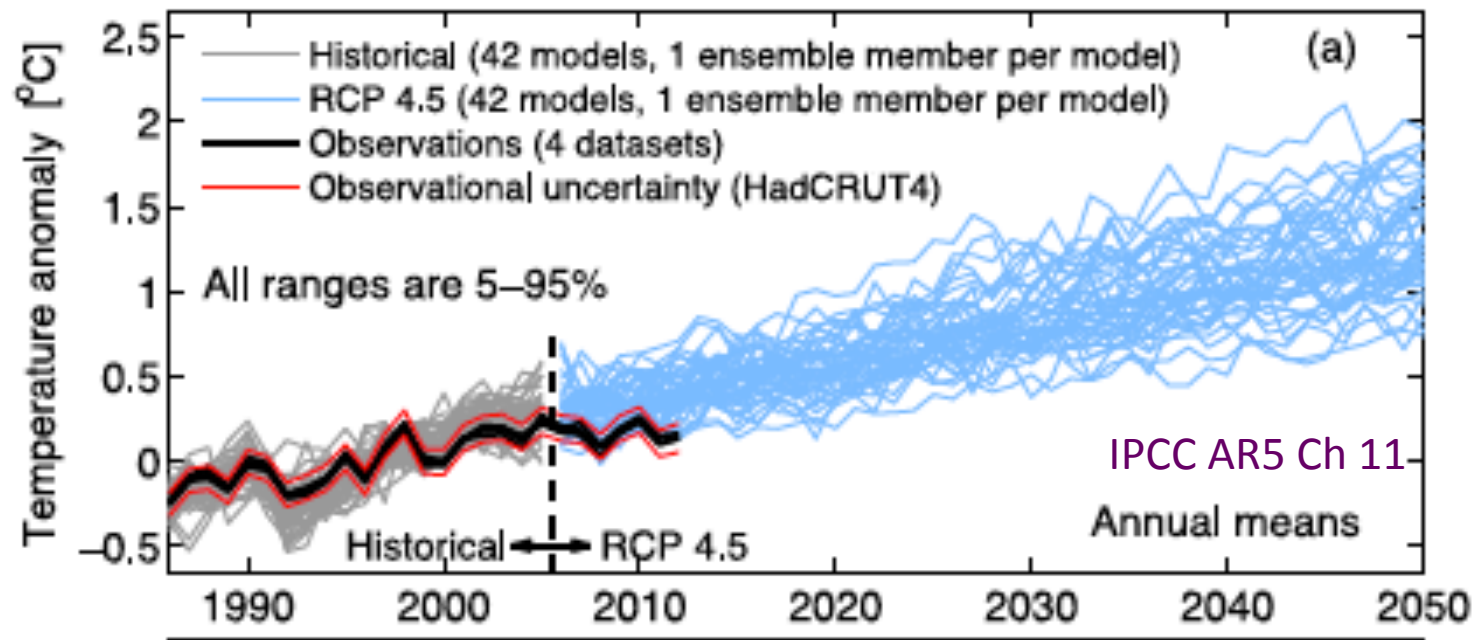


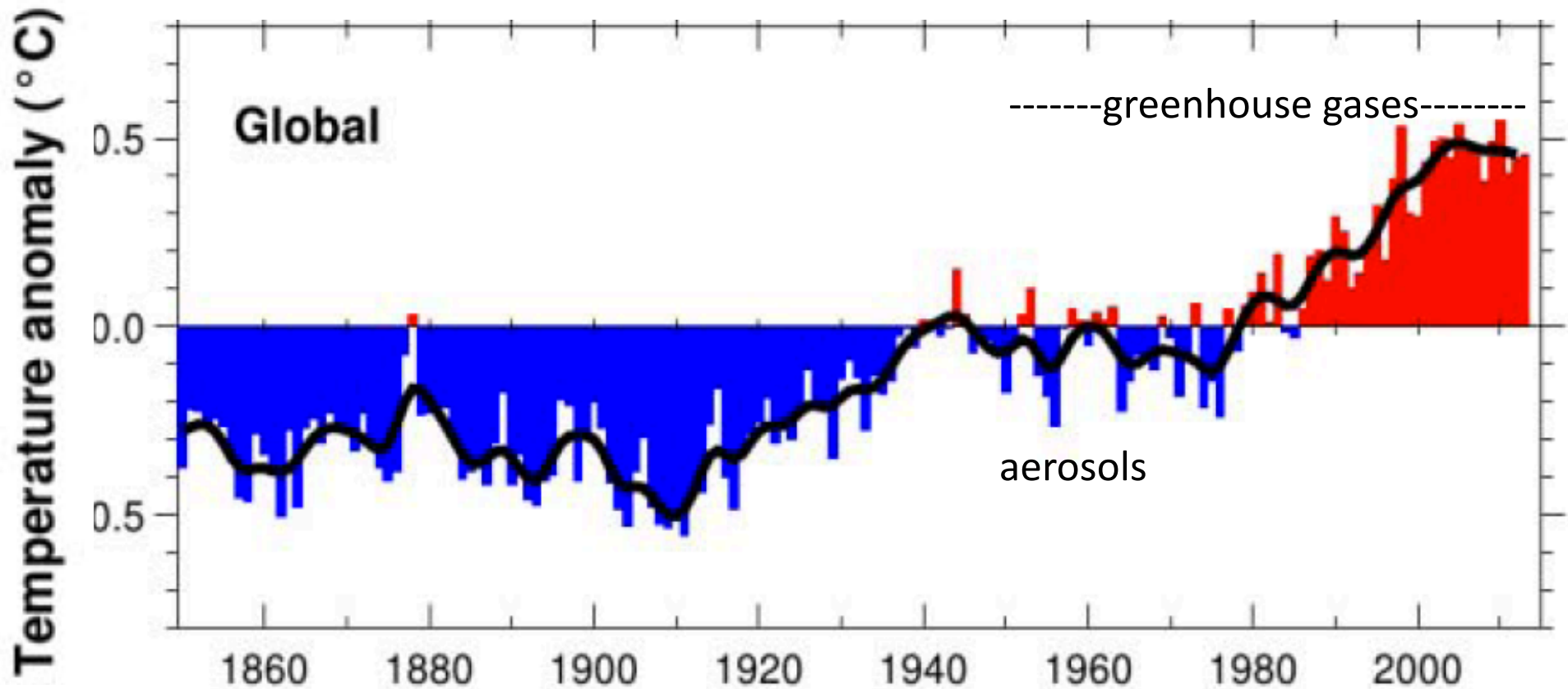
Causes and implications of the growing divergence between climate model simulations and observations



Judith Curry

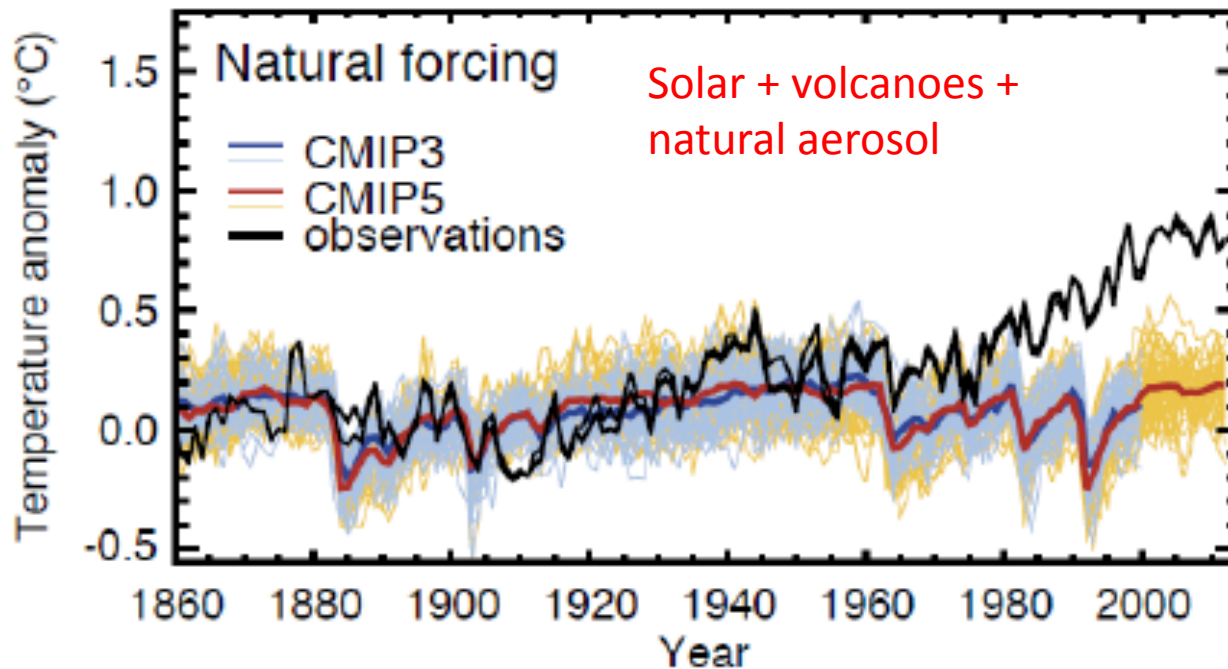


Global surface temperature anomaly – HADCRUT4



IPCC AR5: It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. **The best estimate of the human induced contribution to warming is similar to the observed warming over this period.**

