

**Fig. 1. Left: monthly global temperature anomalies. Right: Nino 3.4 temperature anomaly for past six years and NCEP forecast (green line).**

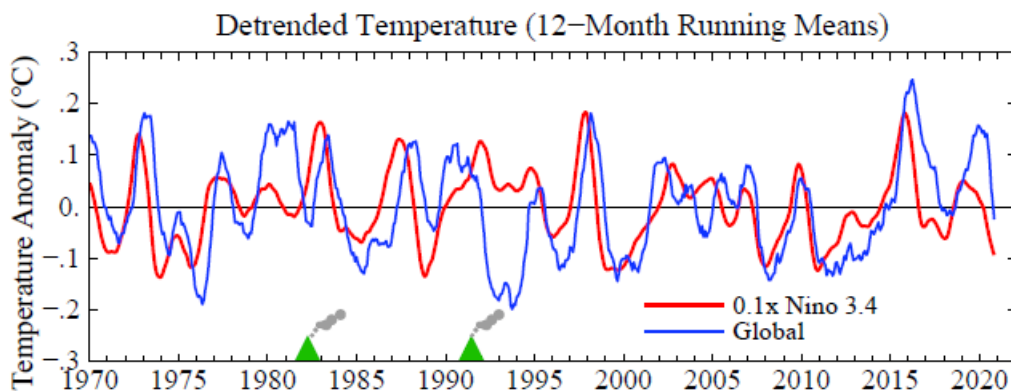
## The World Has Cooled Off – What’s the Significance?

13 May 2021

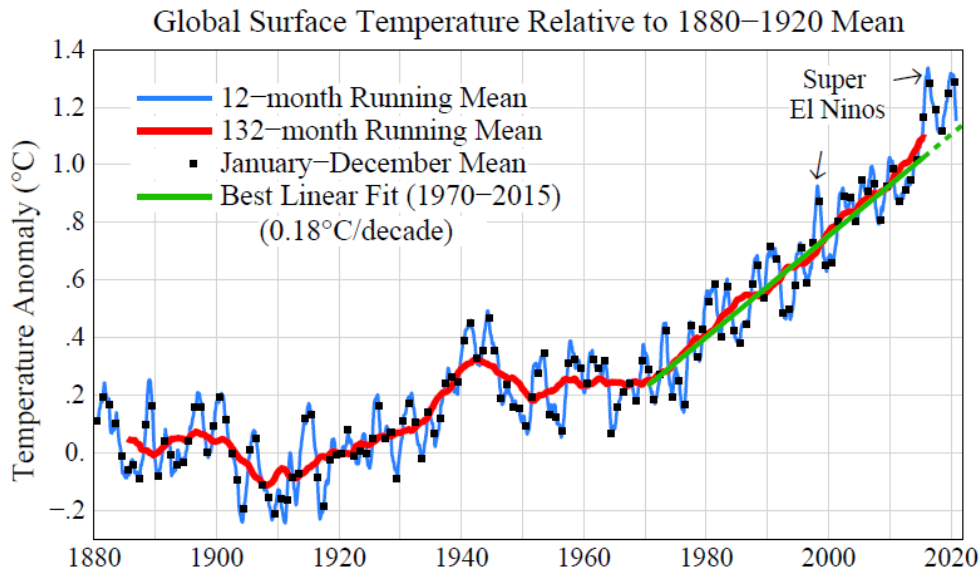
James Hansen and Makiko Sato

Global temperature in April continues to be much less than a year ago (Fig. 1: left side). ENSO (El Niño Southern Oscillation) is the principal cause of year-to-year global temperature change. We are in a moderately strong La Niña (Fig. 1: right side) and NCEP (NOAA’s National Center for Environmental Prediction) current forecast (Fig. 1: right side) suggests that tropical temperatures are headed for a double-dip La Niña. Niño forecasts are notoriously difficult, however, so we need to wait a few months to see.

