Satellite Data Uncertainties: Impact on Detection and Attribution Results

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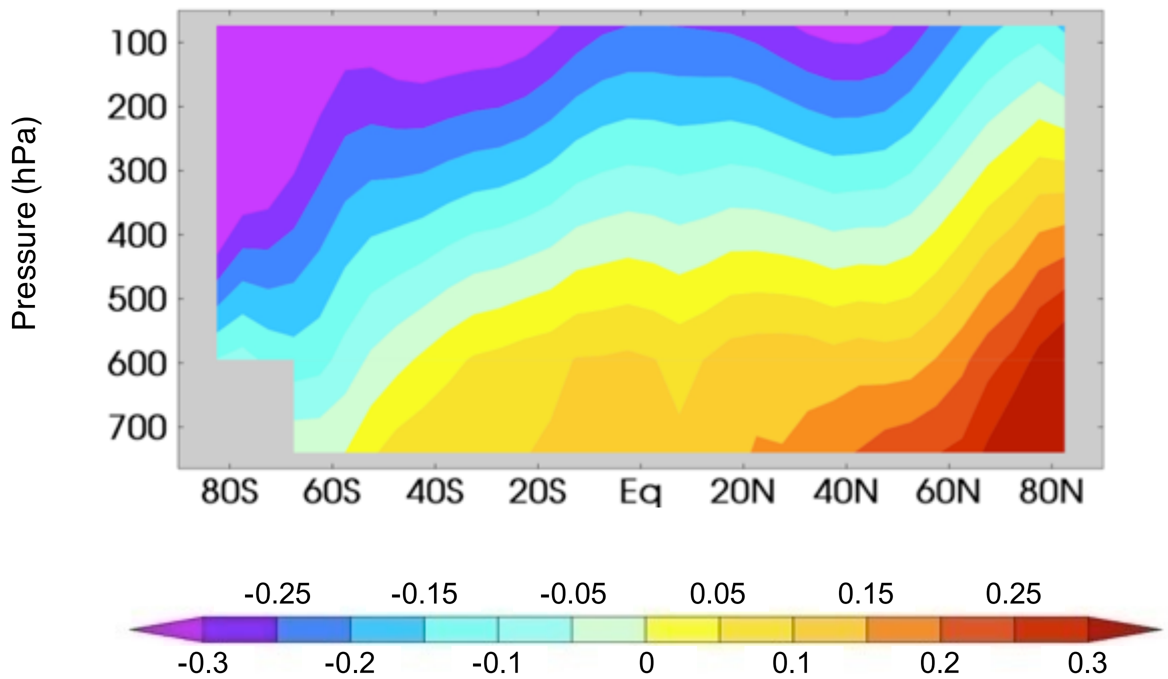
Earth System Model Evaluation to Improve Process Understanding

Aspen, CO. July 31st, 2017



Observations (Santa Rosa)

Trend (°C/decade over 1979 to 2012)

Uncertainties in climate science

1. "The impact today of human activity appears to be comparable to the intrinsic, natural variability of the climate system itself"

2. "Uncertainty is a prime mover and motivator of science and must be faced head-on. It should not be confined to hushed sidebar conversations at academic conferences"

3. "While the past two decades have seen progress in climate science, the field is not yet mature enough to usefully answer the difficult and important questions being asked of it"

"Climate Science is Not Settled". Op-Ed by Prof. Steven Koonin, WSJ, Sept. 20, 2014

Structure

- Introduction
- Global mean changes in the temperature of the troposphere
- How reliable are model estimates of natural variability?
- Beyond the global-mean: Patterns of temperature change
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Measuring atmospheric temperature from space using Microwave Sounding Units (MSU)

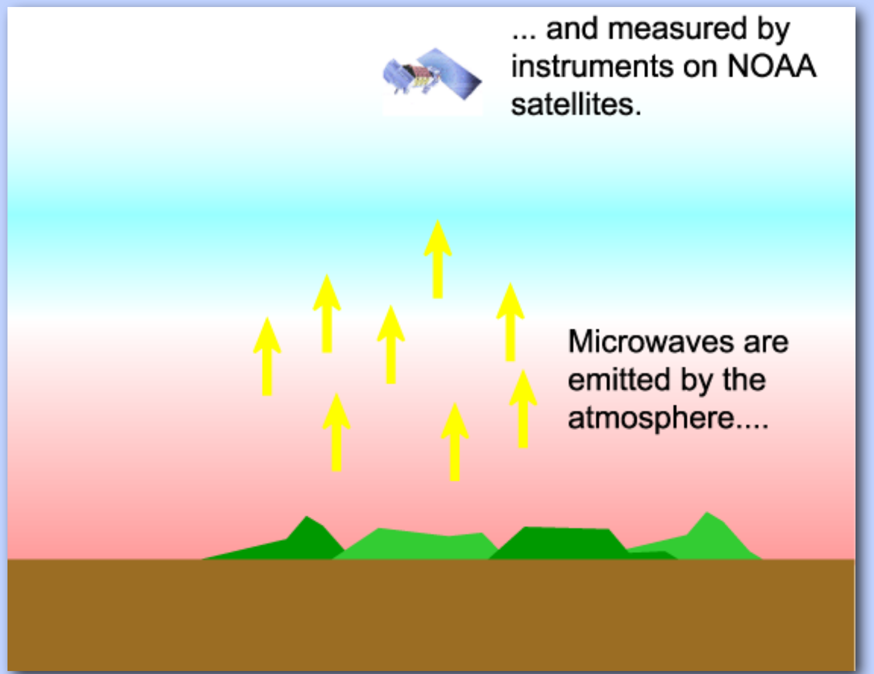

Figure and text courtesy of Carl Mears, Remote Sensing Systems

- Higher temperatures = more microwave emissions from oxygen molecules
- By choosing different microwave frequencies, different layers in the atmosphere can be measured
- Much of the scientific focus at recent Senate and Congressional hearings was on the <u>T</u>emperature of the <u>M</u>id- to upper <u>T</u>roposphere (TMT)

MSU measurements sample different atmospheric layers

- The Temperature of the Mid- to upper Troposphere (TMT) is influenced by temperature changes between the surface and roughly 18 km
- Satellite TMT measurements receive a contribution from the lower stratosphere
- Human-caused cooling of the lower stratosphere contributes significantly to TMT trends

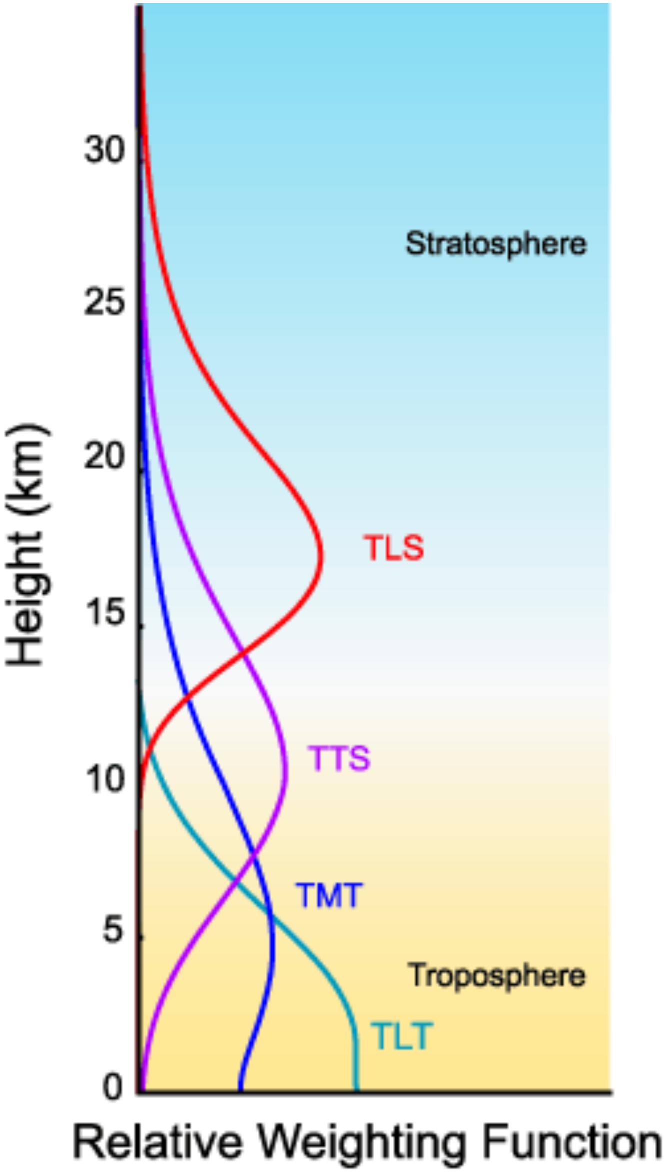

Figure courtesy of Carl Mears, Remote Sensing Systems (Santa Rosa)

