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Firn compaction modelling of the Antarctic ice sheet

Bianca Kallenberg and Paul Tregoning
Australian National University, Research School of Earth Sciences, Canberra, Australia (bianca.kallenberg@anu.edu.au)

Satellite altimetry missions detect elevation changes in ice sheets that are not only related to variations in ice mass balance, but also to snow densification. The compaction of snow induces a change in thickness but not in mass and therefore has to be removed from the altimetry measurements when estimating mass loss from height changes.
The densification of snow is time dependent and varies with temperature, accumulation rate and depth. Different types of densification processes occur in Antarctica due to the climatic differences from warm and moist coastal areas to a cold and dry desert in the Antarctic interior. The intermediate product between snow and ice is called firn and the transition from snow to ice is a slow process that can take up to millennia in some areas. During the compression snow grains undergo different stages with a density change from around 300 kg/m3 for fresh snow to around 900 kg/m3 for glacier ice. The change in density with temperature and depth is not well known and can only be compared with some snow pits that have been taken at a few locations in Antarctica, thus the density profile is of great importance. The lack of data complicates the generation of an accurate firn compaction model and so far only a few models have been established about expected firn densification processes in Antarctica.

We present a time-dependent firn compaction model for Antarctica based on the standard heat-transfer equation after Paterson (1994)* for the temperature profile, and the concept of firn compaction after Zwally & Li (2002)*.
By incorporating a time-dependent accumulation rate, our numerical multilayer model considers not only existing snow layers but also freshly deposited accumulation at the surface as a new introduced layer. The initial density profile as been obtained by spinning up the model until the entire firn layer is refreshed. We compare our results with previous firn compaction models and available in-situ measurements of snow pits.

*Paterson, W.S.B. (1994). “ The physics of glacier”, 3 Edn., Pergamon
*Zwally, H.J. and Li, Jun (2002). "Seasonal and interannual variations of firn densification and ice [U+2010] sheet surface elevation at the Greenland summit." Journal of Glaciology 48(161): 199-207.