

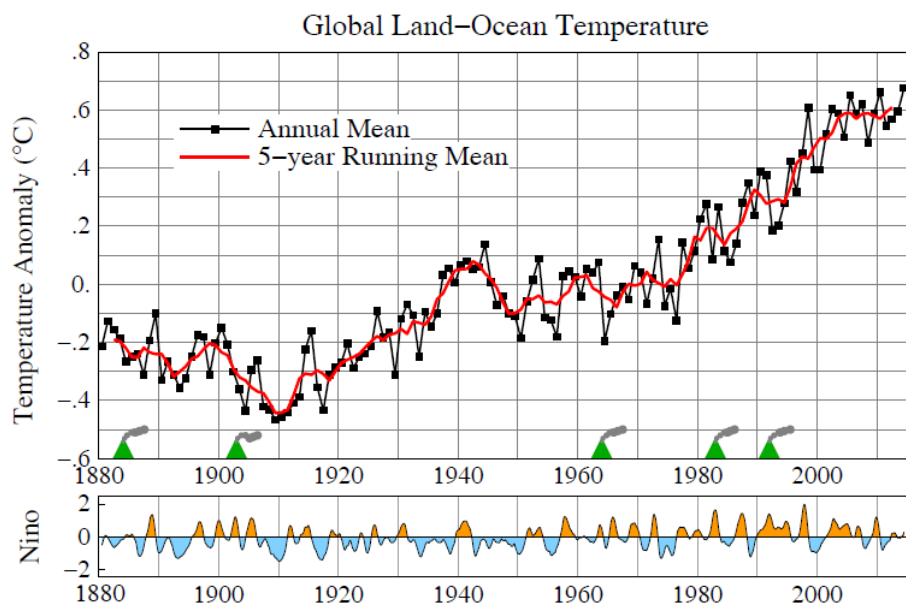
# Global Temperature in 2014 and 2015

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**Abstract.** Global surface temperature in 2014 was  $+0.68^{\circ}\text{C}$  ( $\sim 1.2^{\circ}\text{F}$ ) warmer than the 1951-1980 base period in the GISTEMP analysis, making 2014 the warmest year in the period of instrumental data, but the difference from the prior warmest year (2010), less than  $0.02^{\circ}\text{C}$ , is within uncertainty of measurement. The eastern two-thirds of the contiguous United States was persistently cool in 2014, cooler than the 1951-1980 average in all seasons. Record warmth at a time of only marginal El Niño conditions confirms that there is no “hiatus” of global warming, only a moderate slowdown since 2000. Global temperature in 2015 may further alter perceptions. We discuss the prospects for the 2015 global temperature in view of the seeming waning of the current weak El Niño.

Update of the GISS (Goddard Institute for Space Studies) global temperature analysis (GISTEMP)<sup>1,2</sup> (Fig. 1), finds 2014 to be the warmest year in the instrumental record. (More detail is available at <http://data.giss.nasa.gov/gistemp/> and <http://www.columbia.edu/~mhs119/>; Figs. 2-7 here are available on the latter web site.) The three warmest years in the GISTEMP analysis, 2014, 2010, and 2005 in that order, can be considered to be in a statistical tie because of several sources of uncertainty, the largest source being incomplete spatial coverage of the data. Similarly the next warmest years in our analysis, 1998, 2002, 2003, 2006, 2007, 2009 and 2013, can be taken as a statistical tie for the 4<sup>th</sup> through the 10<sup>th</sup> in our analysis. The 15 warmest years all occurred since 1998 (including 1998). Year-to-year temperature fluctuations in Fig. 1 are caused mainly by natural oscillations of tropical Pacific sea surface temperatures as summarized by the El Niño-Southern Oscillation (ENSO or Niño) index (lower part of Fig. 1), which we discuss further below.

