Climate Complexity

By John Benson

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1. Introduction

I am a member of the American Association for the Advancement of Science (AAAS). As such, I receive an electronic issue of their primary publication, "Science," once every week. Each of these issues is massive, and I rarely read all of the articles, but I recently had enough time to read at least most of them in one issue, and I was glad I did. This reminded me that all activities of humanity, which impact all areas of science, are much more complex than scientists have learned to deal with.

I finally hit an article that was within one of the areas that I write about: climate change (a.k.a. global warming), and sure enough, the same story. I'm excerpting at least part of that for this paper because it contains both useful information, and a useful lesson (see the prior paragraph).

For the past year, alarm bells have been going off in climate science: Last year's average global temperature was so high, shooting up nearly 0.3°C above the previous year to set a new record, that human-driven global warming and natural short-term climate swings seemingly couldn't explain it. Some, like famed climate scientist James Hansen, suggested Earth is entering an ominous new phase of accelerated warming, driven by a rapid decline in sunlight-dimming air pollution. Others, like Gavin Schmidt, director of NASA's Goddard Institute for Space Studies, said the rise might represent a "knowledge gap," some new climate feedback that might tip the planet toward a future even warmer than models predict.[1]

Now, a new series of studies suggests most of the 2023 jump can be explained instead by a familiar climate driver: the shifting waters of the tropical Pacific Ocean. The combination of a 3-year-long La Niña, which suppressed global temperatures from 2020 to 2022, followed by a strong El Niño could account for the unexpected temperature jump, the work suggests. "Earth can do this," says Shiv Priyam Raghuraman, a climate scientist at the University of Illinois Urbana-Champaign, who led one study.

During La Niña, strong trade winds push warm surface water west along the equator toward Indonesia and pull up a fountain of deep, cold water in the eastern Pacific that helps cool the planet. During El Niño, the winds collapse, allowing warm water to slosh east and shut off the ocean air conditioner.

Last year, analyses suggested the combination of global warming and El Niño fell far short of explaining 2023's heat, leading to the worries that something else might be at play. But Raghuraman and his co-authors weren't convinced those studies captured El Niño's full potential. Indeed, looking back, they found that 1977 was an awful lot like 2023, when temperatures rose by more than 0.25°C after a multiyear La Niña tipped into an El Niño.

[1] Paul Voosen, Science, Oct 11, 2024 Issue, "El Niño fingered as likely culprit in record 2023 temperatures," https://www.science.org/doi/10.1126/science.adt7207

But that's just 2 years out of the 70-some for which El Niño records exist. To generate better statistics, Raghuraman and his coauthors compiled every climate model run they could find that simulated the planet in a steady state, unperturbed by humanity, totaling 58,021 years of simulations. Then they looked to see how often temperature spikes higher than 0.25°C occurred.

Their study, accepted for publication in Atmospheric Chemistry and Physics, showed such spikes were rare, happening only 1.6% of the time, nearly always during an El Niño. But when a long La Niña set the stage, the probability of a spike jumped to 10.3%. And during those model years, the geographic pattern of warming often matched what occurred last year, such as a large increase in the tropical Atlantic Ocean. The models show big El Niño jumps are rare but possible, Raghuraman says. "We're not missing something."

The result lines up with another study, published in August in Communications Earth & Environment, which compared sea surface temperatures in 2023 and the recent past. If global warming was accelerating, that trend would also be seen in the oceans. And although the oceans were anomalously hot in 2023, they were only a little warmer than during an El Niño in 2015 and 2016, says study co-author Marianne Tronstad Lund, research director at Norway's Center for International Climate and Environmental Research. "We don't find signs of any rapid acceleration," she says.

Recent runs of a "climate pacemaker" experiment at the Scripps Institution of Oceanography also implicate El Niño as the main culprit in the globe's extra heat. Unpublished results from the experiment, which feeds real-world Pacific temperatures into a climate model, re-created temperature patterns similar to those observed last year, says Scripps climate scientist Shang-Ping Xie, with some exceptions over the North Atlantic.

