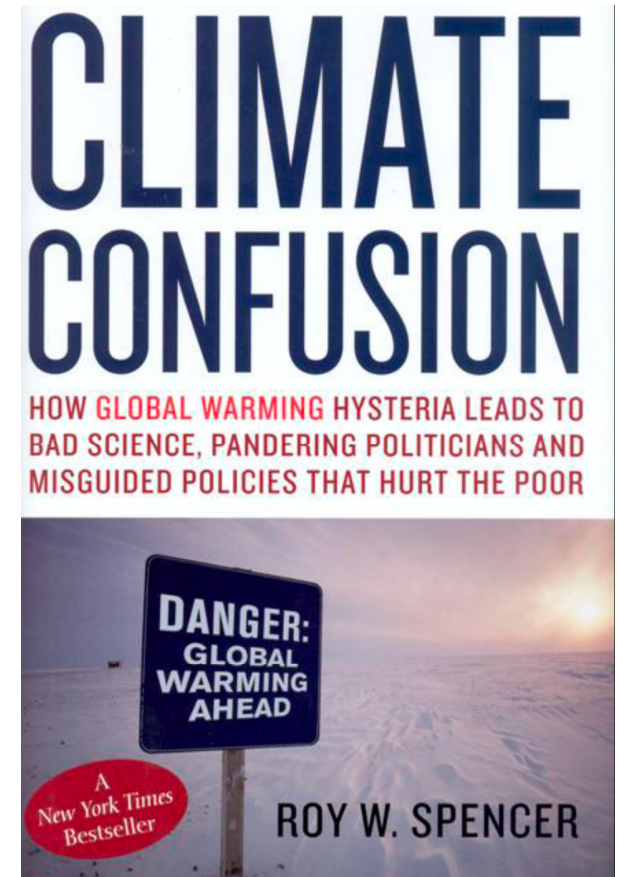
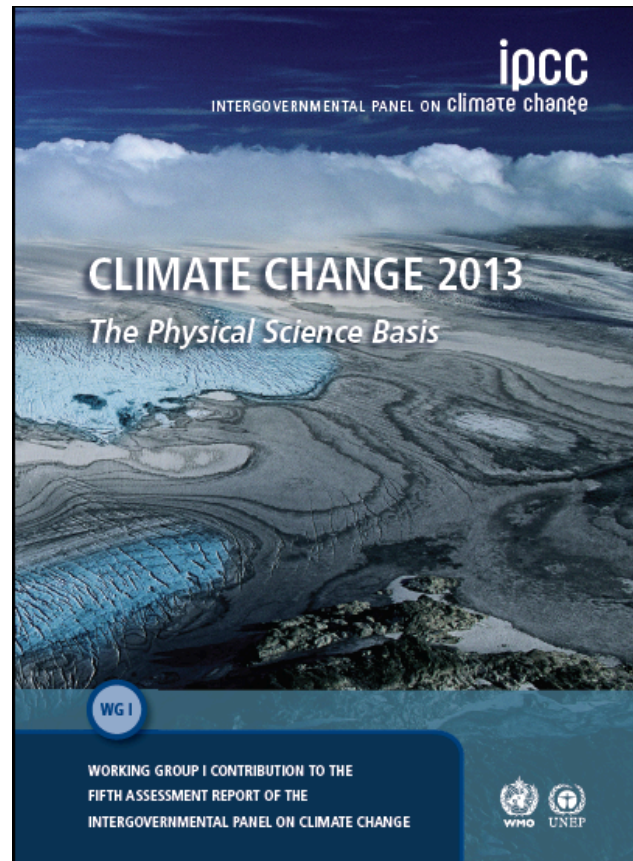
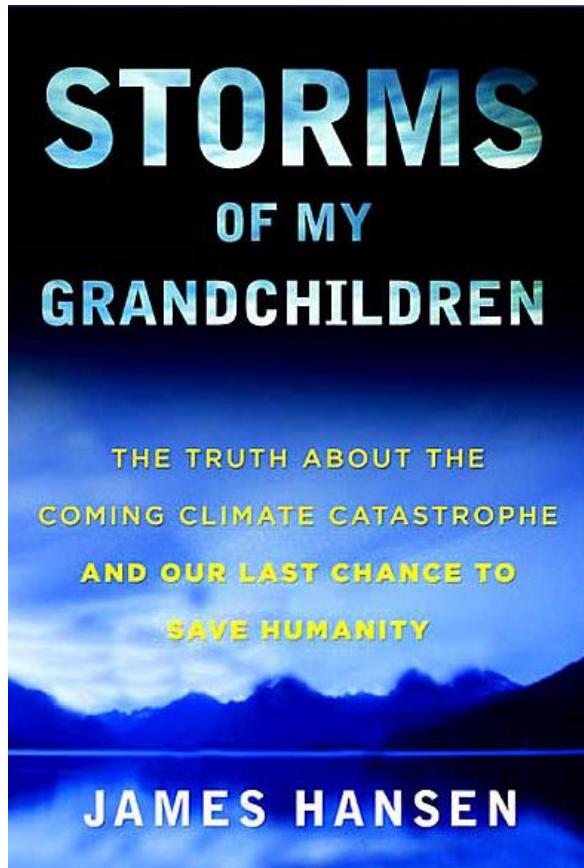


The scientific debate on climate change



Judith Curry



Agreement:

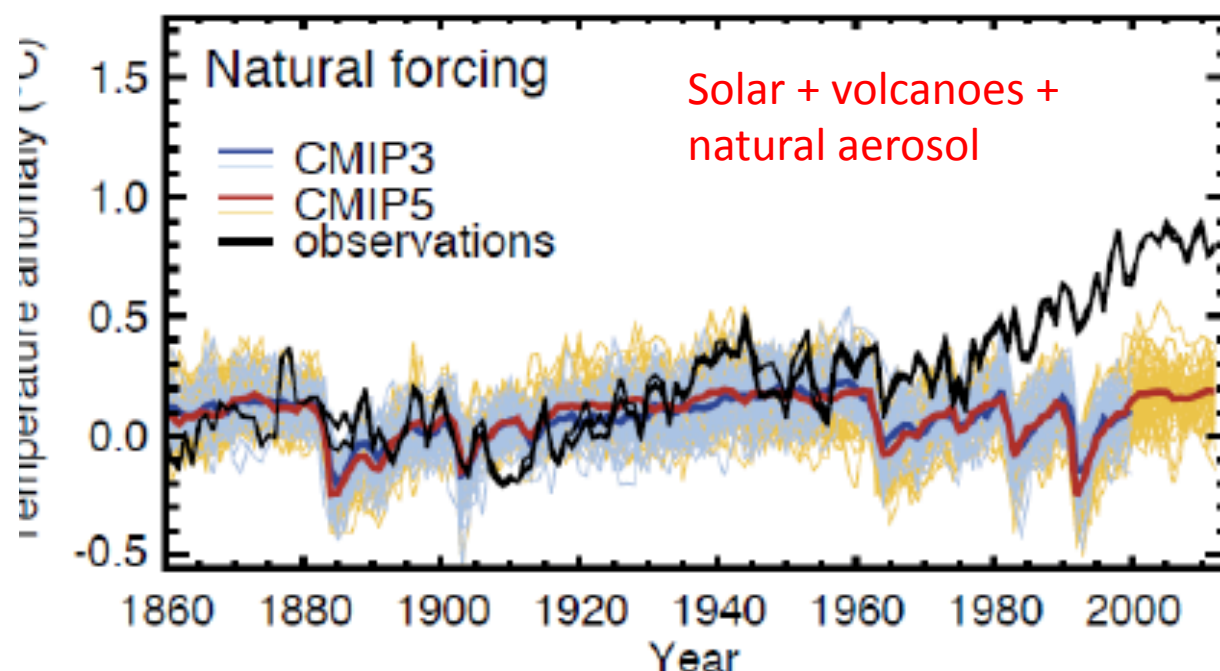
- Globally averaged surface temperatures have increased since 1880
- Humans are adding carbon dioxide to the atmosphere
- Carbon dioxide and other so-called greenhouse gases have a warming effect on the planet

Disagreement:

- **Whether the warming since 1950 has been dominated by human causes**
- **How much the planet will warm in the 21st century**
- Whether warming is 'dangerous'
- Whether we can afford to radically reduce CO₂ emissions



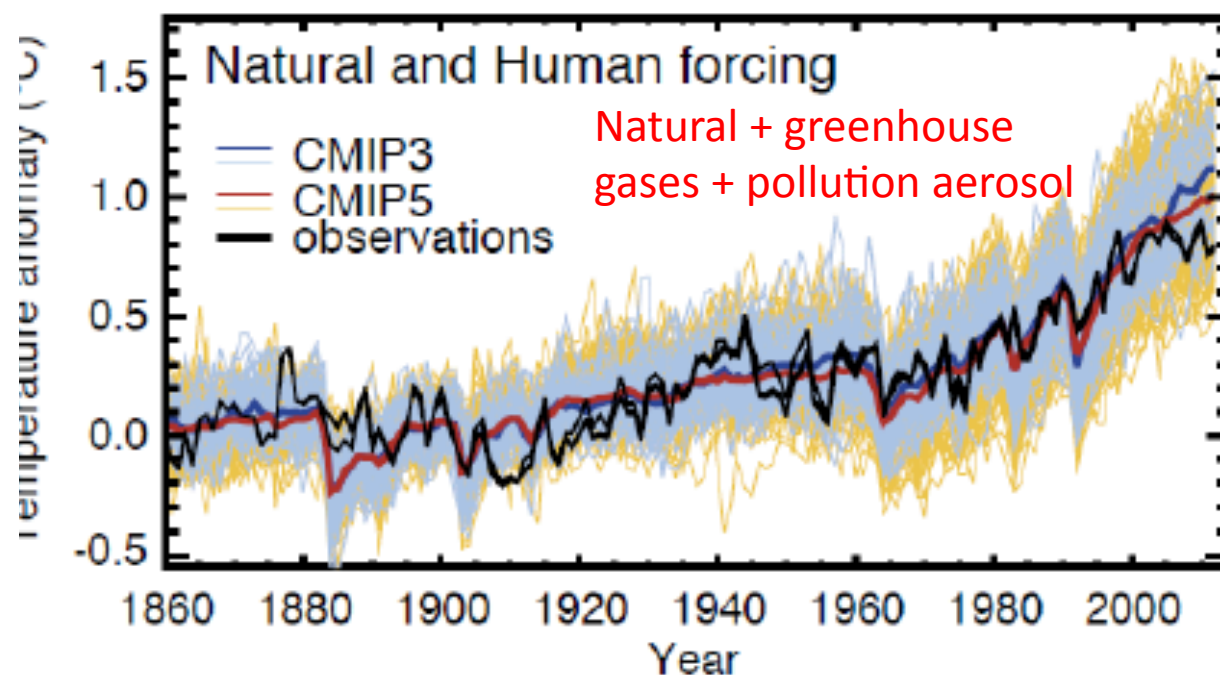
What has caused the warming?



