Can Climate Models Reproduce Observed Changes in Surface and Atmospheric Temperature?

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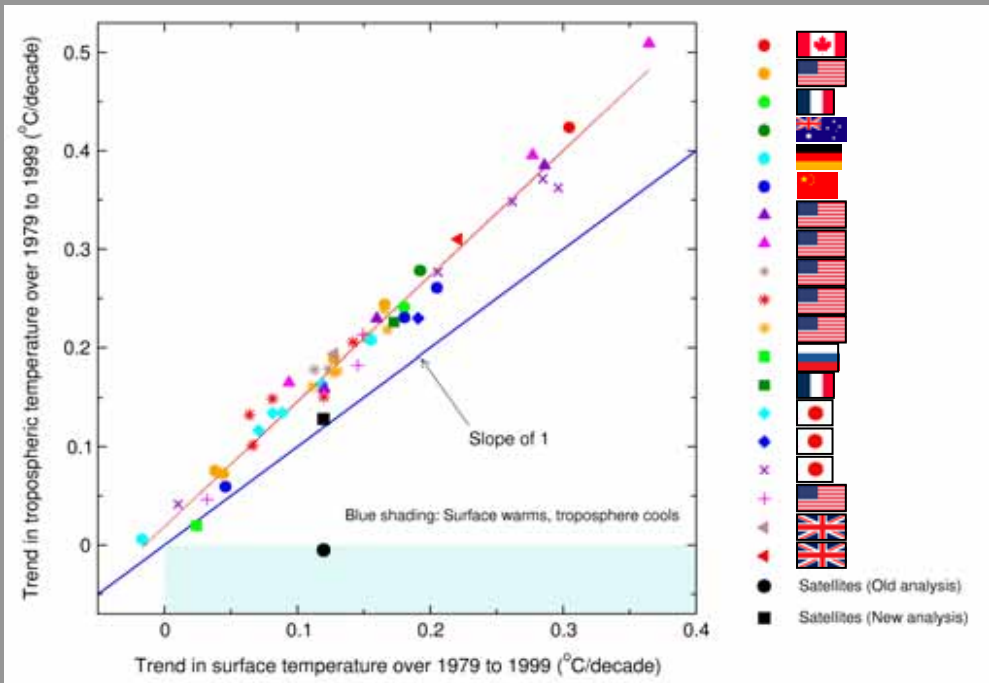
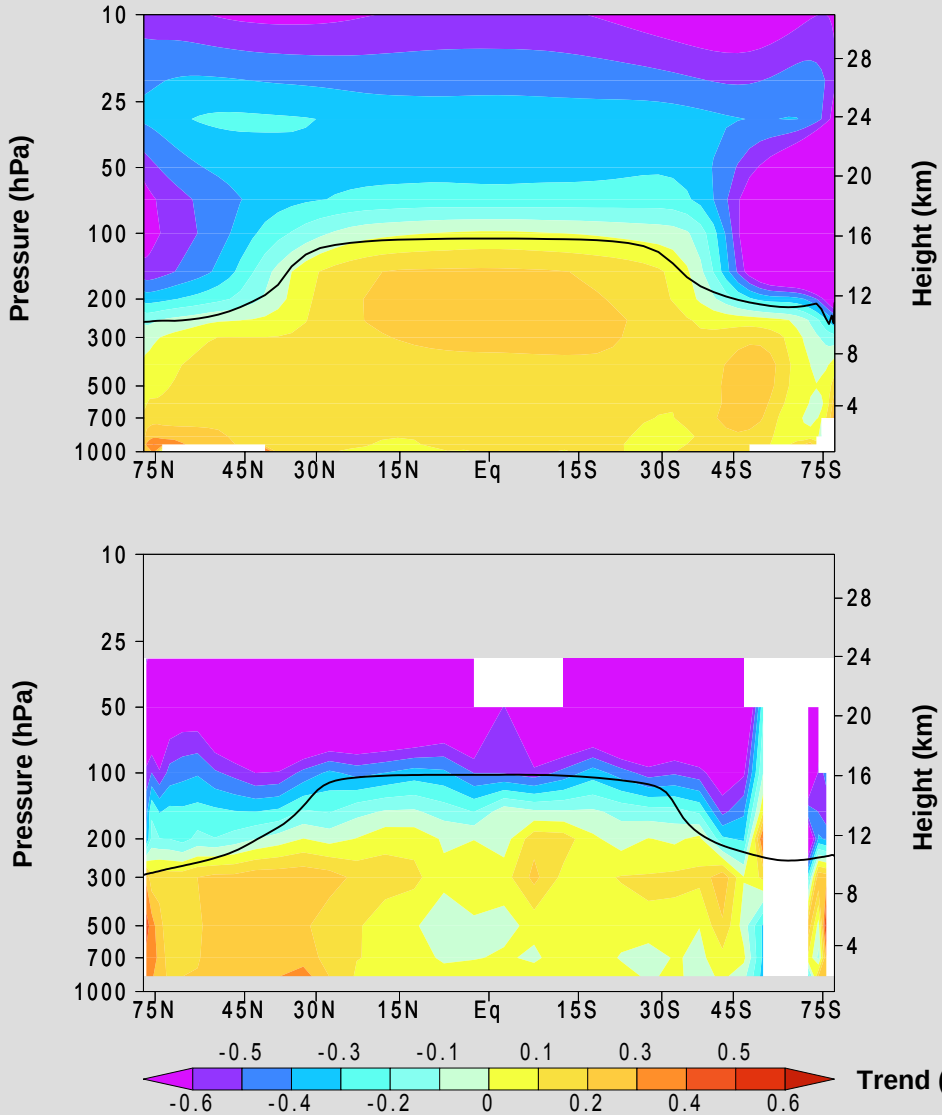


