Modern Observations: Temperature Data and Their Interpretation*

By
Thomas C. Peterson

Search and Discovery Article #110056 (2008)
Posted July 7, 2008

*Prepared for oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

1NOAA’s National Climatic Data Center, Asheville, NC (Thomas.C.Peterson@noaa.gov)

Abstract

The global surface temperature time series reveals that our planet has been warming over the last century and especially over the last few decades. The observing systems that produce the raw instrumental data that go into the time series have undergone a variety of changes that can introduce non-climatic biases into the data. For example, sea surface temperature observations used to be made by sticking a thermometer into a bucket of surface water hauled up on deck. Now ships make their measurements using thermometers in engine cooling water intake pipes which bring in water from several meters below the surface. Such changes have caused a great deal of effort to be expended developing approaches to remove the various non-climatic biases.

This presentation will describe the ongoing efforts to insure robust calculation of global mean surface temperature including improving international data exchange, quality control and homogeneity adjustment methodology. Analyses that evaluate how well these methods remove biases from a variety of sources, such as urban heat islands, will also be described. Lastly, no discussion of global surface temperature data would be complete without interpreting or attributing the climate change signal imbedded in the surface temperature time series. Therefore, the talk will very briefly outline some of the science that supports the statement by the Nobel Prize winning Intergovernmental Panel on Climate Change’s Fourth Assessment Report that “most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.”
Modern Observations: Temperature Data and their Interpretation

Thomas C. Peterson
NOAA’s National Climatic Data Center
Asheville, North Carolina
Outline

- How the climate is changing according to the data
- Efforts to ensure the data base is robust
- Post production quality assurance
- Climate change attribution
- Final comment

- Each of the above topics could be a full presentation on their own
How the climate is changing according to the data
Global temperatures are rising

~0.75°C (~1.3°F) warming in the last 100 years
US temperatures are generally similar
Global warming is not uniform around the globe, e.g., the SE US cooled
More warming in the last few decades

Trend in Annual TMEAN, 1979 to 2007

Deg C / Decade

From IPCC, 2008
The recent observed climate change is beyond the bounds of natural variability

From IPCC 2008
The hottest summertime temperatures are increasing.
Coldest winter temperatures are warming faster

Coldest Temperatures of the Year
North American average

Peterson et al., 2008 permission NRC/AMS © Amer. Meteorological Soc.
Efforts to insure the data base is robust
International data exchange

Note drop in data during WWII

Source: Scott Woodruff, 1992 International COADS Workshop
Quality control

- A wide variety of checks have been developed to identify erroneous data points.

From Peterson et al., 1998, used with permission of RMetS.
Homogeneity adjustments – Sea Surface Temperature example

- Adjust historical data to make them equivalent to being observed by modern instruments at current station locations.

SST measured before ~ 1941 are significantly cooler than later SST, owing to change from using uninsulated buckets to a mixture of insulated buckets and engine coolant water intakes.

Smith & Reynolds, 2002, © American Meteorological Society
Homogeneity adjustments - Land air temperature station example

- **Red** is fully adjusted
- **Black** is only time of observation adjusted
- **Top:** temperatures
- **Bottom:** difference between Reno and mean of 10 nearest neighbors

Reno Nevada annual minimum temperature

Menne et al., 2008 © Amer. Meteorological Soc.
Spatial interpolation to fill in data sparse areas

- Prevents bias towards areas with good international data exchange
- NCDC’s approach uses Empirical Orthogonal Teleconnection Functions
Post production quality assurance
Comparison with other data sets:
They show the same thing

From Menne and Peterson, 2007, updated from IPCC 2007
Comparison of land and oceans: They show the same thing.
Comparison of urban and rural stations: They show the same thing

US Mean Temperature
CONUS Anomaly Time Series

Peterson & Owen, 2005 © BAMS and from IPCC 2007
Some stations have poor siting

Fig. 10. Same as Fig. 3, except for Lamar, CO.

Photographs Davey & Pielke, Sr. 2005 © American Meteorological Society
Comparison of stations with poor and good siting: They show the same thing

Poorly cited stations in this example show less warming
Doesn’t a station over concrete have a warm bias compared to a station over grass?

