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Extreme metamorphism in a firn core from the Allan Hills, Antarctica, as an analogue for glacial conditions

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Understanding processes in near-zero accumulation areas can help to better understand the ranges of isotopic composition in ice cores, particularly during ice ages, when accumulation rates were lower than today. Snow metamorphism is a primary driver of the transition from snow to ice and can be accompanied by altered isotopic compositions and chemical species concentration. High degree snow metamorphism, which results in major structural changes, is little-studied but has been identified in certain places in Antarctica. Here we report on a 5–m firn core collected adjacent to a blue-ice field in the Allan Hills, Antarctica. We determined the physical properties of the snow using computer tomography (microCT) and measured the isotopic composition of δD and δ^{18}O, as well as ^{210}Pb activity. The core shows a high degree of snow metamorphism and an exponential decrease in specific surface area (SSA), but no clear densification, with depth. The micro-CT measurements show a homogenous and stable structure throughout the entire core, with obvious erosion features in the near-surface, where high-resolution data is available. The observed firn structure is likely caused by a combination of unique depositional and post-depositional processes. The defining depositional process is the impact deposition under high winds and with a high initial density. The defining post-depositional processes are a) increased moisture transport due to forced ventilation and high winds and b) decades of temperature-gradient driven metamorphic growth in the near surface due to prolonged exposure to seasonal temperature cycling. Both post–processes are enhanced in low accumulation regions where snow stays close to surface for a long time. We observe an irregular signal in δD and δ^{18}O that does not follow the stratigraphic sequence. The isotopic signal is likely caused by the same post-depositional processes that are responsible for the firn structure, and that are driven by local climate. Mechanical processes such as scouring and spatial distribution of snow by wind are also likely to affect the isotope content. We use ^{210}Pb activity to date the core, but find no signal below 0.3 m. The lack of any ^{210}Pb activity implies that most of the snow is older than 100 years.