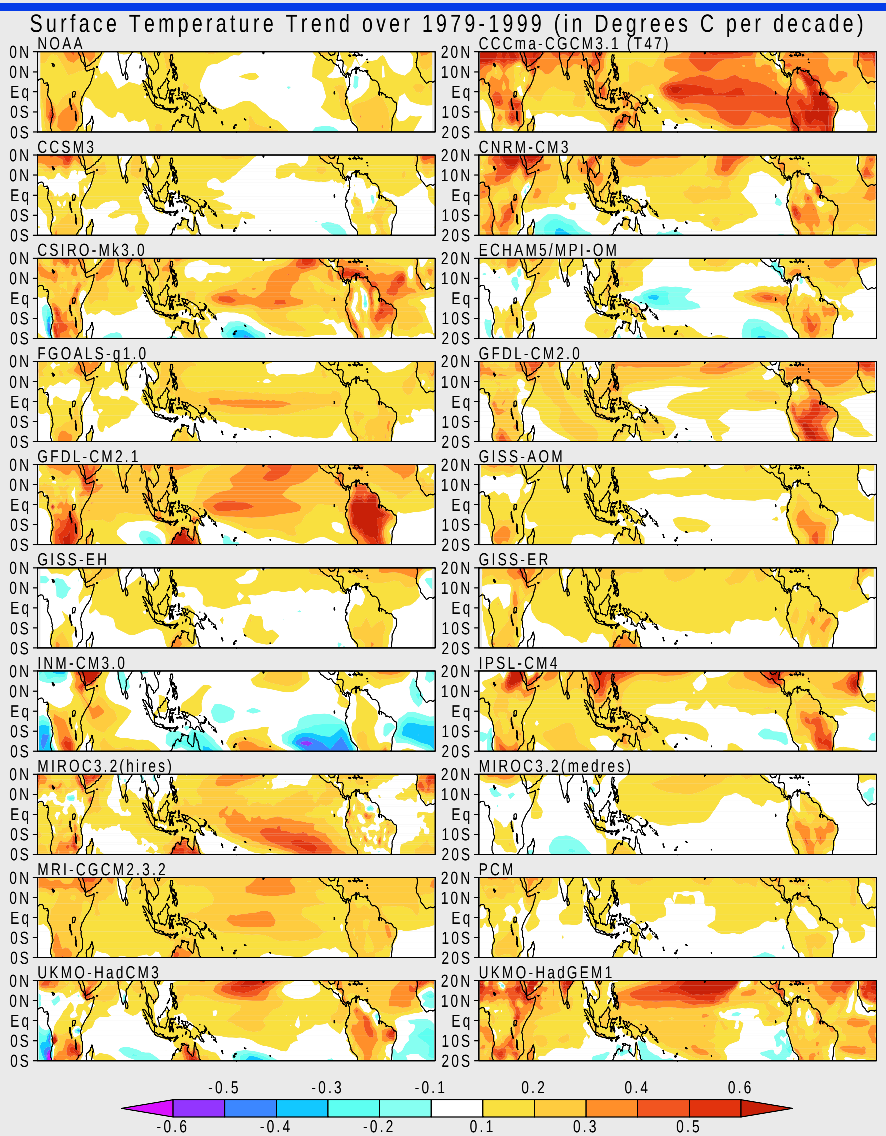
Forcings used in IPCC AR4 “20c3m” simulations

	Model	G	O	SD	SI	BC	OC	MD	SS	LU	SO	V
1	CCCma-CGCM3.1(T47)	■		■								
2	CCSM3	■	■	■		■					■	■
3	CNRM-CM3	■	■	■		■						
4	CSIRO-Mk3.0	■		■								
5	ECHAM5/MPI-OM	■	■	■	■							
6	FGOALS-g1.0	■		■								
7	GFDL-CM2.0	■	■	■		■	■			■	■	■
8	GFDL-CM2.1	■	■	■		■	■			■	■	■
9	GISS-AOM	■		■					■			
10	GISS-EH	■	■	■	■	■	■	■	■	■	■	■
11	GISS-ER	■	■	■	■	■	■	■	■	■	■	■
12	INM-CM3.0	■		■							■	
13	IPSL-CM4	■		■								
14	MIROC3.2(medres)	■	■	■		■	■	■	■	■	■	■
15	MIROC3.2(hires)	■	■	■		■	■	■	■	■	■	■
16	MRI-CGCM2.3.2	■		■							■	
17	PCM	■	■	■							■	■
18	UKMO-HadCM3	■	■	■	■							
19	UKMO-HadGEM1	■	■	■	■	■	■			■	■	■

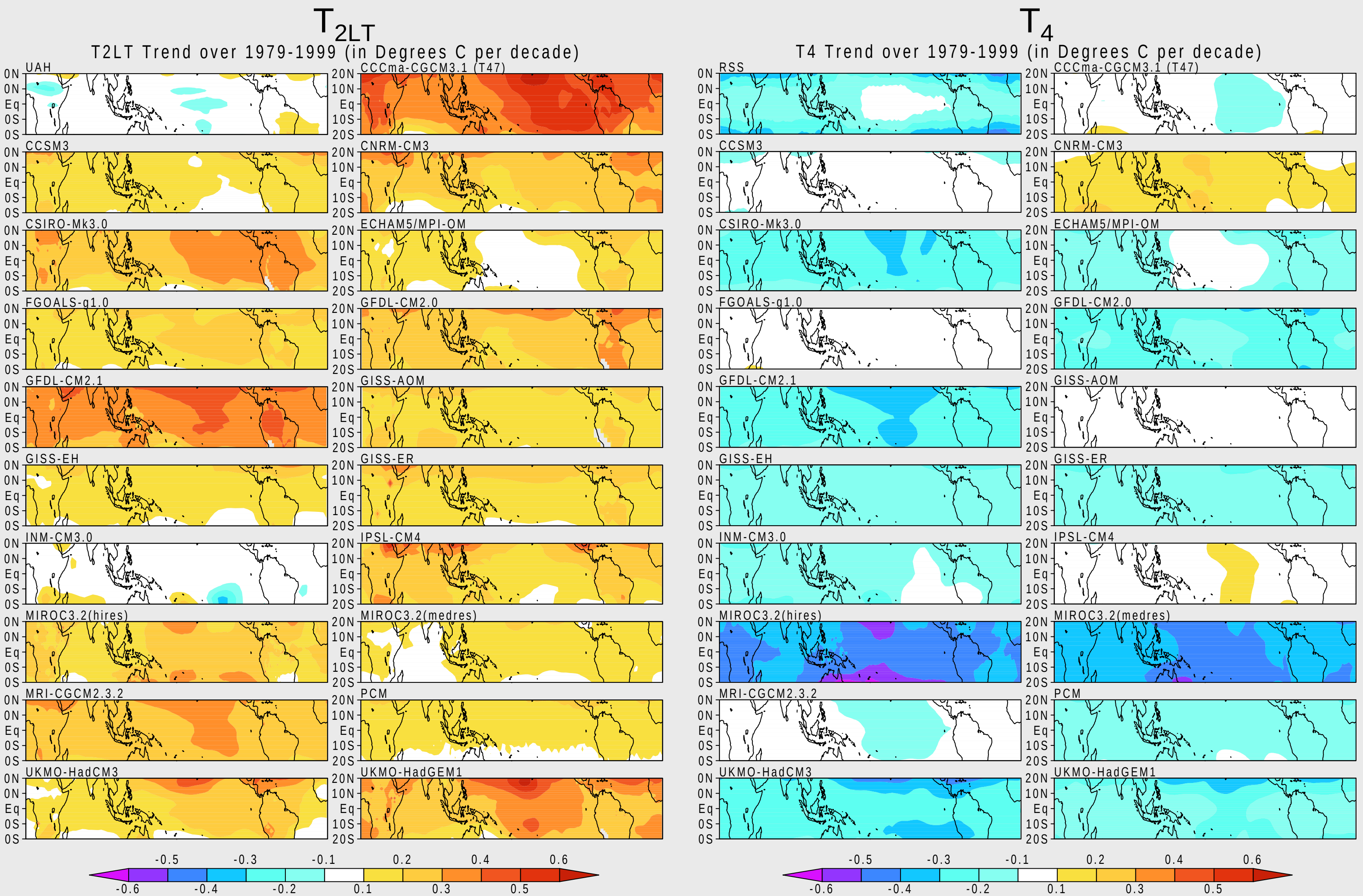
- Well-mixed GHGs
- Ozone
- Sulfate (direct)
- Sulfate (indirect)
- Black carbon
- Organic carbon
- Mineral dust
- Sea salt
- Land use
- Solar irradiance
- Volcanic aerosols

