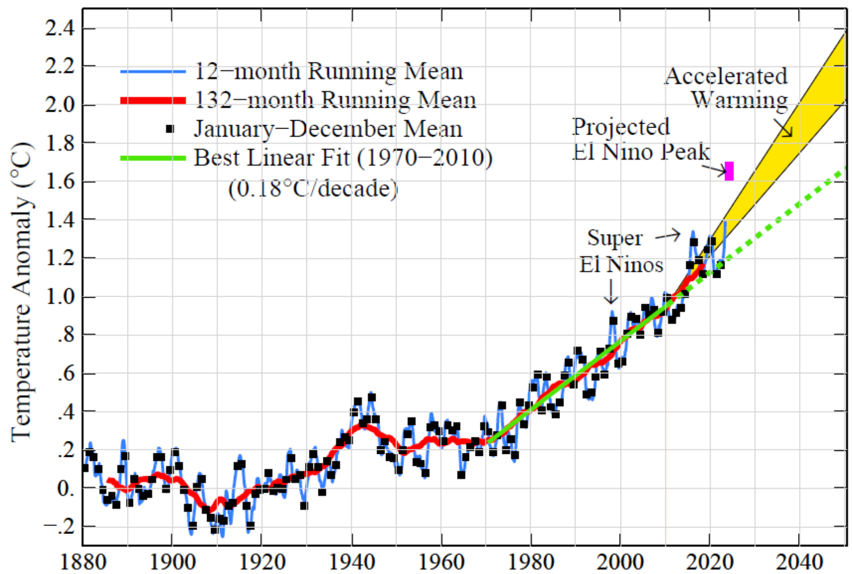

Fig. 1. Global temperature relative to 1880-1920 based on the GISS analysis.[1,2]

Global Warming Acceleration: El Nino Measuring Stick Looks Good

14 December 2023

James Hansen, Makiko Sato, Reto Ruedy

Abstract. Global warming is accelerating because the drive for warming, Earth's energy imbalance, has doubled in the past decade. Measurement of the acceleration is hampered by unforced tropical (El Nino/La Nina) variability, but a good measuring stick is provided by warming between successive large El Ninos. Strengthening of the current (2023-24) El Nino has raised it to a level similar to the 1997-98 and 2015-16 El Ninos. The first six months of the current El Nino are 0.39°C warmer than the same six months of the 2015-16 El Nino, a global warming rate of 0.49°C/decade, consistent with expectation of a large acceleration of global warming. We expect the 12-month mean temperature by May 2024 to eliminate any doubt about global warming acceleration. Subsequent decline of the 12-month temperature below 1.5°C will likely be limited, confirming that the 1.5°C limit has already been passed.

Global temperature has increased 0.18°C/decade since 1970 (Fig. 1). Temperature prior to the current El Nino was ~1.2°C above the preindustrial level (taken to be the 1880-1920 average, the earliest period with reasonable global coverage of instrumental measurements). The goal of the United Nations Framework Convention on Climate Change[3] and the Paris Agreement[4] is for the rate of warming to slow down so that global warming stabilizes at a level of 1.5°C or less. We find,[5] on the contrary, that global warming post-2010 must be in an accelerated warming phase, based on a large increase in Earth's energy imbalance, which is the immediate drive for global temperature change. We project an acceleration of the post-2010 warming rate by 50-100 percent (yellow area in Fig. 1). Thus, global temperature is now accelerating past 1.5°C and it could reach 2°C in the 2030s, barring purposeful actions to reduce or reverse Earth's energy imbalance.

Acceleration of global warming has been hidden so far by the large natural variability of global temperature, especially because of the unusual 3-year period of strong La Ninas that ended this year. If we wait long enough, say another decade, the changed trend will be obvious, but we need to understand the situation sooner. We will argue elsewhere[6] that actions to cool the planet should be taken within less than a decade if we are to have a good chance of avoiding polar climate change

