

State of the Climate Debate

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Confusion

•

Uncertainty

•

Disagreement



Sense of the Senate Resolution 1/20/15

“Climate change is real and not a hoax” (98-1)

“Climate change is real; and human activity significantly contributes to climate change.” (50-49)

Confusion between the scientific and political definition:

- Scientific defn: Climate change may be due to natural processes, or to persistent anthropogenic changes.
- Political defn equates ‘climate change’ with human-caused climate change (UNFCCC)

Natural climate variability versus human-caused climate change is at the heart of scientific and policy debate



Agreement:

- Surface temperatures have increased since 1880
- Humans are adding carbon dioxide to the atmosphere
- Carbon dioxide and other 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, and whether reduction will improve the climate



Why do scientists disagree?

- Insufficient observational evidence
- Disagreement about the value of different classes of evidence (e.g. global climate models)
- Disagreement about the appropriate logical framework for linking and assessing the evidence
- Assessments of areas of ambiguity & ignorance
- **Belief polarization as a result of politicization of the science**

Uncertainty • Doubt • Ignorance

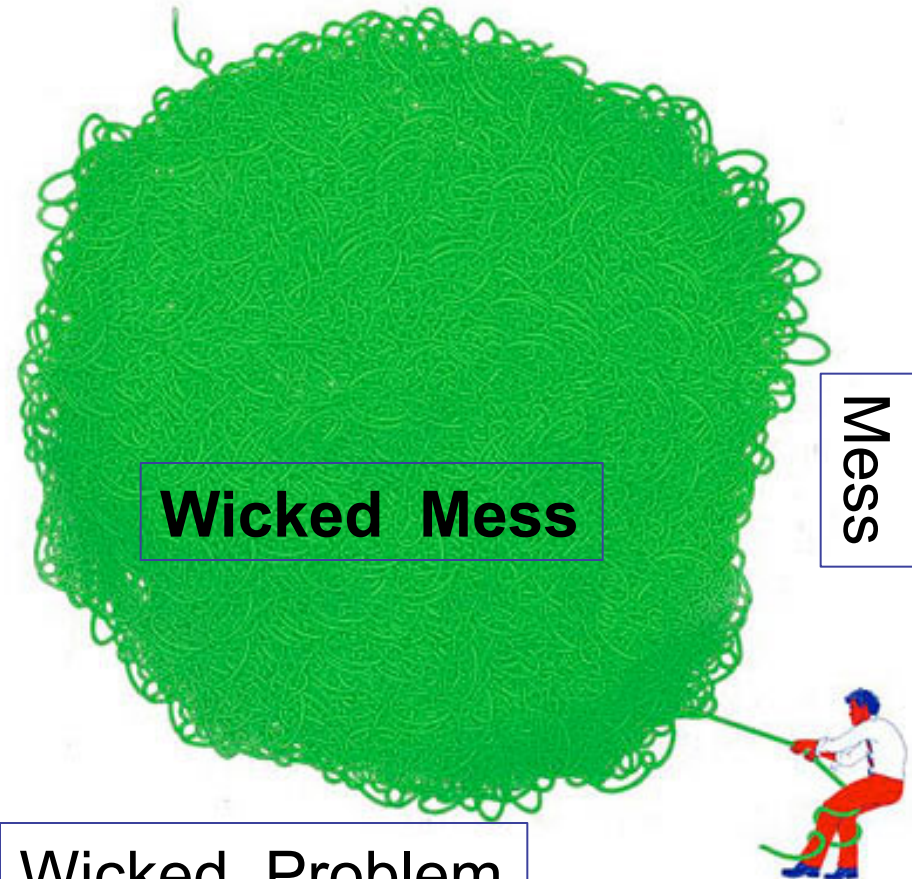
Tame Problem



President Obama: “We don’t have time for a meeting of the Flat Earth Society”

versus

JC: The climate change problem and its solution have been vastly oversimplified.



Wicked Mess

Mess

Wicked Problem

You find what you shine a light on . . .

