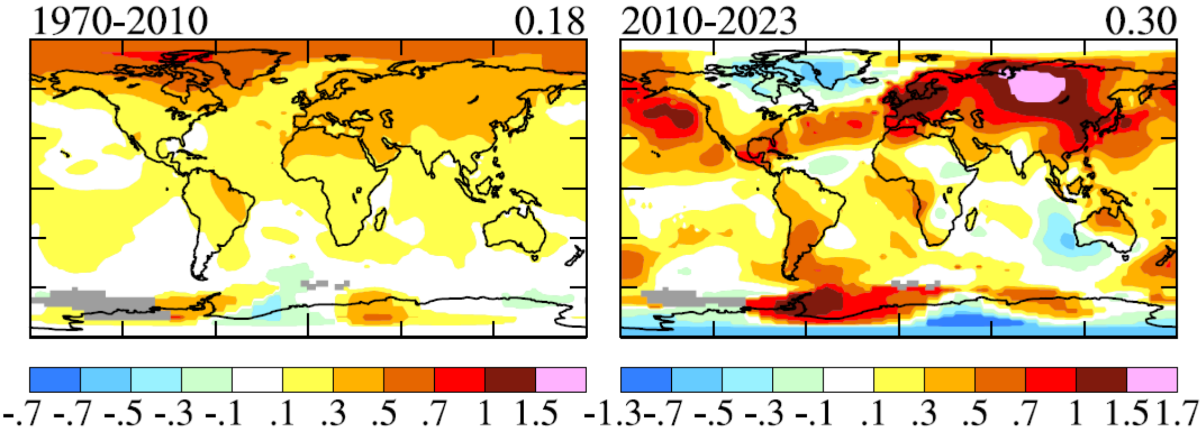

Fig. 1. Local and global (the number in upper right corner) temperature trends in two periods.

Global Warming Acceleration: Hope vs Hopium

29 March 2024

James Hansen, Makiko Sato, Pushker Kharecha

Accumulating evidence supports the interpretation in our *Pipeline* paper: decreasing human-made aerosols increased Earth's energy imbalance and accelerated global warming in the past decade. Climate sensitivity and aerosol forcing, physically independent quantities, were tied together by United Nations IPCC climate assessments that rely excessively on global climate models (GCMs) and fail to measure climate forcing by aerosols. IPCC's best estimates for climate sensitivity and aerosol forcing both understate reality. Preservation of global shorelines and global climate patterns – the world humanity is adapted to – likely will require at least partly reversing global warming. Required actions and time scale are undefined. A bright future for today's young people is still possible, but its attainment is hampered by precatory (wishful thinking) policies that do not realistically account for global energy needs and aspirations of nations with emerging economies. An alternative is needed to the GCM-dominated perspective on climate science. We will bear a heavy burden if we stand silent or meek as the world continues on its present course.

Our paper, *Global Warming in the Pipeline*,[1] was greeted by a few scientists, among the most active in communication with the public, with denial. Our friend Michael Mann, e.g., with a large public following, refused to concede that global warming is accelerating. We mention Mike because we know that he won't take this notation personally.

Accelerated global warming is the first significant change of global warming rate since 1970. It is important because it confirms the futility of "net zero" hopium that serves as present energy policy and because we are running short of time to avoid passing the point of no return. We will focus on advancing our research now and completing *Sophie's Planet* in 2024, so we must limit our interactions this year. We will send out updates every other month for the remainder of this year, as described in a recent *note*.[2] This is the March update.

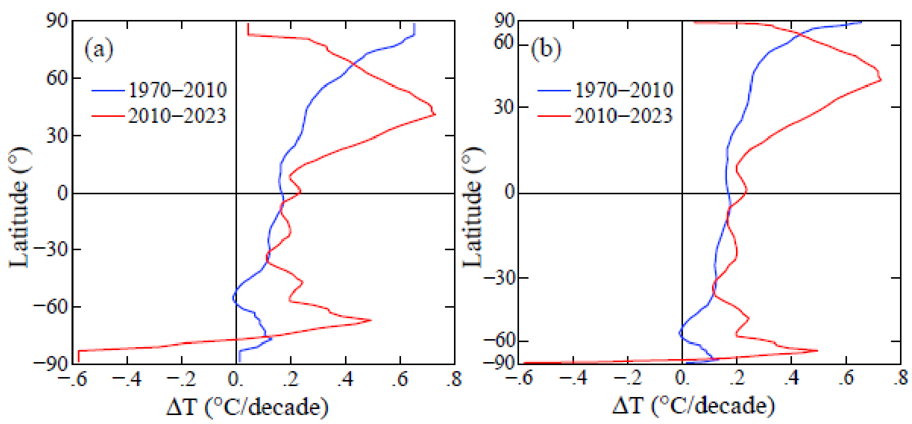

Fig. 2. Zonal-mean temperature trends, plotted linear in latitude (a) and area-weighted (b).

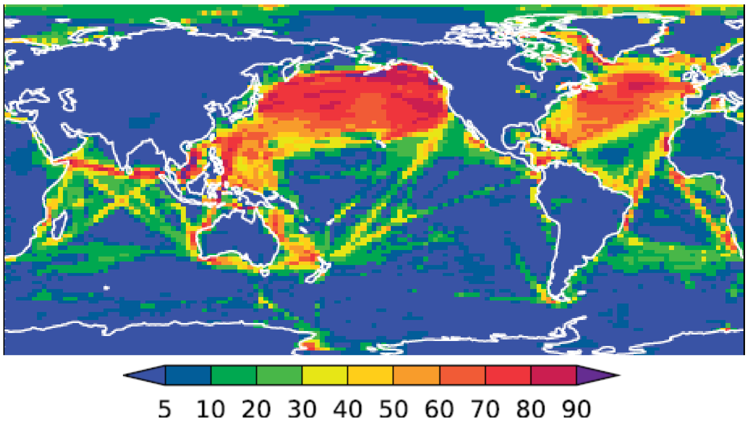

Fig. 3. Percent of sulfate from ships prior to IMO regulations on fuel sulfur (Jin *et al.*[3])

Global warming in 2010-2023 is 0.30°C/decade, 67% faster than 0.18°C/decade in 1970-2010 (Fig. 1). The recent warming is different, peaking at 30-60°N (Fig. 2); for clarity we show the zonal-mean temperature trend both linear in latitude and area-weighted. Such an acceleration of warming does not simply "happen" – it implies an increased climate forcing (imposed change of Earth's energy balance). Greenhouse gas (GHG) forcing growth has been steady. Solar irradiance has zero trend on decadal time scales. Forcing by volcanic eruptions has been negligible for 30 years, including water vapor from the Honga Tunga eruption.[4] The one potentially significant change of climate forcing is change of human-made aerosols. The large warming over the North Pacific and North Atlantic (Fig. 1) coincides with regions where ship emissions dominate sulfate aerosol production (Fig. 3, from Jin *et al.*[3]).