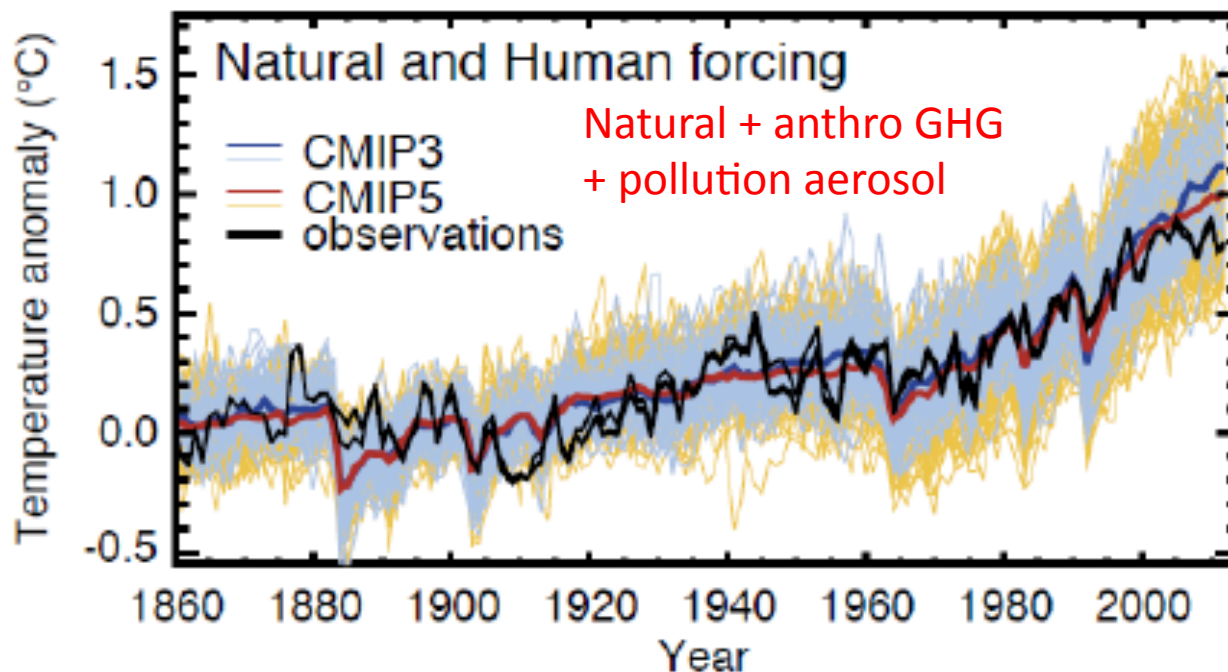
Attribution of warming



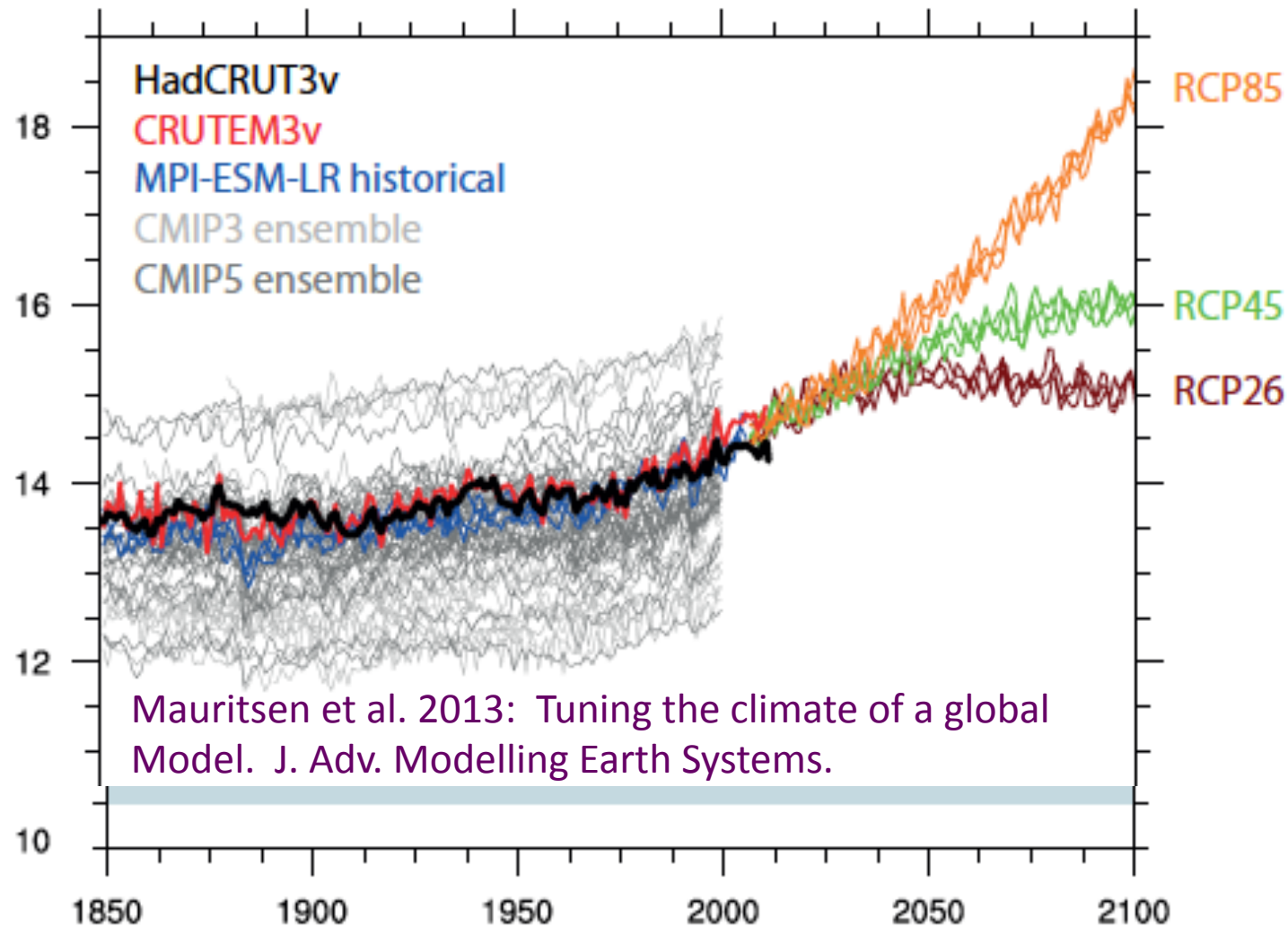
Warming since 1950:
Anthropogenic

Warming 1910-1940:
Models produce slight warming due to reduced volcanic activity and small anthropogenic effects

Cooling 1940-1975:
Not reproduced by the models

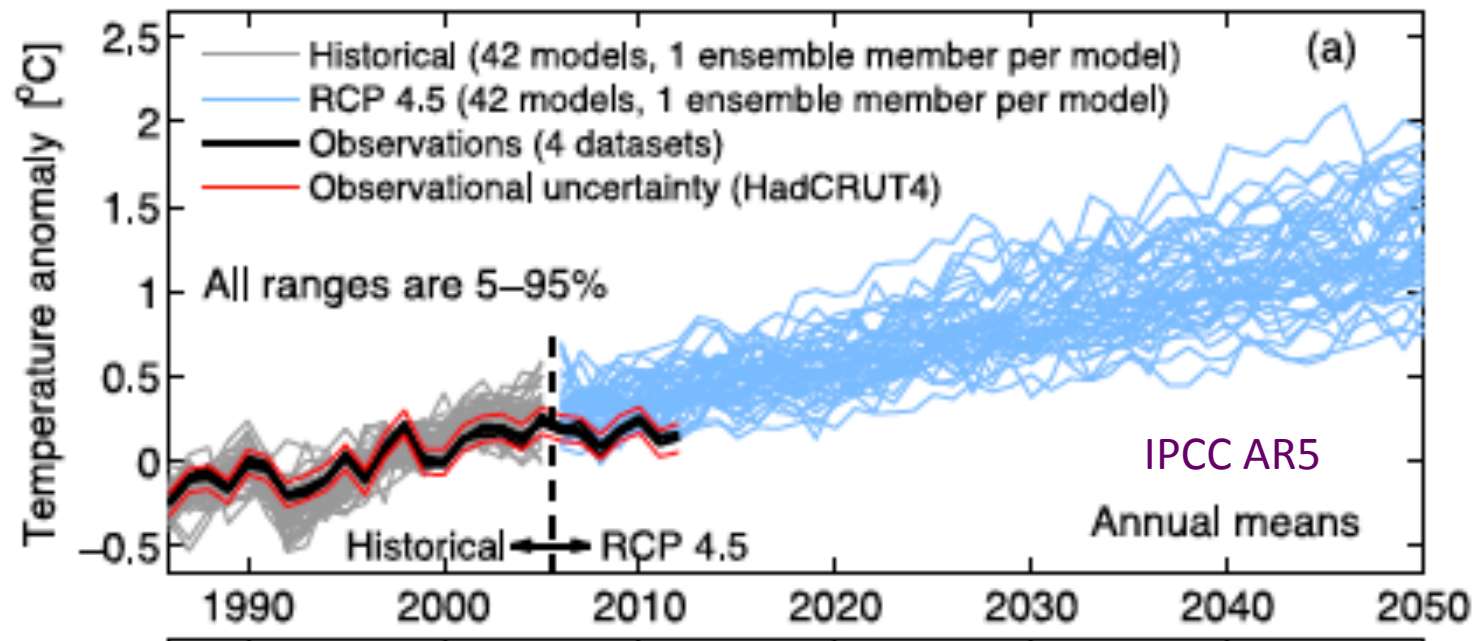


Absolute temperatures from climate model simulations



Biases in modeled climate (up to 2°C) raise serious questions about the ability to simulate key processes and feedbacks that are temperature dependent (e.g. cloud formation, surface evaporation, sea ice freezing/melting)

