Global Surface Temperature Change

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Abstract. We update the Goddard Institute for Space Studies (GISS) analysis of global surface temperature change, compare alternative analyses, and address questions about perception and reality of global warming. Satellite-observed nightlights are used to identify measurement stations located in extreme darkness and adjust temperature trends of urban and peri-urban stations for non-climatic factors, verifying that urban effects on analyzed global change are small. Because the GISS analysis combines available sea surface temperature records with meteorological station measurements, we test alternative choices for the ocean data, showing that global temperature change is sensitive to estimated temperature change in polar regions where observations are limited. We use simple 12-month (and n×12) running means to improve the information content in our temperature graphs. Contrary to a popular misconception, the rate of warming has not declined. Global temperature is rising as fast in the past decade as in the prior two decades, despite year-to-year fluctuations associated with the El Nino-La Nina cycle of tropical ocean temperature. Record high global 12-month running-mean temperature for the period with instrumental data was reached in 2010.

10. Summary Discussion

Human-made climate change has become an issue of surpassing importance to humanity, and global warming is the first order manifestation of increasing greenhouse gases that are predicted to drive climate change. Thus it is understandable that analyses of ongoing global temperature change are now subject to increasing scrutiny and criticisms that are different than would occur for a purely scientific problem.

Our comments here about communication of this climate change science to the public are our opinion. Other people may have quite different opinions. We offer our opinion because it seems inappropriate to ignore the vast range of claims appearing in the media and in hopes that open discussion of these matters may help people distinguish the reality of global change sooner than would otherwise be the case. However these comments, even though based on experience over a few decades, are only opinion. Our primary contribution is quantitative results discussed in the numbered paragraphs below.

Communication of the status of global warming to the public has always been hampered by weather variability. Lay people's perception tends to be strongly influenced by the latest local fluctuation. This difficulty can be alleviated by stressing the need to focus on the frequency and magnitude of warm and cold anomalies, which change noticeably on decadal time scales as global warming increases.

Other obstacles to public communication include the media's difficulty in framing long-term problems as 'news', a preference for sensationalism, a generally low level of familiarity with basic science, and a preference for 'balance' in every story. The difficulties are compounded by the politicization of reporting of global warming, a perhaps inevitable consequence of economic and social implications of efforts required to alter the course of human-made climate change.

The task of alleviating the communication obstacle posed by politicization is formidable, and it is made more difficult by attacks on the character and credibility of scientists [for example: http://mediamatters.org/blog/200911290004 and http://mediamatters.org/mmtv/201001290037].

Polls indicate that the attacks have been effective in causing many members of the public to doubt the reality or seriousness of global warming [http://www.gallup.com/poll/126560/americans-global-warming-concerns-continue-drop.aspx].

Given this situation, the best hope may be repeated clear description of the science and passage of sufficient time to confirm validity of the description. A problem with that prescription is the danger that the climate system could pass tipping points that cause major climate changes to proceed largely out of humanity's control [*Hansen et al.*, 2008]. Yet continuation of careful scientific description of ongoing climate change seems to be essential for the sake of minimizing the degree of future climate change, even while other ways are sought to draw attention to the dangers of continued greenhouse gas increases.

One lesson we have learned is that making our global data analysis immediately available, with data use by ourselves and others helping to reveal flaws in the input data, has a practical disadvantage: it allows any data flaws to be interpreted and misrepresented as machinations. Yet the data are too useful for scientific studies to be kept under wraps, so we will continue to make the data available on a monthly basis. But we are making special efforts to make the process as transparent as possible, including availability of the computer program that does the analysis, the data that goes into the analysis (also available from original sources), and detailed definition of urban adjustment of meteorological station data.

Our principal task remains the scientific one – describing ongoing global temperature change with as much clarity and insight as we can. Contributions of the present paper include:

(1) Insight into why the GISS analysis yields 2005 as the warmest calendar year, while the HadCRUT analysis has 1998 as the warmest year. The main factor is our inclusion of estimated temperature change for the Arctic region. We note that SST change cannot be used as a measure of surface air temperature change in regions of sea ice, and that surface air temperature change is the quantity of interest both for its practical importance to humans and for comparison with the results that are usually reported in global climate model studies.

