



This is the print version of the [Skeptical Science](http://sks.to/urgent) article '[It's not urgent](http://sks.to/urgent)', which can be found at <http://sks.to/urgent>.

Why it's urgent we act now on climate change

What The Science Says:

The ice sheet feedback doubles the climate sensitivity predicted by climate models. That means even the current CO₂ level, if maintained long enough, will cause 2°C of further warming. To prevent tipping points, we must reduce CO₂ from 390 to 350 ppm, which means leaving most remaining fossil fuels in the ground. One more decade of business as usual will make this impossible. It may not be obvious, but the urgency is very real.

Climate Myth: It's not urgent

"There are many urgent priorities that need the attention of Congress, and it is not for me as an invited guest in your country to say what they are. Yet I can say this much: on any view, "global warming" is not one of them." ([Christopher Monckton in testimony to the US Congress](#))

In 1992, 154 nations signed the United Nations Framework Convention on Climate Change, with the objective of achieving "[stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system](#)." This raised the question: what exactly would constitute dangerous anthropogenic interference? In 2008, a team of climatologists led by James Hansen set out to answer that question, and came to the startling conclusion that we are already over the limit: the current level of atmospheric carbon dioxide is already in the danger zone.

The amount of CO₂ in the atmosphere has increased from about 280 ppm preindustrially to 390 ppm today, and continues to rise by 2 ppm/year as we continue to burn fossil fuels. In their paper, "[Target Atmospheric CO₂](#)", Hansen et al argue we should aim to reduce it to 350 ppm in order to stabilize the Earth's climate. And we must hurry, because that task will soon be an impossible one. Their reasoning is complicated, but worth taking some time to understand given that it concerns the future of the world.

The 350 ppm target is based not on climate modeling, but on how the climate has responded to past greenhouse gas changes in the real world. Estimating a CO₂ target from paleoclimate is fraught with uncertainties, but the assumptions made by Hansen et al are not unreasonable ones. Likewise, their value judgements on what is "dangerous" are, in my opinion, no-brainers. Their paper covers a broad array of topics, but at its centre is the question: how sensitive is the Earth's climate when you include "slow feedbacks"?

Climate sensitivity and slow feedbacks

Climate sensitivity is the amount of global warming you get from doubling CO₂ (or an equivalent forcing, which is about 4 watts per square metre or W/m²), and determining its value is the key problem in modeling future climates. Usually we define climate sensitivity as including only "fast feedbacks" such as water vapor, sea ice, clouds, and dust (ice is a feedback because it affects the reflectivity or "albedo" of the surface). Because this definition comes from a landmark 1979 report by the National Academy of Sciences, whose lead author was Jule Charney, it is often called "Charney sensitivity". For clarity I will call it "fast-feedback sensitivity".

But in the long run (and as we shall see, the long run has current policy implications), what will be important is the climate sensitivity when you include not only fast feedbacks, but also "slow feedbacks" such as ice sheets. Greenhouse gases can also be a slow feedback, but Hansen et al do not count it as one because they want to know the long-term sensitivity to an unamplified greenhouse gas forcing.

Fast-feedback sensitivity is 3°C

There is a broad consensus that [fast-feedback sensitivity is 3°C](#) for a doubling of CO₂. Model estimates come with large error bars that have proven difficult to reduce as climate models have become more realistic over the decades, because modeling all the positive and negative feedbacks is so complicated. However, studying past climate changes, which obviously include all existing feedbacks, allows us to circumvent that problem, and paleoclimate-based estimates converge on the same number, 3°C.

Hansen et al reconfirm this with ice core data, by comparing the Holocene (the relatively stable interglacial climate of the last 10,000 years) to the Last Glacial Maximum (LGM) 20,000 years ago. Most of the warming between those two intervals was caused by ice sheets and greenhouse gases, themselves slow feedbacks on tiny orbital forcings sustained over long periods. But for the purpose of finding fast-feedback sensitivity, those slow feedbacks are considered to be forcings (confusing, I know). It is then straightforward to compare the combined forcing (6.5 W/m²) to the global temperature change (5°C), and derive a fast-feedback sensitivity of 0.75°C per W/m² or 3°C per CO₂ doubling, as predicted.

But here we're more concerned with slow-feedback sensitivity.

What about slow-feedback sensitivity?