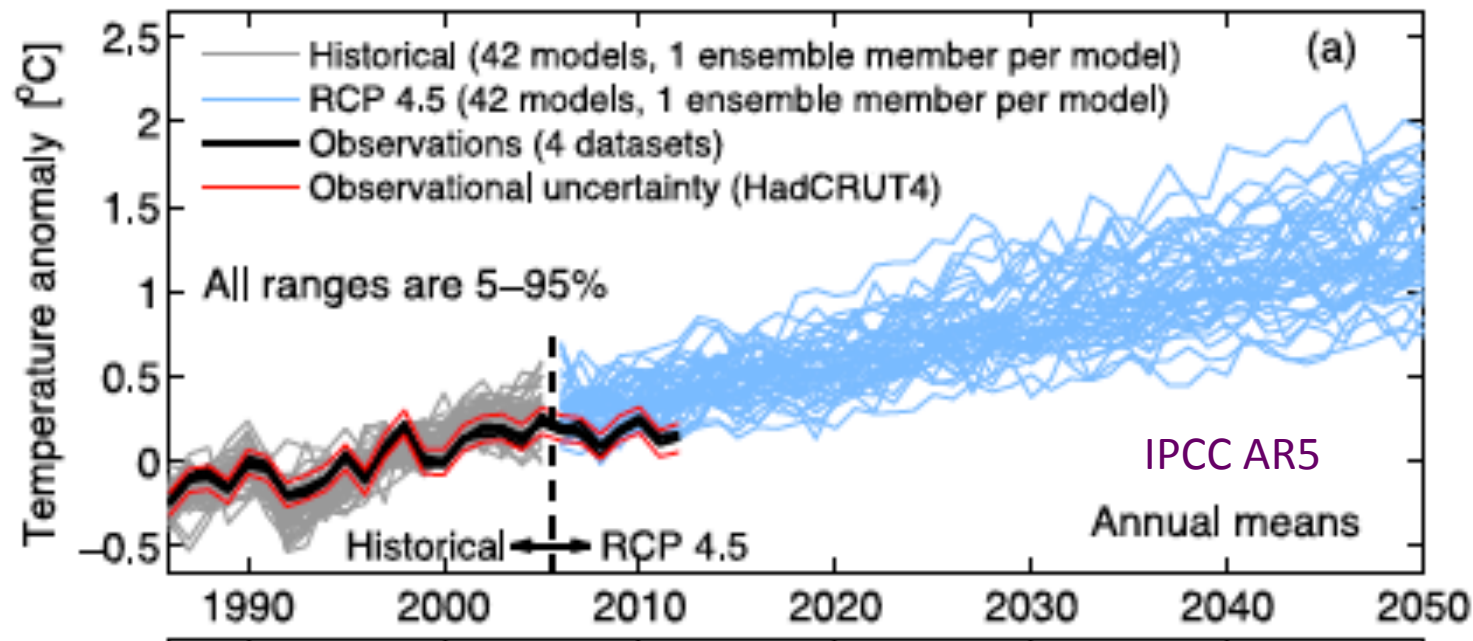
Warming since 1950:
Human forcing

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

Cooling 1940-1975:
Not reproduced by the models



Significance of the 'pause' since 1998



CO₂ concentration since 1998: ~ +25% of total human impact

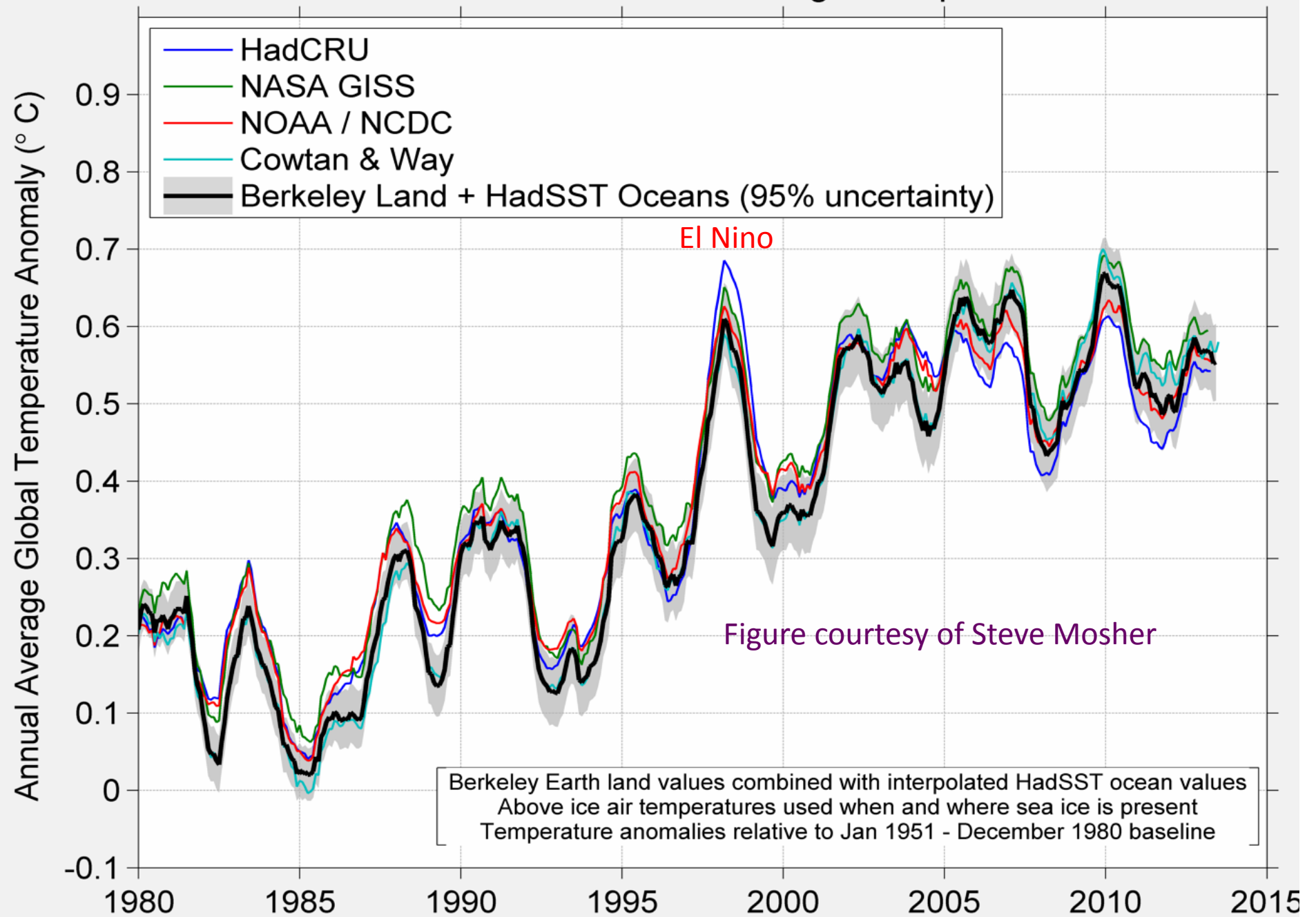
Under conditions of human-caused greenhouse forcing:

- Modeled 'pauses' longer than 15 years are rare; the probability of a modeled pause exceeding 20 yrs is vanishing small

