

Science AMA Series: Climate models are more accurate than previous evaluations suggest. We are a bunch of scientists and graduate students who recently published a paper demonstrating this, Ask Us Anything!

RobustTempComparison¹ and r/Science AMAs¹

¹Affiliation not available

April 17, 2023

Abstract

EDIT: Okay everyone, thanks for all of your questions! We hope we got to them. If we didn't feel free to message me at /u/past-is-future and I will try to answer you specifically! Thanks so much! Hello there, /r/Science! We* are a group of researchers who just published a paper showing previous comparisons of global temperatures change from observations and climate models were comparing slightly different things, causing them to appear to disagree far more than they actually do. The lead author Kevin Cowtan has a backgrounder on the paper here and data and code posted here. Coauthor /u/ed_hawkins also did a background post on his blog here. Basically, the observational temperature record consists of land surface measurements which are taken at 2m off the ground, and sea surface temperature measurements which are taken from, well, the surface waters of the sea. However, most climate model data used in comparisons to observations samples the air temperature at 2m over land and ocean. The actual sea surface temperature warms at a slightly lower rate than the air above it in climate models, so this apples to oranges comaprison makes it look like the models are running too hot compared to observations than they actually are. This gets further complicated when dealing with the way the temperature at the sea ice-ocean boundaries are treated, as these change over time. All of this is detailed in greater length in Kevin's backgrounder and of course in the paper itself. The upshot of our paper is that climate models and observations are in better agreement than some recent comparisons have made it seem, and we are basically warming inline with model expectations when we also consider differences in the modeled and realized forcings and internal climate variability (e.g. Schmidt et al. 2014). You can read some other summaries of this project here, here, and here. We're here to answer your questions about Rampart this paper and maybe climate science more generally. Ask us anything! *Joining you today will be: Zeke Hausfather aka /u/ZekeHausfather Ed Hawkins aka /u/ed_hawkins Peter Jacobs aka /u/past_is_future Michael Mann aka /u/MichaelEMann Robert Way aka <https://twitter.com/labradorice> and perhaps some others if they have time

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ROBUSTTEMPCOMPARISON [R/SCIENCE](#)

ABSTRACT

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Thanks so much!

Hello there, [/r/Science](#)!

We* are a group of researchers who just [published a paper](#) showing previous comparisons of global temperatures change from observations and climate models were comparing slightly different things, causing them to appear to disagree far more than they actually do.

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You can read some other summaries of this project [here](#), [here](#), and [here](#).

We're here to answer your questions about Rampart this paper and maybe climate science more generally. Ask us anything!

*Joining you today will be:

Zeke Hausfather aka [/u/ZekeHausfather](#)

Ed Hawkins aka [/u/ed_hawkins](#)

Peter Jacobs aka [/u/past_is_future](#)

Michael Mann aka [/u/MichaelEMann](#)

Robert Way aka <https://twitter.com/labradorice>

and perhaps some others if they have time

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CORRESPONDENCE:

Do climate models work on historical data as you would expect? In other words, do they predict the past correctly? Is that ability an indicator of their accuracy?

[skinnybuddha](#)

That is essentially the subject of the paper we have just completed - see the links in the opening

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paragraph.

If we examine the simulations of the past 150 years then they show good agreement with the observations over the same period, especially with regard to how much warming we have seen - around 0.8C.

-- Ed

So what can we expect to see in the next 30 years? And the next 100? How will it affect us humans?

[shadowonthewind](#)

Over the next 30 years we expect to see the planet warm further, but not necessarily everywhere. Some regions will warm more than others, so we cannot give precise expectations for specific places for example. We also expect to see further declines in the amount of Arctic sea ice, snow cover, and further rises in sea level. We are also likely to see more extreme events, such as heatwaves and heavy rainfall. This will affect humans in different ways, depending on where we live and how well we can cope with the effects.

Over the next 100 years, more of the same, but the amount of warming will depend on our future emissions of carbon dioxide and other greenhouse gases. Our choices about emissions are the key uncertainty.