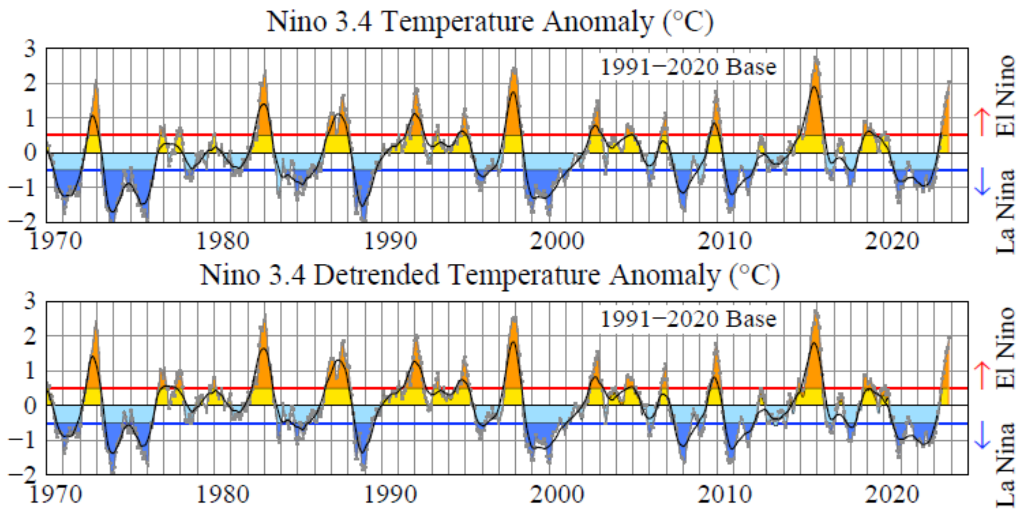

Fig. 2. Temperature in the tropical Pacific region used to define El Nino strength. El Nino (La Nina) is nominally defined to occur when Nino 3.4 is > 0.5°C (< –0.5°C).

amplifications that would be difficult, if not impossible, to reverse. Thus, there is strong desire for earlier, more precise, quantification of global warming acceleration. A useful suggestion by Jeremy Grantham[7] is to check the warming rates between the peaks of successive strong El Ninos, which occur every decade or two. It now seems that the current El Nino will qualify. The usual measure of El Nino strength is the Nino3.4 index (average temperature of the tropical Pacific at longitudes between 170°W and 120°W within 5° latitude of the equator. The raw Nino3.4 index (top chart in Fig. 2) shows the 2015-16 El Nino as stronger than the 1997-98 El Nino, which seems implausible given that the 1997-98 El Nino was unusually strong, sometimes described as the strongest of the 20th century. Ubiquitous global warming surely adds to the Nino3.4 temperature and makes more recent El Ninos artificially strong, as measured by Nino3.4 temperature. The maps in Fig. 3 confirm this interpretation: the 1997-98 El Nino is the strongest of the three El Ninos, even though the maps include the growing global warming driven by increasing greenhouse gases (GHGs). Simple detrending of the Nino3.4 index (lower half of Fig. 2) does not fully remove this bias. A clear picture is provided by maps of the temperature anomalies for the Nino3.4 region (Fig. 4). The 1997-98 El Nino shows greatest warming, but the others are enhanced by background (GHG) warming that existed prior to the El Nino and covers the entire Nino3.4 region.

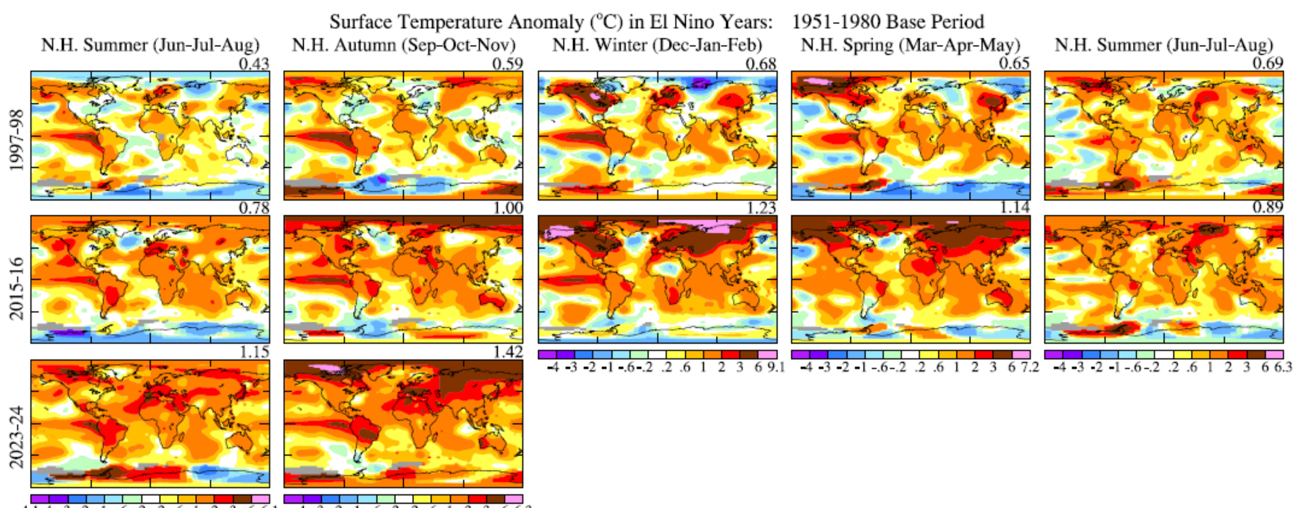

Fig. 3. Global temperature by season during growth and phasedown of the 3 large El Ninos.