Significance of the 'pause' since 1998

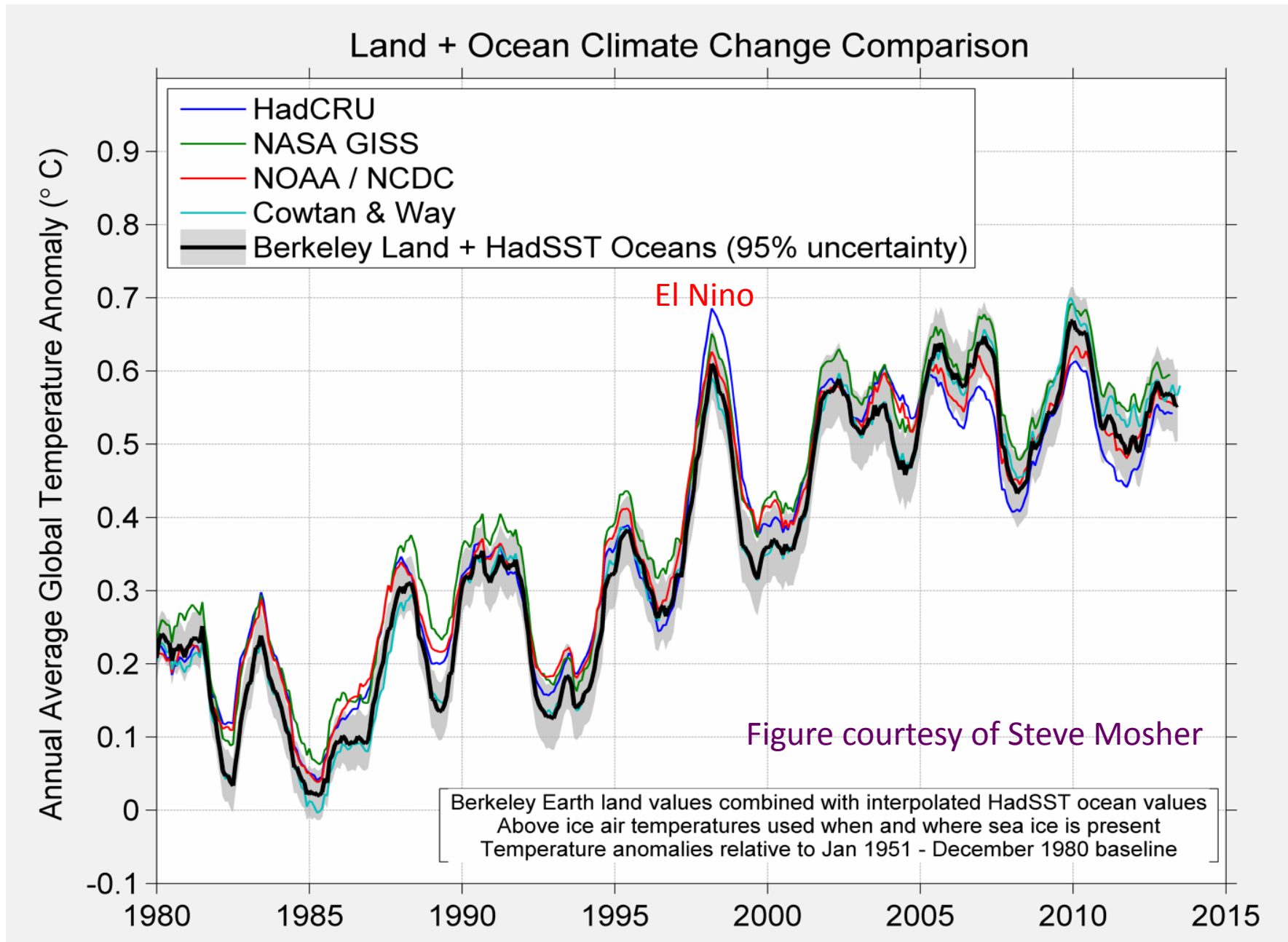


Under conditions of anthropogenic greenhouse forcing:

- Only 2% of climate model simulations produce trends within the observational uncertainty
- Modeled pauses longer than 15 years are rare; the probability of a modeled pause exceeding 20 yrs is vanishing small

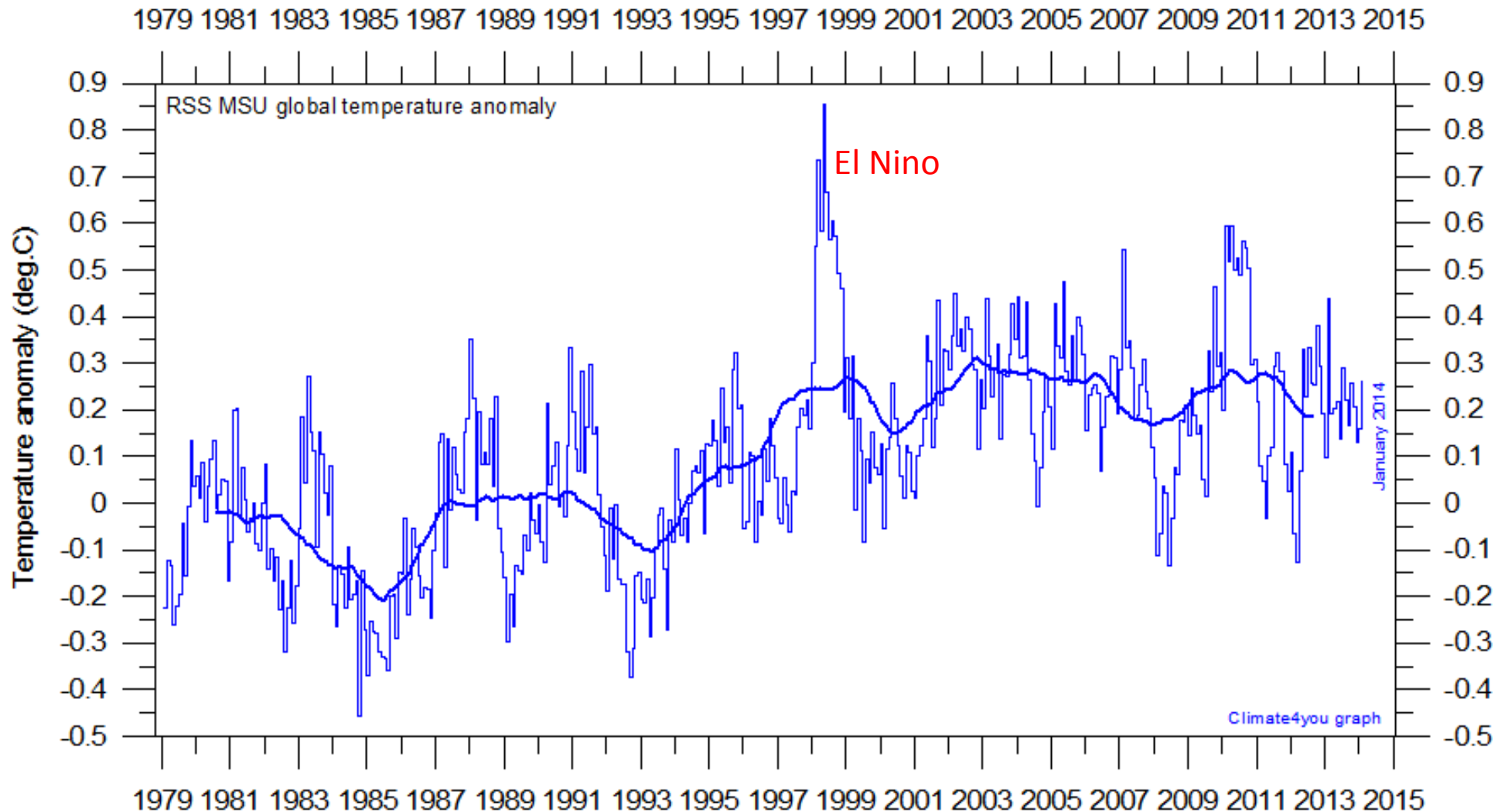
Questions raised by the discrepancy

- Are climate models too sensitive to greenhouse forcing?
- Is climate model treatment of natural climate variability inadequate?
- Is the IPCC's 'extremely likely' confidence level regarding anthropogenic attribution since 1950 justified?
- Are climate model projections of 21st century warming too high?
- How confident are we of the observations?