-- Ed

Elaborating on the "tipping point" question:

Do current climate models suggest that we won't be able to reverse global warming even if we were to stop producing CO2 all together? Or, as some suggest, that even if we reduced CO2 concentrations in the atmosphere that the oceans are already too warm to not melt/break up ice shelves? What are we looking at in terms of rising sea levels? What portion of currently inhabited land mass will be underwater in the next generation? Two? How scary, exactly, are the prospects of our current climate predictions?

[fewofmany](#)

Hi fewofmany,

Models generally suggest that we can bring down temperatures in the future once we reduce GHG emissions below a certain point. The oceans buffer the earth's temperature, which both means that we are slower to heat up than we would otherwise be (a good thing), but also slower to cool down once emissions are reduced (not so good). As has been discussed in other comments, there are some impacts that will be more difficult to reverse (e.g. ice sheet melt), but even there we likely have on the order of centuries to adapt to these impacts, at least in worlds where we take aggressive action to mitigate emissions going forward. To put it more simply, we are far from doomed today, but the longer we delay the harder it becomes to avoid the more serious impacts of climate change.

Here are the scenarios presented in the latest IPCC report for global temperatures under different emissions trajectories through 2300: <http://www.easterbrook.ca/steve/wp-content/IPCC-AR5-Fig-12.5.png>

-- Zeke

How much sea rise can we expect by 2100?

[therock21](#)

This depends strongly on future greenhouse gas emissions. With strong reductions in greenhouse gas

emissions (RCP2.6 emission scenario) global mean sea level will likely rise between 0.26 - 0.55 m in the 21 st century. Following a business-as-usual (RCP8.5) path of emissions, sea level rise will likely be in the range 0.45 - 0.82 m. Regionally these changes might be different. -- Martin

The tipping point...

Are we at the point of no return, as suggested by some papers.

[sarcatosaurius](#)

This is not a simple question, and nor does it have a simple answer!

There is some evidence that the break-up of certain ice shelves is now inevitable for example, but it would be helpful to know if you had any more specific concerns?

-- Ed

As someone who is unwillingly ignorant on the subject of global warming and climate change in general, what book(s) or documentaries could you recommend that are unbiased yet captivating to get me started?

[nagelbitarn](#)

Although it is a bit dated at this point, recent Pulitzer Prize winner Elizabeth Kolbert wrote an excellent series of articles for the New Yorker magazine called The Climate of Man that was turned into a book called Field Notes from a Catastrophe.

[/u/MichaelEMann](#) has a book (with Lee Kump) called Dire Predictions that's now in its second edition.

For more technical discussions, the National Academy of Sciences and the Intergovernmental Panel on Climate Change have several publicly available reports based on the scientific literature and expert input.

-- Peter

I have an interesting climate model question.

Without human intervention, what would the current temperature be?

[TheNaughtyMonkey](#)

Globally temperatures would be about 0.8 C cooler; you can see projections for each continent (as well as land and ocean separately) in this figure from the latest IPCC report, which compares model runs using all forcings (natural + anthropogenic) to those using only natural forcings over the past century:

http://www.climatechange2013.org/images/figures/WGI_AR5_FigSPM-6.jpg

-- Zeke

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[TheNaughtyMonkey](#)

Climate models driven only by natural forcings (such as volcanic eruptions or changes in the solar activity) can't reproduce the observed global warming and show little long-term temperature trends in the 20th century. When both natural and human caused forcings are included, climate models show a good agreement with the observed temperature increase. Please have a look at the 5th IPCC report (<https://www.ipcc.ch/report/ar5/wg1/>) Chapter 10, page 894 for further information. --Martin

Slightly tangential to the actual content of the paper (which is great); what is your stance on geoengineering, e.g. using sulphate aerosols as a way to mitigate climate change?

Cheers!

[syrtus](#)

Speaking only for myself, I think we cannot afford to not research all options at this point. That being said:

- How much you believe we can effectively sulfate-injection geoengineer the climate depends on how much you trust climate modeling. Curiously, some groups pushing this as a solution are also those who claim climate models can't be trusted. That's an indication that the group is probably disingenuously pushing it because it allows business-as-usual behavior for carbon intensive industries. Several US "think tanks" with antiregulatory ideology come to mind.
- If you think an international treaty to agree to limit emissions will be politically difficult, imagine how much more true this is for sulfate injection. Who gets to set the thermostat- the US? China? What's ideal for one country will certainly not be for others, due to regional temperature and (more importantly) precipitation impacts.
- Once you start you effectively can't stop. If the injection stops for any extended length of time, we get hit with decades of built up greenhouse warming on accelerated timescales.
- It does little to prevent a lot of marine impacts, especially ocean acidification.

