Observed Climate Variability and Change

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Overview

- The evidence for observed climate change.
  - Temperature
  - Precipitation
  - Extremes
  - Abrupt Climate Change

- How confident are we in these results?
  - Data and Observational Issues that can lead to uncertainties
Northern Hemisphere 1000 Year Temperature Reconstruction
Annual Global Surface Mean Temperature Anomalies

National Climatic Data Center/NESDIS/NOAA

Land and Ocean

Ocean

Land

Degrees C

Degrees F

Year

1880 1900 1920 1940 1960 1980 2000

-1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6

-2.2 -2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8
Global Temperature Change vs CO₂ Change
ANNUAL NUMBER OF FROST DAYS
TRENDS IN DAYS PER DECADE
1948-1999

Significance

> 90%  *
> 95%  **
> 99%  ***

All U.S. = -0.8**
CHANGE IN FROST-FREE LENGTH
DAYS PER DECADE
1948-1999

Significance

> 90%  *
> 95%  **
> 99%  ***

All U.S. = +2.0***

[Map showing change in frost-free length with significance levels and numerical values for different regions.]
Past Climate From Borehole Records

16 borehole temperature records were averaged to create a temperature reconstruction for High Latitude North America. 20th century temperatures show a major upturn relative to prior 4 centuries. Temperatures rose at a rate of 1.5°F in the 20th Century.

www.ngdc.noaa.gov/paleo
10-15% Decrease in Arctic sea ice revealed by NOAA operational satellites
NH Snow Cover from NOAA Satellites

Year:
- 66
- 68
- 70
- 72
- 74
- 76
- 78
- 80
- 82
- 84
- 86
- 88
- 90
- 92
- 94
- 96
- 98
- 00

Km² x 10⁶:
- -6
- -4
- -2
- 0
- 2
- 4
- 6
- 8
- 10
FAIRBANKS, BONANZA CREEK, 1930-2003
Mean annual ground temperatures

Mean Annual Temperature (°C)

Depth:
- 0.08 m
- 0.3 m
- 0.5 m
- 1 m

TIME (years)

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University of Alaska, Fairbanks
FIFVER@UAF.EDU
Global Sea Level Changes

- TOPEX
- TOPEX2
- Jason
- 60-day smoothing

Univ of Colorado (Boulder)
Leuliette et al. 2004, Marine Geodesy, vol. 27 (1-2)
http://sealevel.colorado.edu/

Seasonal signals removed
Changes in the Hydrologic Cycle

- Global heating - accelerated land surface drying and more water in the atmosphere
  - Increased severity of droughts
  - Increased risk of heavy and extreme precipitation events
    - Even with no change in total precipitation
    - Even stronger when precipitation increases

Observed climatology of daily precipitation intensity (as a percentage of seasonal totals) as a function of observed mean temperature based on 100 worldwide stations
Regions where disproportionate changes in heavy and very heavy precipitation occurred compared to the mean
(first half of 20th century to present)
Abrupt Climate Change

• What is it?

Mechanistic definition
  – Transition of the climate system into a different state (of temperature, rainfall, and other aspects) on a time scale that is faster than the responsible forcing.

Impacts based definition
  – Change of the climate system that is faster than the adaptation time of social and/or ecosystems.
Abrupt Climate Change

GISP2 Ice Core Temperature and Accumulation Data
Alley, R.B. 2000

Temperature
Yellow Dryas
Medieval Warm Period
Little Ice Age

Snow Accumulation

Age - Thousands of Years Before the Present
Abrupt Climate Change

Central Greenland: GISP2

-25
-35
-45
14500 13500 12500 11500 10500

Younger Dryas

Freshwater flux into N. Atlantic

Freshwater (Sverdrups)

Years ago

0 0.1 0.2
14500 13500 12500 11500 10500
How significant are the uncertainties?

✓ State and Forcings Variables

- Few have quantitative confidence intervals (CIs) (including time-dependent biases) e.g., global surface temperature, CO₂
- Most CIs do not include time-dependent biases
- For many, CIs are uncertain or unknown

✓ Why?