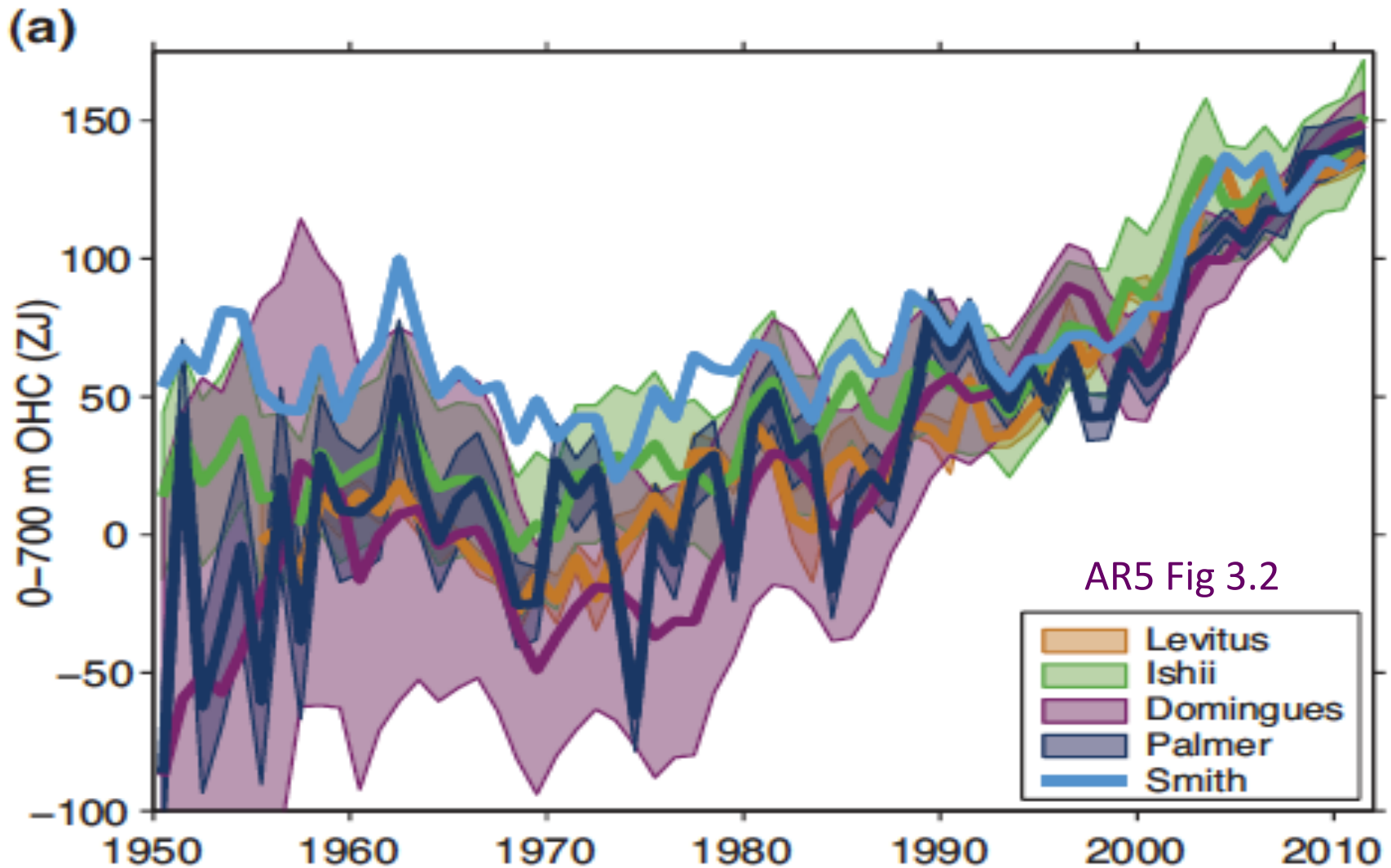
IPCC AR4: Surface temperature expected to increase $0.2^{\circ}\text{C}/\text{decade}$ in early 21st century

Tropospheric temperatures from MSU satellite observations



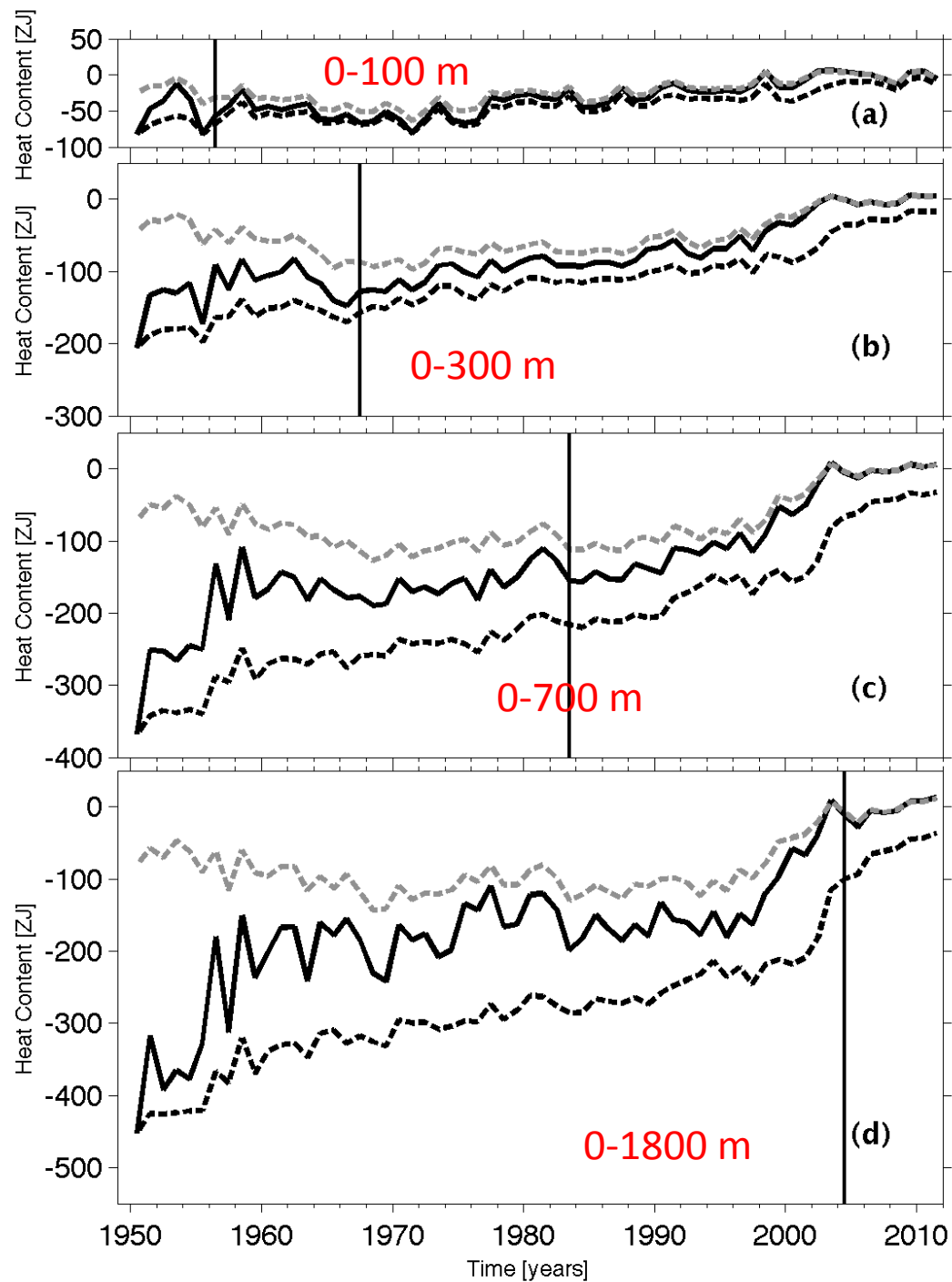
<http://climate4you.com/images/MSU%20RSS%20GlobalMonthlyTempSince1979%20With37monthRunningAverage.gif>

