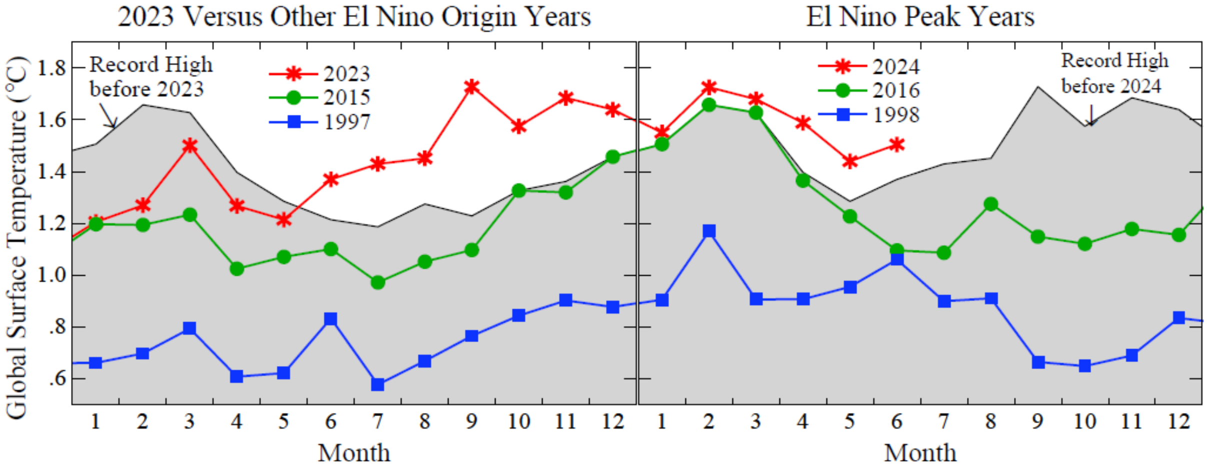

Fig. 1. Global temperature relative to 1880-1920 based on the GISS analysis.[1,2]

Reflections on Time Scales and Butterflies

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Abstract. Breathless reporting on when the present global heat anomaly will begin to fall is understandable, given heat suffering around the world. However, fundamental issues are in question and a reflection on time scales is in order, for the sake of understanding ongoing climate change and actions that need to be taken.

June was the 13th consecutive record monthly global temperature (Fig. 1). The changing gap between this current string and prior records is revealing. The gap is smallest in Northern Hemisphere winter, the months when a strong El Nino gives global temperature the biggest kick, consistent with direct evidence that the recent El Nino was far from a super El Nino. Thus, more than the recent modest El Nino is needed to explain the uniquely large rise of temperature in the past year (Fig. 2).

Reanalyses (computer simulations of global weather post facto, using available observations) show that the first week of July this year was cooler than in 2023 (Fig. 3). Nevertheless, we suggest caution in predictions about July and August for Fig. 1. Almost a dead-heat (sorry, no pun intended) with the 2023 July and August records is possible, even likely. In September, global temperature surely will fall well below the unusually-high September record (Fig. 1); with that, the 12-month running-mean global temperature (Fig. 2) will decline noticeably.

