Climate Change Detection and Attribution

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Ron Stouffer Symposium

Geophysical Fluid Dynamics Laboratory, Princeton, NJ

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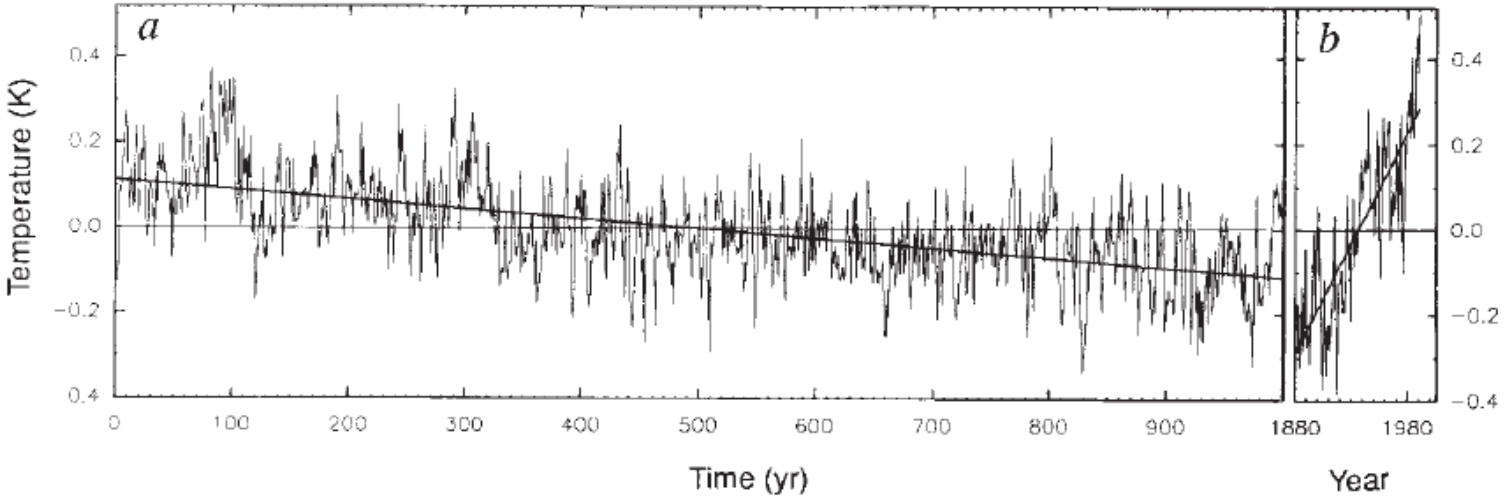
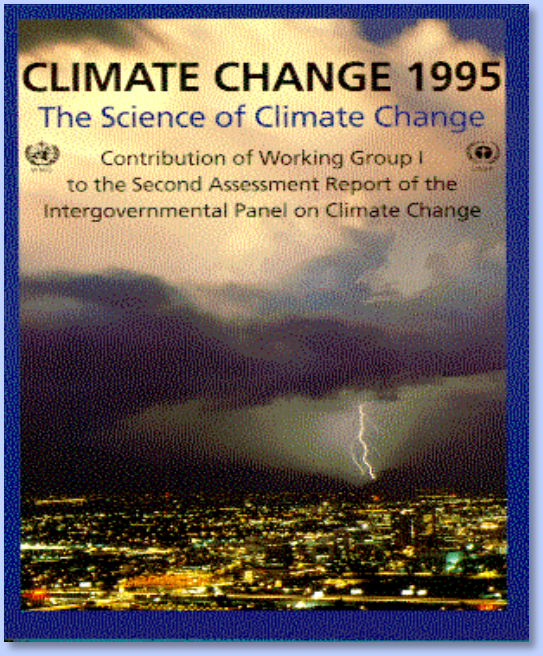


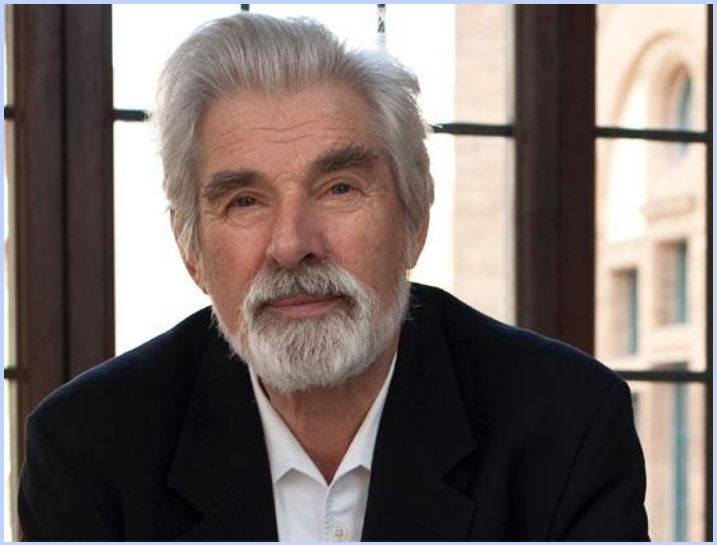
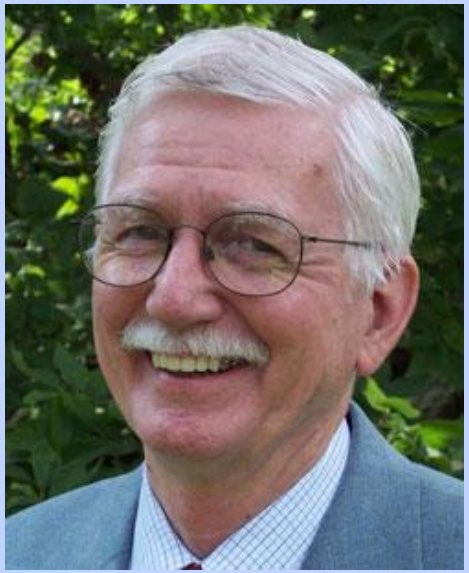
A signal in scientific understanding: Evolving evidence of a discernible human influence on global climate