I still think we are capable of reining in our greenhouse gas emissions, but at this point I think we can't afford not to prep any and all tools we have at our disposal. As long as people understand that sulfate injection geoengineering is in no way an actual viable alternative to reducing GHGs, I support its research. A lot of people disagree with me though, and think it's just too irresponsible to contemplate.

-- Peter

One of the most common arguments I have experienced against the notion that climate change is happening and is agitated by human activity is that we have only actively been recording data for maybe ~150 years. Moreover, the argument continues that we don't have probes or temperature recording equipment to create a uniform coverage of Earth, therefore resulting in greatly misleading data. How much of this is true, and how are we improving our data collection on climate change?

EDIT: Wow! I wasn't expecting that many responses! Thanks a lot for answering my question in detail, it means a lot :)

[5150RED](#)

This has a number of answers but i'll start with a few basic concepts.

First, temperatures vary substantially from location to location on a daily basis but what we call 'temperature anomalies' or departures from the long-term average tend to be strongly related to one another over huge distances (hundreds of km) at the monthly timescale. What this means is that usually if air temperatures are above normal in your location, it is probable that they are also above normal in the areas around as well. This has been tested in a number of papers but notably the work by Hansen and Lebedeff (1987); Rohde et al (2013) and Cowtan and Way (2014).

It has been shown with basic statistical theory that you actually need only a bit over 100 weather stations distributed across the planet to get a reasonable assessment of 'global' temperature changes. However, we want to be able to understand the spatial patterns in temperature change so we need to have many more stations. Unfortunately budget cuts have led to a drop off in the number of stations operating since the 1990s therefore more work is needed to improve the spatial coverage of the station

network.

Atmospheric reanalysis appears to be another reasonable source of data which has greatly improved our understanding of the planet. In essence this involves assimilating all kinds of weather station, weather balloon and satellite data into a numerical weather model to produce a best guess of temperatures (and other variables) across the planet or specific regions. Some studies have excluded all the ground, satellite and weather balloon temperature data and reran the numerical weather models with only sea surface temperatures and surface pressure data and yet they still reproduce the magnitude and pattern of current warming. Overall the surface air temperature record is fairly robust.

-Rob

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[5150RED](#)

150 years is plenty long enough to see our effects. Global temperatures have increased over 0.8C in that time. We don't have observations everywhere, but that is improving. -- Ed

How worried about arctic methane release are you?

[Free Will](#)

I'm not worried about an Arctic methane release and neither are the top permafrost scientists (including my supervisor, president of the international permafrost association).

-Rob

I took an atmospheric science class at Colorado State, taught by Scott Denning....I really love this subject.

How likely do you all BELIEVE an RCP 8.5 future is? And is there any chance of us staying within a 2 degree Celsius rise in temperature?

[TsorovanSaidin](#)

Yes, it's still possible to stay below 2°C, but emissions have to peak soon and then decrease rapidly. <http://www.nature.com/nclimate/journal/v3/n1/full/nclimate1783.html> --Martin

Hi Guys, love the paper! Given this overestimation of sea surface temperature would you expect to see any changes in regards to:

1) El Nino and La Nina? 2) Ocean acidification?

[ipsen26](#)

Our paper looks at the impact of comparing blended near surface air temperatures over land + sea surface temperatures for the ocean in both models and observations, as opposed to air temperatures over the ocean in models. It doesn't actually impact our **observational data** for sea surface temperatures at all. So it doesn't have any bearing on either ENSO or OA.

-- Peter

Hello, I am interested in this topic.

I curious how are current models accurate. We know that in history of earth we have periods of warm and ice ages without humans. How can we be sure it's not just a cycle that is repeating itself. I know humans are adding to it, but how much.