Global temperature is highly correlated (61.4%) with the Niño3.4 index, with global temperature lagging Niño3.4 by 5 months (Fig. 2). The 12-month running mean temperature is dropping fast (Fig. 3) and probably will not reach a minimum until November this year.<sup>1</sup> That minimum is likely to be well below the 1970-2015 trend line (Fig. 3) and 2021 will be much cooler than 2020. Will that global cooling imply that the apparent global warming acceleration of the past six years was a misleading deviation, rather than a significant change of the warming rate?



**Fig. 2. Global surface temperature and Niño3.4 multiplied by 0.1 to make scales similar.**

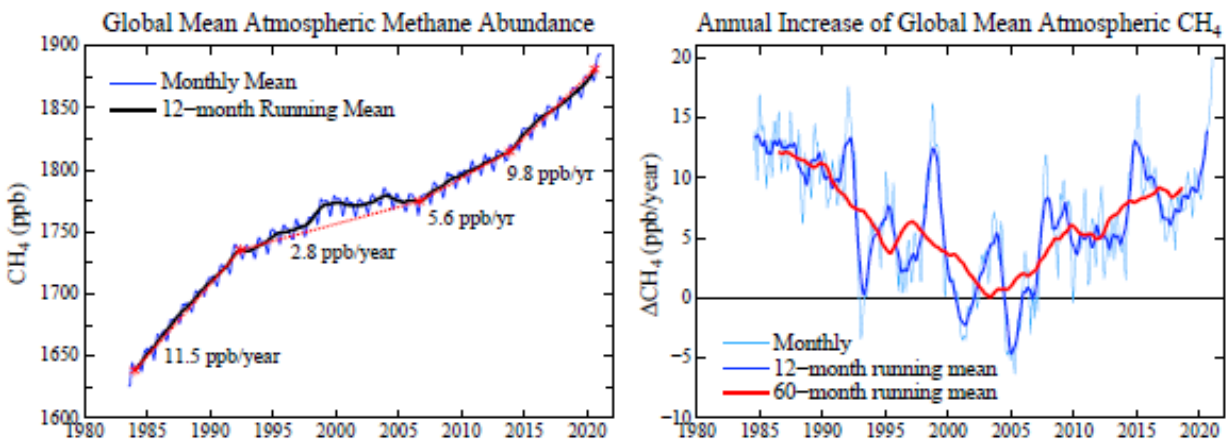


**Fig. 3. Global surface temperature relative to 1880-1920 average.**

No, almost surely not. Global temperature will ultimately respond to global climate forcings. We know that Earth is now out of energy balance – more energy coming in than going out – at a record imbalance<sup>2</sup> close to +1 W/m<sup>2</sup>. Moreover, greenhouse gases (GHGs) continue to increase rapidly and there is growing evidence that human-made aerosols are decreasing. Aerosols have a cooling effect, so they partially offset GHG warming, but that offset is now decreasing, as we will discuss in a future paper and temperature update.

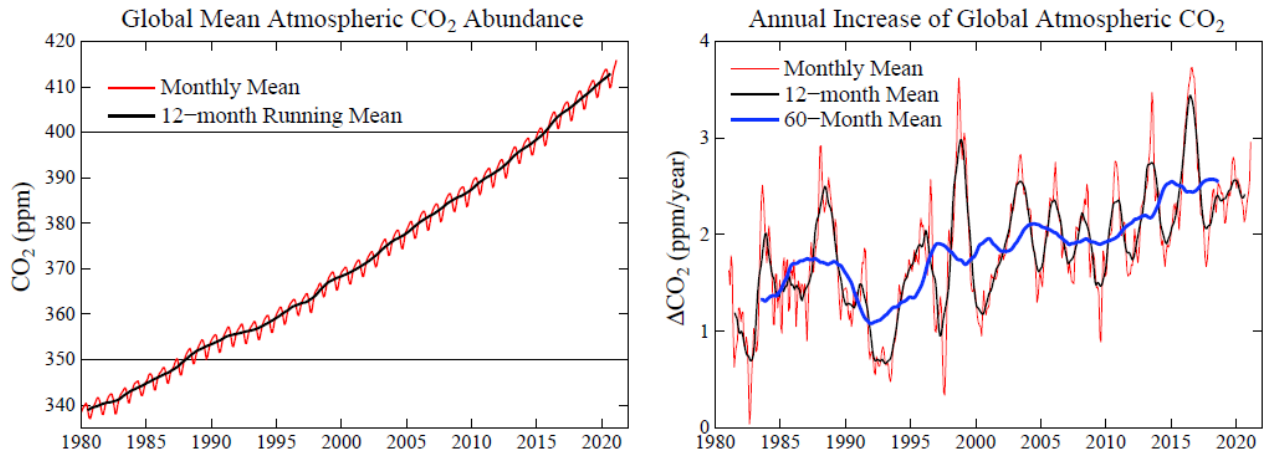
Let’s look at the primary drive for global warming: increasing GHGs. As we will see – despite international concern about climate change and promises by governments to address the matter – GHG growth rates are increasing, not declining.