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Accountability

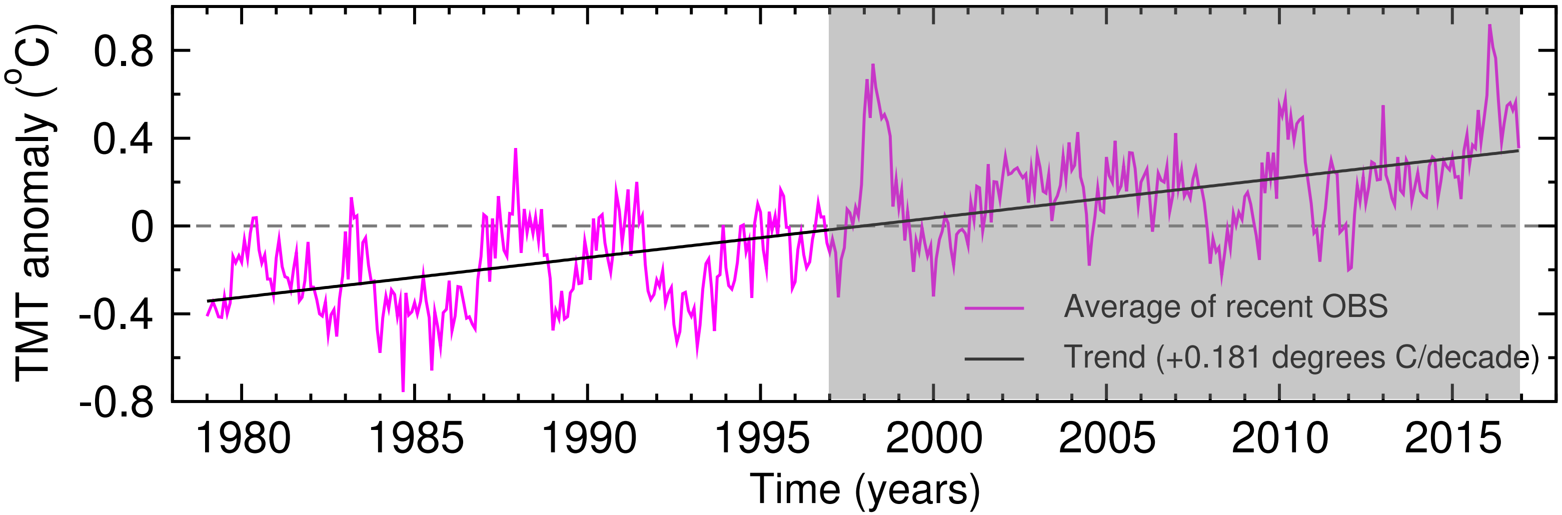
“As scientists, we are accountable for our actions and the science we publish. Our elected leaders must also be accountable”

“over the past two decades satellite data indicate(s) there has been a leveling off of warming” *

*E.P.A. Administrator Scott Pruitt, in a written response to Senator Ed Markey

Global-mean changes

TMT = Temperature of Mid- to Upper Troposphere



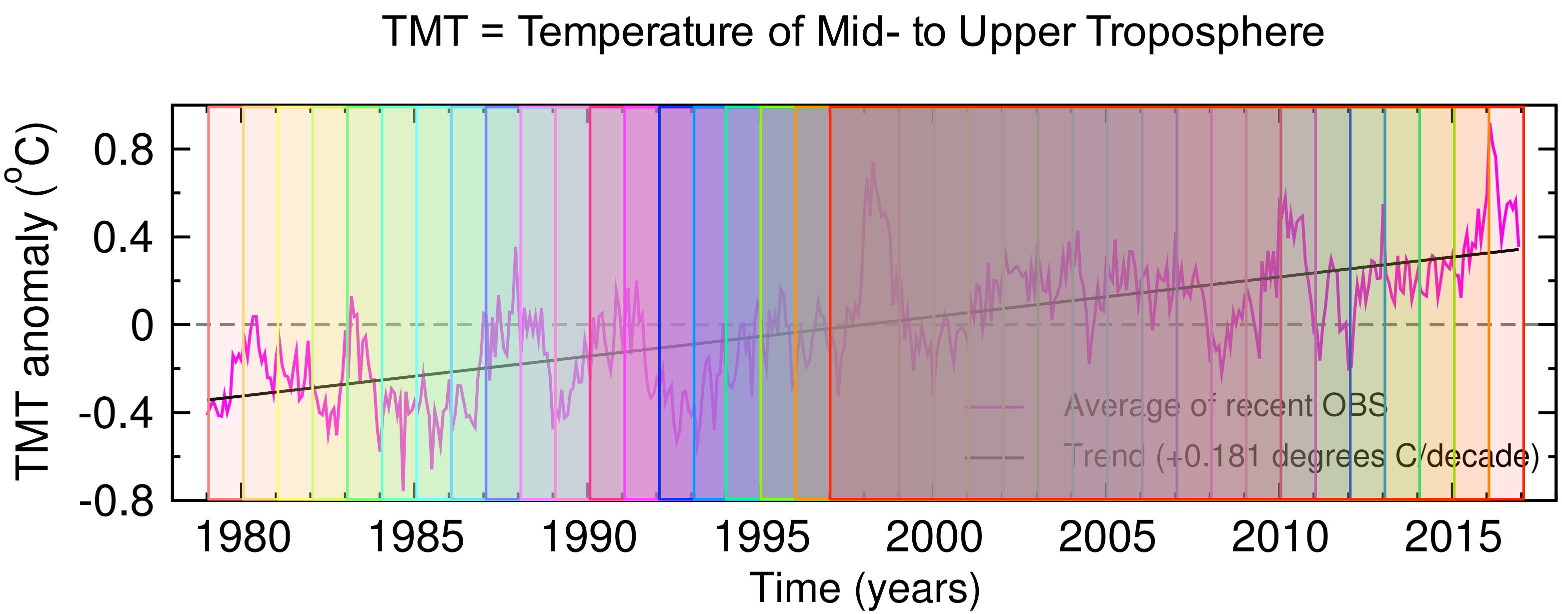
Magenta line is average of 3 satellite data sets:

