The Search for a Human Fingerprint in the Changing Thermal Structure of the Atmosphere

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Lawrence Livermore National Laboratory

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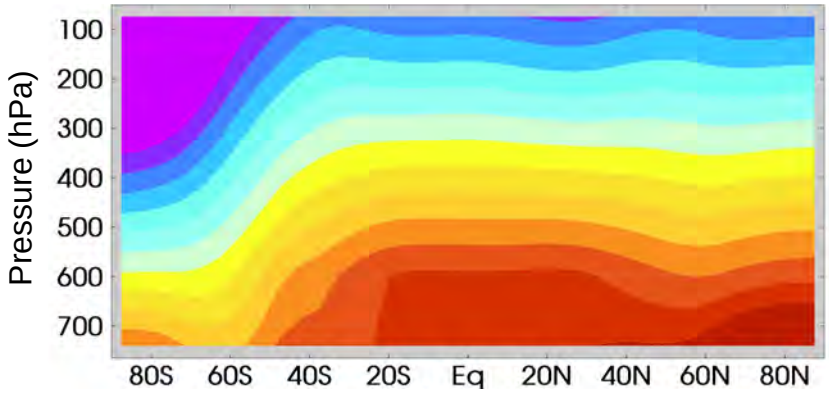
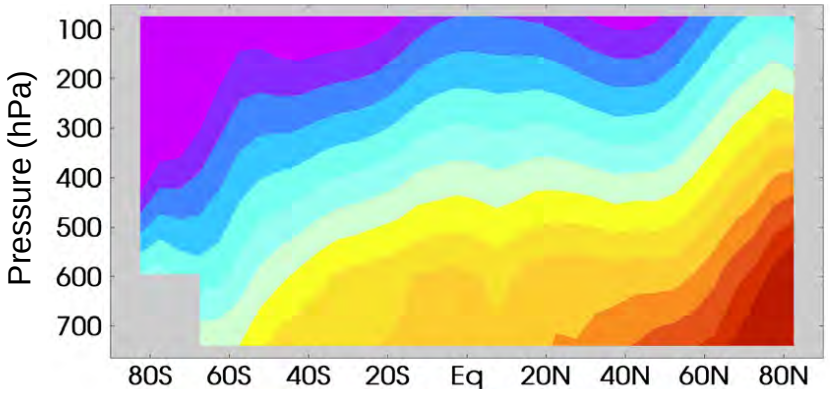
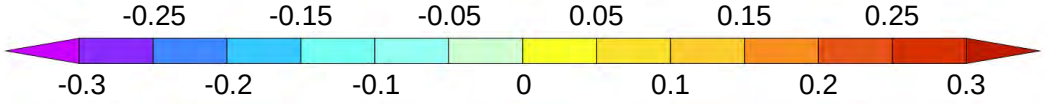
CMIP-5 models (ALL+8.5)



Observations (Santa Rosa)



Trend over 1979 to 2012
(°C/decade)



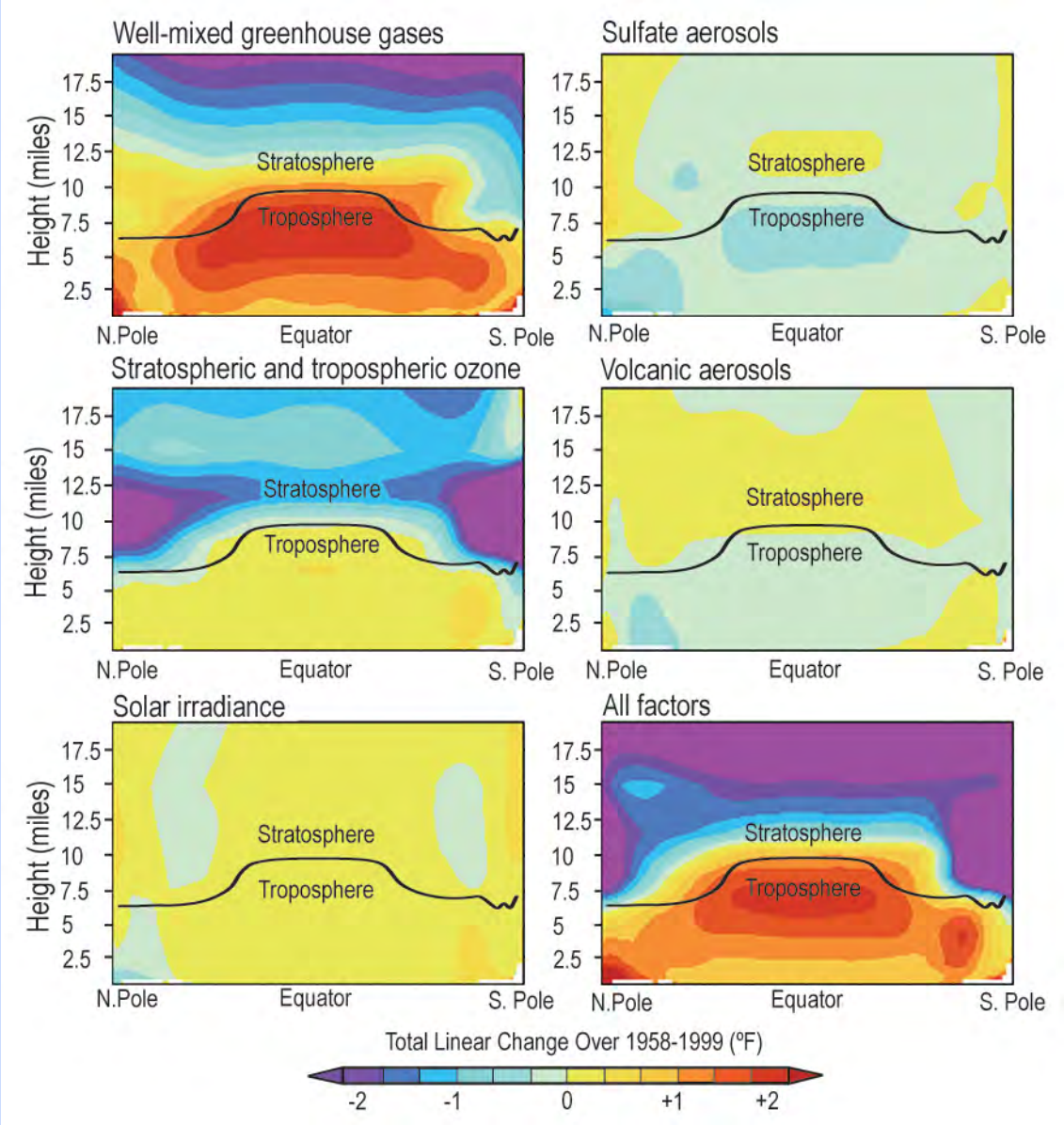
My collaborators and co-authors

- Jeff Painter, Celine Bonfils, Peter Gleckler, Charles Doutriaux, Karl Taylor (Lawrence Livermore National Laboratory)
- Carl Mears, Frank Wentz (Remote Sensing Systems)
- Susan Solomon (M.I.T.)
- Tom Wigley (University of Adelaide)
- Gavin Schmidt (NASA/Goddard Institute for Space Studies)
- Nathan Gillett (Canadian Climate Centre)
- Peter Thorne (National Climatic Data Center)

Structure

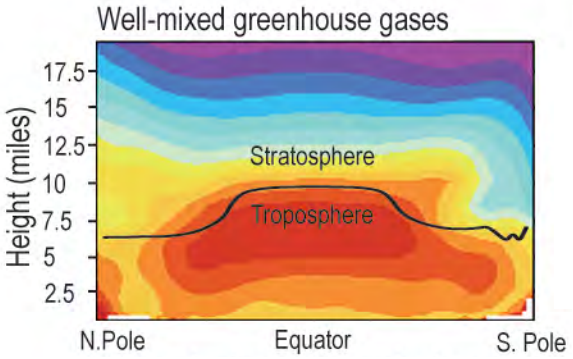
- Identifying human influences on atmospheric temperature
  - Early fingerprint work (mid-1990s)
  - Update with latest satellite data and CMIP-5 simulations
- Comparing modeled and observed temperature variability
- Conclusions

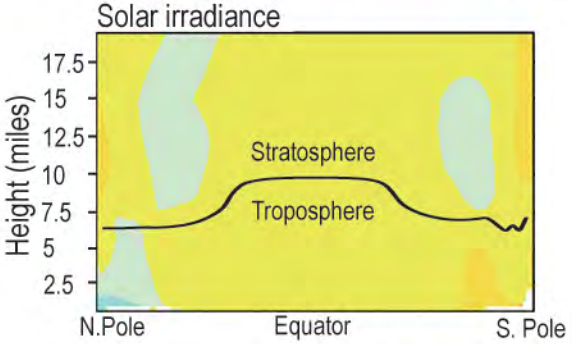
Different factors that influence climate have different "fingerprints"

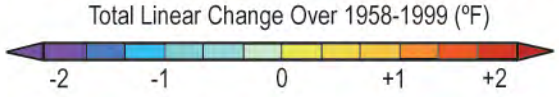


Source: Global Climate Change Impacts in the United States (Karl *et al.*, 2009; modified from Santer *et al.*, 1996, 2006)

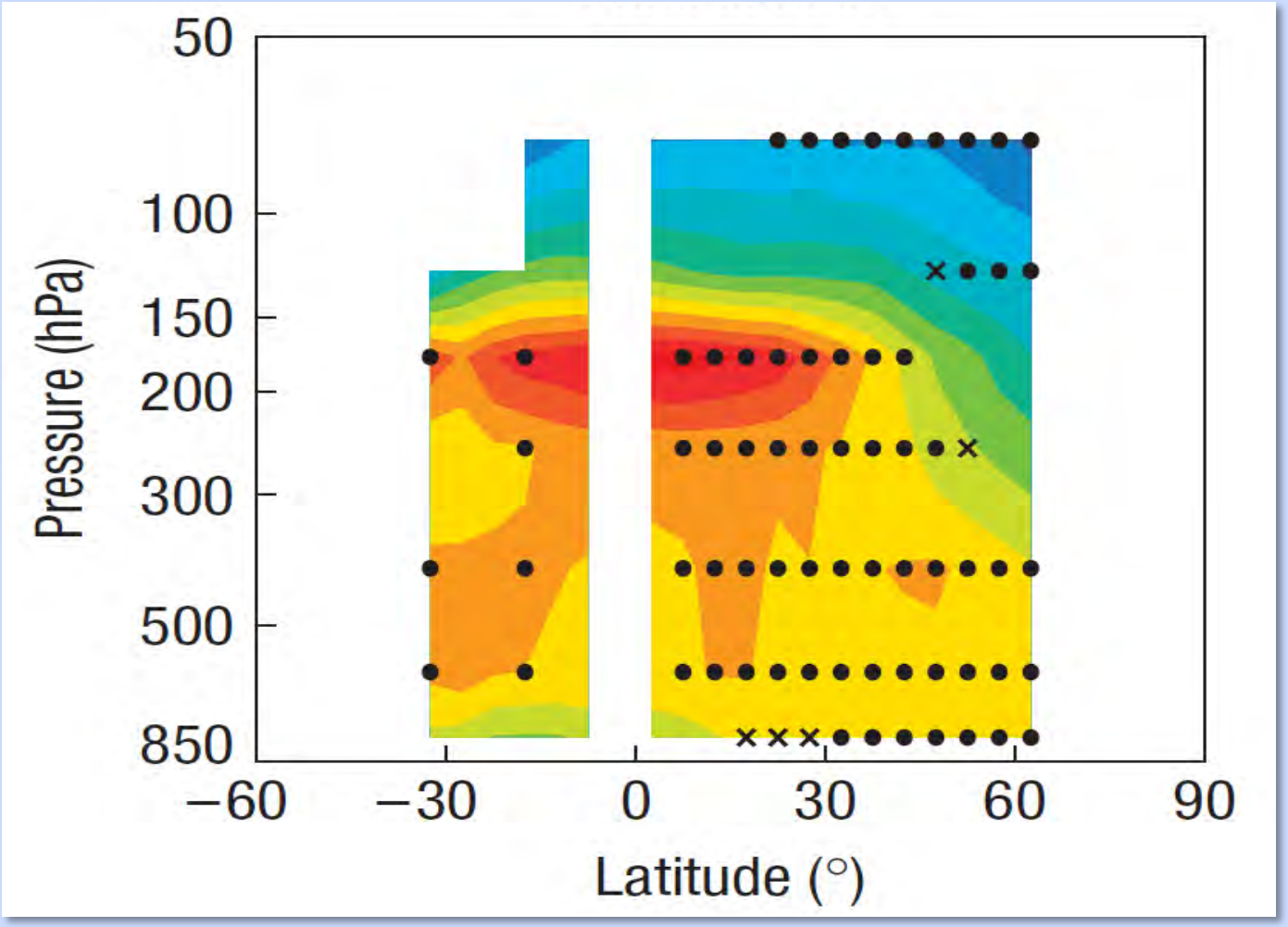
Different factors that influence climate have different fingerprints







