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Identifying viscosities implicit in current firn-densification models: a step toward a physical-process-based constitutive relation for firn

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Firn densification rate determines the age of air in bubbles in ice cores, and is a primary uncertainty in conversion of volume changes to mass changes for altimetry surveys of the polar ice sheets. However, most current firn models are empirically tuned to local temperature and accumulation rate because not all physical processes that affect firn densification at the grain scale are adequately understood or measured. With generally fewer tunable parameters than active physical processes, impacts of such missing processes have instead typically been lumped together. As the next step toward developing a microphysical-process-based constitutive relation for firn, effective viscosity is used as the constitutive parameter in eight firn-densification models. Effective viscosity is implicitly identified in each model, and is dependent on factors such as stress, strain rate, temperature, and grain-growth processes. The models are forced with temperature and accumulation rate to find the effective viscosities. Preliminary results indicate that there are major qualitative differences in some of the models' viscosity definitions, which indicate discrepancies in implicit descriptions of physical processes. Such differences include discontinuous viscosity at the zone 1-2 boundary (at density of 550 $kg\ m^{-3}$), and discrepant viscosity trends that potentially indicate lumping of multiple processes. Each firn model describes densification uniquely, and these results confirm that processes are either oversimplified in different ways or are missing in the definitions. Future work will involve developing a viscosity function based explicitly on multiple processes which will help to prioritize future field measurements and lab studies.