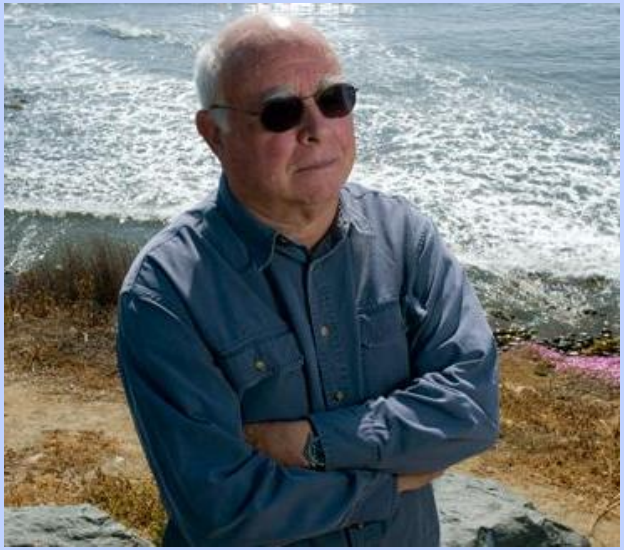


"The balance of evidence suggests a discernible human influence on global climate"

"Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes... It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century"

Early pioneers in climate change detection and attribution



Early pioneers in climate change detection and attribution

A brief history of climate change detection and attribution ("D&A") research

1. Using climate models to understand expected human-caused climate signal

2. Detecting significant global-mean warming
   - Relative to variability inferred from statistical models
   - Relative to variability estimated from climate model control runs

3. "Model only" pattern analyses:
   - Assessing pros and cons of different pattern recognition methods
   - Using models to identify "canaries in the coal mine"
   - Attribution: Understanding fingerprints of different forcing factors

4. Real-world applications of fingerprinting:
   - With temperature
   - With other variables

5. Event attribution and regional D&A studies

Manabe and Wetherald, JAS (1967): CO_2 increases cool the stratosphere and warm the troposphere

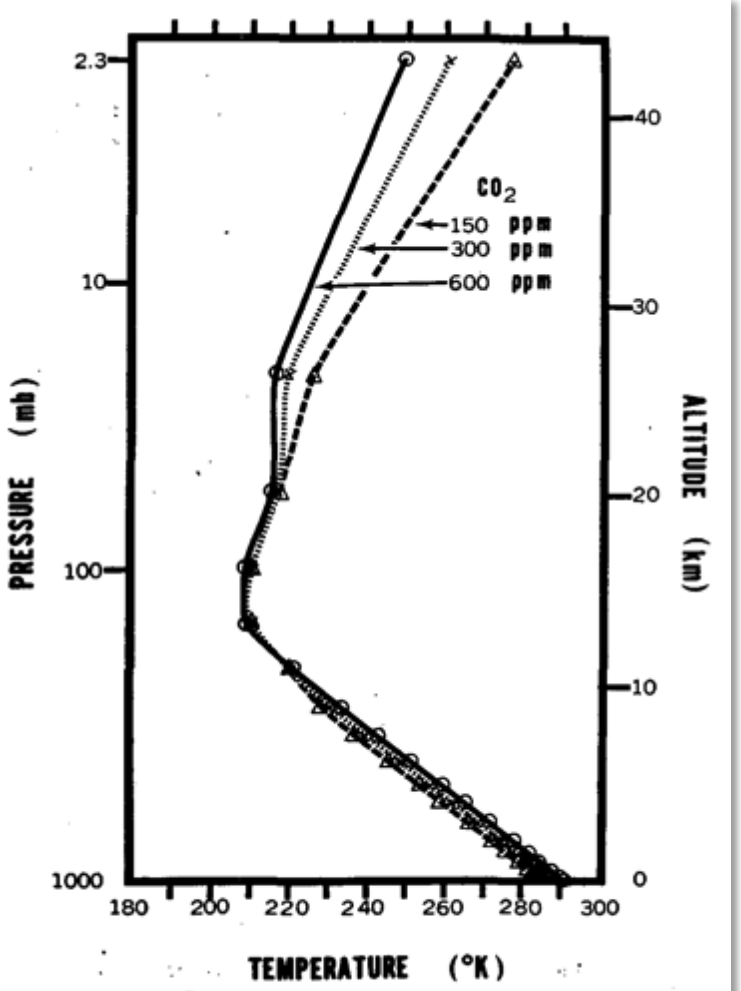


FIG. 16. Vertical distributions of temperature in radiative convective equilibrium for various values of CO_2 content.

Thermal Equilibrium of the Atmosphere with a Given Distribution of Relative Humidity

SYUKURO MANABE AND RICHARD T. WETHERALD

Geophysical Fluid Dynamics Laboratory, ESSA, Washington, D. C.

(Manuscript received 2 November 1966)

"The larger the mixing ratio of carbon dioxide, the warmer is the equilibrium temperature of the Earth's surface and troposphere".

