

Science AMA Series: Hi Reddit! We're Ralph Keeling, Dana Royer and Nicola Jones, and we're talking about how the world passed a carbon threshold and why it matters - Ask Us Anything!

Carbon_Threshold¹andr/ScienceAMAs¹

¹Affiliation not available

April 17, 2023

Abstract

My name is Nicola Jones and I write for Yale Environment 360 magazine and the journal Nature. With a background in chemistry and oceanography, I cover the physical sciences, from environmental issues to quantum physics. In my work as a freelance journalist, I've contributed to Scientific American, Globe and Mail, and New Scientist, and serve as the science journalist in residence at the University of British Columbia. In my recent Yale Environment 360 story, "How the World Passed a Carbon Threshold and Why It Matters" [<http://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters>], scientists Ralph Keeling and Dana Royer join me to understand what Earth's climate was like in previous eras of high CO₂ levels and portray a sobering picture of where we are headed. Last year marked the first time in several million years that atmospheric concentrations of CO₂ passed 400 parts per million. Environmental scientists see this threshold as a clear red line into a danger zone of climate change. But, as humans keep digging up carbon out of the ground and burning it for fuel, what will this mean for our future? My name is Ralph Keeling, and I am the Director of the Scripps CO₂ Program, Professor of Geochemistry at UC San Diego, and Principal Investigator for the Atmospheric Oxygen Research Group at Scripps Institution of Oceanography. My research interests include measurements of variations in atmospheric oxygen, recent perturbations to the global carbon cycle, air-sea gas exchange, detection of ocean heat storage and transport using atmospheric gases and Paleoclimate theory. I continue to research the "Keeling Curve," which was developed by my father Charles David Keeling in 1958, at Scripps CO₂ Program. My name is Dana Royer and I am a Climatologist and Professor of Earth and Environmental Sciences at Wesleyan University. I explore how fossil plants can be used to reconstruct ancient environments (especially CO₂, temperature, and climate sensitivity), and the (paleo-) physiological underpinnings behind these plant-environment relationships. Recent and current projects include the reconstruction of paleo-atmospheric carbon dioxide levels from the stomatal distributions in plant leaves, and the development of mechanistically-grounded proxies for climate and leaf ecology from the size and shape of fossil leaves. I also compile ancient carbon dioxide records and investigate the strength of carbon dioxide-temperature coupling over multi-million-year timescales. We will be answering your questions at 1 pm EST – Ask Us Anything! Thank you everyone for tuning into this dynamic discussion on crossing the carbon threshold. We've received many questions during this AMA session, and tried our best to answer as many as possible. We apologize if we didn't have time to get to your submission. But, please continue this conversation! To stay updated on the latest climate change stories, you can visit our website www.e360.yale.edu or follow us on FB & Twitter (@YaleE360). Cheers, Nicole, Ralph, Dana & Yale Environment 360 staff.

[REDDIT](#)

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CARBON_THRESHOLD [R/SCIENCE](#)

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Cheers,

Nicole, Ralph, Dana & Yale Environment 360 staff.

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CORRESPONDENCE:

DATE RECEIVED:

What do you think are our best options for carbon sequestration? I've heard a lot of people say that we've done too little too late with renewables and at this point just switching (eventually) to 100% renewables isn't going to be enough and we're going to need serious carbon sequestration projects to avoid catastrophic global warming.

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The only "technology" I've heard of so far that actually works is reforestation. What are your thoughts? It seems like it would be tough, but possible:

- [Carbon in all the world's forests is about 638 GtC](#)
- All manmade [carbon emissions add up to about 10 GtC per year](#)
- From 2000 to 2013 we [cut down 7% of the world's forests](#)

So, if instead of spending time and energy to cut down forests, we'd been re-planting forests and had added 7% more over the last 13 years we would've sequestered the equivalent of 50% of human GHG emissions.

[PM_ME_UR_Definitions](#)

Hi, Nicola Jones here (the journalist who wrote the Yale e360 story mentioned at the top). I haven't written specifically about reforestation, but I can say a few things. First, air capture technologies are advancing rapidly and do work, particularly in flu stacks of power plants. I wrote a little about that here: http://e360.yale.edu/features/can_pulling_carbon_from_air_make_a_difference_on_climate Also, I think AVOIDING deforestation is more effective than reforestation per se... the former preserves ecosystems and local livelihoods, if done correctly. Reforestation is complicated by how the land is prepped for trees and what that does to the soils. Here's a good recent report on tropical reforestation: <http://www.cifor.org/library/5544/tropical-reforestation-and-climate-change-beyond-carbon/>

When exploring things people should do, some suggestions I've heard from the scientific community ("everybody should turn vegetarian, everybody should have only 1 kid, everybody should accept a 10% carbon tax") do not match the public's perception of the situation.