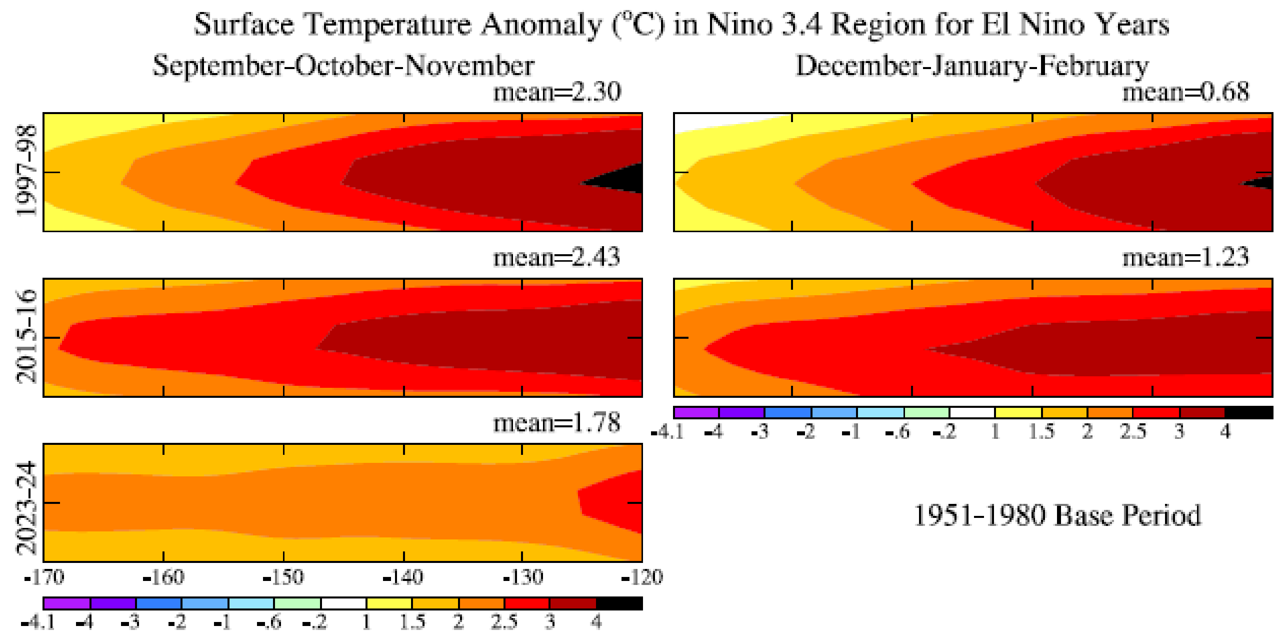

Fig. 4. Surface temperature anomaly in Nino3.4 region during three major El Ninos.

The three successive El Ninos are successively weaker, so global warming acceleration inferred by comparing the three is a bit of an underestimate. However, the current El Nino has strengthened in the past month (see further El Nino data at the end of this communication) and is expected to persist through Northern Hemisphere winter, so it should be nearly as strong as the 2015-16 El Nino. Thus, the three large El Ninos are sufficiently similar in strength to provide a useful measuring stick.

Temperature updates. Global mean temperature in 2022 (relative to 1880-1920) was 1.16°C. The 12-month running mean has already risen to 1.39°C (Fig. 5). We expect[5] the 12-month mean to rise to at least 1.6°C in the next six months (Fig. 1) because of Earth's extreme energy imbalance.