"The larger the mixing ratio of carbon dioxide, the colder is the equilibrium temperature of the stratosphere"

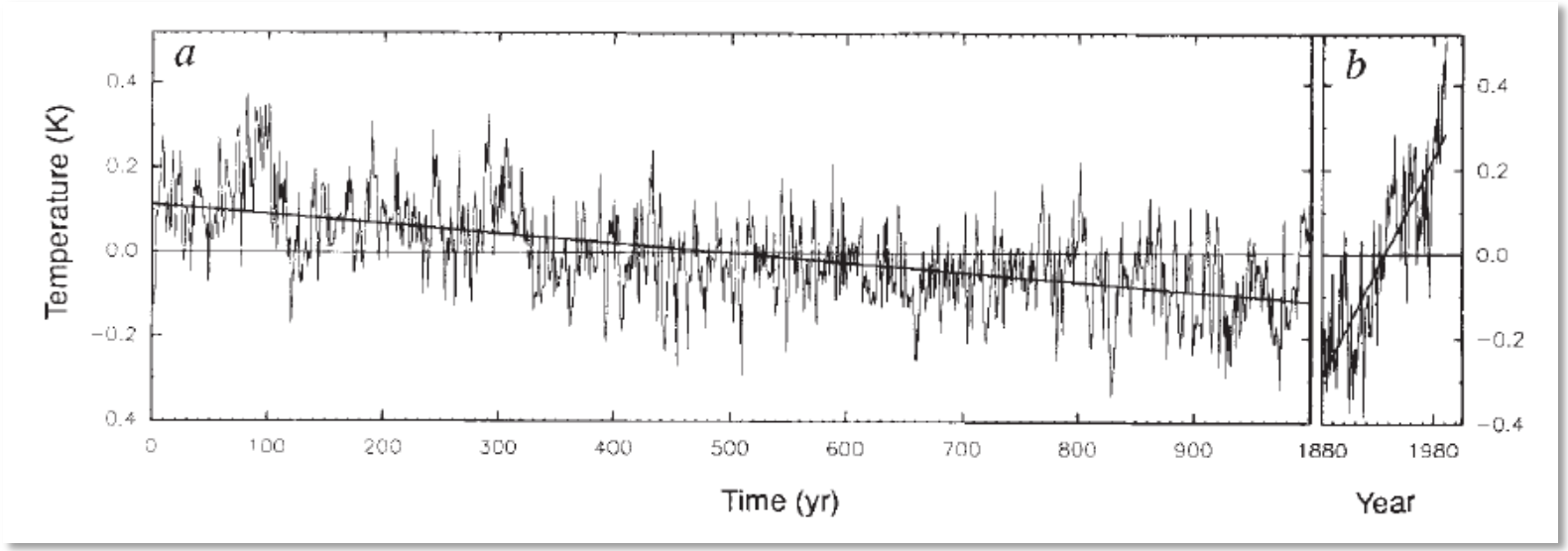
Stouffer, Manabe, and Vinnikov, Nature (1994): Observed warming is larger than internal climate variability

Model assessment of the role of natural variability in recent global warming

R. J. Stouffer, S. Manabe & K. Ya. Vinnikov

Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, New Jersey 08542, USA

"Assuming that the model is realistic, these results suggest that the observed trend is not a natural feature of the interaction between the atmosphere and oceans. Instead, it may have been induced by a sustained change in the thermal forcing, such as that resulting from changes in atmospheric greenhouse gas concentrations and aerosol loading"



Manabe and Stouffer, J. Climate (1996): Evaluating how well models simulate observed variability

OBS

Coupled model

Mixed-layer model

Fixed SST model

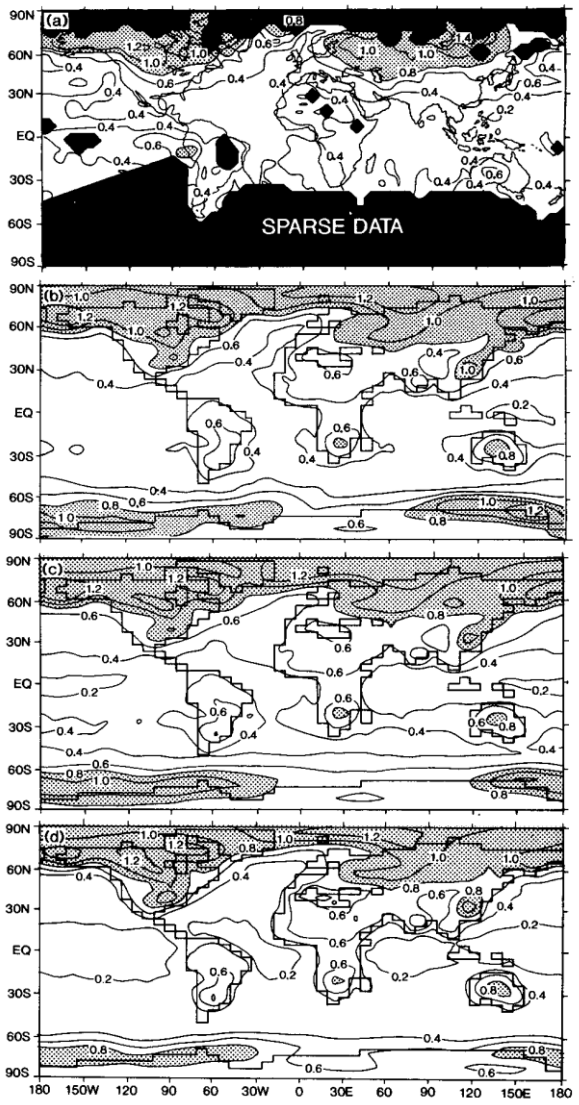


FIG. 1. Geographical distributions of the standard deviation of annual mean SAT anomaly (°C): (a) observed (Jones and Wigley 1991), (b) coupled model, (c) mixed layer model, (d) fixed SST model.