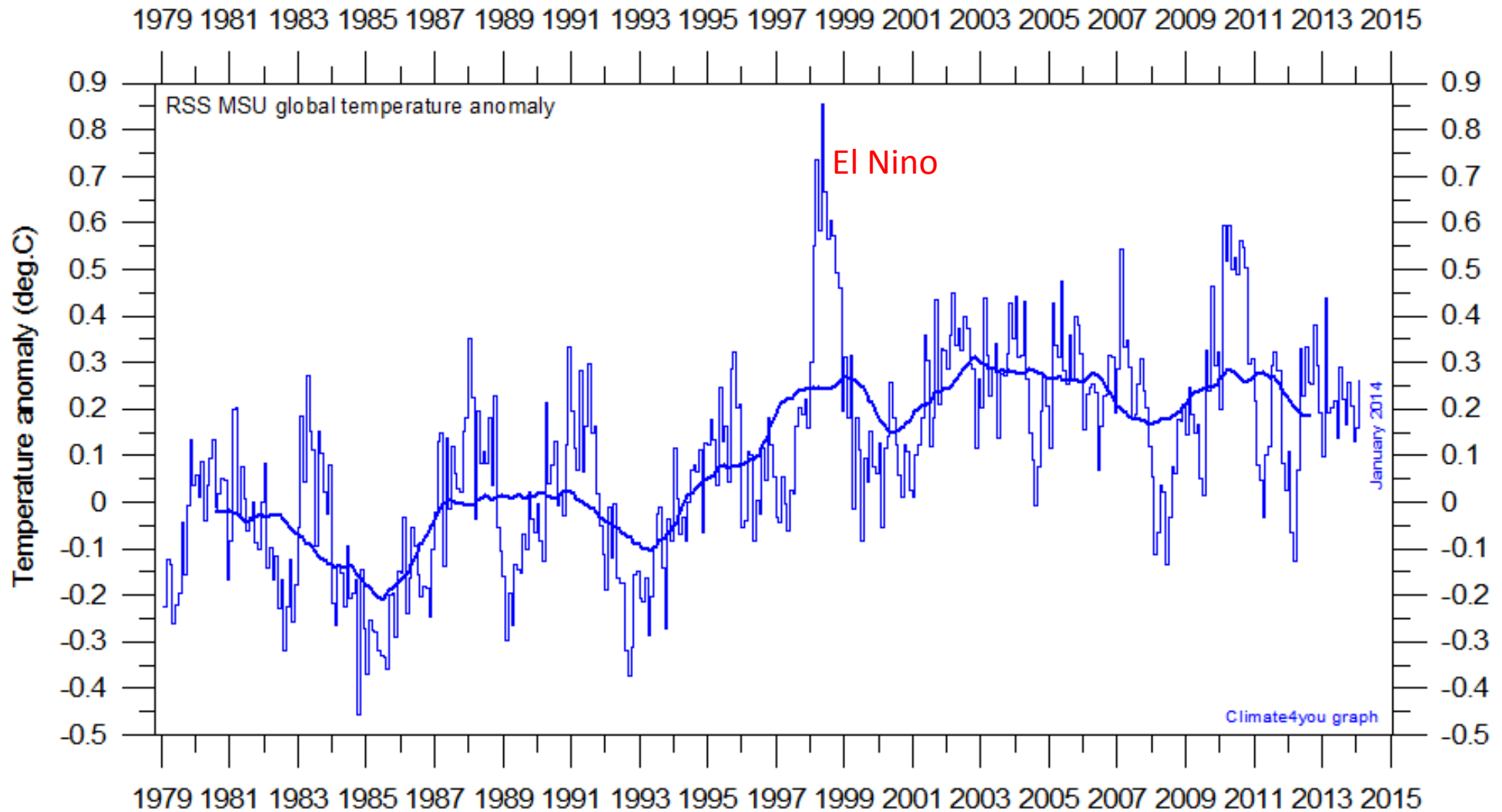
Questions raised by the discrepancy between models & observations

- Are climate models too sensitive to greenhouse forcing?
- Is climate model treatment of natural climate variability inadequate?
- Are climate model projections of 21st century warming too high?
- How good are the observations?