Weather balloon estimates of atmospheric temperature change are consistent with “human influence” fingerprints



Source: Allen and Sherwood, *Nature Geoscience* (2008)

Trend (°C/decade; changes over 1970 to 2005)

Structure

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Measuring atmospheric temperature from space

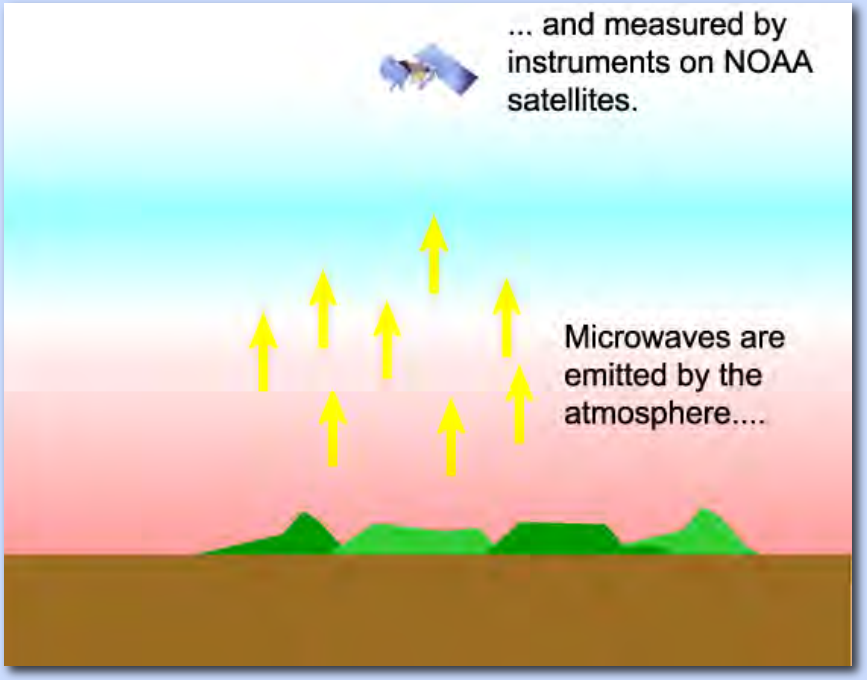
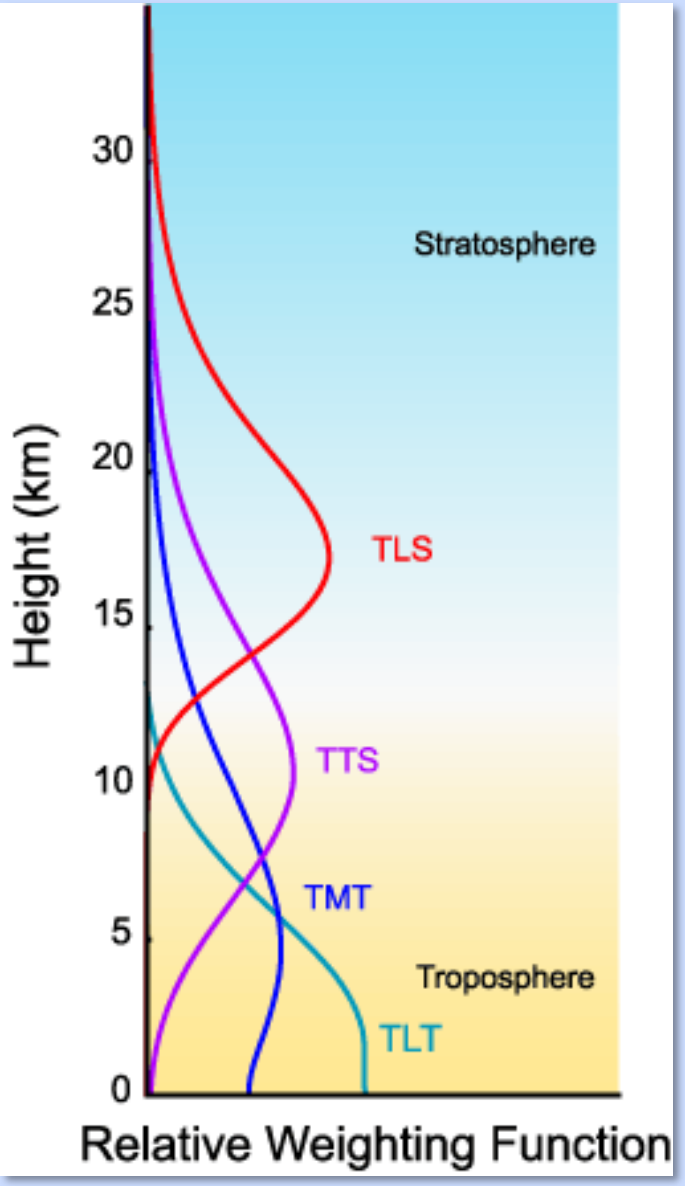


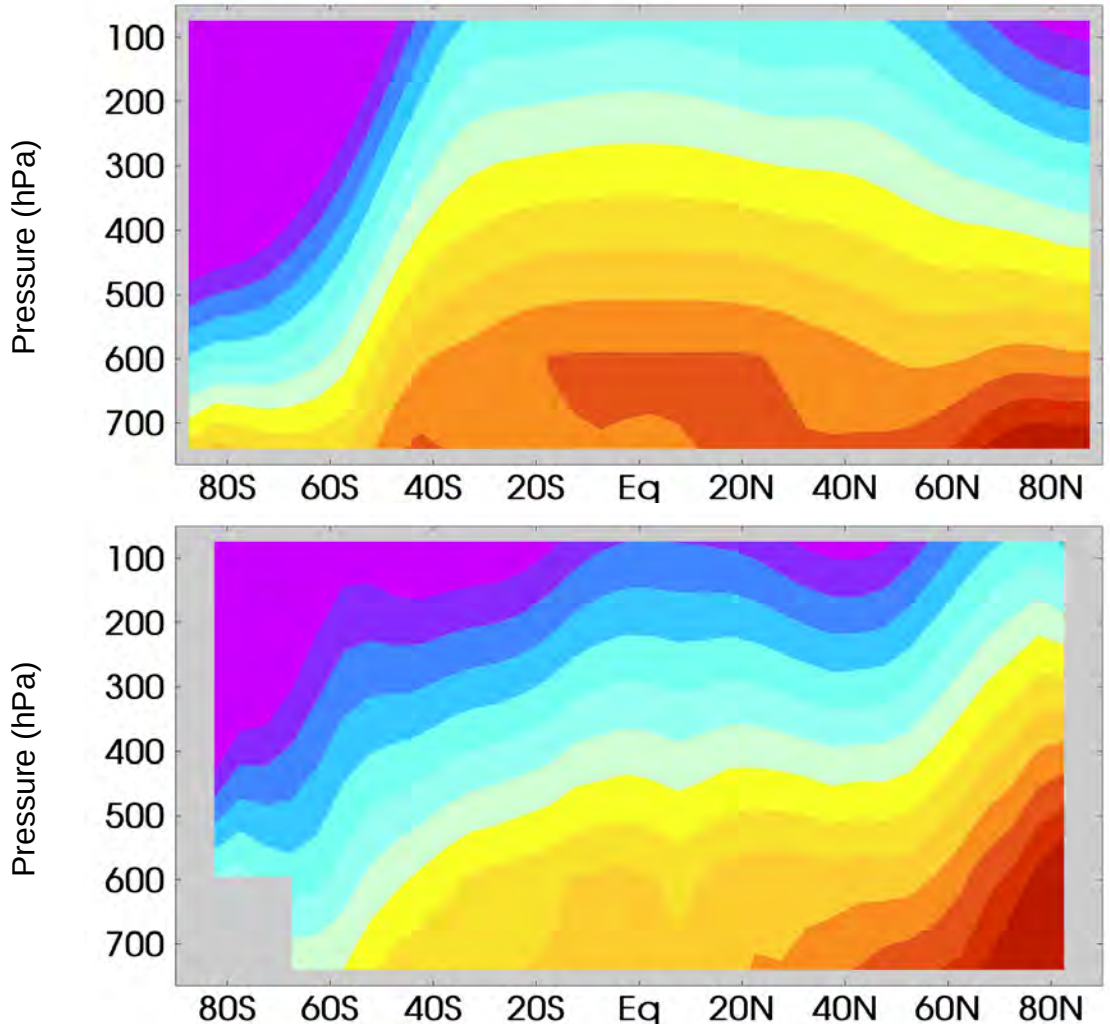
Figure and text courtesy of Carl Mears, Remote Sensing Systems

- Higher temperatures = more microwave emissions from oxygen molecules
- By choosing different microwave frequencies, different layers in the atmosphere can be measured

Our fingerprint study uses zonal-mean changes in the temperature of broad atmospheric layers

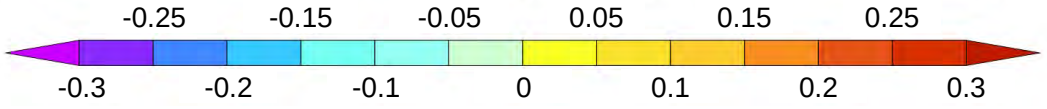


The changing thermal structure of the atmosphere in the latest observations and model simulations



CMIP-5 models (Human effects)

