Ice age begins anew, ca. 2 million years ago

Last Glacial Maximum 18,000 years ago

Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
300,000 years of temperature information

Watanabe et al. 2003 Nature
1,000+ years of local climate from proxies

Ice cores
Boreholes
Pollen
Insects (esp. beetles)
Sea floor, lake bed sediments
Tree growth
Tree-line limits

Glaciers
Bogs (mummies)
Speleothems
Shoreline drifts
Coral
Documentary records
Cultural changes

Worldwide, where evidence is available:
• Medieval Warm Period, ca. 800 to 1300 CE
• Little Ice Age, ca. 1300 to 1900 CE
• 20th century climate is generally not the most extreme in most regions

Note: MWP and LIA anomalies are local events across the globe; averaging over broad spatial scales blurs important information on patterns of environmental change.
Over 6,000 boreholes contain past climate information

Selected Heat Flow Sites

Huang et al., 1997, GRL
Results of 6,000 boreholes show Medieval Warm Period and Little Ice Age.
Wildfire in 1297 C.E.
Figure 2 Lake Johnston Huon pine mean ring-width series in millimetres and sample size (N). The annual data have been smoothed with a 10-year smoothing spline to highlight the multiyear fluctuations. The dashed lines are 95% confidence limits estimated using the bootstrap method. The heavy solid line describes the general shape of the growth trend believed to be largely nonclimatic in origin.
CLIMATE IN PERSPECTIVE

Temperature of the Sargasso Sea from 1000 B.C. to 1975 A.D., in Fahrenheit

Source: Science (1996)
China: Peat cellulose $\delta^{18}O$

Hong et al. 2000

Medieval Warm Period

Little Ice Age

Years Before Present
Quelccaya Glacier, Peru
Global temperature from proxies?

Proxy Reconstructed Global Temperature Anomalies, 200A.D.–1980A.D.
(adapted from Mann and Jones, 2003)

YEAR (A.D.)

TEMPERATURE ANOMALY (°C)

-0.4
-0.2
0.0
0.2
0.4
0.6

- Medieval Warm Period
- Little Ice Age
Mann and Jones, 2003

When the instrumental global temperature record is overlaid on the proxy reconstructed global temperature record it becomes evident that these two sources of temperature information are not of the same character.
<table>
<thead>
<tr>
<th>Region</th>
<th>Time</th>
<th>Life Expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>50,000 years ago</td>
<td>&lt;30 years</td>
</tr>
<tr>
<td>Rome</td>
<td>2,000 years ago</td>
<td>25-30 years*</td>
</tr>
<tr>
<td>England</td>
<td>1200 C.E.</td>
<td>35 years†</td>
</tr>
<tr>
<td></td>
<td>1370 C.E.</td>
<td>18 years†</td>
</tr>
<tr>
<td></td>
<td>1600 C.E.</td>
<td>38 years</td>
</tr>
<tr>
<td></td>
<td>1740 C.E.</td>
<td>33 years</td>
</tr>
<tr>
<td></td>
<td>2000 C.E.</td>
<td>78 years</td>
</tr>
</tbody>
</table>

Notes:
* Males only
† Male landowners only
Citizens of Tournai bury plague victims. These are fortunate to have coffins. Most victims were interned in mass graves. 1349
Pegnitz River – flooding peaks in Little Ice Age

R. Brádzil et al. 2002 PAGES News, 10: 21-23
## Little Ice Age: Resurgence of witch burnings

<table>
<thead>
<tr>
<th>Period</th>
<th>Locale</th>
<th>Number of women burned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1580 - 1620</td>
<td>Pays de Vaud</td>
<td>1000</td>
</tr>
<tr>
<td>1580 - 1595</td>
<td>Lorraine</td>
<td>800</td>
</tr>
<tr>
<td>1581 - 1595</td>
<td>Treves</td>
<td>350</td>
</tr>
<tr>
<td>1626</td>
<td>Bamburg</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>Würzburg</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>Electorate Mainz</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>Westphalia</td>
<td>2000</td>
</tr>
</tbody>
</table>

“Since everybody thought that the continuous crop failure was caused by witches from devilish hate, the whole country stood up for their eradication.”