Land + Ocean Climate Change Comparison

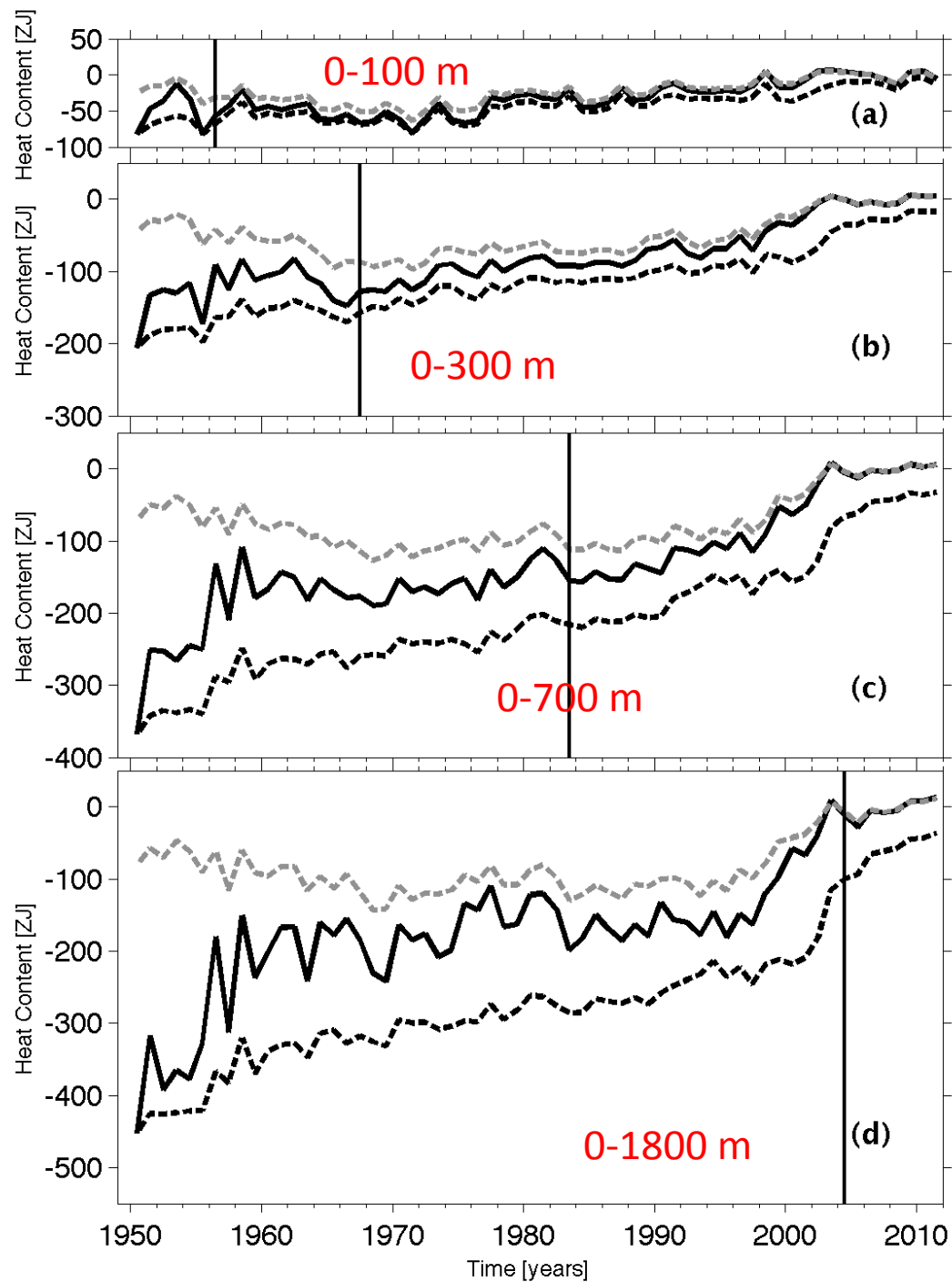


Atmospheric temperatures from satellite observations



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

Ocean Heat Content



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

I. Where is the 'missing heat'?

Hypothesis I: It MUST be hiding in the ocean

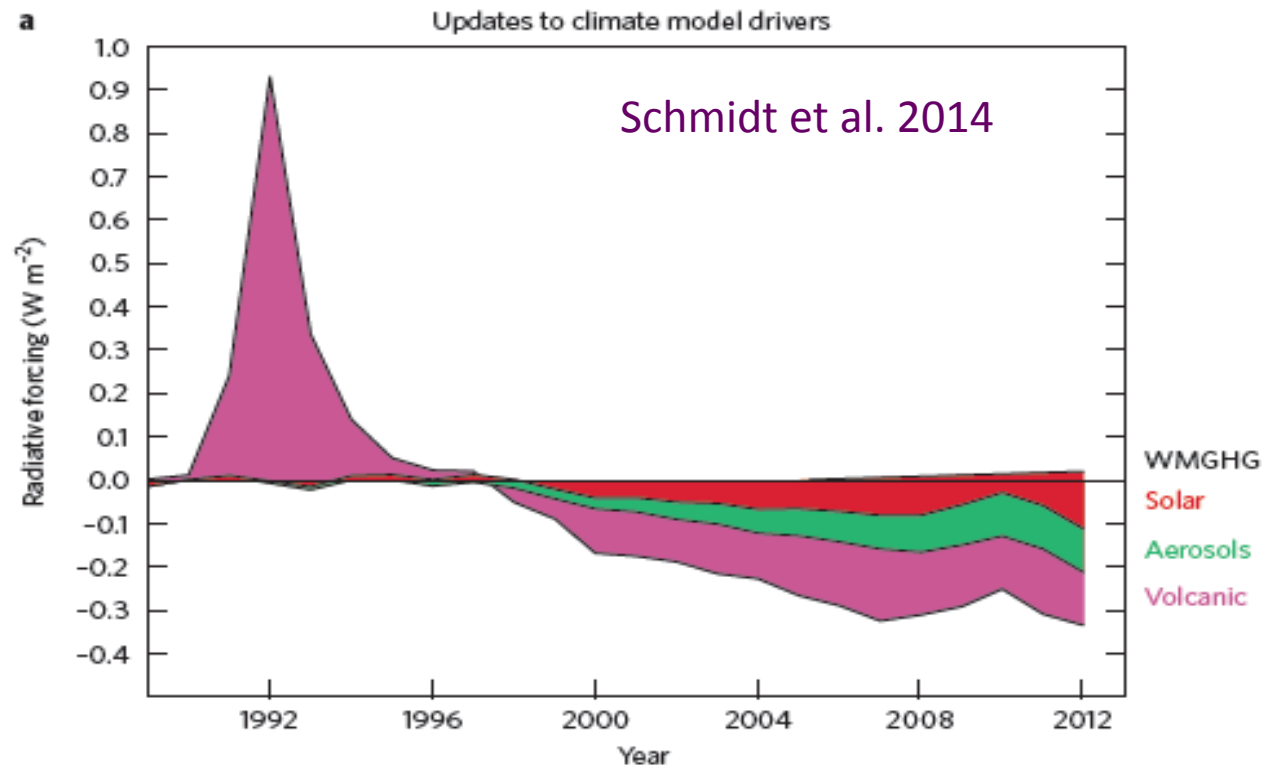
- Few observations of deep ocean temperature prior to 2005
- Mechanism for heat transfer to the deep ocean is not well understood

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

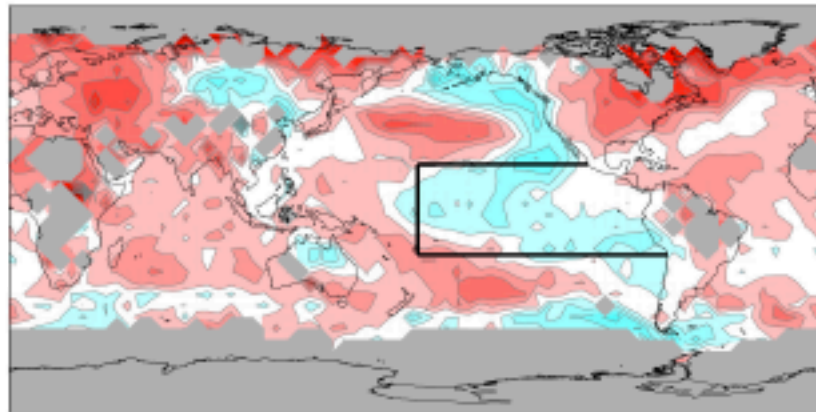


There has been no systematic effort to assess uncertainty in these data sets or the sensitivity of climate models to forcing uncertainty