Simulated and observed surface temperature trends in the deep tropics: Gross structure (I)



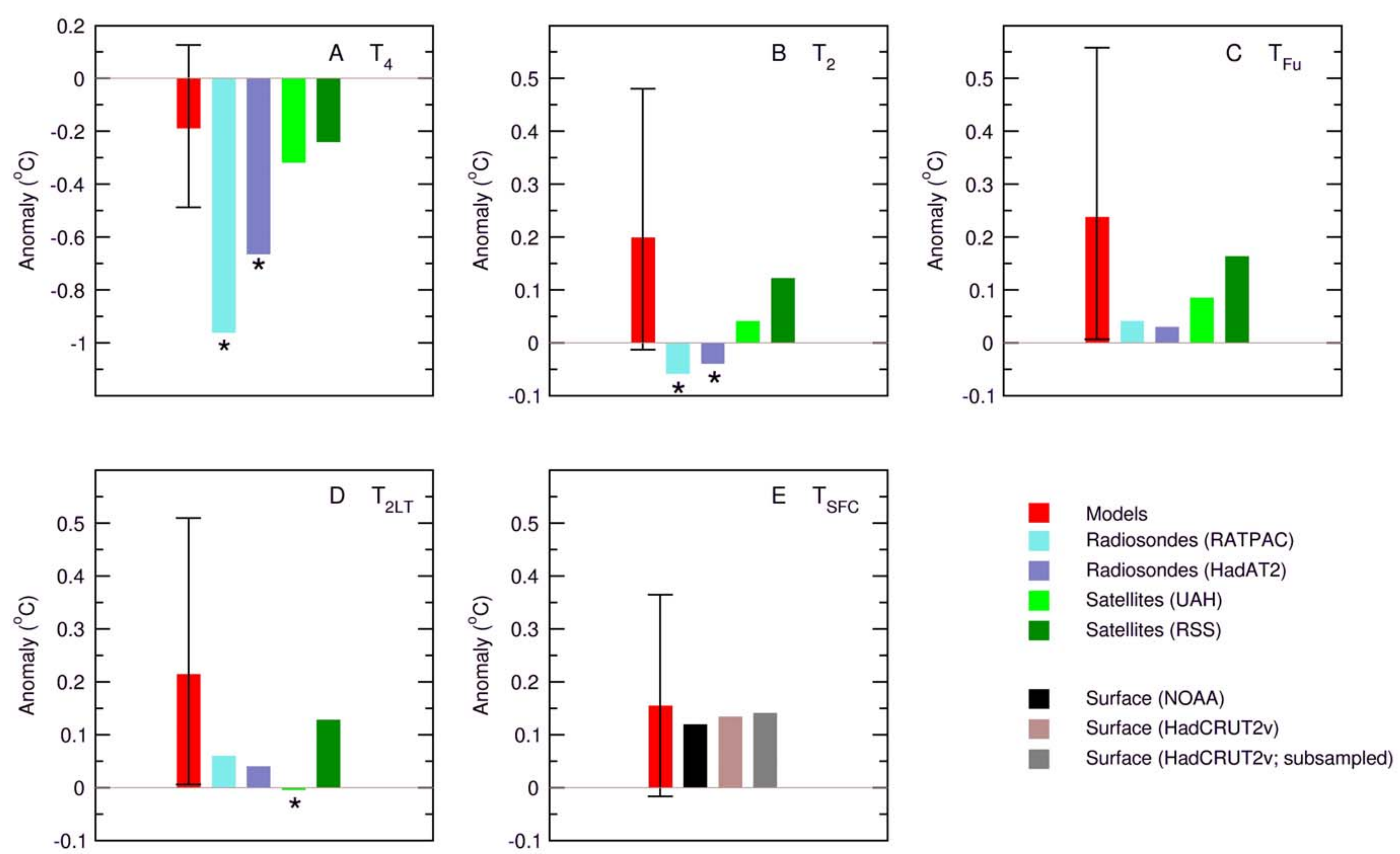
Trends (°C/decade) over 1979-1999

Simulated and observed atmospheric temperature trends in the deep tropics: Gross structure (II)

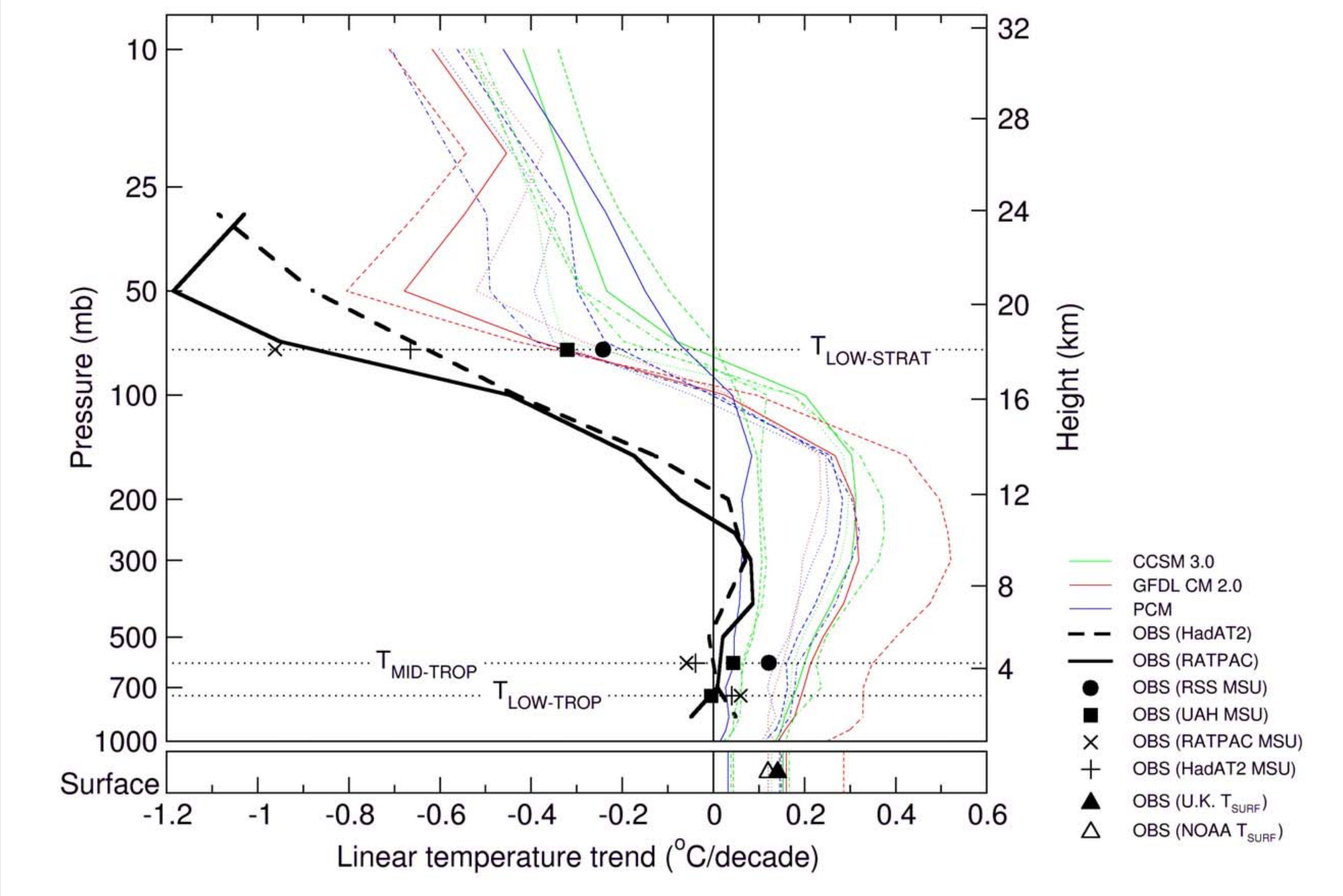


Trends (°C/decade) over 1979-1999

Simulated and observed temperature trends over 1979-99 in the deep tropics (20°N-20°S)