Aerosol climate forcing is unmeasured.[5] Inference of aerosol forcing is thus a herculean task because (1) aerosol forcing operates mainly by altering clouds, (2) clouds are also a climate feedback that is poorly quantified, and (3) clouds have large natural variability. Fortunately, an indirect measure of aerosol forcing can be extracted from precise data for changes of Earth's absorbed solar radiation (ASR) and Earth's energy imbalance (EEI). Unbroken time series of ASR and EEI are available from March 2000 to the present from CERES (Clouds and Earth's Radiant Energy System) instruments[6] with calibration via precise measurement of changing ocean heat content over decades; the calibration depends primarily on an improving global network of deep-diving Argo floats.[7] Continuing data for ASR and EEI will be crucial for guiding young people and future generations.[8]

Global absorbed solar radiation (ASR) has increased dramatically since 2010, more than 1.4 W/m^2, equivalent to a CO_2 increase of more than 100 ppm.[9] The ASR increase is not due to a brightening Sun,[10] it is due to a darkening Earth. Our task is to learn how much of this darkening is climate feedback (due to decreasing ice/snow and cloud albedo, i.e., reflectivity) and how much is climate forcing (due to decreasing aerosols). In *note*, we use the geographical distribution (global map) of ASR to infer that the forcing due to decreased ship aerosols is at least ~0.5 W/m^2. A smaller, additional, forcing is inferred from increased ASR over Europe, which also is likely from reduced aerosols.

Zonal mean ASR (Fig. 4) provides insight. ASR increases strongly since 2020 at latitudes 30-60°N, the region of reduced aerosols we have discussed. In the region where ship aerosols are expected to have a large effect (30-60°N) and in the entire region where ship effects may be significant (30°S-60°N), ASR increases in 2015-2020 and increases more in 2020-2023. The Arctic ASR maxima are associated with sea ice minima in 2007, 2012, 2015-16 and 2020, while the double maximum near Antarctica is caused by increasing polynya (open water) near the Antarctic coast and decreasing ice cover at the northern boundary of Southern Ocean sea ice. The region 30°S-60°S is unlikely to have much ship aerosol effect (Fig. 3), so change of ASR there is more likely due to cloud feedback and unforced cloud variability.

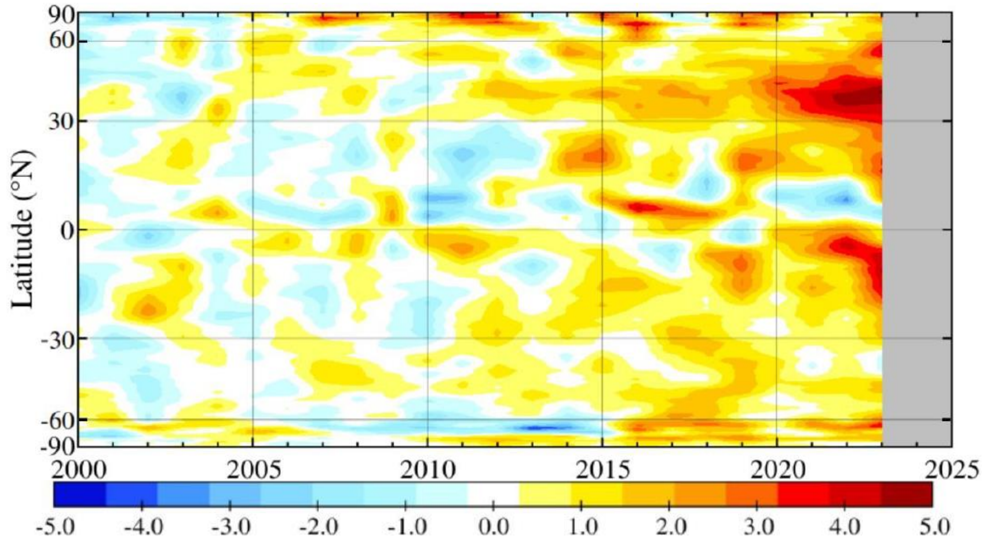

Fig. 4. Zonal-mean absorbed solar radiation (ASR) anomaly relative to mean of first 10 years.

The climate forcing at 30-60°N implied by ASR is so large that we should expect a detectable surface temperature response. A major scientific issue has been raised by an unprecedented increase of global sea surface temperature (SST) in 2023, so it is appropriate to ask whether there is a relationship between the large increase in ASR and increased SST. Fig. 5 shows that the pattern of temperature change corresponds with the location and temporal development of the ASR anomaly. Coincidence does not prove causality, as high temperatures could cause reduced cloud cover and increased ASR, so we must seek additional evidence.

However, first, let's draw attention to important information in Fig. 5. Much ado is being made about the increase of global SST in 2023. It suffices to reference a single article[11] by Scott Dance, because Dance comprehensively describes fears and speculations of climate researchers who describe ocean surface warming as inexplicable, suggesting that the climate system may be undergoing some fundamental change in the way climate physics operates. Fears are expressed that new climate patterns are being established that will be irreversible on time scales from centuries to millennia. The scientists reject, without any evidence to the contrary, the evidence we presented that IPCC's best estimates for climate sensitivity and human-made aerosol forcing are substantial underestimates. They rule out, without evidence, our suggestion that decreases of aerosols, especially those produced by ships, are a significant climate forcing that is causing global warming acceleration. Instead, they make a blatant error by describing the current El Nino as historically strong and express concern that current record warmth may persist even under La Nina conditions.