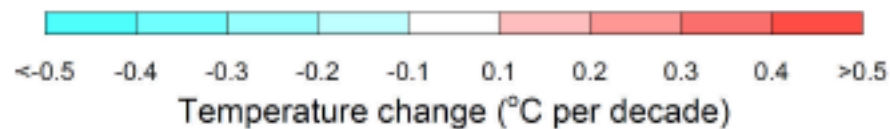
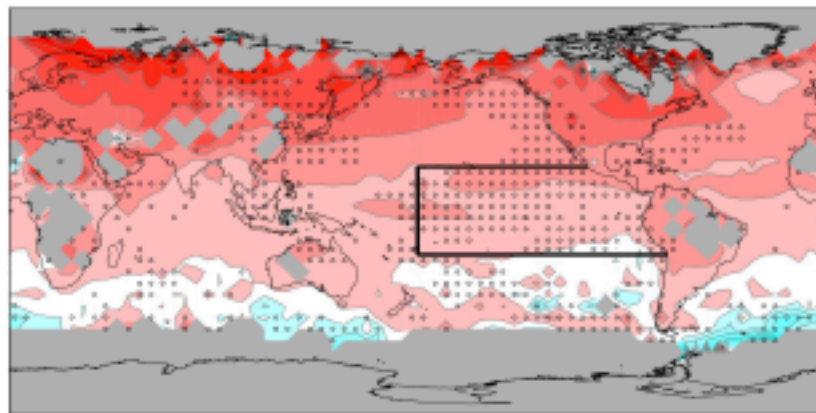
Forcing discrepancies could account for up to 20% of discrepancy