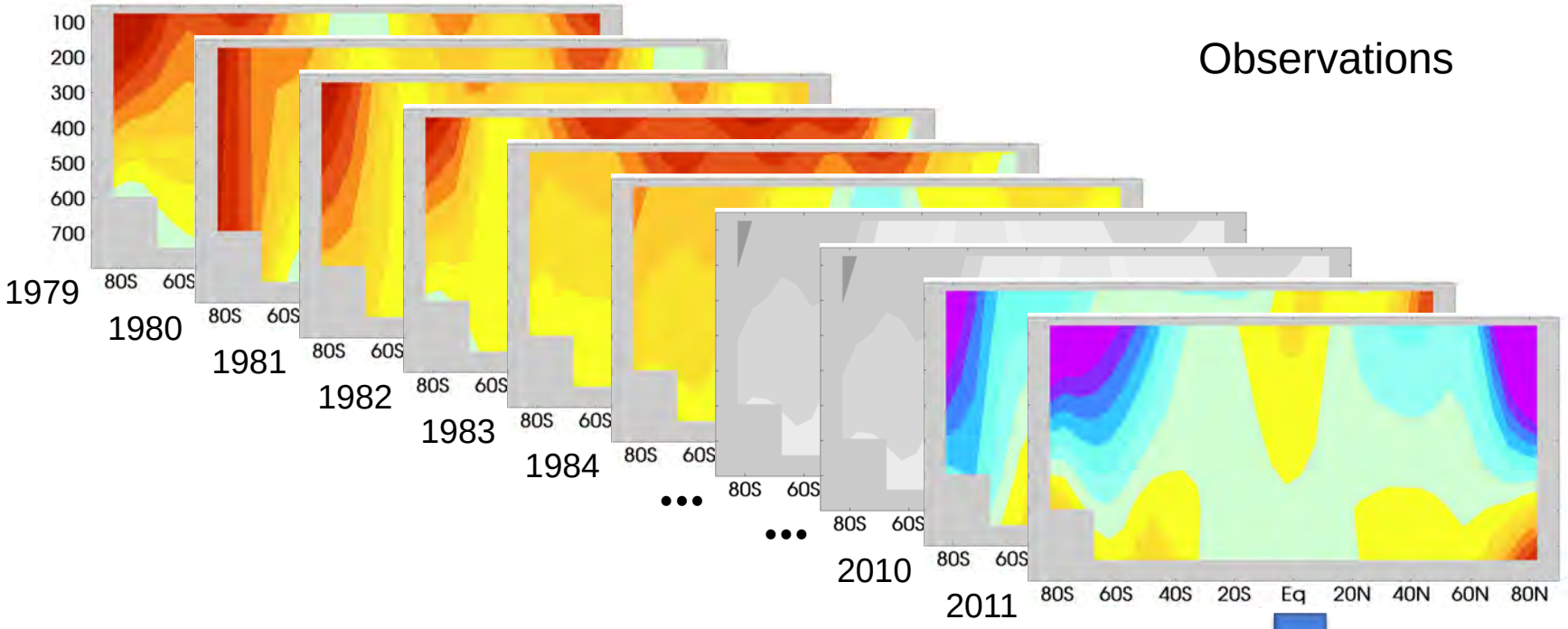
Observations (Santa Rosa)

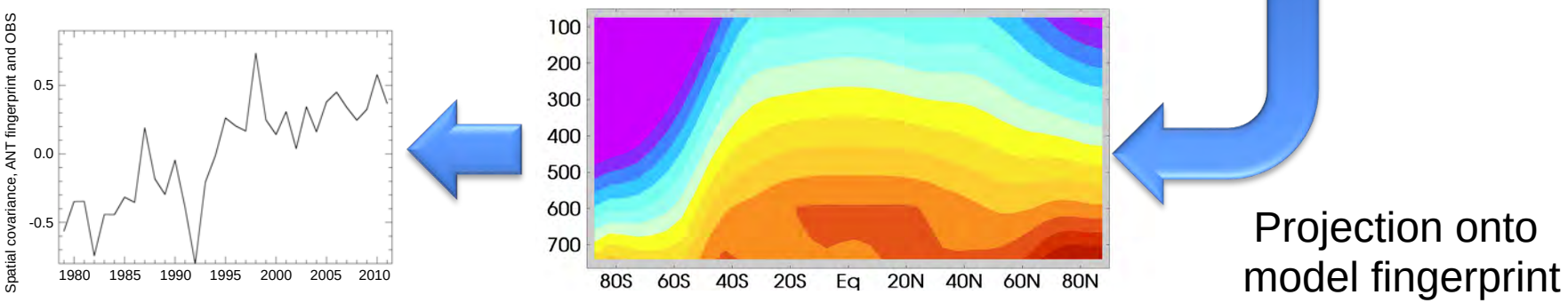


Trend (°C/decade over 1979 to 2012)

Source: Santer *et al.*, *PNAS* (2013b; in press)

Fingerprint detection explained pictorially….



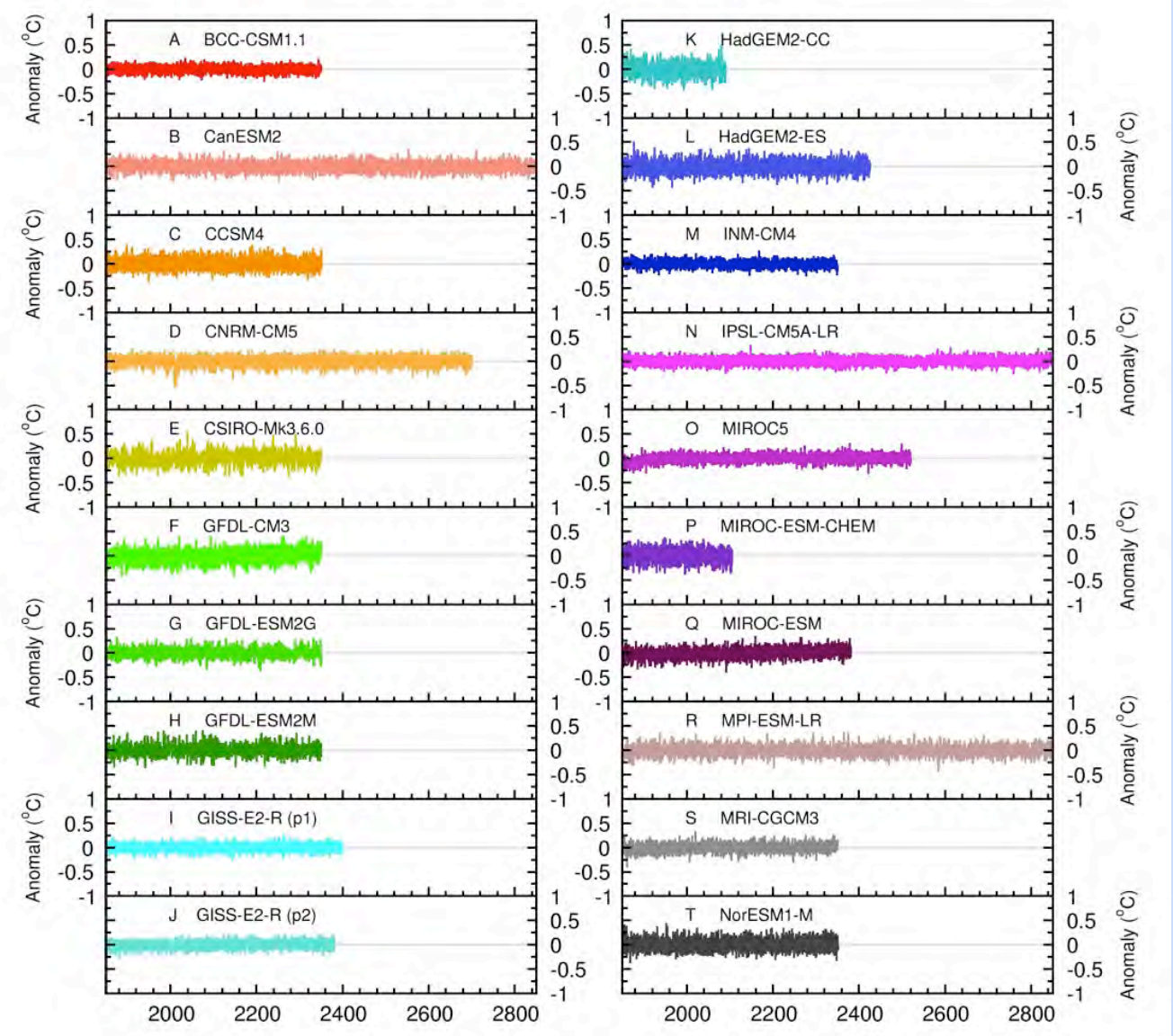


Projection onto model fingerprint

Projection time series

Model ANTHRO fingerprint

Global-mean lower stratospheric temperature changes in CMIP-5 pre-industrial control runs (**CTL**)



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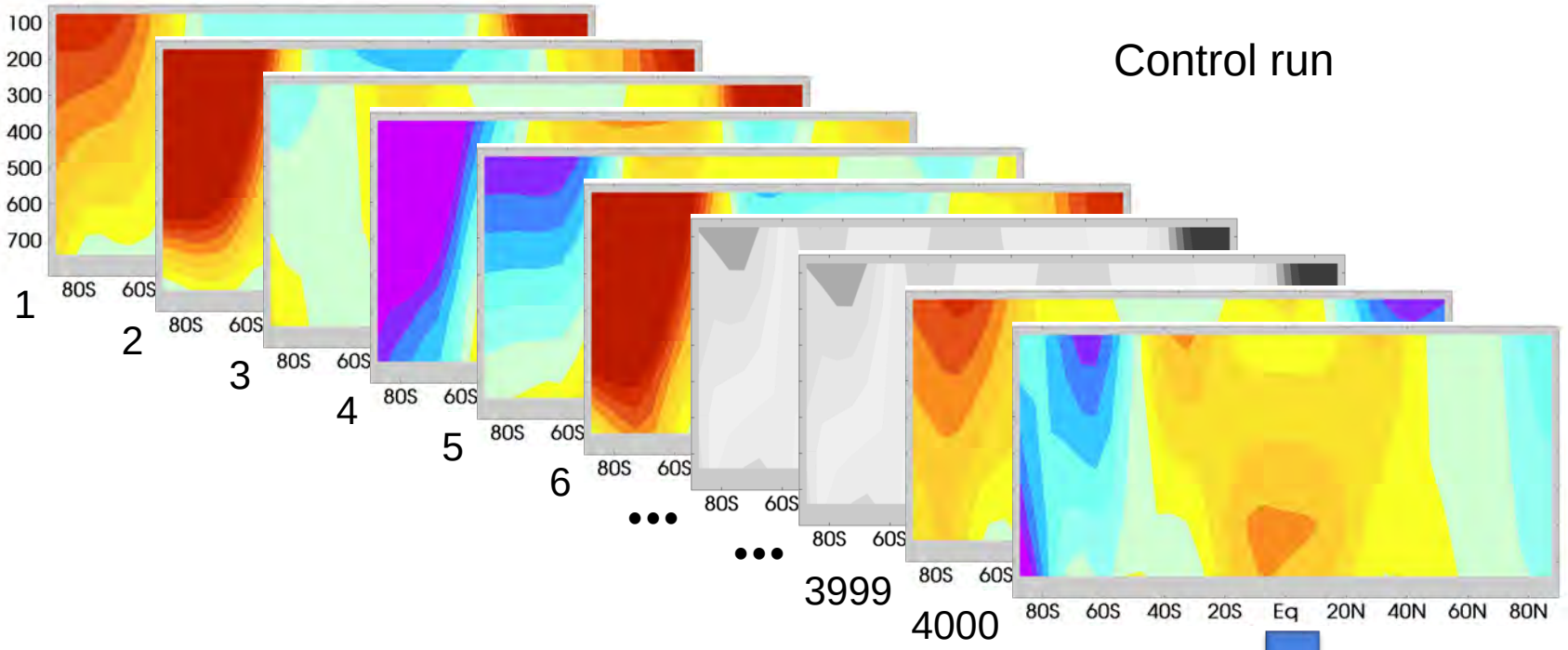