1 Remote Sensing Systems (RSS; version 4.0)

2 NOAA/NESDIS Center for Satellite Applications and Research (STAR; version 4.0)

3 University of Alabama at Huntsville (UAH; version 6.0)

Global-mean changes



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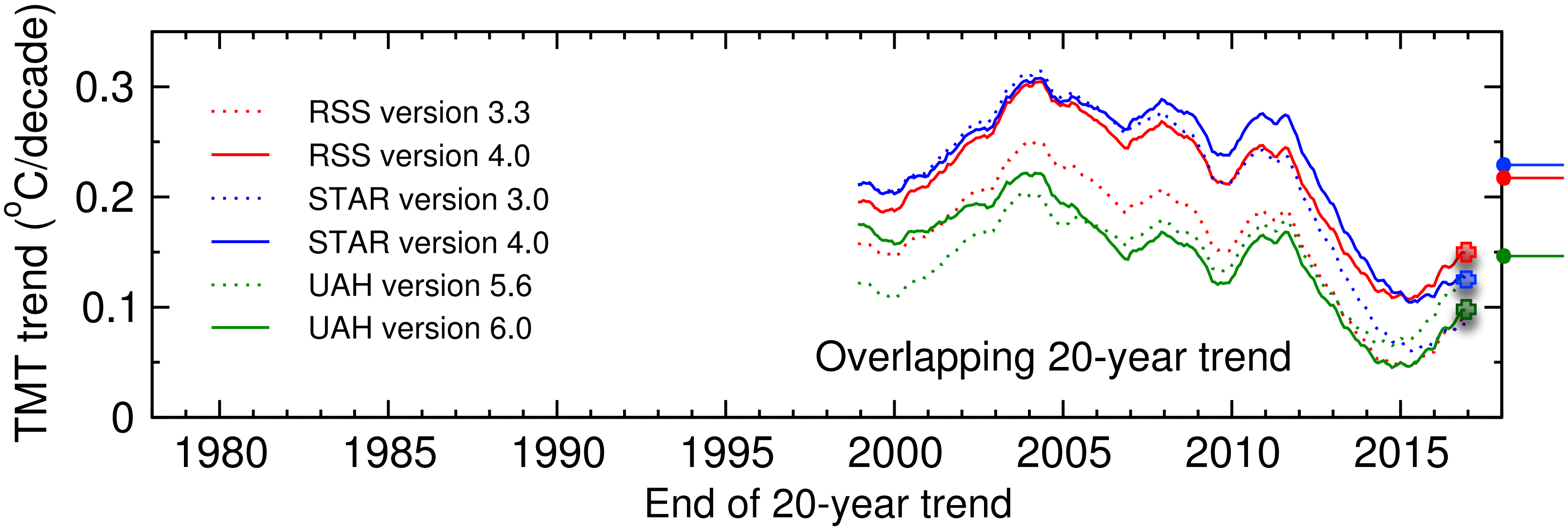
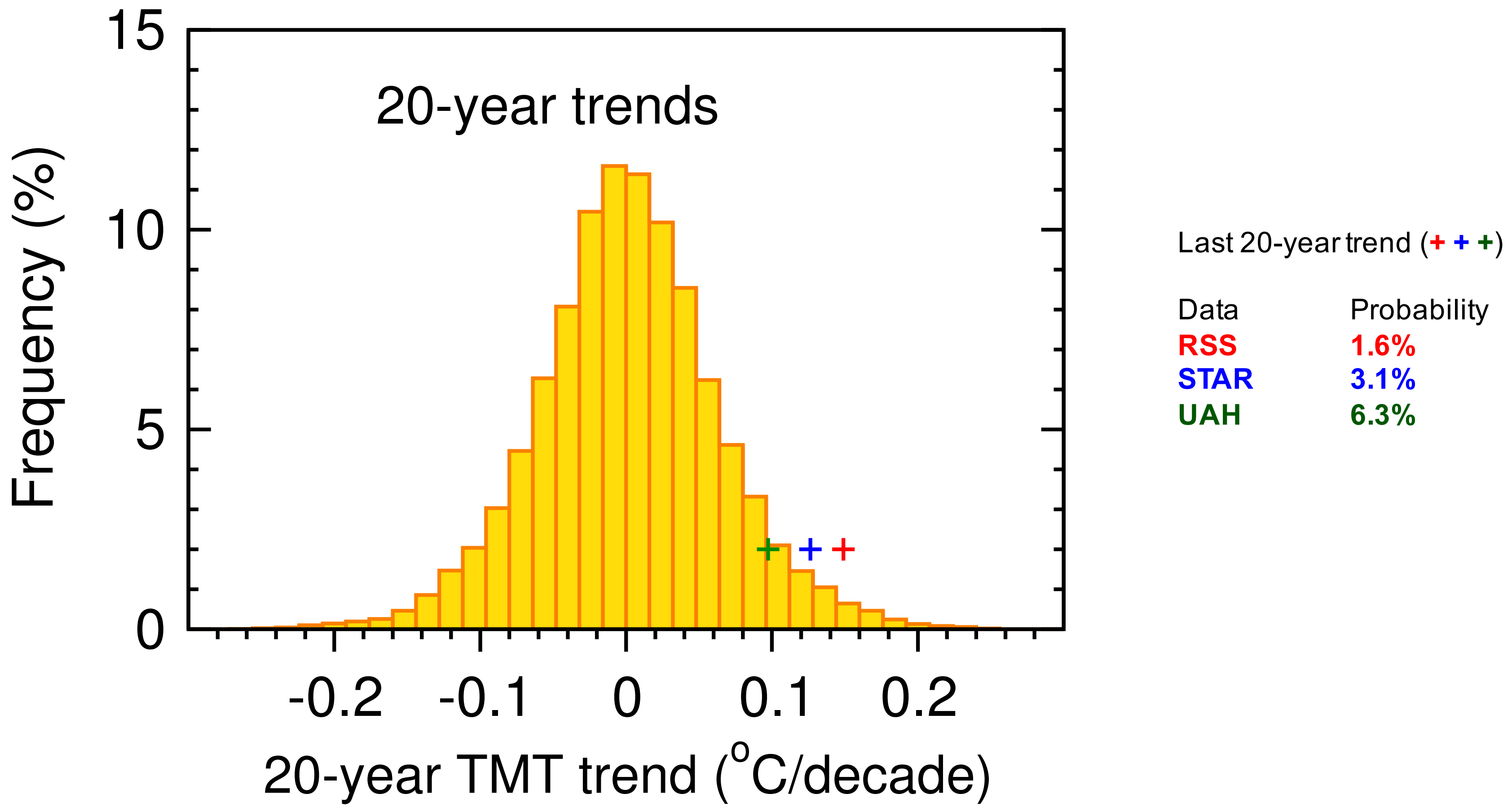
Looking at all possible 20-year temperature trends