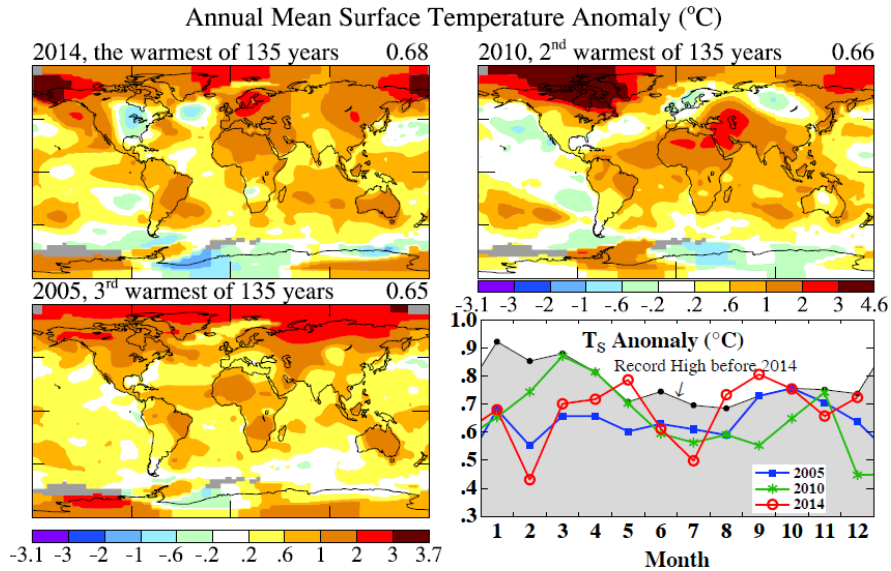


**Fig. 1.** Global surface temperatures relative to 1951-1980. ENSO index (12-month running mean) is based on sea surface temperature in Niño 3.4 area (5N-5S, 120-170W) in tropical Pacific<sup>3</sup> for 1951-1980 base period. Green triangles mark volcanic eruptions producing an extensive stratospheric aerosol layer.

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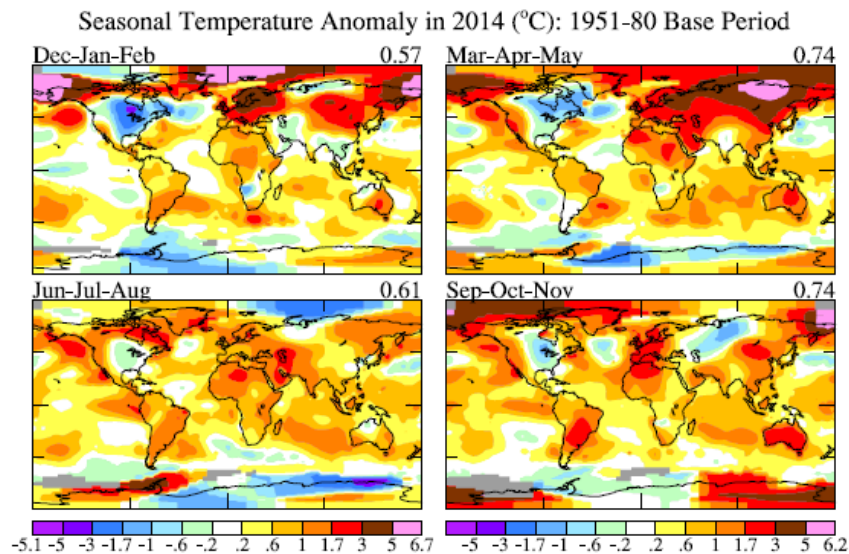
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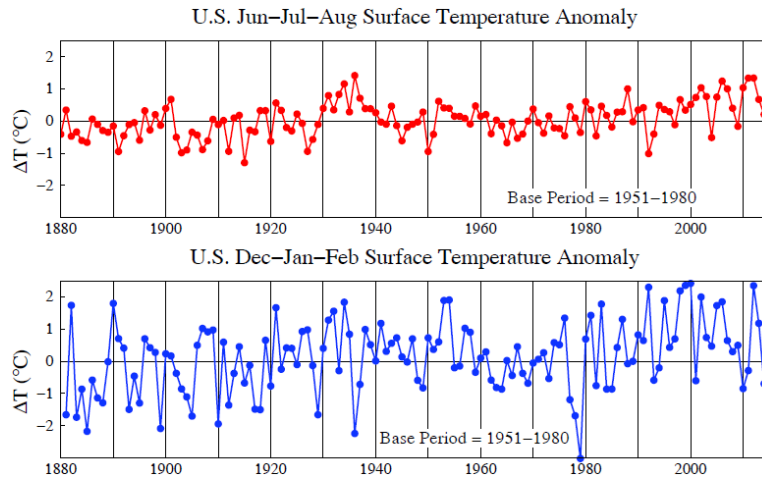
**Fig. 2.** Temperature anomalies in the three warmest years and their monthly global anomalies.

