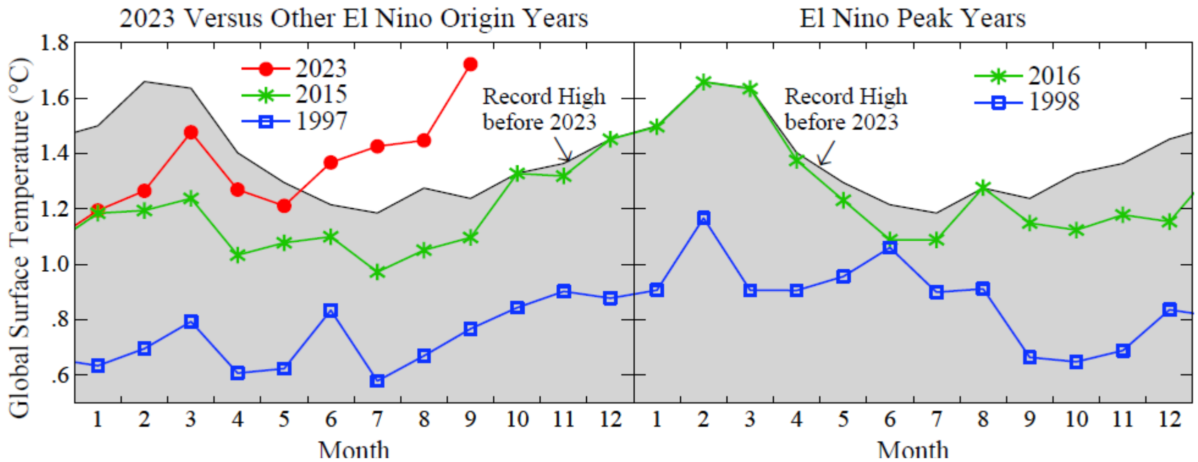

Fig. 1. Global temperature (relative to 1880-1920 mean for each month) for the 1997-98, 2015-16 and 2023-24 El Ninos. The impact of El Nino on global temperature usually peaks early in the year (El Nino Peak Year) following the year in which the El Nino originated.

El Nino Fizzles. Planet Earth Sizzles. Why?

13 October 2023

James Hansen, Makiko Sato, Reto Ruedy, and Leon Simons

Abstract. September 2023 smashed the prior global temperature record. Hand-wringing about the magnitude of the temperature jump in September is not inappropriate, but it is more important to investigate the role of aerosol climate forcing – which we chose to leave unmeasured – in global climate change. Global temperature during the current El Nino provides a potential indirect assessment of change of the aerosol forcing. Global temperature in the current El Nino, to date, implies a strong acceleration of global warming for which the most likely explanation is a decrease of human-made aerosols as a result of reductions in China and from ship emissions. The current El Nino will probably be weaker than the 1997-98 and 2015-16 El Ninos, making current warming even more significant. The current near-maximum solar irradiance adds a small amount to the major "forcing" mechanisms (GHGs, aerosols, and El Nino), but with no long-term effect. More important, the long dormant Southern Hemisphere polar amplification is probably coming into play.