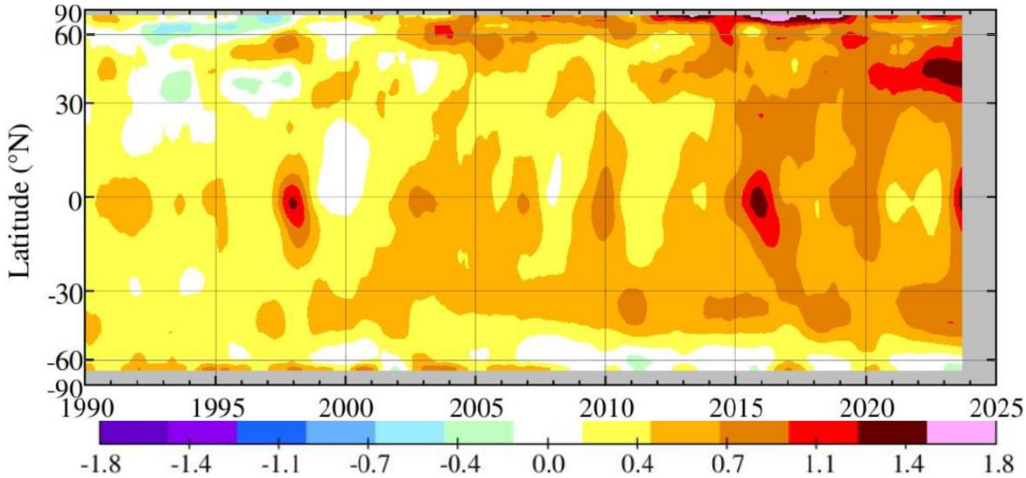

Fig. 5. Zonal-mean SST (12-month running-mean) relative to 1951-1980 base period.

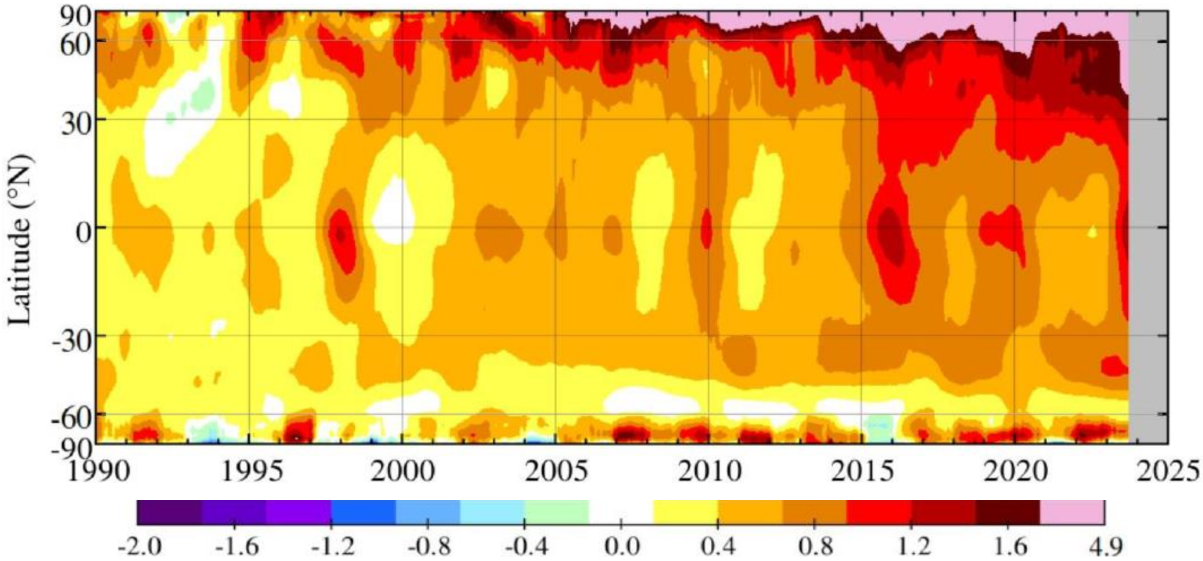

Fig. 6. Zonal-mean surface temperature (12-month running-mean) relative to 1951-1980.

The largest SST change is at 30-60°N (Fig. 5), the region with decreased aerosols. That SST increase did not appear suddenly in 2023 – it was well underway in 2020. During 2020-2022 the tropics were in a La Nina cooling trend with the La Nina depth disguised by the effect of accelerated global warming on the temperature of upper ocean layers. Global SST made a big jump in 2023 because tropical, midlatitude, and polar temperature changes were all suddenly in warming phase. There is no basis for fear that new physics has come into play. The tropics will cool as the El Nino fades later this year, although the present large planetary energy imbalance will inhibit the size of the global temperature decline.

Zonal-mean surface temperature (Fig. 6) based on the GISS temperature analysis[12,13] supports the interpretation of global warming that we have presented here and elsewhere.[1] Warming is accelerating in the past 10-15 years, especially at midlatitudes in the Northern Hemisphere.

The fact that the climate physics is understandable is no reason to relax. On the contrary, we have shown[14] that the world is approaching a point of no return in which the overturning ocean circulation may shut down as early as midcentury and sea level rise of many meters will occur on a time scale of 50-150 years. Time is running short to make the public and policymakers aware of the threat posed by the delayed response of our climate system and of the actions that should replace present wishful thinking (hopium). This education will not happen instantly, but it is realistic to hope that we can greatly improve understanding this decade, a period that should be long enough to expose the fruitlessness of present policies, as well as to verify the physics of ongoing climate change.

As an additional check on our understanding of the cause of global warming acceleration, we examine global average absorbed solar radiation (ASR) and Earth's energy imbalance (EEI). Then we can be quantitative about the additional climate forcing that is needed to produce the observed global warming acceleration and discuss implications for the future.

Global ASR and EEI (Fig. 7) aid understanding of climate change. Increased solar heating of Earth, i.e., increased ASR (Fig. 7a) is a darkening of Earth that must be the combination of aerosol forcing and albedo feedbacks. However, albedo feedbacks contribute at most half of the total (forcing + albedo feedback).[15] So, at least half of the increased ASR since 2015, i.e., at least 0.7 W/m^2, is the added forcing. This comports with our estimate that added aerosol forcing is at least 0.5 W/m^2 based on changes of ASR in the areas of maximum ship effect, as described in *note*.

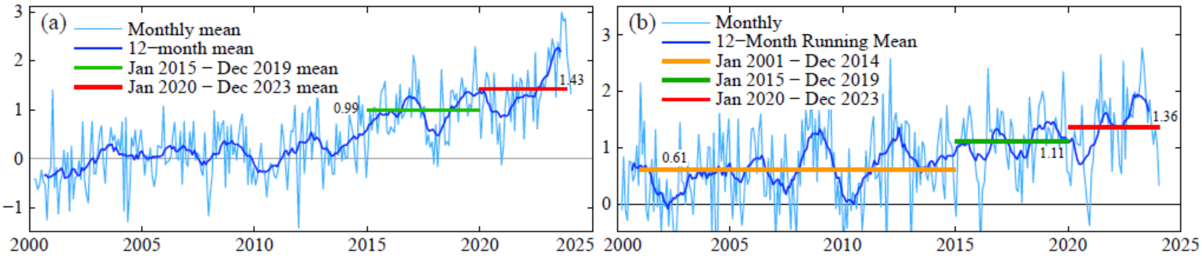

Fig. 7. (a) Global absorbed solar radiation (ASR) relative to the mean of the first 120 months of CERES data (W/m²).[6] (b) Earth's energy imbalance (EEI) from CERES satellite data normalized to the 0.71 W/m² mean for July 2005 – June 2015 based on Argo and other data.[7] CERES data are available at http://ceres.larc.nasa.gov/order_data.php