- For climate change purposes the relevant questions are:
  - Does the bias change over time?
  - Can the changing bias be accounted for?
A poorly sited station compared to its neighbors

- The station is 2° C warmer than neighbors
- But adjusted data’s trend agrees with its neighbors

Marysville, CA, USHCN v2
Comparison of homogeneous and homogeneity adjusted stations: They show the same thing

The stations with good siting only needed two minor and offsetting time of observation adjustments

Peterson 2006©Amer. Meteorological Soc.
Comparison of surface and upper air: Satellites and balloon data also show warming.

From IPCC, 2008
Comparison with non-thermometer data

- Data from sources other than surface thermometers support the climate change that the instrumental observations are indicating.
Arctic sea-ice is shrinking

Trend in Annual TMEAN, 1979 to 2007
Antarctic sea ice is increasing

Southern Hemisphere Extent Anomalies Feb 2008

1979-2000 mean = 2.9 million sq km

slope = 3.4(+/-5.0) % per decade
Lakes and rivers are freezing later and thawing earlier

Figure 4.5

From IPCC, 2007
Figure 4.5
Glaciers are melting

From IPCC, 2007
Sea level is rising

From IPCC, 2007
Plants and animals are acting as if it is warming

- Plants are blooming 1-3 days/decade earlier
  - “Altered timing of spring events has been reported for a broad multitude of species and locations” (IPCC 2007).

- Animals species are moving poleward
  - “Many studies of species abundances and distributions corroborate predicted systematic shifts related to changes in climatic regimes” (IPCC 2007).
What is causing the climate change?
Climate change detection and attribution

• The climate has warmed
  - Statistically significant change
  - Climate change has been detected

• But what has caused the detected change?
  - Climate change attribution
Each climate forcing has its own fingerprint of change in the climate.

Karl, 2006 CCSP 1.1
Models with and without human produced climate forcings reveal:

- “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations” (IPCC 2007).

![Graphs showing temperature anomalies over time for global, global land, and global ocean models with and without natural forcings.](IPCC_2007_WG1_AR4)
Final comment

• Stepping out into record hot weather, a friend who is an expert on climate change detection and attribution was asked if the high temperatures they were experiencing were due to global warming
• He responded:
  - You can’t attribute any one day’s temperature to global warming
  - But unusually warm weather like that does give us the privilege of experiencing the weather we are bequeathing our children and grandchildren
The End
But didn’t all the scientists predict global cooling back in the 1970s?

Global cooling articles only 10% total climate change articles

Peterson et al., 2007©Amer. Meteorological Soc.
Aren’t all the solutions painful?

- Efficiency can work wonders
  - Electricity use per refrigerator has decreased to <30% of 1972 value
  - Meanwhile, refrigerator size has increased
  - And refrigerator price has decreased (in constant dollars).

Brown et al., 2005 used with permission of www.pewclimate.org
Annual Mean Temperature Anomalies 2007
January-March 2008 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA

Precipitation

1 = Driest
114 = Wettest

- Record Driest
- Much Below Normal
- Below Normal
- Near Normal
- Above Normal
- Much Above Normal
- Record Wettest
Jan - Dec 2007

National Climatic Data Center/NESDIS/NOAA

Temperature

- Record Coldest
- Much Below Normal
- Below Normal
- Near Normal
- Above Normal
- Much Above Normal
- Record Warmest
Temperature Anomalies Dec-Feb 2008
(with respect to a 1961-1990 base period)
National Climatic Data Center/NESDIS/NOAA

Degrees Celsius

-5C  -4C  -3C  -2C  -1C  0C  1C  2C  3C  4C  5C
Temperature Anomalies March 2008
(with respect to a 1961-1990 base period)
National Climatic Data Center/NESDIS/NOAA
Annual Mean Temperature Anomalies 1934
Washington D.C. Landsat image, 11 AM in August.
Courtesy of Stephen Stetson, Global Environmental Management, Inc.
Rural stations and full data set show the same thing

- From Peterson et al., 1999’s global analysis
- 7,280 stations in full data set
- 2,290 rural stations based on night lights and map metadata
References

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