Solar indirect effects

Unknown unknowns

Long-term ocean
oscillations

Volcanoes



Greenhouse gases

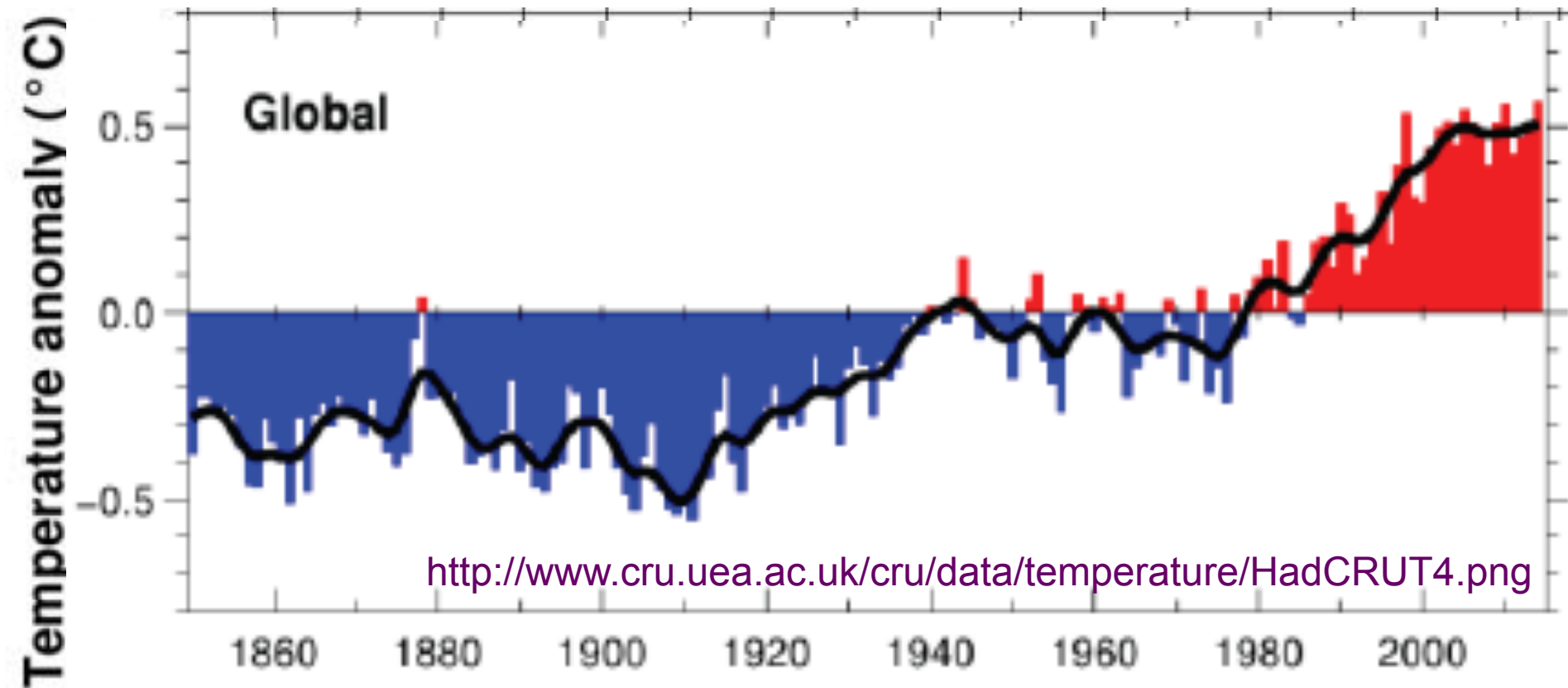
Underwater volcanoes

Land use

Solar system gravitational
& magnetic interactions

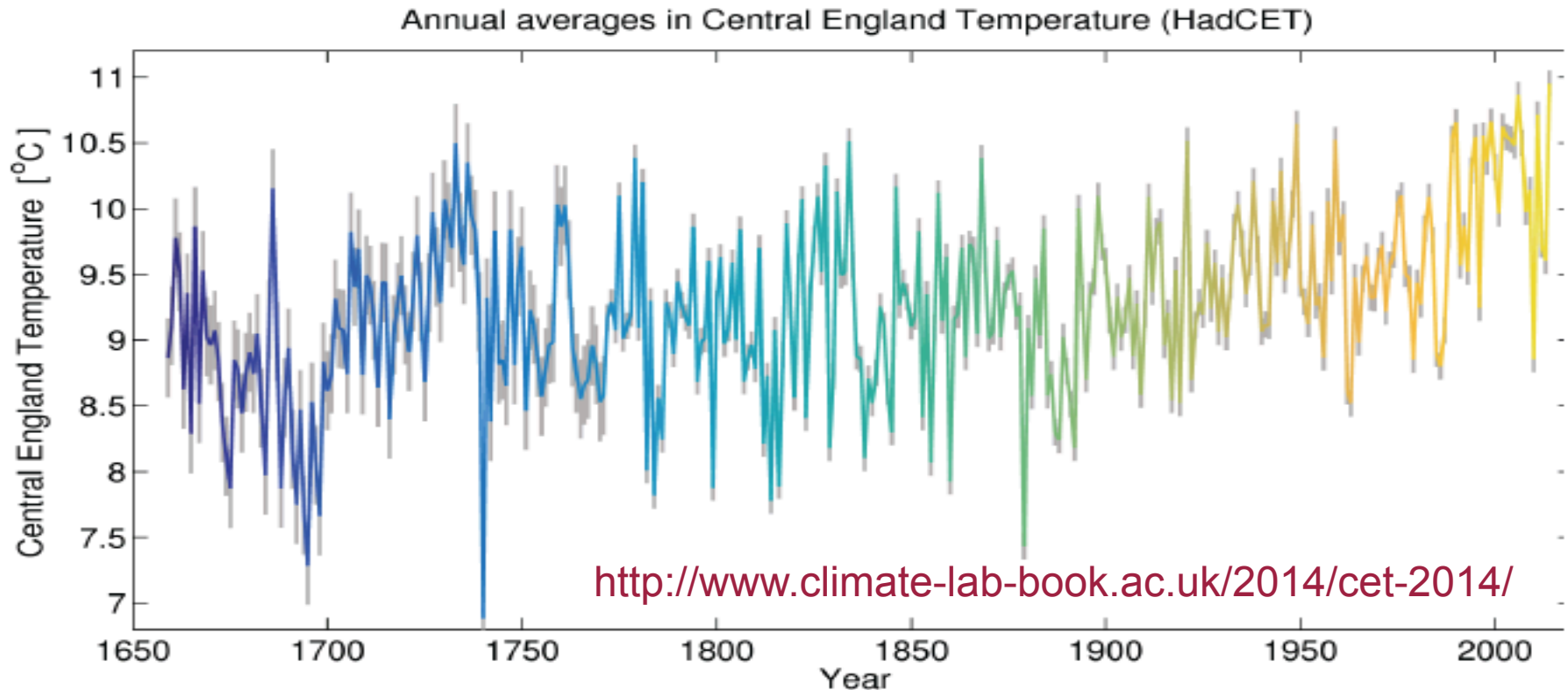
Aerosols

Global surface temperature anomaly



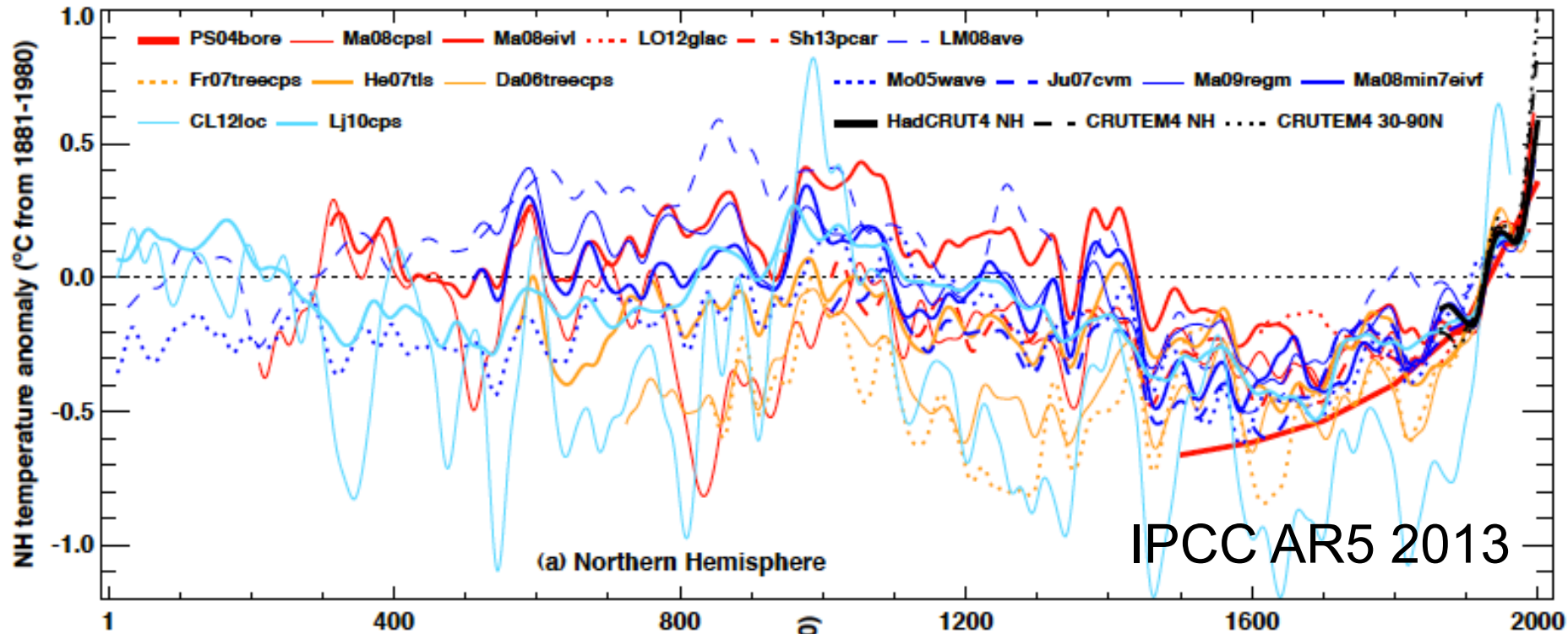
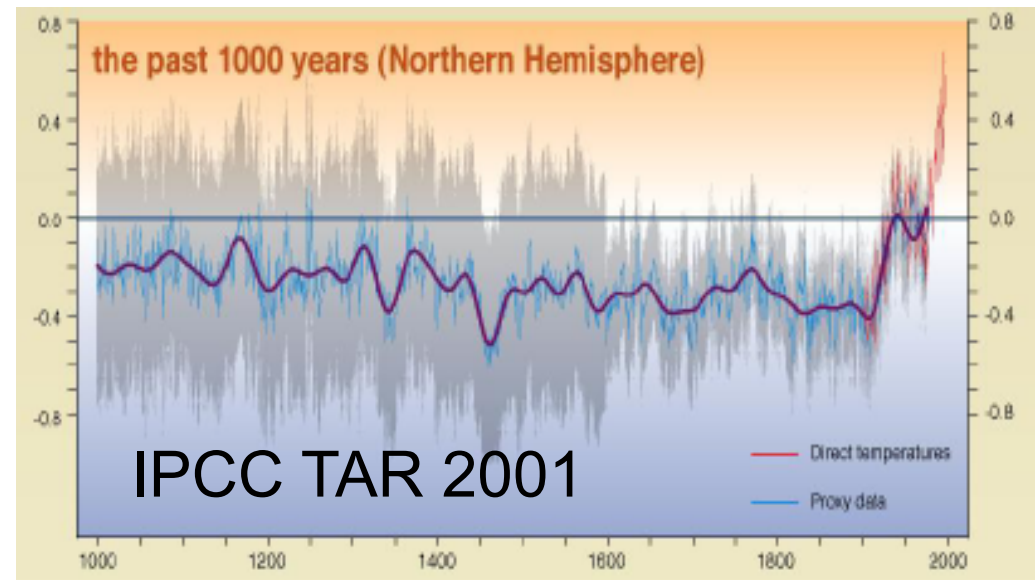
IPCC AR5: *It is **extremely likely** that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by [humans]. The best estimate of the human induced contribution is similar to the observed warming over this period.*