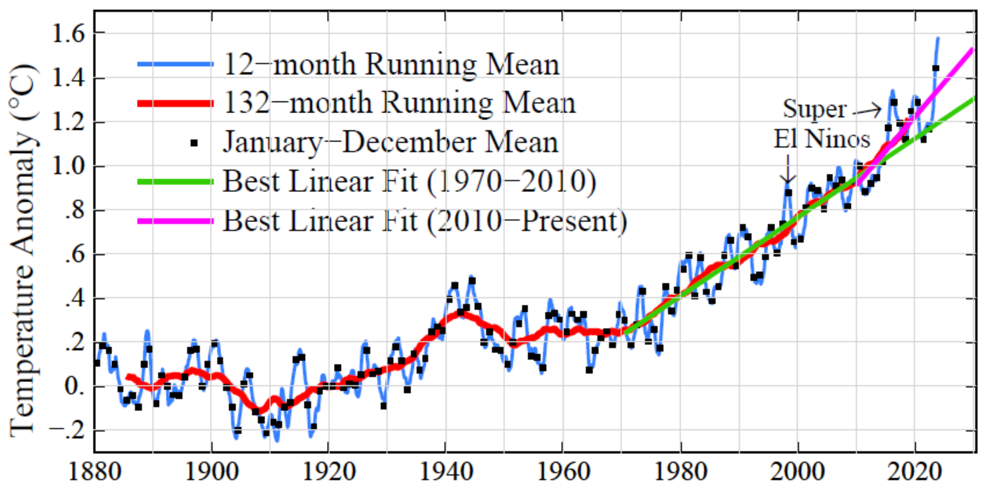

Fig. 2. Global temperature relative to 1880-1920 based on the GISS analysis. Warming rate is 0.18°C/decade for 1970-2010, 0.32°C/decade for 2010-present.

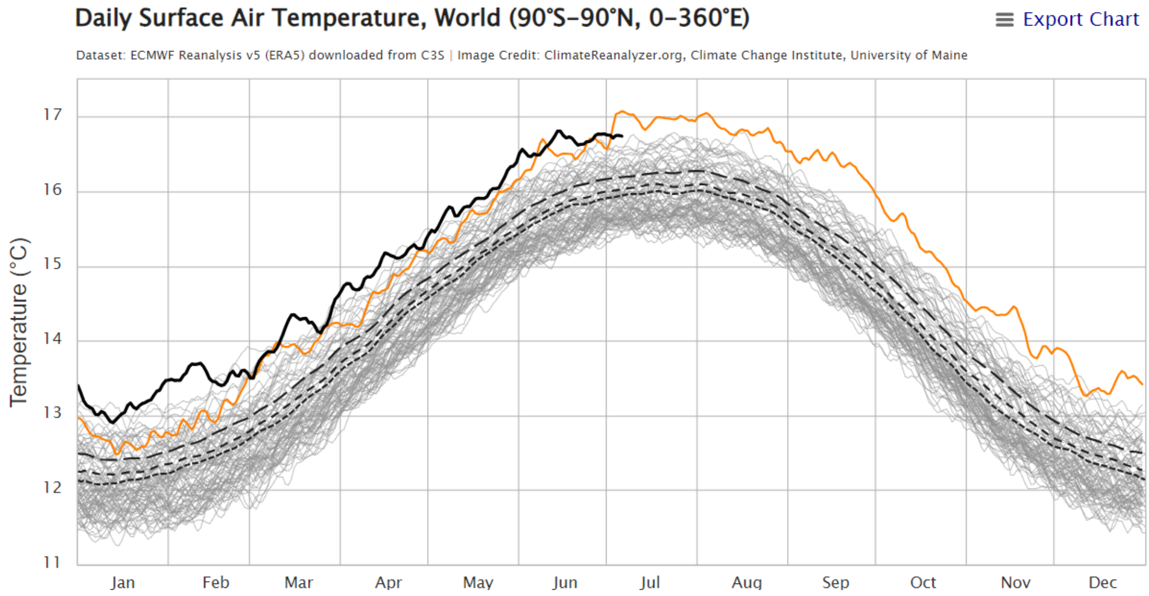

Fig. 3. Global surface air temperature from ECMWF reanalysis, provided by Univ. of Maine.[3]

Tropical surface air temperature (Fig. 4) during the next few months is expected to fall below its El Nino-enhanced 2023 value – but how far below? Sea surface temperature (SST) is a less "noisy," powerful, climate diagnostic because it serves as a measure of the entire depth of the ocean surface "mixed layer," which is well-mixed almost daily by winds. The mixed layer accumulates effects of all the forcings at the ocean surface, capturing effects 24/7/365, not only at the moments of satellite sampling. Thus, SST reduces effects of weather noise, cloud variability, and sampling biases in satellite observations.

Global SST (Fig. 5) reveals the huge warming in the transition from La Nina at the beginning of 2023 to El Nino by mid-2023, exceeding the SST warming in even the strongest El Ninos. The magnitude and stability of the warming imply the need for a substantial mechanism(s) in addition to the El Nino, especially given the modest strength of the El Nino. Our suggestion[4] for a large component of this additional forcing is aerosol forcing that grew especially during the 2020s. A sharp increase of aerosol forcing is expected in January 2020 due to regulations on sulphates in ship fuels. Aerosol forcing occurs mainly via effects on clouds that are highly nonlinear, being most effective in less-polluted air; thus, ship aerosols have a substantial impact, even though the ship portion of total human-made aerosols is small.