Simulated and observed temperature trends in the deep tropics (20°N-20°S)



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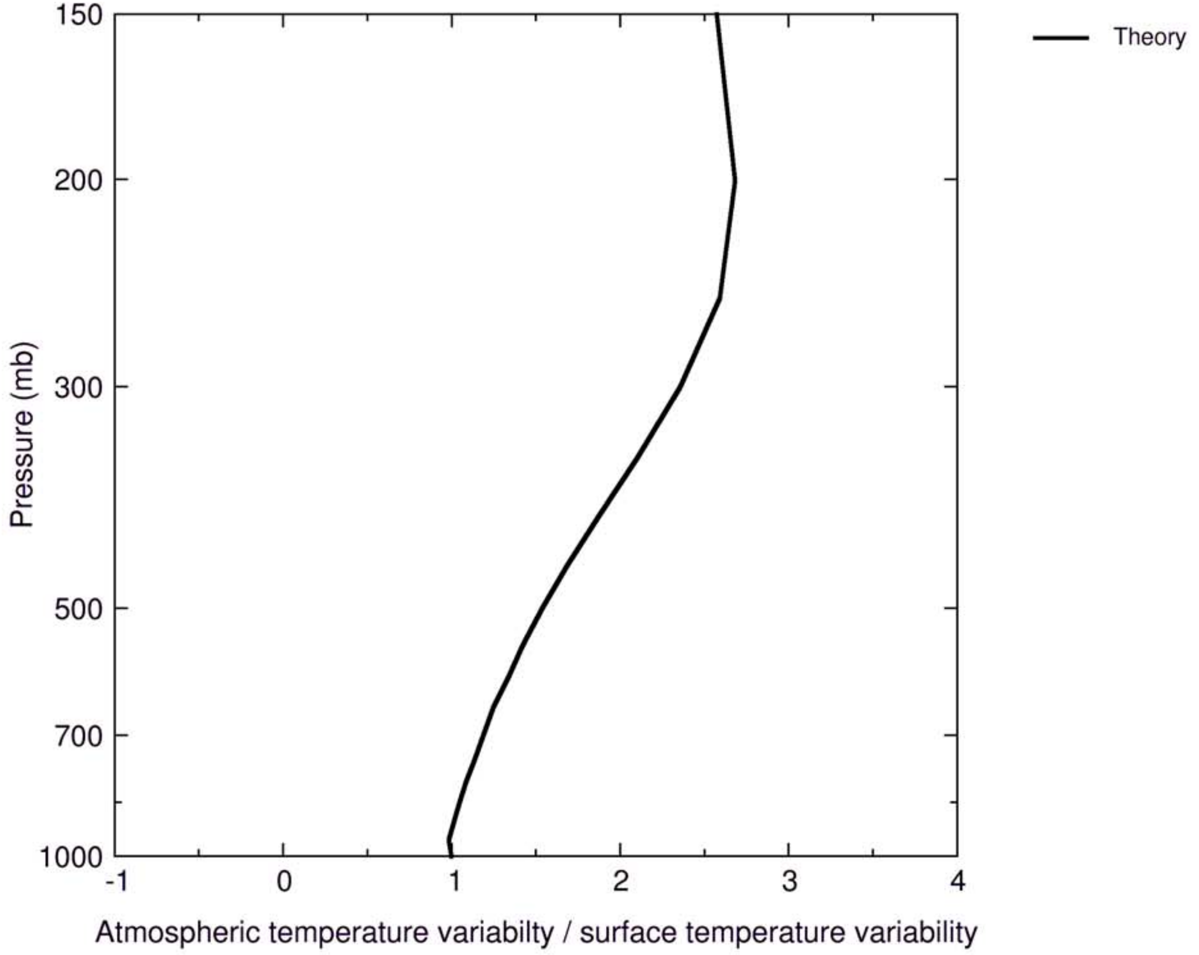
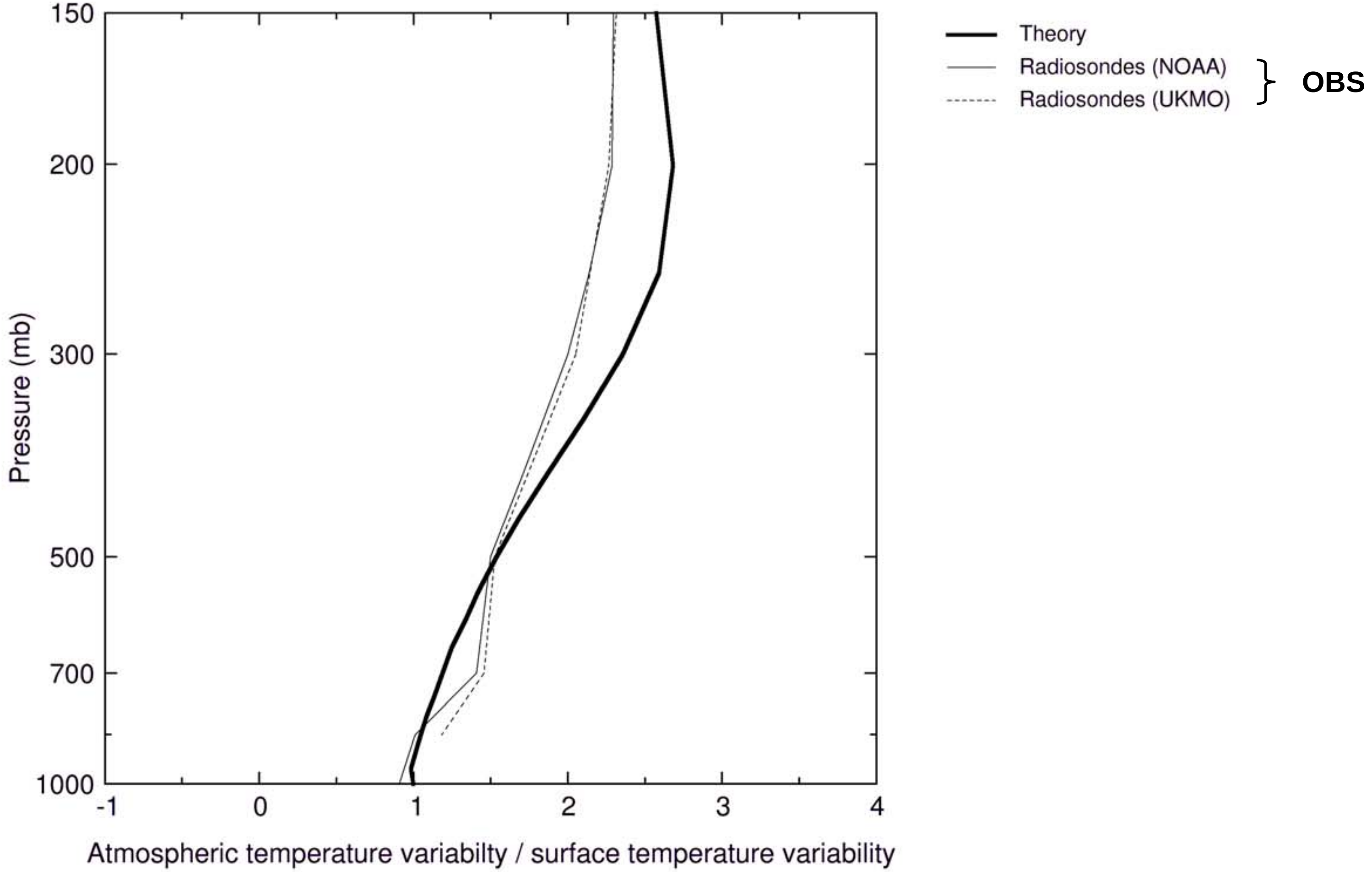
A brief primer on tropical lapse rates