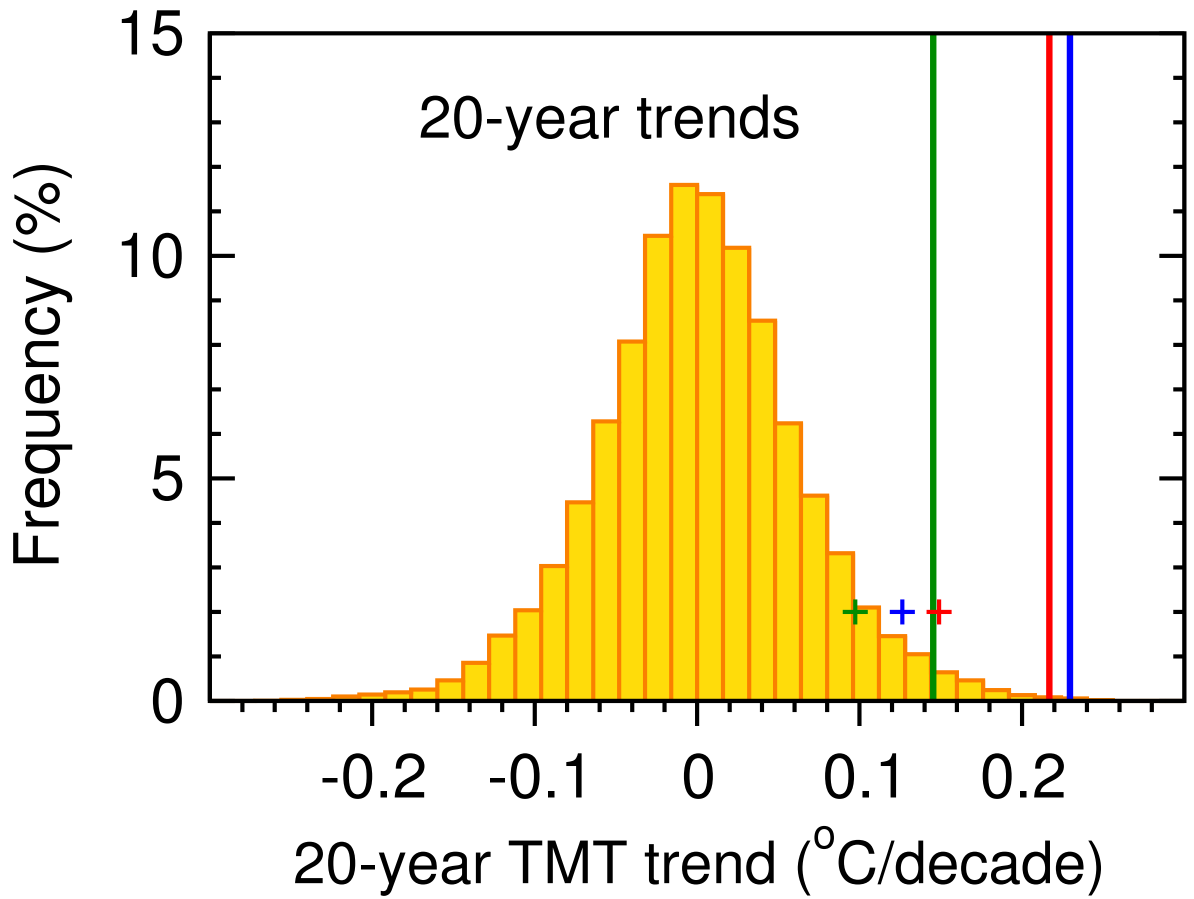


How unusual are temperature trends over the last 20 years?



Santer *et al.*, *Scientific Reports* (2017)

How unusual are the averages of all 20-year trends?



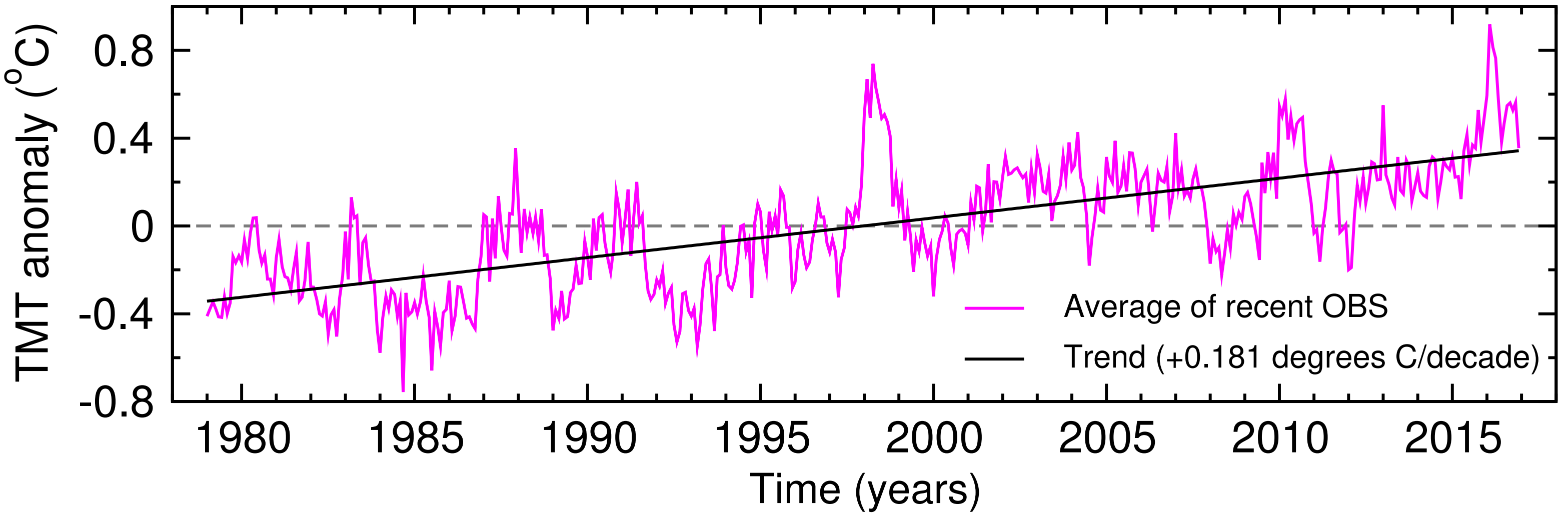
Ave. 20-year trend (I I I)

Data	Probability
RSS	0.007%
STAR	0.006%
UAH	1.7%

Santer *et al.*, *Scientific Reports* (2017)

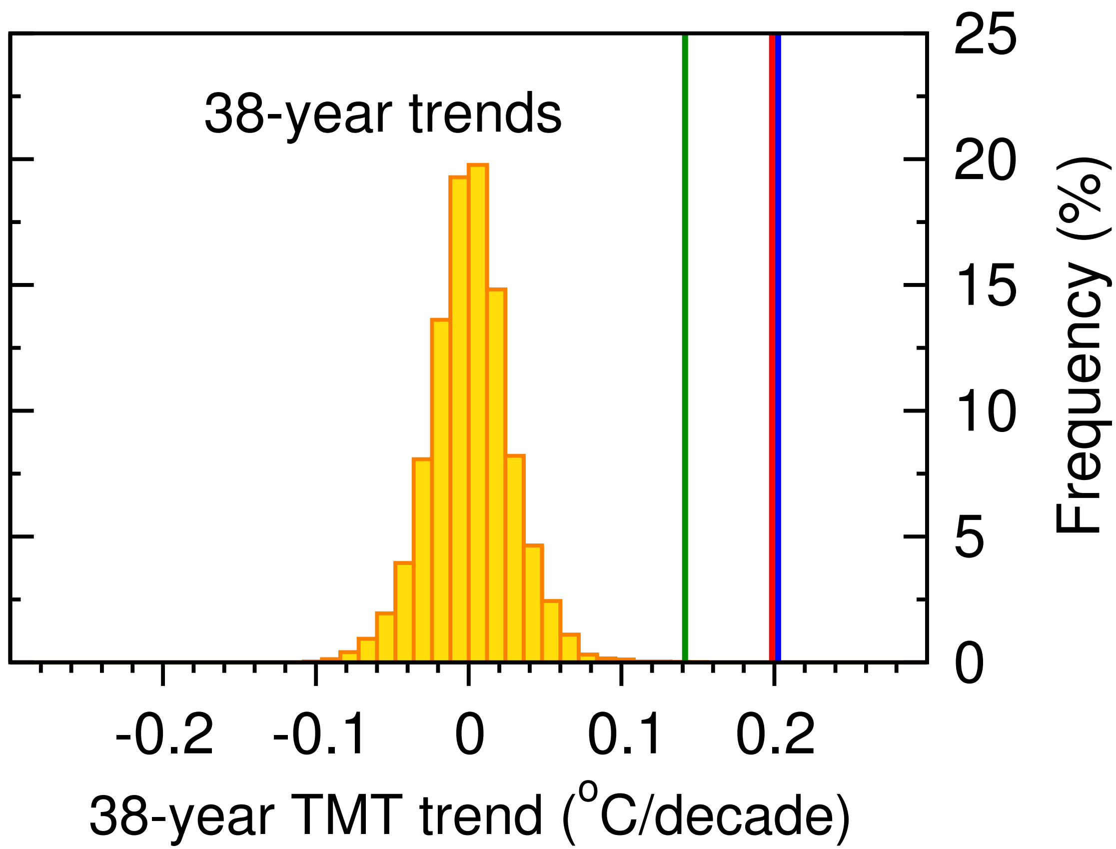
How unusual is the overall 38-year tropospheric warming trend?

