Comment on, "Brief Communication: A submarine wall protecting the Amundsen Sea intensifies melting of neighboring ice shelves", by Gürses et al.

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First of all, I would like to congratulate the authors on an excellent modeling paper answering a concise scientific question. This sort of skeptical engagement from the scientific community is exactly what we were hoping for when we wrote our original geoengineering papers. It is vitally important that all potential side effects of any geoengineering proposal are explored thoroughly, including side effects that the original authors did not think of. This side effect certainly falls under that category; we did not anticipate that blocking warm water from reaching some ice shelves would cause it to increase melting at other shelves.

However, I am worried that casual readers might draw the implication that an intervention which merely redirected melting from one ice shelf to another would therefore be ineffective. It is important to emphasize that what matters from the perspective of human societies is not the floating ice shelves, which already displace their weight in water and thus make no direct contribution to sea level when they melt, but rather the grounded ice, which can raise sea levels if it flows into the ocean. The floating shelves are important only insofar as they act to buttress the grounded ice and prevent grounding line retreat. The authors themselves alluded to this issue in the conclusion, writing, "[I]t is an open question if this triggers Marine Ice Sheet Instability in the other shelves, because the stability depends on the distribution of pinning points, sloping of the bed, depth and width of submarine troughs, and the softness of the bed, for instance. The onshore bed properties of the western Marie Byrd Land, where Pine Island and Thwaites Glaciers are located, are probably more favorable for a stable situation than in the eastern Marie Byrd Land sector."[1]

I would argue that the above statement is far too weak. We can be highly confident that Pine Island and Thwaites Glaciers are more vulnerable to a runaway Marine Ice Sheet Instability than the areas of western Marie Byrd Land onshore of the Getz Ice Shelf. At the simplest level, we can look at the basal topography of these areas of the ice sheet (Fretwell et al., 2013). There is a large overdeepened marine basin onshore of Thwaites Glacier, but there is elevated basal topography, in some places above sea level, onshore of Getz (Fig 1). Thwaites and Pine Island are also retreating at the present day (Turner et al., 2017), and indeed, there have been reasonable suggestions from both

1 This statement needs to switch western and eastern, and it is somewhat ambiguously worded at the end. It would be more accurate to say that the onshore bed properties in eastern Marie Byrd Land, where Pine Island and Thwaites Glaciers are located, are more favorable for a runaway instability than western Marie Byrd Land.

