Learning from the Climate Changes in Past Centuries

CLIMATE CENTRAL

April 26, 2016

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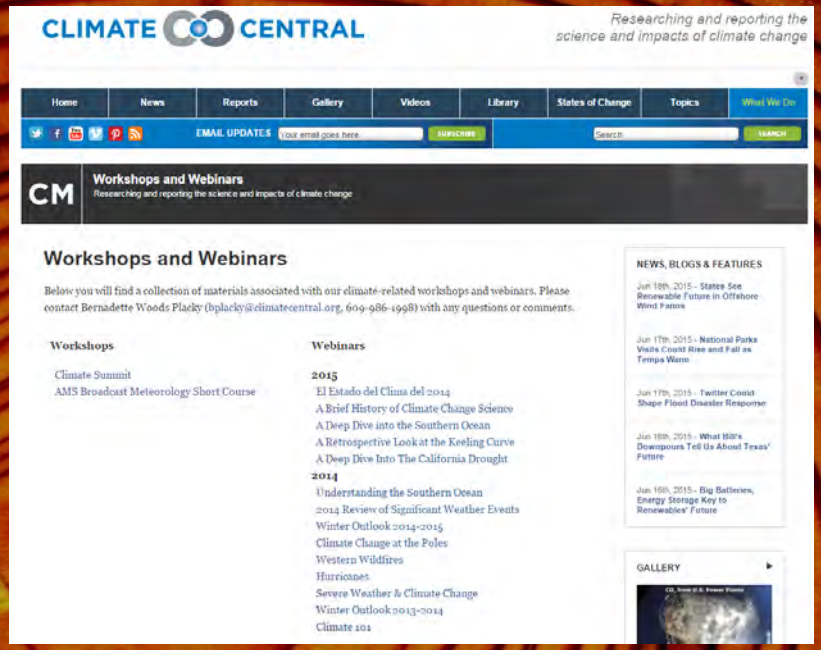
April 26, 2016



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April 26, 2016

Learning from the Climate Changes in Past Centuries

Dr. Michael Mann
Director
Earth System Science Center
Pennsylvania State University

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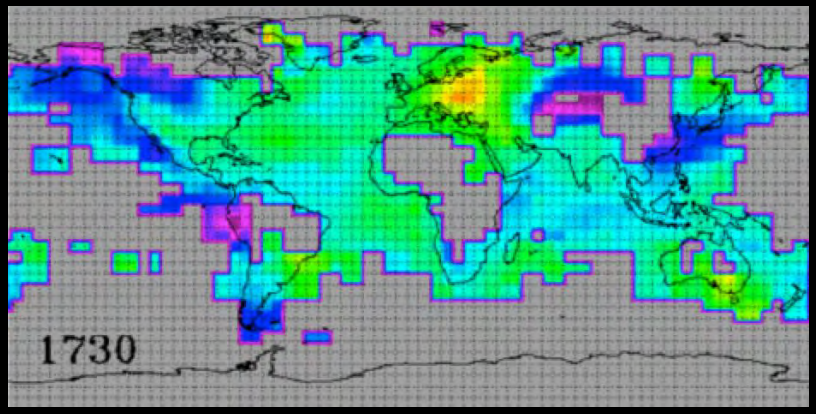
April 26, 2016

The Past as Prologue: Learning from the Climate Changes in Past Centuries



Michael E. Mann

Departments of Meteorology & Geosciences; Earth & Environmental Systems Institute

Penn State University

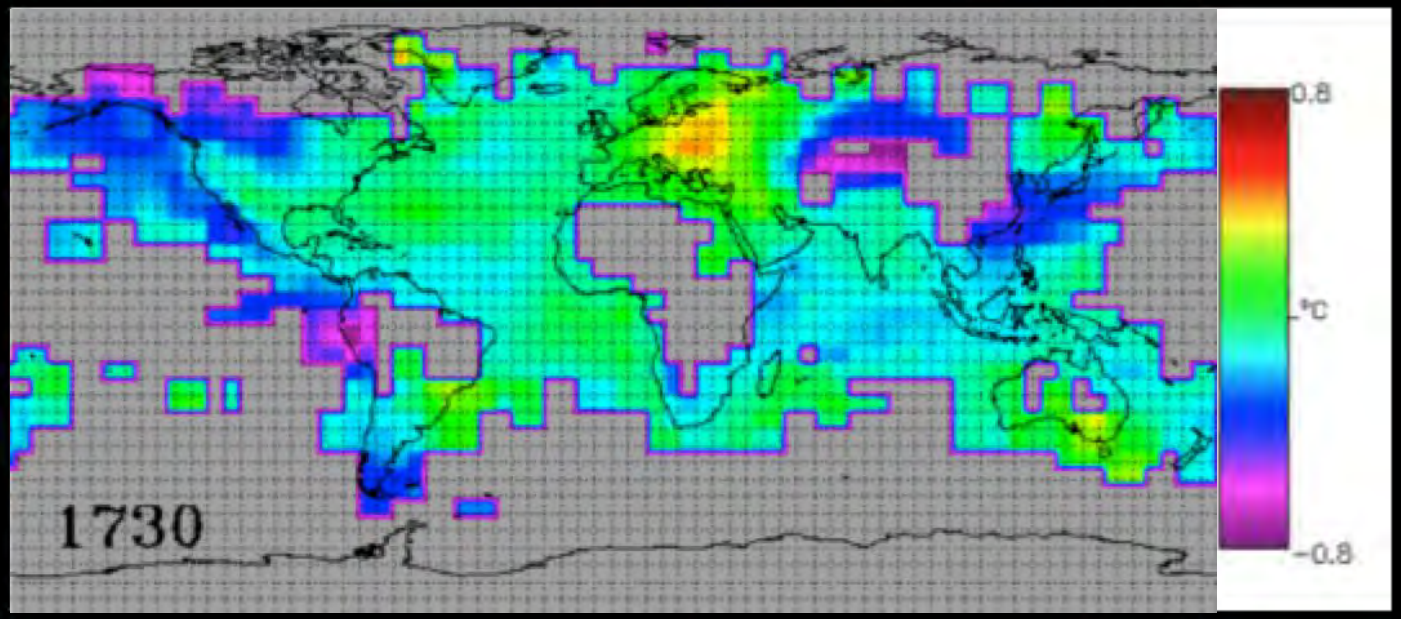
with contributions from:

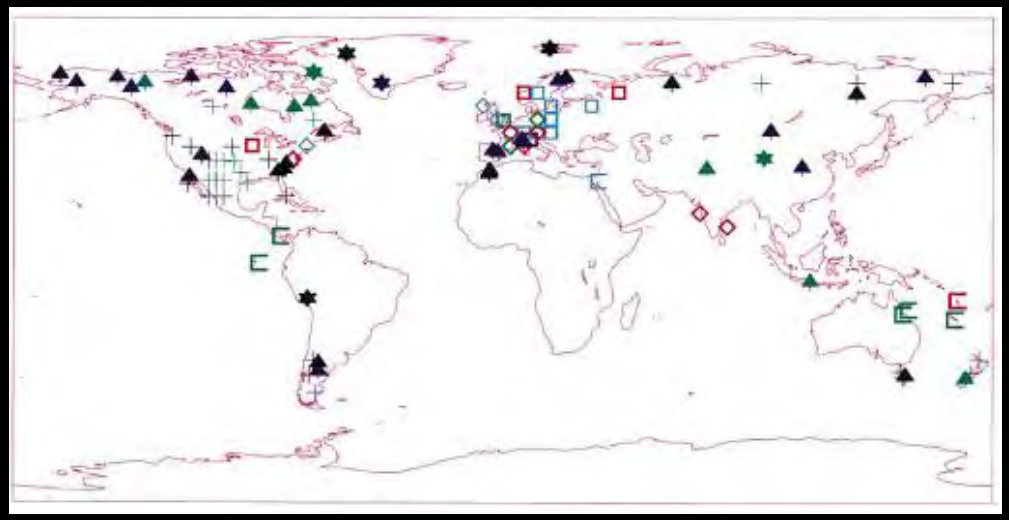
Caspar Ammann, Raymond Bradley, Elizabeth Crespin, Jeff Donnelly, Kerry Emanuel, Fangxing Fan, Jose Fuentes, Hugues Goosse, Malcolm Hughes, Klaus Keller, Andrew Kemp, Stefan Rahmstorf, Scott Rutherford, Drew Shindell, Gavin Schmidt, Ryan Sriver, Eric Steig, Byron Steinman, Axel Timmermann, Jonathan Woodruff, Zhihua Zhang (and others…)

Climate Central Webinar

Apr 26, 2016

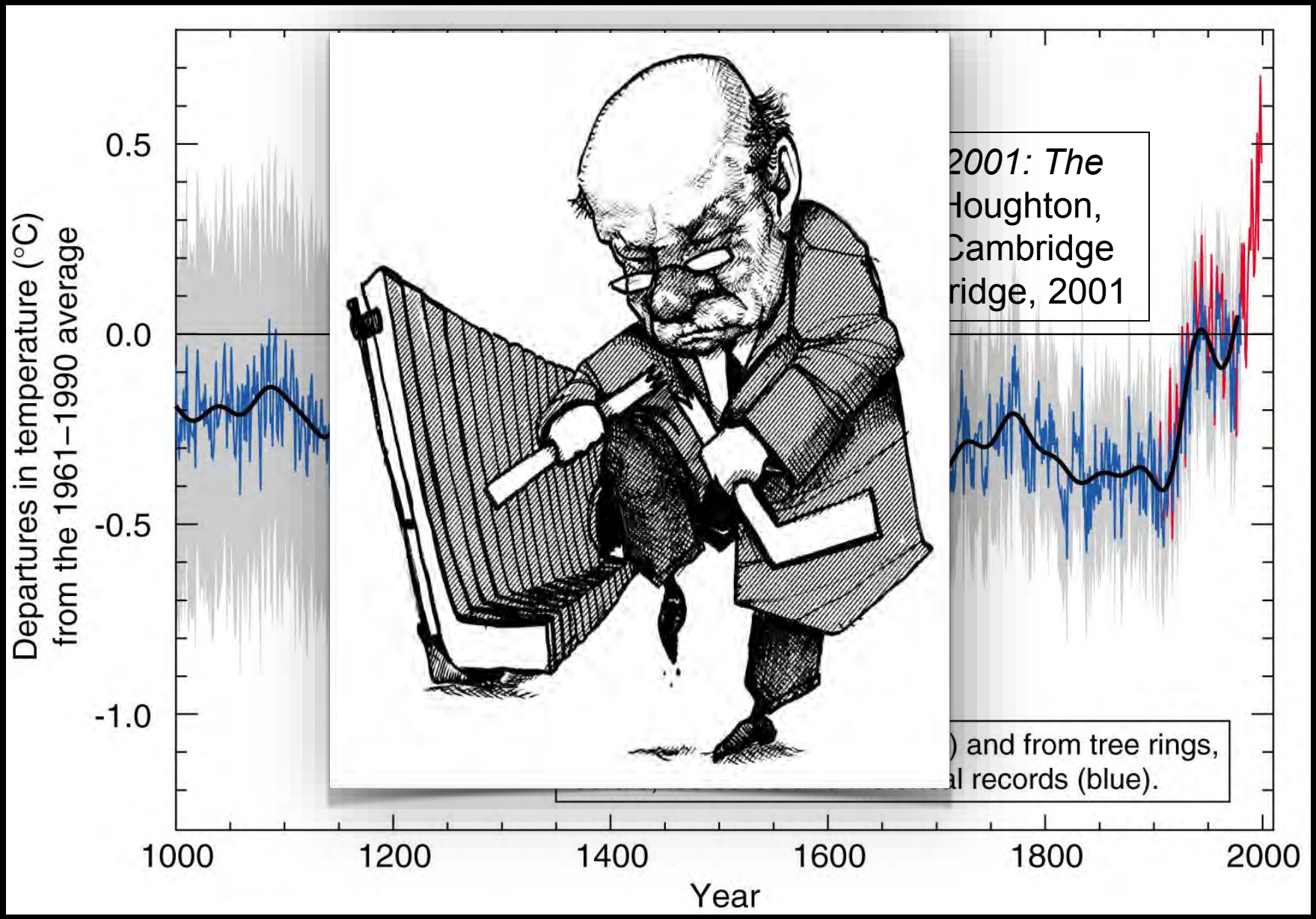
Reconstructions of Past Climate

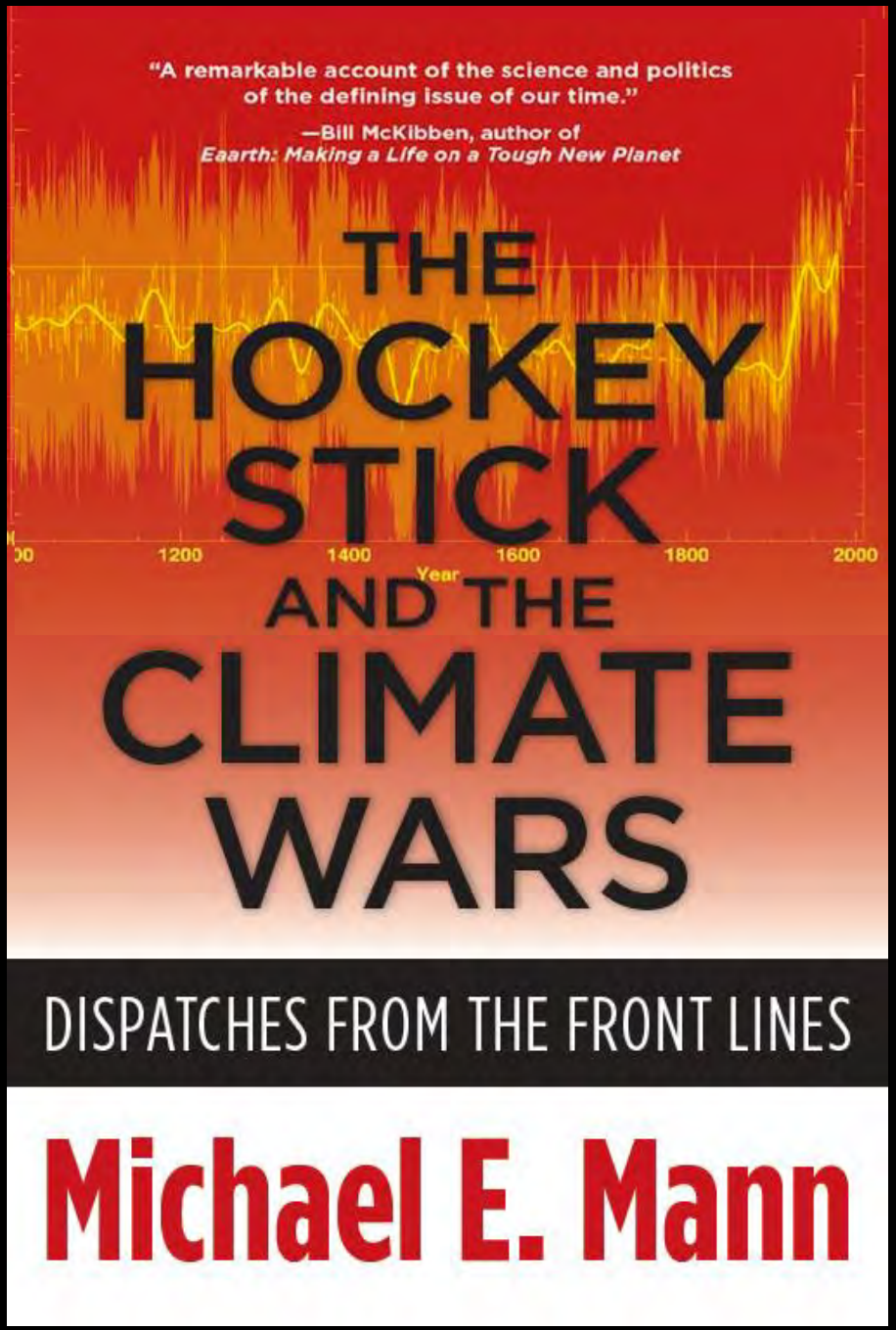




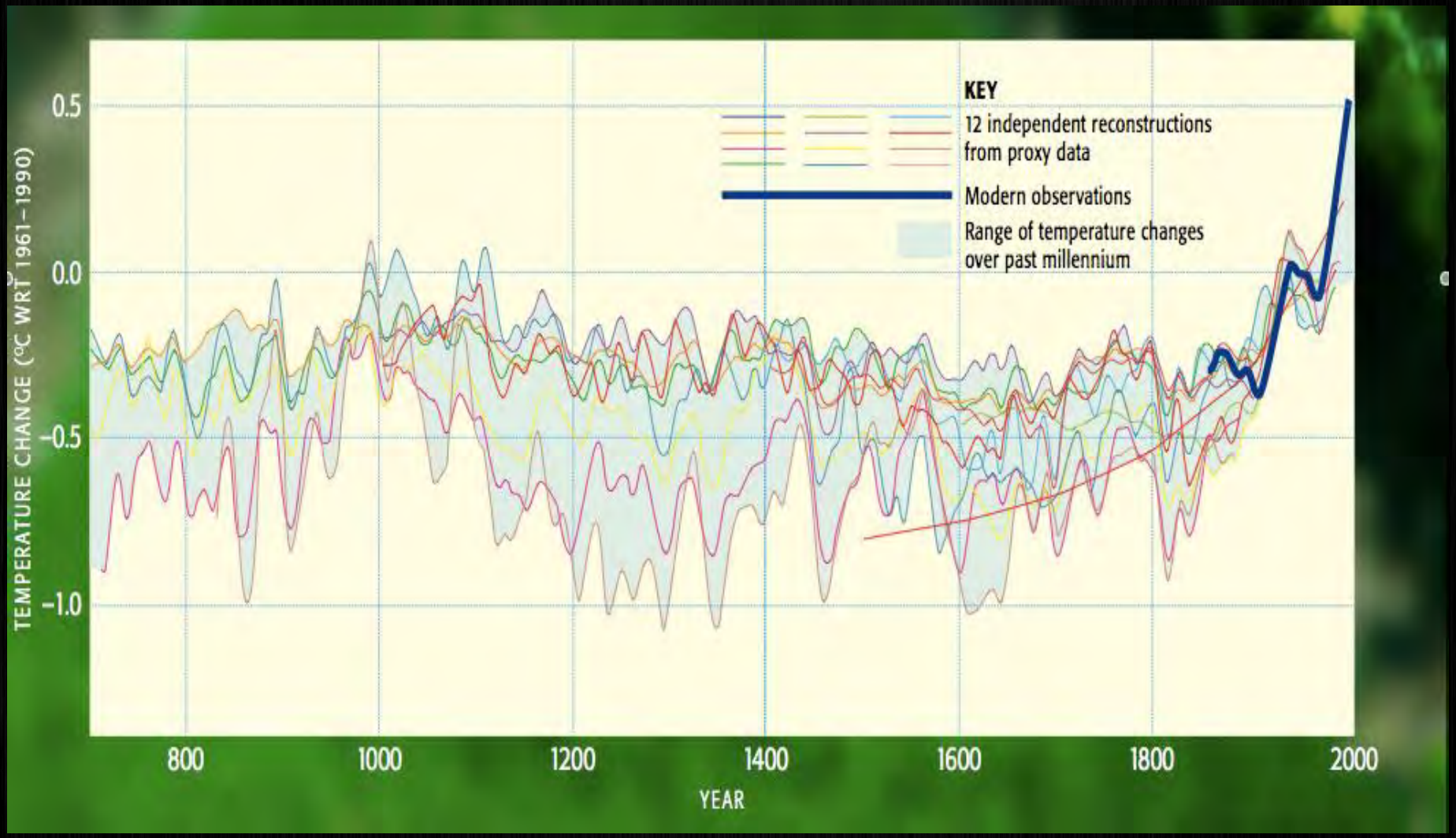
Climate "Proxy" Data…

Reconstructions of Past Climate




"A remarkable account of the science and politics of the defining issue of our time."
—Bill McKibben, author of
Eaarth: Making a Life on a Tough New Planet
THE HOCKEY STICK AND THE CLIMATE WARS
1200
1400
1600
1800
2000
Year
DISPATCHES FROM THE FRONT LINES
Michael E. Mann

Hockey *League*



Hockey *League*

The Telegraph

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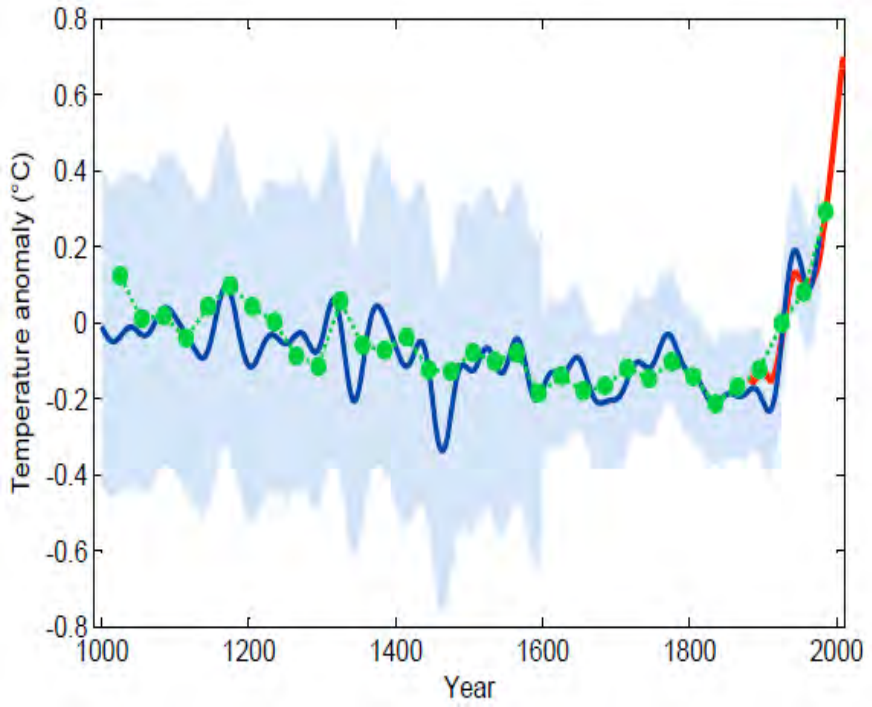
Geoffrey Lean

Geoffrey Lean is Britain's longest-serving environmental correspondent, having pioneered reporting on the subject almost 40 years ago.

Did the contentious global warming 'hockey stick' graph get it right after all?

By Geoffrey Lean Science Last updated: April 26th, 2013 Print this article



FINANCIAL TIMES

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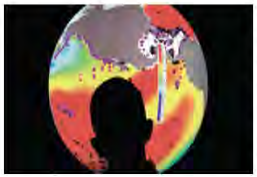
April 21, 2013 6:33 pm

Research backs global warming theory

By Pilita Clark, Environment Correspondent



A study of global temperatures over the past 2,000 years has lent fresh weight to the so-called hockey stick graph which suggests that humans caused global warming.

The graph, first published in the late 1990s by US palaeoclimatologist Professor Michael Mann and colleagues, shows temperatures stayed roughly flat for about 900 years, like the handle of the hockey stick laid down, before rising sharply upwards in the 20th century, like the blade, after the industrial revolution prompted a rise in fossil fuel emissions.

nature geoscience

PROGRESS ARTICLE

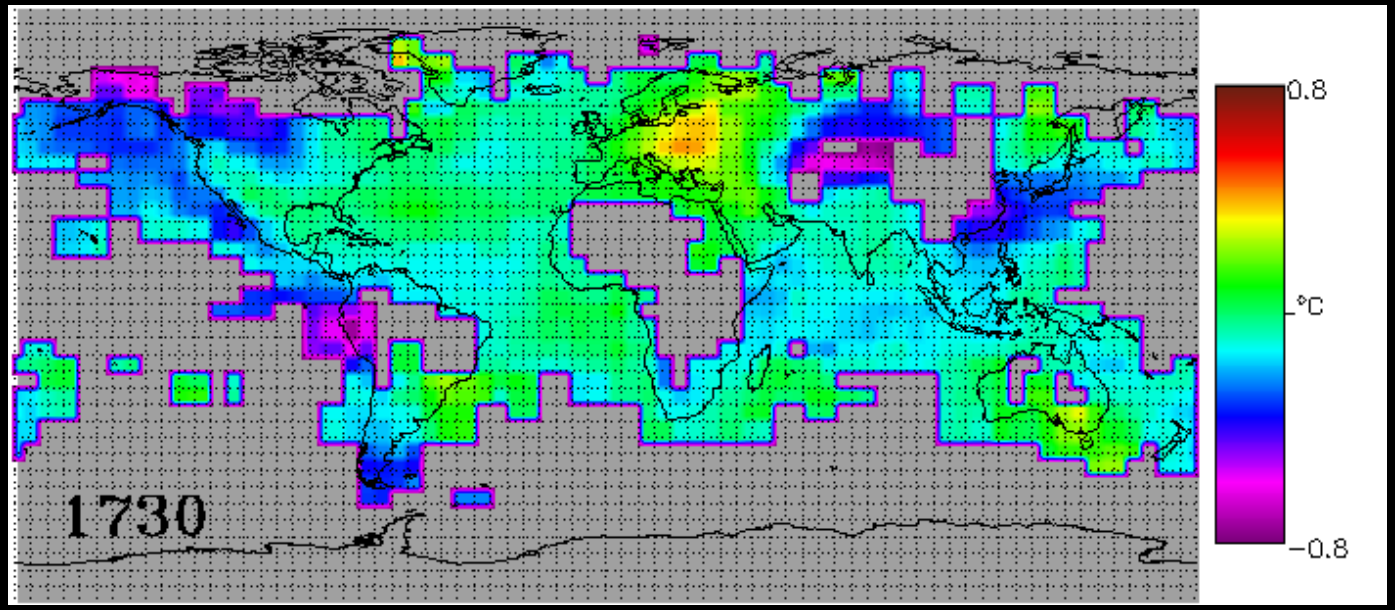
PUBLISHED ONLINE: XX MAY 2013 | DOI: 10.1038/NGEO1797

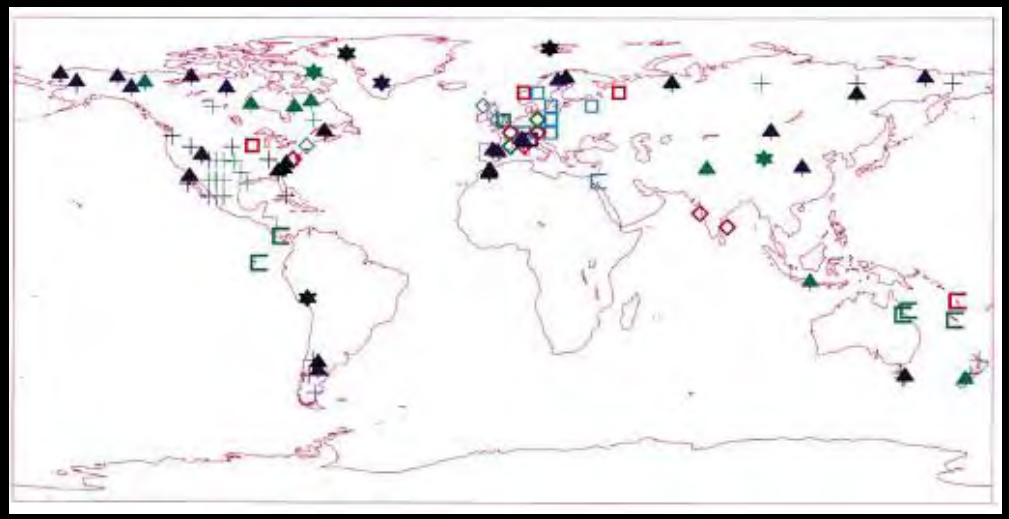
Continental-scale temperature variability during the past two millennia

PAGES 2k Network*

Past global climate changes had strong regional expression. To elucidate their spatiotemporal pattern, we reconstructed past temperatures for seven continental-scale regions during the past one to two millennia. The most coherent feature in nearly all of the regional temperature reconstructions is a long-term cooling trend, which ended late in the nineteenth century. At multi-decadal to centennial scales, temperature variability shows distinctly different regional patterns, with more similarity within each hemisphere than between them. There were no globally synchronous multi-decadal warm or cold intervals that define a worldwide Medieval Warm Period or Little Ice Age, but all reconstructions show generally cold conditions between AD 1580 and 1880, punctuated in some regions by warm decades during the eighteenth century. The transition to these colder conditions occurred earlier in the Arctic, Europe and Asia than in North America or the Southern Hemisphere regions. Recent warming reversed the long-term cooling; during the past 30 years (AD 1971–2000), the area-weighted average reconstructed temperature was higher than any other time in nearly 1,400 years.

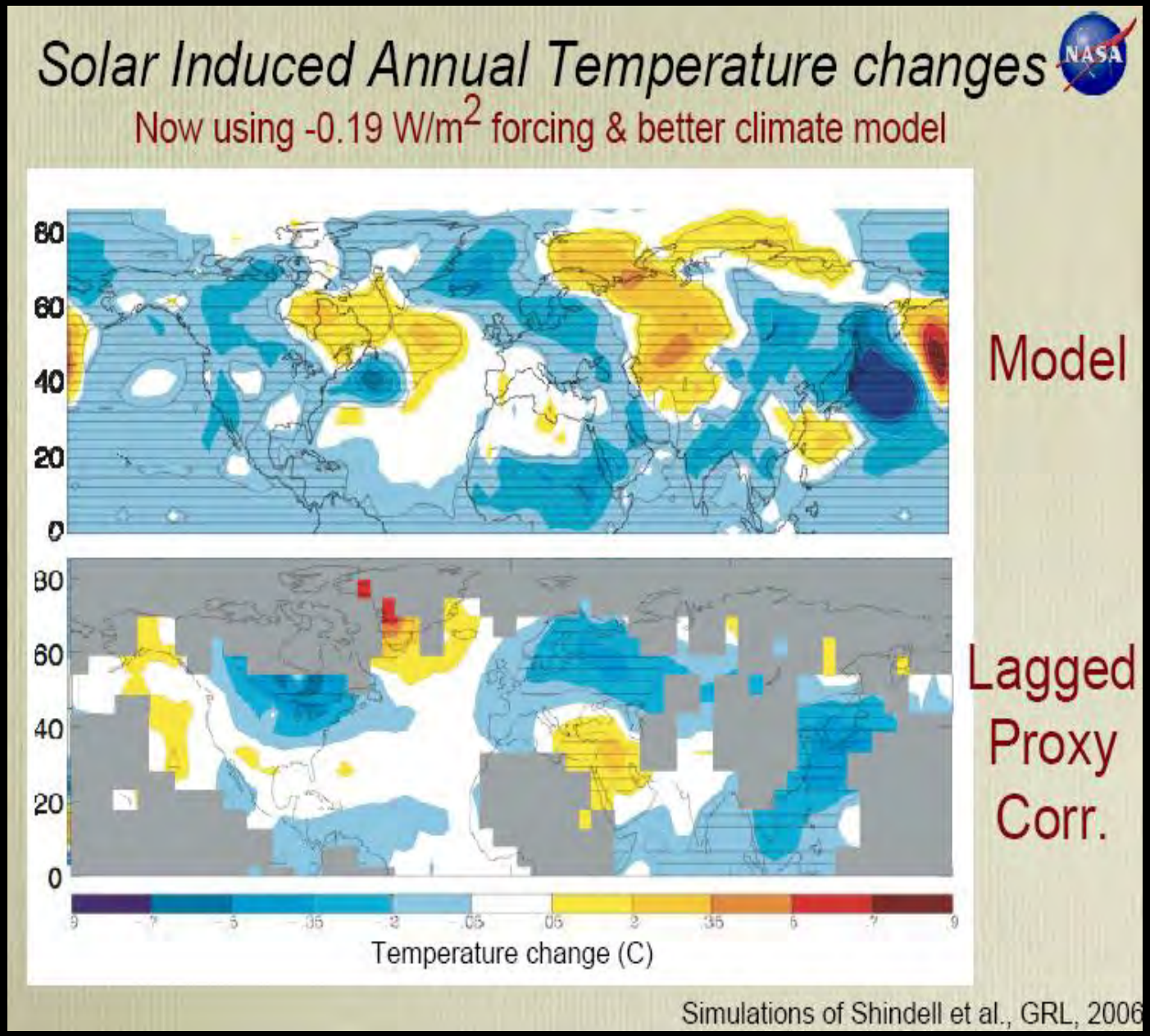
Reconstructions of Past Climate

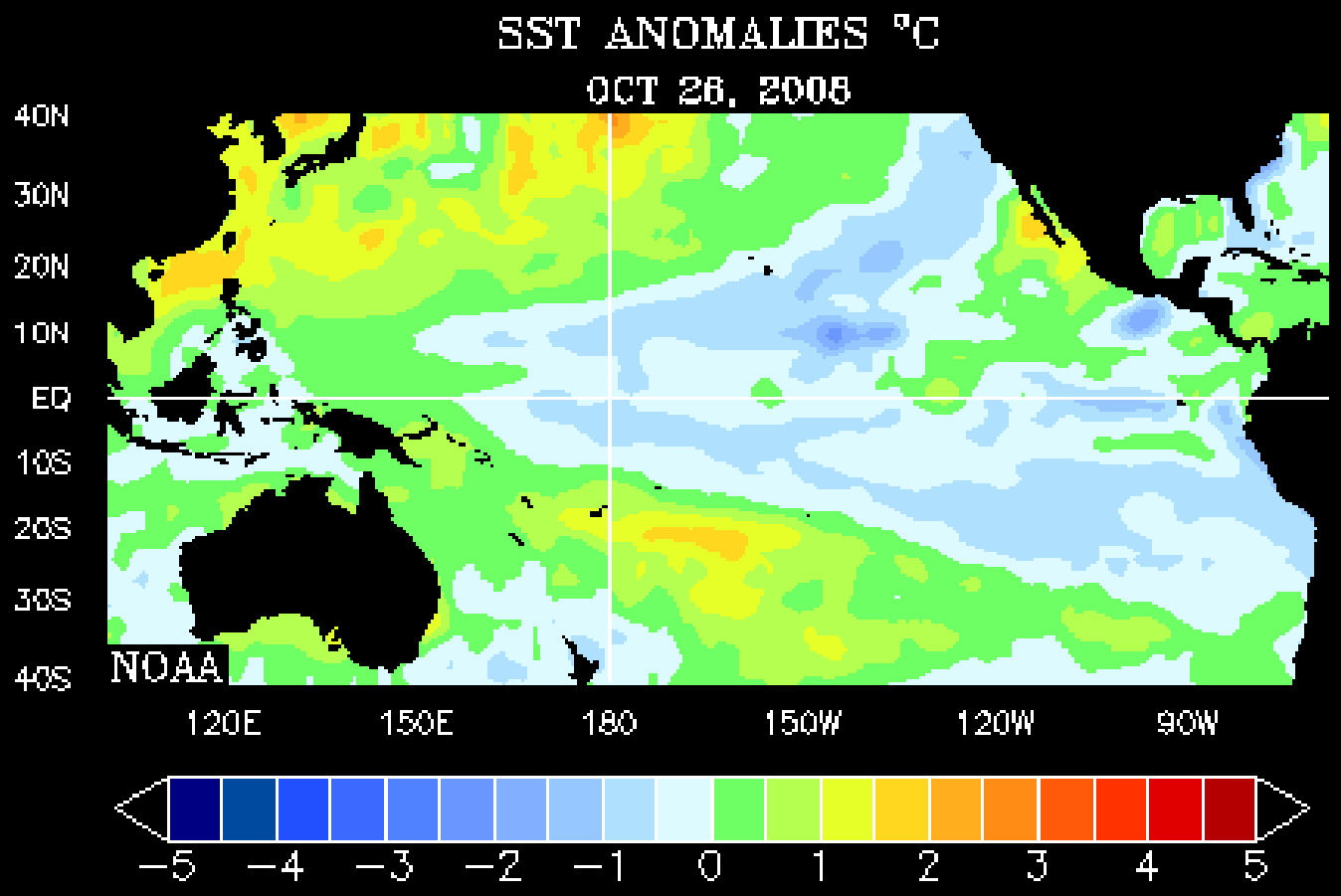




Climate "Proxy" Data…

European Winter Cooling During the *Little Ice Age*




SST ANOMALIES °C
OCT 26, 2008
40N
30N
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10N
EQ
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20S
30S
40S
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120E
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90W
−5
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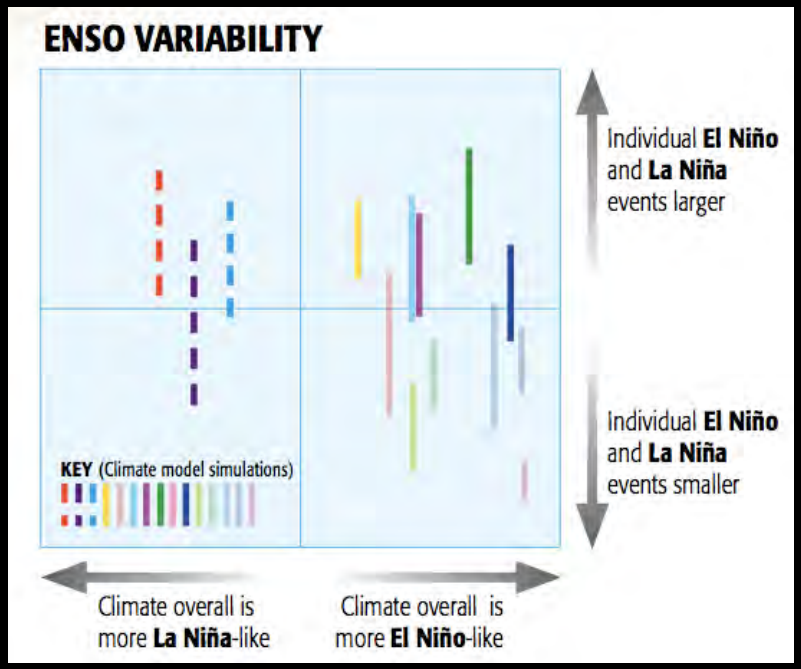
El Nino

Sources of Uncertainty

Influences Atlantic hurricanes, drought in desert southwest, etc,

El Nino



How did Natural Forcings Influence influence ENSO and the Tropical Pacific During the Past Millennium?

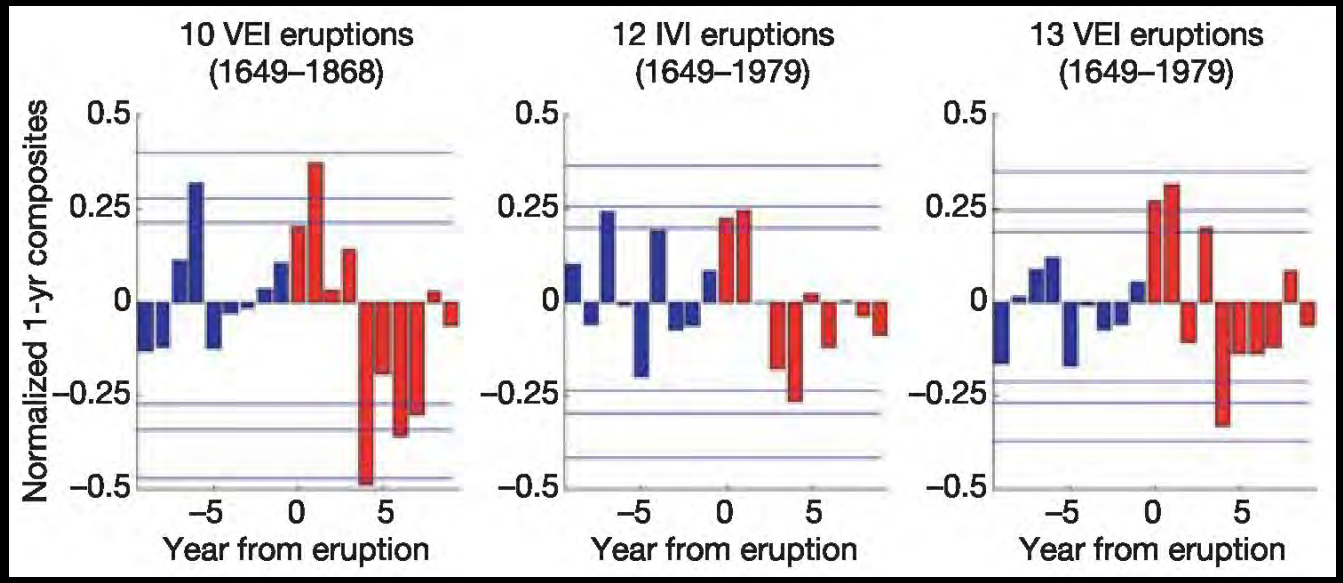
Proxy evidence for an El Niño-like response to volcanic forcing

J. Brad Adams[1], Michael E. Mann[1] & Caspar M. Ammann[2]

[1]*Department of Environmental Sciences, University of Virginia, Clark Hall, Charlottesville, Virginia 22903, USA*
[2]*Climate Global Dynamics Division, National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder, Colorado 80307-3000, USA*

NATURE | VOL 426 | 20 NOVEMBER 2003 | www.nature.com/nature

Brad Adams



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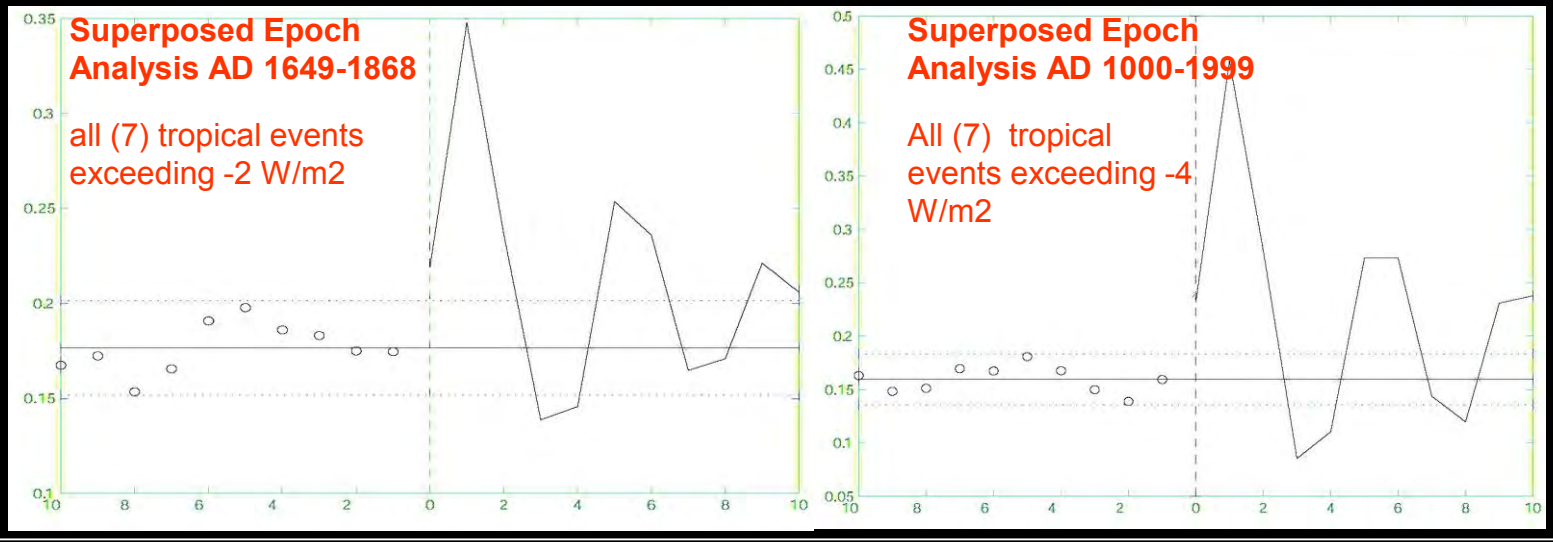
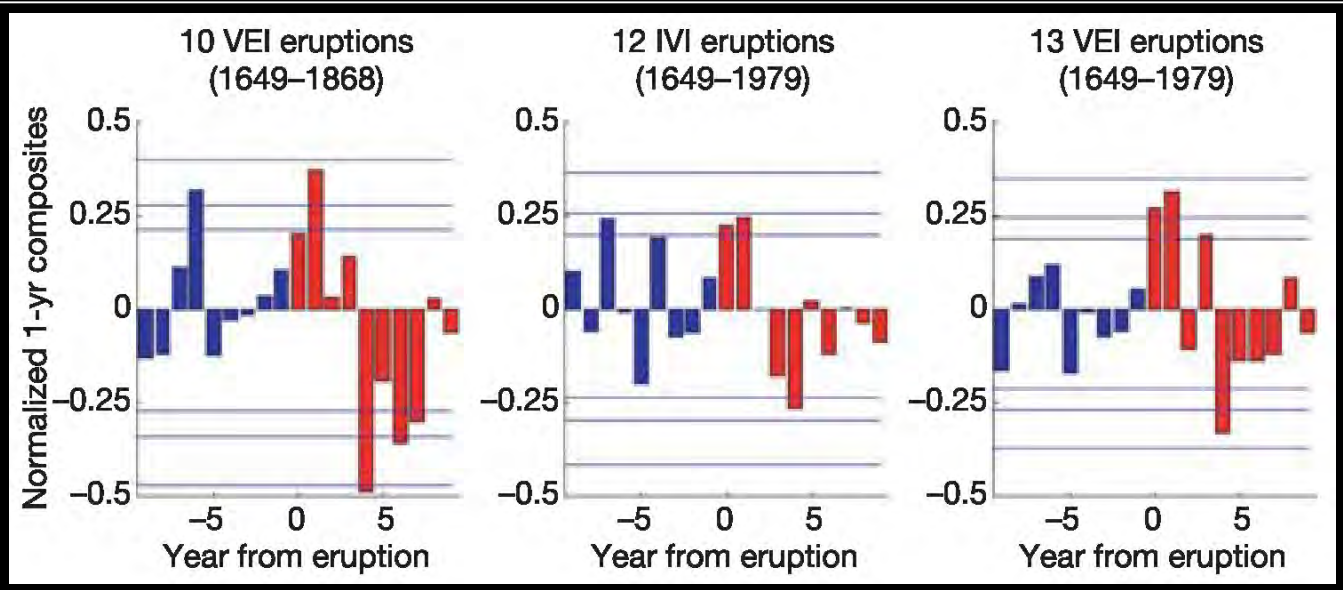


Mann, M.E., Cane, M.A., Zebiak, S.E., Clement, A., Volcanic and Solar Forcing of The Tropical Pacific Over the Past 1000 Years, *Journal of Climate*, 18, 447-456, 2005.



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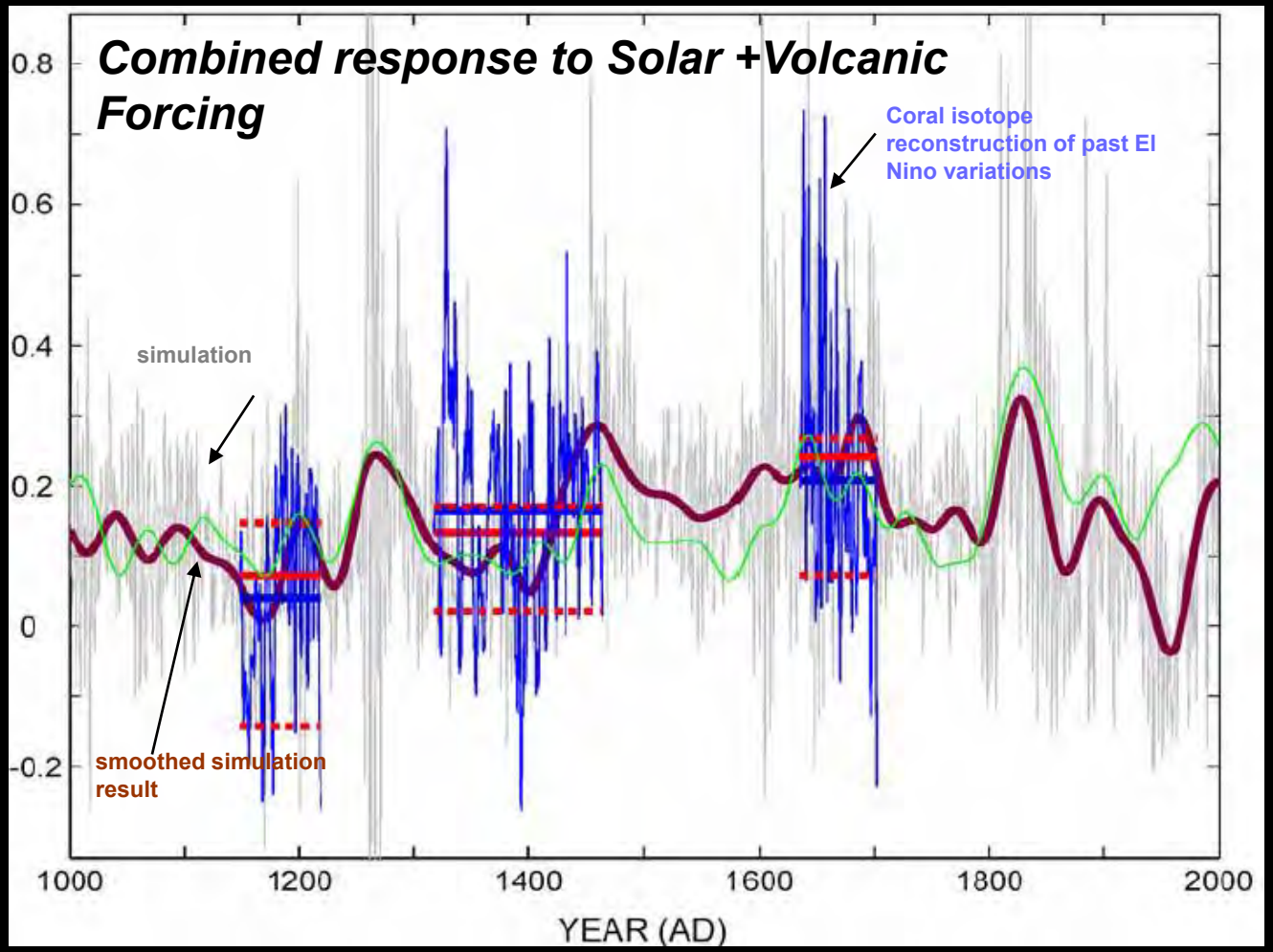
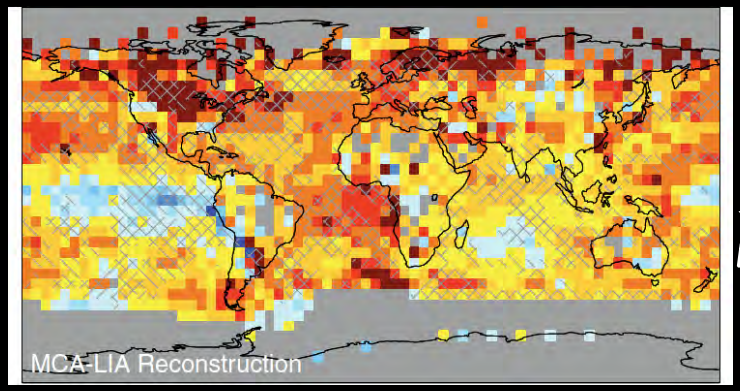
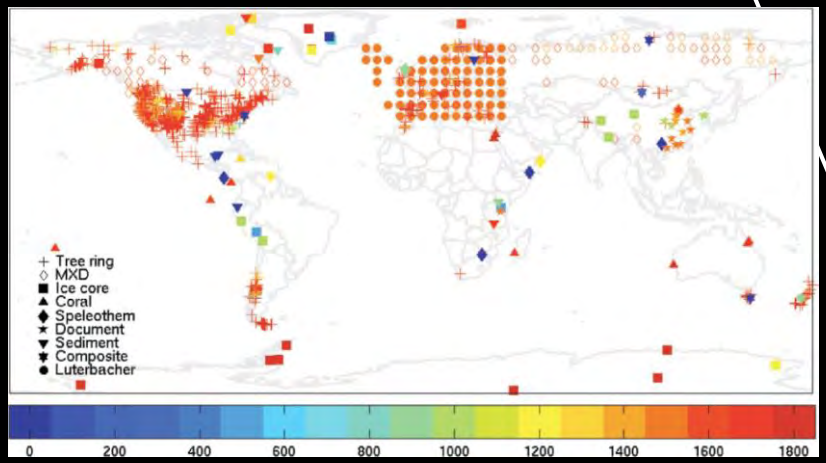
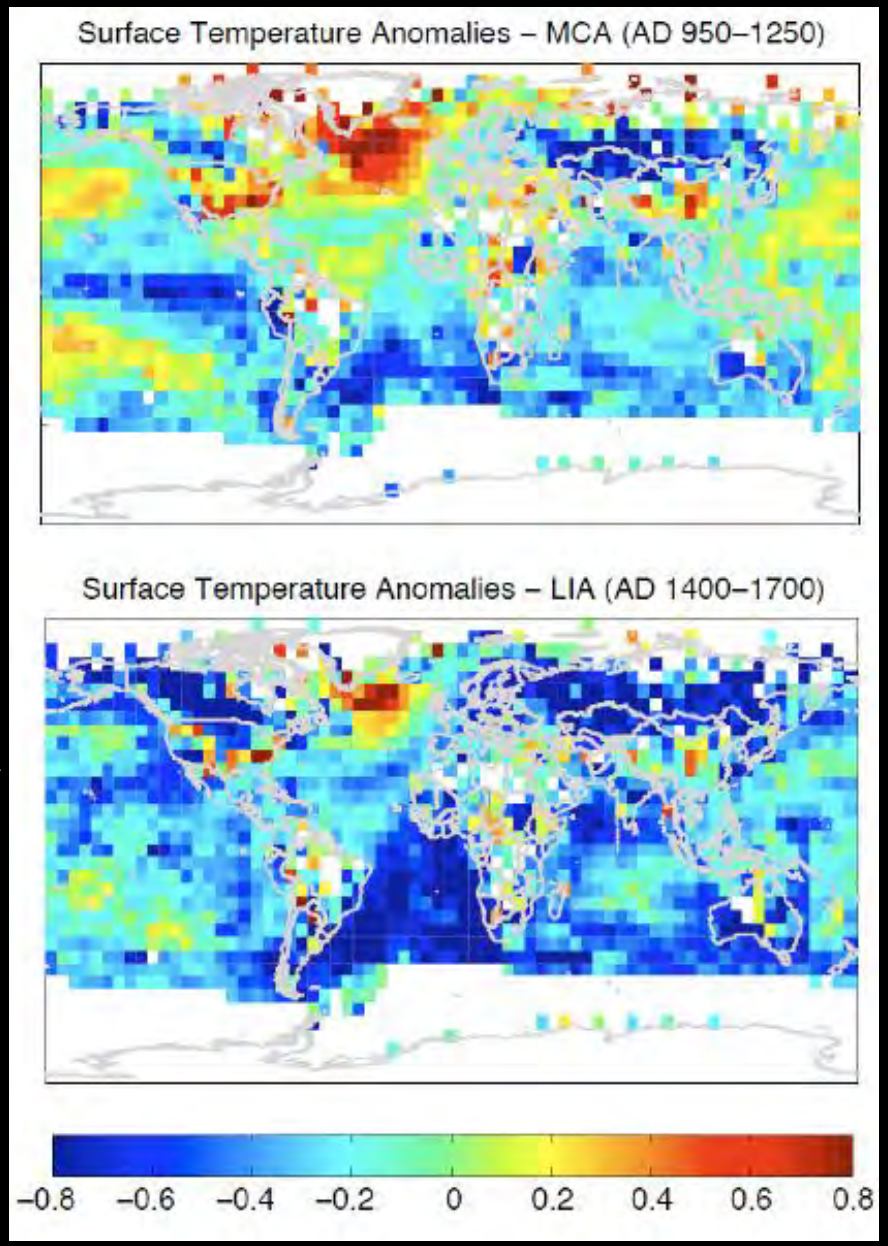


Surface Temperature Reconstructions





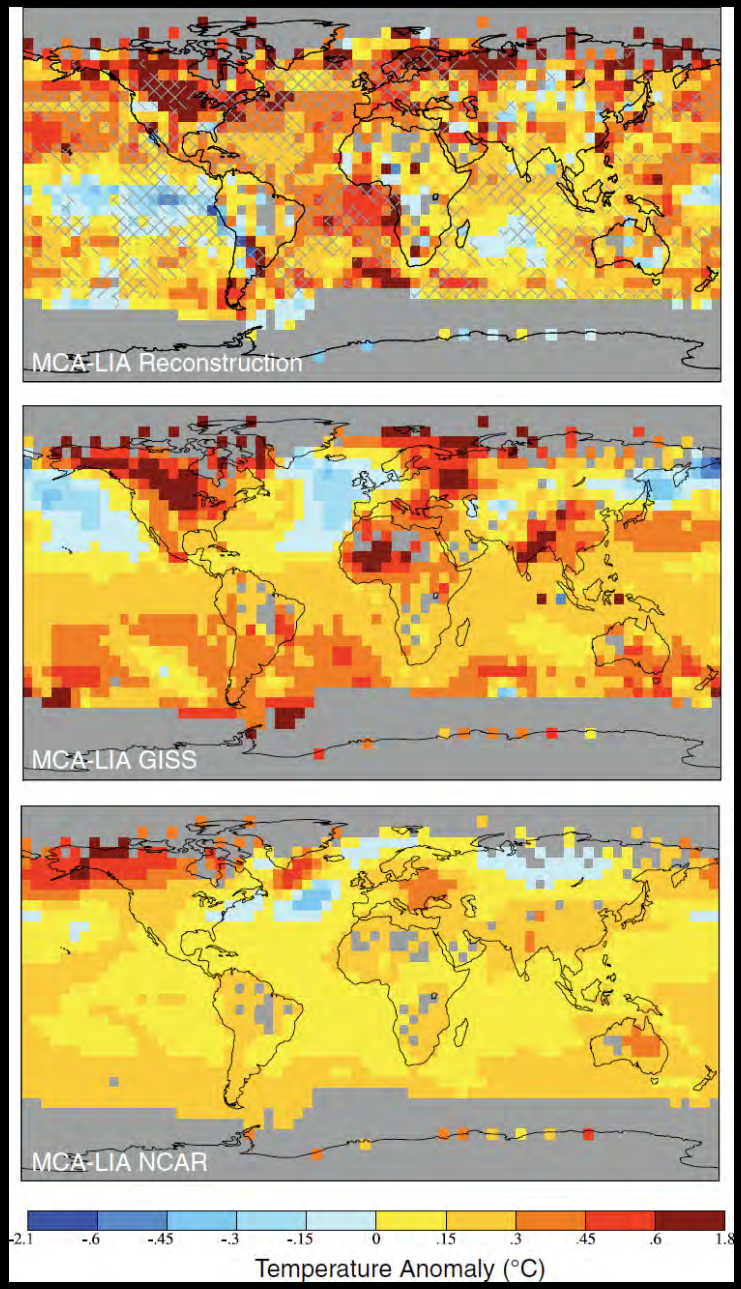


Science (Nov 27, 2009) REPORT

Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly

Michael E. Mann,[1*] Zhihua Zhang,[1] Scott Rutherford,[2] Raymond S. Bradley,[3] Malcolm K. Hughes,[4] Drew Shindell,[5] Caspar Ammann,[6] Greg Faluvegi,[5] Fenbiao Ni[4]

Model-Data Comparisons



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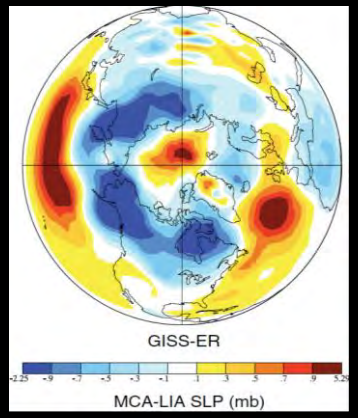
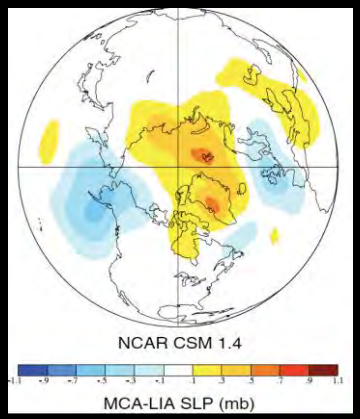
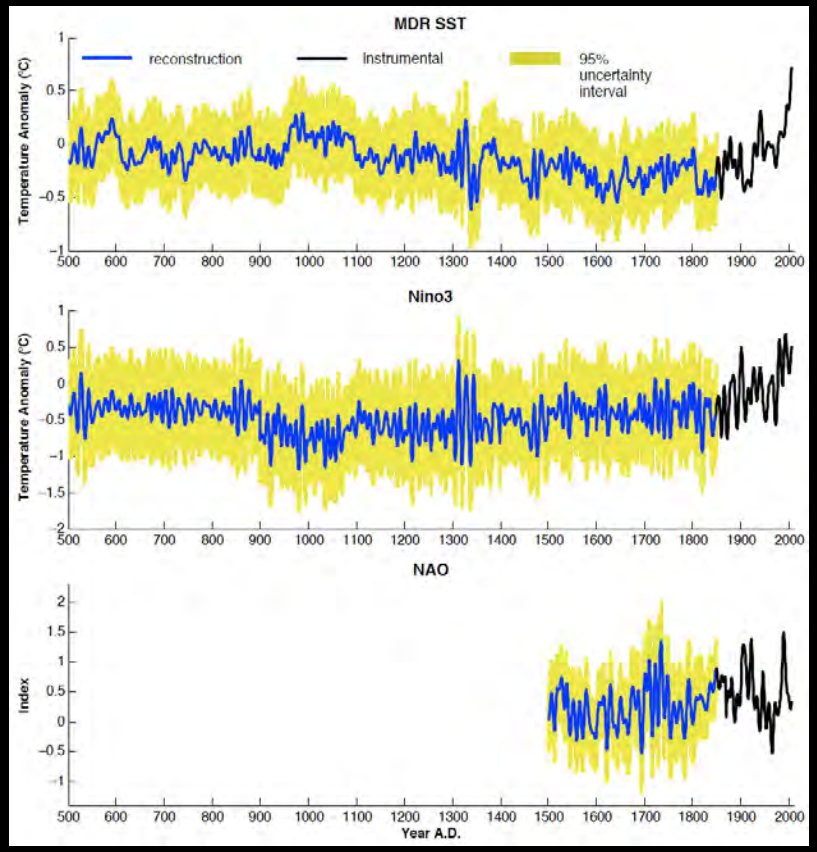
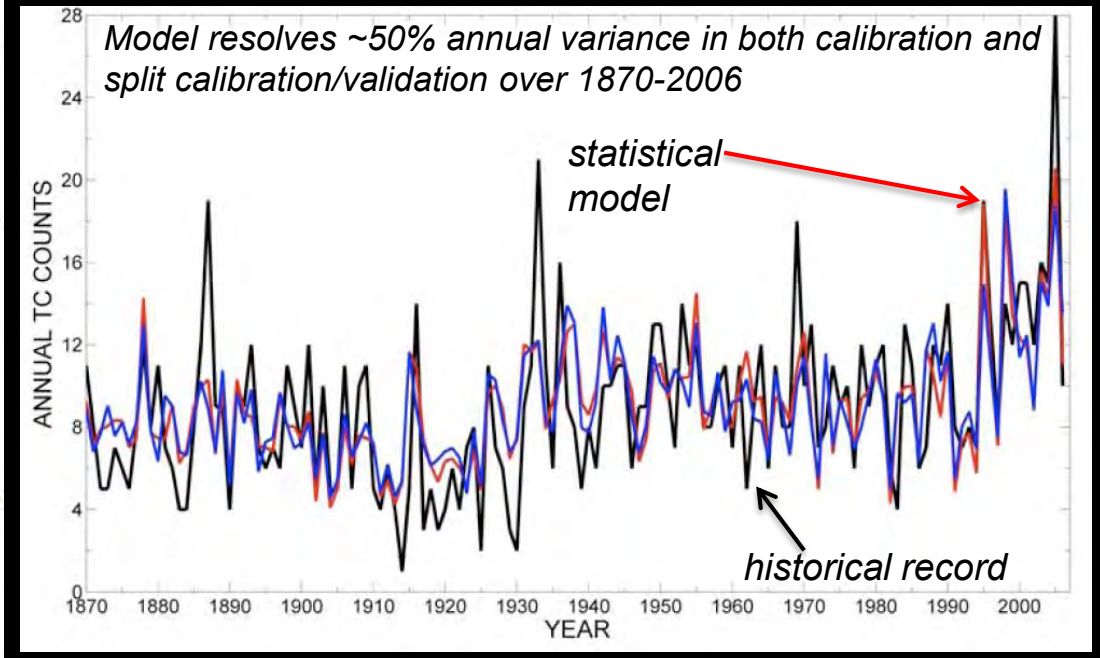


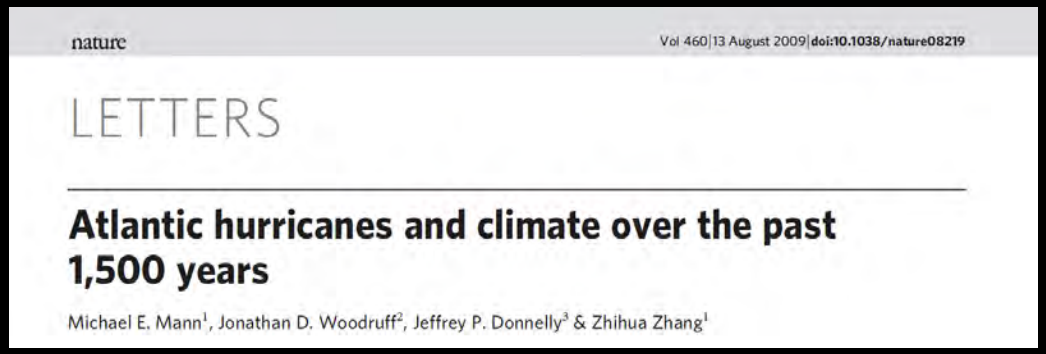


Positive Phase of Northern Annual Mode

Applications: Tropical Cyclones





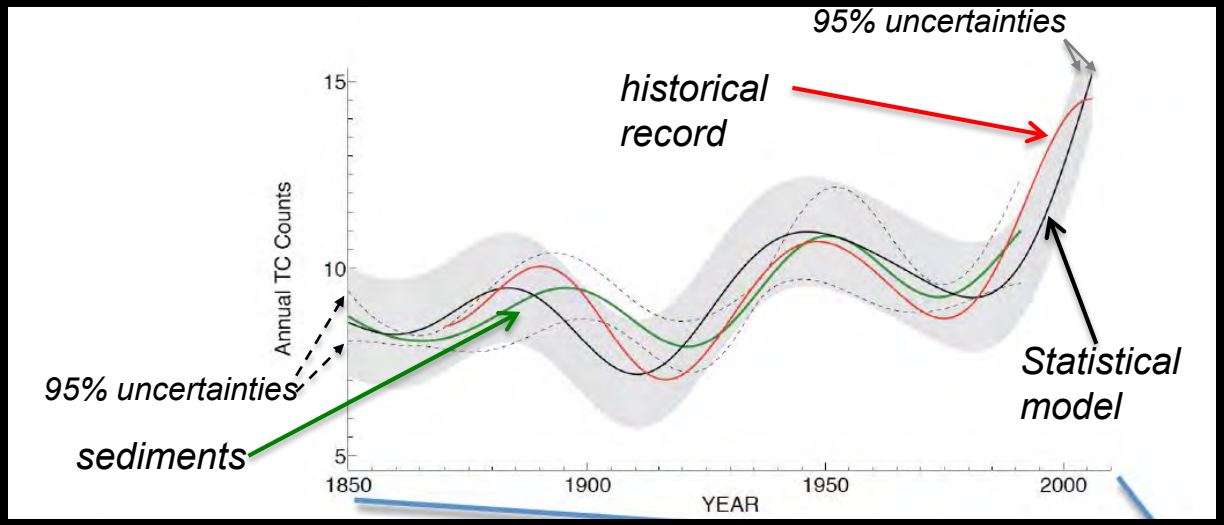

nature Vol 460|13 August 2009|doi:10.1038/nature08219

LETTERS

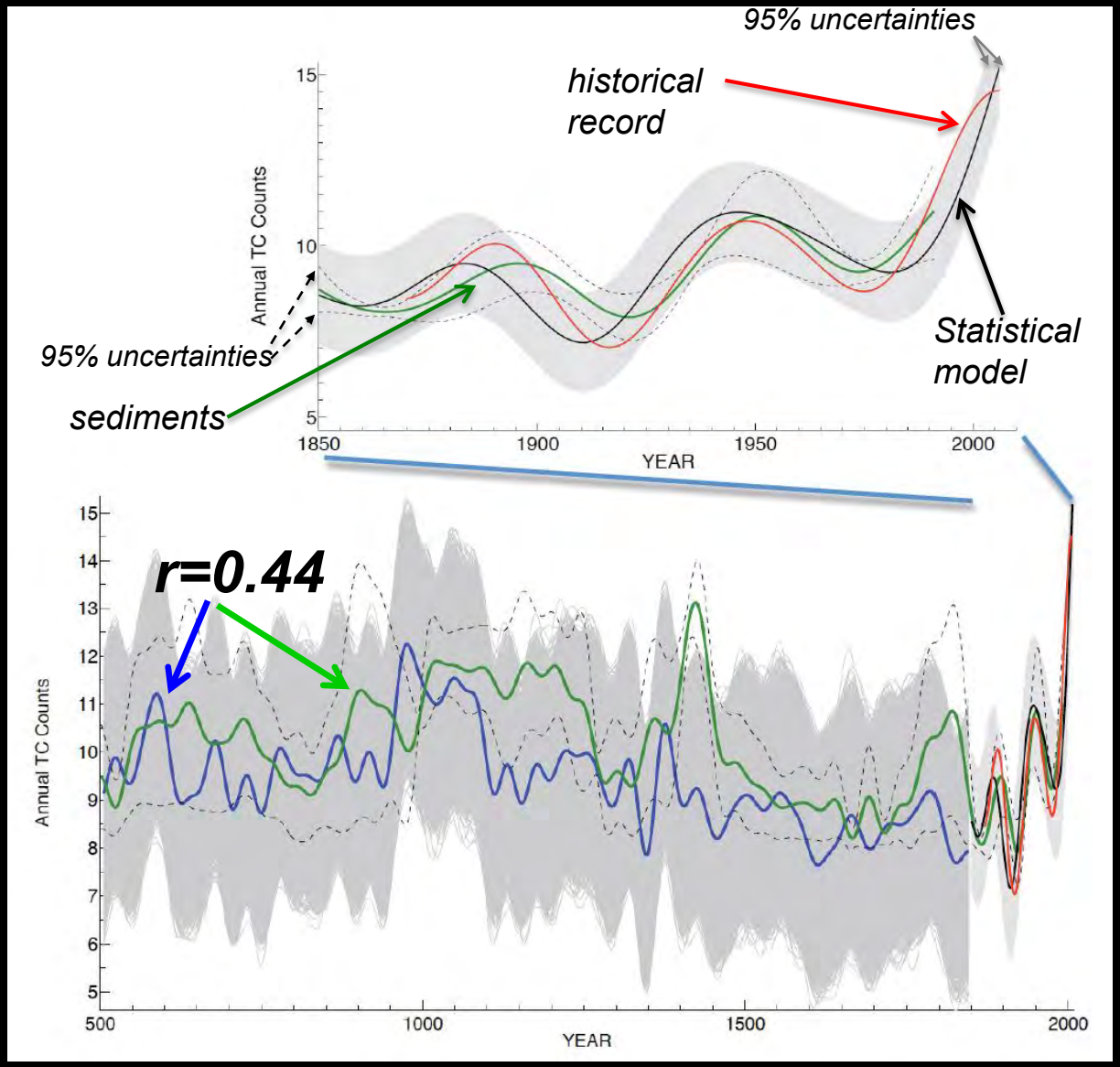
Atlantic hurricanes and climate over the past 1,500 years

Michael E. Mann[1], Jonathan D. Woodruff[2], Jeffrey P. Donnelly[3] & Zhihua Zhang[1]

Applications: Tropical Cyclones

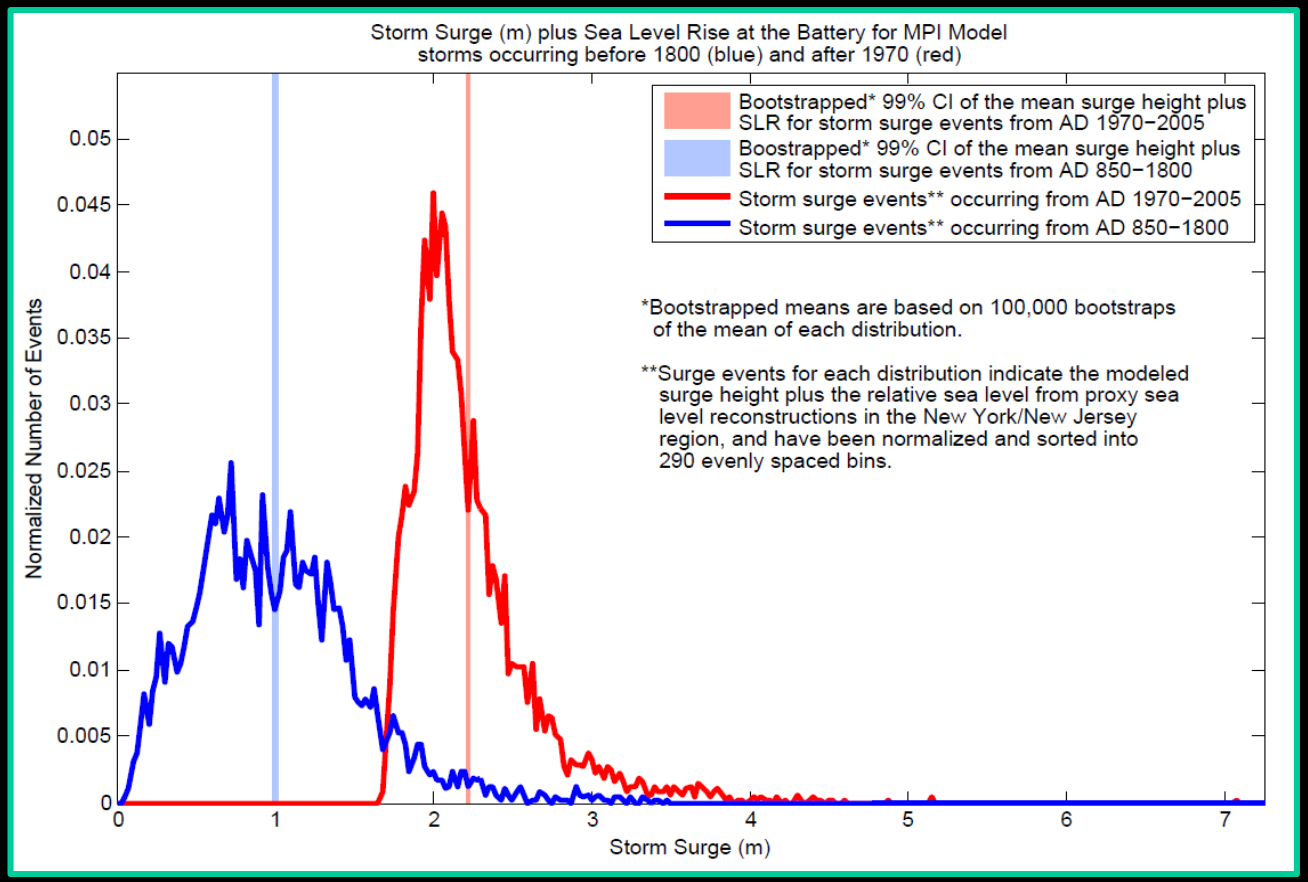


Applications: Tropical Cyclones



An Analysis of North Atlantic Tropical Cyclones and Their Impacts on Coastal Inundation in New York and New Jersey during the Last Millennium

Andra J. Reed, Michael E. Mann,
Kerry A. Emanuel, Ning Lin,
Benjamin P. Horton, and Andrew C. Kemp



CLIMATE CHANGE

False Hope

The rate of global temperature rise may have hit a plateau, but a climate crisis still looms in the near future

By Michael E. Mann

"Temperatures have been flat for 15 years—nobody can properly explain it," the *Wall Street Journal* says. "Global warming 'pause' may last for 20 more years, and Arctic sea ice has already started to recover," the *Daily Mail* says. Such reassuring claims about climate abound in the popular media, but they are misleading at best. Global warming continues unabated, and it remains an urgent problem.

The misunderstanding stems from data showing that during the past decade there was a slowing in the rate at which the earth's average surface temperature had been increasing. The event is commonly referred to as "the pause," but that is a misnomer: temperatures still rose, just not as fast as during the prior decade. The important question is, What does the short-term slowdown portend for how the world may warm in the future?

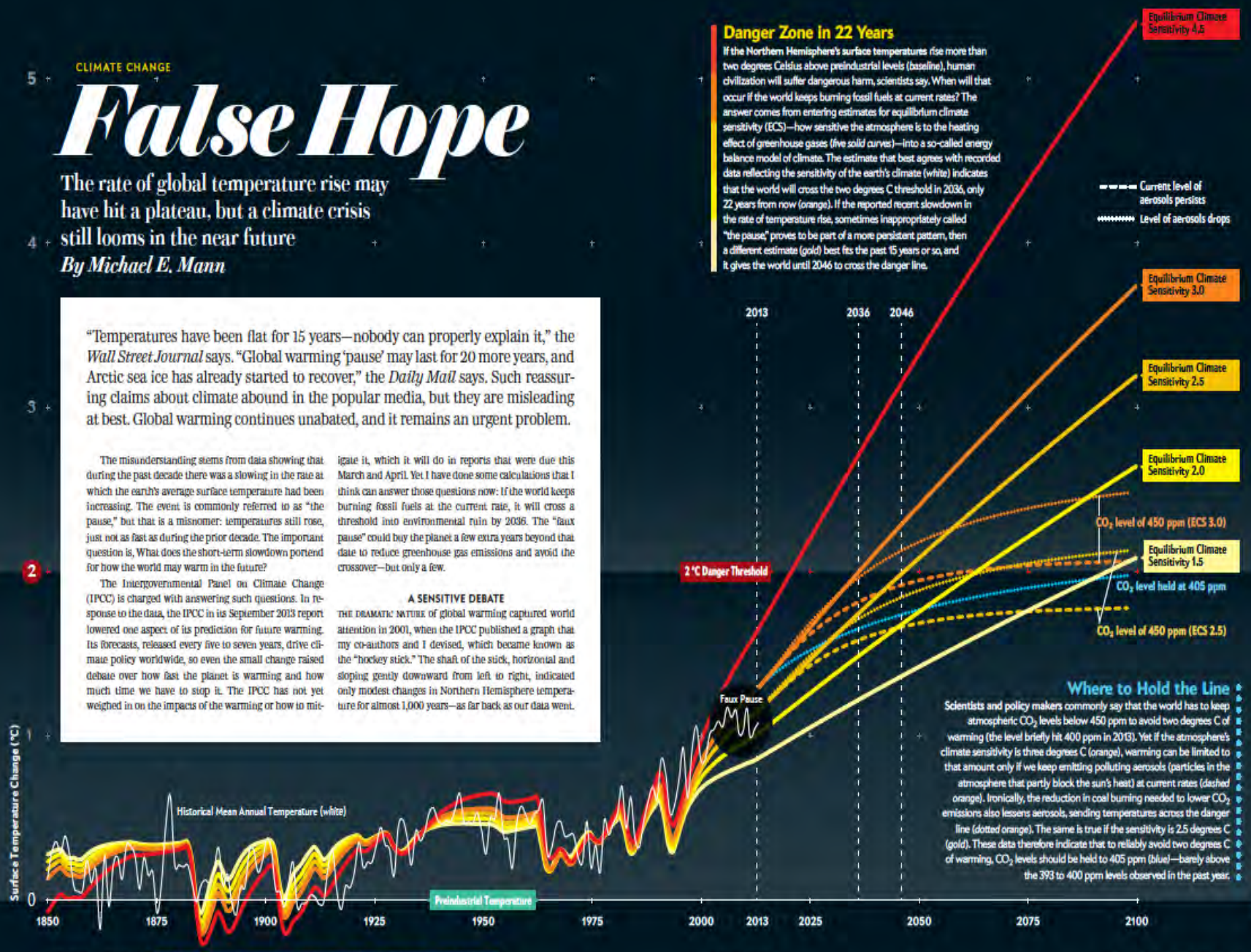
The Intergovernmental Panel on Climate Change (IPCC) is charged with answering such questions. In response to the data, the IPCC in its September 2013 report lowered one aspect of its prediction for future warming. Its forecasts, released every five to seven years, drive climate policy worldwide, so even the small change raised debate over how fast the planet is warming and how much time we have to stop it. The IPCC has not yet weighed in on the impacts of the warming or how to mitigate it, which it will do in reports that were due this March and April. Yet I have done some calculations that I think can answer those questions now: If the world keeps burning fossil fuels at the current rate, it will cross a threshold into environmental ruin by 2036. The "faux pause" could buy the planet a few extra years beyond that date to reduce greenhouse gas emissions and avoid the crossover—but only a few.

A SENSITIVE DEBATE

THE DRAMATIC NATURE of global warming captured world attention in 2001, when the IPCC published a graph that my co-authors and I devised, which became known as the "hockey stick." The shaft of the stick, horizontal and sloping gently downward from left to right, indicated only modest changes in Northern Hemisphere temperature for almost 1,000 years—as far back as our data went.

Danger Zone in 22 Years

If the Northern Hemisphere's surface temperatures rise more than two degrees Celsius above preindustrial levels (*baseline*), human civilization will suffer dangerous harm, scientists say. When will that occur if the world keeps burning fossil fuels at current rates? The answer comes from entering estimates for equilibrium climate sensitivity (ECS)—how sensitive the atmosphere is to the heating effect of greenhouse gases (*five solid curves*)—into a so-called energy balance model of climate. The estimate that best agrees with recorded data reflecting the sensitivity of the earth's climate (*white*) indicates that the world will cross the two degrees C threshold in 2036, only 22 years from now (*orange*). If the reported recent slowdown in the rate of temperature rise, sometimes inappropriately called "the pause," proves to be part of a more persistent pattern, then a different estimate (*gold*) best fits the past 15 years or so, and it gives the world until 2046 to cross the danger line.



Where to Hold the Line

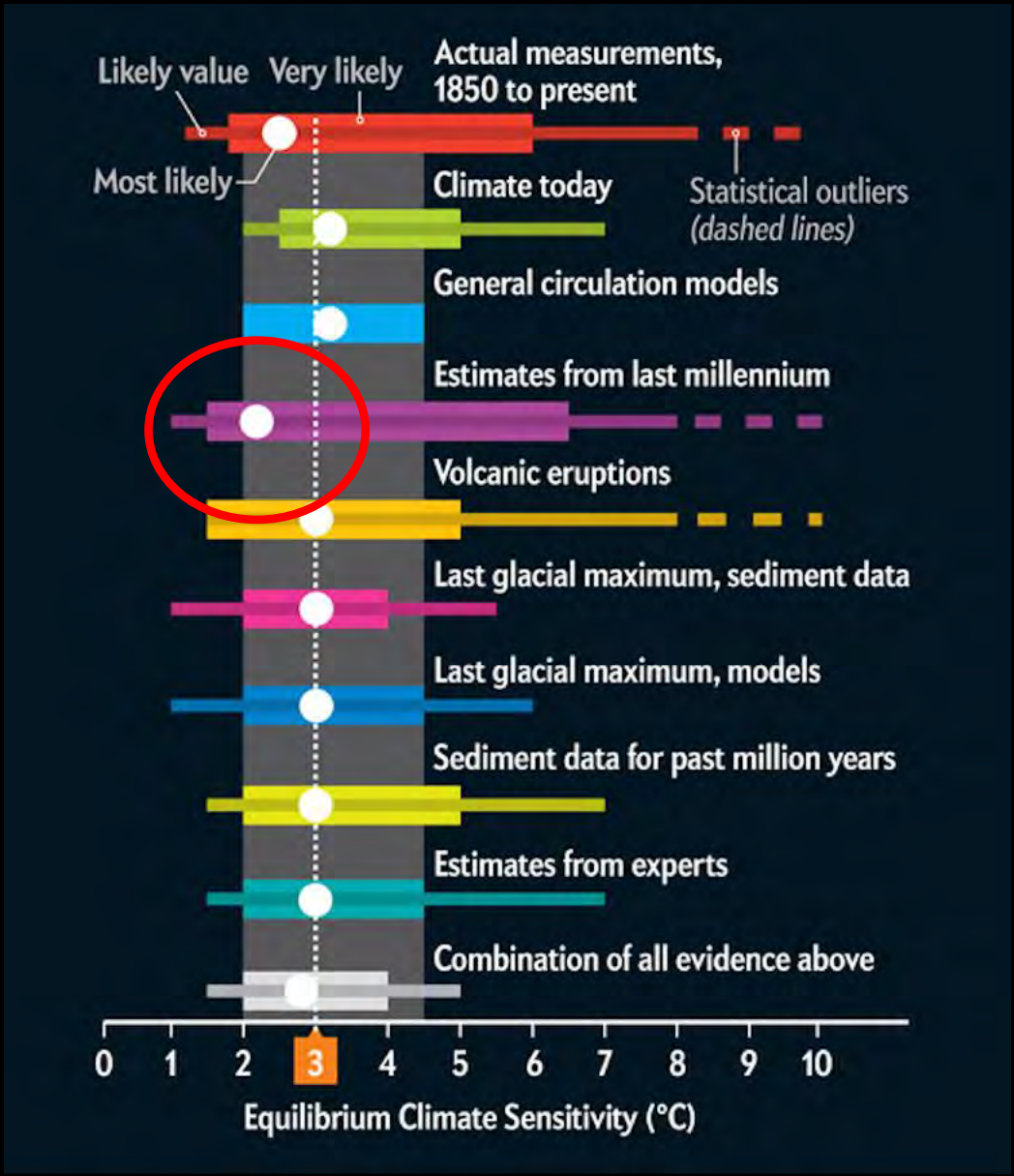
Scientists and policy makers commonly say that the world has to keep atmospheric CO_2 levels below 450 ppm to avoid two degrees C of warming (the level briefly hit 400 ppm in 2013). Yet if the atmosphere's climate sensitivity is three degrees C (*orange*), warming can be limited to that amount only if we keep emitting polluting aerosols (particles in the atmosphere that partly block the sun's heat) at current rates (*dashed orange*). Ironically, the reduction in coal burning needed to lower CO_2 emissions also lessens aerosols, sending temperatures across the danger line (*dotted orange*). The same is true if the sensitivity is 2.5 degrees C (*gold*). These data therefore indicate that to reliably avoid two degrees C of warming, CO_2 levels should be held to 405 ppm (*blue*)—barely above the 393 to 400 ppm levels observed in the past year.

SOURCE: MICHAEL E. MANN

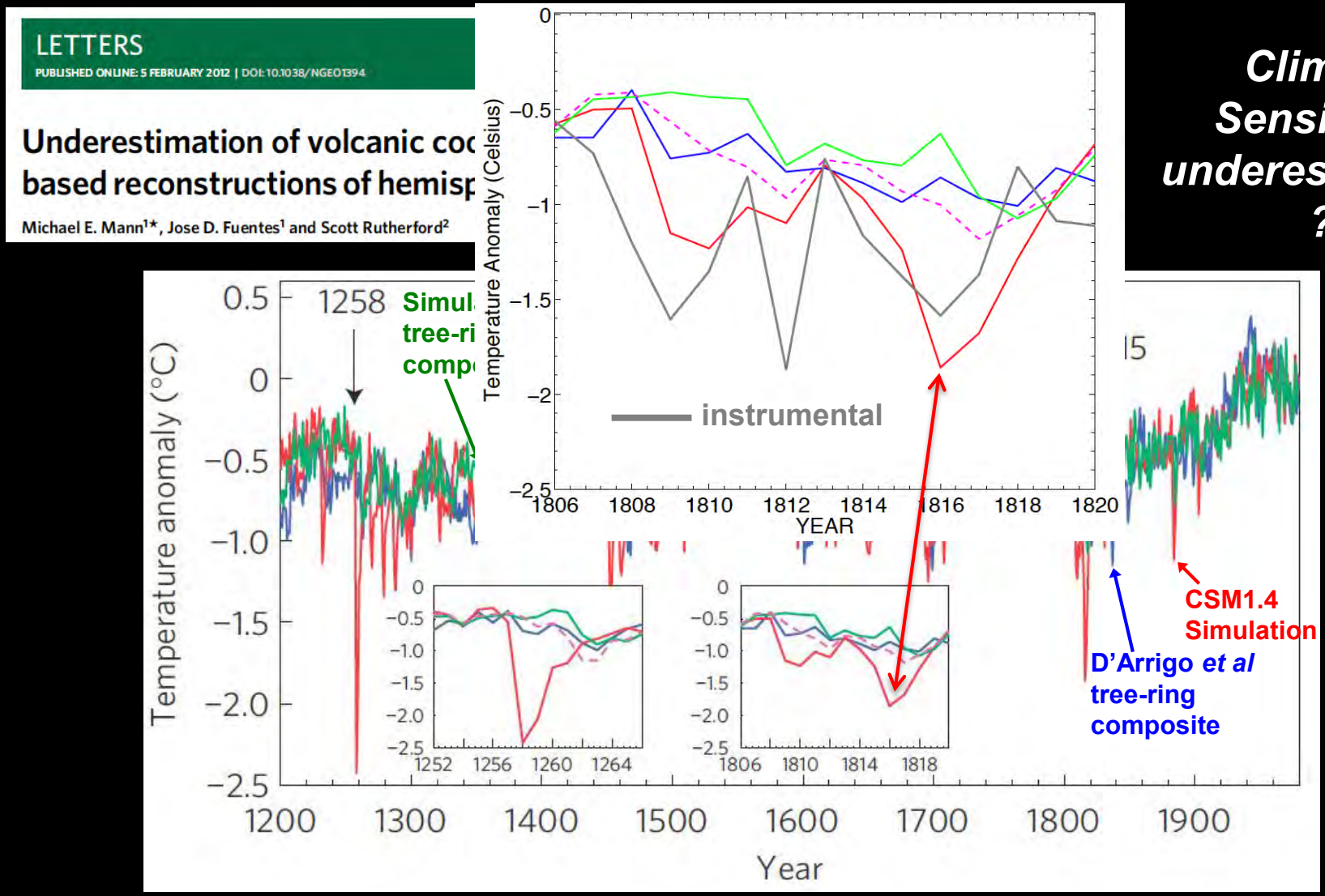
SCIENTIFIC AMERICAN ONLINE Detailed information on the energy balance model simulation is available at ScientificAmerican.com/apr2014/mann

Graphic by Pitch Interactive

Applications: Refining parameter estimates



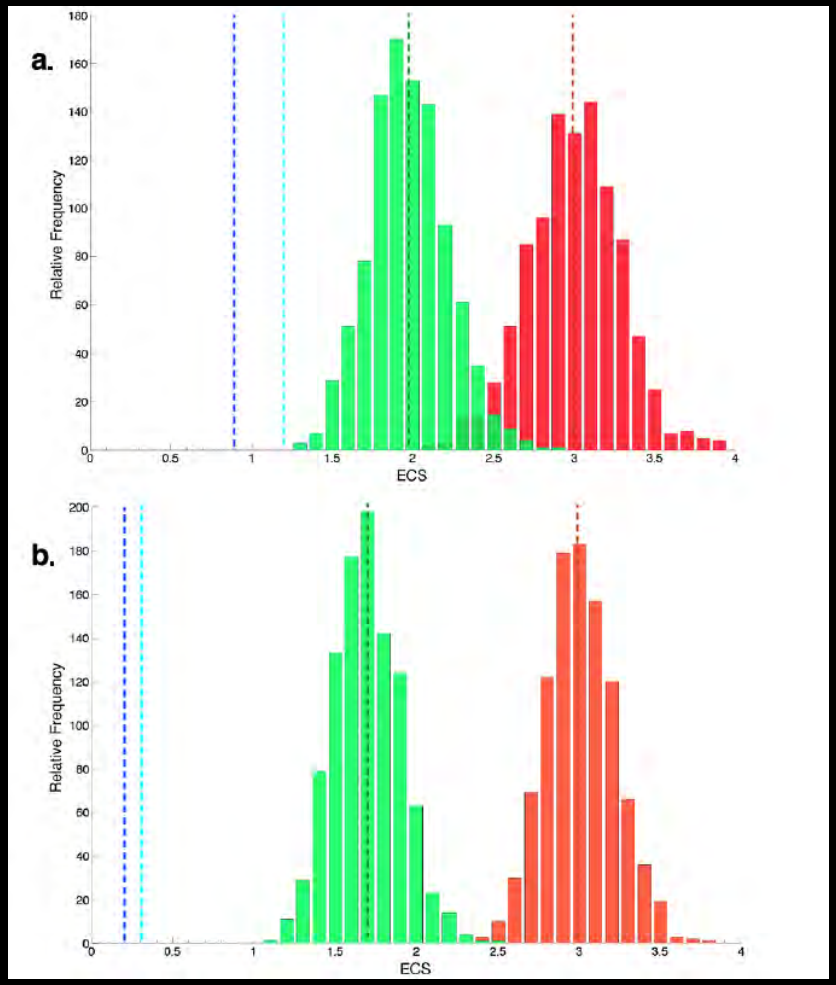
Applications: Refining parameter estimates



Climate Sensitivity underestimated ?

D'Arrigo et al tree-ring based NH reconstruction (blue) along with the climate model (NCAR CSM 1.4) simulated NH mean temperatures (red) and the "simulated tree-ring" NH temperature series based on driving the biological growth model with the climate model simulated temperatures (green). The two insets focus on the response to the AD 1258 and AD 1809+1815 volcanic eruption sequences.

Applications: Refining parameter estimates



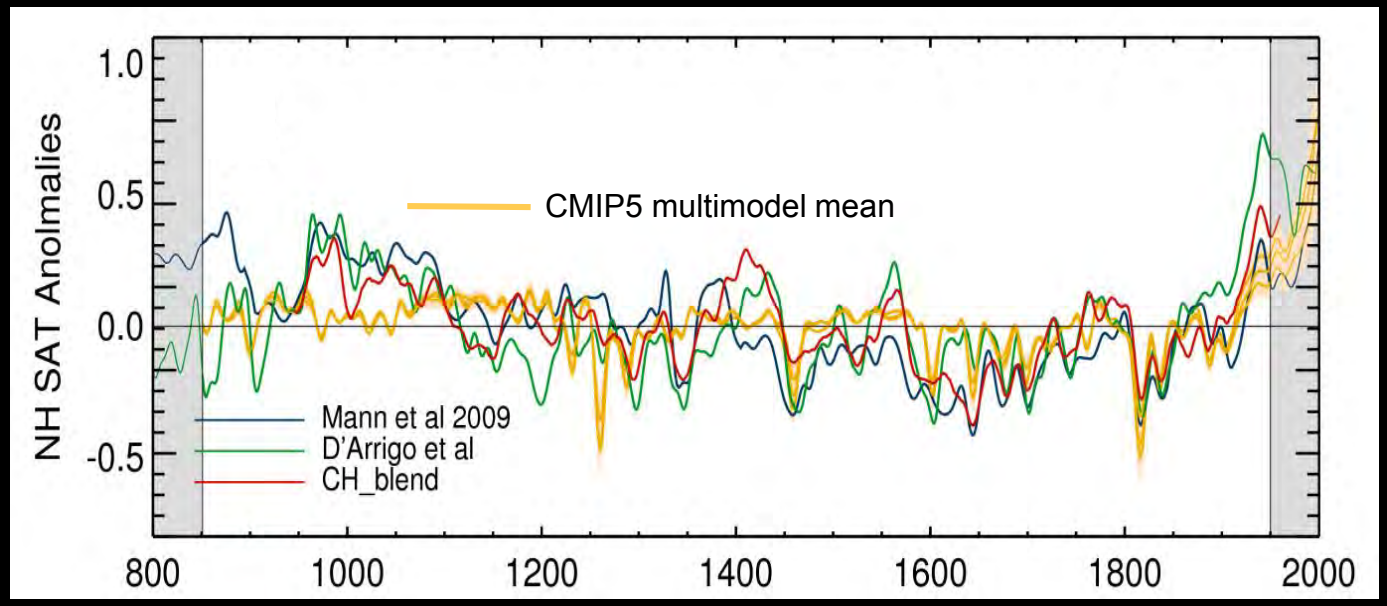
PDF of ECS using decadally smoothed data between (a) AD 1300–1849 and (b) AD 1200–1849 (red = simulated actual temperature series; green = synthetic tree ring temperature series). Shown by dashed vertical lines are mean of the ESC distribution for simulated temperature series (red), mean of ECS distribution for synthetic tree ring temperature series (green), ECS estimate using MFR12 simulated tree ring temperature series where chronological error accumulation due to inferred missing rings is taken into account (cyan), and sensitivity estimate for D06 tree ring temperature reconstruction (blue). True value of ESC is 3.0 in both cases.

JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 7617–7627, doi:10.1002/jgrd.50609, 2013

Discrepancies between the modeled and proxy-reconstructed response to volcanic forcing over the past millennium: Implications and possible mechanisms

Michael E. Mann,[1] Scott Rutherford,[2] Andrew Schurer,[3] Simon F.B. Tett,[3] and Jose D. Fuentes[4]

NH Mean Temperature over past Millennium: Model/Data Comparison



JOURNAL OF CLIMATE VOLUME 26

Separating Forced from Chaotic Climate Variability over the Past Millennium

ANDREW P. SCHURER AND GABRIELE C. HEGERL

School of GeoSciences, The University of Edinburgh, Edinburgh, United Kingdom

MICHAEL E. MANN

Department of Meteorology, and Earth and Environmental Systems Institute, The Pennsylvania State University, University Park, Pennsylvania

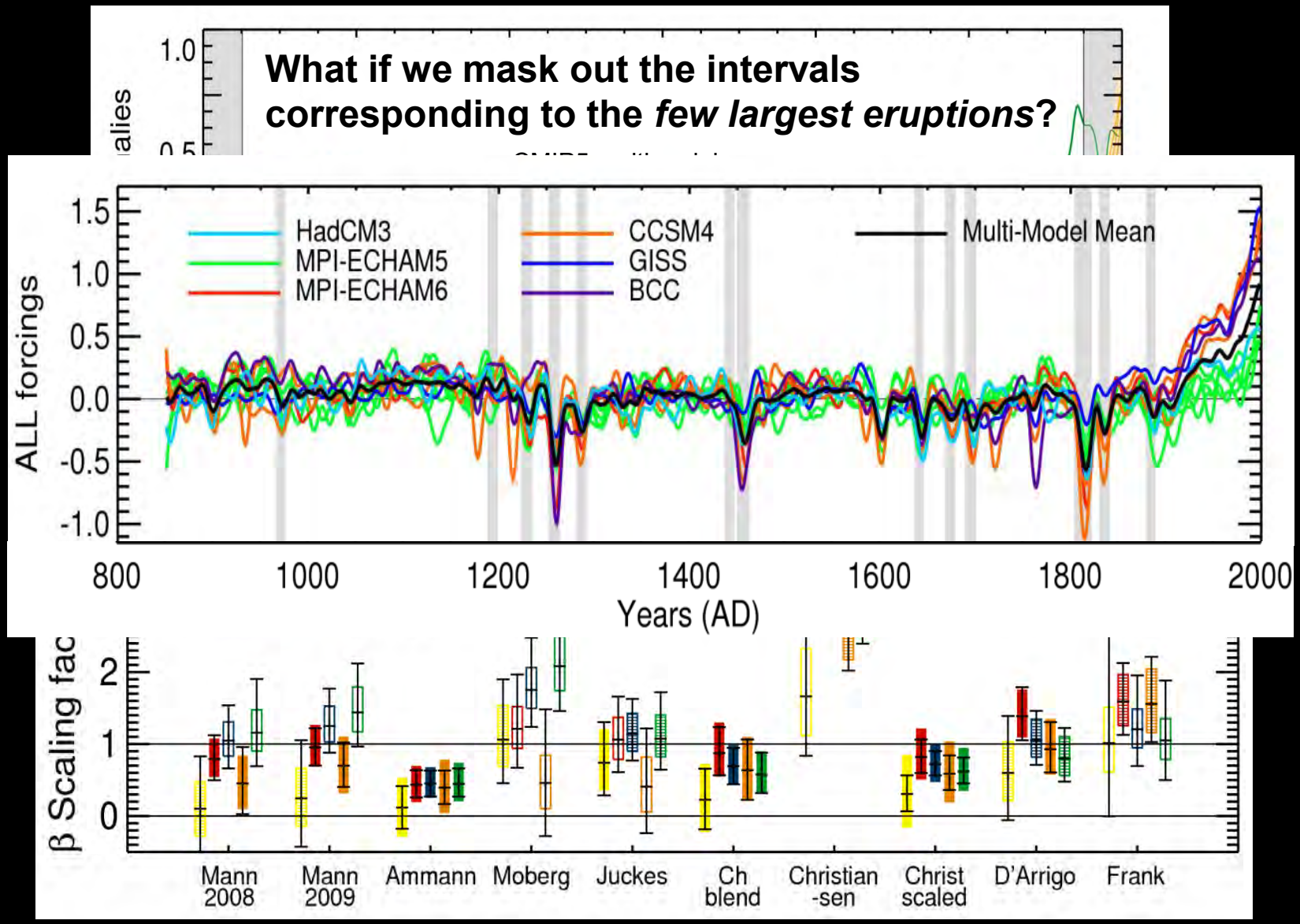
SIMON F. B. TETT

School of GeoSciences, The University of Edinburgh, Edinburgh, United Kingdom

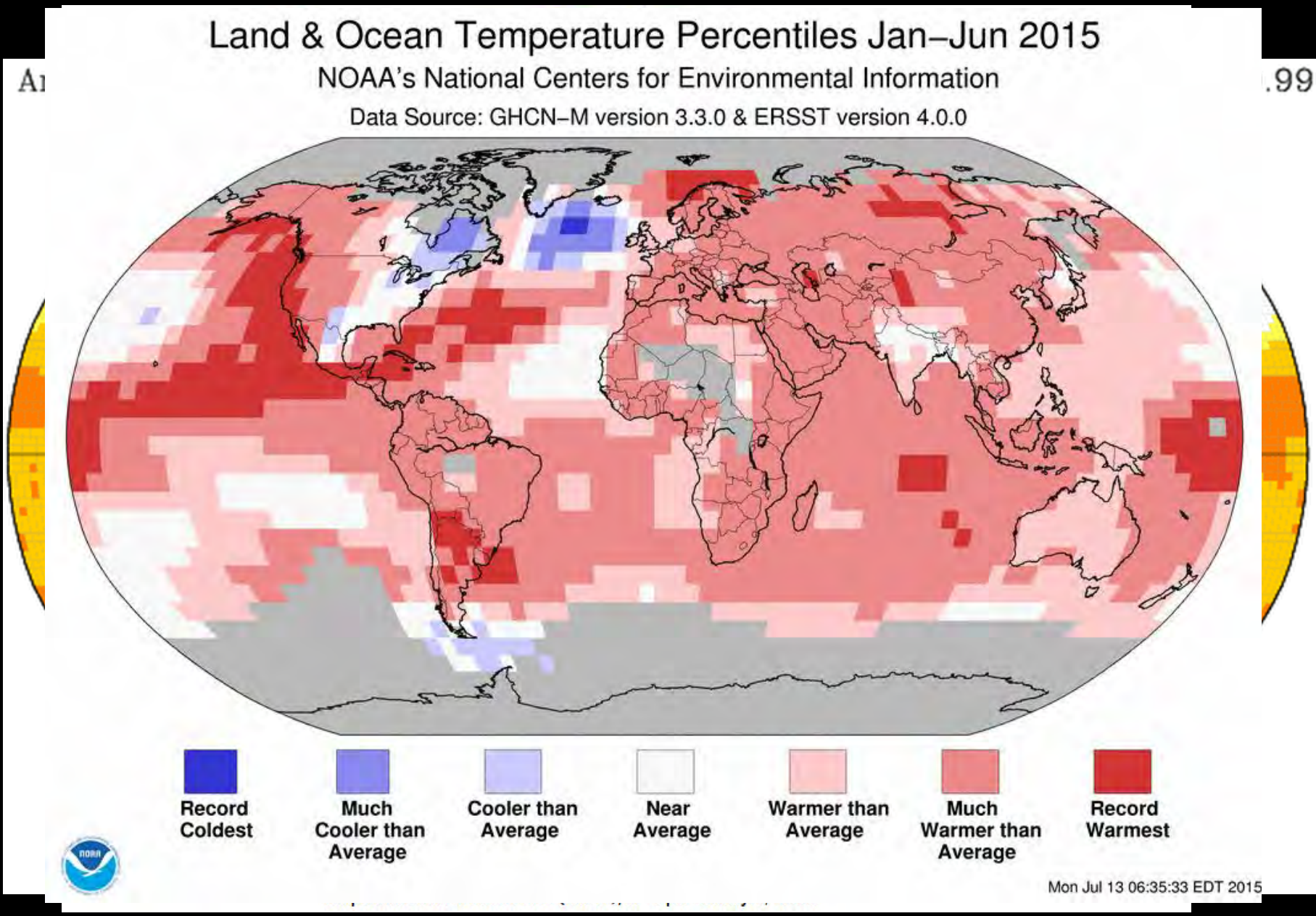
STEVEN J. PHIPPS

Climate Change Research Centre, and ARC Centre of Excellence for Climate System Science, University of New South Wales, Sydney, New South Wales, Australia

NH Mean Temperature over past Millennium: Model/Data Comparison



Projected Future Warming



Projected Future Warming

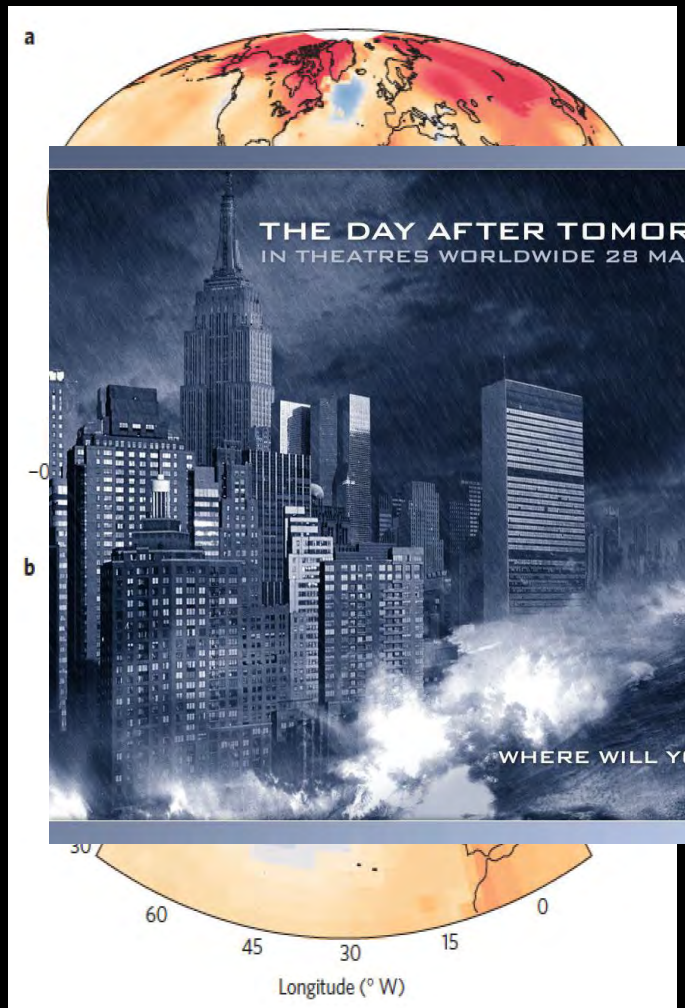
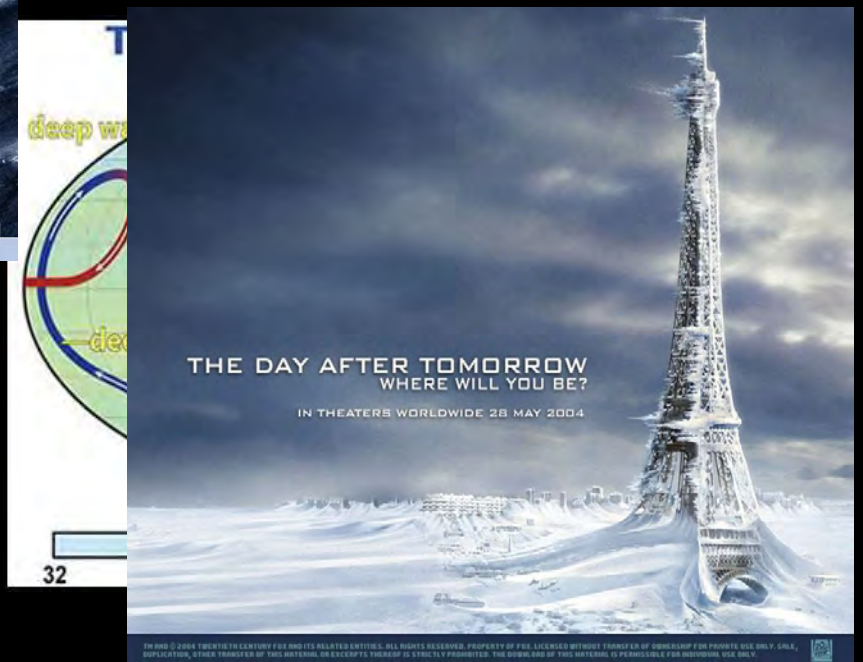


Figure 1 | Linear trends of surface temperature since AD 1901 based on the temperature data of NASA GISS (ref. 47), in °C per century. a, Global



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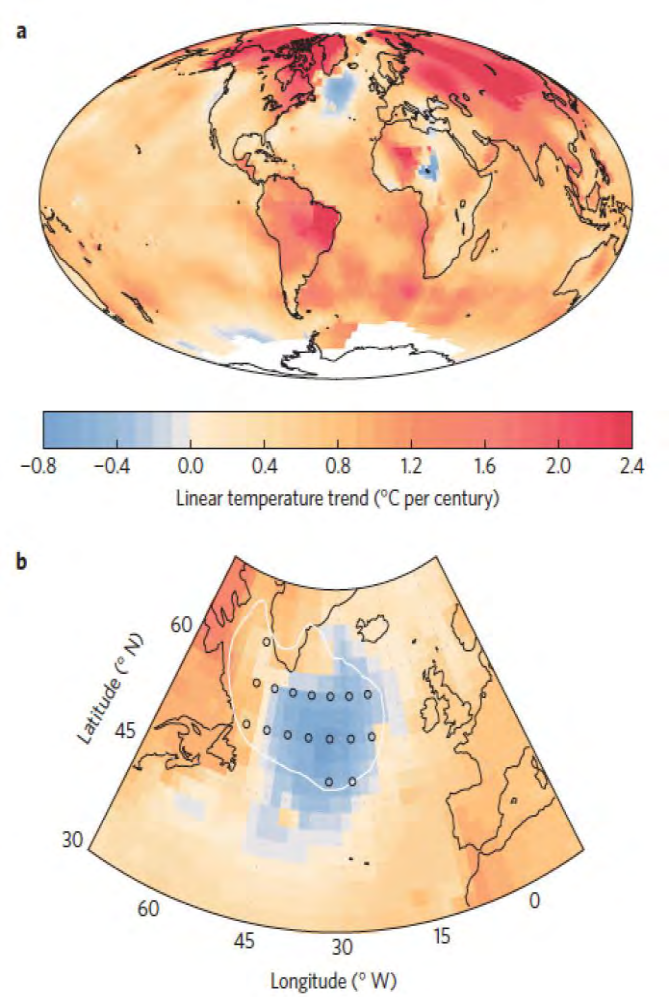

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ARTICLES

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Exceptional twentieth-century slowdown in Atlantic Ocean overturning circulation

Stefan Rahmstorf[1]*, Jason E. Box[2], Georg Feulner[1], Michael E. Mann[3,4], Alexander Robinson[1,5,6], Scott Rutherford[7] and Erik J. Schaffernicht[1]

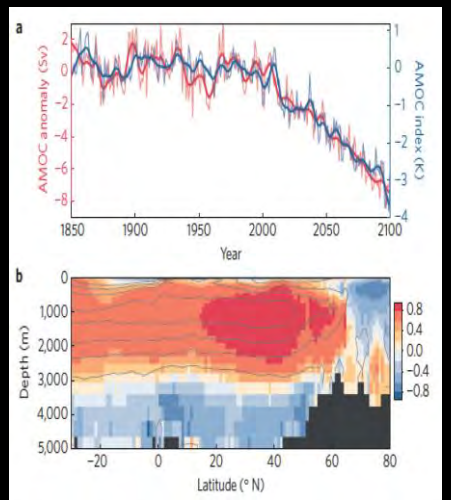


Figure 2 | Connection between the AMOC stream function and the temperature-based AMOC index in a global warming scenario (RCP8.5) simulated with the MPI-ESM-MR global climate model of the Max Planck Institute in Hamburg[11].

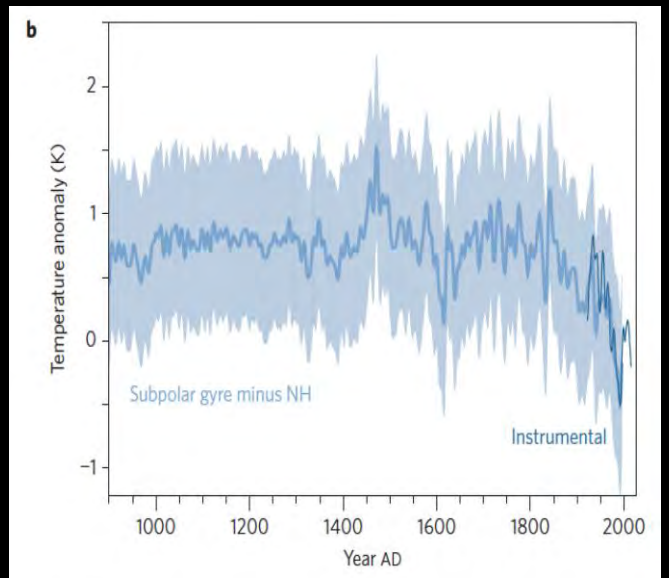
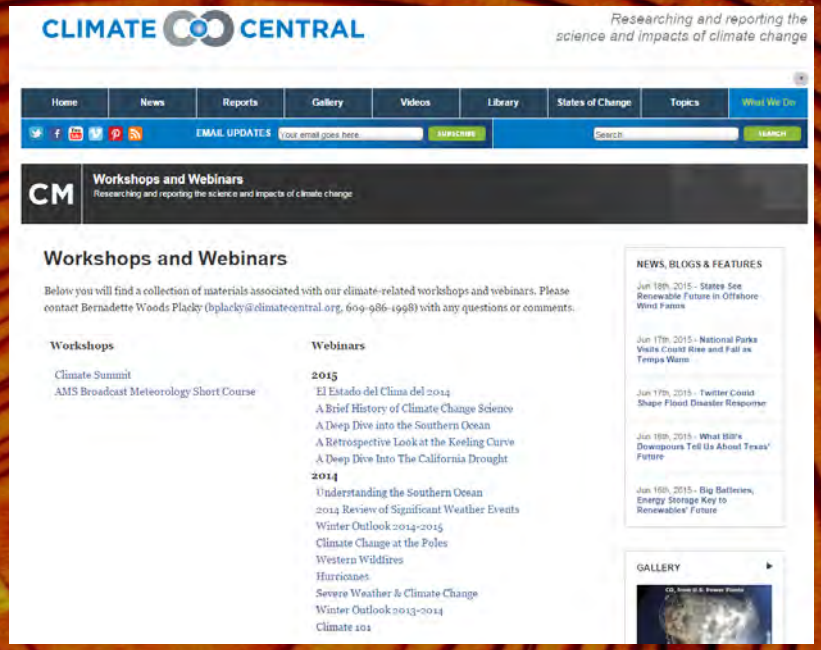


Figure 3 | Surface temperature time series for different regions from the proxy reconstruction of Mann *et al.*[12], including estimated 2-σ uncertainty bands, and from the HadCRUT4 instrumental data[48].

CONCLUSIONS

- Recent hemispheric-scale warmth anomalous in at least a millennial context; can only be explained by anthropogenic radiative forcing
- Prior to the 20th century, warmth and cold was highly regionally variable
- Medieval warmth in high-latitude North Atlantic and parts of North America rivaled modern warmth
- Reconstructed La Nina-like pattern during Medieval times, and El Nino-like anomalies during the "Little Ice Age", suggest a 'thermostat'-like response response to natural radiative forcing
- Response of AO/NAO to natural volcanic and solar radiative forcing appears to explain enhanced 'Little Ice Age' and 'Medieval Warm Period' temperature signal in regions such as Europe
- Combination of warm tropical Atlantic and La Nina-like conditions in the tropical Pacific could explain periods of relatively high past Atlantic Hurricane activity
- Anthropogenic climate change impacts on TCs combined w/ SLR has led to dramatic increase in coastal risk relative to pre-anthropogenic era
- Proxy reconstructions (particularly from tree-ring data) may underestimate certain climate responses—should be taken into account in model/data comparisons and estimates of climate sensitivity from paleodata.
- Evidence that recent weakening of AMOC unprecedented for at least the past millennium



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