Residents of the eastern two-thirds of the United States and Canada might be surprised that 2014 was the warmest year, as they happened to reside in an area with the largest negative temperature anomaly on the planet, except for a region in Antarctica, as shown by the map in the upper left of Fig. 2. The North American cold anomaly in 2014 contrasts with the other two warmest years, 2010 and 2005, when North America and almost all land areas had annual temperatures above the 1951-1980 climatology (Fig. 2). The cold pattern in North America persisted through all four seasons in 2014 (Fig. 3).

Natural variability of regional temperature, even averaged over a three-month season, is larger than the global warming that has occurred since the 1951-1980 base period (Fig. 1). Illustration of regional variability is provided by the average seasonal temperature anomaly for the contiguous 48 states of the United States (Fig 4), whose area is about 1.5% of the global area. The interannual variability is about twice as large in winter (Dec-Jan-Feb mean) as in summer (Jun-Jul-Aug). Thus, even though winter warming is larger than summer warming, the chances of having a season colder than the 1951-1980 climatology are larger in winter than in summer. For example, in the past 15 years (2000-2014) the mean summer anomaly in the U.S. is  $+0.69^{\circ}\text{C}$  and the winter anomaly is  $+0.78^{\circ}\text{C}$ , yet there are only two summers cooler than climatology, but four winters cooler than climatology.



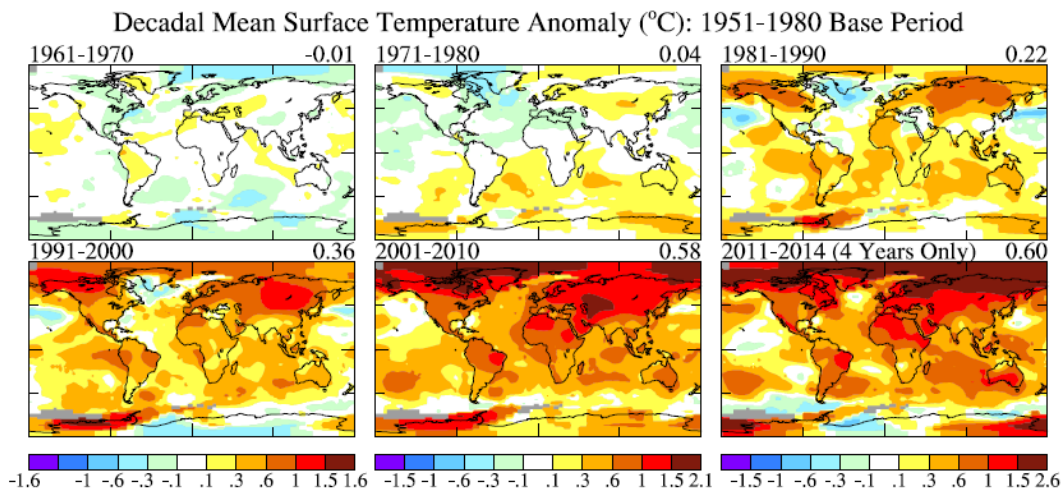
**Fig. 3.** Seasonal-mean temperature anomalies. Dec-Jan-Feb map employs December 2013 data.



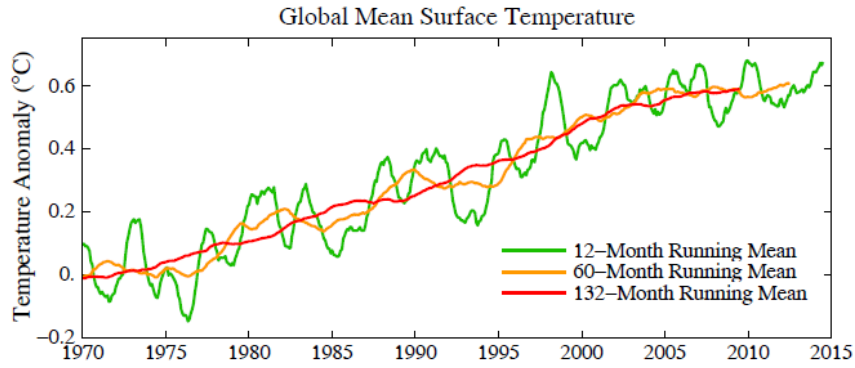
**Fig. 4.** Seasonal-mean temperature anomalies for the contiguous 48 United States.

