2008 Global Surface Temperature in GISS Analysis

James Hansen, Makiko Sato, Reto Ruedy, Ken Lo

Calendar year 2008 was the coolest year since 2000, according to the Goddard Institute for Space Studies analysis [Reference 1] of surface air temperature measurements (Figure 1, left). In our analysis 2008 is the ninth warmest year in the period of instrumental measurements, which extends back to 1880. The ten warmest years all occur within the 12-year period 1997-2008. The two standard deviation (95 percent confidence) uncertainty in comparing recent years is estimated as 0.05°C [Reference 2], so we can only conclude with confidence that 2008 was somewhere within the range from 7th to 10th warmest year in the record.

The map of global temperature anomalies in 2008, Figure 1 (right), shows that most of the world was either near normal or warmer than in the base period (1951-1980). Eurasia, the Arctic and the Antarctic Peninsula were exceptionally warm, while much of the Pacific Ocean was cooler than the long-term average. The relatively low temperature in the tropical Pacific was due to a strong La Nina that existed in the first half of the year. La Nina and El Nino are opposite phases of a natural oscillation of tropical temperatures, La Nina being the cool phase.

Figure 2 (top) provides seasonal resolution of global and low latitude surface temperature, and an index that measures the state of the natural tropical temperature oscillation. The figure indicates that the La Nina cool cycle peaked in early 2008. The global effect of the tropical oscillation is made clear by the average temperature anomaly over the global ocean (Figure 2, bottom). The "El Nino of the century", in 1997-98, stands out, as well as the recent La Nina.

Figure 3 compares 2008 with the mean for the first seven years of this century. Except for the relatively cool Pacific Ocean, most of the world was either near normal or unusually warm in 2008. The temperature in the United States in 2008 was not much different than the 1951-1980 mean, which makes 2008 cooler than all of the previous years this decade. As shown by the right side of Figure 3, most of the United States averaged between 0.5 and 1°C warmer than the long-term mean during 2001-2007.

The GISS analysis of global surface temperature, documented in the scientific literature [References 1 and 2], incorporates data from three data bases made available monthly: (1) the

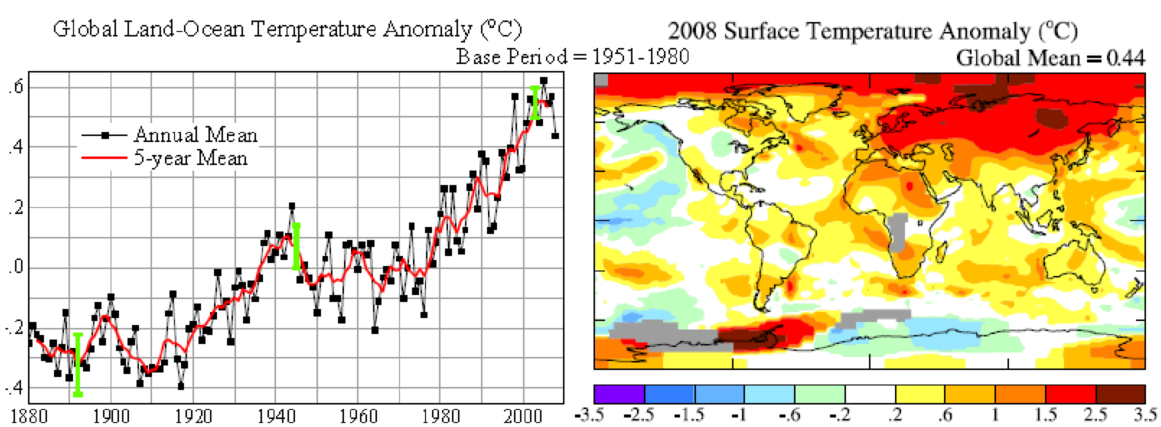

Figure 1. Left: Annual-mean global-mean anomalies. Right: Global map of surface temperature anomalies for 2008.