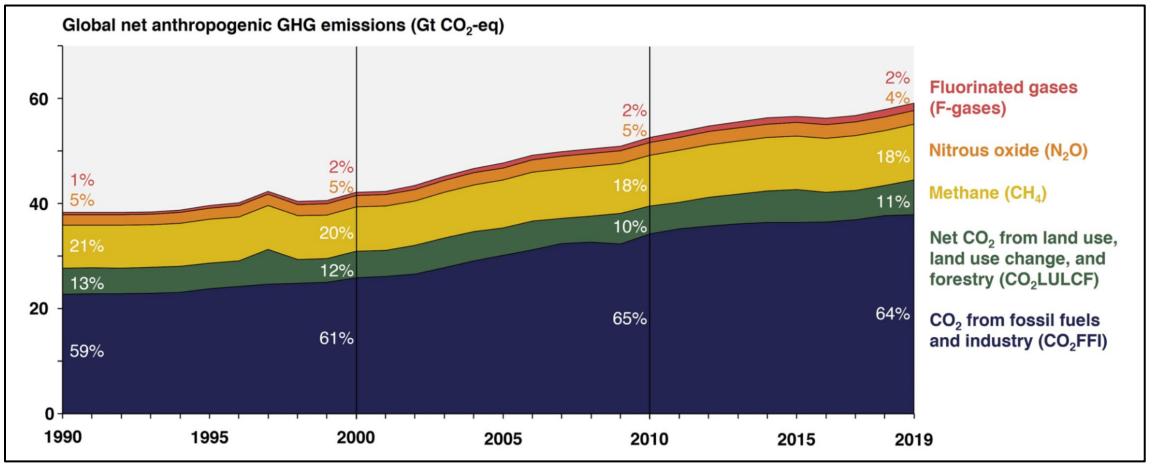
Meanwhile, several studies have found that cleaner, clearer air due to falling pollution from China and lower sulfur marine fuels made only a small contribution to last year's temperatures. One study, submitted to Atmospheric Chemistry and Physics, found that declining pollution could raise global temperatures by 0.03°C over the next 20 years, with the strongest effect not occurring until later this decade. It's not nothing, says study co-author Duncan Watson-Parris, an atmospheric physicist at Scripps, but far too little to explain last year. Taken together, says Mika Rantanen, a climate scientist at the Finnish Meteorological Institute, the results are "a good reminder that it was indeed El Niño that was the major player."

Yet the timing of 2023's heat remains odd, Schmidt says. It came on faster and stronger than in normal El Niño years, and it lingered far longer, even as Earth tips again toward a La Niña. Perhaps the biggest wild card is the increasing amount of sunlight satellites have detected hitting the planet's surface over the past decade (Science, 12 April, p. 147). Falling pollution can only explain some of the increase; the rest might be due to reduced cloudiness or changing surface reflectivity. How much the extra sunlight might have heated the planet in 2023 is unclear.

The new studies aren't the final word on the problem, Schmidt says. Even as the eastern Pacific cools off again, the debate within climate science continues to simmer.

Author's comment: I believe the above shows that we have much more to learn about the causes and effects of climate change. The good news is that we strongly understand the major cause: increasing greenhouse gasses in earth's atmosphere (see chart below). Thus, we know the fix (reduce the amount of greenhouse gasses that humans emit).

However, it will take more than a century to bring greenhouse gas level emissions back to pre-industrial levels, and many more centuries for Mother Nature to reduce carbon dioxide levels to preindustrial levels. The chart below shows that we haven't even started this work (note that the curve is, on average, trending upward).



Source: Data from IPCC (2022); Based on global emissions from 2019, details on the sectors and individual contributing sources can be found in the Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Mitigation of Climate Change, Chapter 2.

I recently found a good NASA Site that had additional information on adapting to climate change. This is presented in the next section.

