Ice Melt, Sea Level Rise and Superstorms: The Threat of Irreparable Harm

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We made a video discussing some of the main points in our "Ice Melt" paper[1], which is about to be published in *Atmos. Phys. Chem.*: https://www.youtube.com/watch?v=JP-cRqCQRc8

The main point that I want to make concerns the threat of irreparable harm, which I feel we have not communicated well enough to people who most need to know, the public and policymakers. I'm not sure how we can do that better, but I comment on it at the end of this transcript.

Video Transcript

Hi, I'm Jim Hansen, Director of the Climate Science, Awareness and Solutions program at Columbia University Earth Institute. I want to discuss some implications of the paper Ice Melt, Sea Level Rise and Superstorms that is being published in Atmospheric Chemistry and Physics, a paper on which I have 18 exceptional American and international co-authors.**[1=Title]**

We have uncovered information and a partial understanding of feedbacks in the climate system, specifically interactions between the ocean and the ice sheets. These feedbacks raise questions about how soon we will pass points of no return, in which we lock in consequences that cannot be reversed on any time scale that people care about.

Consequences include sea level rise of several meters, which we estimate would occur this century or at latest next century, if fossil fuel emissions continue at a high level. That would mean loss of all coastal cities, most of the world's large cities and all their history.

A more immediate threat is the likelihood of shutting down the oceans overturning circulations in the North Atlantic and Southern oceans. That's where superstorms come in. Let me explain.

We use global climate modeling, paleoclimate data – that's Earth's ancient climate history – and modern observations of the ocean and ice sheets to study effects of ice melt on Greenland **[2]** and the Antarctic ice shelves (tongues of ice extending from Antarctica into the Southern Ocean).**[3]**

Greenland and Antarctica are beginning to melt because of global warming. So far it is just a tiny, tiny fraction of the ice sheets that has melted. However, this fresh meltwater spilling out onto the North Atlantic and into the Southern Ocean already is having important effects. [F16]

We conclude that light freshwater added to upper layers of the ocean is already beginning to shut down North Atlantic Deep Water formation and Antarctic Bottom Water formation. This will have enormous consequences in future decades, if full shutdown is allowed to occur.

United Nations IPCC, Intergovernmental Panel on Climate Change, does not report these effects, for two reasons. First, most models used by IPCC simply exclude ice melt. Second, we conclude

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[1] Hansen, J., M. Sato, P. Hearty, R. Ruedy, M. Kelley, V. Masson-Delmotte, G. Russell, G. Tselioudis, J. Cao, E. Rignot, I. Velicogna, E. Kandiano, K. von Schuckmann, P. Kharecha, A.N. LeGrande, M. Bauer, and K.-W. Lo, 2016: Ice melt, sea level rise and superstorms: Evidence for paleoclimate dat, climate modeling, and modern observations that 2°C global warming could be dangerous.. *Atmos. Chem. Phys.*, in press.

that most models, ours included, are less sensitive than the real world to added freshwater, because most models have excessive small scale ocean mixing, which reduces the effect.

[4] The surface manifestation of slowdown of the deep circulations is cooling in the North Atlantic southeast of Greenland and in the Southern Ocean. These coolings are prominent in our model by the middle of the 21st century. However, on multiple grounds, we conclude that the real world responds faster to freshwater than the models do.

First, let's note that North Atlantic cooling, if the overturning circulation shuts down entirely, will have large effects. The tropics continue to warm as CO_2 increases. If Greenland freshwater shuts down deepwater formation and cools the North Atlantic several degrees, the increased horizontal temperature gradient will drive superstorms stronger than any in modern times. All hell would break loose in the North Atlantic and neighboring lands.

[5 1st boulder] Such a situation occurred in the last interglacial period, 118 thousand years ago. The tropics were about 1°C warmer than today because Earth's spin axis was tilted less than today. Ocean core data show that deepwater formation shut down, the North Atlantic cooled, and there is evidence of powerful superstorms at about that time, powerful enough for giant waves to toss 1000 ton megaboulders **[6]** onto the shore in the Bahamas. Some scientists think these boulders may have been tossed by a tsunami, but we present multiple lines of evidence that the boulders and other geologic features are best explained as the result of superstorms.

An important point is that if we let ice melt from Greenland become large enough to fully shut down the AMOC, the Atlantic overturning circulation, it will be permanent as far as the public is concerned. It takes several centuries for AMOC () to get moving again.

However, superstorms will not be the most important consequence of global warming, if it continues to grow. The most important effect will be sea level rise. Here too, the most complete analysis must account for paleoclimate data, which shows that ice sheets, when they disintegrate, can go quickly, non-linearly, yielding multi-meter sea level rise in a century, even when the climate forcing is weaker than the human-made climate forcing.

[7] We show from paleoclimate data that most ice sheet models are more lethargic than the real world, in which sea level is known to have risen rapidly many times. So instead of using an ice sheet model, we simply assume that when warming occurs driven by a growing climate forcing the rate of ice melt will grow nonlinearly. We test several alternative growth rates.

What we find are amplifying feedbacks, just what is needed to feed nonlinear ice melt growth. Greenland meltwater reduces the density of surface water, thus reduces sinking of water to the deep ocean. As meltwater grows it shuts down the ocean conveyor, as Wally Broecker calls it.

More important, for sea level, is what is happening around Antarctica. Sinking of heavy, salty cold water near the Antarctic coast normally forms Antarctic Bottom Water, thus also bringing relatively warm water to the surface, where it releases heat to the atmosphere and space.