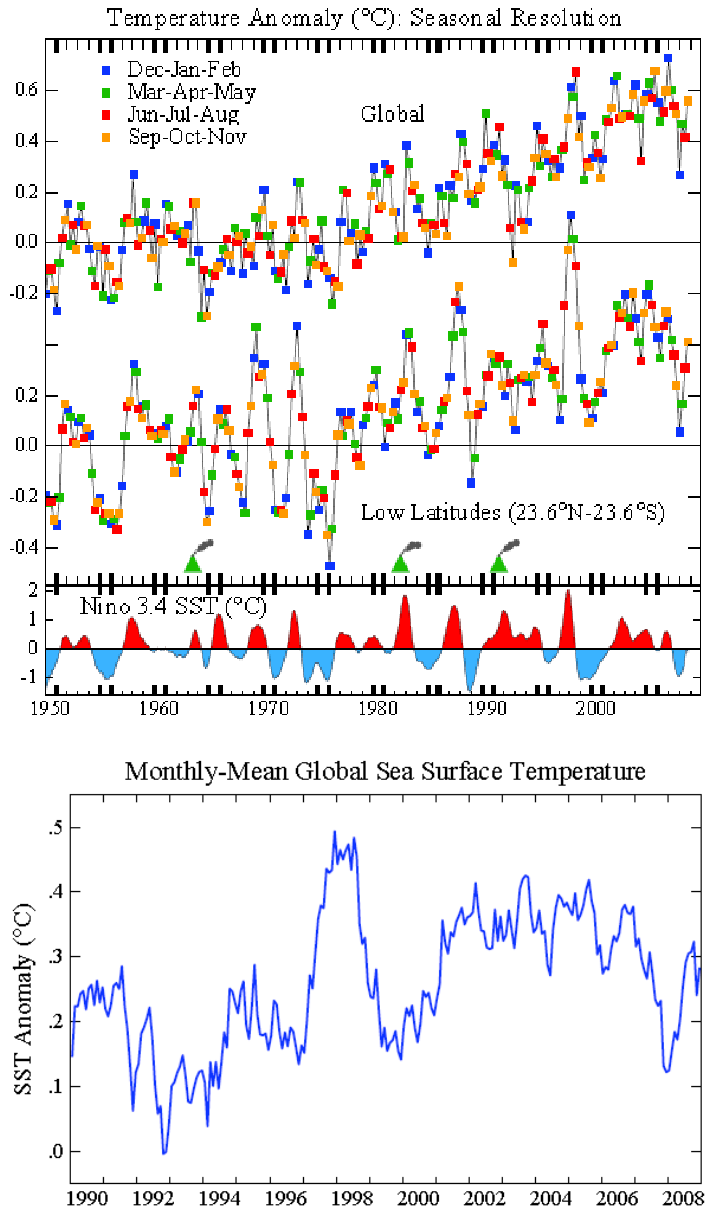

Figure 2. Top: Seasonal-mean global and low latitude temperature anomalies relative to 1951-1980 base period. Bottom: Monthly-mean global-ocean surface temperature anomaly (based on satellite temperature analyses of Reynolds and Smith).

Global Historical Climatology Network (GHCN) of the National Climate Data Center [Reference 3], (2) the satellite analysis of global sea surface temperature of Reynolds and Smith [Reference 4], and (3) Antarctic records of the Scientific Committee on Antarctic Research (SCAR) [Reference 5].

In the past our procedure has been to run the analysis program upon receipt of all three data sets and make the analysis publicly available immediately. This procedure worked very well from a scientific perspective, with the broad availability of the analysis helping reveal any problems with input data sets. However, because confusion was generated in the media after one of the October