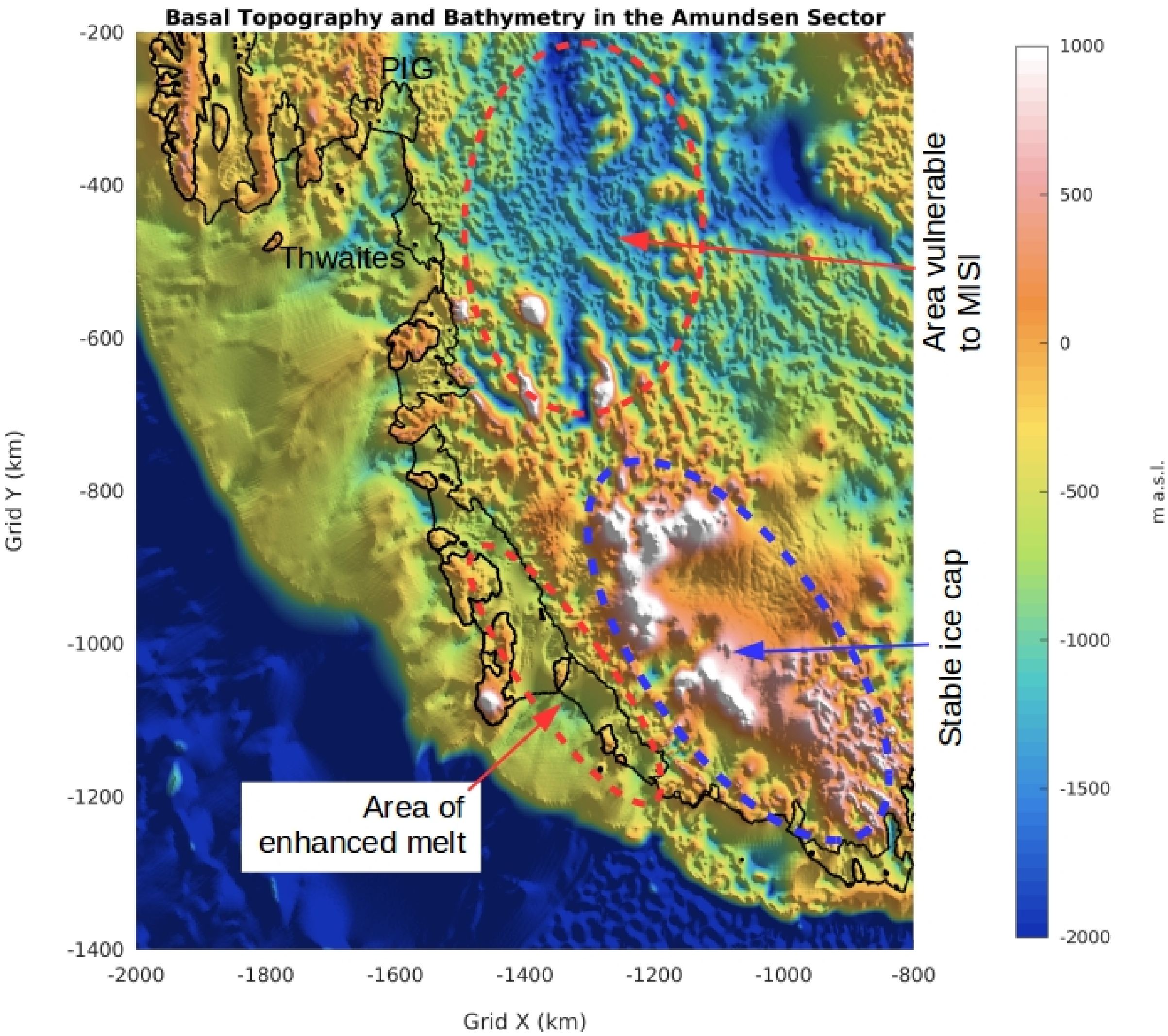

Figure 1: Bed elevation in the Amundsen sector of West Antarctica. Data from BEDMAP2 (Fretwell et al., 2013), visualized as a hillshaded surface with two perpendicular light sources so that all slope orientations are visible. Black lines represent ice front and grounding line. The area of the Getz Ice Shelf where the WALL experiment simulated enhanced basal melt is indicated, as is the elevated basal topography inland of that where the stable relic ice cap forms. This geometry can be compared to the geometry inland of Thwaites, where the bed rapidly deepens and the ice sheet is vulnerable to runaway collapse.

data and models that they have already begun a runaway retreat (Favier et al., 2014; Joughin et al., 2014; Rignot et al., 2014). Furthermore, the geographic position of Thwaites and Pine Island ensures that a runaway retreat there will trigger a general collapse of West Antarctica through a “backdoor” destabilization of the Filchner-Ronne and Ross sectors (Feldmann and Levermann, 2015).

By contrast, ice sheet models almost always show that the ice cap onshore of western Getz is the most stable part of WAIS. The elevated basal topography there (Fig 1) allows a relic ice cap to persist even after the rest of WAIS has collapsed. This relic ice cap can be seen in DeConto and Pollard