The problem: Is there a discrepancy between temperature trends in climate models and observations?

Climate model results

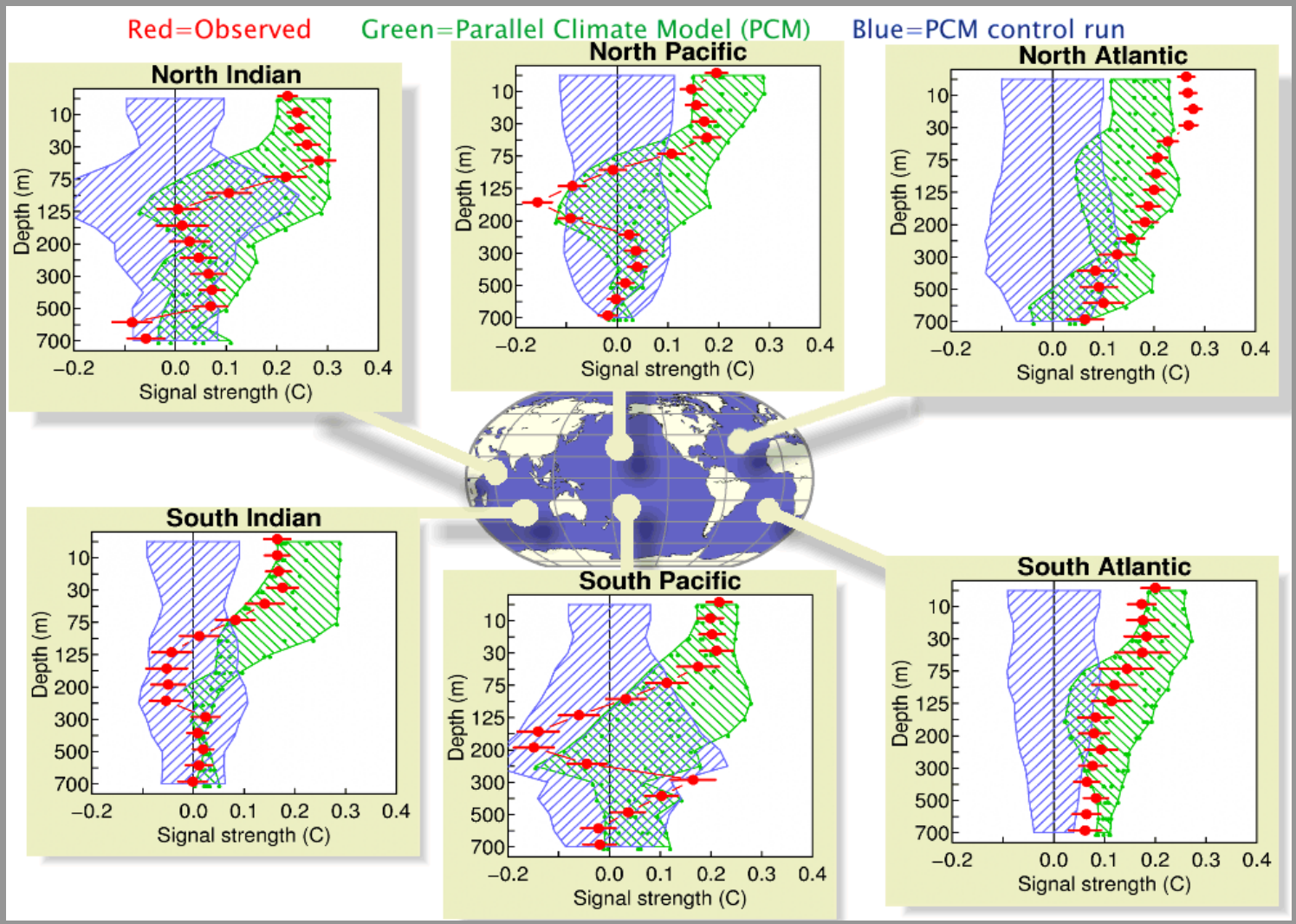
Weather balloon data



This apparent discrepancy has always been puzzling, because…

- Computer models successfully capture many other important features of observed climate change, such as:
  - Increases in Earth's surface temperature over the 20th century
  - Decreases in the temperature of the stratosphere over the last 3-4 decades
  - Warming of the world's oceans in the second half of the 20th century
  - Response of atmospheric temperature and moisture to large volcanic eruptions

Example of a successful simulation of observed climate change: Warming of the world's oceans over 1955-99



Barnett *et al.*, *Science* (2005)

Analysis strategy in Santer *et al*. Science paper

- Compare modeled and observed temperature changes in the deep tropics (20°N-20°S)
  - ➡ This is where modeled and observed temperature changes show largest disagreement
- Focus on relationships between temperature changes at the surface and in the lower troposphere
  - ➡ Examine these relationships for “fast” (month-to-month) and “slow” (decade-to-decade) temperature changes
- Account for uncertainties in both climate models and observations