Is the warming since 1950 unusual?

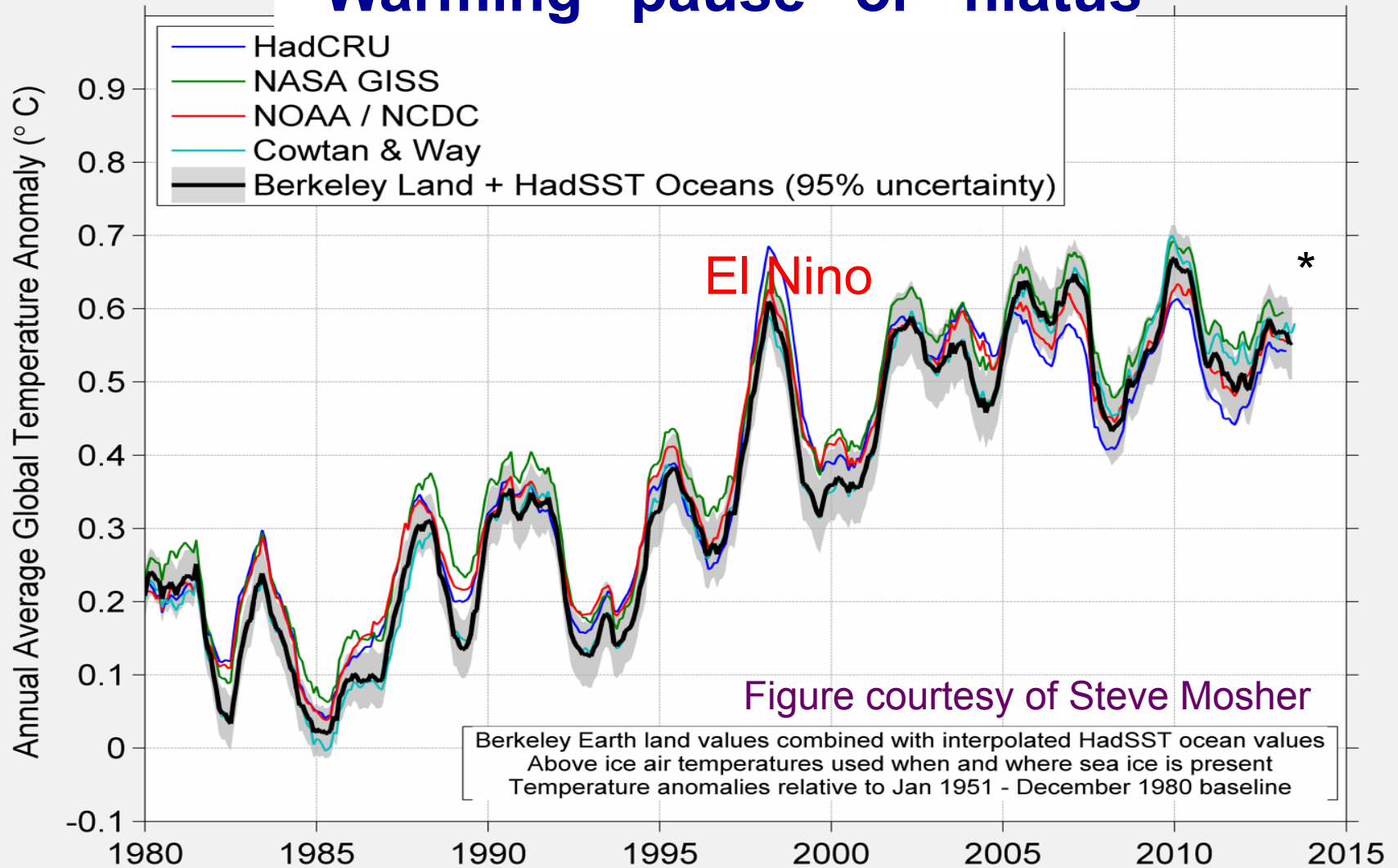


- Long-term warming trend: fossil fuel contribution since 1950
- Year-to-year variations: volcanoes, El Nino
- Multi-decadal variations: solar, ocean circulations

NH paleoclimate surface temperature reconstructions

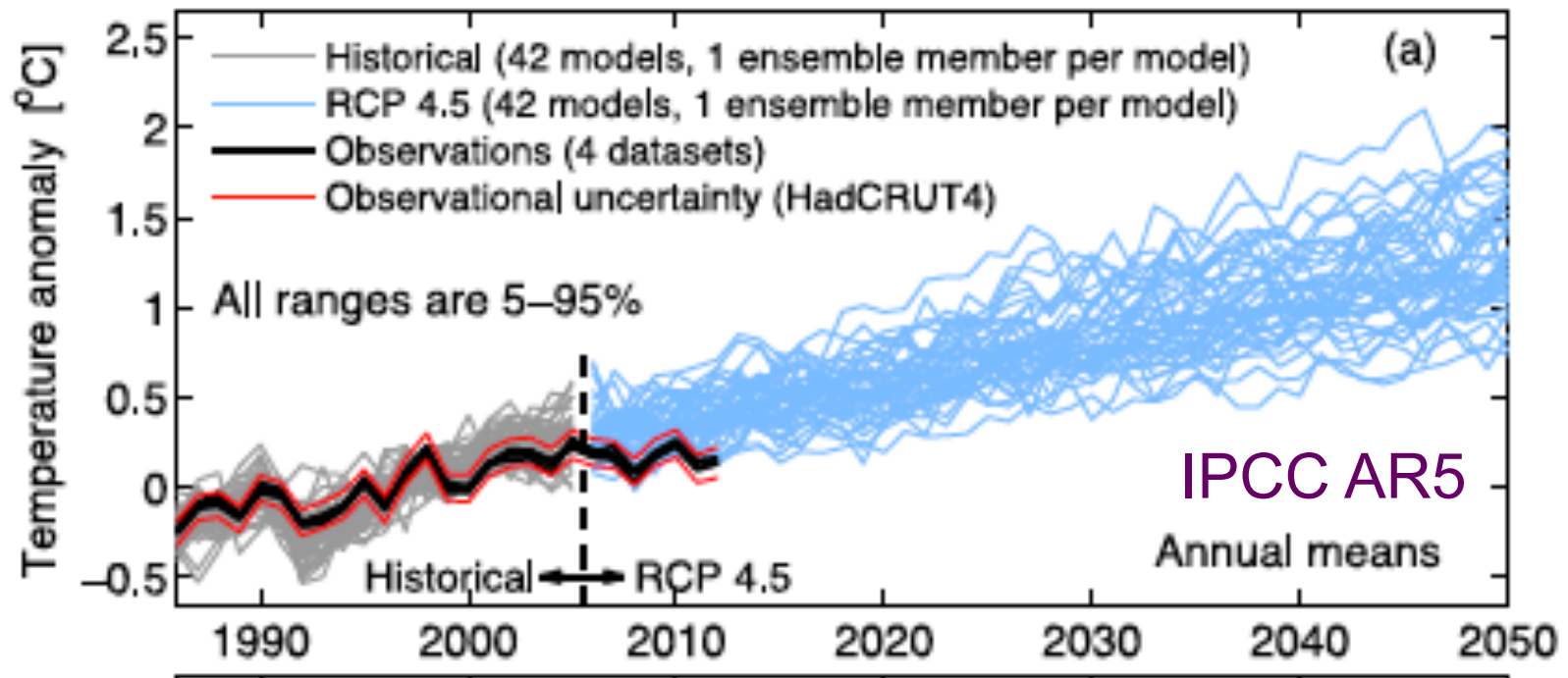


Warming 'pause' or 'hiatus'



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

Significance of the 'pause' since 1998



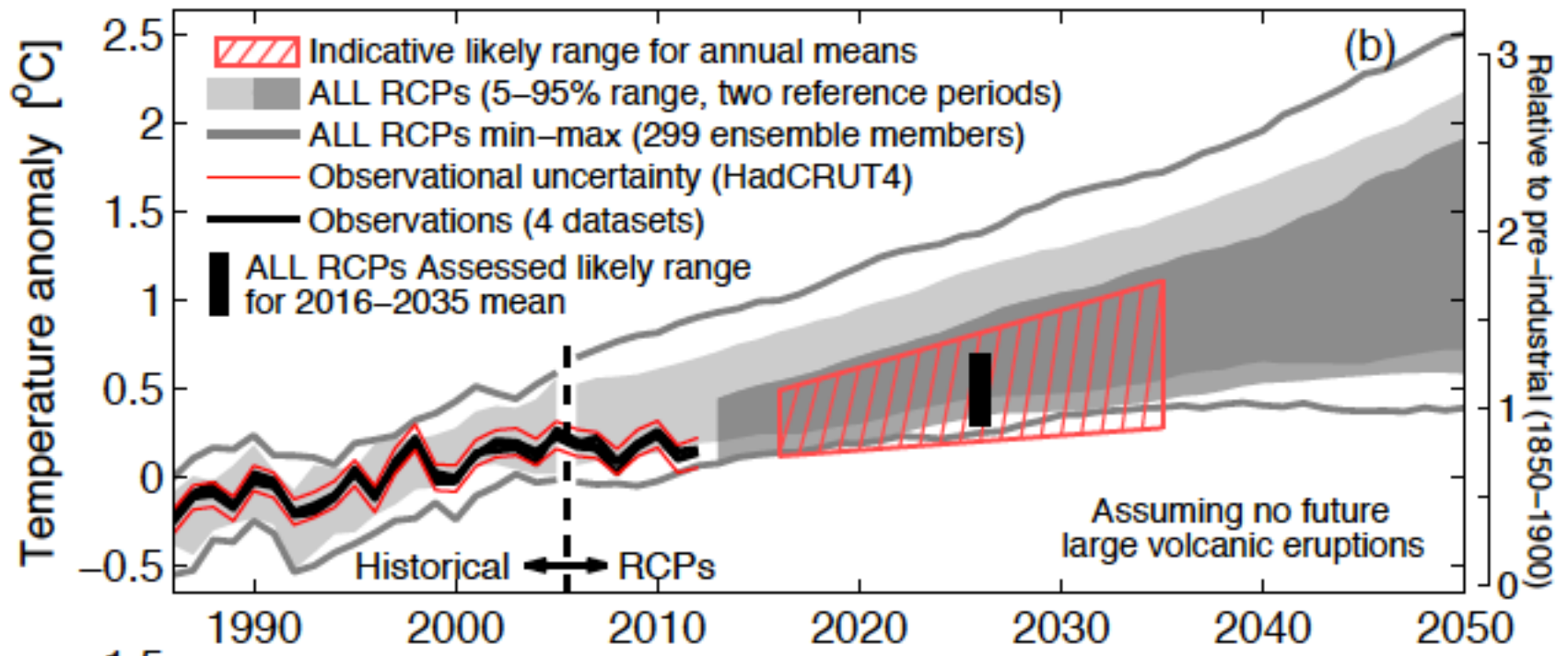
Growing divergence between models & observations:

- Are climate models too sensitive to greenhouse forcing?
- Is modeled treatment of natural climate variability inadequate?
- Are model projections of 21st century warming too high?

Implications for the future:

I. Consensus IPCC view

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



IPCC AR5 Ch 11

Implications for the future:

II. View emphasizing natural variability

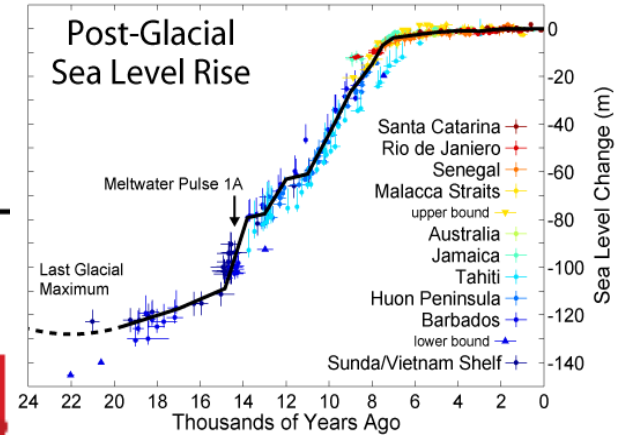
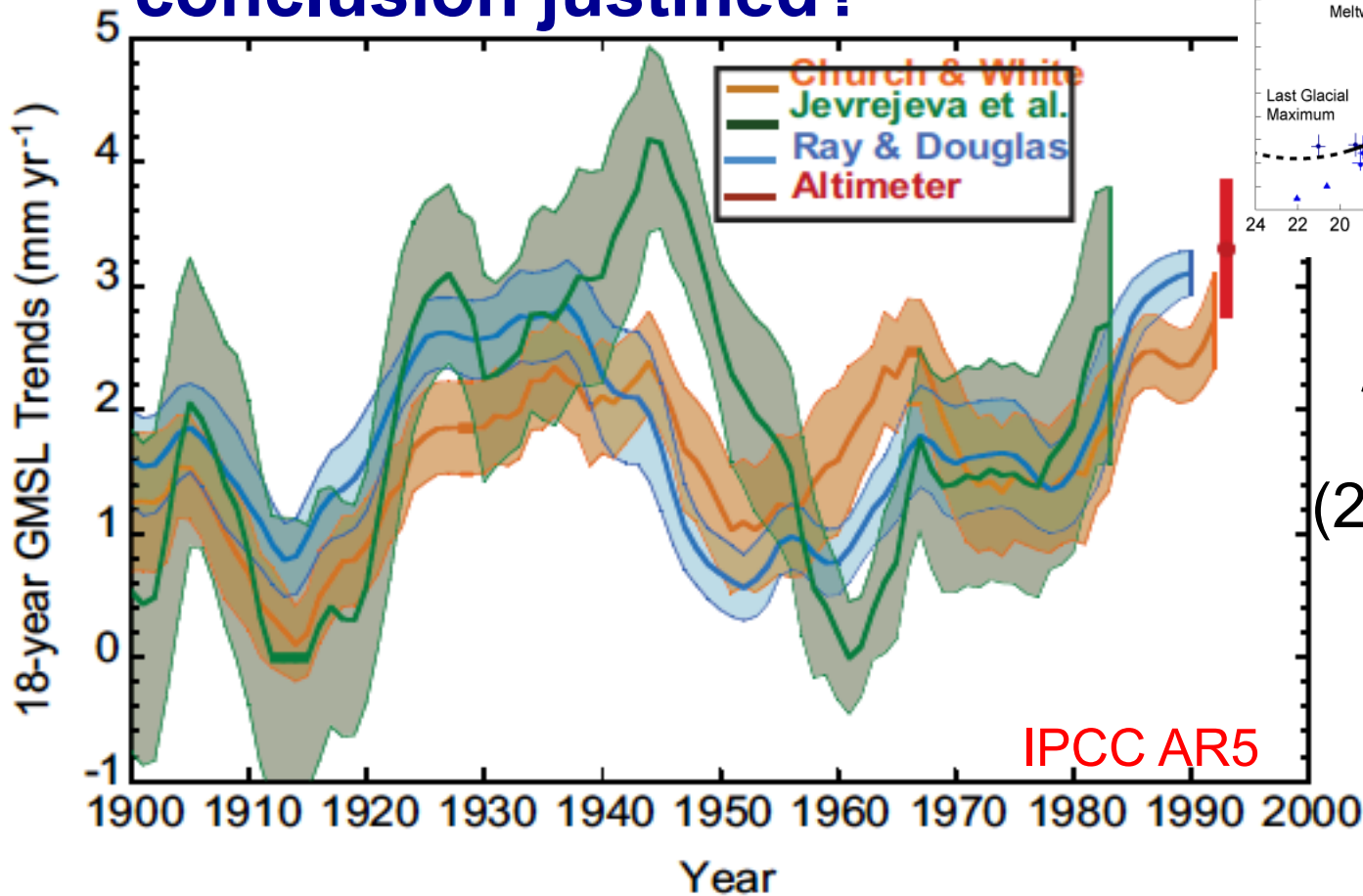
- The 'pause' will continue at least another decade (into the 2030's?); El Ninos weak and infrequent
- Climate models are too sensitive to human forcing; 21st century warming will be on the low end of IPCC projections (or even below)
- Solar variations & volcanoes: wild card. Most are predicting solar cooling in the near term
- Can't rule out unforeseen surprises



Implications for utility regulators

- There is a great deal of uncertainty in our understanding of what has caused the 20th century warming and how the 21st century climate might evolve.
- We need to prepare for surprises – including ‘cold’ ones
- We need to stop treating climate change as a ‘tame problem’, and need to adopt a decision making framework, suitable for conditions of deep uncertainty, that seeks flexible, robust and anti-fragile policies

Is the IPCC's sea level rise conclusion justified?



* (2.4)
(2003-2011)

IPCC AR5

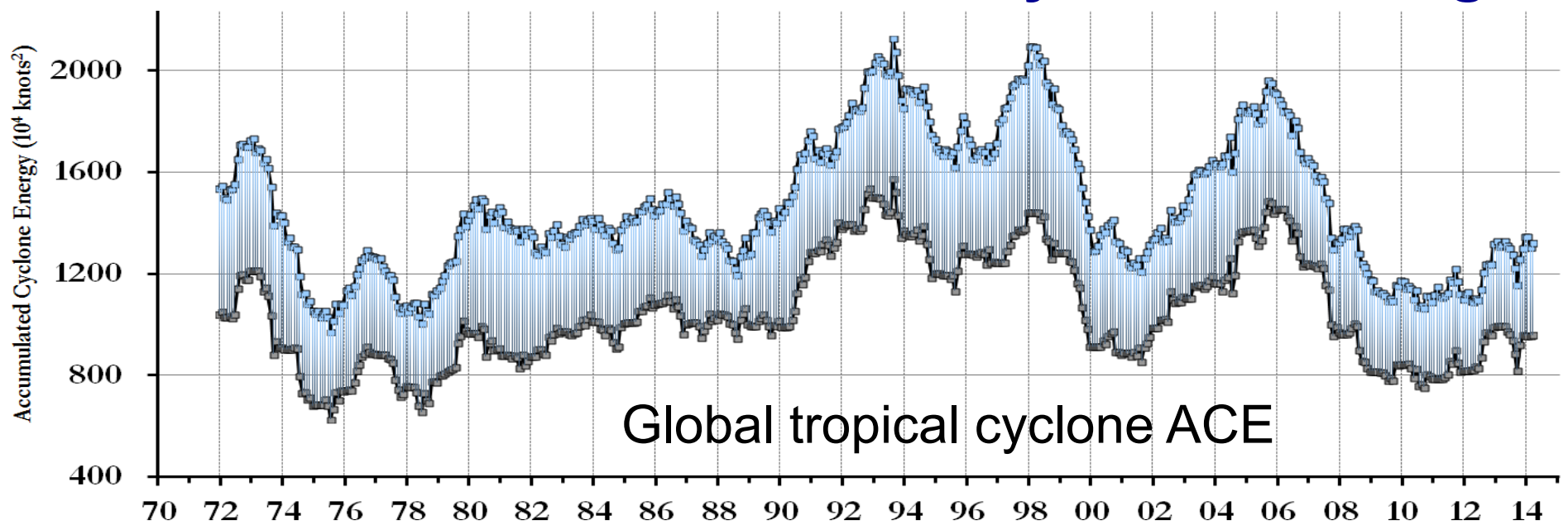
IPCC AR5: “Since the early 1970’s, glacier mass loss and ocean thermal expansion from warming together explain about 75% of the observed global sea level rise (high confidence)”

Sea level rise: coastal threat?

Confounding factors for local sea level rise:

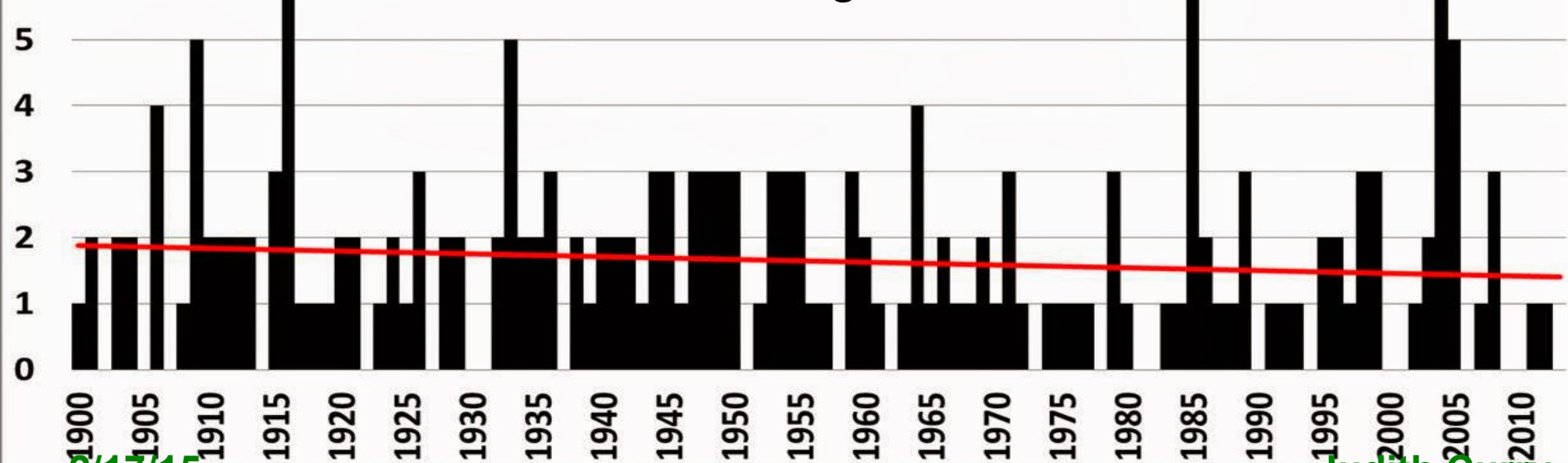
- Geological sinking/rising
- Ground water withdrawal
- River engineering

Are hurricanes made worse by climate change?



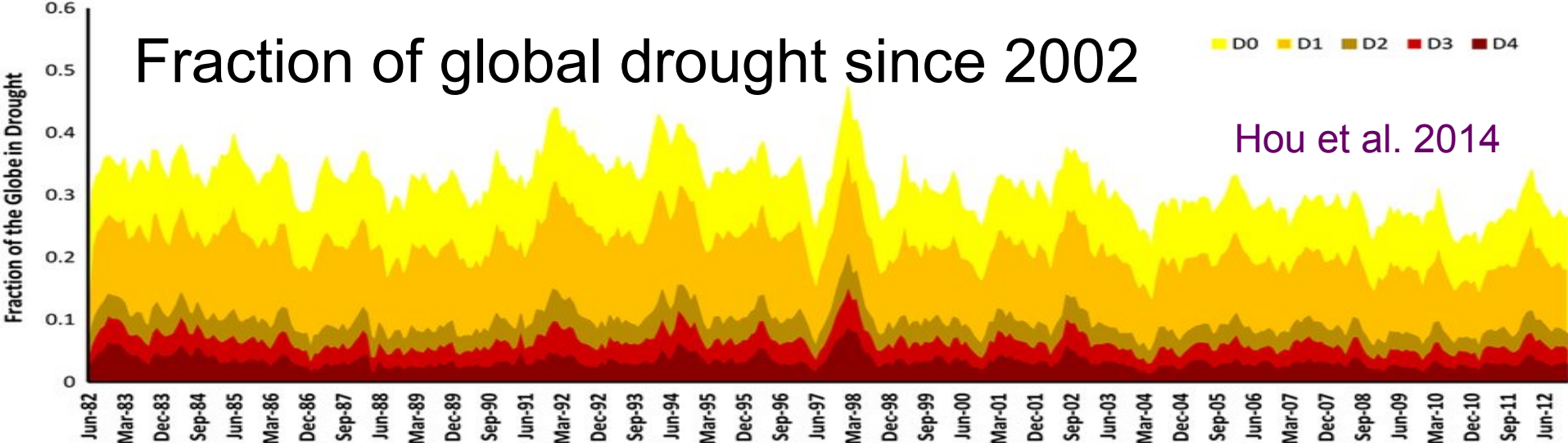
Source: <http://rogerpielkejr.blogspot.com>
22 Nov 2013

US landfalling hurricanes

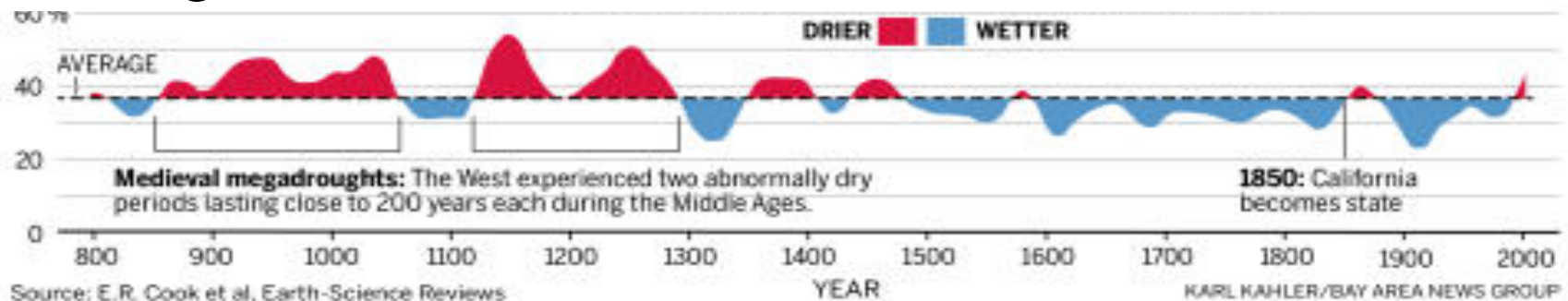


2/17/15

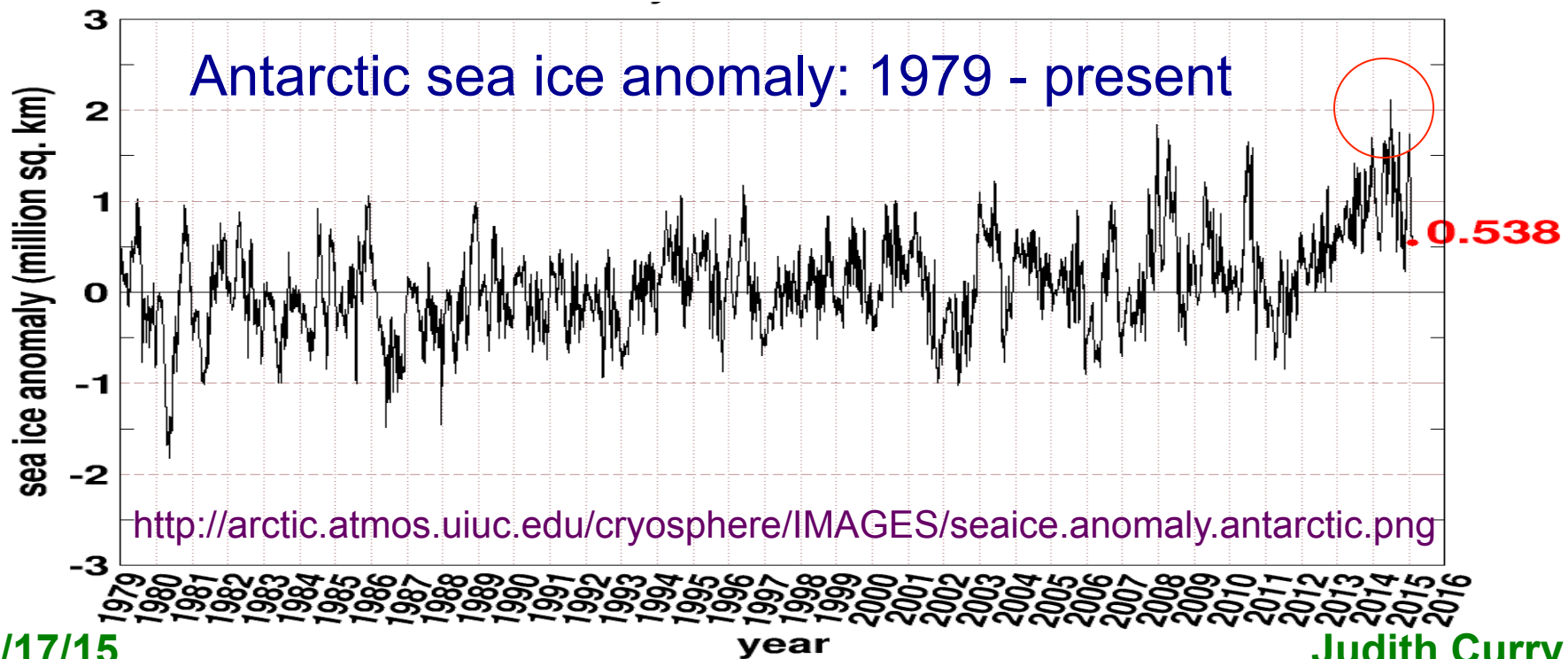
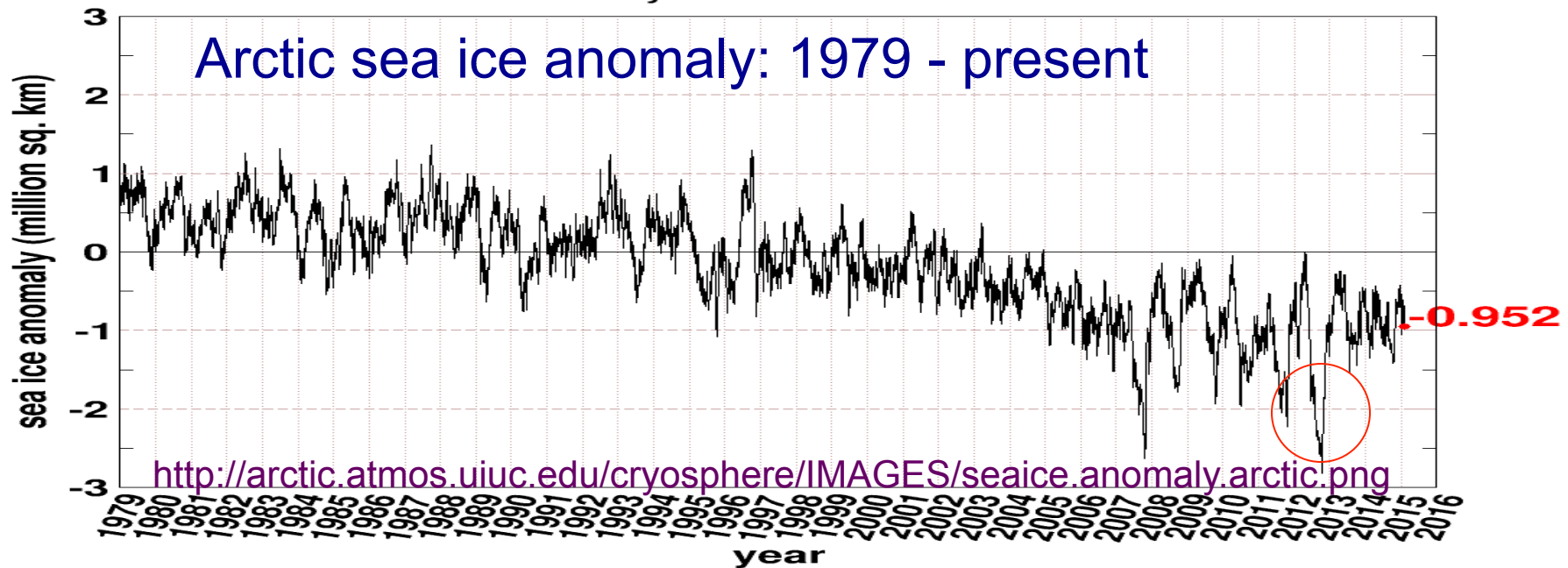
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Drought in the western U.S.



- California drought: comparable drought in 1890's
- Massive droughts in U.S. west during Middle Ages
- Climate models predict MORE rain in western U.S.



IPCC AR5 statements on causes of sea ice changes (Ch 10)

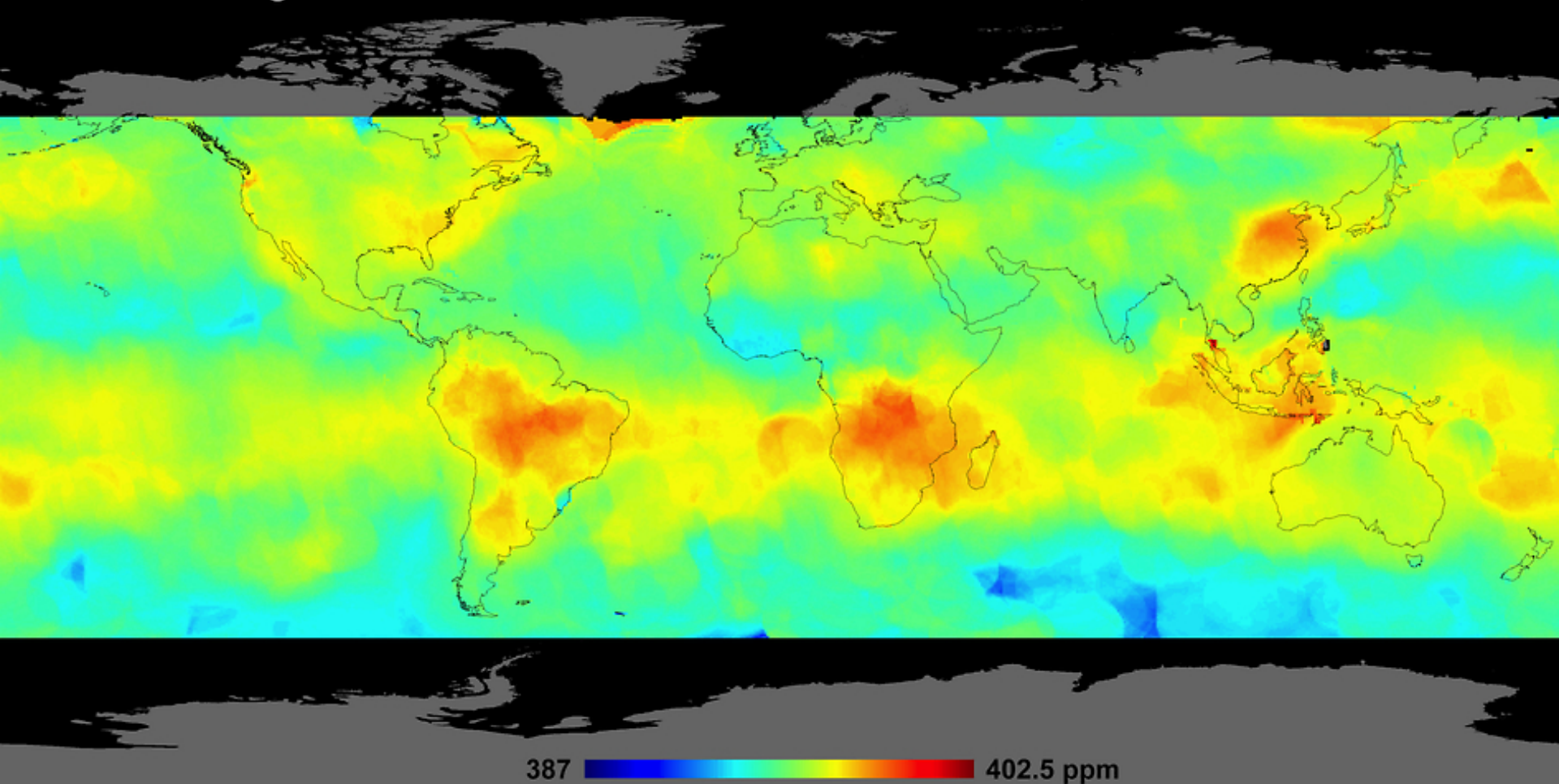
- “Anthropogenic forcings are very likely to have **contributed** to Arctic sea ice loss since 1979.”
- “There is **low confidence** in the scientific understanding of the observed increase in Antarctic sea ice extent since 1979, due to the incomplete and competing scientific explanations for the causes of change and low confidence in estimates of internal variability.”
- “Arctic temperature anomalies in the 1930s were apparently as large as those in the 1990s and 2000s. There is still considerable discussion of the ultimate causes of the warm temperature anomalies that occurred in the Arctic in the 1920s and 1930s.”

Recent global temperature record

- 'Warmest year': 2014 is in a statistical tie with 9 other years since 1998 (uncertainty is 0.1°C)
- No statistically significant trend for past 16+ years. Compare with major warming trend 1976-1998 (22 yrs)
- Since 1998, 25% of human CO_2 has been emitted
- Climate models predicted a trend of $0.2^{\circ}\text{C}/\text{decade}$ in early part of 21st century: growing discrepancy between climate models and observations
- Changes in ocean circulation seems to be dominant reason for 'pause', with solar & volcanoes contributing
- Growing discrepancy raises serious questions about utility of climate models, the cause of warming in the 20th century, and predictions of 21st century warming.

How well do scientists understand sources and sinks of CO₂?

Averaged Carbon Dioxide Concentration Oct 1 - Nov 11, 2014 from OCO-2



Consensus among scientists as to whether humans are dominant cause of 20th century warming?

- The much vaunted '97% consensus' was based on a deeply flawed study that examined the abstracts of published papers.
- Actual surveys of scientists found:
 - American Meteorological Society (2014): **52%**
 - Verheggan et al. (2014) survey of climate scientists: **85%**

Summary of major uncertainties

- Deep ocean heat content variations and mechanisms of vertical heat transfer in the ocean
- Uncertainties in aerosol forcing
- Sensitivity of the climate system to CO₂
- Clouds: trends, feedbacks, & aerosol – cloud interactions
- Nature and mechanisms of multidecadal natural ‘internal’ variability (ocean-atmosphere circulations)
- Unknowns – solar indirect effects, magnetic and electric field effects, orbital (tidal and other) effects, core-mantle interactions, etc.