We don't currently have models that include slow feedbacks (which is why the IPCC hasn't taken them into account), so paleoclimate is the only available tool to estimate them. Further complicating matters is the fact that slow-feedback sensitivity is not stable over geologic time. The ice sheet feedback will only work if there is ice to melt, thus climate sensitivity is higher when the planet has ice on it. On an ice-free Earth, the albedo feedback approaches zero, and slow-feedback sensitivity is about the same as fast-feedback sensitivity (remember, we're not counting greenhouse gas feedbacks).

The planet is currently in an ice age, with a hundred-millennium cycle from brief "interglacial" periods like the Holocene, when ice sheets are confined to Antarctica and Greenland; to long "glacial" periods like 20,000 years ago, when global temperature plunged by 5°C, ice sheets covered much of Canada and Europe, and sea level fell by over 100 metres. The Northern Hemisphere has been in an ice age for the duration of the Quaternary period of glacial-interglacial cycles, which began 3 million years ago. Antarctica has been in an ice age for no less than 34 million years, or the second half of the 65-million-year Cenozoic era.

Hansen et al use the ice core record of the late Quaternary (the last few glacial-interglacial cycles) to estimate the recent slow-feedback sensitivity to a specified greenhouse gas forcing. As before, about half of the global temperature change in each cycle was from ice sheet feedbacks and half from greenhouse gas feedbacks (though they in turn were ultimately caused by tiny variations in the Earth's orbit). Since here we're defining greenhouse gases as a forcing and ice sheets as a feedback, the result is a slow-feedback sensitivity that is double the fast-feedback sensitivity, or 6°C.

However, all of this is ignoring greenhouse gas feedbacks, which we know exist in the real world. For the moment, the carbon cycle is acting as a negative feedback, as oceans and vegetation are removing some of our CO₂ emissions (and we still stand a chance of getting back to a safe level). But as global warming continues, those carbon sinks are expected to fill up and start emitting CO₂, as they have done during the glacial-interglacial cycles. If we warm the planet too much, we could trigger a release of methane (CH₄) trapped on the ocean floor, with catastrophic effects. Eventually, excess CO₂ is removed from the atmosphere by a negative weathering feedback, but this takes hundreds of millennia.

You'll find some discussion of greenhouse gas feedbacks in [a recent book review by Andy S](#), but for the moment it is worth noting that the most important thing Hansen et al 2008 ignores is likely to make things even worse.

So, during the late Cenozoic the total climate sensitivity to greenhouse gases has been 6°C. Half of that is from fast feedbacks, and the other half from slow feedbacks. In the early Cenozoic when there was no ice on the planet, or in a possible future in which we've melted all the ice, there is no ice-albedo feedback and the climate sensitivity is 3°C. If you counted greenhouse gas feedbacks as feedbacks and not forcings, you'd get an even higher slow-feedback sensitivity.

Are slow feedbacks still as strong?

But will there be an equally large ice-albedo feedback on global warming today, now only the ice sheets of Greenland and Antarctica remain? To answer that question, Hansen et al extend their paleoclimate survey

back to before the advent of ice in Antarctica, zooming out to look at the entire 65 million years of the Cenozoic. On this timescale the orbital cycles that caused the glacial-interglacial flips are mere noise on top of a long-term cooling trend. And as it turns out, that long-term climate change can only be explained by CO₂.

Hansen et al take sediment core data and make one simple adjustment to derive global deep ocean temperature. (Specifically, the oxygen isotope ratios which are used as a proxy for temperature are also affected by ice volume, so they assume only half of the change during the late Cenozoic ice age is due to temperature.) The resulting record tells us the deep ocean temperature difference between the peak warmth 50 million years ago and the recent glacial periods was a whopping 14°C.

That breaks down into 8°C cooling until 35 million years ago, a 3°C difference between then and today, and another 3°C between today and glacial periods. The latter is noticeably less than the 5°C observed in ice cores, and we know why: we would expect deep ocean temperature to have changed less than global temperature in the icy late Cenozoic as it approached the freezing point. Thus Hansen et al assume the 3°C difference between 35 million years ago and today also translates to about 5°C globally. The relationship is less clear for the ice-free early Cenozoic, so for the 8°C they allow a conservative range of ±50%.

Using the values of fast-feedback and slow-feedback climate sensitivity derived from the Quaternary glacial-interglacial cycles, Hansen et al calculate the total change in climate forcing required over the 50 million years of cooling. The ice-albedo feedback accounts for about half of the 10°C difference during the late Cenozoic, confirming their slow-feedback sensitivity estimate of 6°C, so only about 7 W/m² of original forcing are required over that period. Assuming the 3°C fast-feedback sensitivity for the ice-free period, the forcing that caused the earlier 8°C cooling was 11 W/m², give or take a few W/m².