This estimate for the ship aerosol forcing is an order of magnitude (factor of ~10) greater than what follows from IPCC estimates. The 2021 IPCC report (AR6) pegs total aerosol forcing as 1.06 W/m² in 2019, with 0.22 direct aerosol forcing and 0.84 the indirect effect on clouds. A 2021 update[16] reduces the aerosol forcing to 0.98 W/m² (0.21 direct, 0.77 indirect). Based on this small aerosol forcing, Hausfather and Forster[17] obtain a forcing of 0.079 W/m² for 100% implementation of 2020 IMO[18] ship emission limits. Our estimate of 0.5-0.7 W/m² refers to the actual (~80%) reduction of sulfates from ships. The difference with the Hausfather and Forster value is so large that it must be possible to resolve this issue within a few years.

Where did the IPCC aerosol forcing come from? Not from global measurements. As will be described in *Sophie's Planet*, such measurements were proposed[19] and strongly supported by engineers at Goddard Space Fight Center (GSFC). However, GSFC management and NASA Headquarters viewed the proposed (Climsat) mission as a threat to the larger Earth Observing System mission and Climsat was not approved. Aerosol forcing requires detailed knowledge of the changing microphysics of both aerosol and cloud particles, which depends on precise measurement of the polarization of reflected sunlight and the spectrum of emitted thermal radiation measured with an infrared spectrometer (Michelson interferometer).[19]

In reality, the IPCC aerosol forcing is the forcing required for GCMs to yield global warming comparable to observed warming. In the many years between successive IPCC reports, the modeling groups make hundreds of climate simulations. Results reported to CMIP (climate modeling intercomparison project) and used by IPCC tend to be model runs with global warming comparable to observations. The ensemble of model results yields a fog of projected future warming. The real world falls within the projected model fog because each successive IPCC report has a new model fog consistent with the new models and updated observations.

Knutti[20] pointed out individual models in the model fog each tend to yield global warming comparable to observations, even though the models differed in many ways and had a range of climate sensitivities. This result is at least partially explained by the fact that the aerosol forcing is not well constrained, which provides each GCM model a degree of freedom in the choice of aerosol forcing. Knutti also pointed out that most GCM simulations did not even include the aerosol indirect climate forcing (the effect of aerosols on cloud cover and cloud albedo). Aerosol and cloud physicists who wrote the aerosol section of IPCC reports suggested that the indirect effect was probably the larger aerosol forcing, yet this larger (negative) aerosol forcing was not employed in most of the GCMs.

There were two reasons that the GCM modelers did not want to include the full aerosol forcing in their models. First, many of the oceans in the GCMs tended to mix heat into the deep ocean too effectively, which meant that the GCM needed a slightly exaggerated forcing to match observed surface warming. Increased net forcing could be achieved with a smaller (less negative) aerosol forcing. Second, and more important, the GCMs tended to have climate sensitivities in the neighborhood of 3°C for 2×CO_2; with such climate sensitivity only moderate aerosol forcing (~1-1.5 W/m^2) is needed to match observed global warming.

[We are not suggesting that modelers were up to something nefarious. For example, the GISS GCM[21] in that era had sensitivity ~3°C for 2×CO_2 and the aerosol forcing was −1.39 W/m^2 (direct = −0.52, indirect = −0.87). It was admitted that we had no ability to compute aerosol indirect forcing; instead, we used a global distribution from an aerosol model multiplied by a factor intended to yield an indirect aerosol forcing of −1 W/m^2. When used in the GCM with computed cloud cover, the aerosol indirect forcing turned out to be −0.87 W/m^2. Other GCM groups made their own choices, but no group had realistic aerosol-cloud modeling.]

The basic difficulty is that cloud modeling is hard and aerosol-cloud modeling is very hard. The simplest cloud models, used for decades, yield climate sensitivity near 3°C for 2×CO_2. Several recent models that attempt to model cloud microphysics more realistically, including mixed phase clouds, yield higher climate sensitivity, ~4-6°C for 2×CO_2. Empirical evaluation of climate sensitivity has finally been achieved thanks to accurate definition of ice age global temperature by Seltzer *et al*.[22] and Tierney *et al*.,[23] with the result that climate sensitivity is 4.8°C ± 0.6°C (1σ), with 3°C sensitivity excluded with 99.7% certainty.[1]

There is independent support for high climate sensitivity. In a webinar,[24] George Tselioudis showed figures of Zelinka *et al*.[25] and Jiang *et al.*[26] revealing that high sensitivity climate models yield much better agreement with satellite observations of seasonal and latitudinal cloud changes; the low sensitivity models do not have even the correct sense of the changes. In addition, Williams *et al.*[27] show that the improved aerosol and cloud physics (particularly production of liquid water in mixed phase clouds) in the British Met Office GCM (widely agreed to be one of the most realistic GCMs) leads to an increase of the model's sensitivity from 3.2°C to 5.5°C for 2×CO_2. As described also by Palmer,[28] the physics changes that yield the higher climate sensitivity also yield improved 6-hour tendencies in the GCM used for short-term (weather) simulations, an insightful approach that has been recommended for assessing the realism of supposed improvements in model physics.

High climate sensitivity is a double whammy. High sensitivity implies a large (negative) aerosol forcing because aerosol forcing, unfortunately, so far has been an implied quantity, not a directly measured quantity. Further evidence that IPCC underestimates aerosol forcing is provided in our *Pipeline* paper.[1] For example, greenhouse gas climate forcing increased by 0.5 W/m^2 over the past 6000 years, yet global temperature held steady or declined slightly, especially in the Northern Hemisphere. Given that greenhouse gases and aerosols are the two significant global forcings and the fact that wood-burning was the fuel source as civilization developed, we argue that the human-made aerosol forcing was already at least (negative) 0.5 W/m^2 in 1750, when IPCC assumes that it was zero, and we argue that the release of aerosols in burning of wood and other biofuels has not decreased globally since 1750.

Decreased aerosol forcing since 2010 accelerates global warming and, in combination with a moderate El Nino, accounts for the magnitude and geographical location of unusual 2023 warming. There is no need for concern that the physics of the climate system has changed.