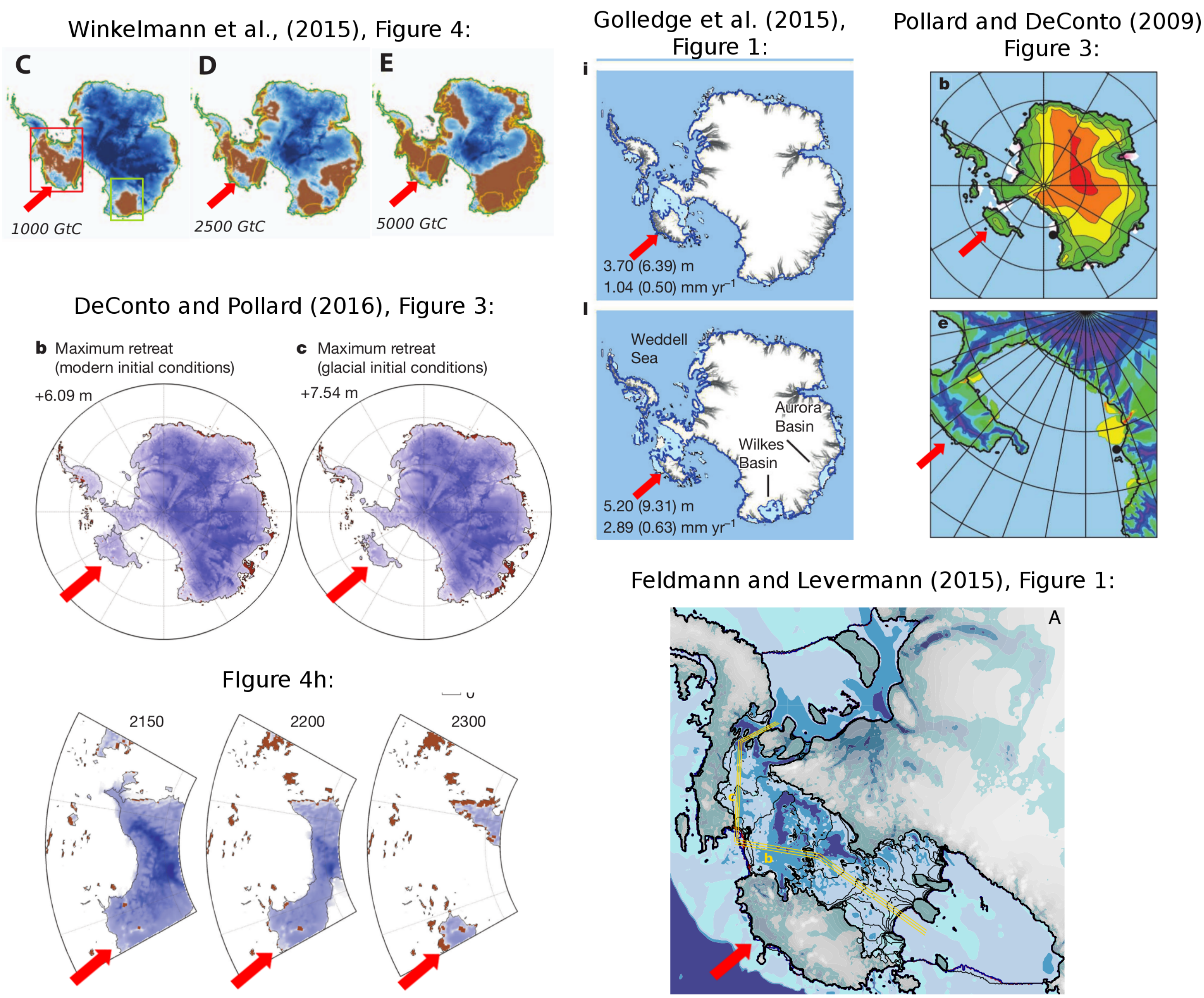

Figure 2: Compilation of model ice sheet geometries showing the relic ice cap in western Marie Byrd Land which persists even after the rest of WAIS has collapsed. Original source for each figure indicated. Images represent simple screenshots of the model output as visualized in their respective papers; I did not make any attempt to standardize the displays. My only change was to add a red arrow indicating western Marie Byrd Land in each plot.

(2016); Winkelmann et al. (2015); Golledge et al. (2015); Feldmann and Levermann (2015); and in Pollard and DeConto (2009). I have compiled snapshots of ice sheet geometry from all of those models in Fig 2. The relic ice cap in western Marie Byrd Land is a robust feature of ice sheet models because all of the models are responding to the elevated basal topography in that region. Based on a convergence of evidence from basic MISI theory, observations, and models, we can have a high degree of confidence that Pine Island and especially Thwaites are the most unstable parts of West Antarctica, while the ice cap in western Marie Byrd Land is the most stable part. In fact, that little ice cap is likely to be the last thing left standing long after the rest of WAIS has collapsed.

The model results presented in this paper indicate that a wall built across the Amundsen Sea Embayment at depth could successfully trade high melt rates at Pine Island and Thwaites for high melt rates at Getz. The current state of glaciological knowledge strongly indicates that the ice cap onshore of the western Getz Ice Shelf is the most stable part of WAIS, and the overdeepened topography of Pine Island and Thwaites are the most unstable parts[2]. While it is always important to quantify all side effects of a potential geoengineering project, not all ice shelves are created equal in their importance to ice sheet stability and sea level rise. In my opinion, a geoengineering effort that shifted high melt rates from the most unstable part of WAIS to the most stable part of WAIS would be a smashing success. From the perspective of humanity's interest in a stable sea level, the trade described by this paper is an excellent one.

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2 Although it is also important to be open to the possibility that our consensus understanding may be wrong. In particular, I worry that a lack of high density ice thickness measurements in western Marie Byrd Land could be hiding deep subglacial troughs and therefore causing us to overestimate the stability of that region.

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