What was the forcing? The ice-albedo feedback contributed to the late Cenozoic cooling, but something caused it. The continents were close enough to their current positions 50 million years ago that their effect on albedo was negligible. The Sun's brightness increased by 0.4%, a forcing of just 1 W/m² and in the wrong direction. However, CO₂ levels fell from over 1,000 ppm in the early Cenozoic to merely 170 ppm in Quaternary glacial periods, approximately a factor of eight, or 12 W/m² — the only forcing which even comes close to explaining the observed cooling.

As an aside, the reason CO₂ varied so greatly was that continental drift affected the geologic carbon cycle: the imbalance of emissions from volcanoes versus absorptions from weathering and fossil fuel formation. I say *geologic* carbon cycle because these processes are far slower than the cycle between atmosphere, ocean, and vegetation that is important on human timescales. CO₂ increased from 65 to 50 million years ago as India's relatively rapid motion reduced sedimentation in what is now the Indian Ocean, but subsequently decreased as the rise of the Himalayas exposed new rock to the air. This natural CO₂ cycle is of mainly academic interest, because we are now emitting CO₂ thousands of times faster than volcanoes can.

Proxy records of CO₂ are uncertain (the error bars are small for the recent past when CO₂ was low, but very large at its peak in the early Cenozoic), but nevertheless the broad sweep of CO₂ must have been mainly responsible for Cenozoic climate change, with perhaps some contribution from other greenhouse gases. So Hansen et al calculate the CO₂ history that best explains the temperature history. In their chosen scenario (which matches the glacial-interglacial cycles and predicts a peak of 1,000-2,000 ppm 50 million years ago, within the broad range of proxy-based estimates), CO₂ was about 450 ppm just before Antarctica became glaciated. 35 million years ago 450 ppm was the freezing point, but if we pass it in the opposite direction it will be the melting point.

The greenhouse gas forcing and global temperature in the current interglacial is about halfway between the Quaternary glacial periods and the formation of the Antarctic ice sheet 35 million years ago. That means the slow albedo feedback is still very much in play. It means we can look forward to much more warming in the pipeline than previously thought. And it means 450 ppm, if sustained long enough for slow feedbacks to take effect, would eventually return the Earth to an ice-free state, raising the global sea level by 75 metres.

How much warming is in the pipeline?

The forcing associated with the dramatic human-caused CO₂ spike since 1750 is [about 1.8 W/m²](#) (and rising by 0.2-0.3 W/m² per decade). However, as yet the climate has responded to [only part of this forcing](#). We know this because the Earth is still gaining more heat than it is losing. This global energy imbalance tells us there is still warming in the pipeline on top of the 0.7°C we've seen so far.

The delay is caused by two sources of inertia in the climate system: the oceans and the ice sheets. Only the former is included in the climate models which IPCC projections are based on. The oceans warm quickly at first, reaching the first third of their response within a few years and the second third within a century, but take over a millennium to fully respond. The oceans are thus “hiding” about 0.6°C of future global warming. However, the long-term sensitivity of 6°C implies that the slow ice-albedo feedback will contribute another 1.4°C, making a total of 2°C (ie. 2.7°C above preindustrial temperature).

To put this in perspective, 2°C of further warming is enough to take us back to the Pliocene several million years ago, when sea level was 25 metres higher. Such a climate has not existed since before the evolution of humans.

How slow are slow feedbacks?

One of the scariest parts is that “slow feedbacks” may not be as slow as everyone used to think. Although in the past ice sheet collapses have taken millennia, perhaps that was only because orbital forcing changed very slowly. Perhaps ice sheets could melt faster if the climate changed faster. You only have to look at the glacial-interglacial cycles to see that ice sheets can melt faster than they build up. And though it takes a lot of energy to get ice sheets moving, once they are in motion they can collapse rapidly.

In the past, sea level changes of metres per century were not uncommon; instead it is the stability of the Holocene that is unusual. In [a particularly dramatic example](#) 14,000 years ago, the sea level rose 20 metres in just four centuries. Even during the last interglacial 125,000 years ago sea level was not as stable as once thought, [apparently varying by several metres](#). In the present, we observe the ice sheets shrinking [100 years ahead of schedule](#) — the IPCC expected them to grow during this century! The fact that ice sheet models do not predict these events seen in the real world suggests they are missing important positive feedbacks.