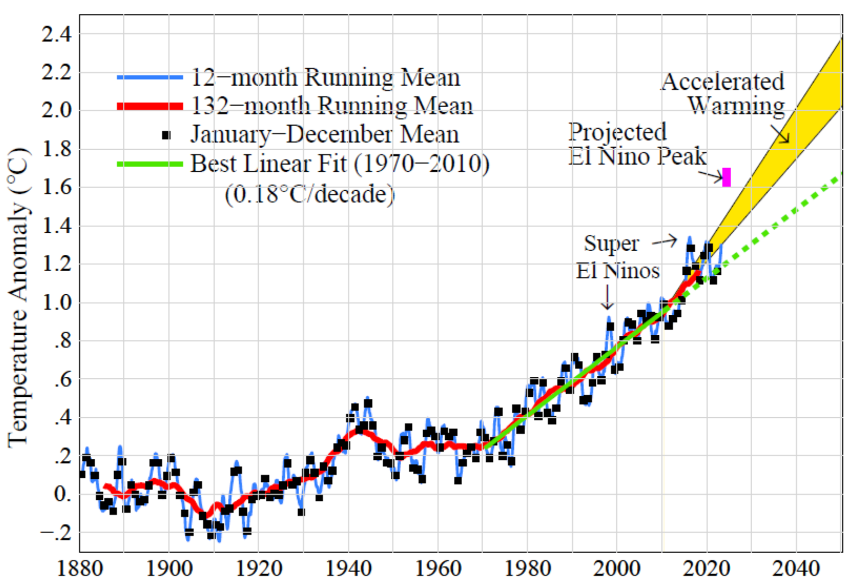

Fig. 2. Global temperature relative to 1880-1920 based on the GISS analysis.[1,2]

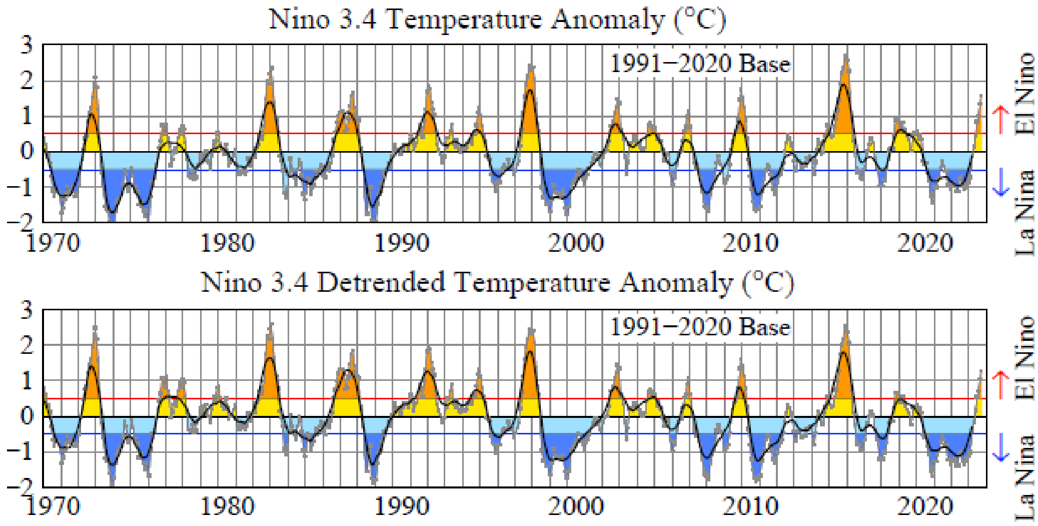

Fig. 3. Temperature in the tropical Pacific region used to define El Nino strength. El Nino (La Nina) is nominally defined to occur when Nino 3.4 is > 0.5°C (< –0.5°C).

The September global temperature anomaly leaped to more than +1.7°C relative to the 1880-1920 mean (Fig. 1). Public discussion has focused on the remarkable magnitude of this monthly anomaly, which exceeds the prior warmest September in the period of instrumental data by about +0.5°C; we will comment on this extreme September anomaly below. However, the average anomaly of the past 4 months (+0.44°C relative to the same months in 2015, the origin year of the 2015-16 El Nino) is probably more important. If this relative anomaly is maintained through this El Nino (through Northern Hemisphere 2024 spring) the peak 12-month mean global warming will reach +1.6-1.7°C relative to 1880-1920. Decline of global temperature following an El Nino peak is 0.2-0.3°C. Thus, if this El Nino peak is as high as we project it will be, global temperature will oscillate about the yellow region in Fig. 2. The 1.5°C global warming level will have been reached, for all practical purposes. There will be no need to ruminate for 20 years about whether the 1.5°C level has been reached, as IPCC proposes. On the contrary, Earth's enormous energy imbalance (references 8, 13, 14 below) assures that global temperature will be rising still higher for the foreseeable future.