(2) Twelve-month (and n×12-month) running mean temperatures provide more information than the usual graphs with calendar-year mean temperature. The magnitude and duration of global temperature effects of volcanoes and the Southern Oscillation can be seen much more clearly in a 12-month running mean graph such as Figure 10. The simplicity of the running mean, compared to filtered time series, is helpful for public communications.

(3) The 12-month running mean global temperature in the GISS analysis has reached a new record in 2010. The new record temperature in 2010 is particularly meaningful because it occurs when the recent minimum of solar irradiance (*Frohlich*, 2006; data at **http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant)** is having its maximum cooling effect. At the time of this writing (July 2010) the tropical Pacific Ocean is changing from El Nino to La Nina conditions in the tropical Pacific Ocean. It is likely that global temperature for calendar year 2010 will reach a record level for the period of instrumental data, but that is not certain if La Nina conditions deepen rapidly.

(4) The cool weather anomalies in the United States in Jun-Jul-Aug 2009 and in both the United States and northern Eurasia in the following Dec-Jan-Feb are close to the cool extreme of the range of seasonal temperatures that are now expected (Figure 17) given the warming of the past few decades. Although comparably cool conditions could occur again sometime during the next several years, the likelihood of such event is low in any given year and it will continue to decrease as global warming continues to increase.

(5) We suggest a new procedure for use of satellite SST data that takes advantage of the high spatial resolution and broad coverage of satellite observations but avoids the bias in the temperature trend in satellite data [*Reynolds et al.*, 2002, 2010]. We adjust the satellite data by a small constant such that the monthly temperature anomalies of satellite and in situ data are equal over their common area. This procedure is used in our current ERSST+OI analysis. We continue to also provide our HadISST1+OI analysis, without such adjustment, as our standard data product. Because of a cold bias in unadjusted OI data, global warming in ERSST+OI exceeds that in HadISST1+OI by about 0.04°C in 2010. Further study is needed to verify which of these data products is superior. Other improvements of the ocean data sets may become available in the near future. For example, none of the publicly available global data sets corrects as yet for a discontinuity in ocean data that has been suggested to exist near the end of World War II [*Thompson et al.*, 2008]. However, note that none of these adjustments or uncertainties is large enough to alter any of our major conclusions in this paper.

(6) Global warming on decadal time scales is continuing without letup. Figure 8, showing decadal mean temperature anomalies, effectively illustrates the monotonic and substantial warming that is occurring on decadal time scales. But because it is important to draw attention to change as soon as possible, we need ways to make the data trends clear without waiting for additional decades to pass. Figure 21 shows the 60-month (5-year) and 132-month (11-year) running means of global temperature. The 5-year mean is sufficient to minimize ENSO variability, while the 11-year mean also minimizes the effect of solar variability. Figure 21 gives the lie to the frequent assertion that "global warming stopped in 1998". Of course it is possible to find almost any trend for a limited period via judicious choice of start and end dates of a data set that has high temporal resolution, but that is not a meaningful exercise. Even a more moderate assessment, "the trend in global surface temperature has been nearly flat since the late 1990s despite continuing increases in the forcing due to the sum of the well-mixed greenhouse gases" [*Solomon et al.*, 2009], is not supported by our data. On the contrary, we conclude that there has been no reduction in the global warming trend of 0.15-0.20°C/decade that began in the late 1970s.

The draft paper "Global Surface Temperature Change" by Hansen, Ruedy, Sato and Lo is available at http://data.giss.nasa.gov/gistemp/paper/gistemp2010_draft0601.pdf. This is an improved version of the paper "Current GISS Global Surface Temperature Analysis" that I made available 19 March (www.columbia.edu/~jeh1).

