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Interactive Comment

Interactive comment on "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming is highly dangerous" *by* J. Hansen et al.

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Hansen gives a robust response to Andy Revkin concerning the possibility of the boulders on North Eleuthera Island, Bahamas, being the product of weathering. However there remains the possibility that the boulders and chevron patterns resulted from a series of tsunami, as Hansen mentions in his short paper (Hansen, 4 July 2015, "Boulders in the Bahamas"):

[Quote] An important characteristic of the chevrons is imbedding of lesser younger

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Interactive Discussion

Discussion Paper

chevrons within those that penetrated furthest inland. This is an expected result of storms while sea level was falling, as Earth moved into the post-Eemian ice age. If, instead, the imbedded chevrons were caused by a tsunami, a series of tsunamis would be required. [End quote]

Detailed support for the tsunami origin of the boulders is given in a book by Edward Bryant (Bryant, “Tsunami: The Underrated Hazard”). However Bryant assumes a single tsunami originating from an earthquake, collapse of a cliff, etc. He does not mention the possibility of a series of tsunamis from the calving of giant icebergs off an ice sheet.

Considering the disintegration of a large ice sheet or dome, with glaciers kilometres across and hundreds of metres thick, it is possible to imagine that, as melting progressed, the integrity would be compromised by moulins, water channels and cracks. There would come a point when huge slabs of ice could break away from the body of the ice sheet and, lubricated by meltwater, slide into the sea, scouring the seabed and producing huge tsunamis. The effect of each slab would be like a cliff collapsing into the sea but with greater horizontal momentum. It is known that a mega-tsunami would be generated if a cliff on La Palma collapsed into the sea.

Could a partial disintegration of the Greenland Ice Sheet have produced a succession of giant tsunamis on Eleuthera? The pressure waves from calving on the west coast of Greenland would have proceeded across the Atlantic in a south-easterly direction. But pressure waves travel through the whole body of water, so there would be a partial reflection of the waves by the mid-Atlantic ridge, where it runs north-south. The island of Eleuthera would receive the full force of this reflected wave arriving from the north-east.

But Hansen points to smaller boulders and chevron structures at a lower height and dated to the Holocene. Could these also be of multiple tsunami origin? Multiple tsunamis would come from the collapse of ice sheets; and collapse of the Hudson Bay Ice Dome about 8.2 thousand years ago turns out to be a prime candidate (Wag-

ACPD
15, C5885–C5889, 2015

ner, 2013, “Model support for forcing of the 8.2 ka event by meltwater from the Hudson Bay ice dome”)

If the boulders at various heights and sizes on the Bahamas were the product of multiple tsunamis resulting from the collapse of the GIS in the late Eemian and the collapse of the Hudson Bay ice dome during the early Holocene, then one has confirmatory evidence of giant icebergs and these could have provided powerful negative forcing, able to switch the Northern Hemisphere from rapid warming into slow cooling, as typically observed after rapid warming events. Such negative forcing has been proposed to result from meltwater equivalent to a metre of sea level rise (Hansen and Sato, 2012, “Update of Greenland Ice Sheet mass loss, exponential?”), but we suggest that meltwater alone was insufficient to cause a switch, and it required the calving of massive icebergs, at least on the occasion of the rapid warming events at the end of the Eemian and the beginning of the Holocene. This calving might have followed after as much as two metres of sea level rise in the case of the Eemian.

There are two ways in which icebergs could cause such a switch. The cooling of the North Atlantic by icebergs could lead to a slowing down or halting of the Atlantic meridional overturning circulation (AMOC). Or the icebergs could restore sea ice and albedo in the Arctic Ocean, following a retreat of the ice and Arctic warming. Let us consider second way (although the two ways are not mutually exclusive).

Sea ice provides a strong positive feedback mechanism for the amplification of global warming. As the sea ice retreats, albedo loss leads to rapid Arctic warming and accelerated melt of the Greenland Ice Sheet, as we have observed over the past two decades at a doubling rate of 5 to 10 years (Hansen and Sato, 2012, as above).

It is known that the Arctic has been seasonally free of sea ice, from the evidence of iceberg debris deposits on the Arctic Ocean floor (Darby et al, 2006 “History of the Arctic”). The albedo loss would give rise to intense regional warming with the production of meltwater pulses. But to switch off this effect would require some kind of dramatic cooling and resurfacing of the Arctic Ocean with freshwater. The giant icebergs calving from local ice sheets could provide such a mechanism.

With the Arctic cooled, the temperature gradient from tropics would be restored or even strengthened, putting more energy into atmospheric circulation, leading to stronger westerlies again. This is the mechanism the paper suggests for producing the giant storms.

Thus, while accepting the argument that giant storms could have created the observed effects on Eleuthera, there is also a plausible argument that they were created by two series of tsunami, originating from calving of giant icebergs: one series from the Greenland Ice Sheet in the Eemian, and one from the Hudson Bay ice sheet, 8.2 thousand years ago.

Note that the paper suggests that the rapid late Eemian sea level rise “was likely related to events in the Southern Ocean”; but here we take the conventional view that there was first rapid sea level rise from the Greenland Ice Sheet, estimated to be 2-3 metres over a few decades by Blanchon et al (2009) referenced in the paper. The driving force for such a rapid sea level rise must have been positive albedo feedback from snow and sea ice retreat in the Arctic. Subsequently there would have been an even greater sea level rise originating from Antarctica.

So what should be done, in the light of the findings above?

Firstly, on the precautionary principle, governments should take measures to safeguard against giant tsunamis, just in case they result from sudden destabilisation of the Greenland Ice Sheet with giant slabs of ice sliding into the sea.

In particular, knowing the devastation in Fukushima, governments should not site nuclear power stations in places which might be liable to tsunami, such as Hinkley point in the Bristol Channel (where there was what appears to have been a tsunami in 1607 with devastating consequences).

ACPD

15, C5885–C5889, 2015

Interactive Comment

Secondly, given the incalculable cost of a possible sea level rise of a few metres by 2050, governments should also be taking precautionary measures to prevent continued warming which could cause such a sea level rise, in particular to prevent further retreat of the Arctic sea ice. Governments must be warned of the great danger of allowing the Arctic Ocean to become seasonally free of ice.

Thirdly, it would not seem sensible for fossil fuel companies to be drilling in the Arctic when the sea ice is in such a critical state, accidental methane release could aggravate the situation, and accelerated discharge of ice from the Greenland Ice Sheet is so ominous.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 20059, 2015.