You're not going to dramatically and negatively change your life to fix something you're not even feeling.

What type of suggestions, resources etc do you suggest to teach people the severity of the problem? How do you make it real in the public's eyes? And how do you make individuals change rather than looking at their neighbors and patiently waiting until someone else makes a move?

[puntoos](#)

Nicola says: Changing the attitudes and daily practices of individual people is extremely hard and will take a long time. I think there's a lot of really interesting work specifically targeting big business instead. If businesses stop offering the most damaging products, or if environmentally-friendly products become cheaper, then the process of shifting consumer habits becomes much easier. I edited a piece for Nature a few years back about how business schools should start teaching about climate change and environmentally-friendly practices, in order to hit the next generation of top influencers (<http://www.nature.com/nature/journal/v466/n7302/full/466030a.html>). Likewise "tree hugger" Nicole Rycroft has specifically targeted businesses to try to shift consumer behaviour; they have moved book publishing companies towards using non-ancient-forest paper stock, for example.

Do you think the impacts on human life caused by passing the threshold will be slow and progressive or sudden and drastic?

Thanks for doing the AMA :)

[crazygirlsbelike](#)

Ralph says: We don't know for sure, but most likely the response will be slow when looked at globally, but with abrupt shifts evident in regions. An example could be that slow tendency toward more drought

in a particular region could be aggravated by a natural cycles towards drier or wetter conditions from decade to decade. People living in that location might therefore find that, over the course of a few years, their ability grow food drops drastically suddenly as the natural cycle swings towards a drier decade, thus reinforcing the longer trend. Even though impact of greenhouses gases is slow, the threshold for food production is crossed somewhat abruptly. A similar issue may happen with sea level rise, which will tend to be slow, but the crises will come with during high water events, brought about by a single storm, impacting only one region. So I expect there will be series of regional "crises" at different places and times rather than one global crisis.

I have been reading that climate change is occurring so quickly species are unable to adapt. Is it possible that a large percentage of organisms will go extinct, larger than what has occurred in the past?

Edit: I was referring to "Great Dying", where about 95% of marine life and 70% of land based vertebrates went extinct. Really I just want to know if anthropomorphic climate change is going to fuck up the Earth in a way that life cannot adapt.

[wild_mountain_time](#)

Nicola says: We are actually currently in the middle of an extinction event (commonly called the Sixth Extinction). The RATE of extinction is currently extremely high; comparable or higher than the rate experienced in previous extinction events. But the overall number of species wiped out is so far relatively low (I think less than 10%, whereas others have been higher than 75%; don't quote me on those numbers!). I don't have a good resource to hand on this, but this Wikipedia article is actually fairly well referenced to academic sources: https://en.wikipedia.org/wiki/Holocene_extinction

Is animal agriculture actually a leading contributor?

[carls27](#)

Nicola says: The UN's Food and Agriculture Organization estimates that livestock are responsible for about 14% of all human-made emissions (see http://www.fao.org/ag/againfo/resources/en/publications/tackling_climate_change/index.htm).

Me and my wife's plan for retirement is to buy some land out in the Northwest and start building a tree farm.

What kind of trees would work best from a "saving the world" perspective? Is it just about mass, or are there species that imbibe/recycle more CO2?

[Darth_Ra](#)

Ralph says: Nice idea. You'll want trees that store biomass and survive a long time. To permanently remove CO2 from the air, you must store the carbon in biomass or wood. I suppose you may also want trees that grow reasonably fast, which might run a bit against long-term survivability. If the wood is harvested and used for long-term wood products, this also would help, because the carbon will still remain captured, and you could then grow more trees. Hope this is useful.

How much of the recent warming trend can be directly associated with human activity? How can we know that this trend isn't just correlative with rising CO2 levels and not causitive. What kind of

resolution do ice cores provide? Are we able to look at 100 year windows of time 1 million years ago to better answer my first two questions?

[Gretna20](#)

Dana here. Climate models give us the strongest evidence for a causal relationship between CO2 and temperature. All of the correlative evidence helps too, but ultimately it is the modeling evidence that is most centrally important.