TMT = Temperature of Mid- to Upper Troposphere



Santer *et al.*, *Scientific Reports* (2017)

Tropospheric warming in two out of three satellite datasets is “unprecedented”



38-year trend (| | |)

Data	b / σ
RSS	**7.4**
STAR	**7.6**
UAH	**5.4**

Santer *et al.*, *Scientific Reports* (2017)

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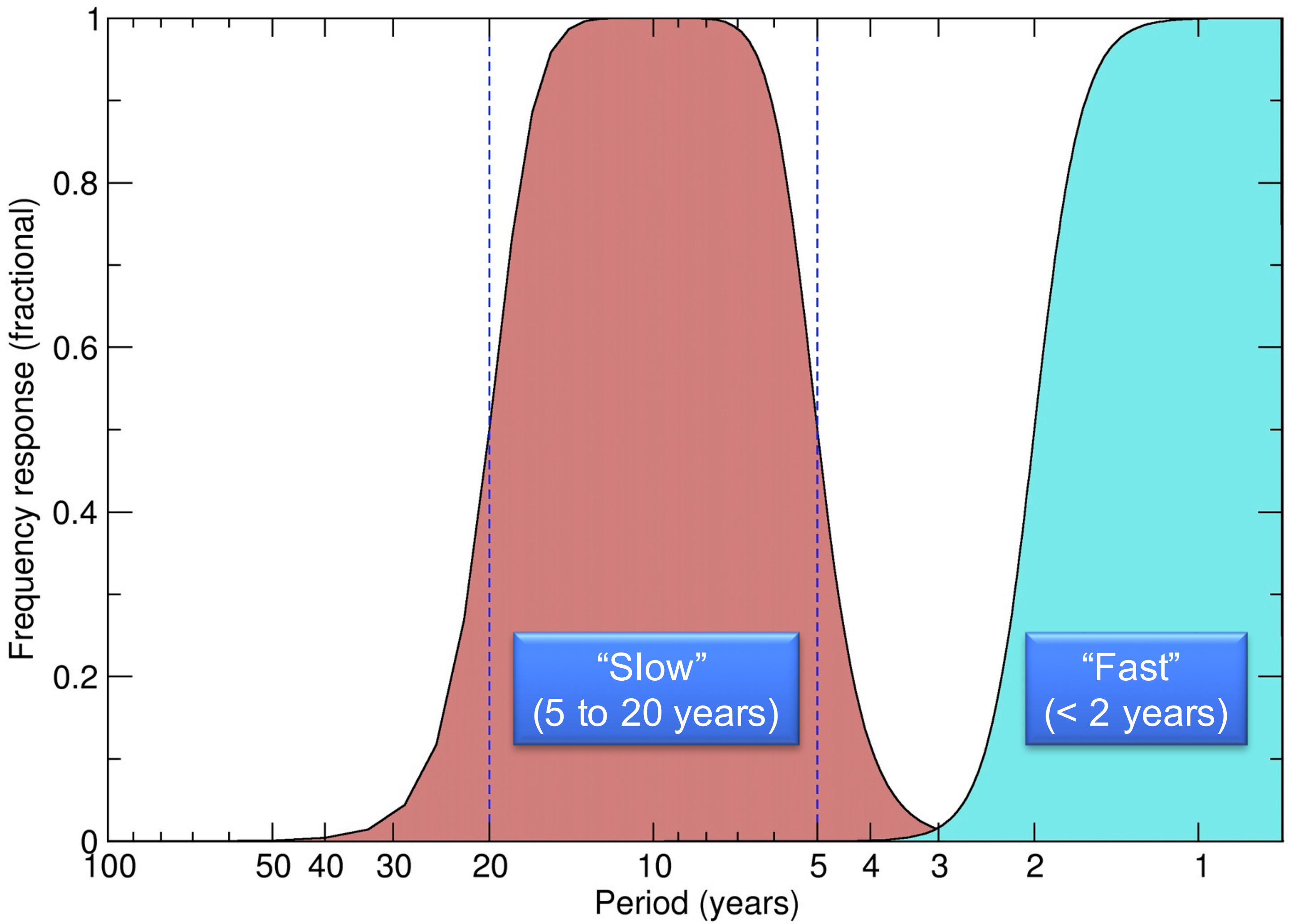
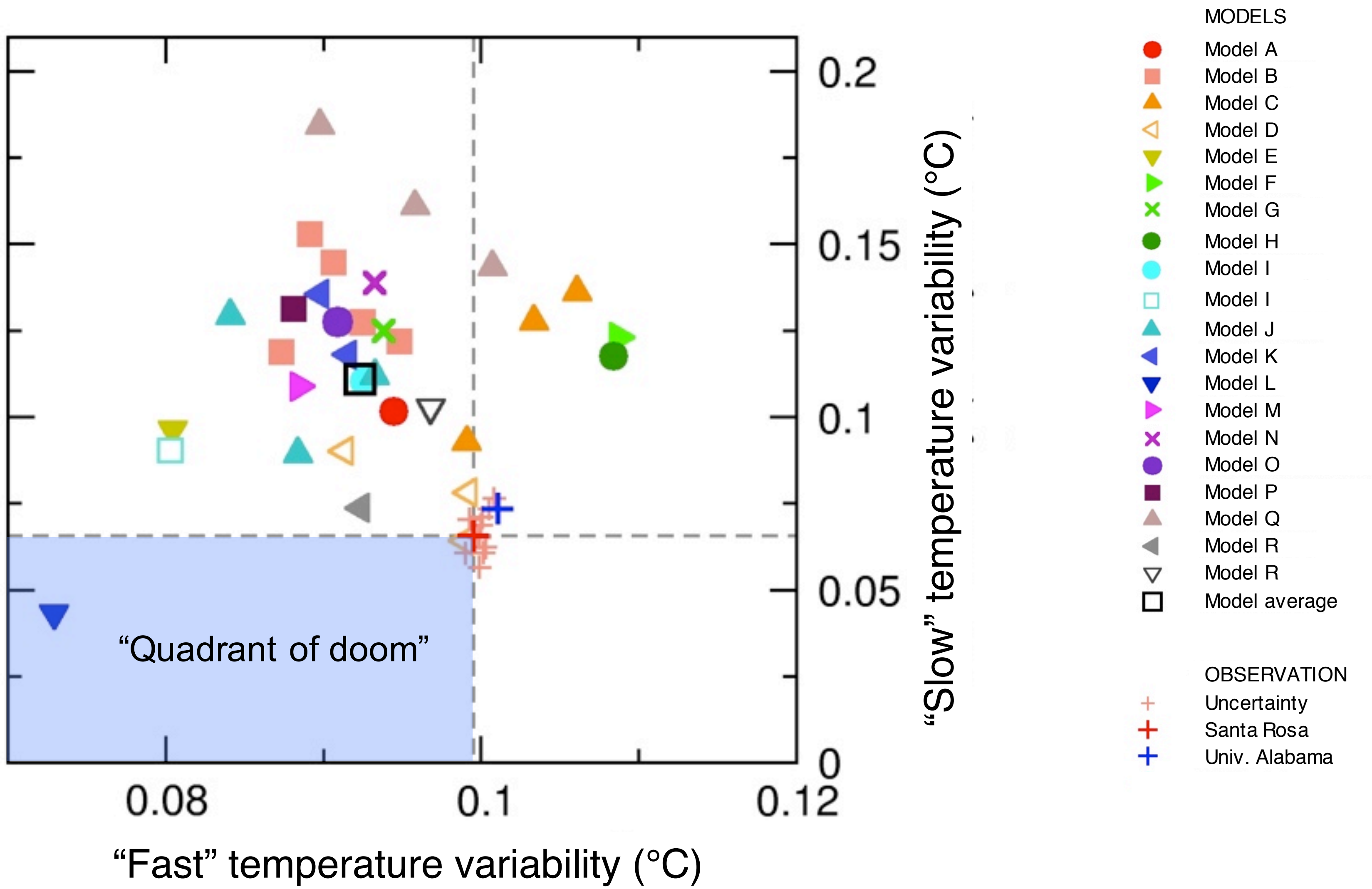
Comparing modeled and observed temperature variability



Santer *et al.*, *Journal of Geophysical Research* (2011)

Do models underestimate the observed “slow” variability of tropospheric temperature?