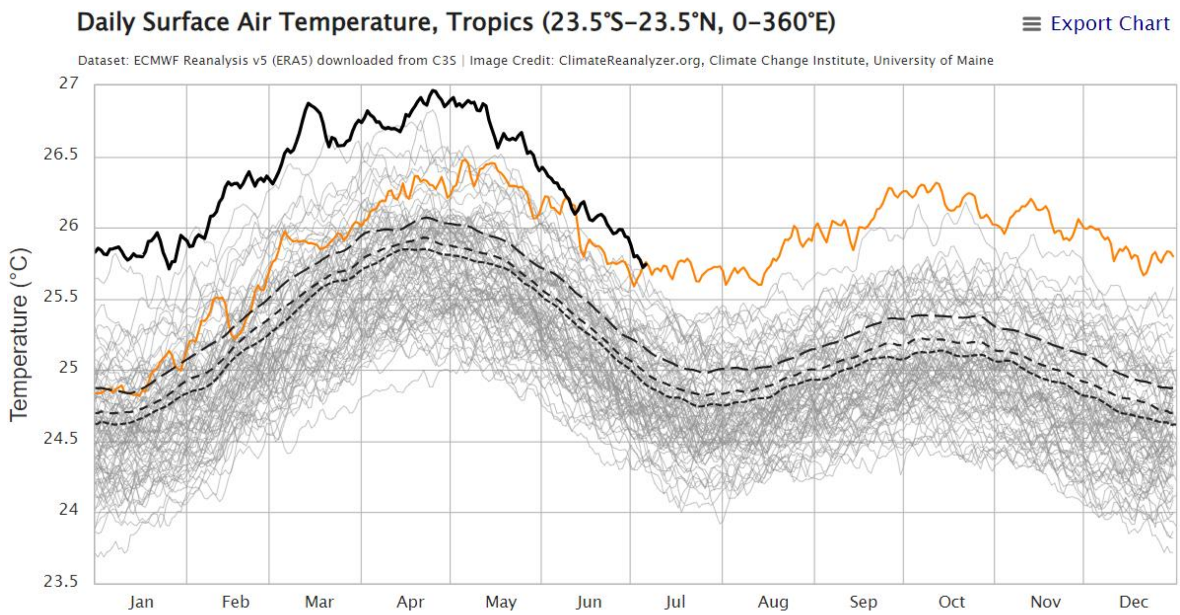

Fig. 4. Tropical surface air temperature from ECMWF reanalysis, provided by Univ. of Maine.