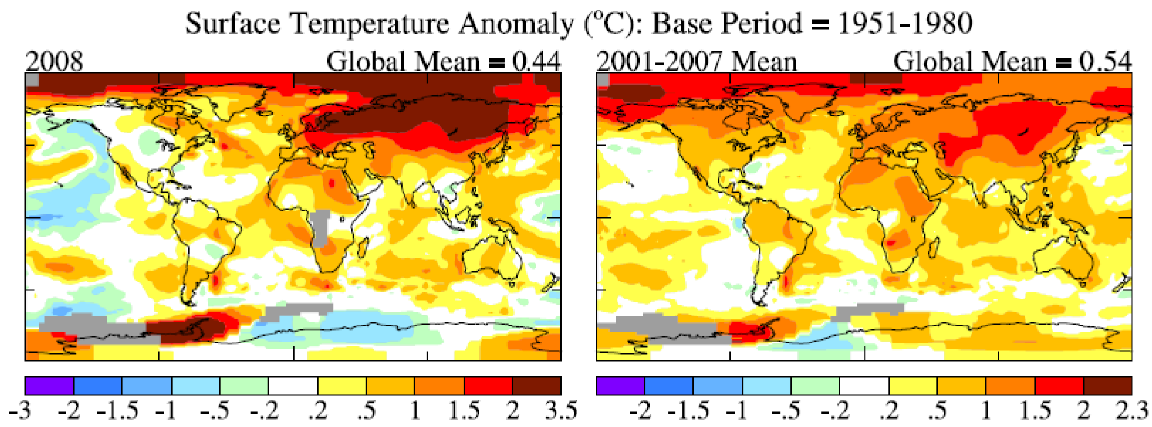

Figure 3. Comparison of 2008 temperature anomalies with the mean 2001-2007 anomalies. Note that this figure uses a slightly different color bar than that of Figure 1 in order to show more structure in the right-hand map.

2008 input data sets was found to contain significant flaws (some October station records inadvertently repeated September data in the October data slot), we have instituted a new procedure. The GISS analysis is first made available internally before it is released publicly. If any suspect data are detected, they will be reported back to the data providers for resolution. This process may introduce significant delays. We apologize for any inconvenience due to this delay, but it should reduce the likelihood of instances of future confusion and misinformation.

Note that we provide the rank of global temperature for individual years because there is a high demand for it from journalists and the public. The rank has scientific significance in some cases, e.g., when a new record is established. However, otherwise rank has limited value and can be misleading. As opposed to the rank, Figure 3 provides much more information about how the 2008 temperature compares with previous years, and why it was a bit cooler (note the change in the Pacific Ocean region).

Finally, in response to popular demand, we comment on the likelihood of a near-term global temperature record. Specifically, the question has been asked whether the relatively cool 2008 alters the expectation we expressed in last year's summary that a new global record was likely within the next 2-3 years (now the next 1-2 years). Response to that query requires consideration of several factors:

1) Natural dynamical variability: the largest contribution is the Southern Oscillation, the El Nino – La Nina cycle. The Nino 3.4 temperature anomaly, bottom of Figure 2 (top), suggests that the La Nina may be almost over, but the anomaly fell back (cooled) to -0.7°C last month (December). It is conceivable that this tropical cycle could dip back into a strong La Nina, as happened, e.g., in 1975. However, for the tropical Pacific to stay in that mode for both 2009 and 2010 would require a longer La Nina phase than has existed in the past half century, so it is unlikely. Indeed, subsurface and surface tropical ocean temperatures suggest that the system is "recharged", i.e., poised, for the next El Nino, so there is a good chance that one may occur in 2009. Global temperature anomalies tend to lag tropical anomalies by 3-6 months.

2) Solar irradiance: the solar irradiance remains low (Figure 4), at the lowest level in the period since satellite measurements began in the late 1970s, and the time since the prior solar minimum is already 12 years, two years longer than the prior two cycles. This has led some people to

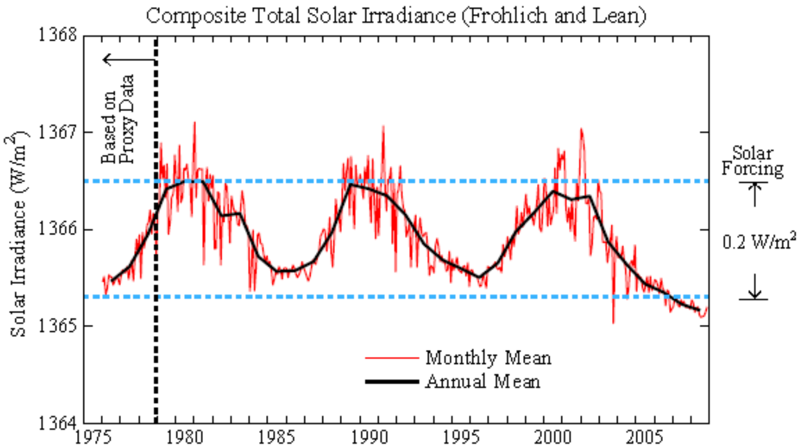

Figure 4. Solar irradiance through November 2008 [Reference 8].