If the ice sheets can begin to respond significantly on the timescale of a century or so, then the “slow” warming in the pipeline has near-term implications. Human civilization developed with the relatively stable sea level of the last seven millennia. More than a billion people currently live within 25 metres of sea level. Yet once an ice sheet begins to collapse there is no way to stop it from sliding into the ocean. We would be subjected to centuries of encroaching shorelines. But this tragedy we have set in motion can still be prevented, if we reduce CO₂ before it is too late.

So where does the 350 target come from?

Humanity has become the driver of the Earth’s climate — human forcings are now far greater than natural ones — but that doesn’t mean we can control it. Unfortunately the climate system contains tipping points, beyond which the climate change we started would spiral out of our control.

The good news is that the inertia in the climate system means that even if CO₂ has passed the “tipping level” (say, 350 ppm) for a given tipping point (say, an ice-free Arctic), we may not yet have passed the “point of no return”. The bad news is that nobody knows exactly where the point of no return is, and we probably won’t know until we’ve already passed it. Hypothetically at least, we might still be able to prevent a tipping point by bringing the global climate back into energy balance before it has time to fully respond.

As well as the paleoclimate-based estimate of warming in the pipeline, many of the changes currently unfolding confirm the conclusion that we have already exceeded the safe level of atmospheric CO₂. Hansen et al estimate that restoring energy balance is necessary to save the Arctic sea ice (if it’s not already too late); to stop the expansion of the subtropics which will cause desertification in places like Australia; to prevent glacier loss which will cause water shortages; to relieve coral reefs from the twin stresses of global warming and ocean acidification; and of course to stabilize the ice sheets. All these problems are already beginning to occur, many faster than predicted.

How do we get the planet back in energy balance? The problem of setting a target is complicated by the existence of many other human effects on climate besides CO₂, but [CO₂ is clearly the dominant one](#). It is the largest and fastest-growing forcing. The non-CO₂ forcings roughly cancel out anyway: the warming effect of other greenhouse gases is offset by the temporary dimming effect of reflective particle pollutants (though the latter is not known with satisfactory precision). In the long run, CO₂ is most important for the warming in the pipeline from slow feedbacks, because it has the longest lifetime in the atmosphere. Whichever way you look at it, CO₂ is the main event.

So now we finally arrive at the central conclusion: a long-term target for atmospheric CO₂. To restore the planet's energy balance, we need to reduce CO₂ to less than 350 ppm. The 350 number refers to CO₂, not CO₂-equivalent, for the reasons explained above. This is not to say other forcings should be ignored, but controlling them would not make much difference to the long-term CO₂ target. The recommendation may be revised as we obtain better measurements of the total forcing and resulting energy imbalance, but 350 ppm provides a useful benchmark for the scale of action that is needed.

Can we get back to 350?

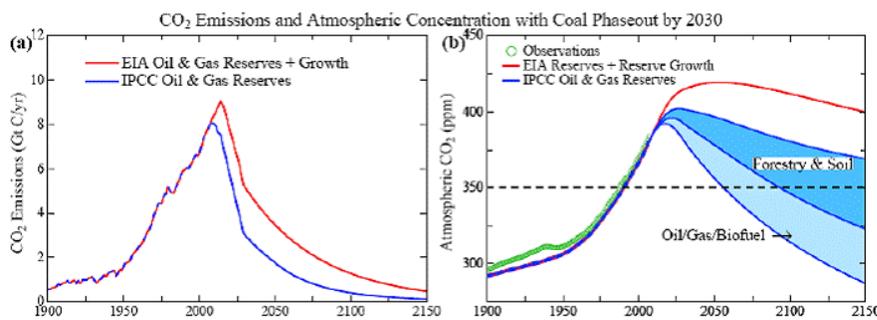
If Hansen is correct and ice sheets can respond faster than has been assumed, then his long-term CO₂ target has near-term policy implications. We need to get CO₂ back to 350 ppm as soon as possible. We still have a window of opportunity to get back to 350 ppm, but that window is rapidly slamming shut. Stabilizing the CO₂ level will require rapidly reducing global emissions until carbon sinks can absorb carbon faster than we emit it. Hansen et al argue the only realistic way to reduce emissions fast enough is to phase out coal.