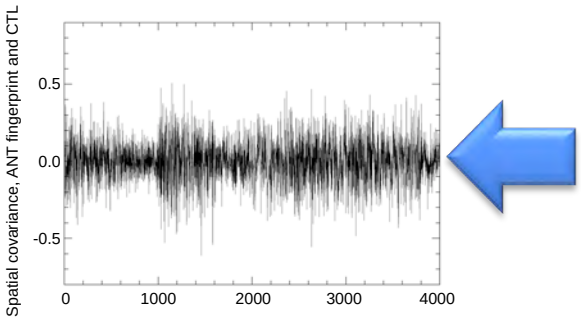

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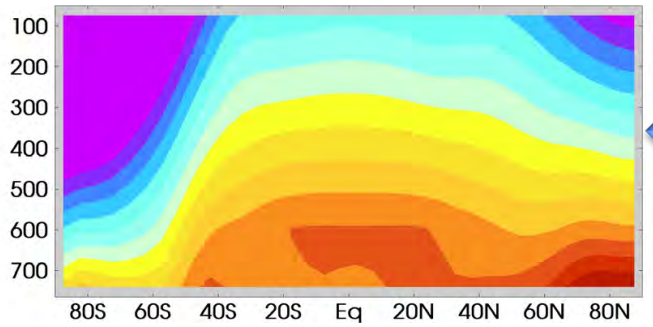
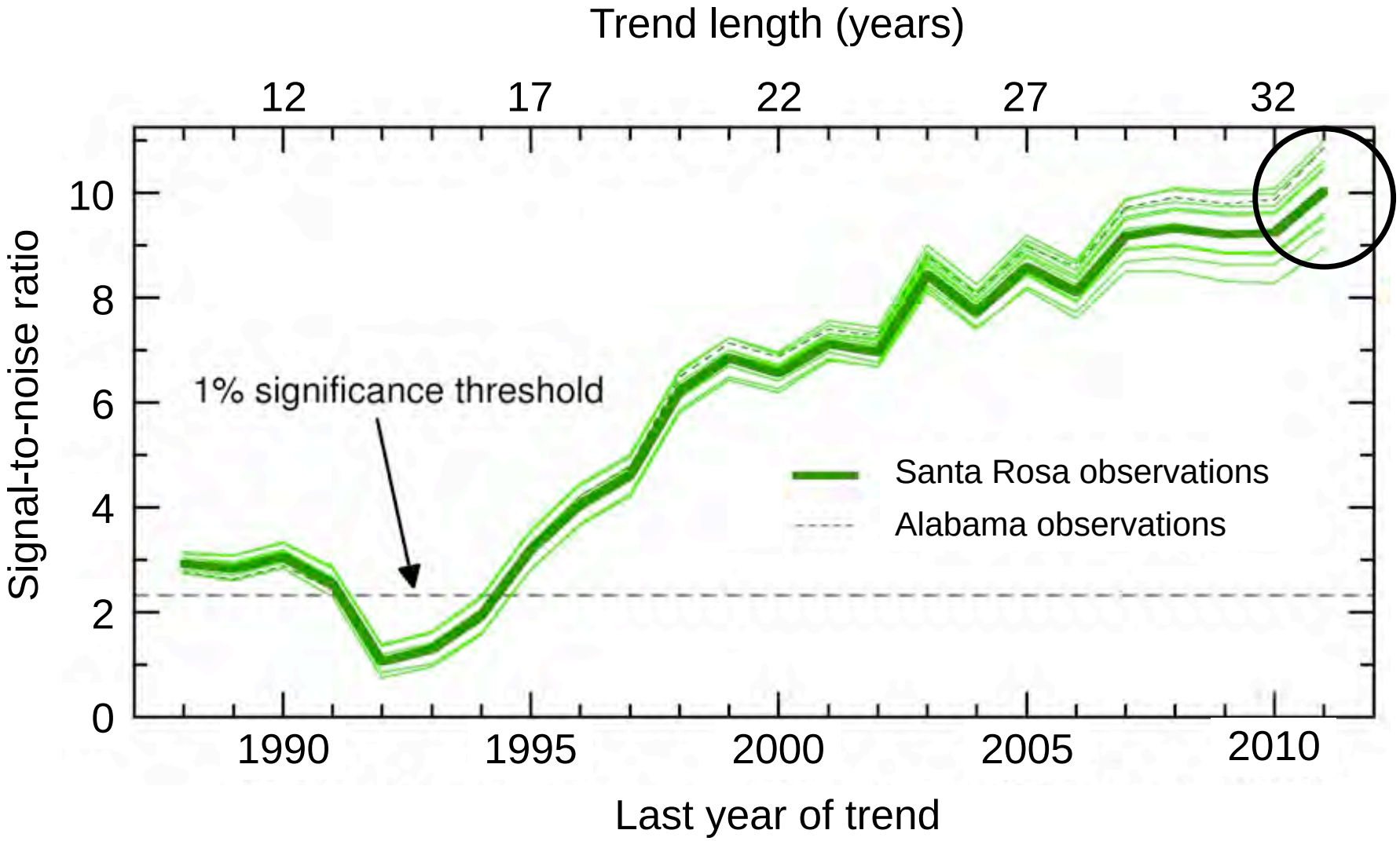