A lot of people are talking we are close/passed the tipping point. But we are not stopping any time soon. Are there any technologies that would revert this in development?

[Dirtysocks1](#)

How can we be sure it's not just a cycle that is repeating itself.

We can do this in a few ways.

1. We can look at what the other natural drivers of climate change should be doing over this time. The net effect of natural climate drivers (orbital forcing, volcanism, solar variation, ocean-atmosphere 'oscillations', etc.) over the past 60ish years would be basically zero, and over the longer term should be causing us to very gradually cool (at least in the higher latitude Northern Hemisphere).
2. Increased greenhouse warming effects the climate system in a different way than something like increased solar activity does. With an increase in solar energy, we would expect the whole system to warm, from the surface to the upper atmosphere. For enhanced greenhouse warming, we expect the surface and lower atmosphere to warm, but the upper atmosphere to cool. And this lower warming upper cooling pattern is what we actually do see.
3. Fundamental physics tells us that the relatively large increase in CO2 we've already emitted should have a certain impact on the climate system. So not only would there have to be a natural driver of climate that is causing the same amount of warming we would expect to see with increased CO2, there would have to be some undiscovered mechanism by which the CO2 we unquestionably emitted was being neutralized from a radiative forcing perspective. In other words, our understanding of atmospheric physics would have to be completely wrong.

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[Dirtysocks1](#)

Hi Dirtysocks1,

You are certainly correct that the Earth's climate has changed in the past without human contributions. If it hadn't, it would be much harder for humans to change it today, since it would indicate that the climate is rather insensitive to changes in external forcings (e.g. changes in solar output, orbital variations, large volcanic events, etc.).

However, as we can see from studying the climate of the past, the Earth is quite sensitive to small changes in forcings. That's why minor variations in the Earth's orbit (called Milankovitch cycles) are able to trigger ice ages, for example. These cycles tend to occur slowly across long periods of time, and we can measure them using modern technologies (satellites can measure solar output in real time,

folks studying orbital dynamics can predict changes in the Earth's orbit thousands of years from today).

Neither of these factors has had any major changes in recent years (if anything, solar output has dropped modestly over the past few decades). At the same time, however, atmospheric levels of CO₂ have increased from a long-term average of 280 parts per million to 400 parts per million, and nearly all the additional CO₂ has come from the combustion of fossil fuels. Models are built based on our best understanding of the physics of radiative transfer and fluid dynamics, and show that the warming we've experienced in recent years can be entirely explained by changes in atmospheric greenhouse gas concentrations.

-- Zeke

How would you respond to this quote from a Forbes article regarding climate change and is what they are saying accurate: "Central to these natural cycles is the Pacific Decadal Oscillation (PDO). Every 25 to 30 years the oceans undergo a natural cycle where the colder water below churns to replace the warmer water at the surface, and that affects global temperatures by the fractions of a degree we have seen. The PDO was cold from the late 1940s to the late 1970s, and it was warm from the late 1970s to the late 1990s, similar to the Atlantic Multidecadal Oscillation (AMO)."

[Dark-Star7](#)

we wrote an article on this in Science recently (article here: <http://www.sciencemag.org/content/347/6225/988.abstract>; my commentary for lay audience here: http://www.huffingtonpost.com/michael-e-mann/climate-change-pause_b_6671076.html). As the person who coined the term "Atlantic Multidecadal Oscillation", I have a particular interest in the discussion. As we show in that article, much of what has been attributed on past studies to the "AMO" and "PDO" is in fact likely forced variability, mis-attributed by procedures that assume an overly simplistic statistical model for the forced component and erroneously call everything left over an "oscillation". That is not to say that the AMO and PDO don't exist, but rather that their magnitude and impacts have been vastly overstated in much past work.

-- Mike

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[Dark-Star7](#)

Sounds pretty reasonable to me! There are ocean cycles (such as the PDO and AMO) which can modify the warming amounts a bit - sometimes to make it slightly faster, sometimes slightly slower, but it doesn't affect our understanding of the causes for the long-term increases in temperature which have lasted for much longer than an ocean cycle. --Ed

How do you know for certain that CO₂ is causing the warming rather than sun activity?