III. Role of El Nino and La Nina

observations

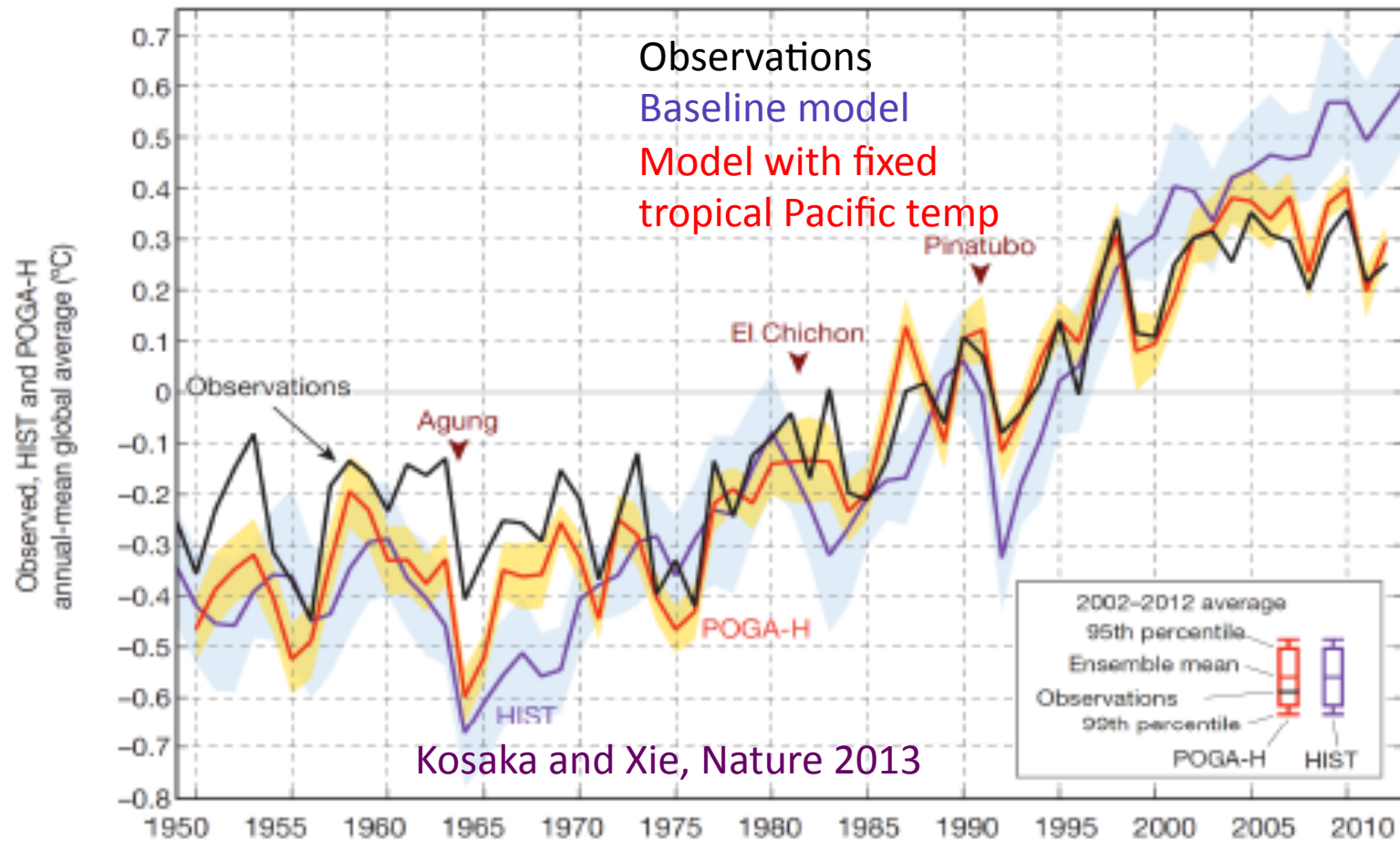


climate models



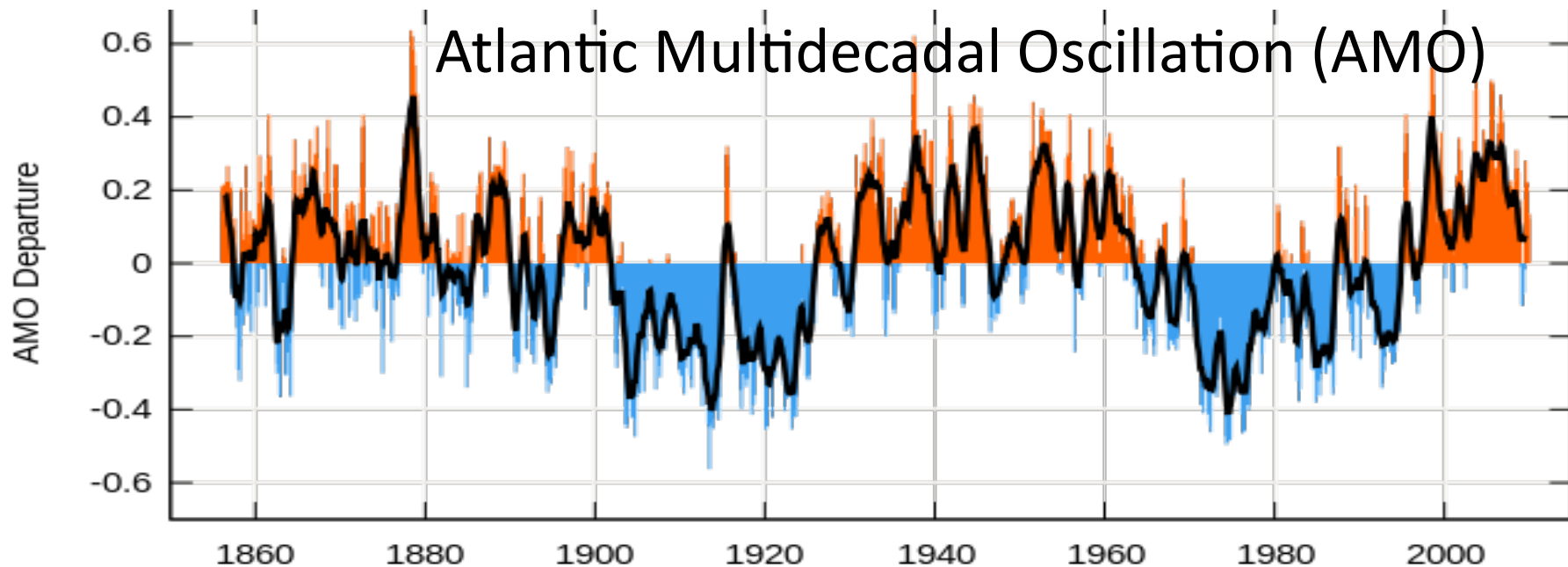
Fyfe & Gillett (*Nature Clim. Change*, 2014)

Influence of the tropical Pacific surface temperatures



El Nino/La Nina doesn't just produce year-to-year noise, but also variability on decadal+ timescales

IV. Multi-decadal modes of natural variability

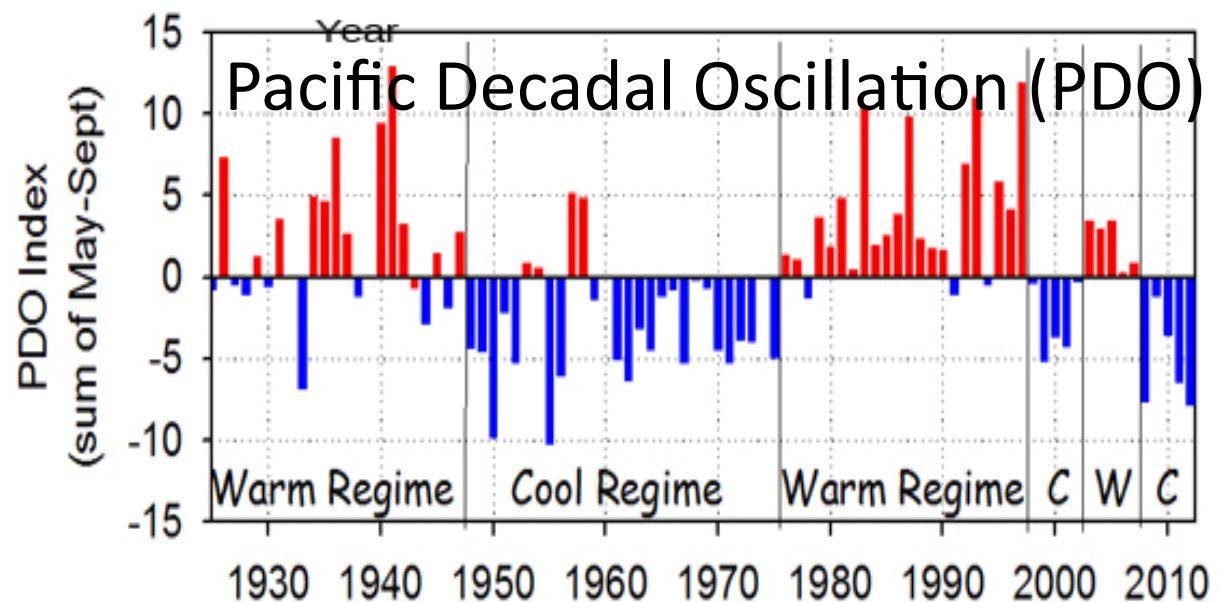


Currently:

- Warm AMO
- Cool PDO

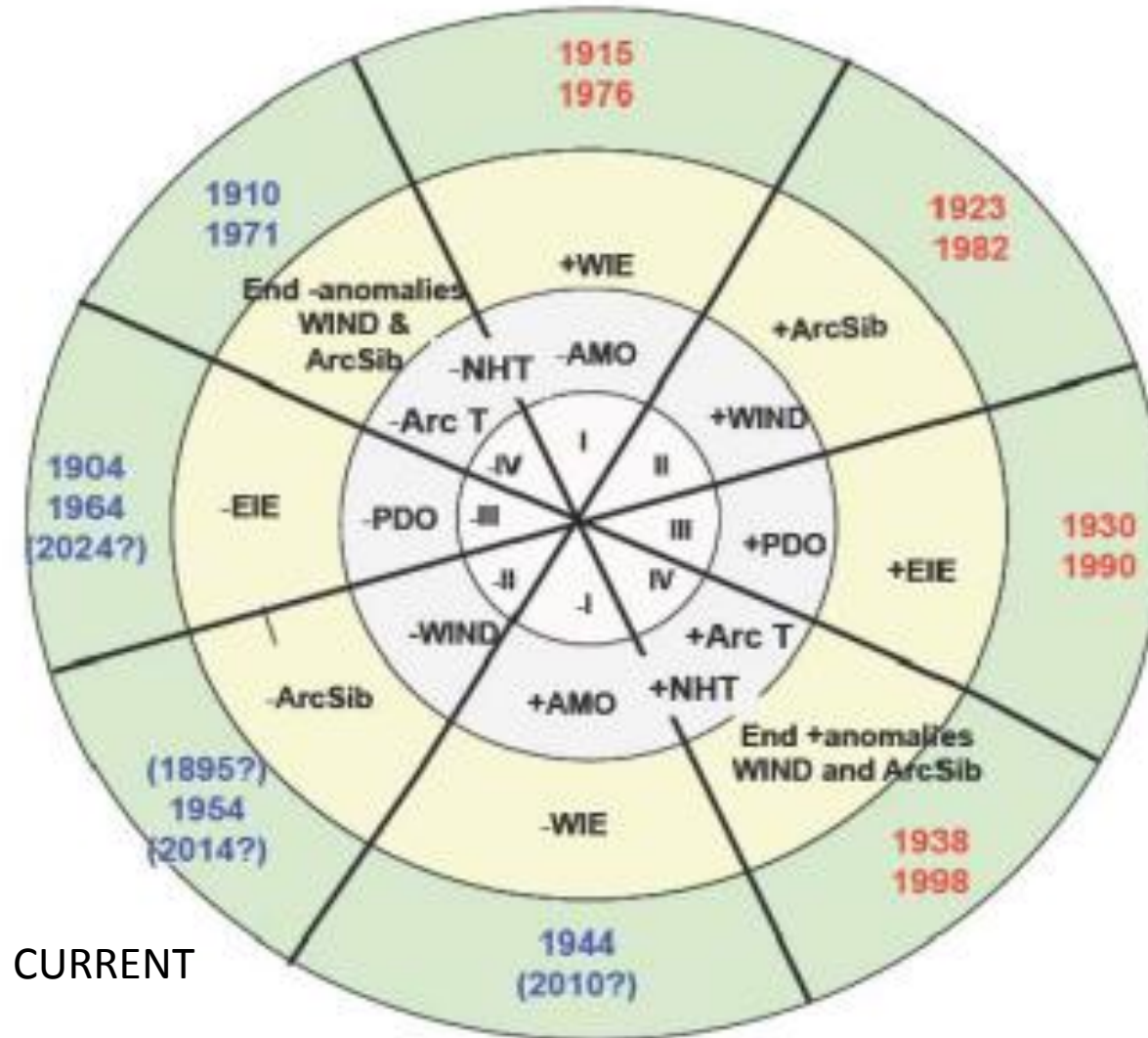
Previous analogue:

- 1946-1964



Natural variability as a Stadium Wave

Wyatt & Curry, 2013: Climate Dynamics



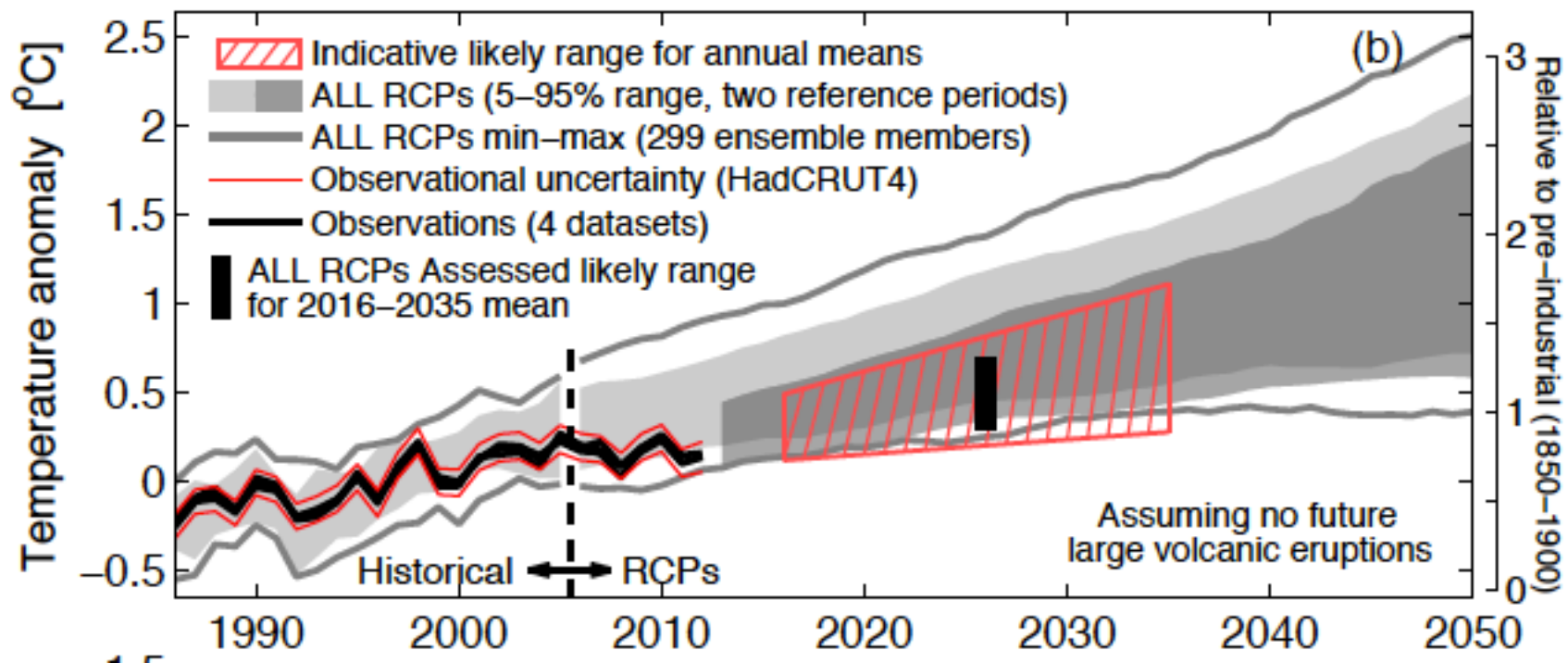
The 'stadium wave' climate signal propagates across the NH through a network of ocean, ice, and atmospheric circulation regimes that self-organize into a collective tempo.

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

Implications for the future:

I. Consensus IPCC view

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



Implications for the future:

II. View emphasizing natural variability

- The 'pause' will continue at least another decade; El Ninos will be weak and infrequent
- 'Pause' persistence beyond 20 years would support a firm declaration of problems with the climate models
- Climate models are too sensitive to human forcing; 21st century warming will be on the low end of IPCC projections (or even below)
- Solar variations and volcanoes are a wild card; most are predicting solar cooling in the near term

Why do scientists disagree?

- Insufficient observational evidence
- Disagreement about the value of different classes of evidence
- Disagreement about the appropriate logical framework for linking and assessing the evidence
- Assessments of areas of ambiguity and ignorance
- Belief polarization as a result of politicization of the science