Johann Linden, Treves, ca. 1590

*Source: W. Behringer 1987, 1995*
20\textsuperscript{th} C SURFACE TEMPERATURE TRENDS NOT CLOSELY LINKED TO THE AIR’S CONTENT OF HUMAN-MADE GREENHOUSE GASES

http://www.cru.uea.ac.uk/cru/info/warming/
Key measurements: Low troposphere shows no meaningful warming trend with more carbon dioxide in the air

J. Christy et al. www.ghcc.msfc.nasa.gov/MSU/msusci.html
A SUN – CLIMATE LINK?
NORTHERN HEMISPHERE LAND TEMPERATURE AND SOLAR CYCLE

Left – Changes in the sun’s output are strongly correlated with terrestrial temperatures where records are available. Data are from S. Baliunas and W. Soon 1995.

Right – YOKOH satellite image of one million C plasma in the sun’s outer atmosphere. The plasma is shaped and heated by magnetic fields.
The last ice age ends
The Mesozoic -- a climate high!
Early mammal ancestor: Morganucodon
70 million years ago, the Pleiades is born
15 million year old ice sheet
Coral contains climate information
Past Global Changes and Their Significance for the Future
Alverson, Oldfield and Bradley eds.
Climate and weather are always changing; the 20th century was not exceptional.

The most sensitive and globally comprehensive measurements (satellite and balloon readings of low troposphere) find no meaningful enhanced greenhouse warming, in contradiction to computer simulations.

The Kyoto Protocol would be ineffective (averts ~0.06 C warming by 2050) and expensive (~2T lost U.S. GDP over ten years).
Earliest writing from Sumer, ca. 3300 BCE?
Key measurements: Low troposphere shows no meaningful global warming trend with more carbon dioxide in the air.
Cro Magnon cave artists were fully human
Wooly Rhinoceroses drawn in Chauvet Cave over 20,000 years ago
Hominid line may be 6 million years old
Instrumental measurements show a long-term warming trend and the greatest rate of warming ca. 1690s – 1730s.
http://www.usefulinfo.co.uk/globalclimate/figure_1.htm
Low troposphere is where human-made warming trend must appear

Enhanced greenhouse must warm low troposphere (1-5 km height) *faster* than surface

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Temperature Change (°C/decade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast (low troposphere)</td>
<td>+0.25</td>
</tr>
<tr>
<td>Surface</td>
<td>+0.15</td>
</tr>
<tr>
<td>Hadley (Balloon)</td>
<td>+0.04</td>
</tr>
<tr>
<td>NCEP (Balloon)</td>
<td>+0.05</td>
</tr>
<tr>
<td>U AH MSU/AMSU (Satellite)</td>
<td>+0.06</td>
</tr>
</tbody>
</table>

Trends computed for 1979-2001

J. Christy et al. 2003 *J. Atmospheric & Oceanic Tech.*, T. Chase et al. 2003 *Climate Research*
Abrupt Changes in the Earth’s Climate
Measured in Central Greenland Over the Last 17,000 Years
Paleo Temperatures & Snowfall - After Cuffey and Clow 1997 / Alley 2000

Temperature (°C)

Accumulation (m ice/year)

Age (thousand years before present)

Little Ice Age
400-150 BP

Medieval Warm Period
800-1300 YBF

1500 Year Spacing

NA Plant Domestication

5300
Iceman of The Alps

1st Dynasty of Egypt

8200: Cooling Event
World Wide

Widespread Forests

Younger Dryas

Birch and Conifer

Widespread Tree Growth (Pollen)

Cooling Steps

Tundra Plants
-6-7°C
Eastern Canada

Africa Dry

El Nino Begins

Languages Develop

Animal and Plant Domestication (Near East)

Squash

Tigris & Euphrates

Early Domestication of Plants?

Allerød Warm

Hunters & Gathers

Americas

Pottery

Bronze Age

Iron Age

Coffee in Ethiopia

Almaty, Kazakastan (Father of Apples)

Corin and Beans

Squash

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