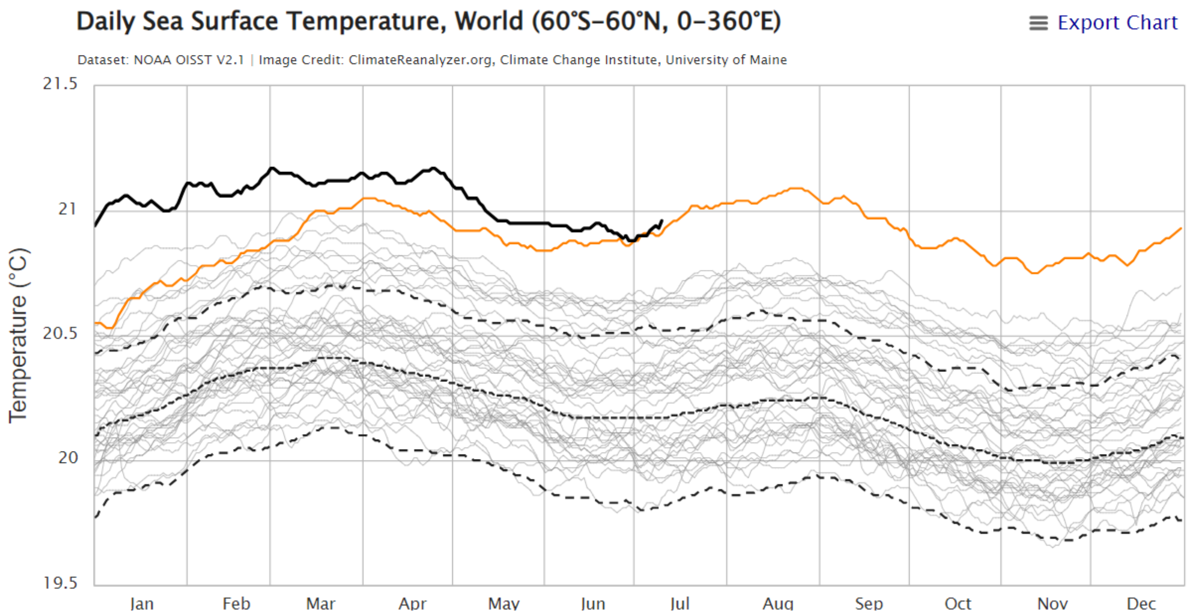

Fig. 5. SST based on NOAA based on OISST satellite data, provided by Univ. of Maine.[5] The orange line is 2023 data and the heavy black line is 2024.

Global SST is now at about the level that it was 12 months ago (Fig. 5), but still far from the pre-El Nino level. Global SST will soon be falling below the elevated late-2023 levels, but we should not expect SSTs to fall back to the pre-2023 level as the aerosol effect continues and greenhouse gas forcing continues to grow. The moderate size of the El Nino suggests that global temperature will probably fall to only about +1.4°C relative to the preindustrial level.

Zonal-mean SST anomalies (Fig. 6) provide an informative summary. In our interpretation, the strong midlatitude warming in the Northern Hemisphere will not disappear. However, the ocean has natural variability on the time scale of years and decades, so others may interpret the warm anomalies in the North Pacific and North Atlantic differently. Given the absence of observations of the global aerosol forcing, a little patience will provide data allowing a more persuasive interpretation of ongoing climate change. In the meantime, let's remember the iconic, but beleaguered Monarch butterfly.

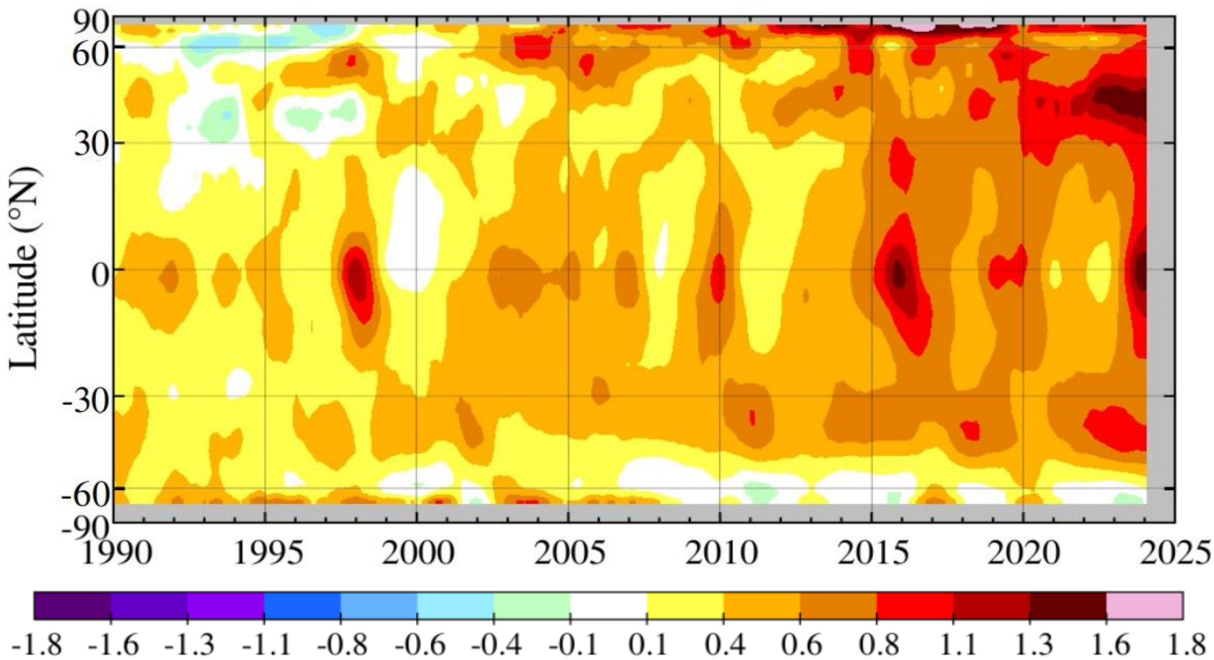

Fig. 6. Zonal-mean SST (12-month running mean) relative to 1951-1980 base period.