2. Responding to Climate Change

Climate change is one of the most complex issues facing us today. It involves many dimensions – science, economics, society, politics, and moral and ethical questions – and is a global problem, felt on local scales, that will be around for thousands of years. Carbon dioxide, the heat-trapping greenhouse gas that is the primary driver of recent global warming, lingers in the atmosphere for many thousands of years, and the planet (especially the ocean) takes a while to respond to warming. So even if we stopped emitting all greenhouse gases today, global warming and climate change will continue to affect future generations. In this way, humanity is "committed" to some level of climate change.[2]

How much climate change? That will be determined by how our emissions continue and exactly how our climate responds to those emissions. Despite increasing awareness of climate change, our emissions of greenhouse gases continue on a relentless rise. In 2013, the daily level of carbon dioxide in the atmosphere surpassed 400 parts per million for the first time in human history. The last time levels were that high was about three to five million years ago, during the Pliocene Epoch.

[2] NASA, "Responding to Climate Change," Jan 30, 2024, https://climate.nasa.gov/solutions/adaptation_mitigation/

Because we are already committed to some level of climate change, current response to climate change involves a two-pronged approach:

- *Reducing emissions of and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere ("mitigation");*
- *Adapting to the climate change already in the pipeline ("adaptation").*

2.1. Mitigation and Adaptation

Mitigation – reducing climate change – involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases (for example, the burning of fossil fuels for electricity, heat, or transport) or enhancing the "sinks" that accumulate and store these gases (such as the oceans, forests, and soil). The goal of mitigation is to avoid significant human interference with Earth's climate, "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner." [3]

Adaptation – adapting to life in a changing climate – involves adjusting to actual or expected future climate. The goal is to reduce our risks from the harmful effects of climate change (like sea-level rise, more intense extreme weather events, or food insecurity). It also includes making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

Throughout history, people and societies have adjusted to and coped with changes in climate and extremes with varying degrees of success. Climate change (drought in particular) has been at least partly responsible for the rise and fall of civilizations. Earth's climate has been relatively stable for the past 10,000 years, and this stability has allowed for the development of our modern civilization and agriculture. Our modern life is tailored to that stable climate and not the much warmer climate of the next thousand-plus years. As our climate changes, we will need to adapt. The faster the climate changes, the more difficult it will be.

While climate change is a global issue, it is felt on a local scale. Local governments are therefore at the frontline of adaptation. Cities and local communities around the world have been focusing on solving their own climate problems. They are working to build flood defenses, plan for heat waves and higher temperatures, install better-draining pavements to deal with floods and stormwater, and improve water storage and use.

According to the 2014 report on Climate Change Impacts, Adaptation and Vulnerability (reference 3) from the United Nations Intergovernmental Panel on Climate Change, governments at various levels are also getting better at adaptation. Climate change is being included into development plans: how to manage the increasingly extreme disasters we are seeing, how to protect coastlines and deal with sea-level rise, how to best manage land and forests, how to deal with and plan for drought, how to develop new crop varieties, and how to protect energy and public infrastructure.

[3] From the 2014 report on Mitigation of Climate Change from the United Nations Intergovernmental Panel on Climate Change, https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

2.2. Climate Risks

The federal government offers several tools that can help you drill down on threats to your community.[4]

FEMA Risk Index: A national map that shows all types of hazards by county, expected losses from damage and how resilient communities are to disasters.

https://hazards.fema.gov/nri/map

Wildfire Risk to Communities: A lookup tool from the U.S. Forest Service that provides community-wide risk rating.

https://wildfirerisk.org/explore/

NOAA Sea Level Rise Viewer: Allows you to model sea-level rise scenarios through 2100.

https://coast.noaa.gov/digitalcoast/tools/slr.html

NASA Flooding Days Projection Tool: Predicts the number of days coastal areas will experience high-tide flooding annually.

https://sealevel.nasa.gov/flooding-days-projection/

[4] Michael J. Coren, Naema Ahmed, Kevin Crowe, Washington Post via MSN, "Where climate change poses the most and least risk to American homeowners," Oct 15, 2024, https://www.msn.com/en-us/money/realestate/where-do-homes-face-the-most-and-least-climate-risk-we-looked-at-the-whole-country/ar-AA1shYTS?ocid=BingNewsBrowse