Little light is shed on global climate change by the IPCC model fog approach. Real world global temperature change always is included within the projected model fog, as reset with each successive assessment, but that does not expose the physics of the climate system.

The real world has its own fog: natural climate variability that makes it difficult to measure human-driven climate change. El Nino/La Nina tropical variability is the main source of global temperature variability. Jeremy Grantham[29] suggested a way to possibly detect and measure global warming acceleration: compare global temperatures at the peaks of strong El Ninos, which provide a well-defined point in the tropical cycle. The 1997-98 and 2015-16

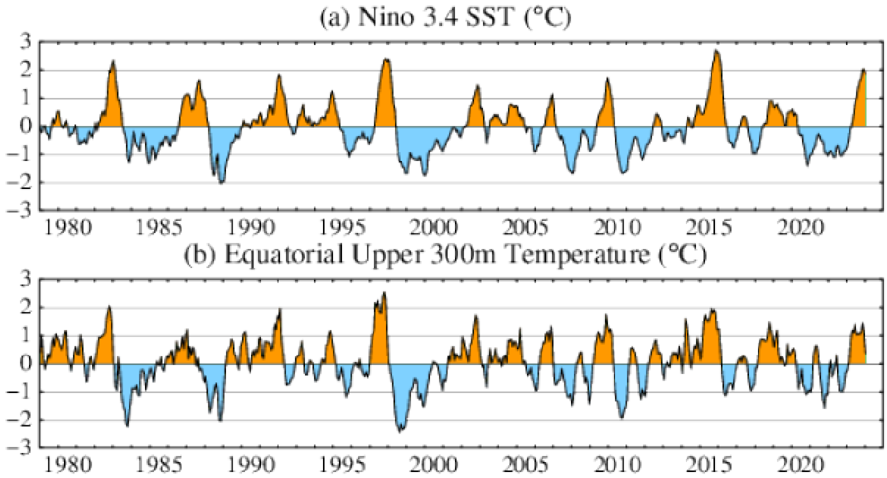

Fig. 8. Nino3.4 SST and temperature anomaly of ocean upper 300m in equatorial region.[30]

super El Ninos were comparably strong, and the global temperature increase between them provided a strong hint that global warming was beginning to accelerate.

Does the present El Nino provide a similar opportunity? We must first ask whether this El Nino is of comparable strength to those two super El Ninos. NOAA declared that the 2023-24 El Nino is a super El Nino, based on the fact that the Nino3.4 temperature (of a small region in the equatorial Pacific) reached 2.0°C. In desperate attempts to explain extreme global temperatures of the past year, the present El Nino has been described as a "historically strong El Nino."[11] Really? Is it a super El Nino?

Nino3.4 SST (sea surface temperature, Fig. 8a) implied that the current El Nino is almost as strong as the super El Ninos. However, heat content data for the upper 300m of the equatorial Pacific (Fig. 8b) show that this El Nino is a weak imposter, no super El Nino. The El Nino/La Nina system operates as a discharge-recharge heat battery:[31,32,33] heat builds up in the tropical western Pacific during the La Nina phase, then, in the El Nino phase, heat moves eastward across the Pacific and poleward within the ocean. Local SST increase causes heat loss to the atmosphere mainly via enhanced evaporation, cooling the ocean, moistening the atmosphere, invigorating convection and atmospheric teleconnections that dispense energy worldwide, especially to the Atlantic and Indian Ocean regions, causing an overall global warming.[34] Fig. 8b shows that the present El Nino started with a battery that was only half full. The heat loss from the equatorial Pacific during the 1997-98 El Nino of the (20th) century was a cooling of the upper 300 m of the ocean by in excess of 4.5°C (peak to trough change in Fig. 8b). The battery discharged 3°C in the 2015-16 El Nino. How far the present El Nino will discharge the battery remains to be seen, but it seems unlikely to approach even the 3°C level.

Fig. 9 confirms that the 2023-24 El Nino is only moderate. Although Nino 3.4 reached 2.0°C in November and December 2023, the global maps show that temperatures throughout the tropics (including the Nino3.4 area) are inflated from global warming by at least 0.6°C in 2023-24. Even with that inflation the narrow El Nino region is notably cooler than in the two super El Ninos. The map in the lower right corner of Fig. 9 will show even less warming in the El Nino region when the March data are added to that map. Consistent with the present El Nino being weak, global temperature during Northern Hemisphere winter, when El Ninos usually have the largest impact on global temperature, was barely larger in 2024 than it was in 2016, despite the strong overall global warming of the past decade.

Even though the current El Nino is weak, we expect the peak global temperature produced by the El Nino to help confirm global warming acceleration. The 12-month-mean is +1.5°C in the GISS analysis through February (Fig. 10). The peak in 2016 was reached in March, but

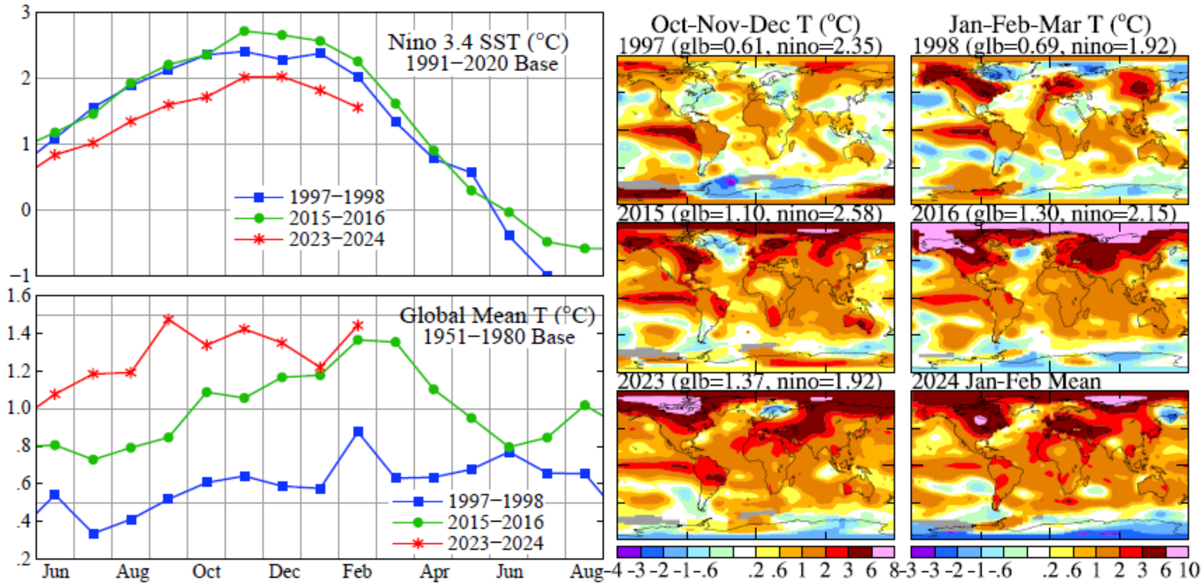

Fig. 9. Nino3.4 index, global mean temperature, and maps of surface temperature during the peaks of the last three large El Ninos. Base period is 1951-80 except 1991-2020 for Nino3.4.