Ocean Heat Content 0-700 m



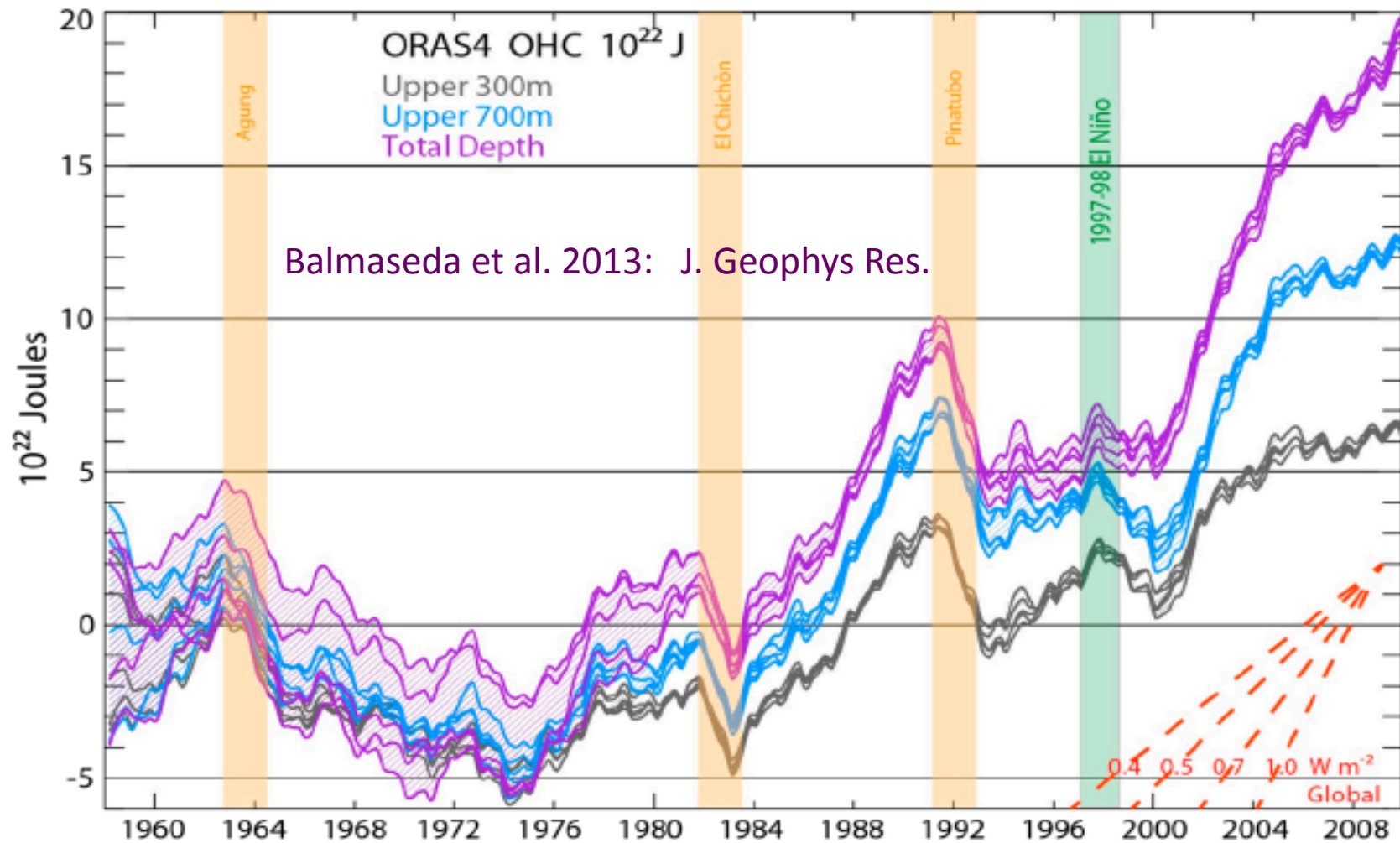
Little warming in upper ocean since 2003

Ocean Heat Content



Lyman & Johnson, 2014:
J. Climate, in press

Ocean Reanalysis – ECMWF



Since 1960, the warming in the 0-2000 m layer is 0.06°C

I. Where is the 'missing heat'?

Hypothesis I: It MUST be hiding in the ocean

- Evidence of deep ocean sequestration is indirect; few observations of deep ocean temperature prior to 2005
- Ocean models do not transfer heat in the vertically any where near as efficiently as inferred from the ECMWF reanalyses
- Concerns about the heat returning to the surface seem unrealizable if the heat is well mixed – 2nd law constraints

Hypothesis II: There is NO missing heat; changes in clouds have resulted in more reflection of solar radiation

- Global cloud satellite dataset only goes back to 1983; calibration issues complicate trend analyses
- Global energy balance analyses are associated with significant uncertainties

II. Maybe the models are OK; the problem is the external forcing

- Solar forcing
- Volcanic forcing
- Pollution aerosol

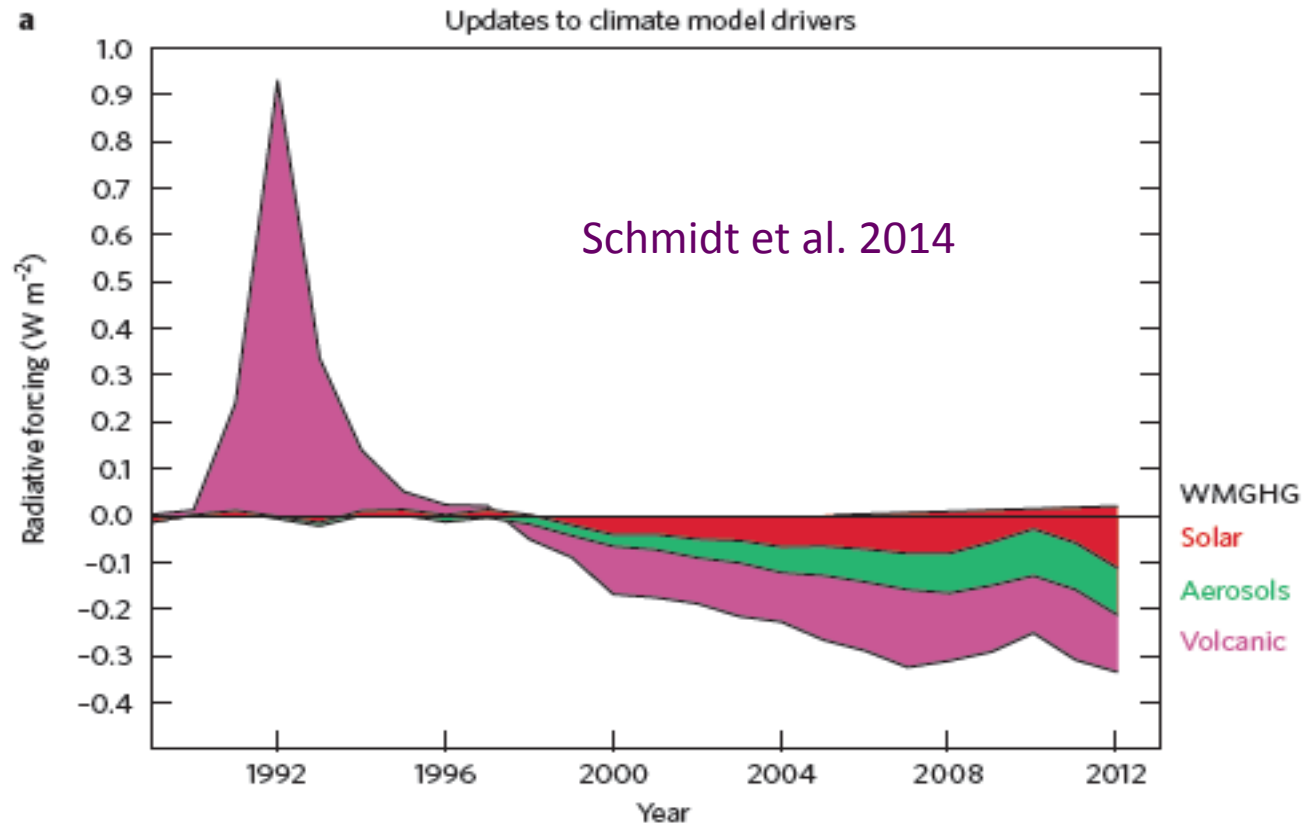
There is significant disagreement among different forcing data sets

CMIP5 simulations were forced by single 'best estimate' data sets

There has been no systematic effort to assess uncertainty in these data sets or the sensitivity of climate models to forcing uncertainty

These uncertainties have not been factored into the 20th century attribution assessments

Updated forcing data

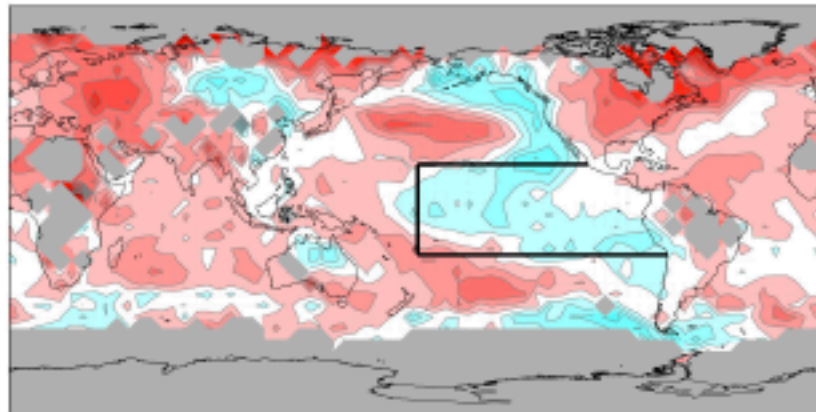


Updated volcanic forcing can explain:

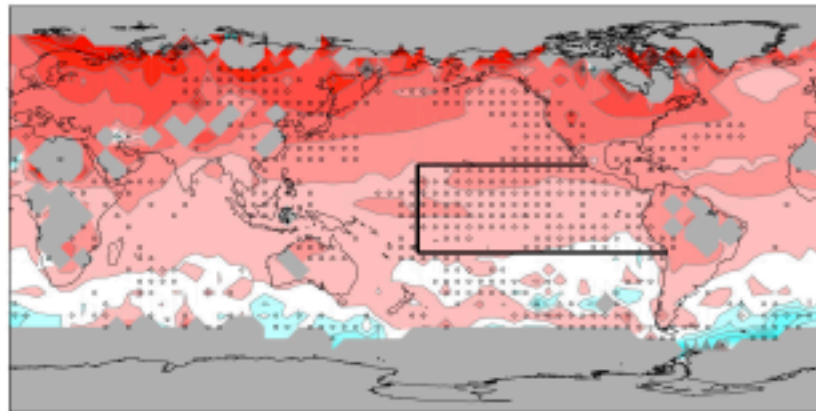
- Schmidt et al.: 1/3 of the discrepancy in surface warming
- Santer et al. (2014): up to 15% of the discrepancy in tropospheric temperatures
- Fyfe et al. (2013): cooling of $0.07^{\circ}\text{C} \pm 0.07^{\circ}\text{C}$ since late 1990s