Why target coal? Because [CO₂ has such a long atmospheric lifetime](#), we must leave most of the remaining fossil fuels in the ground if we are to have any hope of achieving the 350 goal. Of the three conventional fossil fuels (coal, oil, and gas), coal has by far the largest reserves. The phaseout of coal needs to include any conversion of coal to oil or gas — using up coal reserves at a slower rate would make little difference, because the carbon would still build up in the atmosphere and much of it would stay there for a very long time. Remember, carbon sinks have limits. The fundamental problem is with the coal being burned at all.

Hansen et al calculate that if we phase out coal by 2030, CO₂ could peak at around 425 ppm in 2050. Their scenario demands that we also not burn unconventional fossil fuels like tar sands and oil shale, whose reserves are virtually untapped but thought to contain even more carbon than coal. What about conventional oil and gas? There is dispute among energy experts over exactly how much oil and gas is left. Some think we've already burned about half of the available reserves and thus production must peak soon, while others argue there is more oil and gas if we want to go to the effort of extracting it. If the former is correct, or if the latter is correct but we leave the least accessible oil and gas in the ground, CO₂ could peak at just 400 ppm as early as 2025.

Supposing that we succeed in halting the rise of CO₂, we will still be left with the gargantuan task of removing it from the atmosphere. Natural carbon sinks would absorb about 25 ppm by the end of the century. Forestry and soil policies (for example, net reforestation by 2015) might be able to wipe off another 25 ppm.

It won't be easy but it appears to be still possible to get back to 350 ppm by century's end. On the other hand, if unlimited coal-burning continues for even one more decade, CO₂ can be expected to remain in the danger zone for a very long time.



Conclusion

Global warming is an increasingly urgent problem. The urgency isn't obvious because of the inertia of the climate system and the slowness of slow feedbacks. But we must act now before we push the climate beyond a tipping point where the situation spirals out of our control. As [climate blogger Joe Romm](#) likes to say, the time to act is yesterday.

Fast-feedback climate sensitivity is 3°C, but slow-feedback sensitivity is as high as 6°C when there are ice sheets on the planet, as there are today. Even worse, those slow feedbacks may not be nearly as slow as

we used to think. This means there is a large amount of warming already “in the pipeline”, though it is not yet too late to prevent it. To do so we cannot avoid targeting the largest, fastest-growing, and longest-lived forcing; a greenhouse gas which has been a major cause of climate change over geologic time: CO₂.

A CO₂ level of 450 ppm (the lowest target being considered by governments) would eventually melt all the ice on the planet. Both observations of the climate change currently underway, and the paleoclimate-based estimate of slow-feedback sensitivity, suggest even the current level of 390 ppm is too high. If CO₂ is at or above its current level for too long, it will eventually result in a planet unlike the one on which humans evolved: a planet 2°C warmer and with sea level 25 metres higher. Imagine waves crashing over an eight-storey building. It is hard to dispute that this would be “dangerous” climate change.

To stabilize the climate, we must return the Earth to energy balance. And in order to do that, we need to reduce CO₂ to 350 ppm, as soon as possible. To meet this target we must leave most of the remaining fossil fuels in the ground. We need to 1) rapidly phase out coal (including coal-to-liquid-fuels), 2) not burn the tar sands and oil shale, 3) not burn the last drops of oil and gas, and 4) turn deforestation into reforestation. And we must hurry: one more decade of business as usual would make this goal practically impossible. If we fail, we face an uncertain future in which the only certainty is a continually shifting climate.

I'll leave the final word to Hansen et al, whose concluding statements are pretty strongly worded coming from a dense, technical, peer-reviewed, scientific paper:

Present policies, with continued construction of coal-fired power plants without CO₂ capture, suggest that decision-makers do not appreciate the gravity of the situation. We must begin to move now toward the era beyond fossil fuels. Continued growth of greenhouse gas emissions, for just another decade, practically eliminates the possibility of near-term return of atmospheric composition beneath the tipping level for catastrophic effects.

The most difficult task, phase-out over the next 20-25 years of coal use that does not capture CO₂, is Herculean, yet feasible when compared with the efforts that went into World War II. The stakes, for all life on the planet, surpass those of any previous crisis. The greatest danger is continued ignorance and denial, which could make tragic consequences unavoidable.

Advanced rebuttal written by James Wight

Update August 2015:

Here is a related lecture-video from [Denial101x - Making Sense of Climate Science Denial](#)

[see video at [this link](#).]



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