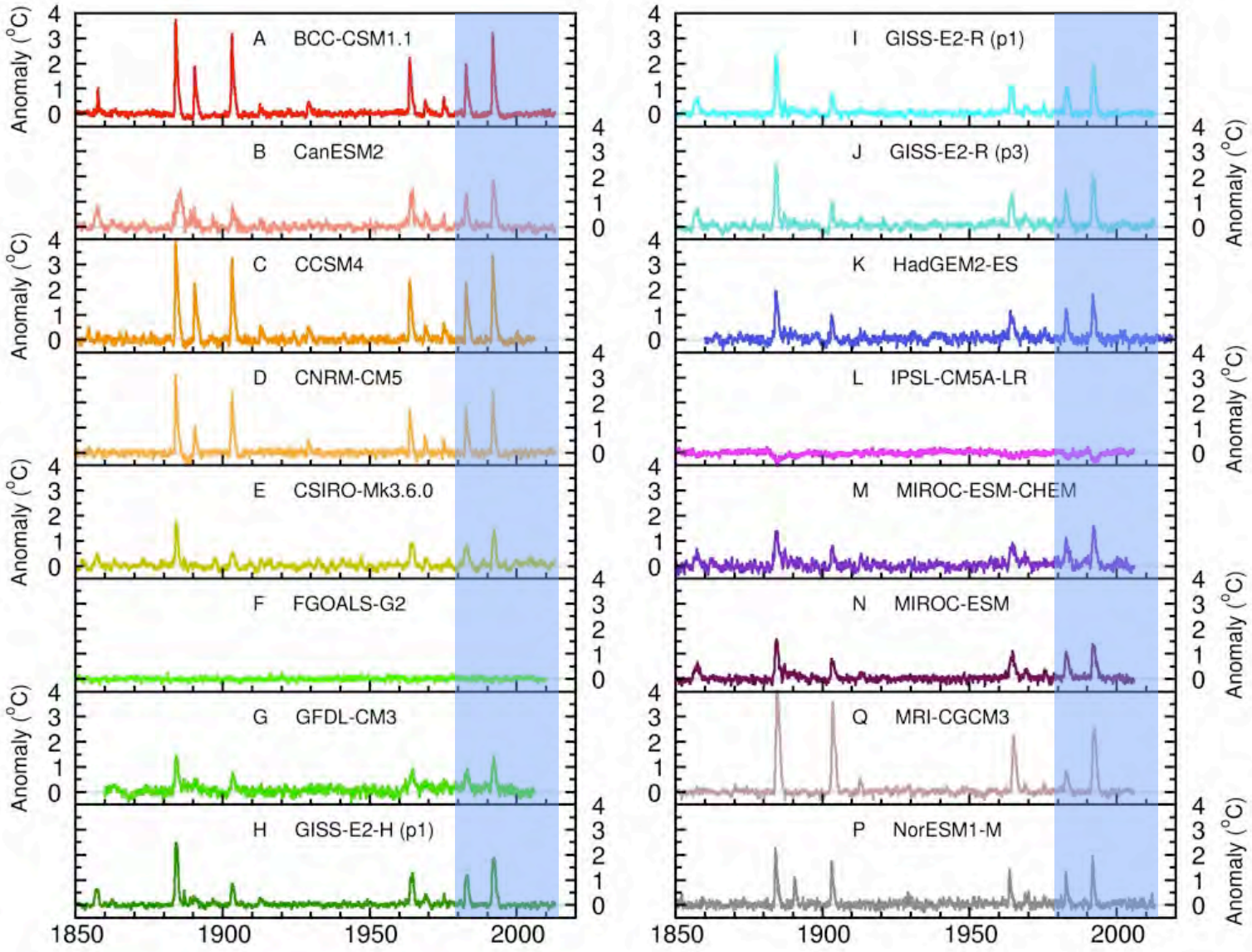
Model ANTHRO fingerprint

Projection onto model fingerprint

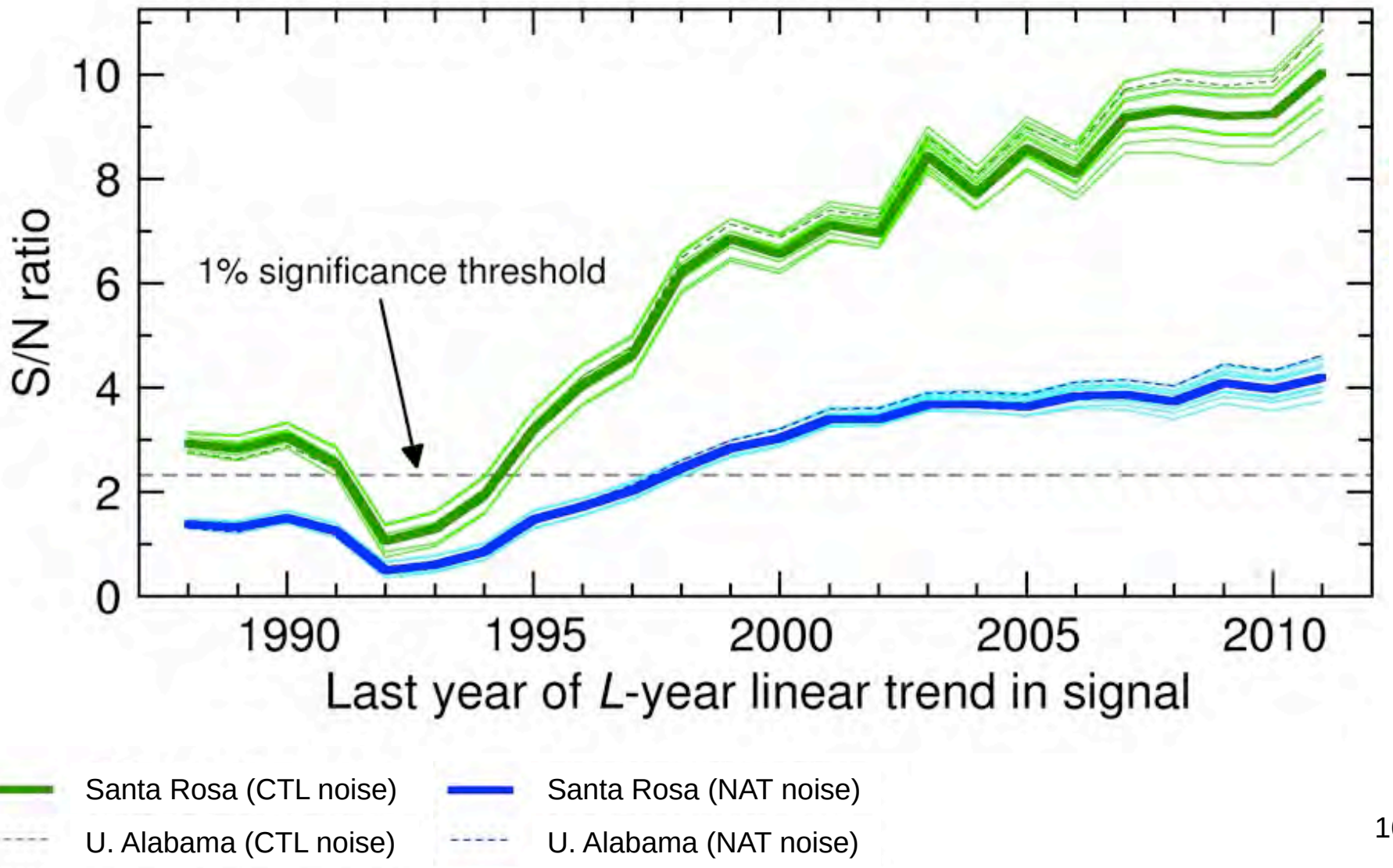
Estimating signal-to-noise ratios



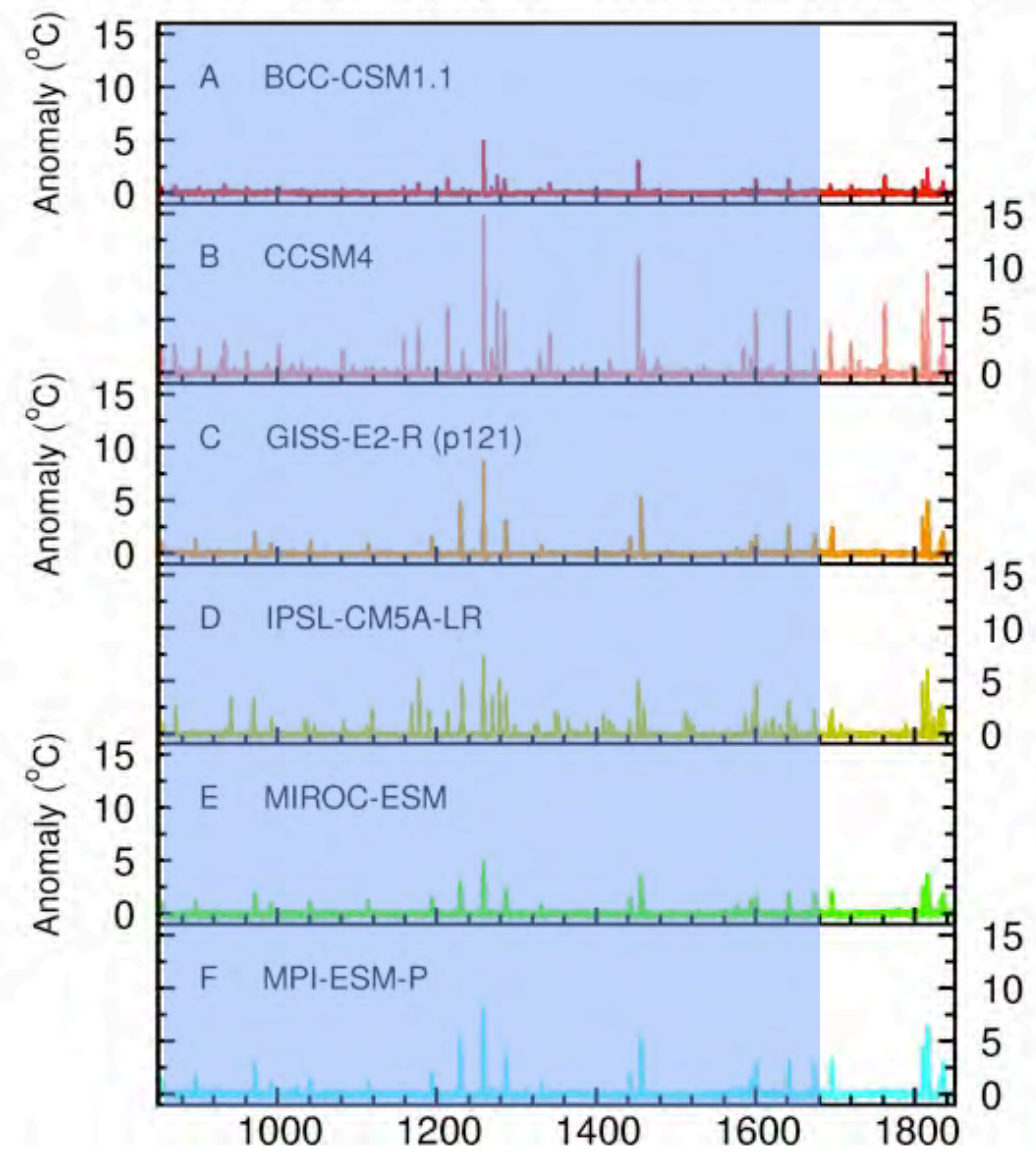
Global-mean lower stratospheric temperature changes in CMIP-5 simulations with solar and volcanic forcing (**NAT**)



Estimating signal-to-noise ratios



Global-mean lower stratospheric temperature changes in CMIP-5 “Last Millennium” simulations (**P1000**)



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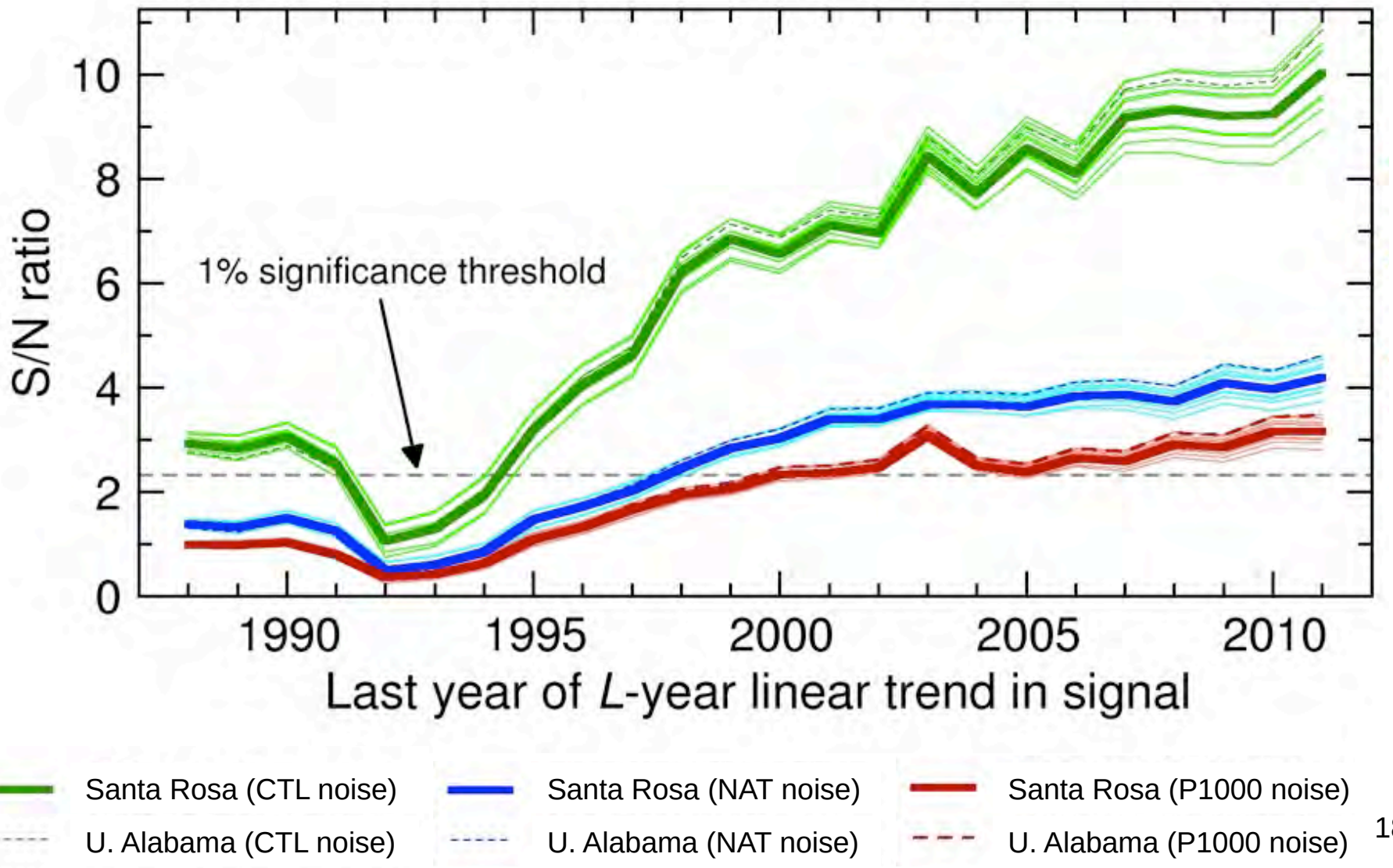
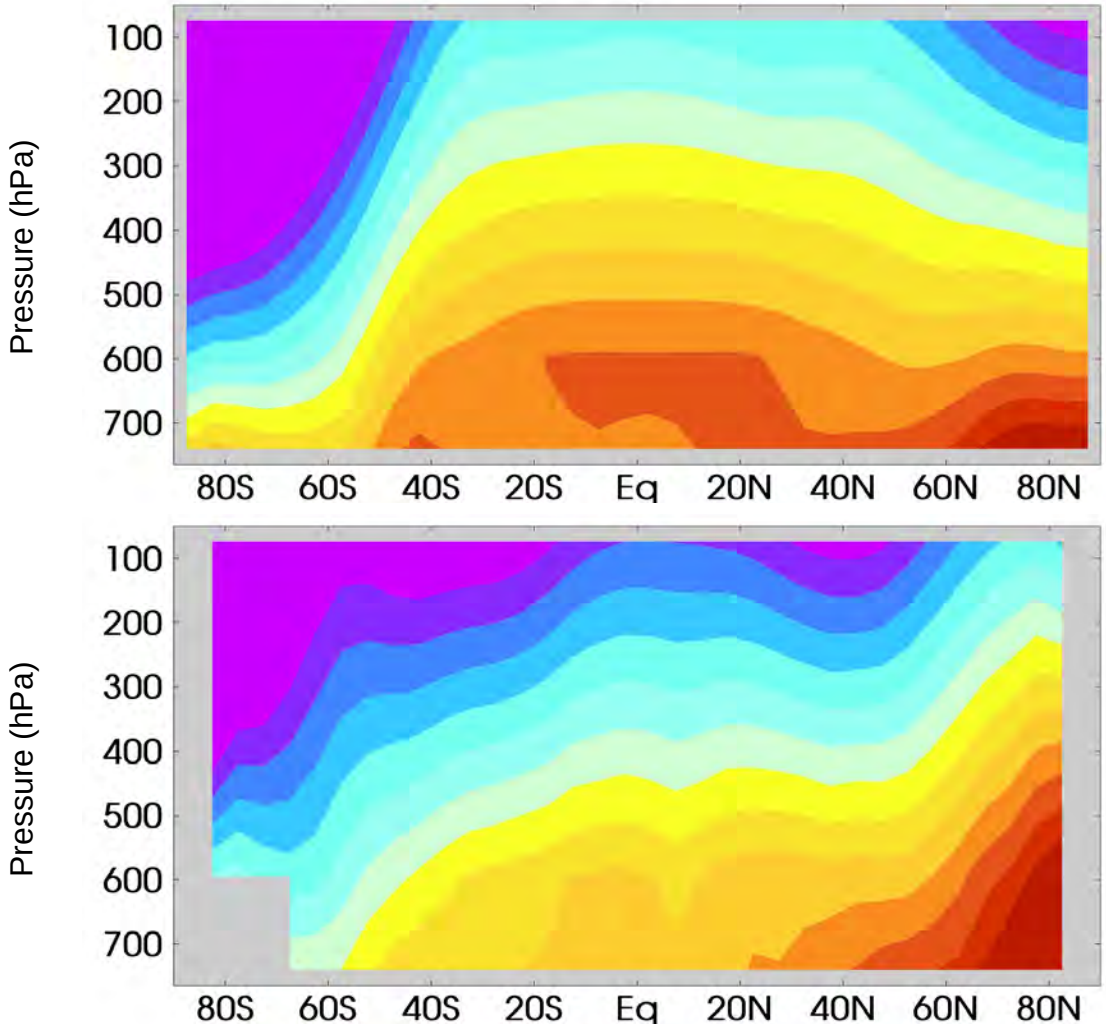