Decadal averages display the nature of global warming patterns clearly (Fig. 5). Warming is larger over land than over ocean and greater at high latitudes than low latitudes, consistent with expectations for climate change driven primarily by increasing greenhouse gases<sup>4</sup>. Each of the past several complete decades has been notably warmer than the prior decade, but that remains to be seen for the current decade.

The rate of global warming has been less since 2000 than in the prior 30 years (Fig. 6). Whether there has been a significant change in the long-term warming rate must await additional data, but the apparent slowdown has led to numerous assertions that “global warming has stopped.” Fig. 6 confirms that there has been little increase of the 60-month (5-year) and 132-month (11-year) running means in the past decade, although it is not obvious that such a slowdown is outside the norm of unforced decadal variability. Although there have been many suggestions for possible contributions to the slowdown of the recent warming rate<sup>5</sup>, a reduced warming rate of the Pacific sea surface temperature seems to be a significant factor. Kosaka and Xie<sup>6</sup> made global climate simulations in which they inserted specified observed Pacific Ocean temperatures; they found that the model simulated well the observed global warming slowdown or “hiatus”, although this experiment does not identify the cause of Pacific Ocean temperature trends. England et al.<sup>7</sup> suggest that the recent Pacific Ocean surface temperature anomalies are related to a strengthening of Pacific trade winds in the past two decades, and that warming is likely to accelerate as the trade wind anomaly abates. In any event, we can anticipate that global warming will continue on decadal time scales, because Earth is out of energy balance – more energy coming in than going out – as a result of increased atmospheric greenhouse gases, especially carbon dioxide<sup>4, 8</sup>.



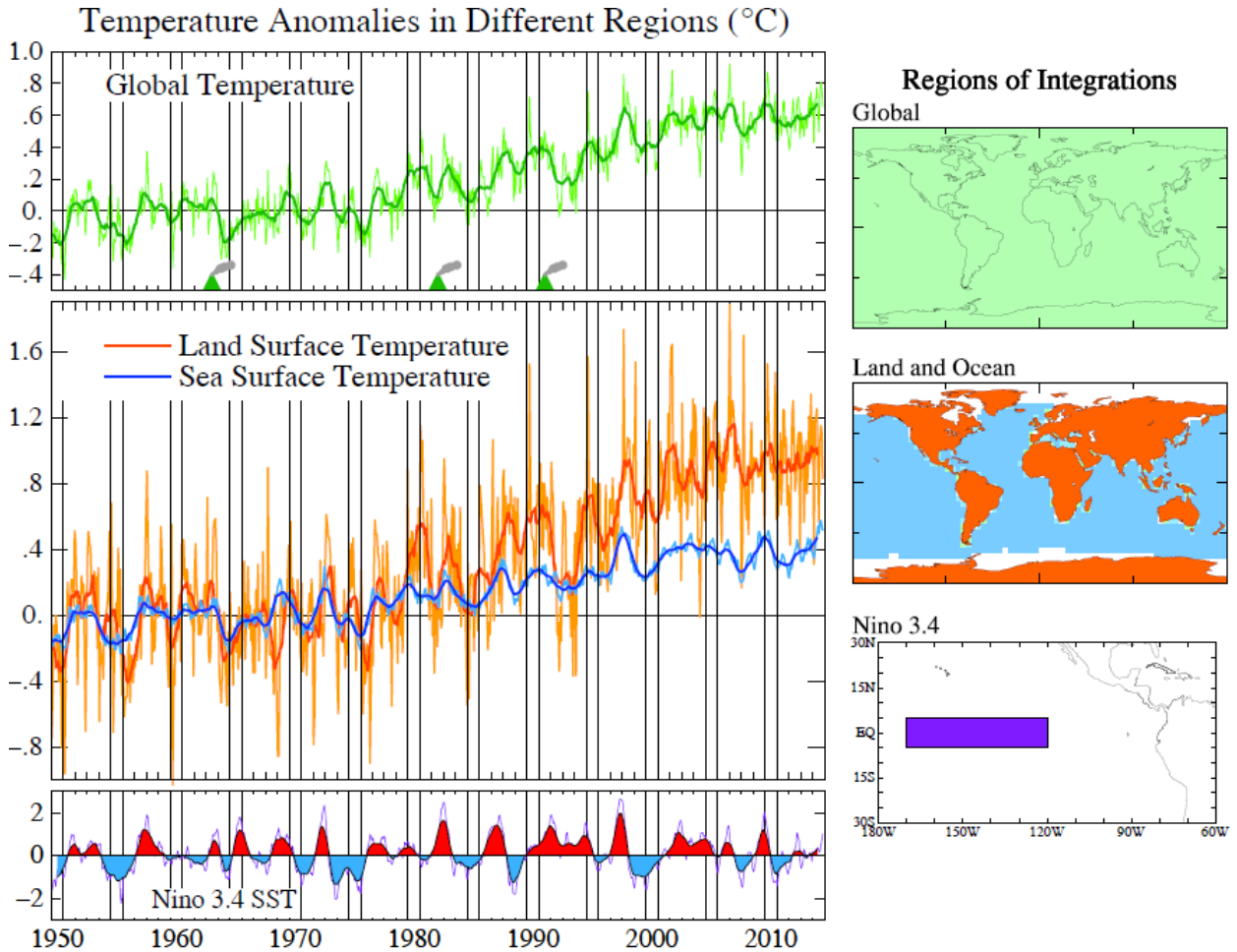
**Fig. 5.** Decadal surface temperature anomalies relative to 1951-1980 base period.