The acceleration of global warming is evident in Fig. 6. The warming in September was famously described by Zeke Hausfather as "gobsmackingly bananas." For the six months since the El Nino began, the average difference between 2023 and 2015 (the prior El Nino) is 0.39°C, a decadal warming rate of 0.49°C/decade, more than double the 1970-2010 rate of 0.18°C/decade, consistent with expectations,[8] given the addition of a post-2015 aerosol forcing of at least 0.5-1 W/m^2.[9]

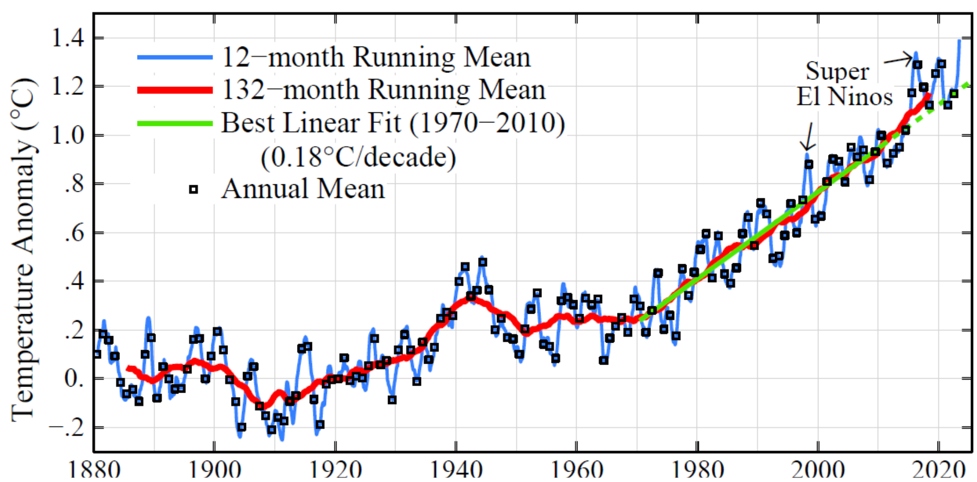

Fig. 5. Global surface temperature relative to 1880-1920 based on GISTEMP analysis.[1,2]

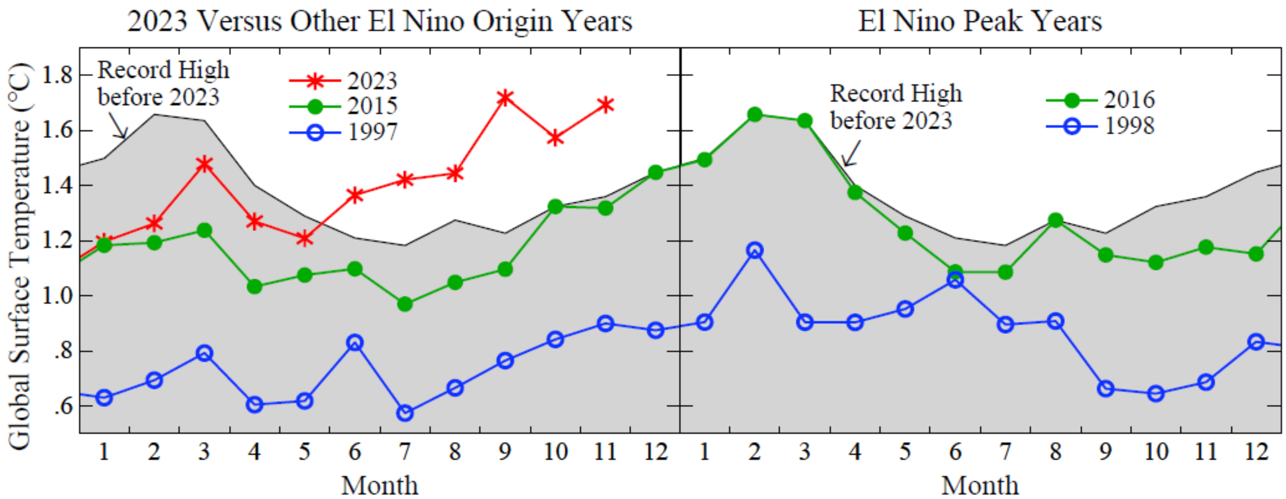

Fig. 6. Global temperature (relative to 1880-1920 mean for each month) for the 1997-98, 2015-16 and 2023-24 El Ninos. The impact of El Nino on global temperature usually peaks early in the year (the El Nino Peak Year) following the year in which the El Nino originated.

The12-month running-mean temperature will begin to decline during 2024 Northern Hemisphere summer, but the magnitude of the decline will be limited by Earth's large energy imbalance. The decline below the 1.5°C level may be less than the preceding rise above that level. In such case, it will be fair to declare that the 1.5°C level has been breached definitively, given the fact that the large planetary energy imbalance assures that global temperature is headed higher. It would be absurd to wait a decade for this declaration, as IPCC's planned procedures would have it. Those procedures seem to be designed more for the protection of IPCC's authority than for protection of the well-being of the residents of the pale blue dot.

