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To cite this article: Jonathan Bamber et al 2009 IOP Conf. Ser.: Earth Environ. Sci. 6 062007

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IOP Publishing doi:10.1088/1755-1307/6/6/062007

IOP Conf. Series: Earth and Environmental Science 6 (2009) 062007

## S06.07

What is the tipping point for the Greenland Ice Sheet?

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The potential irreversible disintegration of the Greenland Ice Sheet beyond some threshold temperature is regularly cited as a key mitigation criterion. Identifying what this threshold temperature might be is, therefore, of some importance. Studies using a suite of IPCC climate projections to force a simple numerical model of the surface mass balance of the Greenland Ice Sheet have indicated that the global threshold temperature increase is about 3° C. Beyond this value, the ice sheet will, apparently, lose mass year and year, resulting in its eventual complete removal and a concomitant eustatic sea level rise of  $\sim 6$  m. We have compared the simple temperature index model used in this analysis with one that includes a complete description of the energy balance at the surface and snow metamorphism. We find that the more complex model has a markedly different sensitivity to a prescribed climate forcing, resulting in a critical threshold at about 6° C: double the previous estimate. All models have tuneable parameters and we do not suggest that our estimate is, necessarily, the correct value. Our results do indicate, however, that there is great uncertainty in the tipping point temperature. We also note that palaeo-climate records indicate a more stable ice sheet than suggested by the simple models. For example, a somewhat smaller ice sheet existed for multiple millennia during the Eemian when temperatures were about 5 ° C higher than today. Further, during MIS stage 11, there was a delay of as much as 20,000 years between the advent of Arctic temperatures 2-4° warmer than present and substantial ice sheet retreat, as inferred from the development of spruce forests. We conclude, therefore, that the threshold temperature has been substantially underestimated in previous studies. Our results also have profound implications for predictions of sea level rise from Greenland over the coming century.