- "Lapse rate" describes the overall vertical decrease in temperature with increasing height
  - ➔ Dry adiabatic lapse rate: 9.8°C/km
  - ➔ Lapse rate may be as low as 4°C/km in the tropics
  - ➔ Mean lapse rate in the troposphere: 6.5°C/km
- In broad regions of the tropics, temperatures behave according to a moist adiabatic lapse rate (MALR)
- Upward motion of moist tropical air eventually produces condensation, leading to latent heat release

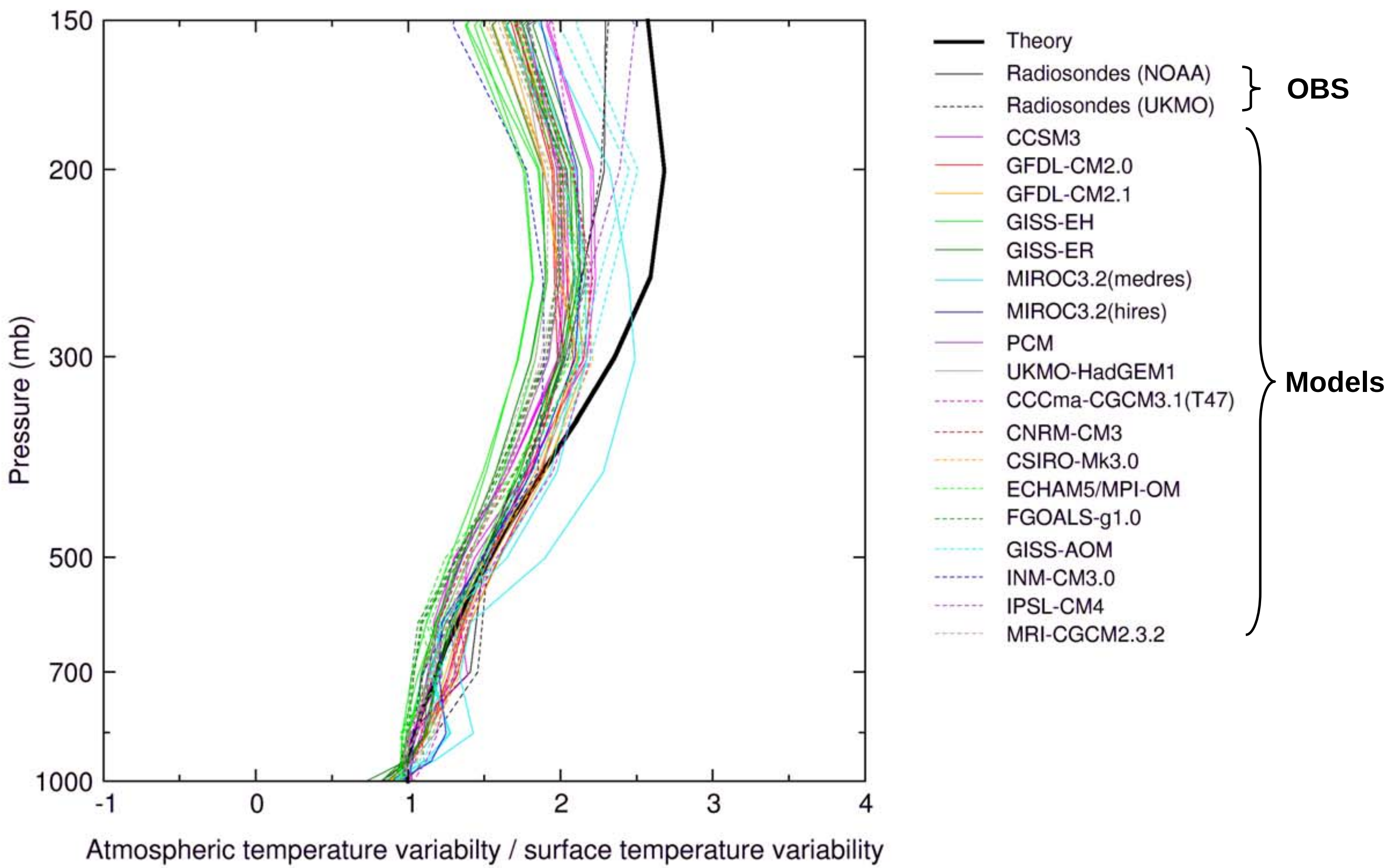
Surface temperature changes are amplified in the tropical troposphere (I)



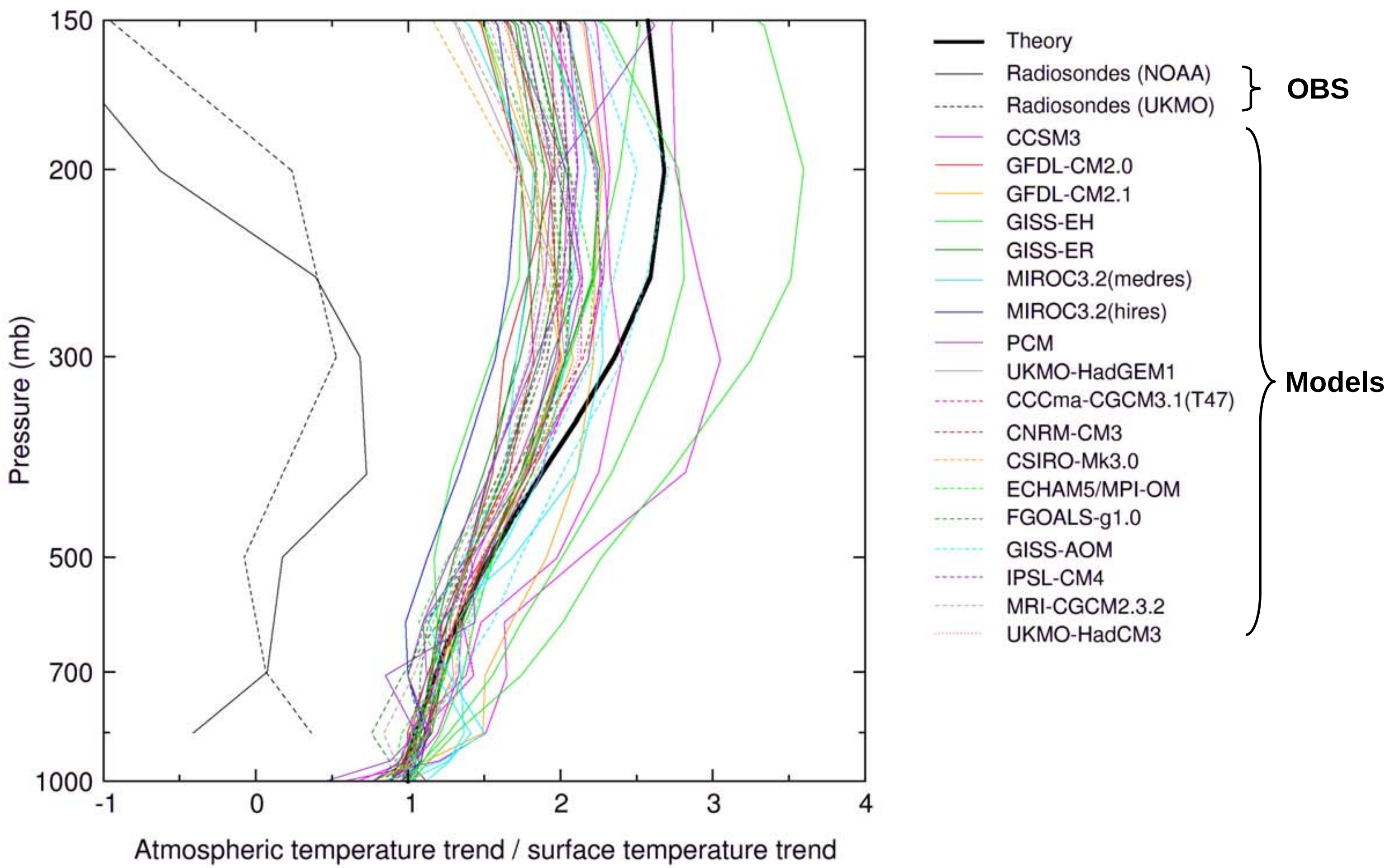
Surface temperature changes are amplified in the tropical troposphere (II)