These high temperatures are occurring despite the fact that the current El Nino may not even qualify as a "super" El Nino, comparable to those of 1997-98 and 2015-16. The Nino3.4 index (Fig. 3) at face value (upper Fig. 3) is now about +1.5°C, but in assessing El Nino strength we should account for the warming trend due to the net human-made climate forcing. The simplest way to do that is to subtract the 1970-2010 trend of the Nino3.4 temperature index, which is 0.1°C per decade (smaller than the trend of global temperature, as expected due to polar amplification of temperature change). With this detrending, the 1997-98 and 2015-16 El Ninos seem to be equally strong. The Nino3.4 index (temperature anomaly in a small region in the equatorial Pacific Ocean) is not a perfect characterization of El Nino strength, however. As the maps in Fig. 4 show, the 1997-98 El Nino is actually stronger than the 2015-16 El Nino. It's too early to conclude the eventual strength of the 2023-24 El Nino, but the early data (Fig. 4) do not suggest a very strong El Nino, even though no trends have been subtracted in the data shown in Fig. 4. Recent NOAA NCEP (Chart 25) forecast[3] has the Nino3.4 index reaching only ~1.5°C. The ensemble average of many models collected by the International Research Institute (IRI) of Columbia University and shown in NOAA Chart 24 has the peak warming at ~1.5°C for the statistical models and ~2°C for the dynamical models. Levine[4] provides a useful discussion of El Nino in general and the current situation in particular. Within the next several months we will be able to accurately assess the current El Nino.

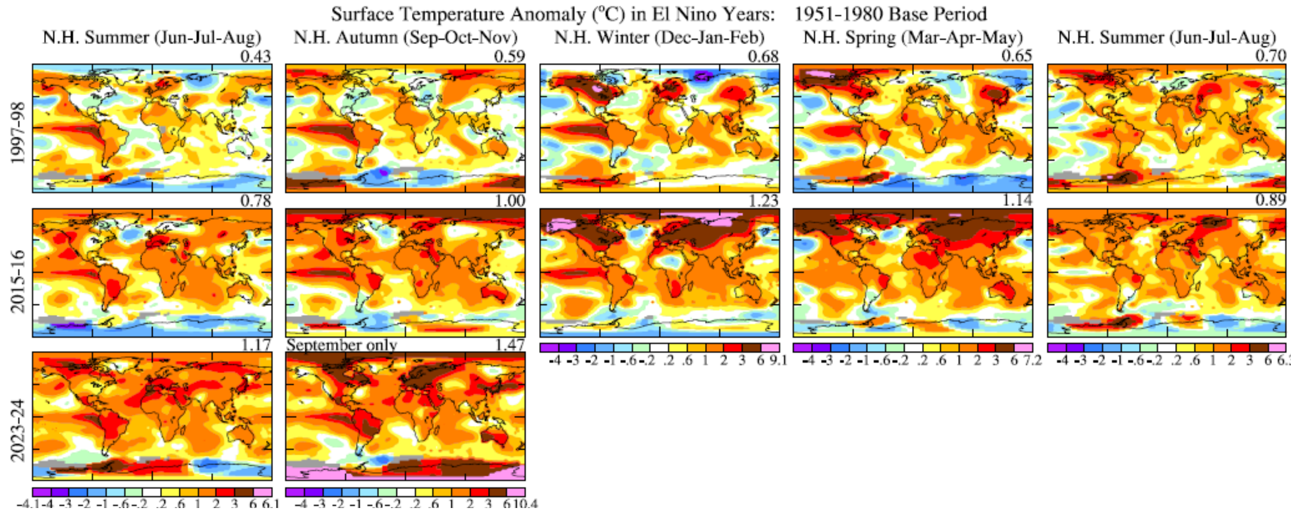

Fig. 4. Surface temperature anomalies during the past two "super" El Ninos and the first four months of the current El Nino. No attempt is made to remove the global warming trend, so the apparent strength of the more recent El Ninos is exaggerated by an unknown amount.