Thanks very much to Nick Rayner, Dick Reynolds and others for comments on the first version.

We will be submitting the paper to Reviews of Geophysics at the invitation of the editors. Criticisms of this version are welcome. Below is the final section of the paper. I have included some discussion about the difficulty of communication on this topic – which may not survive, depending upon advice of editors.

Several of the more interesting charts are collected on two PowerPoint posters available at http://www.columbia.edu/~jeh1/2010/201006_JamboreePosters.ppt.

10. Summary Discussion

Human-made climate change has become an issue of surpassing importance to humanity, and global warming is the first order manifestation of increasing greenhouse gases that are predicted to drive climate change. Thus it is understandable that analyses of ongoing global temperature change are now subject to increasing scrutiny and criticisms that are different than would occur for a purely scientific problem.

Our comments here about communication of this climate change science to the public are our opinion. Other people may have quite different opinions. We offer our opinion because it seems inappropriate to ignore the vast range of claims appearing in the media and in hopes that open discussion of these matters may help people distinguish the reality of global change sooner than would otherwise be the case. However these comments, even though based on experience over a few decades, are only opinion. Our primary contribution is quantitative results discussed in the numbered paragraphs below.

Communication of the status of global warming to the public has always been hampered by weather variability. Lay people's perception tends to be strongly influenced by the latest local fluctuation. This difficulty can be alleviated by stressing the need to focus on the frequency and magnitude of warm and cold anomalies, which change noticeably on decadal time scales as global warming increases.

A greater obstacle to public communication has arisen with the politicization of reporting of global warming, a perhaps inevitable consequence of the economic and social implications of efforts required to alter the course of human-made climate change. We have the impression that the effect of politicization on communication of the science is aggravated by the fact that much of the media is owned by or strongly influenced by special economic interests.

The task of alleviating the communication obstacle posed by politicization is formidable. The difficulty is compounded by continual attacks on the credibility of scientists. Polls indicate that the attacks have been effective in causing many members of the public to doubt the reality of global warming.

Given this situation, the best hope may be repeated clear description of the science and passage of sufficient time to confirm validity of the description. A problem with that prescription is the danger that the climate system could pass tipping points that cause major climate changes to proceed largely out of humanity's control [*Hansen et al.*, 2008]. Yet continuation of this approach seems to be essential for the sake of minimizing the degree of inevitable climate change, even while other ways are sought to draw attention to the dangers of continued greenhouse gas increases.

One lesson we have learned is that making our global data analysis immediately available, with data use by ourselves and others helping to reveal flaws in the input data, has a practical disadvantage: it allows any data flaws to be interpreted and misrepresented as machinations. Yet the data are too useful for scientific studies to be kept under wraps, so we will continue to make the data available on a monthly basis. But we are making special efforts to make the process as transparent as possible, including availability of the computer program that does the analysis, the data that goes into the analysis (also available from original sources), and detailed definition of urban adjustment of meteorological station data.

Our principal task remains the scientific one; trying to describe with increasing clarity and insight the global temperature change that is occurring. Contributions of the present paper include:

(1) insight into why the GISS analysis yields 2005 as the warmest calendar year, while the HadCRUT analysis has 1998 as the warmest year. The main factor is our inclusion of estimated temperature change for the Arctic region. We note that SST change cannot be used as a measure of surface air temperature change in regions of sea ice, and that surface air temperature change is the quantity of interest both for its practical importance to humans and for comparison with the results that are usually reported in global climate model studies.

(2) 12-month (and n×12-month) running mean temperatures provide more information than the usual graphs with calendar-year mean temperature. The 12-month running mean fully removes the annual cycle, which exists even in temperature anomaly time series. The magnitude and duration of global temperature effects of volcanoes and the Southern Oscillation can be seen much more clearly in a 12-month running mean graph such as Figure 10.