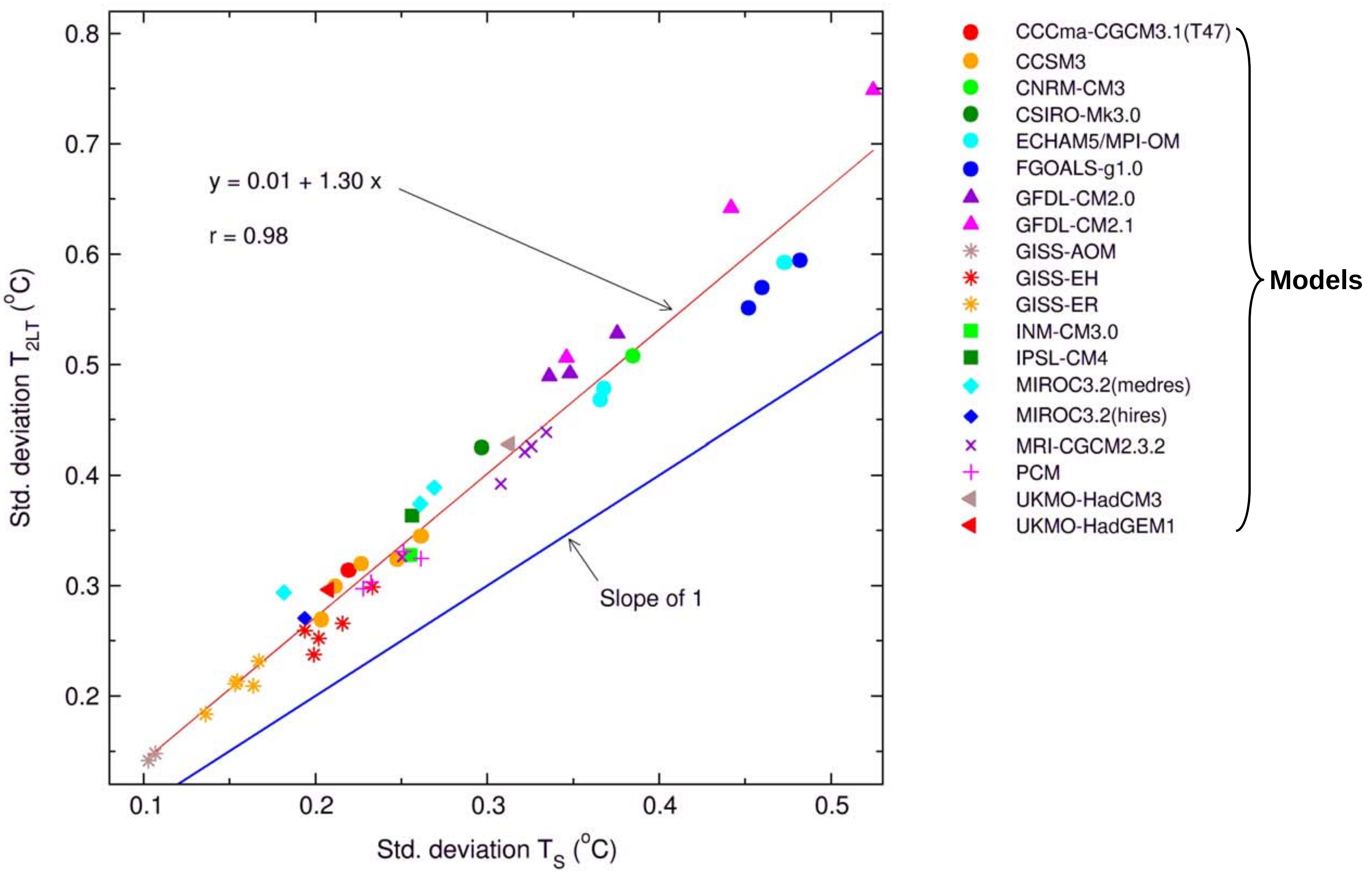
Surface temperature changes are amplified in the tropical troposphere (III)



Surface temperature changes are amplified in the tropical troposphere (IV)

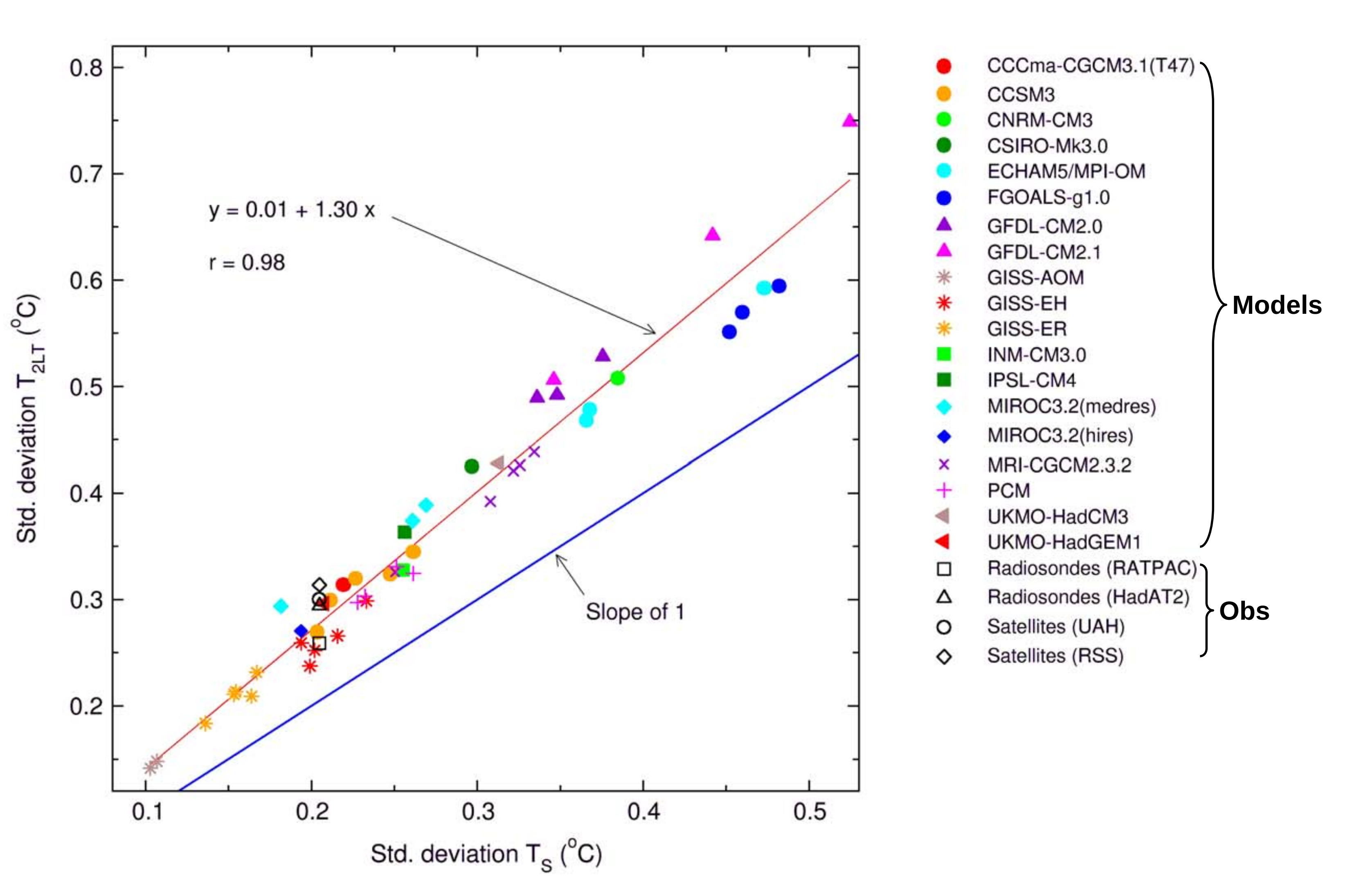


“Amplification factors” in the tropics: Results for month-to-month variability (I)