The two dominant global climate forcings – by far – are human-made greenhouse gases (GHGs) and human-made aerosols. Although GHG changes are monitored precisely (and thus the GHG climate forcing can be accurately computed), the aerosol forcing is not similarly available. Direct measurement of aerosol climate forcing requires global monitoring of aerosol and cloud particle microphysics[5] as the principal aerosol forcing is via the effect of aerosols on cloud microphysics. Aerosol and cloud particle monitoring of sufficient accuracy would require high precision data for the polarization of reflected sunlight and a high precision infrared spectrometer in near-polar orbit. Although such measurements are possible,[6] it was decided not to include them in NASA's Earth Observing System, and thus the aerosol forcing must be estimated as well as possible from existing data in combination with aerosol and cloud modeling.

An indirect indication of global aerosol forcing will be provided by the magnitude of global warming at the peak of the current El Nino,[7] which is expected to occur next Northern Hemisphere Spring, i.e., within the next six months. A moderate reduction of global aerosol amount has occurred due to reduced aerosol precursor emissions in China and from ships.[8] Thus, instead of aerosols reducing the rate of global warming, aerosol changes now should be adding to global warming. We attribute the lack of an apparent acceleration of global warming to date to the effect of the recent prolonged La Nina. When the Nino3.4 record is corrected (Fig. 3, lower part) to remove the trend caused by global warming, it becomes apparent that the recent La Nina was strong, comparable to those of the mid-1970s and late 1990s. The El Nino thus provides a crude measure of possible acceleration of global warming. A 50% acceleration of the long-term (1970-2010) global warming rate (0.18°C per decade) is shown by the lower edge of the yellow region in Fig. 2, while the upper edge is 100% acceleration to 0.36°C per decade.

Although it is difficult to predict future aerosol climate forcing, we expect a continual decline of the aerosol effect because of desire to reduce particulate air pollution, which causes several million deaths per year. Much of the aerosol pollution arises from fossil fuels, so, as the world moves to clean energies, aerosol amounts should decline and unmask the GHG warming that had been compensated by aerosol cooling. (We long ago[9] described this aerosol cooling as a Faustian bargain, and later[10] discussed it in more detail.) Thus, for the next few decades – barring purposeful actions to reduce Earth's energy imbalance – we expect the global warming rate will be accelerated to at least the rate (50% increase) of the lower boundary of the yellow area.

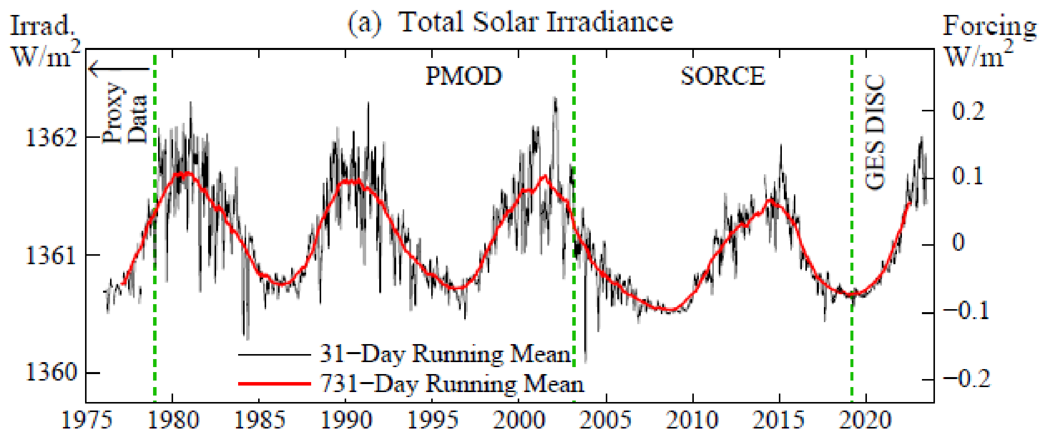

Fig. 5. Solar irradiance and climate forcing, the latter being 0.175 ×irradiance change, where 0.175 = (1 – Earth's albedo)/4, where Earth's albedo = 0.3. Data sources: Physikalisch Meteorologisches Observatorium, Davos, University of Colorado Solar Radiation and Climate Experiment, and Total Irradiance Monitor on the International Space Station (GES DISC).