Now, as fresh meltwater from Antarctic ice shelves increases, it tends to put a cold low density lid on the Southern Ocean. This reduces exchange with the surface, so the heat stays in the ocean, raising the temperature of ocean water at the depth of ice shelves, an amplifying feedback.

In a global perspective, cold freshwater lenses around Antarctica increase the planet's energy imbalance. The added energy goes into the ocean where it is available to melt ice shelves.

These feedbacks support our conclusion that melt in response to strong forcing will be nonlinear. These feedbacks, with meltwater driving subsurface warming, also help us understand and gain a consistent picture of rapid nonlinear climate oscillations in the paleoclimate record.

[8] Paleoclimate data makes clear that when ice sheets melt, they can go fast. However, we do not know the characteristic time for the nonlinear ice sheet response to growing climate forcing. Eventually ice sheet models may give us an answer, but for now our best guide is observations.

Unfortunately records of growing annual mass loss by the ice sheets are short. The Greenland data can be fit as well by 10-year or 20-year doubling times, but already Greenland is losing several hundred cubic kilometers of ice per year. Feedbacks for Greenland, with its surface melt, are different than for Antarctica, but there are several amplifying feedbacks. Greenland response to global warming will be nonlinear, but likely with a different characteristic doubling time.

[9] Antarctic mass loss is smaller. Most melting so far is ice shelves, which does not show up in gravity satellite measurements of mass change. However, as ice shelves disappear, the discharge of non-floating ice will accelerate.

If ice sheet mass loss has a 10-year doubling time, meter-scale sea level rise would be reached in about 50 years, and multi-meter sea level rise a decade later. 20-year doubling time would require about 100 years.

The data records are too short. But if we wait until the real world reveals itself clearly, it may be too late to avoid sea level rise of several meters and loss of all coastal cities. I doubt that we have passed a point of no return, but frankly we are not certain of that.

[10] There's an analogous, but I believe more imminent, situation with shutdown of overturning ocean circulations. The cold regions southeast of Greenland and around Antarctica are signs of the beginning of shutdowns of the AMOC, in the North Atlantic, and the southern Ocean SMOC.

We note that effects of meltwater seem to be occurring 1 or 2 decades earlier in the real world than in our model. Why would models be less sensitive to today's moderate meltwater amounts? We present evidence for excessive small scale ocean mixing in many models, including ours.

[11] One key diagnostic is the climate response time. In 100 years our model achieves only 60% of its equilibrium response. I have checked three other major climate models, two American and one British, finding similar slow response. However, we have shown that Earth's measured energy imbalance requires the 100-year climate response to be about 75% if equilibrium climate sensitivity is about 3°C, as paleoclimate data show to be the case.

The explanation for why the surface response is so slow in the model is that the model ocean mixes heat too rapidly into the deeper ocean. This same excessive mixing causes the models to be less sensitive to the freshwater lens on the ocean surface, which also tends to mix too fast.

There is other data, besides Earth's energy imbalance, supporting this interpretation, including the sensitivity of paleoclimate to freshwater forcing. However, there is one recent paper that is especially important, by Winton et al. (2014), who show that a model with 0.1° resolution, fine enough to resolve small scale ocean motions and avoid parameterized mixing, yields a surface temperature response about a quarter larger after 50-100 years, consistent with our interpretation.

It would be valuable if all models would report their surface climate response function as well as their equilibrium climate sensitivity, and examine the model sensitivity to a standard rapidly increasing rate of meltwater injection. **[4]**

The relevance is that I believe we are already witnessing the beginning of this cooling southeast of Greenland and cooling around Antarctica in response to freshwater from ice melt.

[10] In that case observed cooling southeast of Greenland and the extra warming along the United States East Coast are not natural fluctuations – when AMOC slows down it causes both of those. This interpretation implies that Greenland meltwater is already having significant effects. The warm water along the East Coast is the reason that "Sandy" retained hurricane force winds all the way up to the New York City area – the nearby Atlantic was about 3°C warmer than normal. This unusually warm ocean water has also been able to provide the moisture for record snowstorms in recent years.

These are small effects compared to what happens if AMOC shuts down entirely.

So the question arises again: have we passed a point of no return, is ice melt sure to increase so that AMOC shutdown is a foregone conclusion? I doubt it, but it's conceivable, depending on how fast we slow down human-made climate forcing.

I think the conclusion is clear. We are in a position of potentially causing irreparable harm to our children, grandchildren and future generations.

This is a tragic situation – because it is unnecessary. We could already be phasing out fossil fuel emissions if only we stopped allowing the fossil fuel industry to use the atmosphere as a free dumping ground for their waste.If we collected a gradually rising fee from fossil fuel companies, we could phase over to clean energies – if done right it would spur the economy and create jobs.

But that's a story for another day.

One final point. This is a complex story, but one with important practical implications. I find that the public sometimes misinterprets our science discussions, how research is done. Skepticism is the lifeblood of science. You can be sure that many scientists, indeed most scientists, will find some aspects in our long paper that they would interpret differently. That's entirely normal. It takes time for conclusions to be agreed upon and details sorted out.

So after you have talked to a scientist about this topic, ask him or her a final question. Do you agree that we have reached a dangerous situation? Do you think we may be approaching a point of no return, a situation in which our children inherit a climate system undergoing changes that are out of their control, changes that will cause them irreparable harm? That's the bottom line.

Thanks for listening.