this year the 12-month mean may continue to rise as much as a few months longer due to the extreme planetary energy imbalance. The pink range in the Fig. 10 projection was based on Earth's unprecedented energy imbalance and assumption that the current El Nino was similar to the super El Ninos.[35] This El Nino is actually half-baked, not a super El Nino, but the 12-month mean global temperature may still approach ~1.6°C. Peak 12-month temperature during the 2016 super El Nino was 1.34°C, so a 1.6°C El Nino peak would be a warming rate between El Ninos (1.6-1.34)/(8 years) = 0.33°C/decade, an 84% acceleration over the 0.18°C/decade rate of 1970-2010, which is within the 50-100% acceleration expected due to the observed doubling of Earth's energy imbalance.[1] Better assessment of acceleration – independent of El Nino strength – will be provided by the average temperature of the El Nino peak and the next La Nina valley. We expect the average of the El Nino maximum and the La Nina minimum of global temperatures to be ~1.5°C. Given Earth's huge energy imbalance – more energy coming in than going out – it will be clear that for all practical purposes the 1.5°C global warming level has been reached in the mid-2020s.

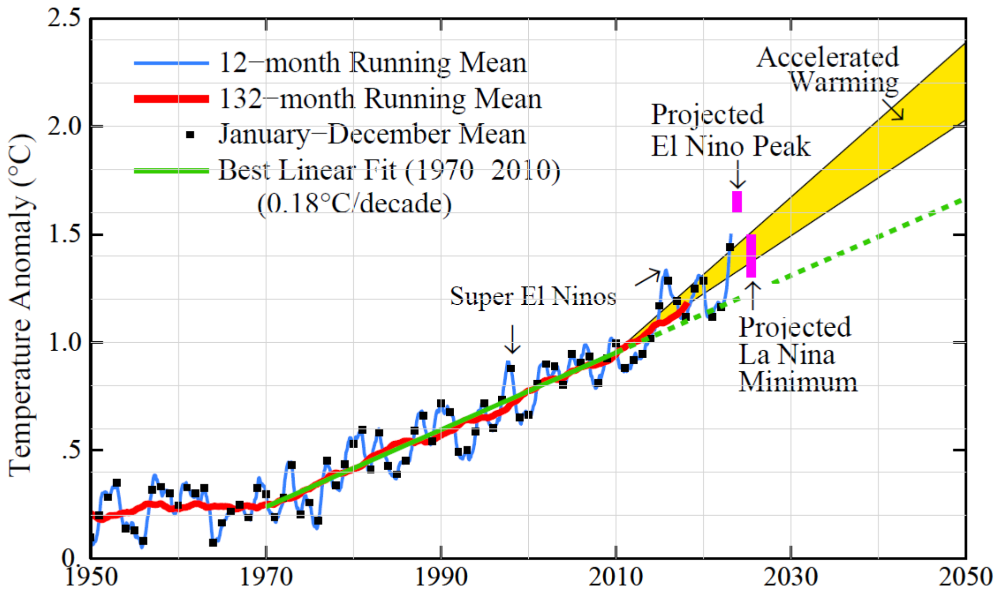

Fig. 10. Global temperature relative to 1880-1920 based on the GISS analysis.[36,37]

Summary

1. Our Three-Pronged Research Approach

Our research approach[38] gives comparable weight to paleoclimate, GCM modeling, and observations of ongoing climate physics. Housing these three in the same university or the same climate assessment report is not sufficient. They must be housed in the same brains.

IPCC's overemphasis on GCMs, in contrast, causes IPCC to be purblind to evidence of climate change, a slowness with grave consequences for effective policy-making because of the delayed response of the climate system. Let's give one pertinent example (another more consequential one is discussed below under "point of no return"). As soon as paleoclimate evidence made it clear that equilibrium climate sensitivity was greater than 3°C for $2\times CO_2$, alarm bells should have gone off: "Uh-oh, we also fxcked up on aerosol climate forcing!"

Aerosol physicists knew that aerosol forcing could be large because of the difficulty in quantifying the effect of aerosols on cloud cover and cloud lifetime. But GCM modelers, of course, tended to employ an aerosol forcing that allowed their models to approximately reproduce global warming of the past century. Sometimes this was explicitly admitted, e.g., in a review[39] that concluded aerosol forcing had to be smaller than 1.6 W/m^2 because otherwise the GCMs would not yield observed global warming. The IPCC modeling community dressed this up with a sophisticated appellation "emergent constraint," preferring that to its more useful description in the olden days as an adjustable "fudge factor."

The result is that two independent physical quantities, climate sensitivity and aerosol forcing, were tied together via excessive reliance on GCMs as a basis for climate assessment. One response of modelers has been: oh, well, it doesn't really matter – the policy requirement is still that we must reduce greenhouse gas emissions rapidly; everybody must promise to have zero "net emissions" by mid-century. Oh, boy. That's another story. Enough on this for now.

2. Global Warming Is Accelerating

Fig. 1 shows that global warming accelerated since 2010, especially in regions where aerosol forcing is believed to have declined due to IMO fuel restrictions. Based on the increase of absorbed solar radiation (ASR) in these regions, we estimated an increase of aerosol forcing of at least 0.5 W/m^2. Based on the 1.4 W/m^2 global increase of ASR, and expectation that only about half of this could be feedbacks on the short time scale of change, we estimate an aerosol forcing near 0.7 W/m^2. The increase of ASR is the reason Earth's energy imbalance (EEI) since 2020 is nearly double what it was in the first decade of the 21st century. From this increased energy imbalance, we conclude that global warming in 2010-2030 should be 50-100 percent greater than the warming rate in 1970-2010. This acceleration follows from the climate response function for a high climate sensitivity,[1] without the need to run a GCM.