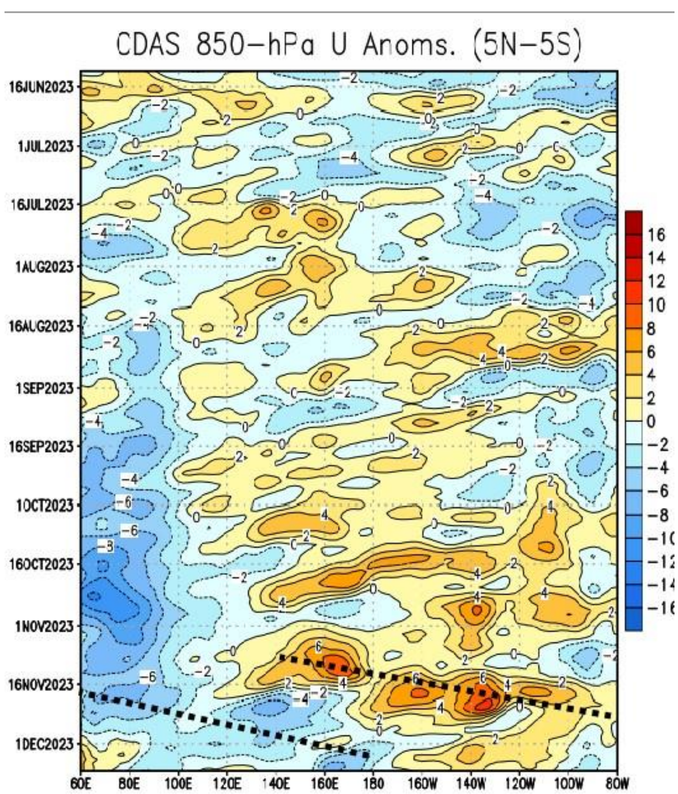

Fig. 7. Low-level (850 hPa) zonal (east-west) wind anomalies (m/s) in the equatorial Pacific Ocean.

El Nino development. Until November the current El Nino was of moderate strength and the NOAA NCEP climate model predicted a maximum Nino3.4 warming of only about 1.5°C. The warming of the equatorial Pacific Ocean during an El Nino is associated with anomalous westerly winds (winds blowing from the west, the yellow and orange colors in Fig. 7) in the equatorial (5°N-5°S) Pacific Ocean. In November, a strong burst of westerly wind anomalies propagated across the Pacific (Fig. 7), pushing warm waters of the west toward South America, strengthening the El Nino. The Nino3.4 index has risen to ~2°C (Fig. 2) and the strength of the current El Nino is predicted by most models to be comparable to the 2015-16 El Nino, thus letting us use global temperature during these El Ninos as a measuring stick for possible global warming acceleration. A review paper[10] on ENSO forecasting skill by Azhar Ehsan and colleagues is still under review, but available. In general, the dynamical models have developed a useful skill in predicting the onset of warm and cold ENSO (El Nino Southern Oscillation) events, but the present NCEP model has a cold bias that probably accounts for its under-prediction of the strength of the 2023-24 El Nino.

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[2] Hansen J, Ruedy R, Sato M *et al.* Global surface temperature change. *Rev Geophys* 2010;**48**:RG4004

[3] United Nations Framework Convention on Climate Change. *What is the United Nations Framework Convention on Climate Change?* https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change) (30 November 2022, date last accessed)

[4] Paris Agreement 2015, UNFCCC secretariat, (last access 20 August 2023), 2015

[5] Hansen J, Sato M, Simons L *et al*. Global warming in the pipeline. *Oxford Open Clim Chan* 2023;3(1):kgad008, doi.org/10.1093/oxfclm/kgad008

[6] Scientific paper and a book (*Sophie's Planet*) in preparation.

[7] Grantham, J., The Race of Our Lives Revisited, GMO White Paper, August 2018

[8] Hansen J, Kharecha P, Sato M. "A Miracle Will Occur" Is Not Sensible Climate Policy, 07 December 2023.

[9] The warming rate is not proportional Earth's energy imbalance. Early surface temperature response to an imposed imbalance is much larger per unit imbalance than it is for residual imbalance. The last half of the imbalance is more effective in raising the deep ocean temperature than in warming the surface. Expected surface temperature response should be obtained from the climate response function. See references 5 and 8.

[10] Ehsan MA, L;Heureux M, Tippett M, Robertson A, Turmelle J. Real-time ENSO forecast skill evaluated over the last two decades, with focus on onset of ENSO events, Research Square preprint.