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Antarctic Surface Mass Balance from 1980 to 2017

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The regional climate model HIRHAM5 developed for Greenland ice sheet applications has now been updated to also simulate Antarctic conditions. The outputs of the Antarctic runs have been used to force an offline subsurface model, to give estimates of the Antarctic surface mass balance (SMB) from 1980 to 2017. Here, we compare two different versions of this offline subsurface model and evaluate how they simulate the physical properties of the uppermost part of the Antarctic firn pack. We find that the total calculated SMB of Antarctica is sensitive to the subsurface model variant. One model version uses an Eulerian framework, meaning that mass is advected through layers of fixed mass. When snowfall occurs at the surface, it is added to the first layer and an equal mass from that layer is shifted to the underlying layer. The same goes for each layer in the model column, and vice versa for mass loss. The other model version uses a Lagrangian framework for the layer development. Layers evolve through splitting and merging dynamically based on a number of weighted criteria.

The model simulations are validated against in situ observations of firn temperature and subsurface density. We find a mean temperature bias of 0.42-0.52 [illegible] and a mean bias in modelled density of -24.0±18.4 kg m^{-3} and -8.2±15.3 kg m^{-3} for layers less than 550 kg m^{-3} for the Eulerian and Lagrangian framework, respectively. For layers with a density above 550 kg m^{-3} the bais is -31.7±23.4 kg m^{-3} and -35.0±23.7 kg m^{-3} for the Eulerian and Lagrangian framework, respectively. The modelling framework also affects the resulting SMB. The Lagrangian framework, estimates a total SMB of 2473.5±114.4 Gt yr^{-1} while the Eulerian framework results in slightly higher modelled SMB of 2564.8±113.7 Gt yr^{-1}. The majority for this difference in modelled SMB is pinpointed to the ice shelves (the SMB over grounded ice only differs 30 Gt yr^{-1}) and demonstrates the importance of firn modelling in areas with substantial melt. Both the Eulerian and the Lagrangian SMB estimates are within each other's uncertainties and within range of other SMB studies. However, the Lagrangian version has the best statistics for modelling the densities. Given the importance of precipitation to Antarctic SMB, climate models must accurately simulate regional circulation patterns that modulate precipitation rates. We therefore investigate the relationship between SMB in individual drainage basins and the southern annular mode (SAM), using Monte Carlo simulations. This shows a robust relationship between SAM and SMB in half of the basins (13

out of 27). In general, when SAM is positive there is a lower SMB over the Plateau and a higher SMB on the westerly side of the Antarctic Peninsula, and vice versa when the SAM is negative.