Abstract ID : **102**

Insolation sensitivity tests on near-surface snow properties: towards a constraint for the mechanisms of elemental fractionation during pore close-off in polar firn

Content

Processes controlling pore closure are broadly understood yet defining the physical mechanisms controlling elemental fractionation remains ambiguous. Ice core $\delta O_2/N_2$ records, used as a dating tool, are a proxy for local summer solstice insolation. It is understood that $\delta O_2/N_2$ - reflecting the amount of O_2 that escaped from the air bubbles during the pore closure process - is controlled by the firn microstructural properties and the duration of pore-closure. The relationship between local insolation and $\delta O_2/N_2$ is believed to be linked to near-surface snow metamorphism driven by changes in temperature and temperature gradients, but the mechanisms are yet to be definitively identified.
Using the Crocus snowpack model, we carry out sensitivity tests to identify the effect of change in insolation on microstructural properties of the near-surface snow. The sensitivity tests are setup using snow density and optical radius data from Dome C to initialise the snowpack and then forcing the model with ERA5 reanalysis data. Keeping all other variables constant, the incoming shortwave radiation is modified to represent the range of summer solstice insolation values over the past 800 kyr. Sensitivity analysis of the model outputs allows us to quantify the effect of insolation on density, grain properties, and stratification near the surface. This effect can then be implemented into firn models to improve predictions of pore-closure depths, and to better constrain firn air transportation. To support the modelling effort, we have compiled $\delta O_2/N_2$ records from several polar ice cores and found that the mean and variability varies between sites. We therefore compare Crocus model outputs for two Antarctic sites, South Pole and Dome C, where mean $\delta O_2/N_2$ differs by ~3 ‰, to test the sensitivity of snow properties to local insolation and accumulation rate inputs.

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Track Classification: Progress in proxy development and interpretation