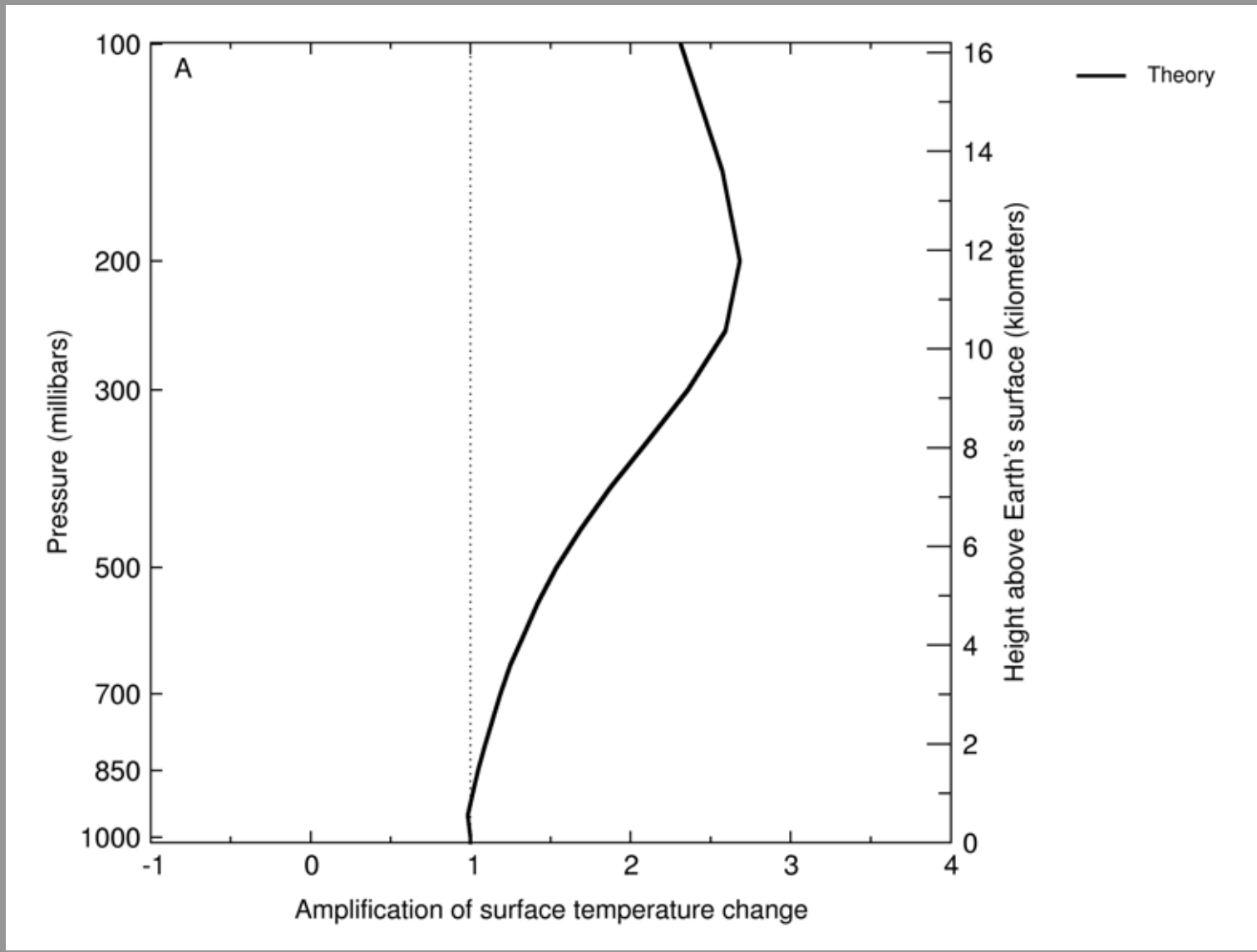
Datasets used in analysis

- Results from 19 different climate models
  - 49 realizations of "20th century" runs performed in support of Fourth Assessment Report of the IPCC
- Two satellite lower tropospheric temperature datasets
  - University of Alabama at Huntsville (UAH; "Old analysis")
  - Remote Sensing Systems, Santa Rosa (RSS; "New analysis")
- Three surface thermometer datasets
  - NOAA, UKMO, NASA

