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A new look at calibration of densification models for dry firn

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(1) Most dry-firn densification models are based on the Robin hypothesis, i.e. fractional porosity decreases in proportion to added overburden load. This is inherently a steady-state assumption. Most models are also calibrated empirically using current depth-density profiles, and site accumulation rate A and temperature T. However, depth-density profiles have developed in response to changing climate A and T over the age of the firn column, i.e. past centuries or millennia. Directly measuring compaction rate in real time with vertical strain meters or ApRES (Autonomous phase-sensitive Radio-Echo Sounding) provides an additional data constraint on model calibrations, and reduces the need to assume steady state over the full age of the firn column. We introduce initial results testing models with data from site USP50, which is 50 km upstream from South Pole. Measurements completed or in progress include depth profiles of strain rate and temperature for 2 years; depth-age; impurities; density, which provides an overburden-load profile; and micro-CT scans, which show evolution of microstructure.
(2) A and T are widely recognized to be the primary climate factors controlling firn density; however, since A and T are often correlated through saturation vapor pressure, separating their individual contributions to compaction rate can also be problematic. Comparing sites where A and T do not co-vary provides an opportunity to disentangle those coupled influences. Taylor Dome offers one such opportunity for future measurements; A varies from 25 cm/yr to less than 2 cm/yr along a 20 km transect, while T deviates from -40 C by $\sim$1 deg C or less.
Sites with an accumulation rate A that can be found on Taylor Dome, but with significantly different T, can also be identified. At USP50, A=8 cm/yr, but T is 10 deg C colder. We have also identified a site at Siple Dome with A=8 cm/yr, and T that is 20 deg C warmer. If Taylor Dome and Siple Dome can be sampled in future, those sites together with USP50 would allow the impact of T alone to be measured over a range of 30 deg C.
(3) Finally, firn densification depends on distributions of microstructural properties such as grain size, grain-to-grain bond areas, and coordination numbers. MicroCT measurements on dated cores can allow evolution equations for those controlling microstructure properties to be calibrated, and new physics-based models to be developed. (e.g., see B. Horlings et al., this session.)