Spatial distribution of crusts in Antarctic and Greenland snowpack and implications for snow and firn studies

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Abstract

The occurrence of snowpack features has been used in the past to classify environmental regimes on the polar ice sheets. Among these features are thin crusts with low porosity, which contribute to firn stratigraphy and can have significant impact on the firn ventilation as well as on remotely inferred properties like accumulation rate or surface mass balance. The importance of crusts in polar snowpack has been acknowledged, but nonetheless no large scale statistics on their distribution is available.
From snow profiles measured by means of microfocus X-ray computer tomography we created a unique dataset showing the spatial distribution of crusts in snow on the East Antarctic Plateau as well as in northern Greenland including a measure for their local variability. With this method, we are able to find also weak and oblique crusts, to measure the high-resolution density and count their frequency of occurrence.
Crusts are a local feature with a small spatial extent in the range of tens of meters, but from several profiles per sampling site we are able to show a decreasing number of crusts in surface snow along a traverse on the East Antarctic Plateau. Combining samples from Antarctica and Greenland with a wide range of annual accumulation rate, we find a positive correlation between accumulation rate and crusts per annual layer in surface snow. By also counting crusts in two Antarctic firn cores, we can show the preservation of crusts with depth and discuss their temporal variability as well as the sensitivity to the accumulation rate.
We find a postdepositional influence of crusts on firn stratigraphy due to the formation of high-porosity layers below them. In local applications we test the robustness of crusts as a temporal proxy in comparison to chemical records like impurities or stable water isotopes. While in regions with high accumulation rates crusts show signs of seasonality, in low accumulation areas dating of the snowpack should be done using a combination of volumetric and stratigraphic elements. Our findings can bring new insights for the study of firn permeability, improving of remote sensing signals or development of new proxies in snow and firn core research.