Coincidence of regions of strong warming with regions of aerosol reduction does not prove causality. Anomalous ocean circulation, for example, may have produced hot regions in the North Pacific and North Atlantic. If high SSTs led to reduced cloud cover, this might explain increased ASR. Fig. 5, repeated here for convenience, suggests how unusual this ocean dynamical explanation is, needing to produce an unprecedented hot spot in the midlatitudes of the Northern Hemisphere. For this ocean dynamics explanation to be taken seriously, evidence for and explanation of the ocean circulation change should be presented.

Instead, Fig. 5 suggests that the sudden increase of global SST in 2023 was the combination of two phenomena: (1) growth over the past decade, especially since 2020, of warming due to decreased aerosols with the maximum effect where expected, at northern midlatitudes, and (2) the switch in mid-2023 from a prolonged, strong, La Nina to a moderate El Nino. This

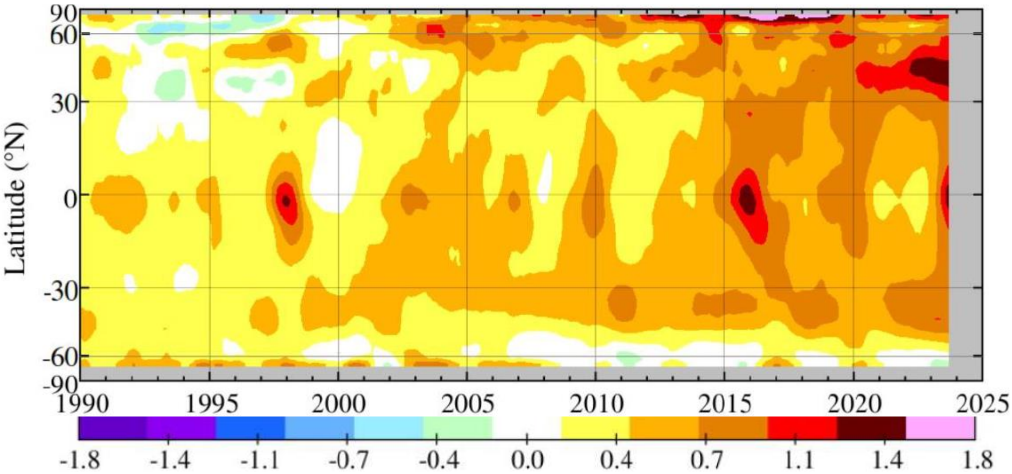

Fig. 5. Zonal-mean SST (12-month running-mean) relative to 1951-1980 base period.

obvious interpretation of Fig. 5 allows us to dispense with the notion that new climate physics is required to explain the sudden increase of global warmth in the past 12 months.

Additional insights are contained in Fig. 5. The apparent strength of the 2015-16 and 2023-24 El Ninos relative to the 1997-98 El Nino of the century is misleading because it results from the more recent El Ninos being bathed in growing, widespread, global warming. Fig. 5 also suggests a delayed spreading of El Nino warmth to higher latitude ocean areas. El Nino ocean heat is transported between ocean basins via interesting atmospheric teleconnections.[40] The warming in Southern Hemisphere midlatitudes is likely to include significant amplifying cloud feedback because high climate sensitivity implies amplifying cloud feedback and the southern midlatitudes are the main region of stronger positive cloud feedback in the increased sensitivity CMIP6 model ensemble.[25]

A feature of special note in Fig. 5 is the lack of warming in the Southern Ocean at latitudes near 60°S. This feature is an indicator of approach to the point of no return.

3. The Point of No Return

The "tipping point" concept, implying an unstable climate response, is misused and overused, thus encouraging a fatalistic public response or climate change denial.[41] Most phenomena described as tipping points are amplifying, reversible, feedbacks, not runaway processes. Take melting permafrost and decreasing Arctic sea ice; these amplifying feedbacks increase regional and global climate change on decadal and longer time scales. The feedbacks grow while Earth's radiation balance is positive – more energy coming in than going out – but once we reduce the climate forcing enough that Earth's energy imbalance becomes slightly negative, feedbacks will work in the opposite sense, helping us move global temperature and climate patterns back toward their condition before human alterations of the planet began.

Attention should be focused on the danger of passing the point of no return, when we lock in disastrous consequences that cannot be reversed on any time scale humans care about. The prime point of no return is collapse of the West Antarctic ice sheet. If we allow that to get well underway, we will lose that entire ice sheet quickly (by paleo standards). That ice sheet must have collapsed in the Eemian period, when global temperature was similar to today; sea level rose several meters in less than a century.[42] Moreover, today's greenhouse gas level and climate forcing now exceed even that of the early Pliocene, when sea level was 15-25 meters (50-80 feet) higher than today. Thus, West Antarctic ice sheet collapse would initiate a long period of continuously changing shorelines. Combined with shifting climate zones, greater climate extremes, and increasingly inhospitable low latitudes, this is a picture of future climate that must and can be avoided.

How close are we to locking in West Antarctic ice sheet collapse? Nobody knows for sure. Better understanding of that issue was an objective of a proposal[43] (unfunded) that we made a few years ago. This topic provides an example of why our three-pronged research approach is needed as a complement to the GCM-dominated IPCC approach. We concluded in our *Ice Melt* paper,[14] based on observed rates of ice shelf melting, that the world is nearing shutdown of the Atlantic Overturning Meridional Circulation (AMOC) and shutdown of deepwater formation near Antarctica (which we term SMOC for its analogy to the Northern Hemisphere process), if the rate of ice melt continues to grow. AMOC shutdown occurs in midcentury in our GCM simulations, if ice melt continues to grow. We interpret lack of real-world warming in the Southern Ocean near Antarctica as a telltale sign that freshwater from melting ice shelves is already slowing SMOC and beginning to reduce Southern Ocean SST. We describe in *Note*[2] how the GCM-dominated approach allows censorship of alternative perspectives, when the models have a common, or at least widespread, problem: lack of realistic sensitivity to injection of freshwater into the upper layers of the ocean.

What is a realistic timeframe on which "the point of no return" should be understood much better and its implications communicated? By 2030, the date when nations are expected to have made measurable progress in climate policies, it may, at long last, be recognized that the "hopium" approach to climate policy – goals and promises of "net zero" emissions at some distant date, without realistic plans for reliable, carbon-free, energy – is hopeless. By then scientists need to have improved their communication with the public, especially with young people, who, we will argue, have great potential to affect the future of their planet.

4. Communication

We need to communicate energy/climate science better. It is tempting to relax into comfort of scientific reticence, described in section 7.2 of our *Pipeline* paper. But who is going to communicate science to policymakers and the public if scientists retreat into reticence? It's especially important, we think, to communicate with young people to help them realize that they have great potential to help assure that they have a bright future.