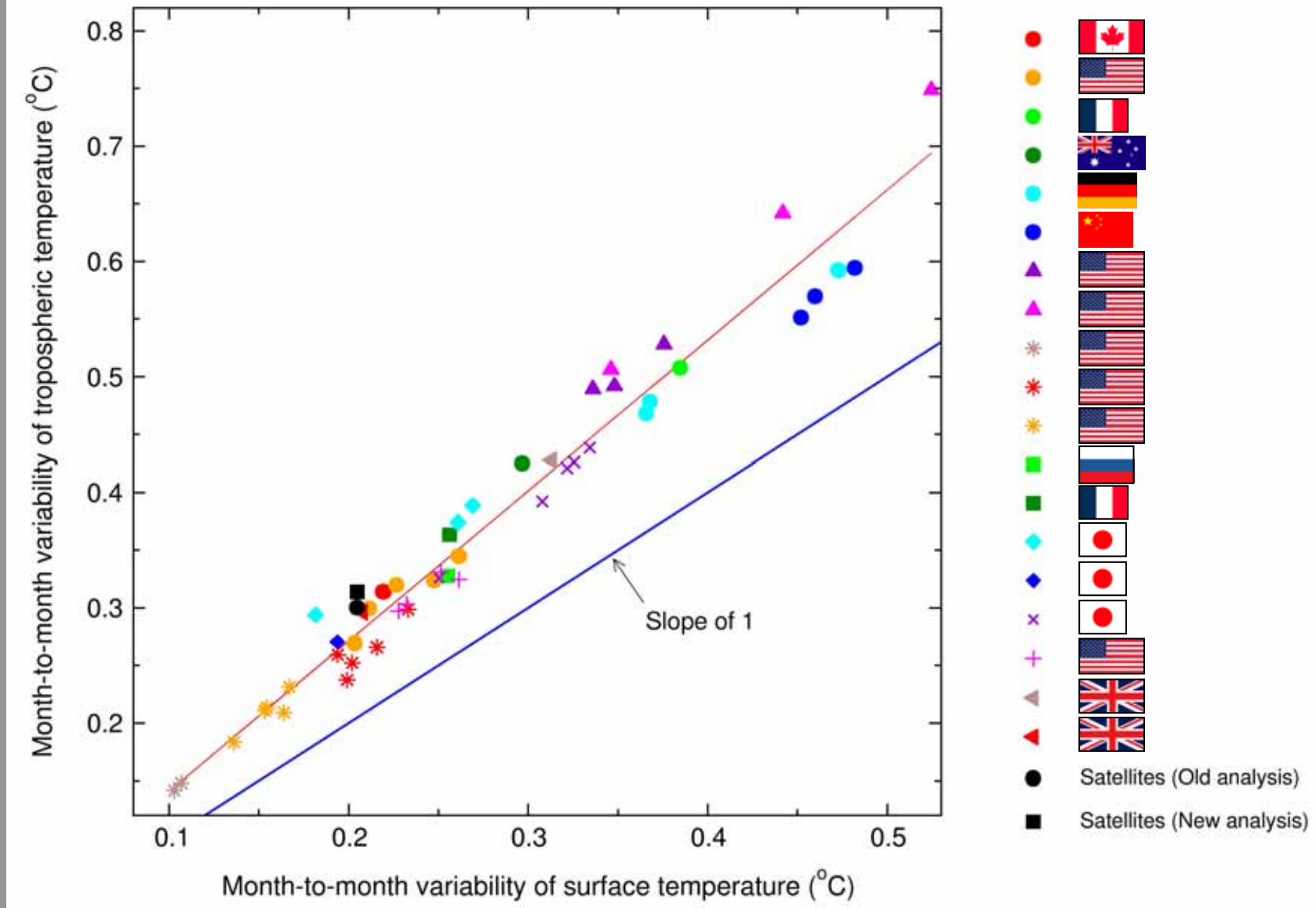
A brief primer on tropical lapse rates

- "Lapse rate" describes how atmospheric temperature decreases with increasing height
  - For dry air: Decrease of 9.8°C per kilometer
  - For moist tropical air: Lapse rate may be as low as 4°C per kilometer
- Why are dry and moist lapse rates different?
  - Upward motion of moist air eventually produces condensation, leading to latent heat release