"It appears significant that not only the coupled model but also the mixed layer model without ocean currents can approximately simulate the power spectrum of observed, global mean SAT at decadal to interdecadal timescales. However, neither model generates a sustained, long-term warming trend of significant magnitude such as that observed since the end of the last century".

Low-Frequency Variability of Surface Air Temperature in a 1000-Year Integration of a Coupled Atmosphere–Ocean–Land Surface Model

SYUKURO MANABE AND RONALD J. STOUFFER

Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, New Jersey

(Manuscript received 28 February 1995, in final form 18 July 1995)

Stouffer, Hegerl, and Tett, J. Climate (2000): Using multi-model ensembles in detection and attribution

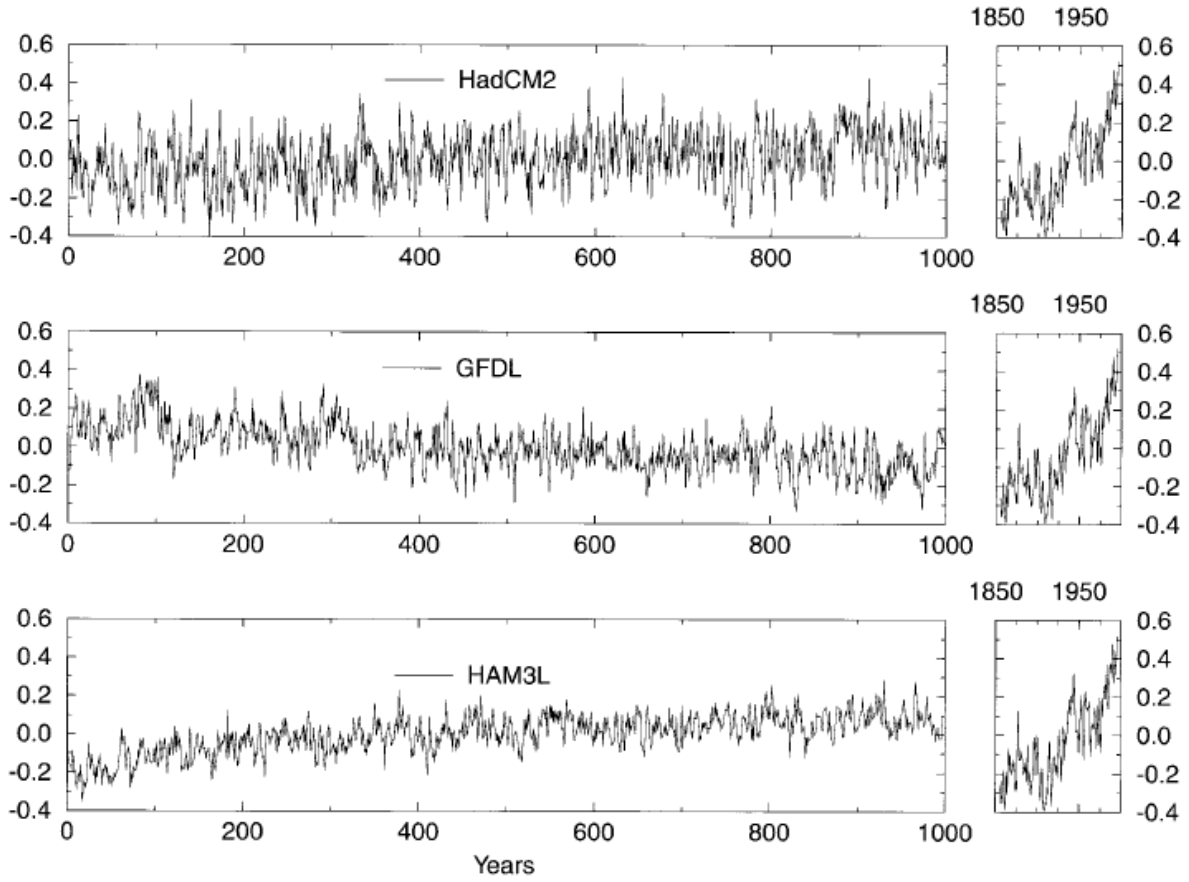
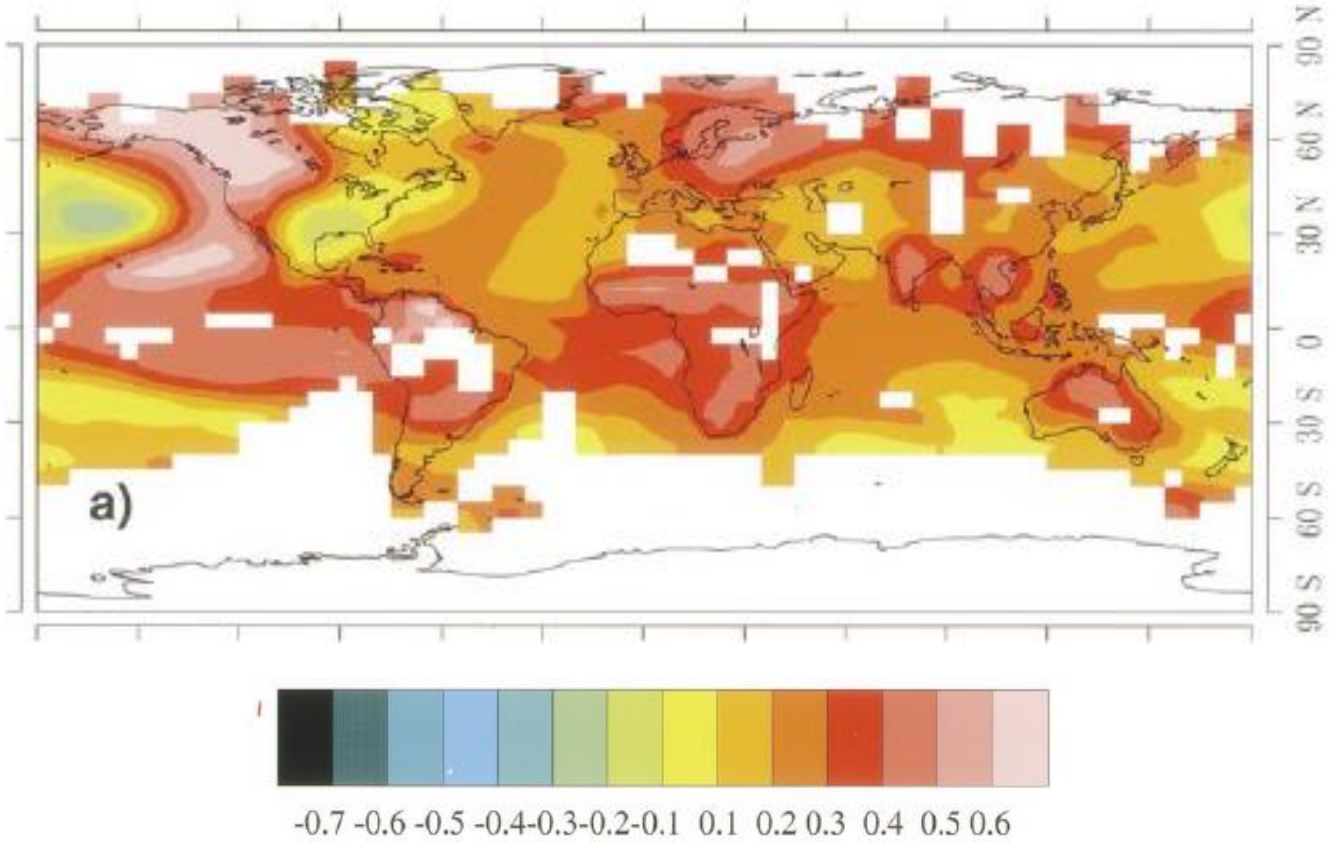