Santer *et al.*, *PNAS* (2013)

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What is “climate fingerprinting”?

- Strategy:

  Search for a computer model-predicted pattern of climate change (the “fingerprint”) in observed climate records

- Assumption:

  Different influences on climate have different signatures in climate records

- Method:

  Statistical techniques are applied to estimate the level of agreement between:

  - The fingerprint and observations
  - The fingerprint and estimates of natural climate variability

- Why we use it:

  Allows tests of competing hypotheses about the causes of recent climate change

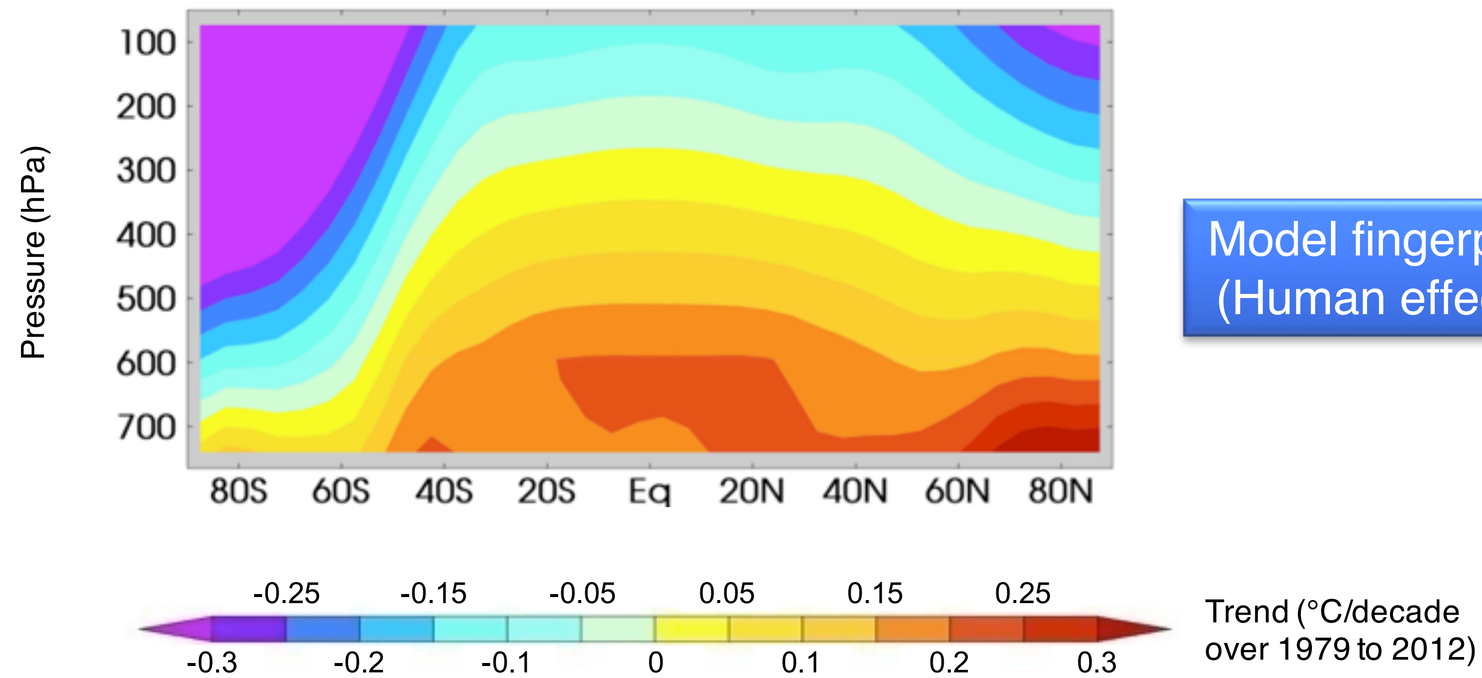
Science questions addressed in Santer *et al*. (2013) "vertical fingerprint" paper

- Can we identify a human-caused latitude/altitude pattern of atmospheric temperature change (the "fingerprint") in satellite data?

- Is identification of a human fingerprint robust to uncertainties in:
  - Satellite temperature data?
  - Model fingerprint estimates?
  - Model estimates of the "noise" of internal climate variability?

- Can we identify a human-caused fingerprint embedded in "total noise"?

How does "fingerprinting" actually work?

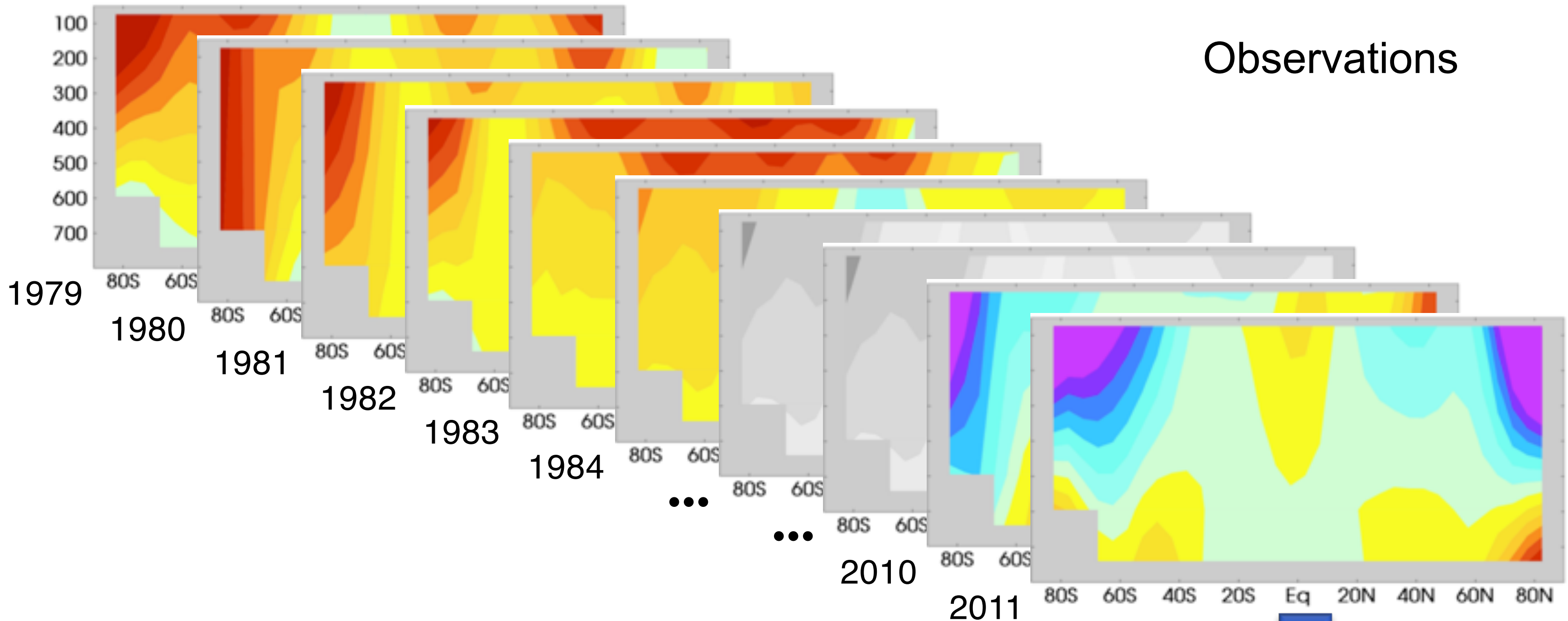


Model fingerprint (Human effects)