Why do we obtain such large S/N ratios?



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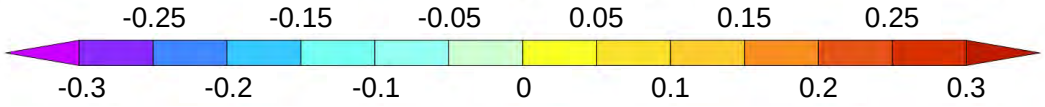
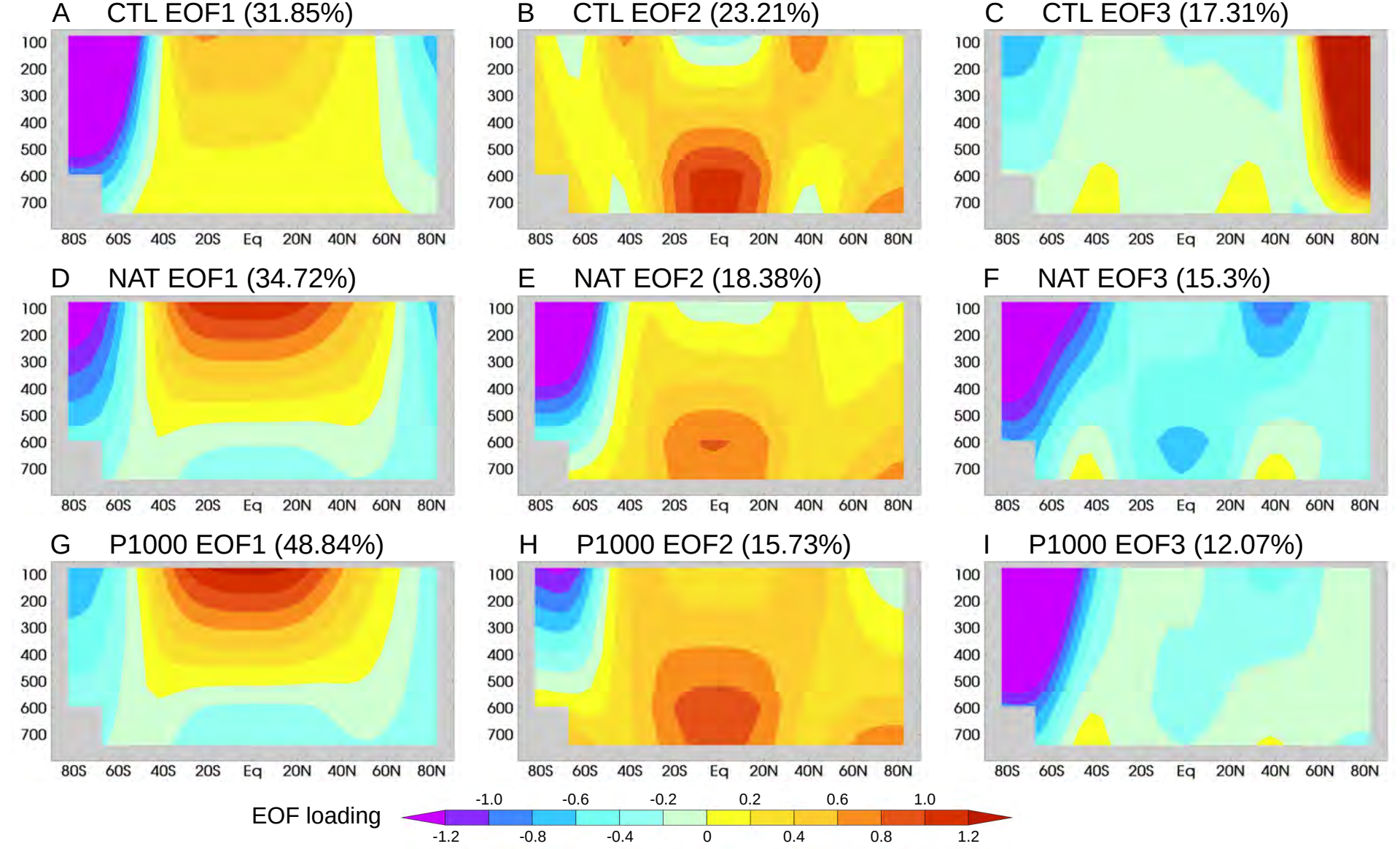


Trend (°C/decade over 1979 to 2012)

Source: Santer *et al.*, *PNAS* (2013b; in press)

The dominant patterns of internal and “total” natural variability do not look like the searched-for fingerprint



Structure

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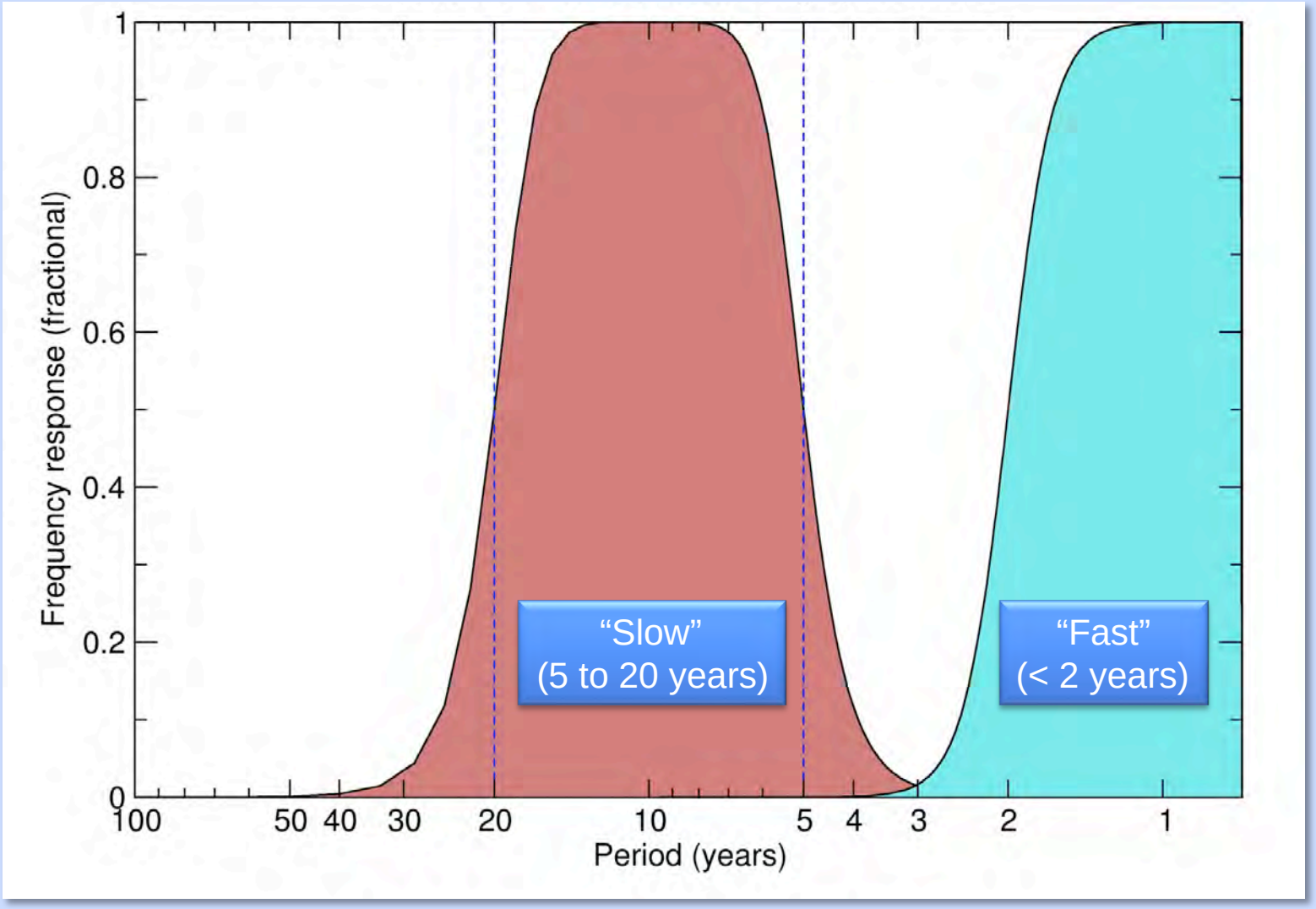
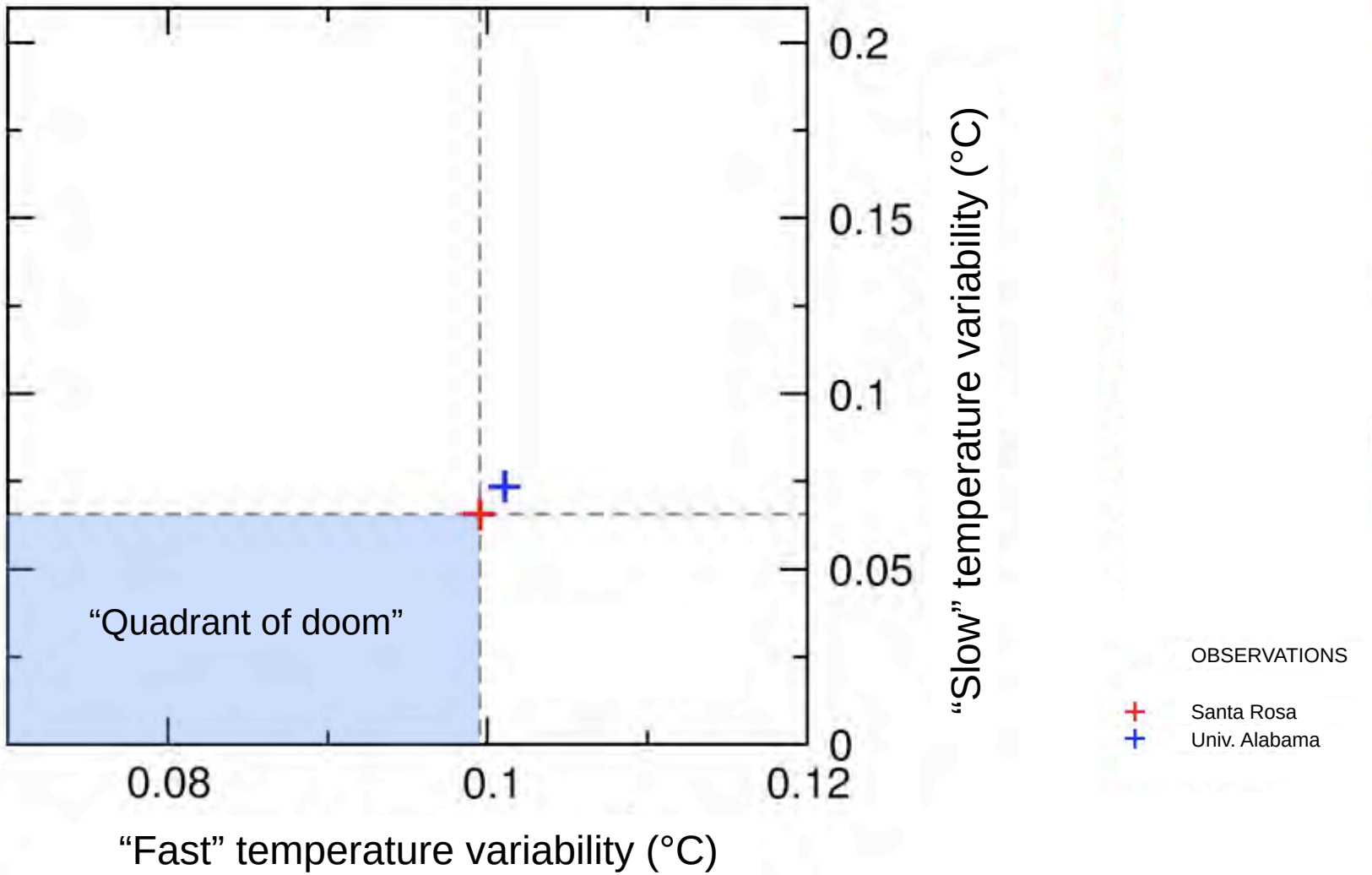
Comparing modeled and observed variability