[nomoreclintonorbush](#)

https://www.reddit.com/r/science/comments/3flzb4/science_ama_series_climate_models_are_more/ctq1hfd

-- Peter

From a brief overview of your paper, I've gathered that you're essentially combining various temperature points instead of simply one type. While this has compensated for the errors in the past, how can we trust it to be predictive? It seems very much like corrections to the data collection are being made on the fly. We were told to trust the models from the outset, yet clearly it was necessary to improve those models through various techniques, including what you have done here with your paper. Why should we be certain this time around that we finally can trust these computer models to not be wrong yet again?

[Narfu187](#)

This comment seems to misinterpret what was done in our paper.

All our paper does is present a 'like for like' comparison between observations and climate models. Prior work had just taken the 2-m air temperature field from climate model output and compared it to observations. However, observations are not 'only' from the 2-m air temperature field - they are a mixture of 2-m air temperature over land and temperatures in the near surface of the ocean (known as sea surface temperatures).

Because air temperatures are warming faster than sea surface temperatures (as is expected from theory) it introduces a bias when you compare 2-m air temperatures from a model to this blend in the observations. This paper simply takes model output and processes it in the same way as we do for observations so that comparisons can be like for like.

The main reason this hadn't been done before was that it had been assumed that the difference wouldn't be appreciably but our study has shown it is an important consideration.

Not sure if I'm understanding this correctly but are you saying that previous models assumed all temp readings to be air readings rather than a mix of air and water readings? If so; doesn't this raise huge concerns in itself given that researchers are overlooking key details of how their data is sourced?

[rlgod](#)

No - we always knew where the data came from and we did not assume that all readings were air temperatures.

The comparisons we have done show small differences when the simulated data is treated like the observations in more exact details - these are important to understand but it does not change the big picture of our understanding of how and why the climate is changing.

-- Ed

This question should be a breeze for you guys: How do I convince people that humans are causing global warming, and it's not just a natural process?

[project_spex](#)

A couple of thoughts:

- 1) Carbon dioxide levels have increased in the atmosphere due to us burning fossil fuels. We have direct measurements of this for the past 60 years, and data from ice cores before that.
- 2) The greenhouse effect is real - it is rather basic physics and you can measure the physical processes in a laboratory. This was first done by John Tyndall in 1861 and verified many times since. Carbon dioxide and other gases absorb infra-red radiation which means that adding more of it to the atmosphere will warm the planet.

This should not be controversial!

-- Ed

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[project_spex](#)

There are direct measurements of an increasing greenhouse effect at the wavelengths at which CO2 is most effective. This has been measured with satellites and ground based measurements (there was a recent paper showing a decade of GHE measurements showing the increase for example). This is direct, objective evidence that the greenhouse effect is increasing and that increasing CO2 is a major driver.

-Rob

most climate model data used in comparisons to observations samples the air temperature at 2m over land and ocean.

This seems to be a very important distinction, and I'm amazed that the observation that the models and observations were actually showing different measurements has not been made public before this.

There has been a claim that most of the warming in the last 15 to 18 years has gone into the oceans below the surface, and that's why the models and observations have diverged over that time period. There are models of projected sea temperature changes, and I believe those models do not model the air 2 meters above, but actual water temperatures.

Given that the models that we are normally presented with have historically depicted air temperatures, and 71% of the planet is ocean, where air temperatures are not measured, but water temperatures are, and given that we know that the ocean depths are warming, but water takes a lot more energy per unit temperature change, is the current use of air temperature at the surface in any way a reasonable way to depict Climate Change?

The biggest, most often used warning issued by Climate Scientists and activists is that the world will warm by $3^{\circ} \pm 1.5^{\circ}$ C after a doubling of CO2. But, is that "air temperature, 2 meters off the ground?" and if we're not measuring the air temperature, 2 meters off the ground for most of the planet, should we be using a different warning altogether?