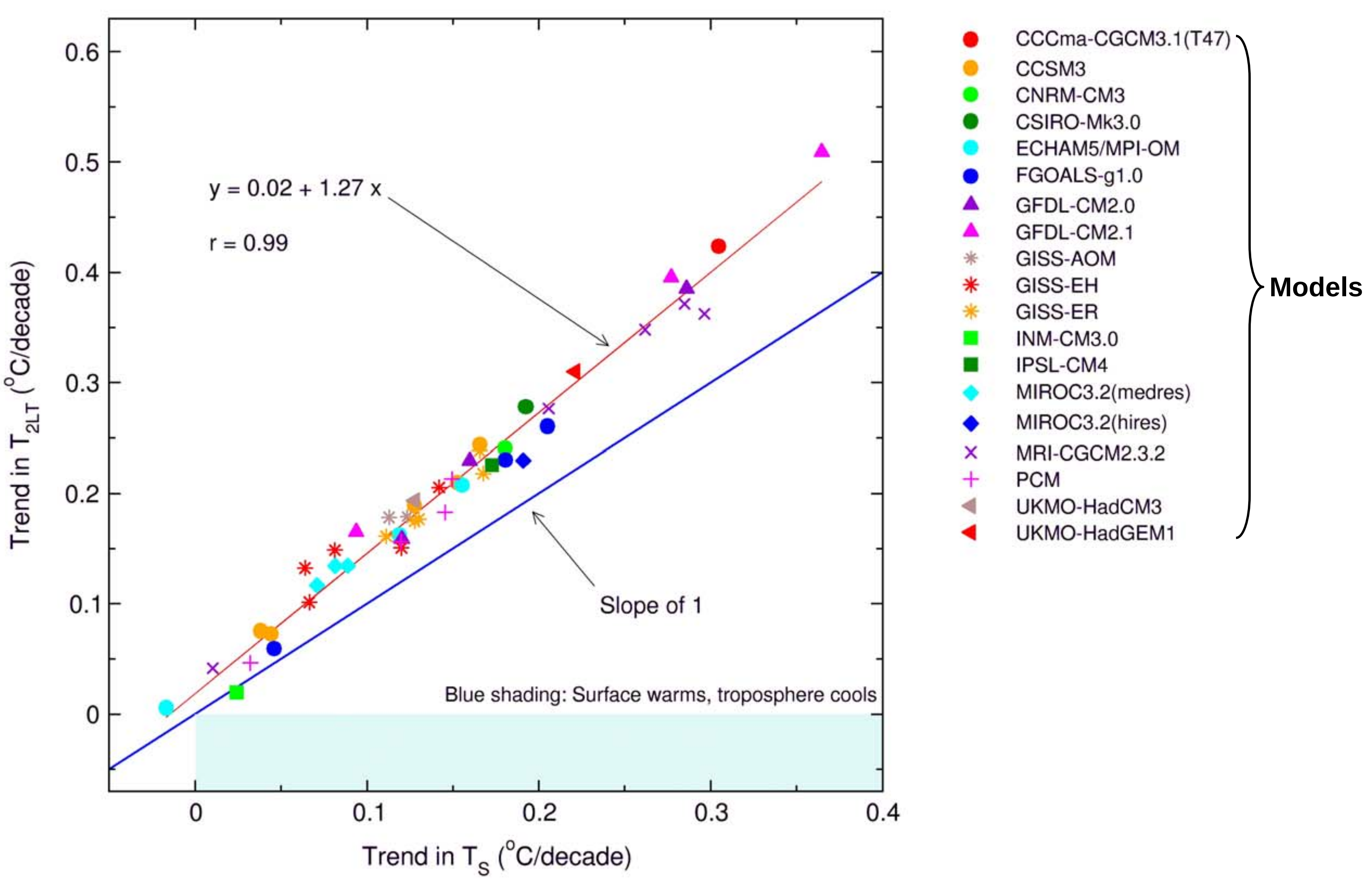
“IPCC class” climate models, tropics (20°N-20°S)

"Amplification factors" in the tropics: Results for month-to-month variability (II)



"IPCC class" climate models, tropics (20°N-20°S)

“Amplification factors” in the tropics: Results for decade-to-decade changes (I)