- Examples provide numerous insights into observing and data system deficiencies

Smoothed annual anomalies of global combined land-surface air and sea surface temperatures (°C).
Current Stratospheric Temperatures: from satellites and weather balloons.
Current Tropospheric Temperatures: from satellites and weather balloons.
Observing and Data System Deficiencies

GCOS Upper Air Network (GUAN) Performance, Aug 2001

Reliable stations have at least 90% of possible CLIMAT TEMP data between Jan 1992-Dec 1999

- **GREEN ▲**: GUAN station, CLIMAT TEMP report received (98)
- **RED •**: Unreliable GUAN station, no report received (49)
- **BLACK ○**: Reliable non-GUAN station, CLIMAT TEMP report received (144)
Effect of lengthening radiosonde cords at 13 Japanese stations in 1968.

Source: (Gaffen, JGR, 1994)
Changing local observation time leads to aliasing of diurnal signal into long term trends

Corrected Global Time Series
Uncorrected Global Time Series

Difference (expanded scale): 0.15K over 20 years

Courtesy Frank Wentz
Observing and Data System Deficiencies

- Issues with Surface-based observations

- Most observations taken for other purposes, e.g., weather forecasting

Change in the average March temperatures (°C) resulting from changing the time of observation from 5 P.M. to 7 A.M. local time
Observing and Data System Deficiencies

- Urban Heat Island Effects
- Land use vs temperature
The Climate Observing System: What is needed?

U.S. Climate Reference Network
Real-time Network Performance Monitoring

NC Arboretum

High Quality Temperature Measurements

<table>
<thead>
<tr>
<th>Degrees Centigrade</th>
<th>8/19/01</th>
<th>8/27/01</th>
<th>9/05/01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference in temperature of 2 nominal sensors</td>
<td>Difference in temperature between a nominal and faulty sensor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the past, these small biases could take years to detect, if ever.
Common Misperceptions

- **Last winter was cold and snowy - - - so much for global warming!**
  - Actually - - - last winter was warmer than average across the USA
  - Cold weather struck during the coldest weeks of the year!
  - Probability of cold winters are decreasing (9 of last 10 above average)

- **Satellites show global cooling not warming!**
  - True in the mid 1990s
  - Now - - - more data and improved analyses reveal significant warming at the surface and in the troposphere

- **Heat islands lead to over-exaggerated claims of observed warming!**
  - Strong warming over oceans (unaffected by heat islands), snow and ice extent decreasing
  - Heat island effect examined and addressed in the temperature records
  - Lake and river ice extent decreasing
  - Paleo data reveal warming (bore holes, tree rings, ice cores, etc.)
Common Misperceptions (cont’d.)

- **Solar variations are responsible for any global warming!**
  - Best evidence today suggests warming in first part of the 20th century influenced by solar radiation
  - Since satellite measurements (late 1970s) no significant changes in solar output - - - at time of rapid global temperature increases

- **Global warming will be negligible due to the planet’s self regulating thermostat (the “iris effect”!)
  - Tropical clouds are supposed to allow more heat to escape into space as globe gets warmer
  - BUT - - - Observational data (in-situ and satellite) show the opposite
  - Earth’s history (Ice sheets/Atmospheric Composition - - - including volcanic eruptions) demonstrates the climate is indeed sensitive to changes in forcings (about 0.75°C for 1 w/m² of forcing).
Conclusions

✓ Temperatures over past 100 years have warmed
  ✓ Greatest warming in high latitudes.
  ✓ Decrease in Arctic Sea Ice.
  ✓ Decrease in NH snow cover
  ✓ More warming in minimum (nighttime) temperature.
  ✓ Tropospheric warming, Stratospheric cooling.
  ✓ Observed Sea level rise.

✓ Large-scale precipitation over land has increased.
  ✓ Increase in high latitudes, decrease in Tropics.
  ✓ Evidence for increases in heavy precipitation events.

✓ Uncertainties due to observing system issues, etc. but taken together balance of evidence points to discernable human influence on the climate.