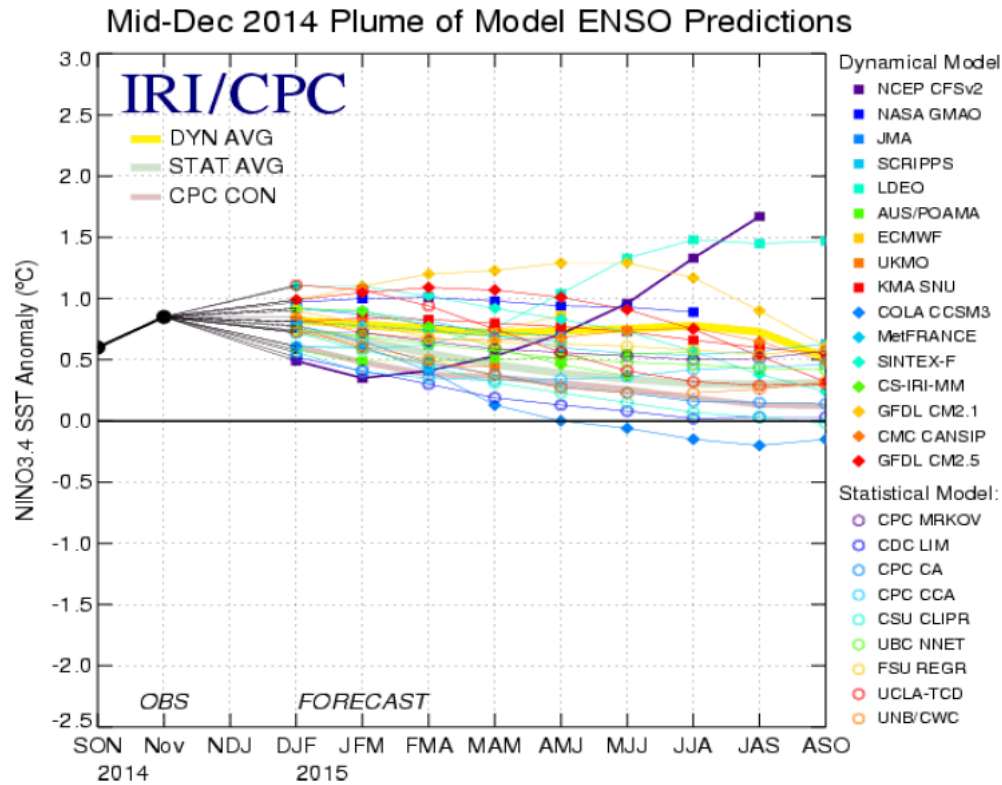
**Fig. 6.** 12-month, 60-month and 132-month running means of global surface temperature.

Global SSTs (blue line in Fig. 7) are now near the level reached at the peak of the 1998 “El Niño of the century.” Land temperature (gold line) is now consistently 1.0°C or more warmer than in 1951-1980.

It is of interest to know whether global warming will become more apparent in the near-term. It is notable that the record global warmth of 2014 was achieved in a year in which the tropical Pacific Ocean surface temperatures were in a nearly ENSO (El Niño Southern Oscillation) neutral or very weak El Niño state (Fig. 1). There is a high correlation of global temperature with the Niño index, global temperature lagging the Niño index by a few months (Fig. 1). Thus it is expected, as a consequence of the slightly elevated Niño index, that the 12-month running mean global temperature will continue to rise in the next few months to its highest level in the record, even if the recent weak El Niño continues to fade away.



