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Parametrizing drifting snow sublimation in the saltation layer

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Modelling the surface mass balance of Antarctica and snow and ice surfaces in general is challenging, yet it is important for making reliable projections of sea level rise. One of the terms with the largest uncertainties is sublimation (and vapor deposition) of drifting and blowing snow. Large-scale atmospheric models strongly simplify or completely neglect the underlying physical processes. In particular, they do not resolve the vertical profiles of particle concentration and sublimation in the saltation layer, corresponding roughly to the lowest 10 cm of the atmosphere. However, small-scale studies based on large-eddy simulations (LES) demonstrate that most of the sublimation of drifting and blowing snow can take place in the saltation layer, at least for shallow layers of drifting snow. As these events occur very frequently, current large-scale models may strongly underestimate snow sublimation. Even in deep blowing snow layers, the saltation layer may be relevant for the overall moisture exchange because strong vapor deposition may occur in an oversaturated layer with a high particle concentration close to the surface. The goals of this study are to (i) propose a parametrization for sublimation of drifting snow in the saltation layer and (ii) evaluate two parametrization options using LES simulations as a reference. The simulations reproduce four situations with different weather conditions measured at the Syowa and Davis Stations, Antarctica. We focus on a suitable parametrization of air temperature, humidity, and sublimation, not yet the representation of the drifting snow concentration. We implement our parametrization in a simple one-dimensional (1D) model that is inspired by the large-scale model CRYOWRF and can be compared to the LES simulations. The 1D model computes temperature and specific humidity at ten vertical levels between the surface and a height of 9 m, of which six levels are in the lowest 0.1 m. The first option uses a prognostic solver at all levels, accounting for turbulent transport and the exchange of moisture and heat between snow particles and the atmosphere. The second, simpler option, uses Monin-Obukhov bulk formulas to estimate the profiles below a height of 2.25 m. The concentrations of drifting and blowing snow are taken from the LES simulations and assumed to remain constant in time. The parametrization computes sublimation of drifting snow using the common formula of Thorpe and Mason (1966). On the contrary, the LES model applies a more accurate approach based on the transient mass and heat balance equations for Lagrangian particles. Only the lowest 9 m of the LES domain (38 x 19 x 18 m^3) are used for comparison with the 1D model to limit undesirable effects of the Neumann upper boundary conditions. The prognostic parametrization option yields satisfactory results, while the bulk formulas can lead to a significant bias. We show how the 1D model performs in different weather conditions and discuss the benefits and remaining challenges of the parametrization.