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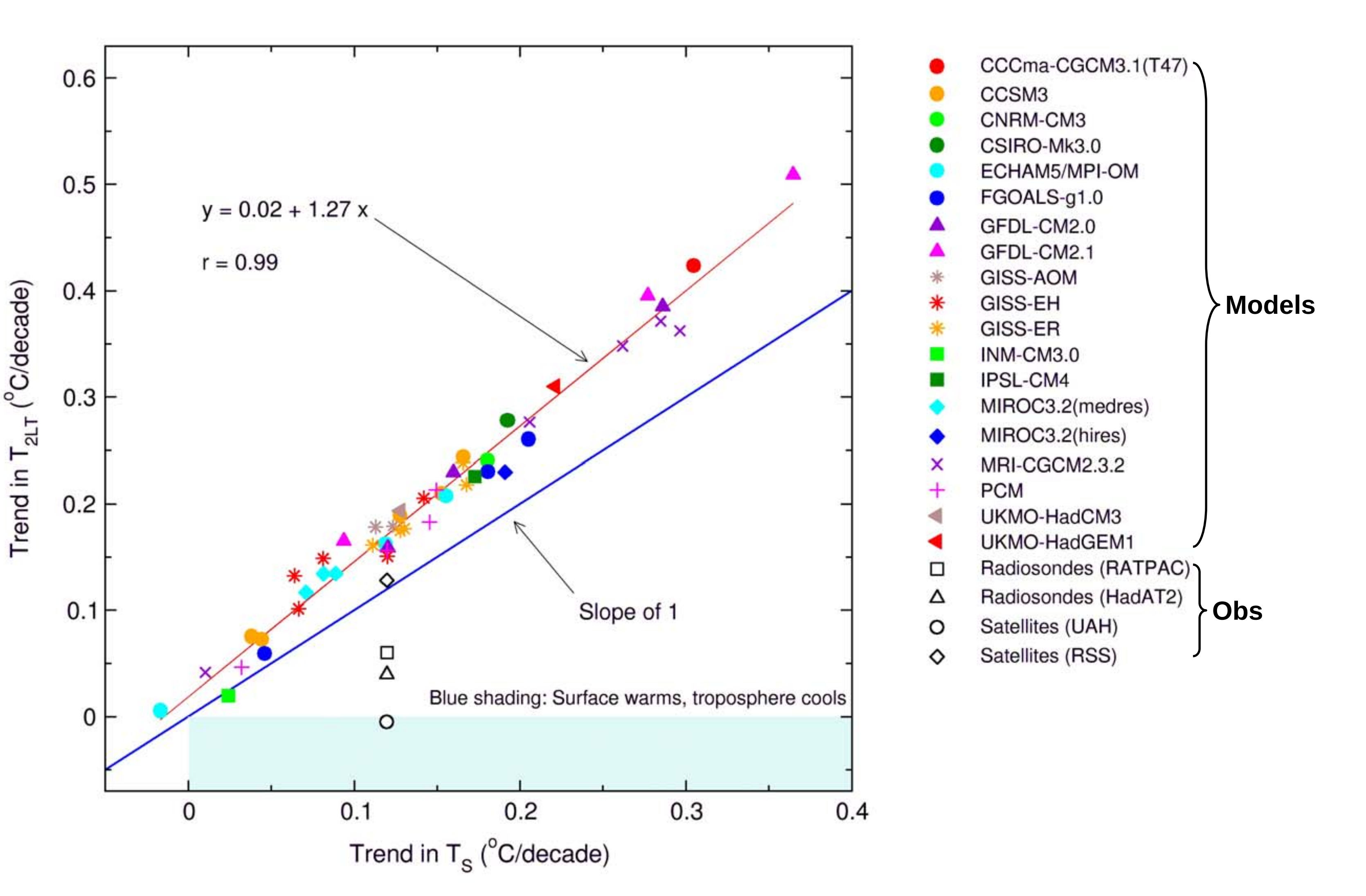
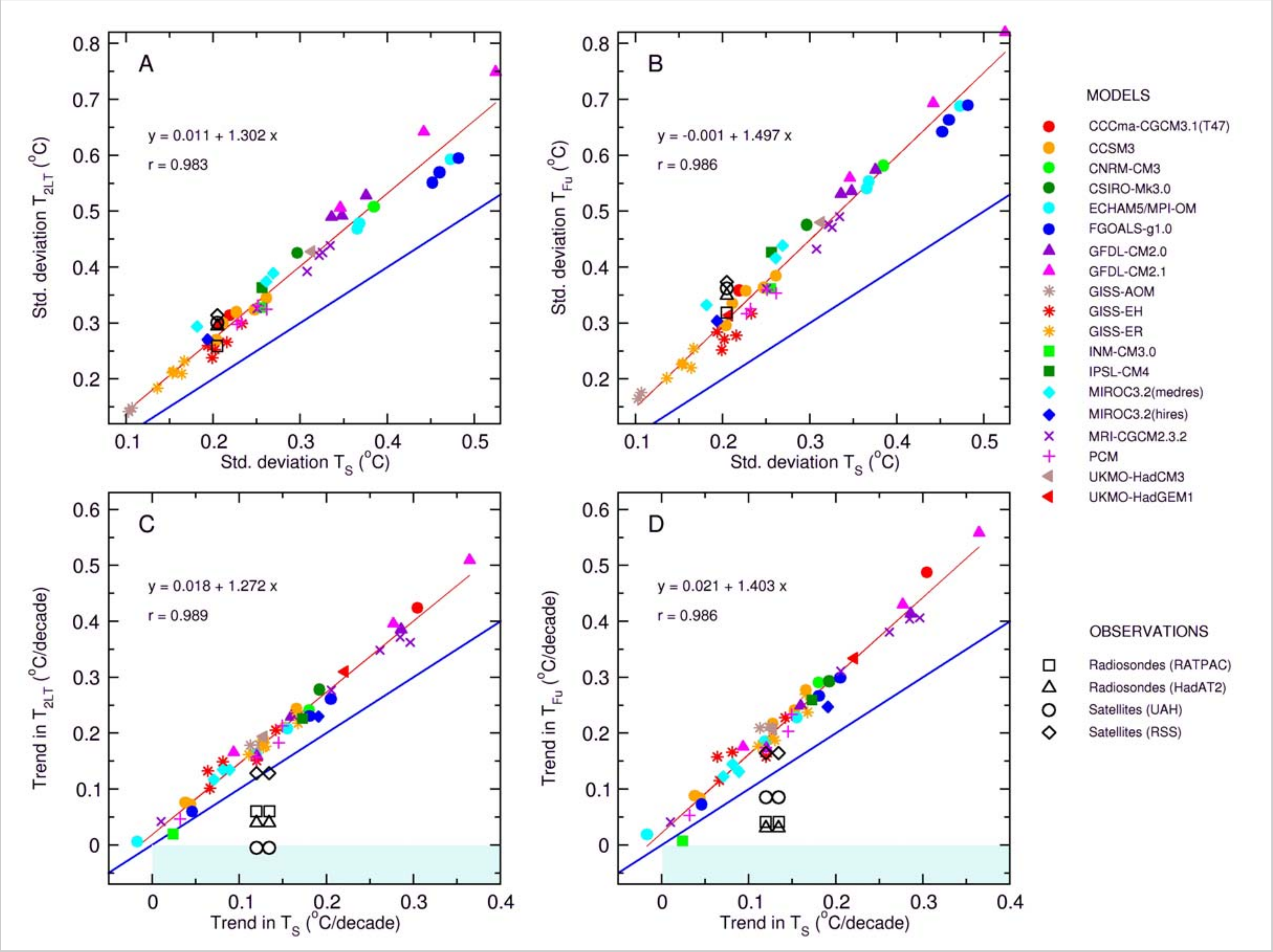
“Amplification factors” in the tropics: Results for decade-to-decade changes (II)



“IPCC class” climate models, tropics (20°N-20°S)