The methane (CH<sub>4</sub>) growth rate<sup>3</sup> is shocking (Fig. 4). A CH<sub>4</sub> increase causes tropospheric ozone (O<sub>3</sub>) and stratospheric water vapor (H<sub>2</sub>O) to also increase. Including these indirect effects, the climate forcing by observed CH<sub>4</sub> growth is half as large as the climate forcing by CO<sub>2</sub>.



**Fig. 4. Left: Global CH<sub>4</sub> amount. Right: Annual CH<sub>4</sub> growth rate.**

Data source: Ed Dlugokencky, NOAA/GML ([https://gml.noaa.gov/ccgg/trends\\_ch4/](https://gml.noaa.gov/ccgg/trends_ch4/))



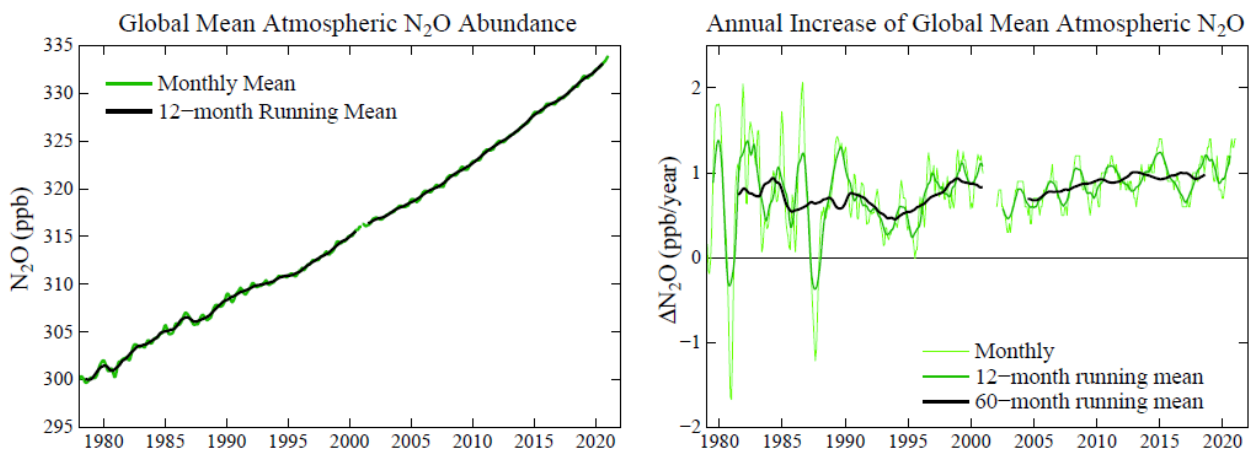
**Fig. 5. Left: Global CO<sub>2</sub> amount. Right: Annual CO<sub>2</sub> growth rate.**

Data source: NOAA Global Monitoring Lab (<https://gml.noaa.gov/ccgg/trends/global.html>)

Any realistic plan to limit global warming must include a *reduction* of atmospheric CH<sub>4</sub>, as discussed in *Young People's Burden*.<sup>4</sup> Such a CH<sub>4</sub> reduction is feasible because of the short (about 10 year) lifetime of CH<sub>4</sub>, but it requires reducing CH<sub>4</sub> sources. Instead, after CH<sub>4</sub> nearly stabilized early this century, growth has returned and recently accelerated to its highest rate in the period of accurate global data, with increased growth at least in part as a result of “fracking” for gas and reliance on gas as the complement to intermittent renewable energies.