III. ENSO (natural internal variability) is masking the greenhouse warming

HadCRUT4

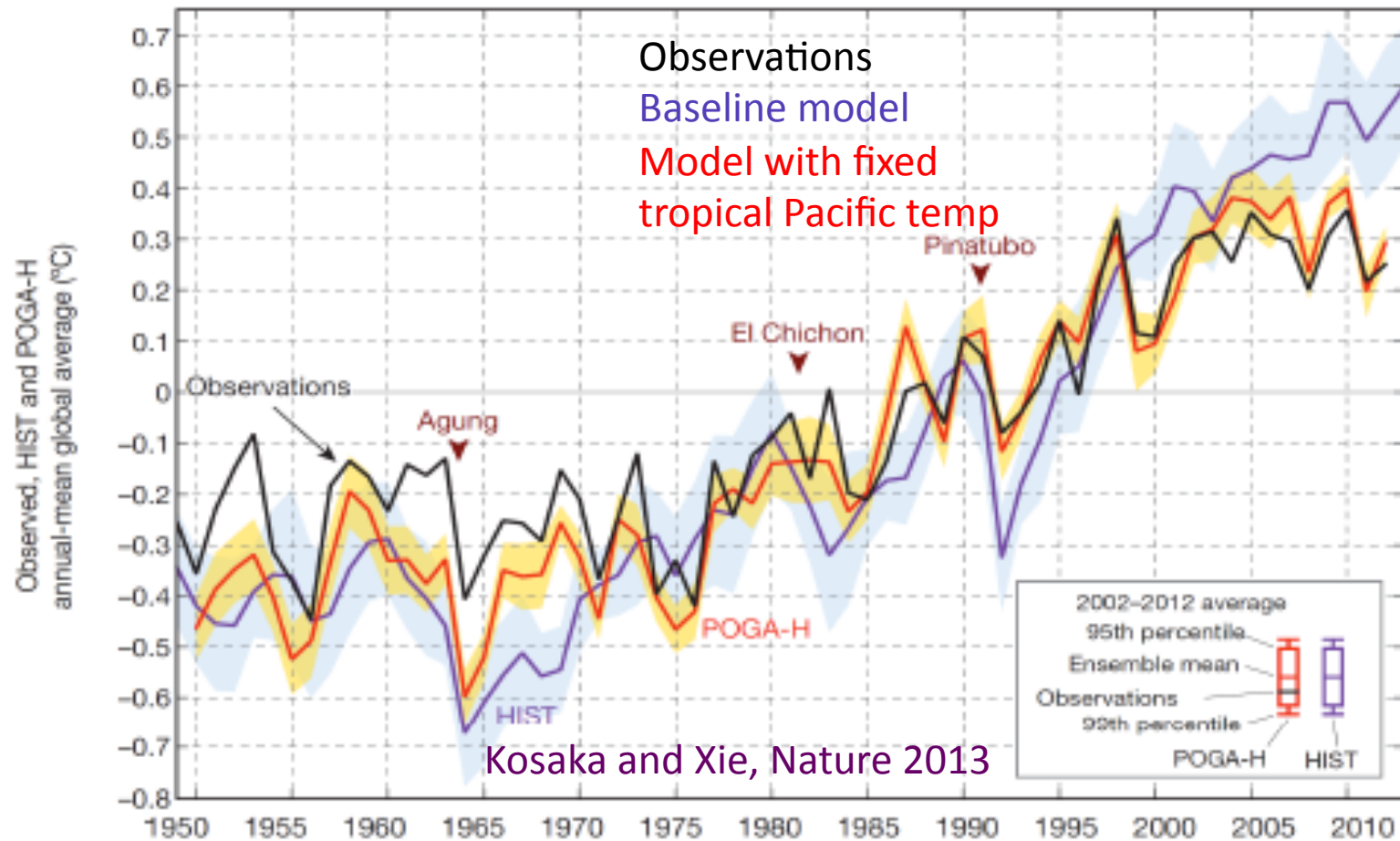


CMIP5



Fyfe & Gillett (*Nature Clim. Change*, 2014)

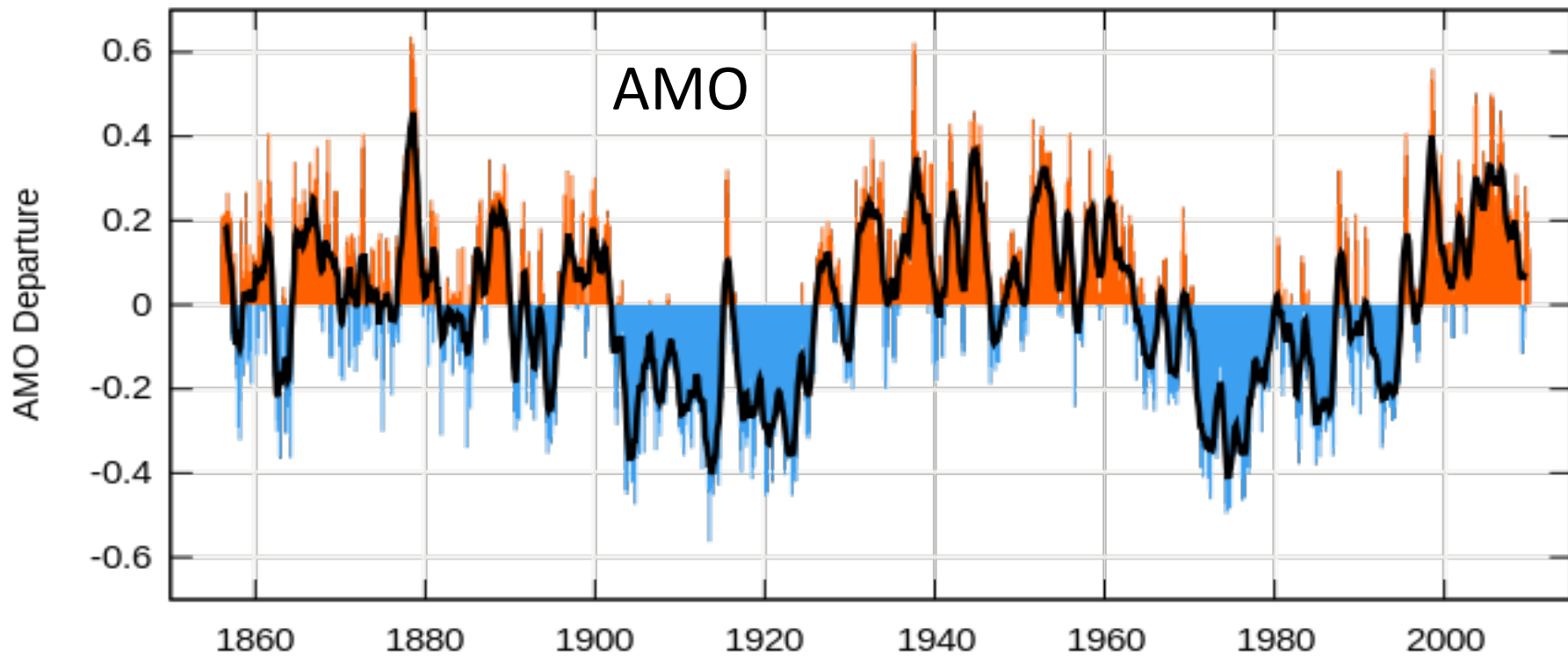
Influence of the tropical Pacific surface temperatures



ENSO doesn't just produce interannual variability,
but also variability on decadal+ timescales

IV. Multi-decadal modes of natural internal variability

- A. Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), etc. are superimposed on the anthropogenic warming trend, and should be included in attribution studies and future projections
- B. Climate shifts hypothesis: synchronized chaos framework for natural internal variability (shift ca. 2001)
- C. **Stadium wave hypothesis:** spatio-temporal pattern of signal propagation through a synchronized network of climate indices; quasi-periodic 50-80 yr tempo, with amplitude and tempo modified by external forcing

