Global Temperature in 2019

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Abstract. Global surface temperature in 2019 was the 2\textsuperscript{nd} highest in the period of instrumental measurements in the Goddard Institute for Space Studies (GISS) analysis. The rate of global warming has accelerated in the past decade. The 2019 global temperature was +1.2°C (~2.2°F) warmer than in the 1880-1920 base period; global temperature in that base period is a reasonable estimate of ‘pre-industrial’ temperature. The five warmest years in the GISS record all occur in the past five years, and the 10 warmest years are all in the 21\textsuperscript{st} century. Growth rates of the greenhouse gases driving global warming are increasing, not declining.

Update of the GISS (Goddard Institute for Space Studies) global temperature analysis (GISTEMP\textsuperscript{1,2,3}) (Fig. 1), finds 2019 to be the 2\textsuperscript{nd} warmest year in the instrumental record. More detail is available at http://data.giss.nasa.gov/gis temp/ and http://www.columbia.edu/~mhs119/Temperature. Figures shown here are available from Makiko Sato on the latter web site.

We use 1880-1920 as baseline, i.e., as the zero-point for temperature anomalies, in part because it is the earliest period with substantial global coverage of instrumental measurements. Global temperature in 1880-1920 should approximate ‘preindustrial’ temperature, because the small warming from human-made greenhouse gases in that period tends to be offset by unusually high volcanic activity then\textsuperscript{4}.

The five warmest years in the GISS record are the past five years, 2015-2019. 2014 is the 6\textsuperscript{th} warmest year, but its temperature is practically indistinguishable from that of 2010. Figure 2 compares the temperature anomalies for each of these years relative to the 1951-1980 base period. We use 1951-1980 as base period for global maps because it allows good global coverage, including data for Antarctica.

![Global Surface Temperature Relative to 1880–1920 Mean](image)

\textbf{Fig. 1.} Global surface temperatures relative to 1880-1920 based on GISTEMP data, which employs GHCN.v4 for meteorological stations, NOAA ERSST.v5 for sea surface temperature, and Antarctic research station data\textsuperscript{1}.

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Fig. 2. Temperature anomalies in the past six years relative to the 1951-1980 base period.

Decadal average surface temperature anomalies (Fig. 3) show that since the 1970s each decade has been notably warmer than the prior decade. Average warming over land is twice as large as over ocean, and warming is greatest in the Arctic (Figs. 2 and 3). Average warming over land is now about 3°F (more than 1.5°C). The warming is reaching magnitudes at which it is easier for the public to notice that warming is occurring, even though it is small compared with the magnitude of weather fluctuations.

Cooling or absence of warming southeast of Greenland and in the Southern Ocean surrounding Antarctica is associated with and likely a consequence of injection of freshwater in the upper ocean layers as a result of increasing melt of ice shelves and the ice sheets. If the melting rate continues to increase, the associated regional cooling will increase and may put a damper on (slow the rate of) global warming. That relative cooling effect, if it occurs, would be no cause for celebration, as it would imply an increased heat flux into the ocean, an increased warming rate within the ocean that further increases the melt of ice shelves, and an accelerating rate of sea level rise.5

Fig. 3. Temperature anomalies relative to 1880-1920 for global land and global ocean areas.
Fig. 4. Global surface temperature since 1960 relative to the 1880-1920 base period. The red-blue diagram is the Niño3.4 index, which is the temperature in a region along the equator in the Pacific Ocean used to characterize the El Niño status. Green triangles mark volcanic eruptions that produced a large amount of stratospheric aerosols.

Interannual variability of global temperature is highly correlated with the tropical Southern Oscillation, the El Niño/La Niña cycle (Fig. 4). The rate of warming had been almost constant for several decades, at about 0.18°C/decade, if short-term variability is removed by 132-month (11-year) running mean (Fig. 4). However, data for the past several years suggest that the warming rate may be accelerating.

Global warming is linked to increasing long-lived atmospheric greenhouse gases, especially CO₂ and CH₄, and in turn these are linked to a substantial degree with fossil fuel use. Thus we also update here fossil fuel CO₂ emissions, CO₂ and CH₄ growth rates, and the resulting growth rate of greenhouse gas climate forcing. The latest data on global energy use and fossil fuel emissions (Fig. 5) are through December 2018. Greenhouse gases are up-to-date within a few months, and are estimated to the end of 2019, as is the resulting climate forcing. Energy use and CO₂ emissions are continuing to rise (Fig. 5).

Fig. 5. Global energy consumption and fossil fuel emissions through December 2018. Energy is based on Boden et al. to 1965 and BP subsequently. CO₂ is based on Boden through 2014 and subsequently BP.
Annual growth of atmospheric CO₂ has increased from less than 1 ppm (parts per million) per year when Keeling began his measurement in the late 1950s to about 2.5 ppm per year averaged over the past several years (Fig. 6). The CO₂ growth rate has a strong correlation with the global temperature anomaly with CO₂ lagging the temperature by 10 months. This suggests that the CO₂ growth rate may increase in 2020, but this is uncertain because the recent tropical and global warming was weak (Fig. 4).

The annual growth of atmospheric CH₄, after falling to near zero in the early 21st century, has increased to about 10 ppb (Fig. 7). Mechanisms that may have contributed to this resurgence of methane growth include leakage during increased use of hydrofracturing in fossil fuel mining, increased emissions from warming wetlands, increased emissions from melting tundra and methane hydrates, but contributions from these processes have not been adequately quantified.
Fig. 8. Greenhouse gas climate forcing annual growth rate. Colored areas are 5-year running means. Gray dots connected by grey lines are annual changes of the total forcing by all gases. Greenhouse gas amounts are from NOAA/ESRL Global Monitoring Division. O₃ changes are not fully included, as they are not well measured, but O₃ tropospheric changes are partially included via the effective CH₄ forcing. MPTGs are Montreal Protocol Trace Gases and OTGs are Other Trace Gases. The added future warming (right scale) is the equilibrium warming for the added forcing, assuming a climate sensitivity of 0.75°C per W/m².

As a result of the increasing growth rates of the greenhouse gases, the annual growth of the greenhouse gas climate forcing is tending to increase. Large interannual fluctuation in the CO₂ growth causes interannual fluctuation in annual growth of the total greenhouse gas climate forcing, but the smoothed growth rate has increased steadily over the past decade.

References


3 The current GISS analysis employs NOAA ERSSST.v5 for sea surface temperature, GHCN.v4 for meteorological stations, and Antarctic research station data, as described in references 1 and 2.