Your question about 100 year windows is a good one. Ice cores that go back hundreds-of-thousands-of-years cannot resolve annual changes. As you go back further in time, when you need to rely on rocks, sediment, and fossils, temporal resolution is likely thousands-of-years at best (because sediment gets churned as it gets buried, etc.). One exception is lake sediments with annual layering. But those are hard to come by. Thus, it is important to be mindful of the limits on temporal resolution in deep-time records.

Hey guys, why is the threshold 400 specifically - it seems a very round, very arbitrary and very specific number - what is different at 395 compared to 405?

[DoctorZMC](#)

Ralph says: I agree with some of the other responses. 400 is special only because it is a round number and therefore resonates as a benchmark for measuring where we are and where we have come.

What are a few things the "average joe" could do or change in their daily life to help slow or reverse climate change? Thanks for doing this AMA!

[Weasel302](#)

Nicola says: Eat less meat. Shift to friendlier forms of transport (walking, cycling, buses) for small, daily commutes. Make climate a consideration when making purchases: try to buy local foods, recycled products, second hand clothes, etc. Invest in your home's appliances, insulation and windows instead of remodeling your kitchen countertops. Vote with environmental considerations in mind.

What permanent changes to our planet will we witness in the next 50 years assuming our efforts to combat climate change continue as they are now with renewables getting cheaper and cheaper than fossil fuels?

[h-st-ry-19-17](#)

Ralph says: I believe we are bringing on a new era as different from the past as other geological eras have been from the present. Massive changes in the Arctic seem inevitable, as do large shifts in rainfall belts and risks from droughts and floods in other areas. It will be world with less ice and snow overall and steadily rising sea levels. Changes of this sort are already underway and further changes are probably unstoppable even if rapid steps are taken to decarbonize the energy supply and slow CO2 growth. Not all of this will necessarily be catastrophic, but we need science to help us know where we are headed as well as help us move to renewables to avoid making the challenges even greater.

Do you think we would reach a point where the damage done would be irreversible? Or are we already at that point where some parts of the world are experiencing climate change where it could never go

back to the conditions they were thousands of years ago?

Of course some could argue that extinction from climate change has already done irreversible damage to the ecosystem.

[Hanmin147](#)

Dana here. It will take ~100,000 years to return to pre-industrial values (unless we actively pull CO2 out of the atmosphere). In short, the carbon needs to return to the Earth's crust in the form of organic-rich rocks and carbonate rock.

If we completely eliminate human-caused CO2 emissions, temperatures will not start to cool for hundreds or maybe even thousands of years. So our current anthropogenic climate is permanent on those timescales. This is long enough for the sluggish parts of our Earth system--like continental ice sheets--to respond to the warming. Long term, we are in for big changes.

Hey guys. How do you feel about the planetary boundaries framework, and how do you think it could be best used to inform environmental policy in order to prevent other thresholds from being transgressed?

[caffeineasshole](#)

Ralph says: The planetary boundaries framework seems to be a concept for packaging the science to be more "policy ready" and to generate awareness. To me, it seems a bit overly simplistic because the attempt to define exact thresholds is not very scientific. I can't imagine it will have much traction in many countries.

I've heard multiple times that there's nothing we can do for the planet anymore and stopping the burning of fossil fuels will no longer stop our current dissent, just slow it down. Is there any truth in this statement? This is also with the assumption we stop it soon which I don't think we will, do you even believe with the common anti climate change attitude we can come back from this?

[TyrDem](#)

Nicola says: I am an optimist. Global emissions have flatlined over the past 2 years, despite an increase in global GDP. That's a great sign. I think world governments are on the whole moving towards action on this issue (though the US may backslide on this for the next 4 years). New technologies will make it ever-easier to reduce emissions.

Why do people say that stopping emissions will only slow the problem? That's because the planet will take a while to process all the extra carbon we have already pumped into the atmosphere... in my Yale e360 article I quote experts saying that the upper oceans will soak up most of the extra carbon within 100 years; the deep ocean within 1000 years. But some of the extra carbon in the air will take tens of thousands of years to soak back into the planet. And some processes, like the melting of the ice in Greenland and the Antarctic, may keep going even if emissions slow or stop (http://e360.yale.edu/features/rising_waters_how_fast_and_how_far_will_sea_levels_rise). BUT stopping emissions will clearly stop the problem from getting WORSE. It's still worth it!

