Learning from the Climate Changes in Past Centuries

April 26, 2016
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The Past as Prologue: Learning from the Climate Changes in Past Centuries

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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

Departures in temperature ($^\circ$C) from the 1961–1990 average

Year

1000 1200 1400 1600 1800 2000


...and from tree rings, paleo-ice core records (blue).
Hockey League
Hockey League

**The Telegraph**

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

**FINANCIAL TIMES**

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Research backs global warming theory

By Pittie 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**

Continental-scale temperature variability during the past two millennia

PAGES 2k Network

Past global climate changes had strong regional expression. To elucidate their spatial-temporal 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 continental 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 colder conditions between ca 1500 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 (ca 1975-2000), 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*

**Solar Induced Annual Temperature changes**

Now using -0.19 W/m² forcing & better climate model

Model

Lagged Proxy Corr.

Temperature change (°C)

Simulations of Shindell et al., GRL, 2006
El Nino
Sources of Uncertainty

El Nino

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 Adams¹, Michael E. Mann¹ & Caspar M. Ammann²

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

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

Superposed Epoch Analysis AD 1649-1868
all (7) tropical events exceeding -2 W/m²

Superposed Epoch Analysis AD 1000-1999
All (7) tropical events exceeding -4 W/m²

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

Surface Temperature Reconstructions

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 Ni4

Science (Nov 27, 2009)
Model-Data Comparisons

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

Michael E. Mann,1, 2 Zhuhua Zhang,2 Scott Rutherford,2 Raymond S. Bradley,1 Malcolm K. Hughes,1 Drew Shindell,5 Caspar Ammann,6 Greg Faluveci,5 Fenbiao Ni4

Positive Phase of Northern Annual Mode
Applications: Tropical Cyclones

Model resolves ~50% annual variance in both calibration and split calibration/validation over 1870-2006

statistical model
historical record

Atlantic hurricanes and climate over the past 1,500 years

Michael E. Mann¹, Jonathan D. Woodruff², Jeffrey P. Donnelly³ & Zhuhua Zhang¹
Applications: Tropical Cyclones

![Graph showing historical record and 95% uncertainties for sediments and statistical model over years from 1850 to 2000.](image)
Applications: Tropical Cyclones

95% uncertainties
sediments
historical record
Statistical model

$95\%$ uncertainties

$r=0.44$
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

Storm Surge (m) plus Sea Level Rise at the Battery for MPI Model
storms occurring before 1800 (blue) and after 1970 (red)

- Bootstrapped* 95% CI of the mean surge height plus SLR for storm surge events from AD 1970–2005
- Bootstrapped* 95% CI of the mean surge height plus SLR for storm surge events from AD 850–1800
- Storm surge events** occurring from AD 1970–2005
- Storm surge events** occurring from AD 850–1800

*Bootstrapped means are based on 100,000 bootstraps of the mean of each distribution.

**Surge events for each distribution indicate the modeled surge height plus the relative sea level from proxy sea level reconstructions in the New York/New Jersey region, and have been normalized and sorted into 290 evenly spaced bins.
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 leveling in the rate at which the earth’s average surface temperature had been increasing. The term 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 to ask 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 predictions for future warming. Its forecast, 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 it might be mitigated. It will do so in reports that are 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 instrumental warming by 2018. The “pause” would be dead by then. The “pause” would be dead by then. It would cause a rise in greenhouse gas emissions and avoid the crossover—but only for a few years.

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 dipping gently downward, left to right, indicated only modest changes in Northern Hemisphere temperatures for almost 1,000 years—far less than our data went.

Scientists and policy makers commonly say that the world has to keep atmospheric CO₂ levels below 450 ppm to avoid two degrees of warming (the level briefly hit 450 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 CO₂ 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 of warming, CO₂ levels should be held to 405 ppm (blue)—barely above the 392 to 400 ppm levels observed in the past year.

Where to Hold the Line

Scientists and policy makers commonly say that the world has to keep atmospheric CO₂ levels below 450 ppm to avoid two degrees of warming (the level briefly hit 450 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 CO₂ 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 of warming, CO₂ levels should be held to 405 ppm (blue)—barely above the 392 to 400 ppm levels observed in the past year.
Applications: Refining parameter estimates
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.

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. Fuentes1

NH Mean Temperature over past Millennium: Model/Data Comparison

[Graph showing NH SAT anomalies from 800 to 2000 AD, with CMIP5 multimodel mean highlighted.]
NH Mean Temperature over past Millennium: Model/Data Comparison

What if we mask out the intervals corresponding to the few largest eruptions?
Projected Future Warming

Land & Ocean Temperature Percentiles Jan–Jun 2015
NOAA’s National Centers for Environmental Information
Data Source: GHCN–M version 3.3.0 & ERSST version 4.0.0
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
Projected Future Warming

Exceptional twentieth-century slowdown in Atlantic Ocean overturning circulation

Stefan Rahmstorfer*, Jason E. Box², Georg Feulner¹, Michael E. Mann³,⁴, Alexander Robinson¹,⁵,⁶, Scott Rutherford⁷ and Erik J. Schaffernicht¹

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

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 Hamburg²⁶.

Figure 3 | Surface temperature time series for different regions from the proxy reconstruction of Mann et al.¹², including estimated 2σ uncertainty bands, and from the HadCRUT4 instrumental data⁴⁸.
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.