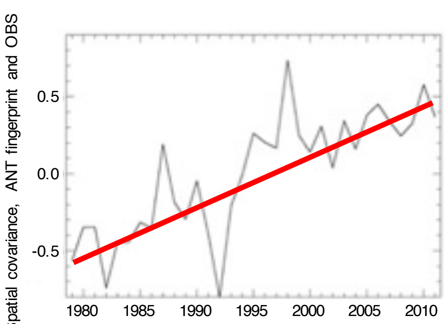
Source: Santer *et al.*, *Proceedings of the U.S. National Academy of Sciences* (2013)

Fingerprint detection explained pictorially….

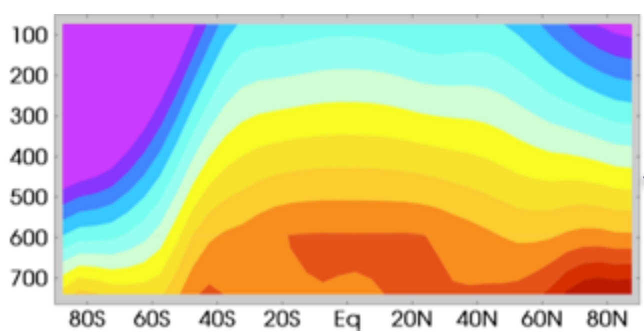
Observations



Compare with model fingerprint

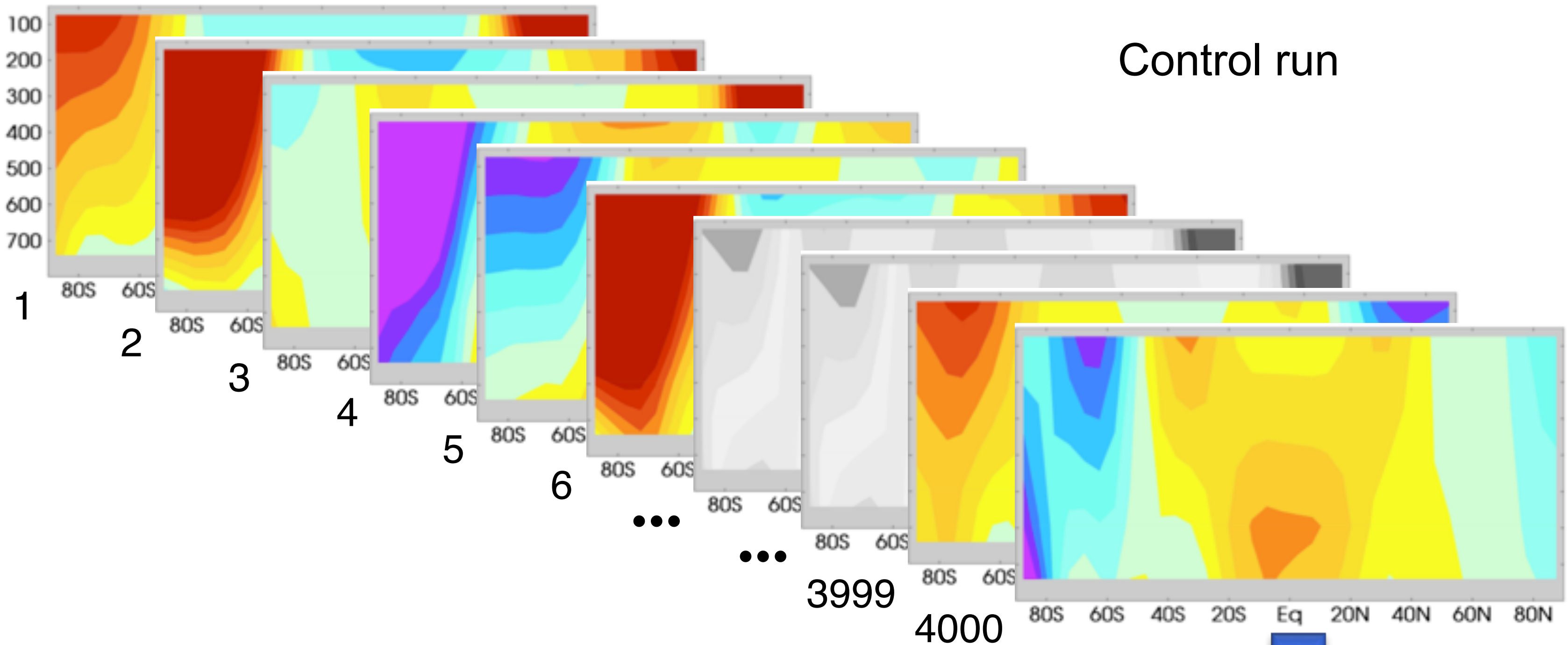


Pattern similarity time series



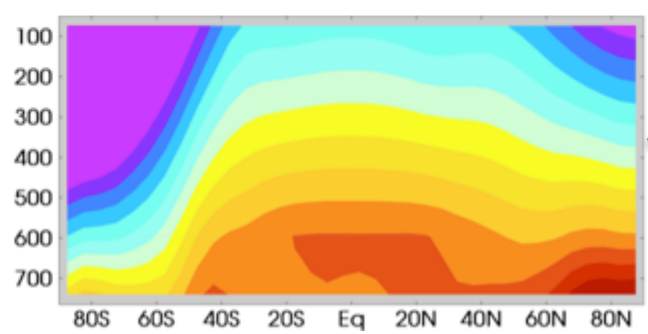
Model HUMAN fingerprint

Generating distributions of pattern similarity trends for the "no human-caused climate change" case

