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Discussions

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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This review of Hansen et al (2015) focuses only on glaciological elements, principally for Antarctica. The paper is well referenced and uses very recent data and appropriate data for mass change of both the GIS and AIS. The assessments of potential vulnerabilities and feedbacks that will lead to enhanced ice sheet volume losses are well articulated and will lead to continued increases in ice volume losses. I applaud the authors for the level of analysis they have brought to this large and complex topic.

I will focus on just one essential point, the difficulty in continuation of a doubling of volume losses over a significant span of this century. It is not difficult to have a rapid doubling rate initially, as is correctly identified for both the GIS and AIS, when you are emerging from a period of near equilibrium. To sustain this is more difficult, as even substantial increases in volume loss that led to the previous doubling will no longer yield a doubling. A useful analog is alpine glacier mass balance. The World Glacier Monitoring Service (WGMS, 2015) collects annual mass balance data from alpine glaciers around the globe and reports them in millimeters of water equivalent (mm w.e.). The mean annual balance by decade indicates a doubling rate of ten years initially. With a mean of -198 mm w.e. a-1 in the 1980's, doubling to -382 mm w.e.a-1 in the 1990's, and again a near doubling to -740 mm w.e. a-1 in the 2000's (Pelto, 2013). The period from 2005-2014 exhibits a mean annual balance of -794 mm. w.e. a-1. The decade of the 2010's is not over, by any means but it will be difficult to reach a rate of -1480 mm w.e.a-1 though the increase in mass loss may exceed the previous greatest decadal gain of -358 mm w.e.a-1.

In Antarctica the paper has focused on regions where mass losses have been accelerating without, in the text at least, equal consideration to regions where this is not the case. Barletta et al (2013) figure 4 indicate trends of loss of more than 10 GT per year from 4 of 28 basins in Antarctica, with nine losing mass overall, 10 near equilibrium and eight with positive balances. The overall loss is correctly noted by the authors; however, there is no critique of why a number of basins continue to have modest positive mass gains, and why this might reverse. Liu et al. (2015) et al, note a 34% increase in discharge from feeder glaciers after ice shelf loss on the WAP, which is a primary means of acceleration for any outlet glacier buttressed by an ice shelf, this is far less than a doubling. Depoorter et al (2013) observe areas of low basal melt or ice gain in figure 2, that include the two largest ice shelves, the Ross and Ronne/Fitchner, Mertz, the Ninnis and Cook Glacier region and the Amery Ice Shelf. This again requires a more detailed explanation of what will change, to drive a rapid basal ice loss. Clearly the current ocean warming is not leading to much basal ice melt in these important regions. Liu et al (2015) in Figure 1 identify the calving flux in various sectors and identify the low basal melting and calving in similar regions including the Ross Sea sector, Weddell Sea sector, Amery Ice Shelf and Mertz-Ninnis-Cook region. This underlines that the basal melting that is missing from these areas is likely connected to the low calving rates. Each region has a different physical oceanography and it is not identified how the current beneath ice region would change to enhance basal melt.

An examination of BEDMAP2 (Fretwel et al, 2013) illustrates a number of deep troughs extending beneath the ice sheet that are not mentioned in the paper, and are in areas of limited ice loss now, these include Denman, Recovery, Slessor, Academy and Lambert Glaciers. In order to have exponential increase these glaciers with deep long beds will have to alter their behavior. What will trigger this is not identified? Mouginot et al (2011) developed a velocity map of Antarctica that is also instructive. Denman, Recovery, Slessor, Academy and Lambert Glaciers already have quite high velocities extending far inland thanks to the deep beds, converging flow and thick ice. This does not mean they cannot accelerate, but means they are already fast flowing glaciers, with limited ability to exponentially increase flow. The focus is placed on the Amundsen Sea sector and Totten Glacier in this paper. The Amundsen Sea sector analysis in this paper is spot on and all of the feedbacks are at work, to lead to high volume losses and accelerating losses. For Totten Glacier, Greenbaum (2015) figure 2, note significant pinning points along the coast and two main basins with a sill between. This is not a continuous retrograde basal profile. The basal topography is not as simple as below Pine Island Glacier. A look at BEDMAP2 supports this point. The point is that it is not all Antarctic glaciers are behaving the same or will follow the same path of behavior evolution. This will make it quite difficult to sustain a doubling rate as envisioned in this paper. This does not mean that volume losses cannot double from current levels and continue to rise thereafter.

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