Do CMIP-5 models underestimate the observed "slow" variability of tropospheric temperature?



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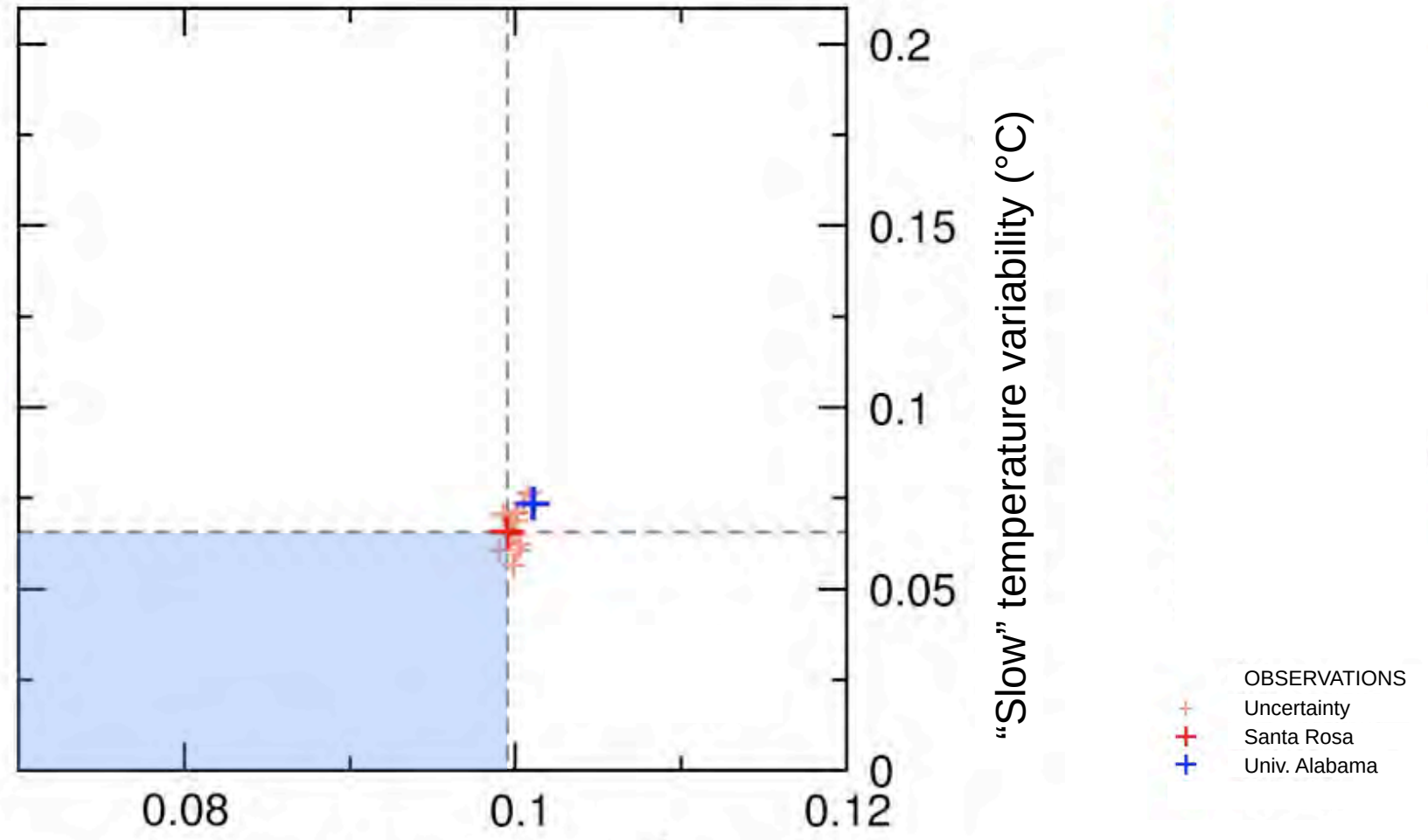

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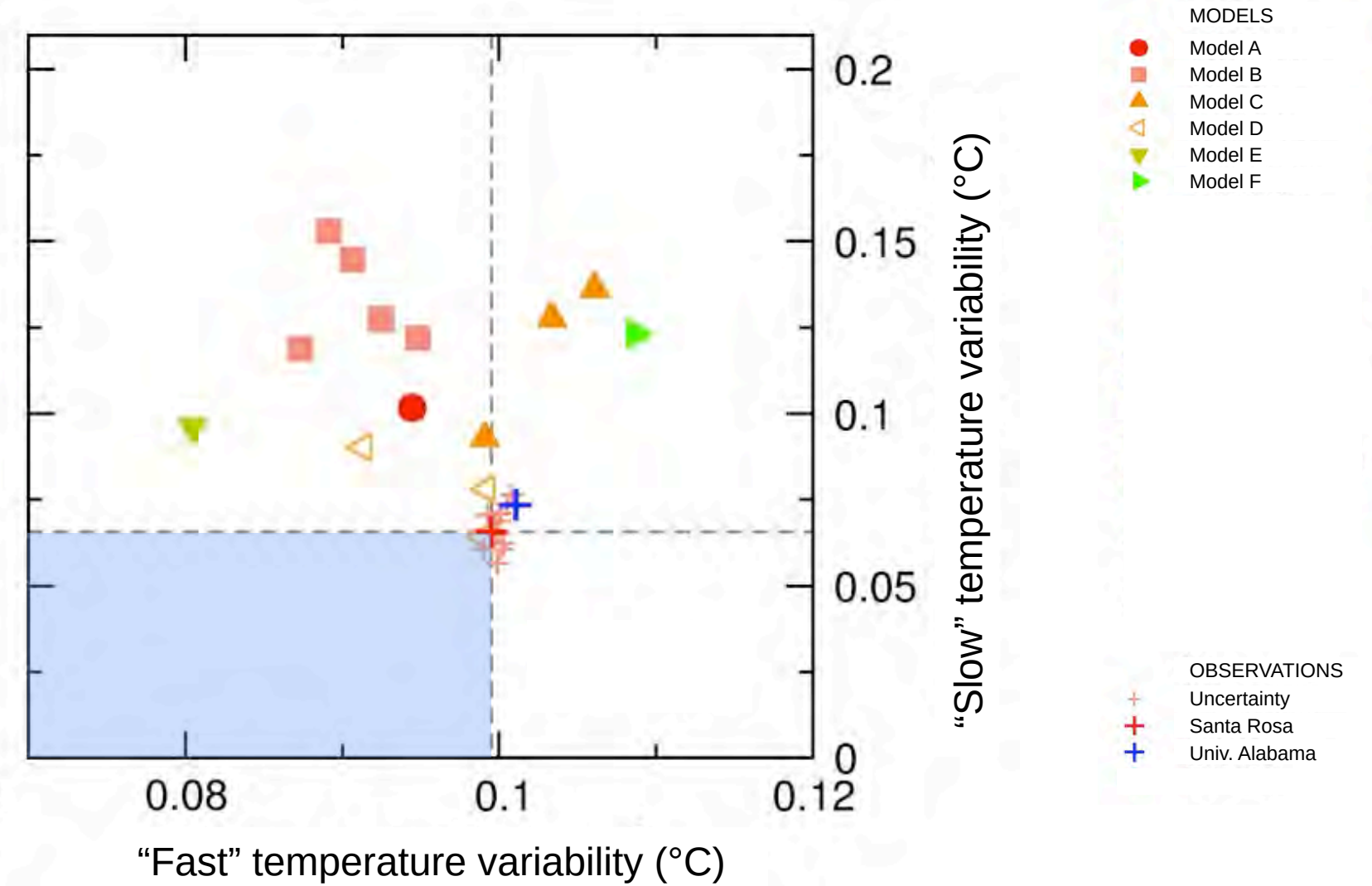