Other than GHGs and aerosols, the climate forcing most likely to affect current global warming is solar irradiance, which is presently nearing the maximum of the ~11-year solar cycle (Fig. 5). Because of the oscillatory nature of the solar forcing and its limited magnitude (half-amplitude ~ 0.1 W/m^2) it is a minor but not negligible forcing. Hypotheses that the solar forcing could be amplified by some feedback can be tested by searching for an effect of the solar cycle on Earth's energy imbalance (EEI). Fig. 6, comparing solar irradiance and EEI, presents little evidence in favor of a substantial solar effect. There is a very weak correlation (maximum ~0.3) with the irradiance leading EEI by 30-45 months (the expected sense), but the record is too short and effect too small to suggest any role for the Sun other than that expected for its very small irradiance variation.

The Hunga Tonga volcanic eruption in early 2022 also affects EEI in the past two years. Jenkins *et al.*[11] estimate that water vapor injected into the stratosphere caused a small warming forcing (+0.12 W/m^2), but Schoeberl *et al.*[12] found that the cooling effect of stratospheric aerosols injected by Hunga Tonga yielded a net cooling effect, with forcing peaking in mid-2022 at about –0.5 W/m^2. By today, the Hunga Tonga forcing is small and declining.

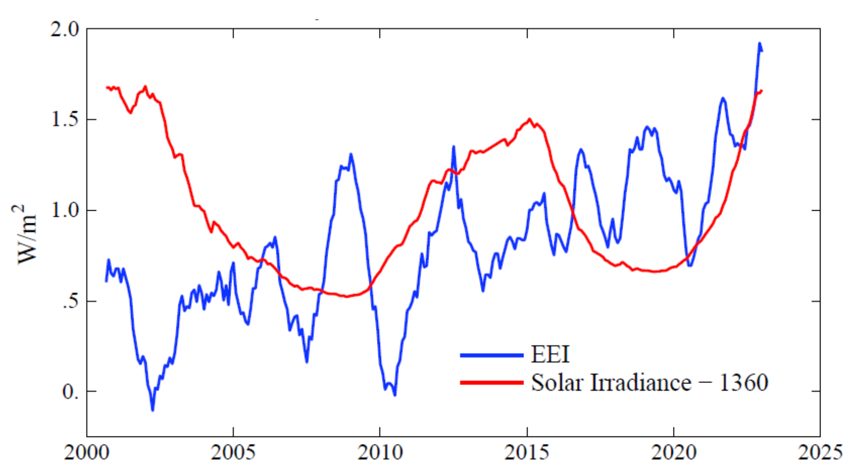

Fig. 6. Solar irradiance variations (see Fig. 4) and Earth's energy imbalance.[13,14]

The important point is that there are two large human-made climate forcings: GHGs and aerosols. The aerosol forcing is poorly understood. The magnitude of global warming during a large El Nino provides a measuring stick that can help us detect acceleration of global warming, but we need more detailed, quantitative information on aerosol effects. The sharp change in aerosol emissions caused by changes in regulations on the sulfur content of ship fuels provide an opportunity to evaluate the aerosol effect, especially in the North Pacific and North Atlantic regions of heavy ship traffic.

One final comment. The discussions of the remarkable September global warming have noted that much of the warming is associated with an extreme warming anomaly over Antarctica, with the suggestion that this warming is a weather effect that will disappear. While it is true that Antarctic temperature fluctuates greatly from month to month, we note that there is a latent southern Hemisphere polar amplification of warming that has long been dormant, as Southern Hemisphere sea ice cover has been relatively constant for several decades. The recent decline of sea ice area may be an indication that, averaged over weather, Antarctica will become a more important contributor to global temperature change.

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