speculate that we may be entering a "Maunder Minimum" situation, a period of reduced irradiance that could last for decades. Most solar physicists expect the irradiance to begin to pick up in the next several months – there are indications, from the polarity of the few recent sunspots, that the new cycle is beginning. However, let's assume that the solar irradiance does not recover: in that case, the negative forcing, relative to the mean solar irradiance is equivalent to seven years of CO_2 increase at current growth rates. So do not look for a new "Little Ice Age" in any case! Assuming that the solar irradiance begins to recover this year, as expected, there is still some effect on the likelihood of a near-term global temperature record due to the unusually prolonged solar minimum. Because of the large thermal inertia of the ocean, the surface temperature response to the 10-12 year solar cycle lags the irradiance variation by 1-2 years. Thus, relative to the mean, i.e, the hypothetical case in which the sun had a constant average irradiance, actual solar irradiance will continue to provide a negative anomaly for the next 2-3 years.

3) Volcanic aerosols: colorful sunsets the past several months suggest a non-negligible stratospheric aerosol amount at northern latitudes. Unfortunately, as noted in the 2008 Bjerknes talk [http://www.columbia.edu/~jeh1/], the instrument capable of precise measurements of aerosol optical depth (SAGE, the Stratospheric Aerosol and Gas Experiment) is sitting on a shelf at Langley Research Center. Stratospheric aerosol amounts are estimated from crude measurements to be moderate. The aerosols from an Aleutian volcano, which is thought to be the primary source, are at relatively low altitude and high latitudes, where they should be mostly flushed out this winter. Their effect in the next two years should be negligible.

4) Greenhouse gases: annual growth rate of climate forcing by long-lived greenhouse gases (GHGs) slowed from a peak close to 0.05 W/m^2 per year around 1980-85 to about 0.035 W/m^2 in recent years due to slowdown of CH_4 and CFC growth rates [Reference 6]. Resumed methane growth, if it continued in 2008 as in 2007, adds about 0.005 W/m^2. From climate models and empirical analyses, this GHG forcing trend translates into a mean warming rate of ~0.15°C per decade.

Summary: the Southern Oscillation and increasing GHGs continue to be, respectively, the dominant factors affecting interannual and decadal temperature change. Solar irradiance has a non-negligible effect on global temperature [see, e.g., Reference 7, which empirically estimates a somewhat larger solar cycle effect than that estimated by others who have teased a solar effect out of data with different methods]. Given our expectation of the next El Nino beginning in 2009 or 2010, it still seems likely that a new global temperature record will be set within the next 1-2 years, despite the moderate negative effect of the reduced solar irradiance.

References

1. Hansen, J., R. Ruedy, J. Glascoe, M. Sato, GISS analysis of surface temperature change, J. Geophys. Res. 104, 30997-31022, 1999.
2. Hansen, J., M. Sato, R. Ruedy, K. Lo, D.W. Lea, M. Medina-Elizade, Global temperature change, Proc. Natl. Acad. Sci. 103, 14288-14293, 2006.
3. Peterson, T.C., R.S. Vose, An overview of the Global Historical Climatology Network temperature database, Bull. Amer. Meteorol. Soc.78, 2837-2849, 1997.
4. Reynolds, R.W., T.M. Smith, Improved global sea surface temperature analyses, J. Clim. 7, 929-948, 1994.
5. Scientific Committee on Antarctic Research (SCAR), http://www.scar.org/
6. Hansen, J., M. Sato, Greenhouse gas growth rates, Proc. Natl. Acad. Sci. 101, 16109-16114, 2004.
7. Tung, K.K., J. Zhou, C.D. Camp, Constraining model transient climate response using independent observations of solar-cycle forcing and response, Geophys. Res. Lett. 35, L17707, doi:10.1029/2008GL034240, 2008.
8. Frohlich, C., J. Lean, Solar radiative output and its variability: Evidence and mechanisms. Aston. Astrophys. Rev. 12, 273-320, 2004.
9. Hansen, J.E., Climate Threat to the Planet: Implications for Energy Policy and Intergenerational Justice. Bjerknes Lecture presented at American Geophysical Union, San Fransisco, on Dec. 17, 2008. (Available at www.columbia.edu/~jeh1.)