FIG. 12. Time series of globally averaged, annual mean SAT anomaly (K) from the three models (top left: HadCM2; middle left: GFDL; bottom left: HAM3L). The right plots are all identical and represent the globally averaged, SAT observations compiled by Jones and Briffa (1992).

"…detection of climate change and its attribution to different external forcings may differ when unperturbed climate variability in surface air temperature is estimated with different coupled models".

Stouffer, Hegerl, and Tett, J. Climate (2000): Looking at joint modes of climate variability

Common EOF 1



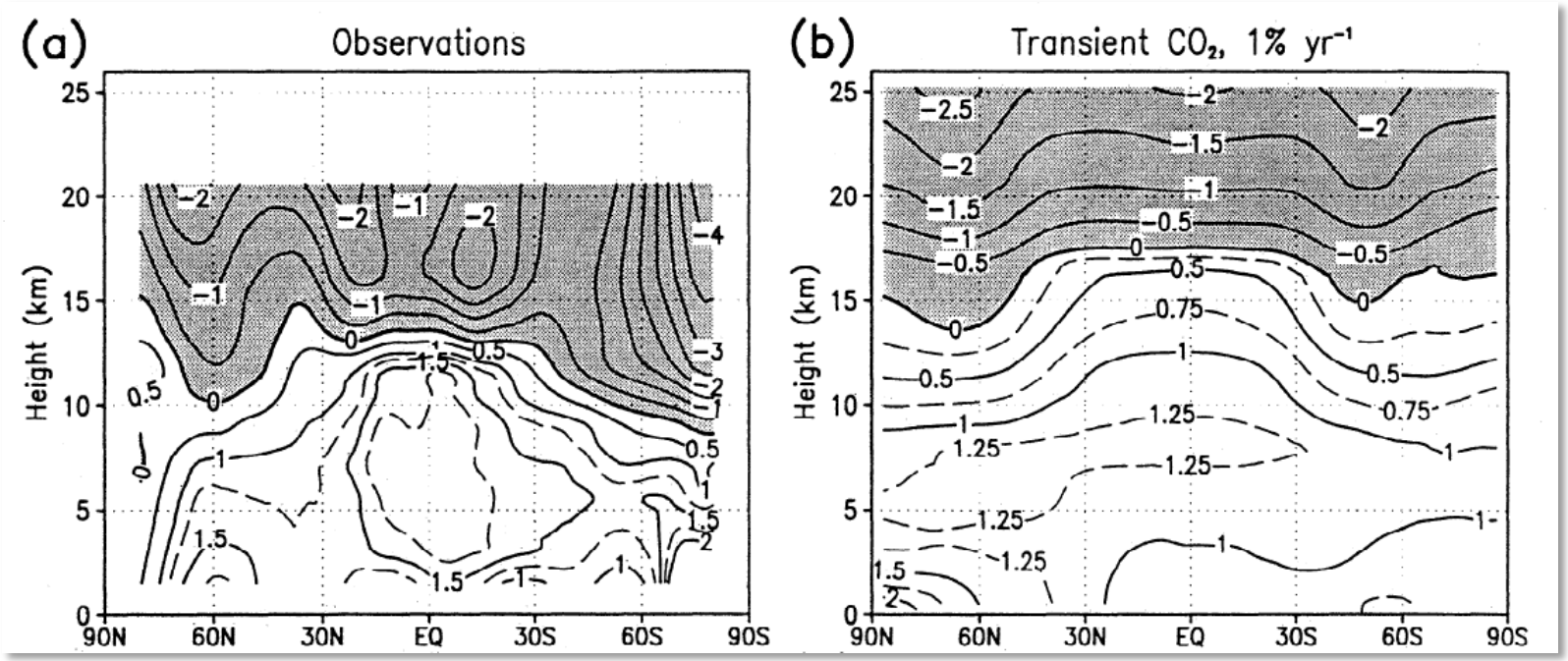
"…the models generally agree on the most prominent patterns of variability… the amplitudes of the dominant modes of variability differ to some extent between the models and between the models and observations".