[deck_hand](#)

Yes - the traditional measures of how much warming we expect - the 3C you quote - is done assuming air temperatures 2m above the ground. The differences we have identified are around 0.2C at the most, so a very small amount compared to the 3C, so it doesn't change our expectations for the future very much. -- Ed

Does it bother you that despite your best efforts to convince people that climate change is real, no one is going to do anything about it until we're well beyond the tipping point? :(

[Titanium Expose](#)

No, because the international scientific and policy communities are trying to do something. We're nowhere near the point of having "solved" the issue, and we will see some amount of climate change in the future. But I truly believe we will avoid a high emissions future. I'm a hopeless optimist though!

-- Peter

I'm gonna play a little Devil's Advocate here.

Don't you think it's entirely possible that you and others have gone tunnel vision in your studies? In other words, we know how idealistic people can be; couldn't one argue you all were

highly determined to demonstrate that apocalyptic climate change is happening, and thus were led primarily to evidence which supported this claim, since that was what you were searching for?

[sehecman](#)

any scientist who could demonstrate rigorously that the scientific consensus (i.e. that climate change is real and caused by us) is wrong would become a superstar. The incentives in science are for contradicting conventional wisdom, not simply confirming it. You don't get articles in Nature and Science by simply showing the other guy/gal is right. Carl Sagan discussed the matter at length in "Demon-Haunted World" and I discuss the matter in the context of climate science specifically in my book "The Hockey Stick and the Climate Wars" (see in particular the chapter 6, "A Candle In The Dark" and especially the section "It's the Anomalies, Stupid" ;
http://www.meteo.psu.edu/holocene/public_html/Mann/books/hockeystick/index.php).

-- Mike

Basically, the observational temperature record consists of land surface measurements which are taken at 2m off the ground, and sea surface temperature measurements which are taken from, well, the surface waters of the sea. However, most climate model data used in comparisons to observations samples the air temperature at 2m over land and ocean. The actual sea surface temperature warms at a slightly lower rate than the air above it in climate models,

This may be a silly question, but...why hadn't anyone noticed (before you did)? At least superficially, this sounds like one of those slap-yourself-in-the-face moments.

[gnql](#)

This was known about, but people assumed the difference would be small. And in the grand scheme of things, it is relatively small. But it turned out to be larger than a lot of people assumed, and recent events have made even small differences between the model and obs come under tremendous scrutiny.

The lead author, Kevin Cowtan, has run into a few of these sort ('we know it's an issue, but it's probably not a big deal') of issues. He is just particularly relentless about quantifying their impacts before deciding they are indeed not a big deal. Sometimes they are indeed not worth pursuing. Other times, they turn out to be more interesting than we previously thought.

Along with Robert Way, who is also commenting here, Kevin published a paper showing the impact of gaps in our coverage of the rapidly warming Arctic. That was also a known issue, but he (and Robert) actually bothered to test what the impact was whereas other people assumed it existed but was small. They got a very nice paper and a lot of kudos for that work as well.

[/r/theydidthemath](#) in other words.

-- Peter

I heard a lot of climate models actually undershot the devastation of what our actual climate is.

[environmental_Micro](#)

It depends on the target one is looking at. The decline in Arctic sea ice, for example, appears to be taking place faster than predicted. We have a retrospective comparison of past model predictions with the subsequent observational data in the new (2nd) edition of our book Dire Predictions (see here: http://www.meteo.psu.edu/holocene/public_html/Mann/books/direpredictions/index.php)

-- Mike

are you going to provide a link to the full article that isn't hidden behind a pay wall, i would like to read more than the abstract.

[anderaaron](#)

Yes: http://www.meteo.psu.edu/holocene/public_html/Mann/articles/articles/grl53276.pdf --Martin

What version control software did you use while preparing this project, if any? Would you be interested in publishing the software on GitHub, Bitbucket, or some alternative, rather than as the ZIP files provided on the site?

[dark_magnetar](#)

I can't speak for the lead author who archived the code and data, Kevin Cowtan, as he's on a well-deserved break, but I would be interested in the idea of moving code to a place like GitHub in the future. I will raise the issue with Kevin. Thanks.

-- Peter

What I love about science papers is when they sit so firm behind a paywall.

[tksmase](#)

A free version is available:

http://www.meteo.psu.edu/holocene/public_html/Mann/articles/articles/grl53276.pdf --Martin