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3D viscosity maps for Greenland and effect on GRACE mass balance estimates

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The GRACE satellite mission measures mass loss of the Greenland ice sheet. To correct for glacial isostatic adjustment numerical models are used. Although generally found to be a small signal, the full range of possible GIA models has not been explored yet. In particular, low viscosities due to a wet mantle and high temperatures due to the nearby Iceland hotspot could have a significant effect on GIA gravity rates. The goal of this study is to present a range of possible viscosity maps, and investigate the effect on GRACE mass balance estimates.

Viscosity is derived using flow laws for olivine. Mantle temperature is computed from global seismology models, based on temperature derivatives for different mantle compositions. An indication for grain sizes is obtained by xenolith findings at a few locations. We also investigate the weakening effect of the presence of melt. To calculate gravity rates, we use a finite-element GIA model with the 3D viscosity maps and the ICE-5G loading history. GRACE mass balances for mascons in Greenland are derived with a least-squares inversion, using separate constraints for the inland and coastal areas in Greenland. Biases in the least-squares inversion are corrected using scale factors estimated from a simulation based on a surface mass balance model (Xu et al., submitted to The Cryosphere). Model results show enhanced gravity rates in the west and south of Greenland with 3D viscosity maps, compared to GIA models with 1D viscosity. The effect on regional mass balance is up to 5 Gt/year. Regional low viscosity can make present-day gravity rates sensitivity to ice thickness changes in the last decades. Therefore, an improved ice loading history for these time scales is needed.