Vinnikov, Robock, Stouffer, and Manabe, GRL (1996): Looking at patterns of climate change

Vertical patterns of free and forced climate variations

Konstantin Ya. Vinnikov[1], Alan Robock[1], Ronald J. Stouffer, and Syukuro Manabe
Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, New Jersey

"...assuming that the model patterns of variability are a good representation of the natural internal fluctuations of the climate system, the present results suggest that the climate change of the past three decades cannot be attributed solely to natural internal climatic variability, and is likely to have been caused at least partly by human activities".



Collaborating with Ron, Ram, Bram, and Dan (Nature, 1996)

A search for human influences on the thermal structure of the atmosphere

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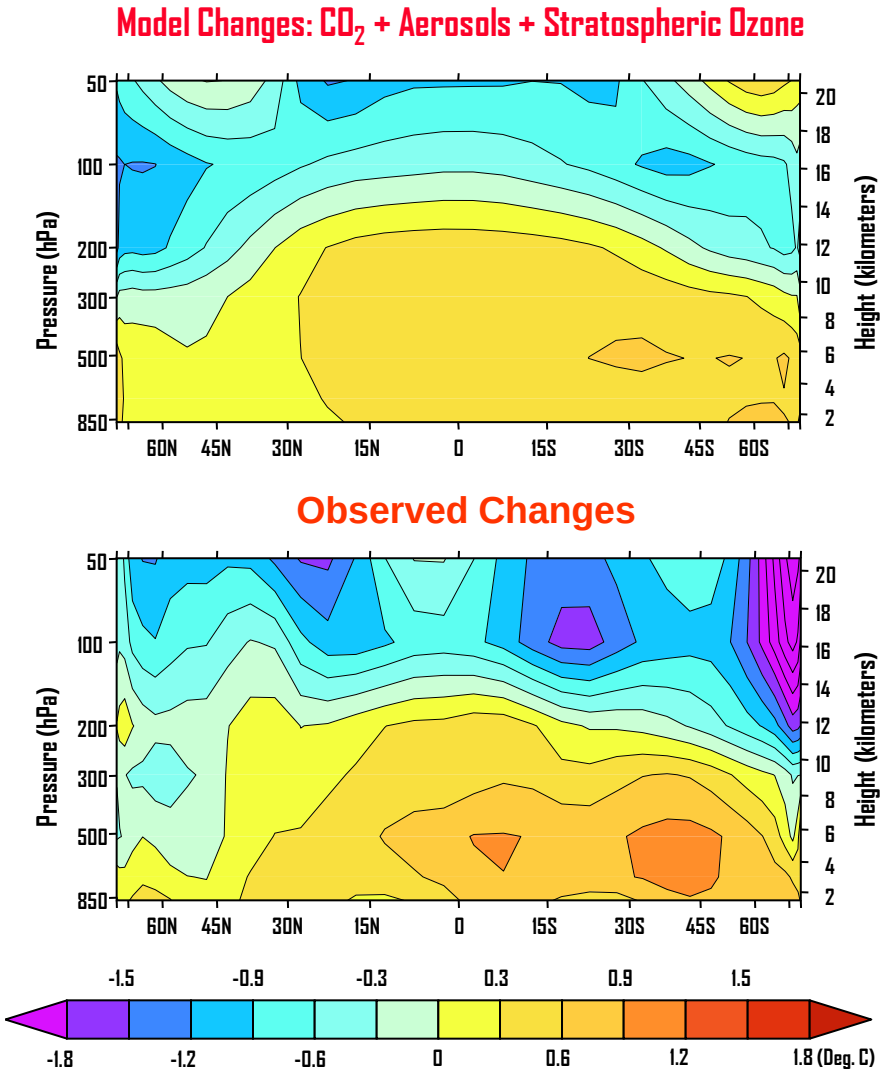
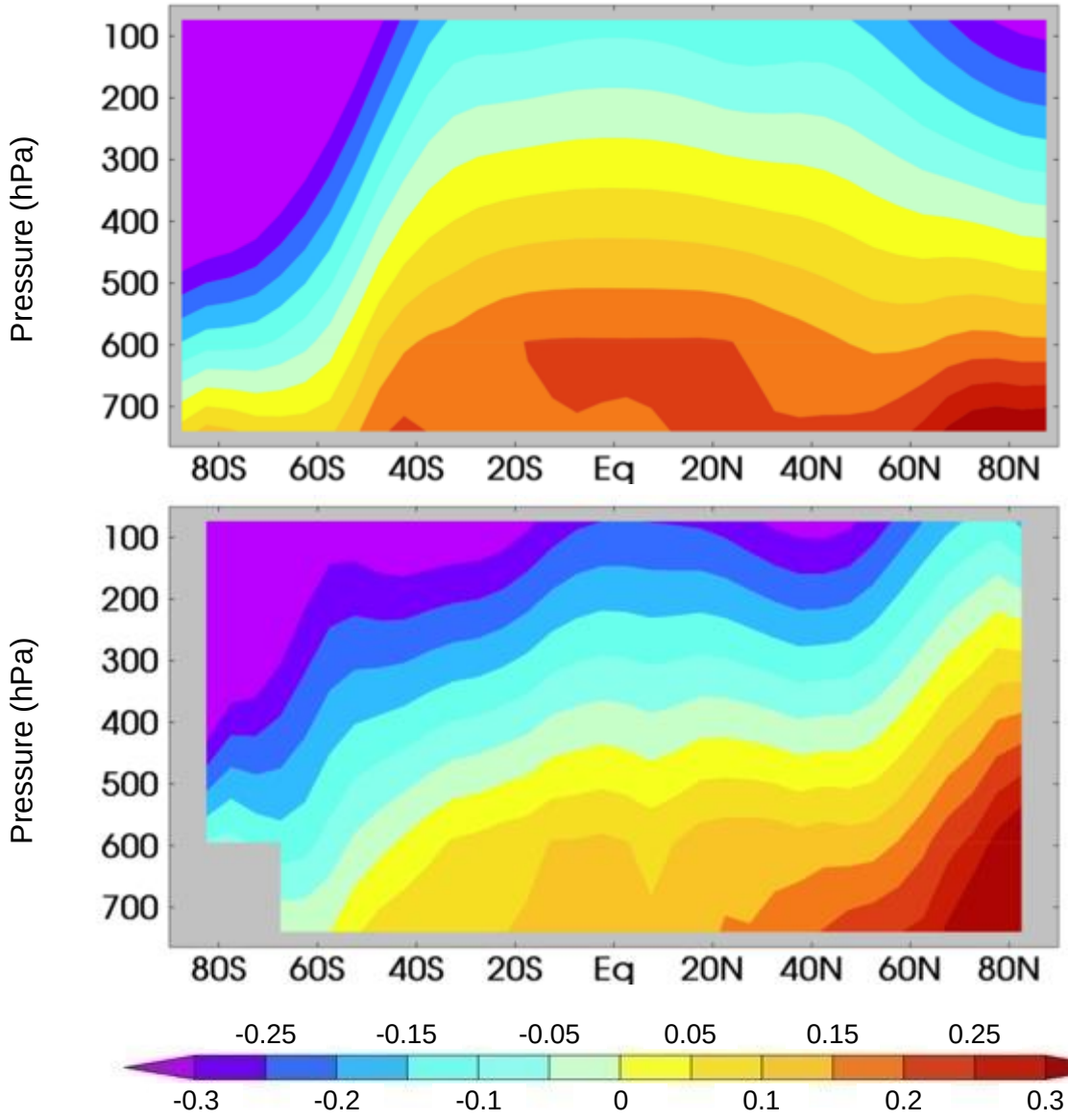
*Program for Climate Model Diagnosis and Intercomparison, †Atmospheric Science Division, Lawrence Livermore National Laboratory, Livermore, California 94550, USA ‡National Center for Atmospheric Research, Boulder, Colorado 80307-3000, USA §Hadley Centre for Climate Prediction and Research, Meteorological Office, Bracknell RG12 2SY, UK ‖Climatic Research Unit, University of East Anglia, Norwich NR4 7TJ, UK ¶Cooperative Research Centre for Southern Hemisphere Meteorology, Monash University, Clayton VIC 3168, Australia £ NOAA/Geophysical Fluid Dynamics Laboratory, PO Box 308, Princeton University, Princeton, New Jersey 08542, USA



Satellite data and model “human influence” simulations show tropospheric warming and stratospheric cooling