Which area will be hit the hardest? Can we predict the outcome if more threshold are passed ?

[wuanlai654](#)

Ralph says: I'm not the best expert on this. But I do know that the science is not very mature on the question of exactly what is going to happen in any given region. The places of greatest concern are regions where people are already living at the margins.

Hi, I am an undergrad paleoclimatologist and I was wondering why you picked 400 ppm as a threshold? Certainly it is a milestone in human's and earth's history to have increased the CO2 level this much in such a short time but 400 ppm is not a certain threshold at which the earth's climate irreversibly changes. My second question is more philosophical; do you think humans in the near future (couple of thousands of years) can use CO2 as sort of a natural thermostat to adapt to orbitally driven changes?

[RootyM](#)

Dana here. There is nothing innately special about 400 ppm; it's an emblematic number (and one that we just surpassed). Long-term, if our goal is to retain a Holocene-like climate, CO2 should be below 350 ppm.

In principle you are correct about the thermostat. But we would only need small changes. Remember that we came out of the last ice age with a CO2 concentration of 280 ppm.

Keep up your studies and good luck!

How can we know that "Last year marked the first time in several million years that atmospheric concentrations of CO2 passed 400 parts per million." When we haven't been able to measure CO2 on this planet for that long?

Is that speculation, or do we have actual models and predictions that tell us beyond a doubt that this is how the past looked?

Edit: I'm bad at reading.

[not_a_real_name](#)

Dana says: For the last ~800,000 years we have fairly direct records of CO2 from air trapped in ice. Before then, we rely on proxies--that is, we measure something in the geologic record that today co-varies with CO2. Proxies have larger uncertainties associated with them (at best, around +/- 20%), so we don't know with perfect confidence that last time in Earth's history when CO2 exceeded 400 ppm. But probably around 3 million years ago.

Science teacher here. I am aware of many studies and graphics out there that illustrate both the increase in CO2, and the increase in global temperature. That being said, I am always on the hunt for better ways to show it, ideally from multiple sources. Can you share any sources/graphics/studies that can help me illustrate this further to my students? Thanks!

[ultralightdude](#)

Nicola says: My most recent feature for Yale was very heavy on graphics, so check that out: <http://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters> A really good resource is the oddly-named SkepticalScience website ("getting skeptical about global warming skepticism"). Eg <https://www.skepticalscience.com/co2-temperature-correlation-intermediate.htm> and <https://skepticalscience.com/co2-lags-temperature.htm>

On a personal level, what kind of *outlooks* do you and your colleagues have?

I used to be a Public Defender - a job where I saw a lot of the bad parts of humanity and really got used to losing. My colleagues and I reveled in 'gallows humor.' Is that a thing for you guys? How do you stay positive screaming against the wind?

[VlJoe](#)

Ralph says: It may seem surprising, but I didn't get into this field with the goal of changing policy or producing a political outcome. I got into it because of the potential for making exciting discoveries, much like an astronomer who dreams of finding life another planet, or a biologist who dreams of understanding the origin of cancer. The science is not less exciting and the potential for discovery is not smaller if we continue on the business as usual tact, burning more fossil-fuels each year. Really the other way around. The "screaming wind" - as you call it - therefore doesn't touch me as much as you might think. My concern comes, not from my personal goals a scientist, but as a citizen: I also care about the world my kids will inherit.

How are scientists such as yourselves going to bridge the gap between the general public and experts, if using rationality and evidence isn't working how else do you get people without scientific backgrounds to back and understand your research?

[ReadThisInABadAccent](#)

Dana here. Not with science, of course. This is frustrating as a scientist. Collaborations with experts in the social sciences are necessary.

How are scientists such as yourselves going to bridge the gap between the general public and experts, if using rationality and evidence isn't working how else do you get people without scientific backgrounds to back and understand your research?

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Ralph says: I "inherited" the role of being a prime spokesperson for the Mauna Loa CO2 record, aka "Keeling curve". This curve is a good starting point because it powerfully conveys the big picture. It's one limitation is that, as drawn, it is always basically a line with wiggles extending from the lower left to the upper right of the plot. In that sense, it looks static, year to year. Of course, the y axis must be rescaled to accommodate the relentless rise, but this is subtle and doesn't convey well how fast things are actually changing. A good way to overcome that is for people to become aware, not just of the whole curve, but of the latest levels. The 400 ppm threshold was particularly valuable in that context. In a matter of a few years or less, we will be crossing the 410 threshold. With the numbers embedded in the public awareness, so to is the fact that things are really changing. The curve may also eventually become a symbol of hope, if it starts to curve the other way, towards a plateau. I hope I live long enough to see that day.