We became involved in the broad energy/climate problem more than 20 years ago after we became concerned that the Kyoto Protocol was ineffectual and the climate scenarios being considered by IPCC were all problematical. We wrote a paper, *An Alternative Scenario*,[44] and organized two workshops[45] at the East-West Center in Hawaii to discuss the possibility of addressing the problems of air pollution and climate simultaneously. What is the most useful way to communicate the perspective that we gained in the following 20 years from our efforts to understand the energy/climate problem? We think that completion of the long-planned *Sophie's Planet* might help the public understand the situation.

The potential political power of young people has been demonstrated. Without funding, but communicating among themselves, they had a large role in elevating Barack Obama to his nomination in the 2008 Democratic Presidential primary, and their support of Bernie Sanders in 2016 almost led to the improbable nomination of a democratic socialist as a major party nominee. College and high school students[46] can understand the need for a simple, honest, carbon fee-and-dividend that economists[47] support. It's also necessary, however, to have insight about how the best interests of the public can be foiled by special financial interests.

Consider the example of nuclear power. When U.S. President Bill Clinton, in his first State of the Union address following his 1992 election, declared "We are eliminating programs that are no longer needed, such as nuclear power research and development," he was acting under the spell of Amory Lovins, whose policy prescriptions were based not on science but on a vision, a vision of a world that needed no coal, no oil, no gas, no nuclear power, no large hydro, no carbon tax – all that was needed was "soft" renewable energies such as solar panels and windmills, and these renewables could totally replace all other energies by 2025.

Reality is different. Lovins' later book, *Reinventing Fire*,[48] has a fawning Foreword written by the President of Shell Oil Company, which is not surprising since Lovins had adjusted his graphs so that fossil fuel phaseout was moved to 2050, and no doubt the phaseout in such heuristic graphs can be moved further. It is unsurprising that annual reports of Lovins' Rocky Mountain Institute include Shell and BP among corporate donors providing minimum annual support of $500,000 each. In defense of Lovins, we note his more recent op-ed[49] in the New York Times, expressed support for carbon fee-and-dividend, which he had categorically dismissed as unnecessary a decade earlier in discussions with the first author (JEH).

One of the things that JEH learned from a conversation with the leader of one of the largest "Big Green" environmentalist organizations is that Big Green cannot support nuclear power because they would lose a substantial fraction of their donations if they did. The fossil fuel industry is a significant contributor to the Big Green organizations, and many of these organizations are financially invested in renewables and fossil fuels, so they do not want to see nuclear power as a competitor. Big Green is green mainly as the shade of a dollar bill.

The 30-year delay in support for nuclear power denied the industry the R&D needed to develop its potential. Based on the amount of material (steel, concrete, fuel, etc.) required for a power plant, nuclear power should be our cheapest energy, if it was supported equally. There is no need to cry over spilled milk, though. By 2030, there should be multiple options for modern ultrasafe nuclear power that can serve as the needed complement to renewable energies to produce carbon-free electricity.

In 2024 in the United States, the essential political need for the sake of the energy/climate problem is preservation of democracy and thus the potential for future political influence. However, once the 2024 election is over, our opinion is that young people need to reconsider how to most effectively use their enormous potential political power. Is it really by joining one of the sides in the cultural war that prevents effective governance? In *Sophie's Planet*, we will discuss some ideas that we believe are worth considering.

5. Funding

Most philanthropic organizations will not support organizations that are positive about nuclear power, so we greatly appreciate the people who helped Climate Science, Awareness and Solutions survive and even achieve some rejuvenation in the past year. It started with Isabelle Sangha, who did the calculations for the Cenozoic Era section of the *Pipeline* paper (there is still more to extract from that study – we will argue that it provides a more realistic history of atmospheric CO_2 than that from proxy CO_2 measurements, as well as other insights). Isabelle was taking a year off from studies after her BaSci; the bureaucracy for creating a position at Columbia took so long that we employed her through CSAS.inc. Isabelle is now off to Cambridge University in the UK for a Ph.D. program, but the Columbia advertisement uncovered another gem, Joe Kelly, similarly in a period prior to Ph.D. studies. Joe, under guidance of George Tselioudis, is making great progress in understanding cloud behavior in the GISS climate models, and he produced the "good news" (item 6 below). Makiko Sato will retire late this year. It is impossible to replace her, as her contributions are spread widely across our program in data set compilations, climate analysis, graphics, and keeping our group together. The crucial requirement is someone who can maintain, expand, and work with climate data sets. We aim to find someone at an entry level position who is eager to learn – in our view, working with data is at least as interesting and important as climate modeling. If we can afford it, we would like to start someone this summer to have a period of overlap with Makiko.

In the list of our major donors over the past several years, published at the end of the *Pipeline* paper, we forgot to include the grant received from the Alex C. Walker Foundation, and since *Pipeline* was published, we received a gift from Michael Dorrell. A list of those who have supported CSAS over the past several years, more complete than given in our *Pipeline* paper is the Grantham Foundation, Frank Batten, Eric Lemelson, James and Krisann Miller, Carl Page, Michael Dorrell, Alex C. Walker Foundation, Peter Joseph, Ian Cumming, Gary and Claire Russell, Donald and Jeanne Keith Ferris, Aleksandar Totic, Chris Arndt, Larry Travis, Jeffrey Miller, Ron and Gail Gester, Judy Lamana, Morris Bradley, and about 200 members of the public to CSAS at Columbia University and about 100 contributors to CSAS.inc in response to funding appeals.

6. Good News

The good news comes from Joe Kelly, who investigated the large "ultrafast" response of Earth's energy imbalance (EEI) to a 2×CO_2 forcing in the GISS (2020) GCM. Specifically, we reported in *Pipeline* that the initial 4 W/m^2 imbalance dropped by about 30% (to 2.7 W/m^2) in year 1 after the forcing was imposed. A drop by 10-15% is not surprising, even expected, because land areas respond rapidly to a forcing, but 30% requires an additional explanation. For want of an alternative, we speculated that it may be a rapid cloud feedback.

Joe made 60 runs of the model from different points on the control run, finding year 1 responses ranging from 2.5 to 3.7 W/m^2, with an ensemble mean 3.1 W/m^2 and standard deviation 0.3 W/m^2. He found no evidence of an immediate cloud adjustment. The large variability in the GISS (2020) GCM might be related to its excessive "Nino" variability.

In any case, there is an ultrafast response in many of the GISS models, which does limit the rate at which the ocean takes up heat and restores planetary energy balance, but it is not likely to be as large as found in the single run of the GISS (2020) model. It would be useful if all GCMs reported both their temperature and EEI response functions.

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