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Response of Greenland and Antarctic Ice Sheet to cloud radiative forcing

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The role of clouds on the surface mass balance of ice sheets remains a point of debate as there is no scientific consensus on the role of the cloud radiative effect (CRE) on the two major ice sheets. For the Greenland Ice Sheet, for example, conflicting studies argue either that clouds reduce surface melt through their radiative effect by blocking short-wave radiation (cloud cooling) or enhance surface melt by reducing meltwater refreezing (cloud warming). For the Antarctic Ice Sheet, on the other hand, the impact of the CRE effects on the ice sheet remain poorly quantified, although it can play a major role on the melt processes on ice shelves.

To assess the impact of the CRE on surface snow and firn conditions on both ice sheets, simulations have been performed with SNOWPACK, a physically-based snow model forced with and without cloud radiative forcing. For this purpose, a state-of-the-art hybrid dataset has been created to represent the cloud forcing on the surface mass balance. This hybrid data set is a combination of CloudSat-CALIPSO satellite observations and data from the regional climate model, $RACMO_2.3$. The combination of both data sets results in an observation-based forcing dataset with higher temporal resolution than the satellite observations can provide. Simulations are performed such that the response of the firn can be separated in a short-term and long-term component.

Results show that the seasonal variation of the CRE is positive throughout the year, which implies a net cloud warming. Additionally, the simulations highlight that cloud cooling and cloud warming occur on different time scales: the first being a more direct, short-term effect and the latter having a long-term effect by initiating a feedback response that changes firn conditions. The long-term response of the firn to the CRE is shown to be dominant in summer, enhancing meltwater production and runoff by initializing a melt-albedo feedback.

The long-term CRE impact on firn conditions during the melt season highlights the importance of the (initial) firn conditions when performing cloud radiation studies. It calls for the need of either detailed information of the firn surface layers or the inclusion of a snow-model that can accurately model firn response in such studies.