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Antarctic firn thickness variations from multi-mission satellite altimetry and firn modelling

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On interannual to decadal timescales, surface mass balance (SMB) exerts an important control over variations in the overall mass balance of the Antarctic Ice Sheet (AIS). A proper characterization of this variability is required to determine statistically significant long-term trends in SMB in a robust manner. To do so, we quantify variations in SMB and firn thickness by combining results from multi-mission satellite altimetry and SMB/firn modelling at grid scale. The objective of this study is twofold: First, we characterise the errors in both the altimetry and firn model in a spatially and temporally highly-resolved way. Second, we introduce a new approach that sets the stage for inferring long-term trends in SMB and firn processes at grid scale by taking into account interannual firn thickness variations. We use observed altimetric elevation changes of the AIS from Schröder et al. (2019; doi: 10.5194/tc-13-427-2019) and Nilsson et al. (2022; doi: 10.5194/essd-14-3573-2022) and modelled elevation changes of the AIS from IMAU-FDM v1.2A over the period 05/1992 to 12/2017. We assume that the firn model is able to capture the timing of variations in SMB and firn processes, but not necessarily the amplitude of these variations. The location-dependent amplitude is adjusted to the altimetry observations. We detect highest absolute differences between modelled and observed amplitudes at lower elevations, near the AIS margins. In a relative sense, the largest mismatch in amplitude is found in the dry interior of the East AIS across wind glazed areas of e.g. megadune fields. About 37 % of the variance in altimetry is captured by the adjusted firn thickness variations while about 64 % cannot be explained and is still included in the residuals. These residuals contain both altimetry errors (time-variable penetration and scattering effects of radar signals, intermode and intermission offsets) and firn model errors, like real SMB and firn processes not captured by the model. We identify that the time series of altimetric residuals are highly correlated and conclude that we need to consider an appropriate noise model for determining long-term trends and their uncertainties.