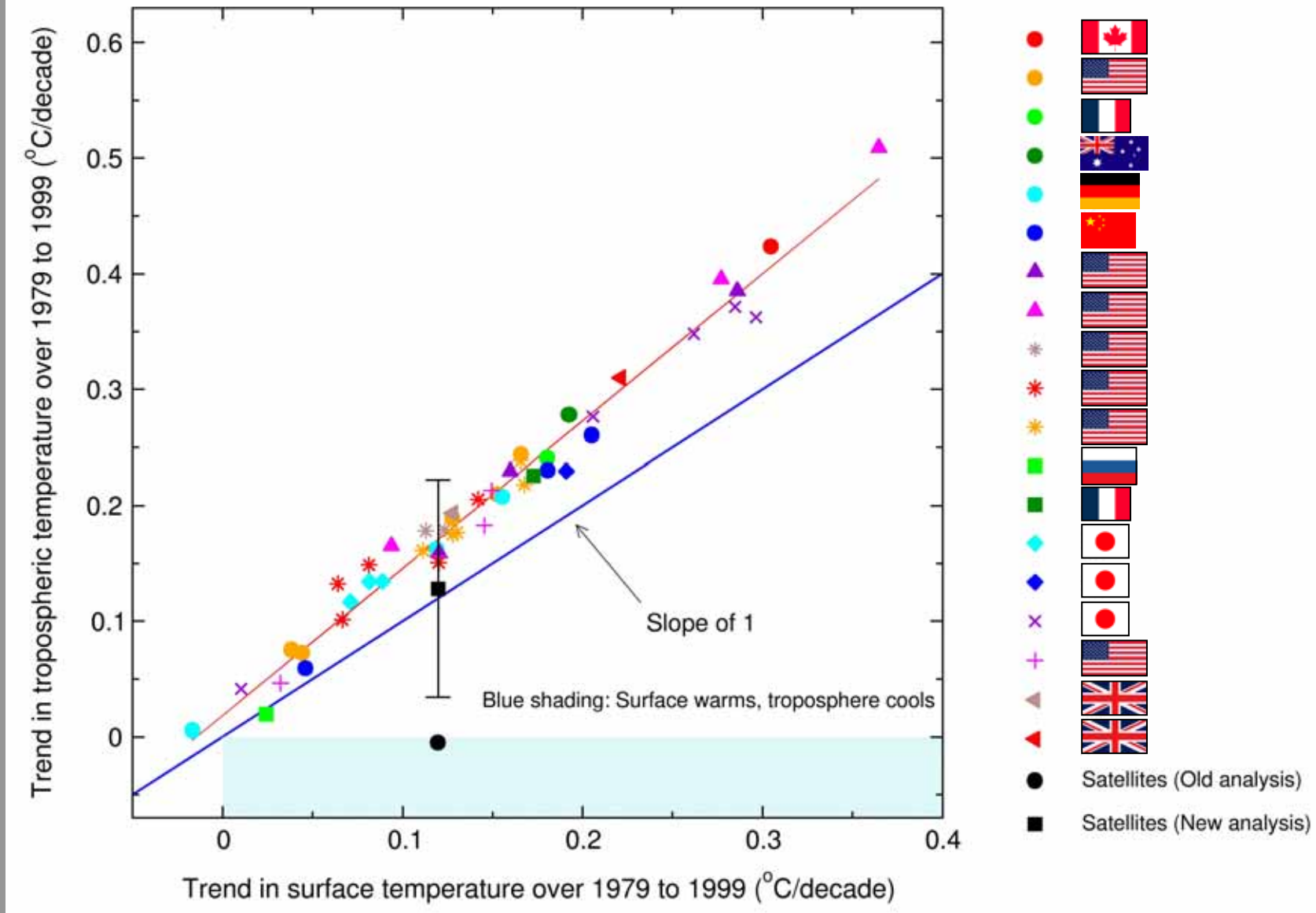
Temperature changes in the troposphere are larger than at the surface



Relationship between temperature changes at the surface and in the lower troposphere: CASE I ("Fast")



Relationship between temperature changes at the surface and in the lower troposphere: CASE II ("Slow")



Other evidence that supports warming of the tropical troposphere since 1979

- Increases in the amount of atmospheric water vapor
- Accelerated retreat of high-altitude tropical glaciers
- Increase in the height of the tropical tropopause

Conclusions

- Computer models are the best tool we have for forecasting future climate
  - An important model test: How well can they reproduce past climate fluctuations?
- Models predict that temperature changes in the tropical troposphere are larger than at the surface
  - "Amplification" results are similar for both rapid and slow changes
- OLD  DATA: Consistent with models and theory for rapid changes, but not for slow temperature changes over decades
- NEW  DATA: Consistent with models and theory, both for rapid and slow temperature changes
- Identifying and adjusting for errors in  data has removed a major stumbling block in our understanding of the causes of climate change