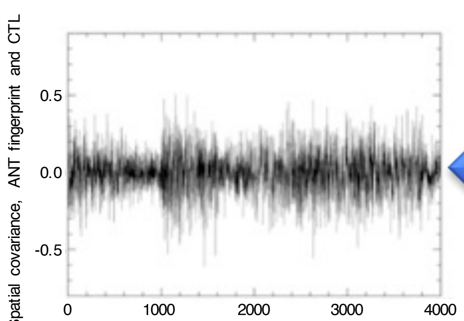


Control run

Compare with model fingerprint

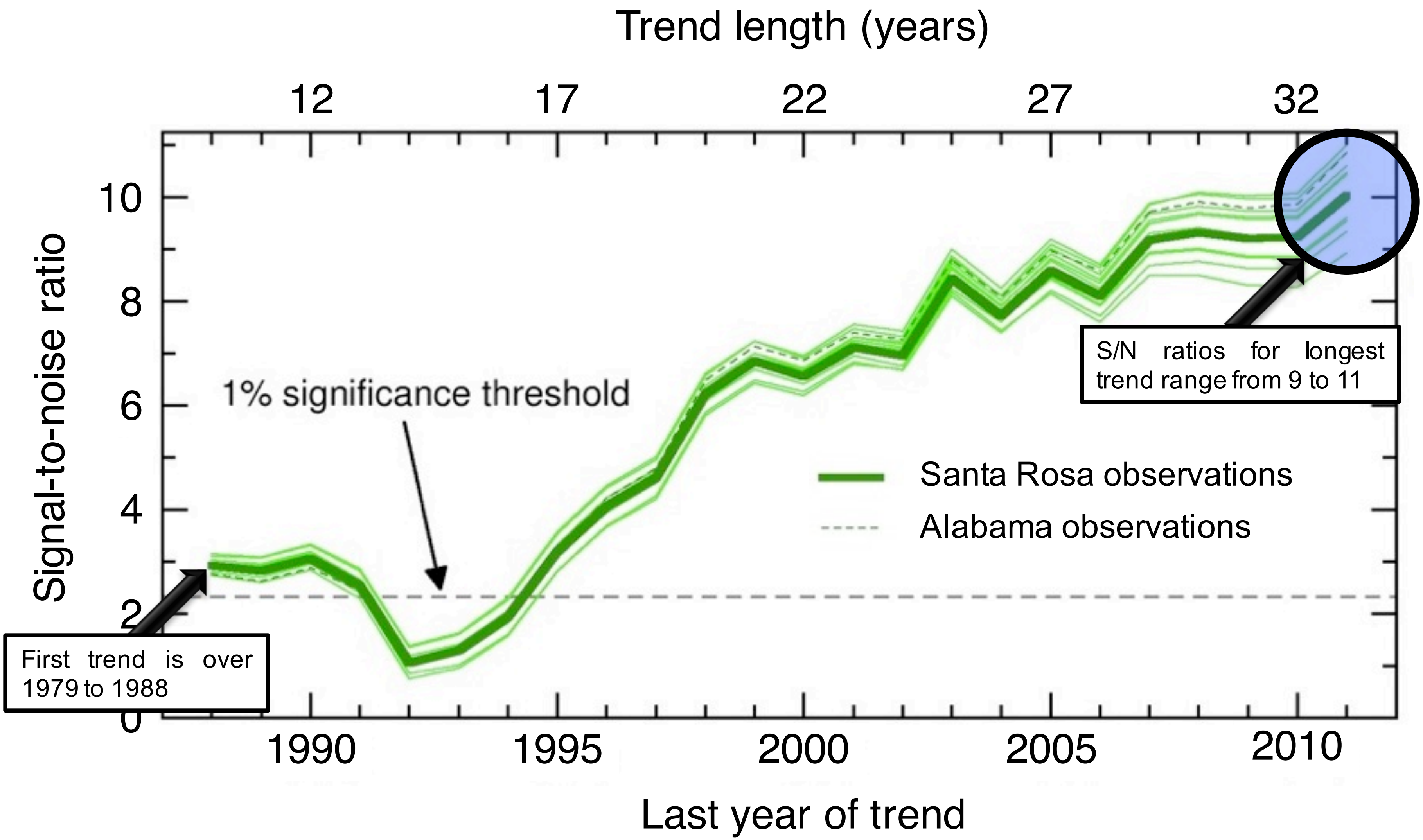


Model HUMAN fingerprint

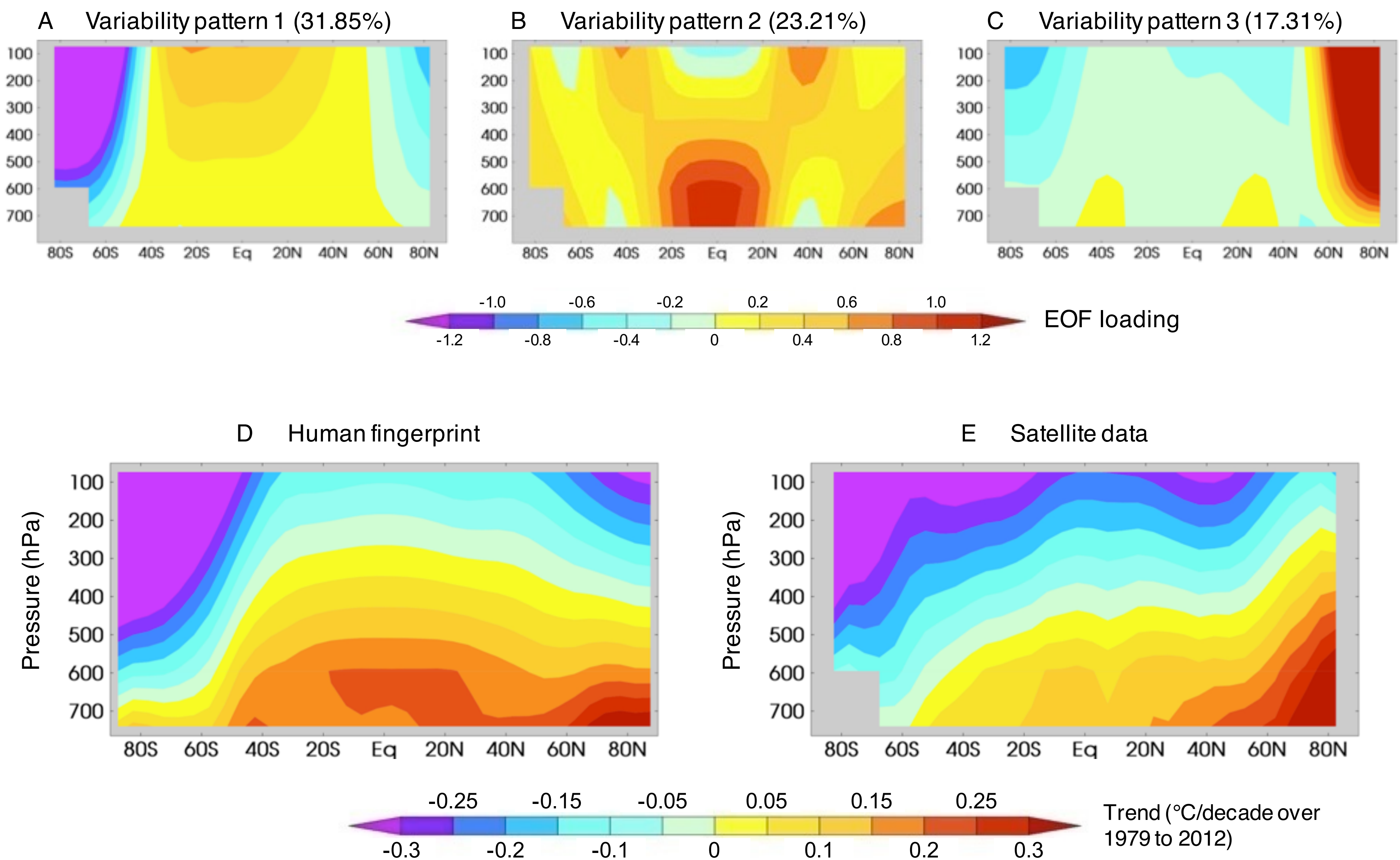


Pattern similarity time series

Estimating signal-to-noise ratios



The dominant patterns of natural internal variability do not look like the human fingerprint or satellite data



Conclusions

- In many hearings in the U.S. Senate and Congress, satellite tropospheric temperature data were “Exhibit A” in the case against global warming
- Satellite atmospheric temperature data actually provide compelling evidence for a large human effect on global climate
- In two out of three satellite datasets, global-mean tropospheric warming is “unprecedented” relative to current estimates of natural variability
- Evidence for human effects on climate is even stronger in pattern-based studies (higher Signal-to-Noise ratios)
- As expected, there are natural, decade-to-decade fluctuations in warming rates - but there is no evidence of “leveling off” of recent warming
- The narrative that climate scientists ignore key uncertainties is false