Accounting for the layering of snow and firn

On the link between density and grain size variability

micro snow

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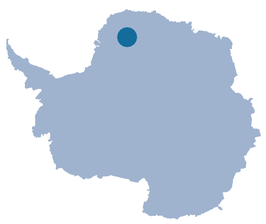
Introduction

- microwave (MW) interaction with dry polar firn is influenced by the variability of firn density and grain size
- due to the integration of MW measurements over firn depths of several meters, the effect of layering can be significant
- in the retrieval of geophysical parameters from MW data in the polar regions, the variability due to layering is often unconsidered or treated as a stochastic process
- in this study, we examine the connection between density and grain size variability to improve the representation of firn layering and examine the impact on the modeled MW signal

The B36 test site



- B36 is a firn core drilled to ~80 m depth at Kohnen Station, