Climate Change Insights from the Paleoclimate Record of Past Centuries

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with contributions from:
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Global Surface Temperature Changes

- Long-term trend over the last 25 years
- Long-term trend for the full record
- Global average surface temperature
- Margin of uncertainty

TRENDS IN GLOBAL SURFACE TEMPERATURE 1901–2005

[Graph showing global temperature changes over time with a trend line and temperature change map]
Global Surface Temperature Changes

Climate “Proxy” Data...
Reconstructions of Past Climate


Global-scale temperature patterns and climate forcing over the past six centuries

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Climate “Proxy” Data…
Surface Temperature Reconstructions
Surface Temperature Reconstructions

NORTHERN HEMISPHERE TEMPERATURE CHANGES OVER THE PAST MILLENNIUM

A number of independent estimates have been made of temperature changes for the northern hemisphere over the past millennium. While there is some variation within the different estimates, which make use of different data and techniques, they all point to the same conclusion: the most recent warming is without precedent for at least the past millennium.
Surface Temperature Reconstructions

Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia


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Surface Temperature Reconstructions

![Graph showing temperature changes over time with various simulations and data sets.](image)

**Reviews of Geophysics (2004)**

**CLIMATE OVER PAST MILLENNIA**

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Surface Temperature Reconstructions

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

Michael E. Mann, Zhihua Zhang, Scott Rutherford, Raymond S. Bradley, Malcolm K. Hughes, Drew Shindell, Caspar Ammann, Greg Faluvegi, Fenbiao Ni
Surface Temperature Reconstructions

Regional Time Series
Applications: Atlantic Tropical Cyclones

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

Statistical model

Historical record

Evidence for a modest undercount bias in early historical Atlantic tropical cyclone counts

Michael E. Mann, Thomas A. Sabbatelli, and Urs Neu

Received 22 August 2007; revised 10 October 2007; accepted 18 October 2007; published 24 November 2007.
Applications: Atlantic Tropical Cyclones

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

Atlantic hurricanes and climate over the past 1,500 years

Michael E. Mann¹, Jonathan D. Woodruff², Jeffrey P. Donnelly³ & Zhihua Zhang⁴
Applications: Atlantic Tropical Cyclones

95% uncertainties

Historical record

Statistical model

Sediments

95% uncertainties

Annual TC Counts

YEAR

1850 1900 1950 2000

0 5 10 15
Surface Temperature Reconstructions

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

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Science (to appear 11/27/09)
Surface Temperature Reconstructions
Sources of Uncertainty

El Niño

LARGE-SCALE IMPACTS OF EL NIÑO (NORTHERN HEMISPHERE WINTER)
El Niño events influence global patterns of temperature and rainfall. The effects of
La Niña events are roughly opposite to those shown here for El Niño events.

ENSO VARIABILITY

Individual El Niño and La Niña events larger

Individual El Niño and La Niña events smaller

Climate overall is more La Niña-like

Climate overall is more El Niño-like
How did Natural Forcings Influence influence ENSO and the Tropical Pacific During the Past Millennium?

**Combined response to Solar + Volcanic Forcing**

Ensemble mean Nino3 (100 realizations of CZ model)

40 year smooth

Palmyra coral isotopes (standardized to have same mean and standard deviation as Nino3 composite series)

Model-Data Comparisons

Positive Phase of Northern Annual Mode

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,1 Malcolm K. Hughes,1 Drew Shindell,3 Caspar Ammann,1 Greg Faluvegi,3 Fei Biao Li4

Science (to appear 11/27/09)
Paleoclimate Data Assimilation

PROXIES

MODEL

Past Natural Arctic warming
Paleoclimate Data Assimilation

Past Natural Arctic warming
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’ response to natural radiative forcing

• Response of Northern Annular Mode/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 can explain periods of relatively high past Atlantic Hurricane activity
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‘Little Ice Age’ wet in Kenya: El Nino-like conditions

Combined response to Solar +Volcanic Forcing

Coral isotope reconstruction of past El Nino variations

smoothed simulation result
How did Natural Forcings Influence ENSO and the Tropical Pacific During the Past Millennium?

Cook et al, *Science*, ‘04

‘Little Ice Age’ wet in southwestern U.S.: El Nino-like conditions

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Reconstructed Temperature Patterns