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Examining the strength of the link between surface temperature and surface mass balance in ice cores and models over the last centuries in Antarctica

Marie G. P. Cavitte[1], Quentin Dalaiden[1], Hugues Goosse[1], Jan T.M. Lenaerts[2], and Elizabeth R. Thomas[3]
[1]Université catholique de Louvain, Georges Lemaître Centre for Earth and Climate Research, Louvain-La-Neuve, Belgium (marie.cavitte@uclouvain.be)
[2]Department of Atmospheric and Oceanic Sciences, University of Colorado Boulder, Boulder CO, USA
[3]British Antarctic Survey, Madingley Road, Cambridge, CB3 0ET, UK

Ice cores constitute an important record of the past surface mass balance (SMB) of the ice sheets, with SMB ultimately modulating the ice sheets' sea level impact. For the Antarctic Ice Sheet (AIS), SMB is dominated by snow accumulation and strongly controlled by atmospheric circulation. Large-scale atmospheric depressions collect warmth and moisture from further north that they then release over the AIS in the form of widespread accumulation or focused atmospheric rivers. This implies that snow deposited at the surface of the AIS should show strongly coupled SMB and surface air temperatures (SAT) variations. Ice cores do not record SAT directly but their $d^{18}O$ record is often used as a temperature proxy.

Here, using the PAGES 2k Network ice core compilations of SMB and $d^{18}O$ of Thomas et al. (2017) and Stenni et al. (2017), we obtain a weak correlation between SMB and $d^{18}O$ over historical timescales, and an equivalently weak correlation between SMB and SAT based on the Nicolas & Bromwich (2014) SAT reconstructions. However, we calculate a strong and positive SMB-SAT correlation in the majority of regions of the AIS using Global Climate Models (GCM) and the regional model RACMO2.3p2.

To resolve the discrepancy between measured and modeled signals, we show that averaging the ice core records in close spatial proximity increases their SMB-SAT correlation. This increase in measured SMB-SAT correlation likely results from noise present in the ice core records, but is not enough to match the strong correlation calculated in the models. On the model side, the high spatial resolution of the RACMO2.3p2 model allows us to highlight a number of areas of the AIS where SMB and SAT are not strongly correlated. We describe how wind-driven processes acting on the SMB and SAT locally, through Foehn and katabatic effects, can overwhelm the large-scale atmospheric input that induces the positive SMB-SAT correlations. In particular, we focus on

Dronning Maud Land, East Antarctica, where each ice promontory clearly shows this wind-driven snow redistribution. Nevertheless, those regions displaying a low SMB-SAT correlation cover only a small fraction of the AIS and are not sufficient to explain the model-data discrepancy, suggesting a critical role of processes at a scale smaller than the one resolved by the regional model.

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