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Solid Earth and local sea-level change effects on grounding-line stability of the Antarctic ice sheet

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Both isostatic effects of ice sheet volume changes and gravitationally-consistent local sea-level variations are known to have a large impact on timing and magnitude of retreating and advancing ice through grounding-line migration on glacial-interglacial time scales.
Full self-gravitating viscoelastic solid-Earth models (SGVEM) incorporate gravitational, rotational and bedrock deformational responses to ice-ocean mass redistribution and are thus able to solve the sea-level equation. On the other side of the spectrum are ELRA models (Elastic Lithosphere-Relaxed Asthenosphere), often used in conjunction with ice-sheet models. They consider an elastic lithosphere, defined by a given effective lithosphere thickness and a relaxation equation for asthenospheric response with a characteristic response time as a function of asthenosphere viscosity. However, several recent studies suggest strong lateral variations in lithospheric thickness and asthenosphere viscosity between Eastern and Western Antarctica. More specifically, effective lithosphere thickness and mantle viscosity variability in Antarctica induce large spatial variations - across several orders of magnitude - of both the flexural rigidity and the asthenospheric response time, with weaker Earth structure than previously thought in Western Antarctica. It has been shown that the combination of bedrock uplift and local sea-level lowering associated with grounding-line retreat reduces Antarctic ice sheet (AIS) mass loss, with greater stabilization occurring for weaker solid Earth (Gomez et al., 2015, Konrad et al., 2015). Properly approximating the interactions of the ice sheet with the solid Earth and local sea-level response is thus key to understand the stability and evolution of the AIS.

Here, we develop a simplified Earth model based on the ELRA model that approximates the lateral variations of the Antarctic Earth structure, leading to spatially varying asthenospheric response time and effective lithosphere thickness. This is further combined with a gravitationally consistent description of the local sea-level near the margin of ice sheets as a reaction to local mass changes. We explore the sensitivity of the ice sheet-solid Earth-sea level system by performing a series of perturbations in fringing ice shelves leading to grounding line retreat and analyse the effect of different model configurations on the stability of grounding lines.