Is co2 a pollutant?

How much of an effect has the sun had on our climate changing?

How much of an effect has water vapor had on our climate changing?

How much of an effect has human activity had on our climate changing?

In the total carbon cycle of our planet, what percentage of carbon emissions come from human activity and what percentage comes from water vapor?

Thanks for your answers

[TMac1128](#)

Ralph says: Whether CO₂ is considered a pollutant has to be viewed in a legal context. It's true that CO₂ is not toxic (at least at levels we are worried about here), but that cannot be the litmus test: Phosphate is also not toxic, but wrecks havoc on rivers because it promotes algae overgrowth. Like phosphate, CO₂ also has powerful effects on the environment. The main difference between phosphate and CO₂ is the scale at which they operate: the impacts of phosphate are local, while those of CO₂ are felt remotely, i.e. at the scale of the entire planet. Is this difference sufficient that CO₂ should be given a pass on being a pollutant? You decide.

Quick answers to your other questions:

-The sun has had only minor impacts over the past 50 years. -Water levels in the air are controlled by climate. Best not to think of water as causing changes, because changes in water are part of the response. -The large-scale warming of the Earth over the past 50 years is mostly human driven. It's possible that natural process have slightly offset or reinforced this warming. - The rise in CO₂ is effectively 100% due to humans. How could it not be, considering that levels are rocketing beyond anything seen for millions of years? Also, we know how much Co₂ we are emitting each year from fossil-fuel burning. The amount burnt is more than enough to account of the observed rise.

Could you talk about the difference in the rate of CO₂ release between today and a historic period like the Paleocene-Eocene Thermal Maximum?

[simplyderping](#)

Dana here. Most current studies find that it took somewhere between 1000 and 10,000 years to emit the main pulse of carbon during the PETM. There is one study that suggests a more rapid release, but this needs further vetting by the community.

So, we are probably releasing carbon at least 10x faster today than during the PETM. Because we are releasing carbon faster than the ocean circulates (~1000 years to mix surface and deep waters), more of our carbon today will get "stuck" in the atmosphere and surface oceans for several hundred years. This means warmer surface temperatures and more acidic surface waters relative to the PETM with an equal (but slower) carbon release.

Nicola Jones, can you discuss the logarithmic relationship between CO₂ concentration and radiative forcing?

Ralph Keeling, why does the Keeling Curve rise linearly from 1960 to 2017 when anthropogenic CO₂ emissions have been increasing over the same time period?

Is it true that almost a third of all historic anthropogenic CO₂ emissions have occurred since 1998, and if so, why doesn't the Keeling Curve reflect this? Shouldn't the slope of the curve be steeper as the rate of anthropogenic emissions increases?

[HotHotHot_Cosby](#)

Ralph says: It's true that a roughly third of the fossil-fuel emissions have occurred since 1998, but it's not true that the Keeling curve has been "linear". The curve has also accelerated upwards (trying holding ruler up against it), and this meshes well with what we know about sources and sinks of CO₂.

In particular: The rise rate is determined by human emissions (mostly from fossil-fuel burning, but also from land-use changes) minus the sinks in the land and oceans. At this point, the emissions from fossil-fuel burning are quite well known as is the uptake rate by the ocean. This means we can “solve” the system to resolve what’s going on land. What we find is that there has been a growing sink for CO2 in land ecosystems. This is interesting, but not unexpected because trees tend to grow faster under higher CO2 levels and other changes may also have promoted recent growth. The Global Carbon Project has some good summaries on this.

Hello to you guys, and thankyou for the work you do for the planet!

I'm a UCSD student and I recently took a class examining the roles microorganisms can play in different environments and the genetic factors that influence these. With the new advances in genetic engineering, what role do you think microbes could play in the rehabilitation of the environment?

A side question, I'm currently in between degree choices, how important was your original degree choice in your eventual careers?

[ArmoredCorndog](#)

Ralph says: Glad to see some local following! I'd need to learn more about your ideas for microbes in the environment. There's exciting work going on with biofuels, as you probably are aware. I majored in physics, and never regretted this choice, because it provide training that could be applied in many fields. But don't be afraid to spend a few years following your passions, while also being sure you get some solid background.