(3) the 12-month running mean global temperature in the GISS analysis has reached a new record in 2010. The new record temperature in 2010 is particularly meaningful because it occurs when the recent minimum of solar irradiance (*Frohlich*, 2006; data at **http://www.pmodwrc.ch/pmod.php?topic=tsi/composite/SolarConstant)** is having its maximum cooling effect. At the time of this writing (May 2010) the tropical Pacific Ocean has changed from El Nino conditions to ENSO-neutral and is likely headed into the cool La Nina phase of the Southern Oscillation. The 12-month running mean global temperature (Figure 9b) may continue to rise for a few more months before the ENSO change causes the next decline. It is likely that global temperature for calendar year 2010 will exceed the 2005 record, but that is not certain if a deep La Nina develops quickly.

(4) the cool weather anomalies in the United States in Jun-Jul-Aug 2009 and in both the United States and northern Eurasia in the following Dec-Jan-Feb are close to the cool extreme of the range of seasonal temperatures that are now expected (Figure 17) given the warming of the past few decades. Although comparably cool conditions could occur again sometime during the next several years, the likelihood of such event is low in any given year and it will continue to decrease as global warming continues to increase.

(5) we suggest a new procedure for use of satellite SST data that takes advantage of the high spatial resolution and broad coverage of satellite observations but avoids the bias in the temperature trend in satellite data [*Reynolds et al.*, 2002, 2010]. We adjust the satellite data by a small constant such that the monthly temperature anomalies of satellite and in situ data are equal over their common area. This procedure is used in our current ERSST+OI analysis. We continue to also provide our HadISST1+OI analysis, without such adjustment, as our standard

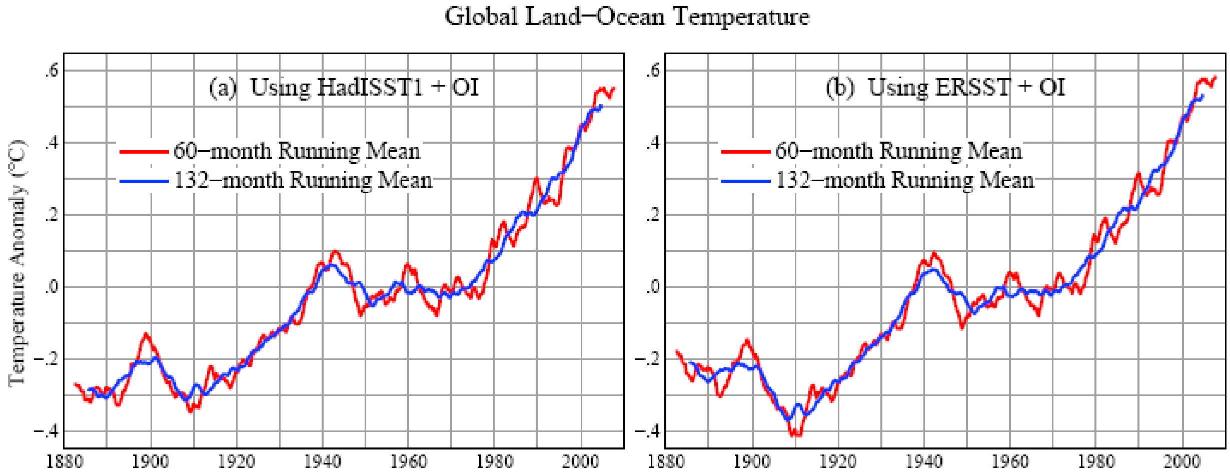

Figure 21. 60-month and 132-month running means through April 2010 for two alternative choices for the ocean data set.

data product. Because of a cold bias in unadjusted OI data, global warming in ERSST+OI exceeds that in HadISST1+OI by about 0.04°C by 2010. Further study is needed to verify which of these data products is superior. It is likely that other improvements of the ocean data sets will be available in the near future. For example, none of the publicly available global data sets corrects as yet for a data discontinuity that occurs near the end of World War II [*Thompson et al.*, 2008]. Note that none of these adjustments or uncertainties is large enough to alter any of our major conclusions in this paper.

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