**Fig. 7.** Monthly and 12-month running means temperatures and Niño index.



**Fig. 8.** IRI/CPC Pacific Niño 3.4 SST Model Outlook (<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml#discussion>).

Furthermore, it is possible that the ENSO warming trend that has occurred since the 2011 La Niña may not have run its course. There could be a surge this coming Northern Hemisphere Spring, the season in which Nature tends to roll the El Niño dice<sup>3</sup>, to a strong El Niño. Sea surface temperatures in the Western Pacific are well above climatology, and it has been argued<sup>9</sup> that the warmth in the Western Pacific along with the lack of an equivalent long-term warming trend in the Eastern Pacific, increase the chances of a “super El Niño”, comparable to the two strongest El Niños of the past century, which occurred in 1998 and 1983. If 2015 is significantly warmer than 2014, there is clearly no hiatus.

So, what do dynamical ENSO models predict? Two models, LDEO (Lamont Doherty Earth Observatory) and NCEP (National Center for Environmental Prediction), indeed predict a strong swing next spring to a strong El Niño (Fig. 8). All the other models have the El Niño petering out. We asked an ENSO expert, Mark Cane: “What is the physics behind the LDEO and NCEP forecasts that makes them so opposite to the other models?” His response: “Good question. The honest answer is that I don’t know, and neither does anyone else. LDEO is an intermediate model of just the tropical Pacific, NCEP is a full coupled GCM. There may be no salient differences in the physics of these vs. the rest; it may have to do with the initialization schemes. ...If it is physics, my best guess is that the LDEO and NCEP models have a stronger thermocline feedback than the others. It will be interesting to see how 2015 develops.”

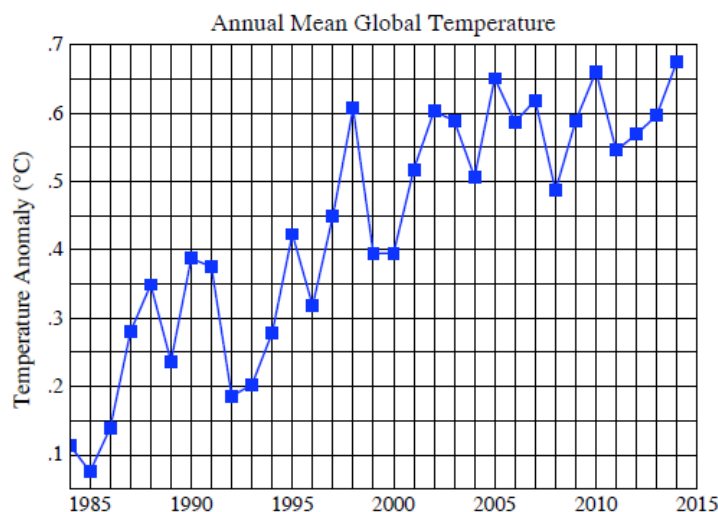
**Summary.** Record global temperature in 2014, achieved with little assistance from the tropical ENSO cycle, confirms continuing global warming. More warming is expected in coming years and decades as a result of Earth’s large energy imbalance, more energy coming in than going out<sup>d</sup>, and with the help of even a mild El Niño 2015 may be significantly warmer than 2014.

<sup>d</sup> The measured planetary energy imbalance (0.6 W/m<sup>2</sup>) equals the amount of energy in exploding 400,000 Hiroshima atomic bombs per day, 365 days/year. A better analogy (from Sarah Purkey and Greg Johnson): it is the amount of energy if every person on Earth runs 44 1000-Watt hair dryers 24 hours/day, 365 days/year.

## Appendix

**Table 1. Rankings of annual global temperature in the GISTEMPS analysis.**

2014	0.68 (0.675)	Statistical Tie 1-3
2010	0.66 (0.661)	Tie 1-3
2005	0.65 (0.651)	Tie 1-3
2007	0.62 (0.619)	Tie 4-10
1998	0.61 (0.607)	Tie 4-10
2002	0.60 (0.603)	Tie 4-10
2013	0.60 (0.596)	Tie 4-10
2009	0.59 (0.589)	Tie 4-10
2003	0.59 (0.589)	Tie 4-10
2006	0.59 (0.587)	Tie 4-10



**Fig. 9.** Expanded recent temperatures to clarify year-to-year changes.

## References

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