The CO<sub>2</sub> growth rate (Fig. 5) is now a bit below the peaks that occur in conjunction with strong El Ninos. However, the CO<sub>2</sub> growth rate is not declining. CO<sub>2</sub> growth has not even slowed as a result of the reduced economic activity associated with Covid-19.

The growth rate of the third strongest greenhouse gas, N<sub>2</sub>O, does not provide any good news. Its growth rate (Fig. 6) continues to increase.



**Fig. 6. Left: Global N<sub>2</sub>O amount. Right: Annual N<sub>2</sub>O growth rate.**

Data source: Ed Dlugokencky, NOAA/GML ([gml.noaa.gov/ccgg/trends\\_n2o/](https://gml.noaa.gov/ccgg/trends_n2o/))

There is a wide gap between reality and the picture that governments paint about the status of actions to limit global warming. Actual government policies consist of little more than tinkering with domestic energy sources, plus goals and wishful thinking in international discussions.

Solution of the global warming problem has two fundamental requirements.

The first, underlying, requirement is for a simple rising carbon fee. The fee could be made near global via border duties on products from countries without the fee. The public would accept a rising carbon fee if all of the resulting funds was distributed uniformly to domestic citizens.<sup>5</sup>

The second requirement is for technology to produce baseload dispatchable carbon-free electric power at a price below that of fossil fuels. Based on the price of nuclear fuel and the amount of material (concrete, steel, etc.) in a power plant, one technology with that potential is modern nuclear power. However, governments chose not to support the development of that technology. Instead, they chose an unlimited hidden subsidy of renewable energies via renewable portfolio standards for electricity as well as explicit subsidies of renewables. If uniform support had been provided for all clean energies, for example via clean energy portfolio standards, we would now be well on the way to stabilizing climate, and we would have a cleaner, healthier atmosphere.<sup>6</sup>

Our children and grandchildren will pay the price for our energy policy incompetence.

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<sup>1</sup> As we advance one month, the change to the 12-month running mean is obtained by adding the most recent point on the red curve and deleting the same month from the green curve. So as long as the red curve remains below the green one, the 12-month mean will keep declining. Record global temperatures in September and November 2020 are unlikely to be exceeded this year.

<sup>2</sup> von Schuckmann, K., et al.: [Heat stored in the Earth system: where does the energy go?](#), *Earth System Science Data* **12**, 2013-2041, 2020.

<sup>3</sup> Dlugokencky, E. J., L. P. Steele, P. M. Lang, and K. A. Masarie (1994), [The growth rate and distribution of atmospheric methane](#), *J. Geophys. Res.*, 99, 17,021– 17,043, doi:10.1029/94JD01245.

<sup>4</sup> Hansen, J., M. Sato, P. Kharecha, K. von Schuckmann, D.J. Beerling, J. Cao, S. Marcott, V. Masson-Delmotte, M.J. Prather, E.J. Rohling, J. Shakun, P. Smith, A. Lacis, G. Russell, and R. Ruedy, 2017: [Young people's burden: requirement of negative CO<sub>2</sub> emissions](#). *Earth Syst. Dynam.* **8**, 577-616, 2017.

<sup>5</sup> Hansen, J.: [Student Leadership](#) on Climate Solutions, 31 July 2020.

<sup>6</sup> Hansen, J.: [Sophie's Planet #36](#): Chapter 47 (China and the Global Solution), 4 March 2021.