“Amplification factors” in the tropics: Summary of results



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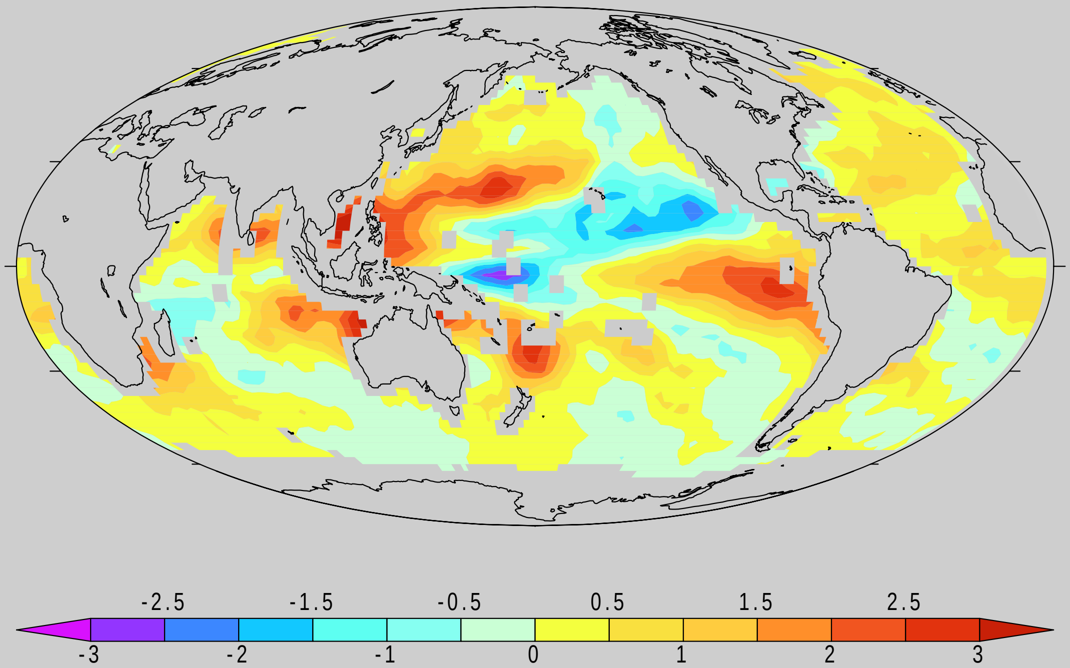
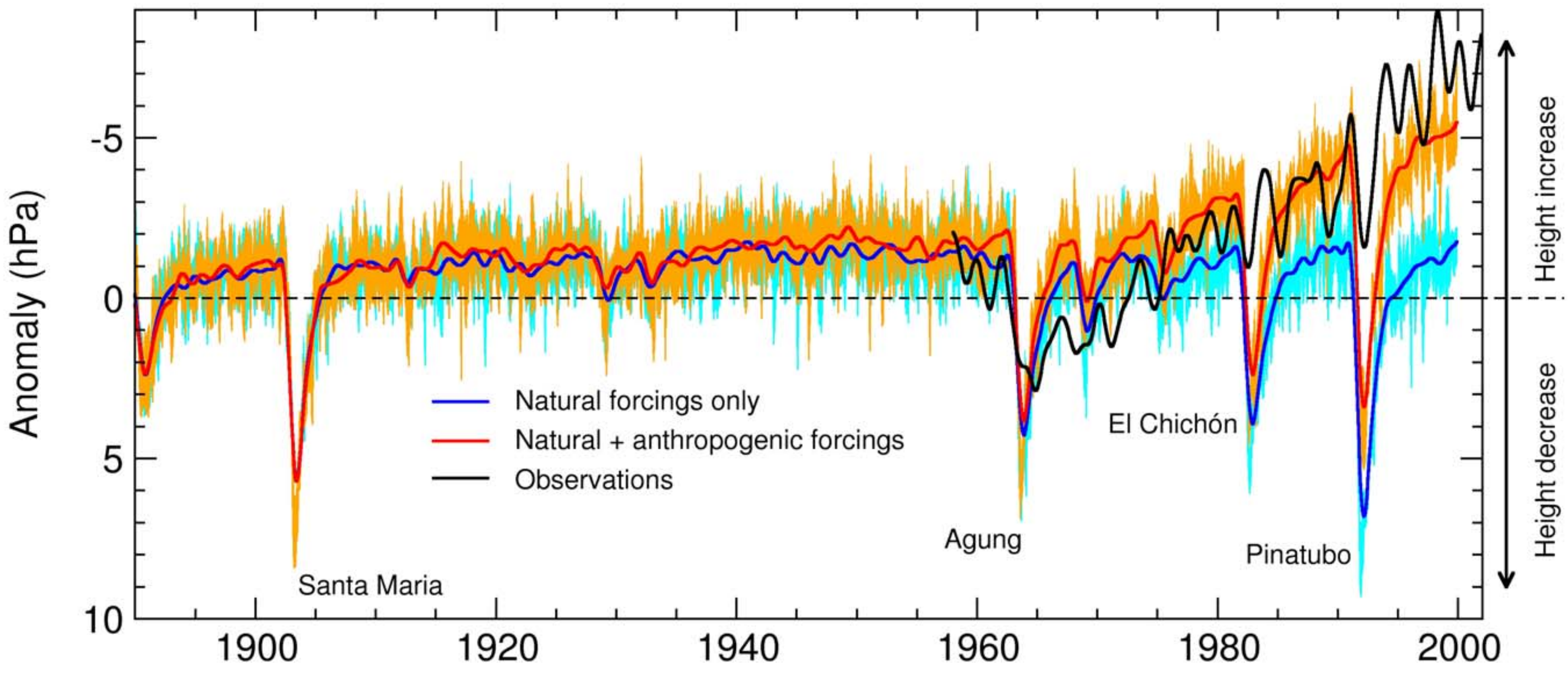
Observed water vapor increases support the picture of a warming troposphere

SSM/I (1988-2001; 0.32 kg/m^2/decade)



Trend in total column water vapor (kg/m^2/decade)

Tropopause height increases also support tropospheric warming



Santer *et al.*, *Science* (2003)

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Conclusions (I)

- In the tropics, the month-to-month variability of temperature is larger in the troposphere than at the surface

- This "amplification" is similar in a wide range of observations and model simulations, and is in accord with basic theory

- On decadal timescales:
  - ➔ Simulated surface warming is amplified aloft, consistent with behavior on monthly timescales
  - ➔ One satellite dataset (Mears *et al*.) agrees with models and theory
  - ➔ Other observational datasets show much smaller (or even negative!) amplification
  - ➔ Observations with relative cooling aloft imply that different physical mechanisms govern amplification processes on monthly and decadal timescales

Conclusions (II)

- Observed water vapor and tropopause height increases are consistent with a warming troposphere
- Human activities have strongly influenced recent changes in surface and atmospheric temperatures
- Natural external forcings have also affected recent changes in surface and atmospheric temperatures
- It is important to account for observational uncertainty in model-data comparisons
  - ➔ Like beauty, model-data consistency depends on one's observational perspective!

Idea 1: Use common historical forcing scenarios

- **IPCC requests that modeling groups perform common scenario calculations for future emissions of trace gases and aerosols**
  - ***e.g.***, SRES, stabilization and “commitment” calculations
- **No requirement for calculations with common estimates of <u>historical</u> forcings**
  - Well-mixed GHGs, ozone, volcanic aerosols, solar irradiance changes
  - Anthropogenic aerosols?
- **This hampers intercomparison and interpretation of differences in model responses to historical forcings**
  - Without common historical forcing scenarios, model comparisons in IPCC 2007 will be convolving differences in both applied forcings and simulated responses!

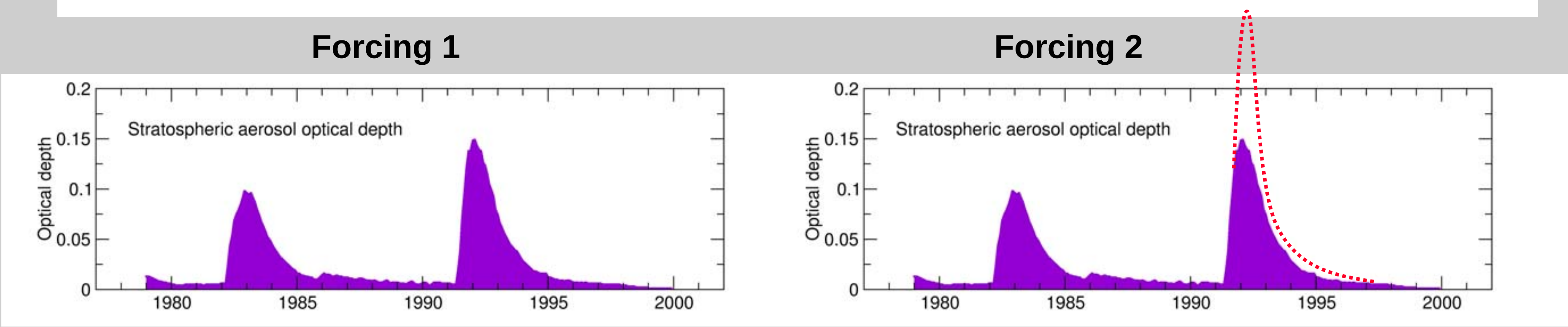
Idea 2: Search for “fingerprints” of anthropogenic aerosols in observations

- **Most statistical “fingerprint” detection studies have considered only direct scattering effects of anthropogenic sulfate aerosols**
  - Few studies have incorporated sulfate aerosol indirect effects, or direct/indirect effects from soot and biomass aerosols, mineral dust, *etc.*
- **This leaves current detection work open to justifiable criticism – a potential problem for IPCC 2007**
- **High priority to repeat detection and attribution studies with best estimates of climate fingerprints arising from soot, biomass, and mineral dust aerosols**
  - We should be able to identify these fingerprints if they are as large as hypothesized
  - Some of these forcings should have signals with great regional and seasonal specificity!

Idea 3: “Double blind” detection studies

- **Do current forcing uncertainties really matter for climate change detection work?**

Forcing 1 **Forcing 2**



- **Perform 5 realizations with Forcing 1 and 5 realizations with Forcing 2**
- **Provide detection groups with the 10 (shuffled) sets of climate responses**
  - Remove any “identifying” information on forcings applied
- **Exercise detection codes!**
  - Can two different “classes” of response be distinguished?
  - If so, is one class of response in better agreement with observations?

Correcting for drift in sampling the diurnal cycle

- Local measurement time for each satellite drifts due to orbital drift
- This leads to drift in the sampling of any diurnal cycle present
- Can alias diurnal cycle into the long-term temperature record