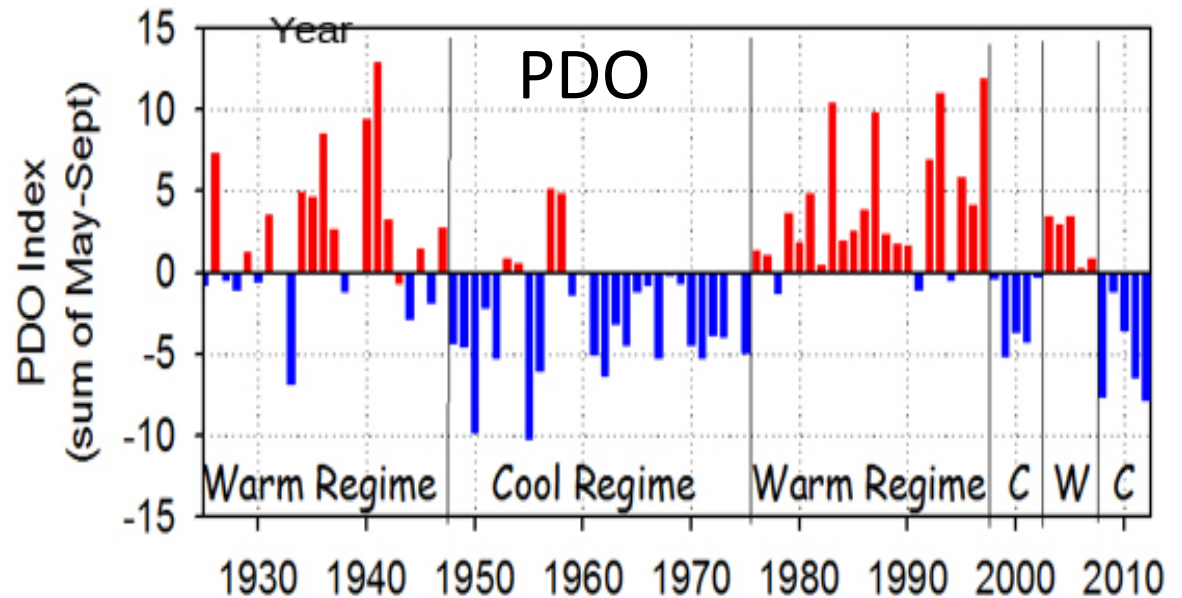


Currently:

- Warm AMO
- Cool PDO

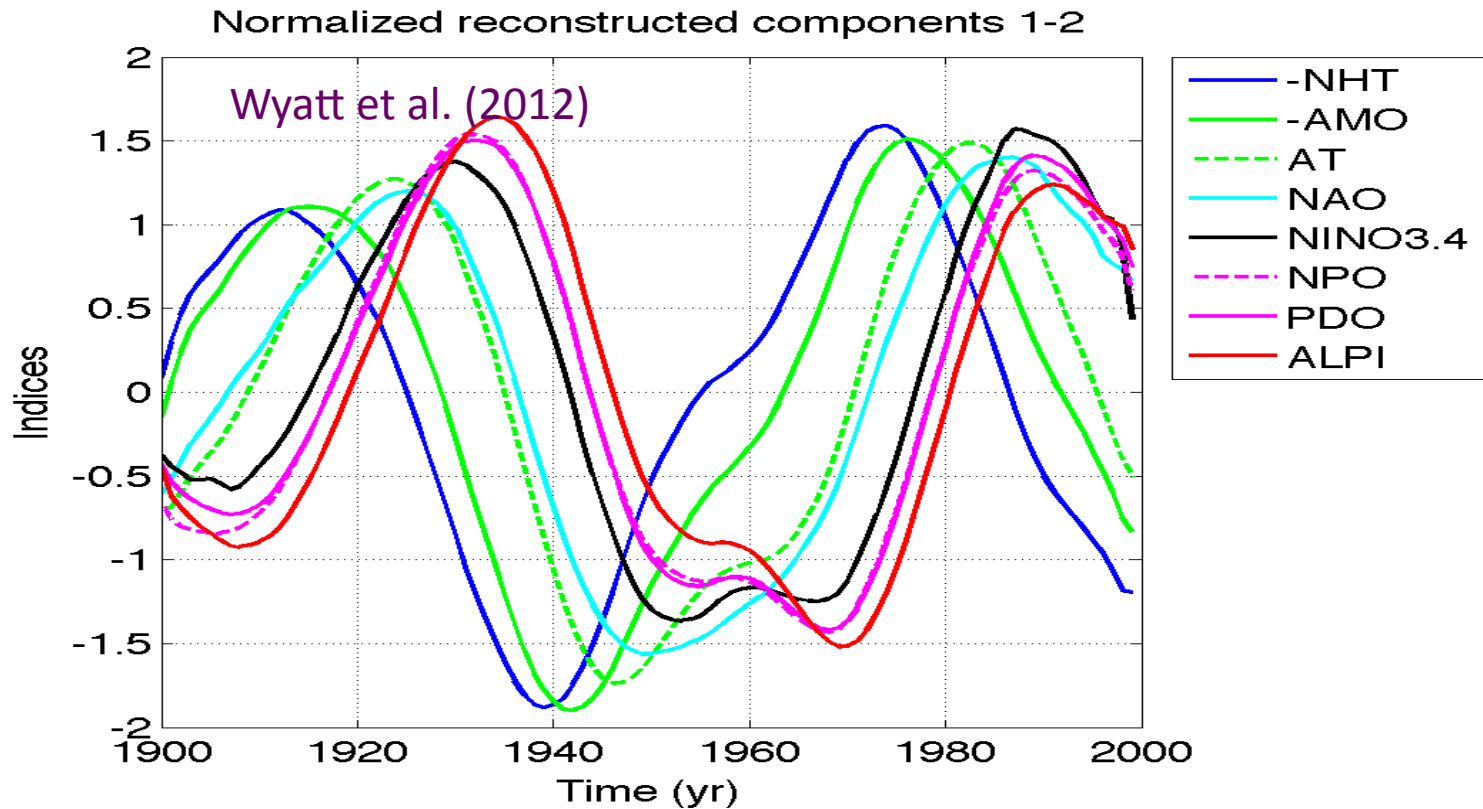
Previous analogue:

- 1946-1964



Climate as a stadium wave

www.wyattonearth.net



The 'stadium wave' climate signal propagates across the NH through a network of ocean, ice, and atmospheric circulation regimes that self-organize into a collective tempo.

M-SSA is used to extract and characterize dominant spatio-temporal patterns of variability shared by indices within a network.

