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Potential of the solid-Earth response for limiting long-term West Antarctic Ice Sheet retreat

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The West Antarctic Ice Sheet (WAIS) is assumed to be inherently unstable because it is grounded below sea level in a large part, where the bedrock deepens from today's grounding line towards the interior of the ice sheet. Idealized simulations have shown that bedrock uplift due to isostatic adjustment of the solid Earth and the associated sea-level fall may stop the retreat of such a marine-based ice sheet (Gomez et al., 2012). Here, we employ a coupled model for ice-sheet dynamics and solid-Earth dynamics, including a gravitationally consistent description of sea level, to investigate the influence of the viscoelastic Earth structure on the WAIS' future stability (Konrad et al. 2015). For this, we start from a steady-state condition for the Antarctic Ice Sheet close to present-day observations and apply atmospheric and oceanic forcing of different strength to initiate the retreat of the WAIS and investigate the effect of the viscoelastic deformation on the ice evolution for a range of solid-Earth rheologies. We find that the climate forcing is the primary control on the occurrence of the WAIS collapse. However, for moderate climate forcing and a weak solid-Earth rheology associated with the West Antarctic rift system (asthenosphere viscosities of 3x10̂19 Pa s or less), we find that the combined effect of bedrock uplift and gravitational sea-level fall limits the retreat to the Amundsen Sea embayment on millennial time scales. In contrast, a stiffer Earth rheology yields a collapse under these conditions. Under a stronger climate forcing, weak Earth structures do not prevent the WAIS collapse; however, they produce a delay of up to 5000 years in comparison to a stiffer solid-Earth rheology. In an additional experiment, we test the impact of sea-level rise from an assumed fast deglaciation of the Greenland Ice Sheet. In cases when the climatic forcing is too weak to force WAIS collapse by itself, the additional rise in sea-level leads to disintegration of the WAIS for asthenosphere viscosities of 3x10̂20 Pa s or higher.

References

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