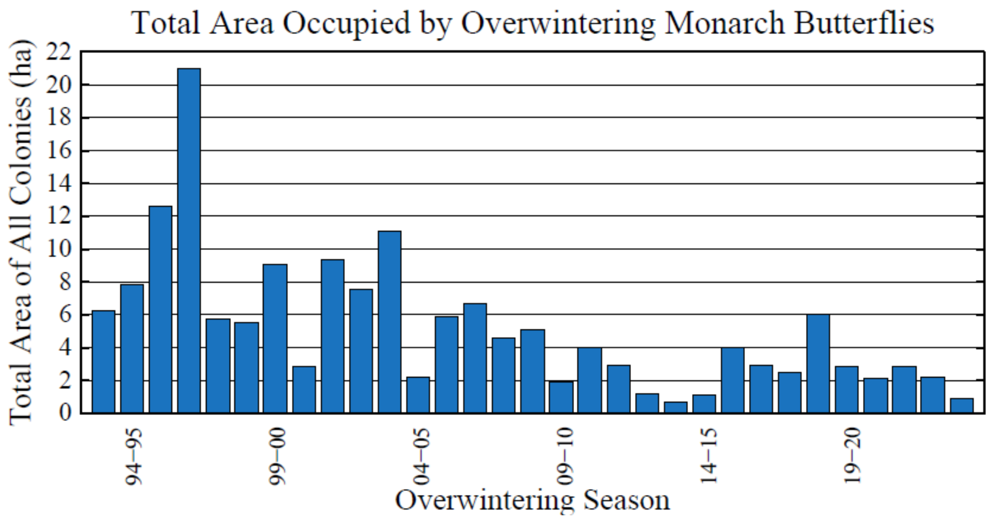

Fig. 7. Monarch population estimated by the area of the colonies in which they cluster together for winter hibernation (graph updated from Brower et al., *Insect Conser. & Diver.* **5**, 95, 2011.)

Last winter the number of Monarchs making it to Mexico for hibernation in their mountain colonies was the second smallest on record, barely beating the number during the minimum a decade earlier (Fig. 7). That earlier minimum was at the time of the remarkable broken-wing butterfly that I (JEH) described in a letter to my oldest grandchild.[6] At that time, we thought the main factor in the Monarch decline was their reduced food source, possibly due to the extensive use of herbicides, with climate change probably exacerbating that problem. A new suggestion is that insecticides are a contributing factor,[7,8] a timely reminder of the need for better protection by the Environmental Protection Agency, not a weakened EPA. These chemicals take a toll on humans, as well as on other life on our planet.

We have been reflecting on the changes we have seen during the past several decades, as we prepare to move back to New York City fulltime (to avoid the time used in commuting and in taking care of outdoor property, thus to have more time to work with students on research). We are certain that there are not only fewer butterflies now, but fewer fireflies and fewer birds, the latter reduction unsurprising as insects are food for the birds. Reflections to be continued – need to get back to the book.

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[1] Lenssen NJL, Schmidt GA, Hansen JE *et al.* Improvements in the GISTEMP uncertainty model, *J Geophys Res Atmos* **124(12)**, 6307-26, 2019
[2] Hansen J, Ruedy R, Sato M *et al.* Global surface temperature change. *Rev Geophys* **48**:RG4004, 2010
[3] This ECMWF reanalysis graphic is provided by the Climate Change Institute, University of Maine.
[4] Hansen J, Sato M, Simons L *et al*. Global warming in the pipeline. *Oxford Open Clim Chan* **3(1)**, doi.org/10.1093/oxfclm/kgad008, 2023
[5] This graphic based on NOAA SSTs is provided by the Climate Change Institute, University of Maine
[6] Hansen J. Quest of a broken-wing butterfly.31 January 2014.
[7] Einhorn C. New ‘Detective Work’ on Butterfly Declines Reveals a Prime Suspect. *New York Times*, 20 June 2024
[8] Van Deynze B, Swinton SM, Hennessy DA *et al.* Insecticides, more than herbicides, land use, and climate, are associated with declines in butterfly species richness and abundance in the American Midwest. *PLoS ONE* 19(6): e0304319