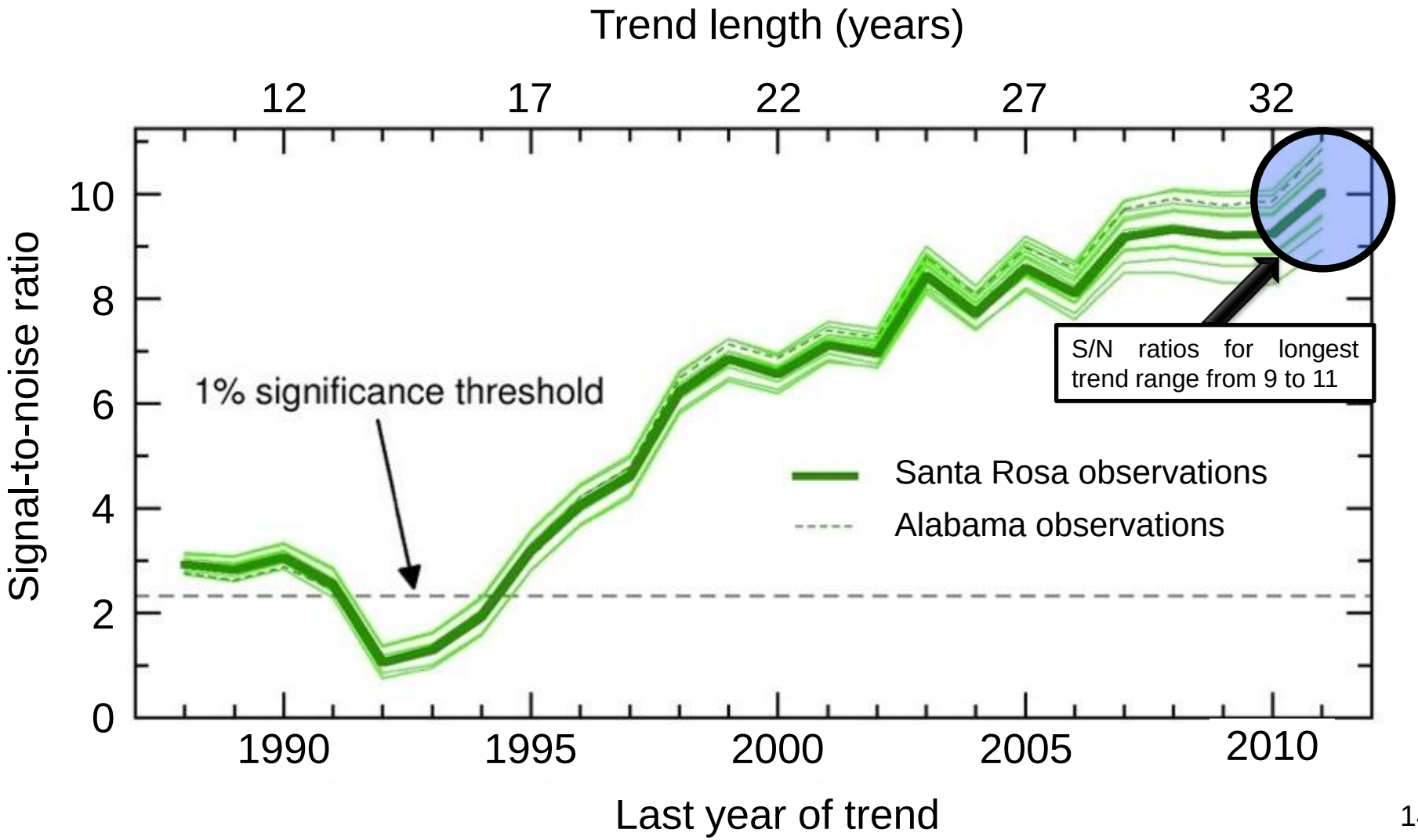


CMIP-5 models (Human effects)

Observations (Santa Rosa)

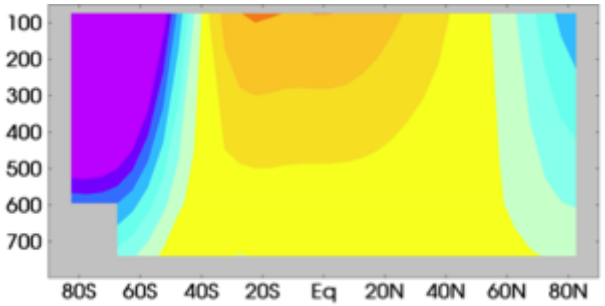
Trend (°C/decade over 1979 to 2012)

Signal-to-noise ratios for vertical structure of atmospheric temperature change

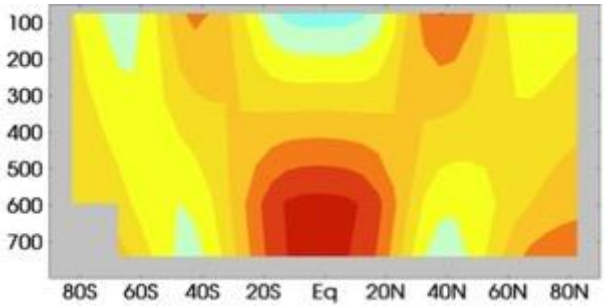


The dominant patterns of internal and “total” natural variability do not look like the human fingerprint

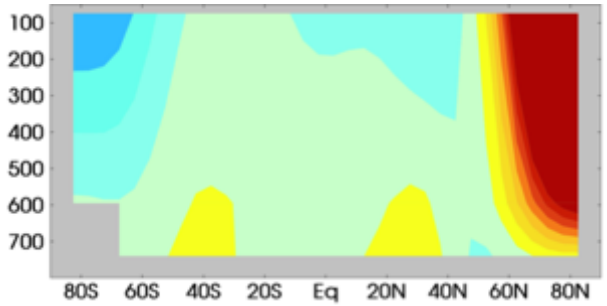
A Control EOF1 (31.85%)



B Control EOF2 (23.21%)



C Control EOF3 (17.31%)



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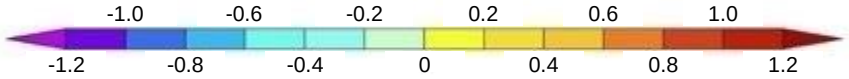

Final thoughts

- Climate scientists have identified human “fingerprints” in a number of different aspects of the climate system:
  - Temperature (land and ocean surface; stratosphere and troposphere; zonal-mean profiles through the atmosphere; upper 700 meters of the ocean; ocean heat content; height of thermal tropopause)
  - Atmospheric circulation (mean sea-level pressure, geopotential height)
  - Components of the hydrological cycle (zonal-mean rainfall; surface specific humidity; total water vapor over oceans; continental runoff; clouds; salinity)
  - The cryosphere (Arctic sea-ice extent)
- The climate system is telling us a physically- and internally-consistent story
- Ron is one of the key scientists who helped to tell this story