EGU22-5983
https://doi.org/10.5194/egusphere-egu22-5983
EGU General Assembly 2022
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Influence of surface mass balance on the high-end sea-level commitment from the Antarctic Ice Sheet

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Over the last decades, the Antarctic Ice Sheet (AIS) has been losing mass, mainly through ice discharge and sub-shelf melting (Rignot et al., 2019). More specifically, recent observations show that the AIS is currently losing mass at an accelerating rate in areas subject to strong ocean-induced melt. At the same time, no long-term trend in snowfall accumulation changes can be detected in the interior of the ice sheet. Due to these current trends, basal melting has often been considered as the main driver of future Antarctic mass loss. However, even though stronger basal melting of ice shelves is projected to drive future AIS mass loss, recent studies (e.g. Seroussi et al., 2020) have shown that surface mass balance (SMB, the balance of accumulation through snowfall and ablation through erosion, sublimation and runoff) has a strong potential in controlling the future stability and evolution of the Antarctic Ice Sheet. With increasing temperatures, SMB is expected to increase in Antarctica in the future as a result of enhanced snowfall. As long as the warming remains modest, other AIS SMB components (such as runoff) will likely continue to play a minor role in future SMB changes (Lenaerts et al., 2019; Kittel et al., 2021). Under high-emission scenarios, however, future runoff is likely to significantly compensate for mass gain through snowfall (Kittel et al 2021). The balance between these competing processes is still a matter of debate and, as of yet, there is no consensus on estimates of the future mass balance of the Antarctic Ice Sheet (Seroussi et al., 2020).

Here, we investigate the relative importance of SMB changes and ocean-induced melt on the long-term (multi-centennial to multi-millennial) AIS response as well as their associated uncertainties. To do so, we force two ice sheet models (fETISh and PISM) with atmospheric and oceanic projections inferred from a subset of models from the sixth phase of the Coupled Model Intercomparison Project (CMIP6) under the Shared Socioeconomic Pathways (SSP) 5-8.5 and SSP1-2.6. Changes in precipitation rate and air temperature are corrected for elevation changes and used as inputs to a positive degree-day scheme which estimates changes in snowfall, rainfall and surface runoff. Climate projections are used as forcing until the year 2300 and afterwards no climate trend is applied, allowing to investigate the long-term impacts of early-millennia warming (often called sea-level commitment).

Taking into account key uncertainties in both atmospheric and oceanic forcing, our results predict that atmosphere-ice surface interactions will have an important role on the AIS stability under high-end future emission scenarios. We also show the increasingly important role of the melt-elevation feedback for multi-centennial projections of the AIS. Finally, we find that modelling choices regarding the atmosphere forcing have a significant influence on the future sea-level contribution from the AIS under high-end emission scenarios, leading to a spread from a few centimeters to several meters contribution over the coming millennia.