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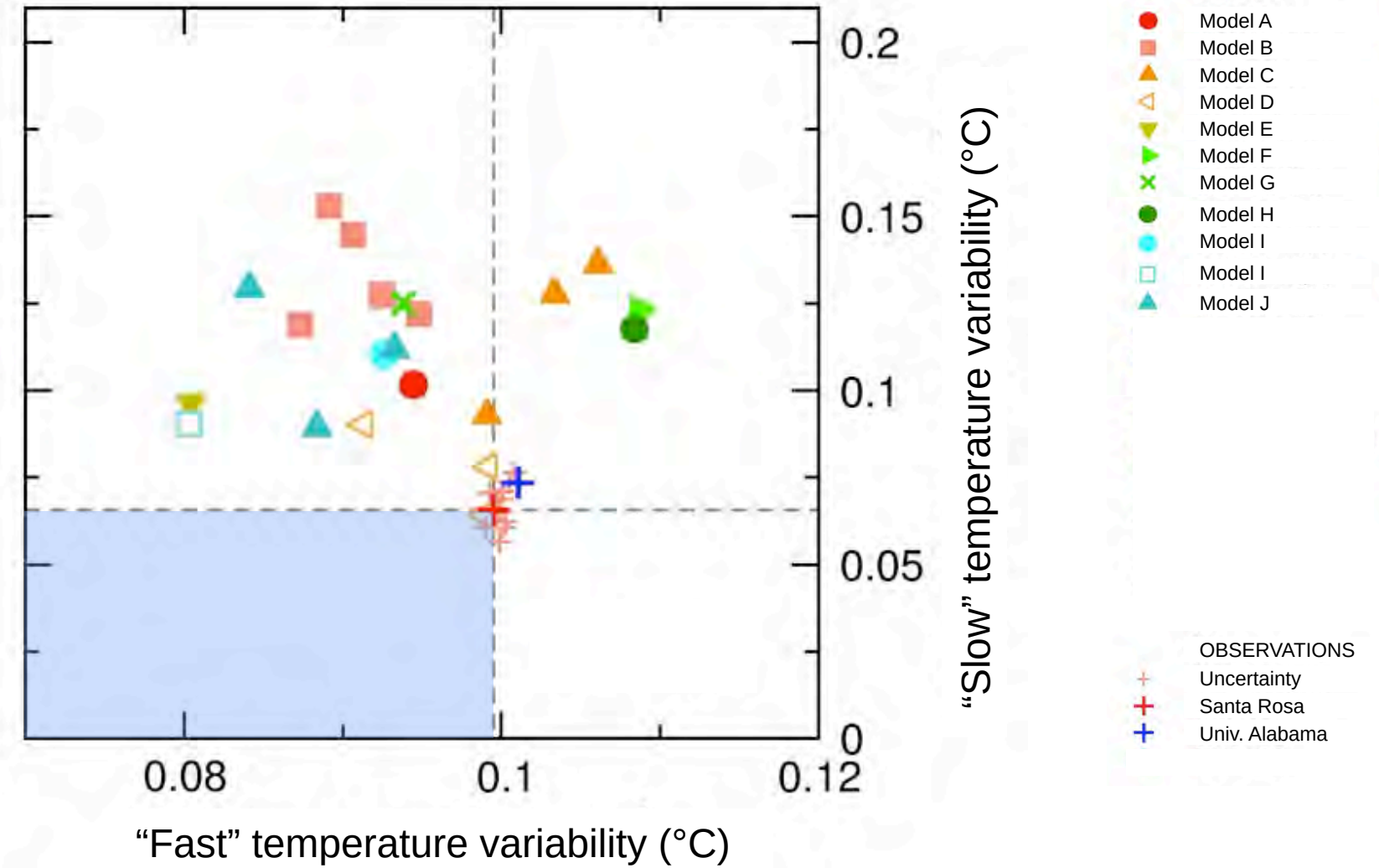

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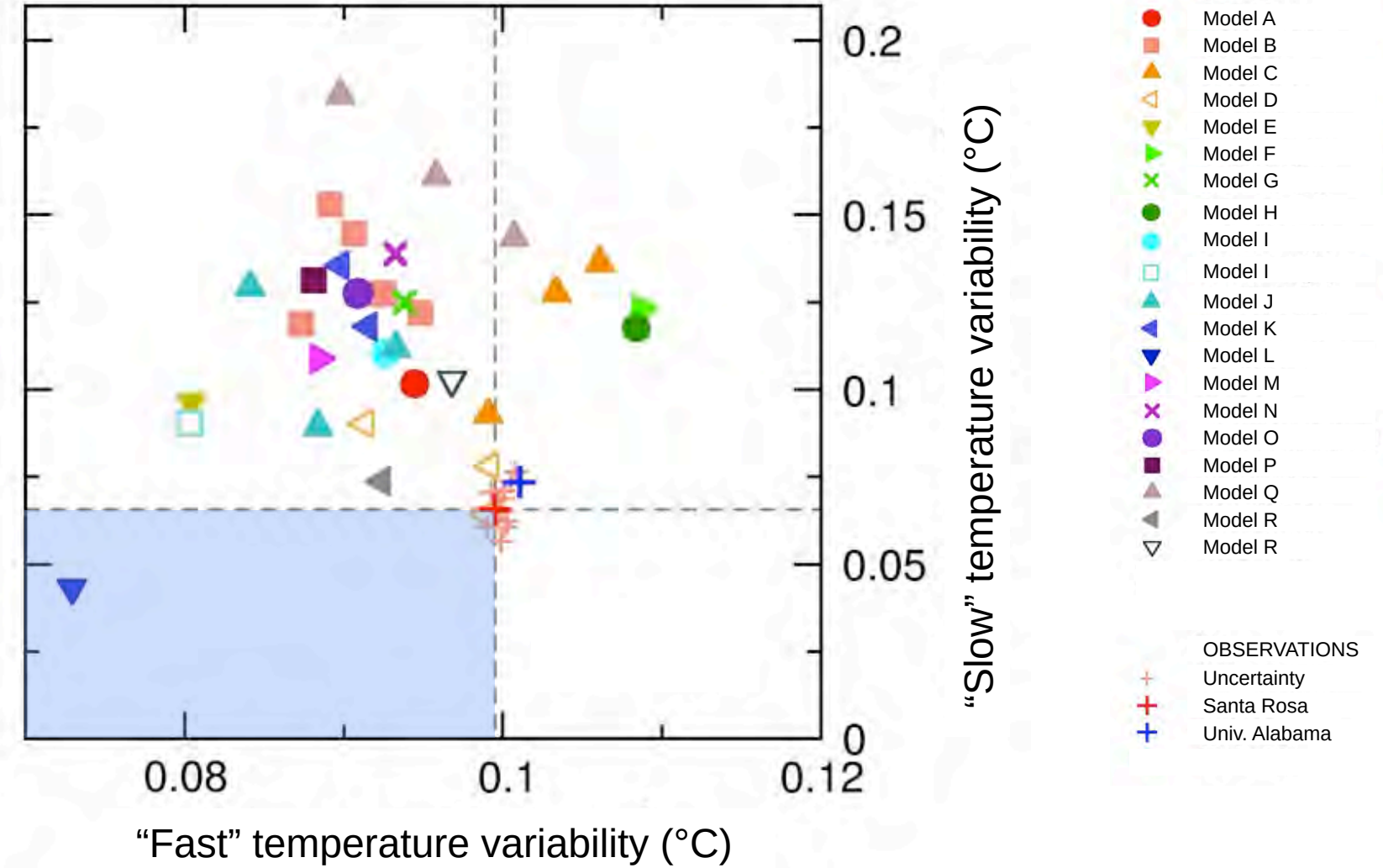

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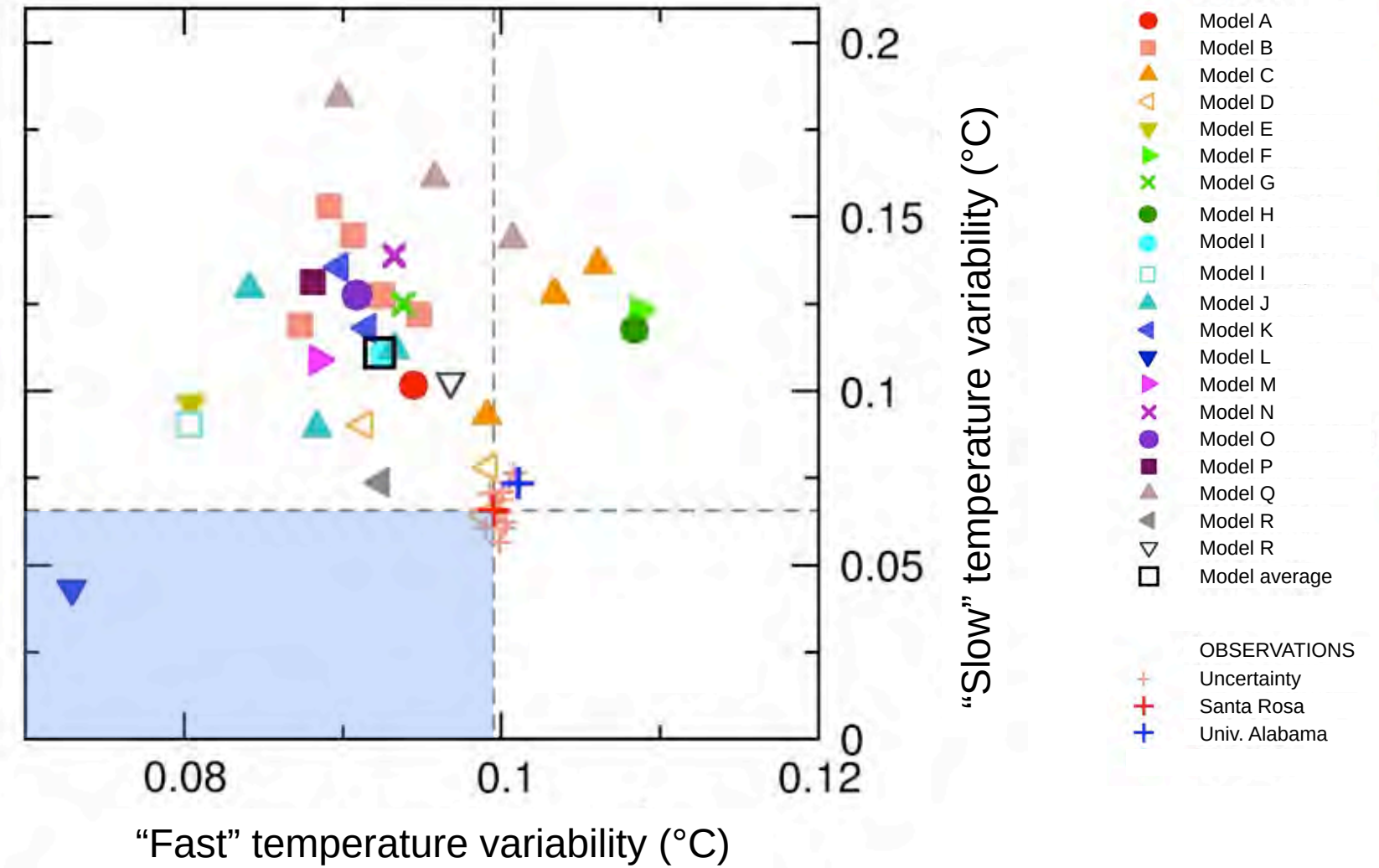

Source: Santer *et al.*, *PNAS* (2013a)

Conclusions

- A human-caused latitude/altitude pattern of atmospheric temperature change is consistently identifiable in satellite observations
- This “fingerprint” of tropospheric warming and stratospheric cooling can be discriminated from the background noise of:
  - Internal climate variability (**CTL**)
  - Variability caused by natural changes in solar irradiance and volcanic aerosol loadings (**NAT**, **P1000**)
- Our significance testing framework is highly conservative
  - **NAT** and **P1000** “total” noise estimates include volcanic eruptions and solar irradiance changes much larger than those observed over the satellite era
- Internal and “total” natural variability cannot produce sustained global-scale warming of the troposphere and cooling of the stratosphere