Stadium Wave Wheel

Wyatt & Curry, 2013: Climate Dynamics

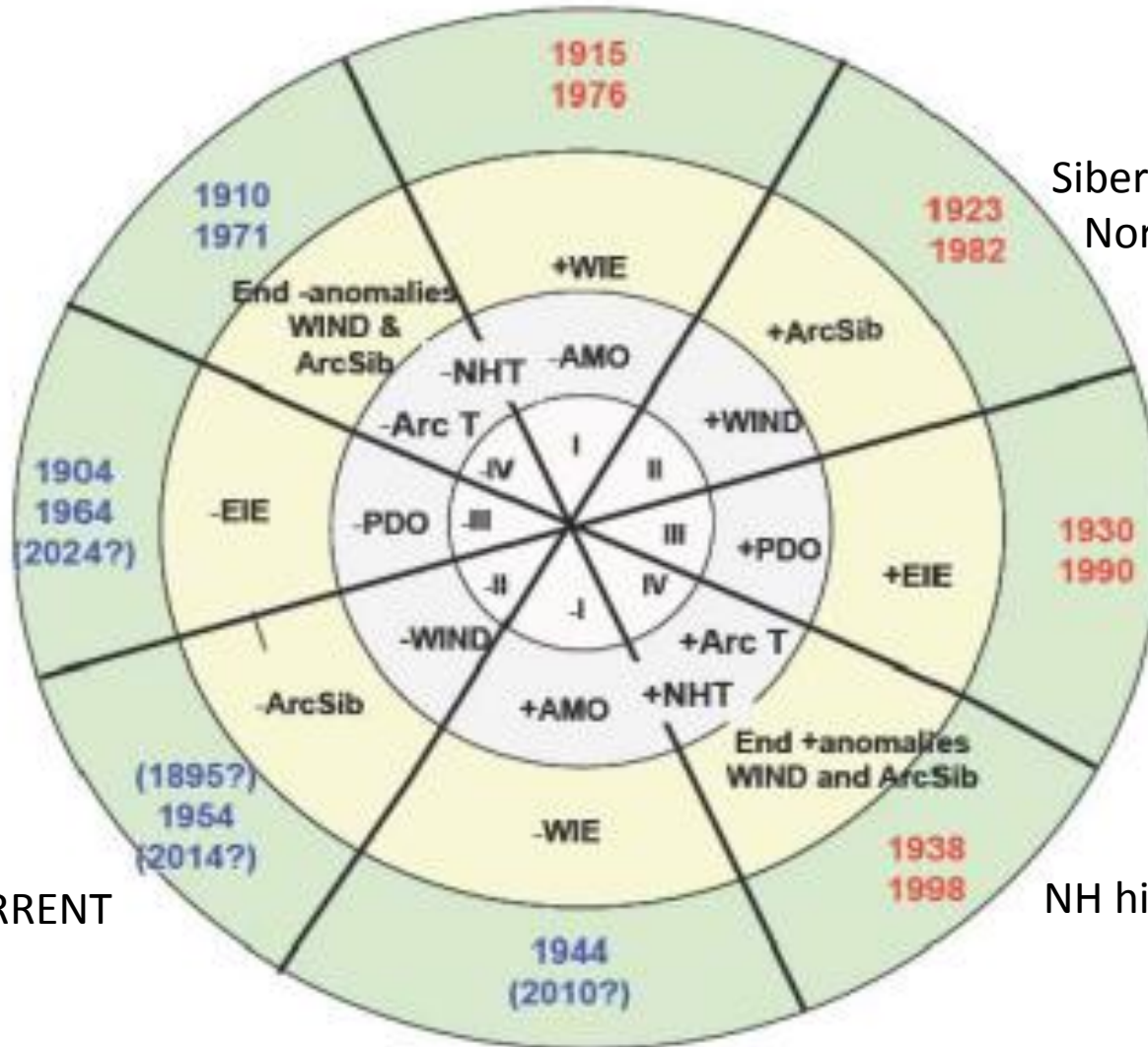
N. Atlantic sector of the Arctic

Siberian sector of the Arctic;
North Pacific

North Pacific

NH high latitudes

CURRENT

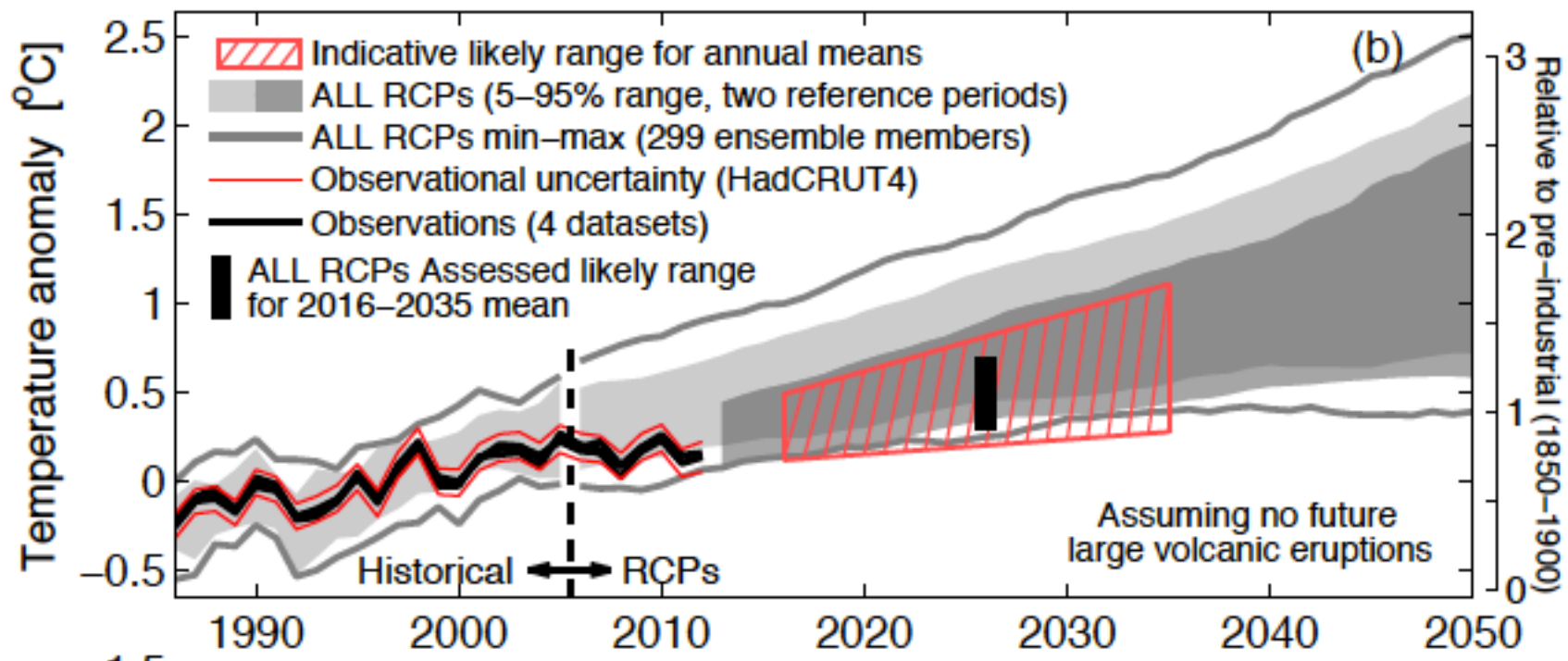


- 19th & 20th century tempo of 60-64 years.
- Continued cool phase into the 2030's

Implications for the future:

I. IPCC AR5 view

- The 'hiatus' will end soon, with the next El Nino



Implications for the future:

II. View emphasizing natural variability

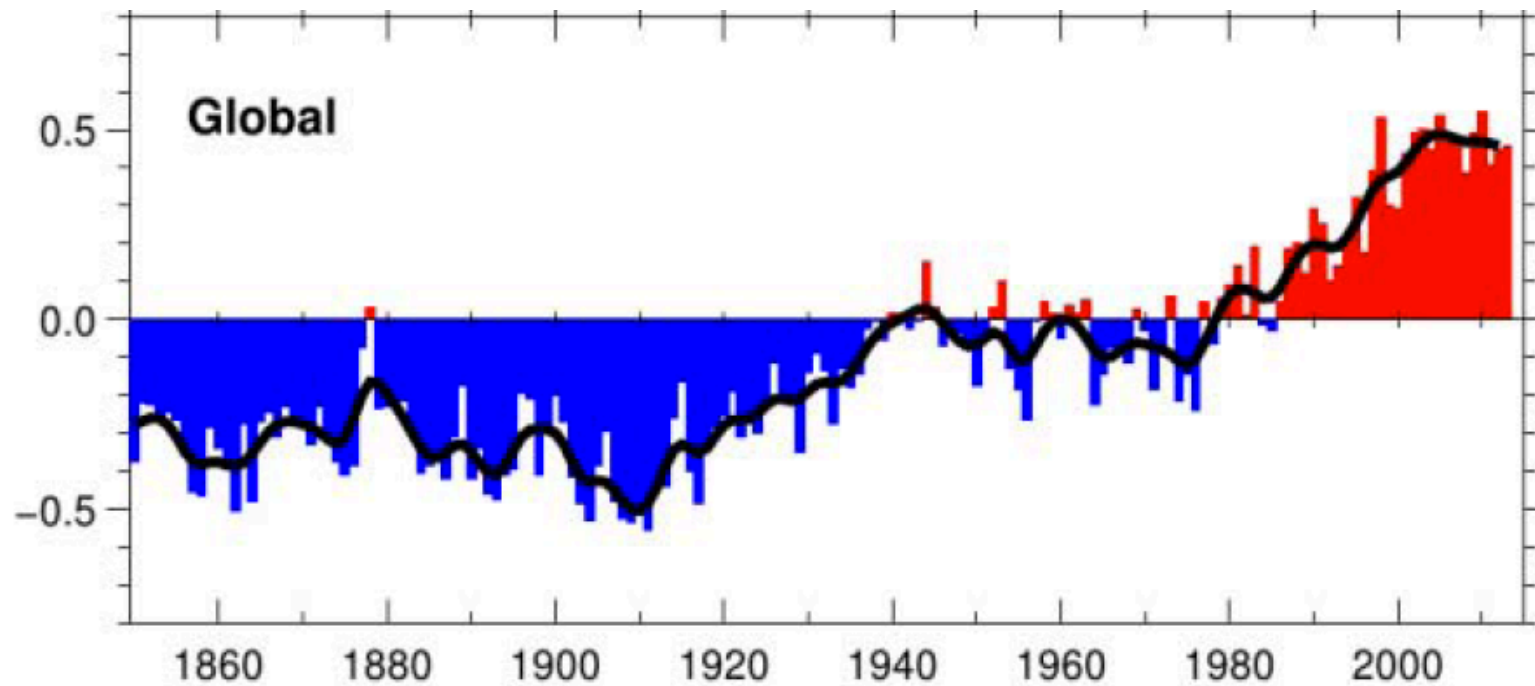
- The 'hiatus' will continue at least another decade
- Climate models are too sensitive to external forcing
- Hiatus persistence beyond 20 years would support a firm declaration of problems with the climate models
- Incorrect accounting for natural internal variability implies:
 - Biased attribution of 20th century warming
 - Climate models are not useful on decadal time scales

Summary of major uncertainties

- Deep ocean heat content variations and mechanisms of vertical heat transfer between the surface and deep ocean
- Uncertainties associated with external forcing data and implications for attribution analysis and future projections
- Sensitivity of the climate system to external forcing
- Clouds: trends, forcing, feedbacks, and aerosol – cloud interactions
- Nature and mechanisms of multidecadal natural ‘internal’ variability
- Unknowns – solar indirect effects, magnetic and electric field effects, orbital (tidal and other) effects, core-mantle interactions, etc.

Overconfident?

IPCC AR5: It is **extremely likely** that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. The best estimate of the human induced contribution to warming is similar to the observed warming over this period.



APS 2007 Statement on Climate Change

“The evidence is incontrovertible: Global warming is occurring.

If no mitigating actions are taken, significant disruptions in the Earth’s physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now.”

Concerns about such statements made by professional societies:

- Such statements don’t meet the norms of responsible advocacy
- Institutionalizing consensus can slow down scientific progress and pervert the self-correcting mechanisms of science

POPA Review of APS Climate Change Statement

Workshop (Jan 8) invited experts:

- William Collins – UC Berkeley
- Judith Curry – Georgia Tech
- Isaac Held – Princeton
- Richard Lindzen – MIT
- Ben Santer – Lawrence Livermore Natl Lab
- John Christy – U. Alabama Huntsville

Complete transcript at:

<http://www.aps.org/policy/statements/upload/climate-seminar-transcript.pdf>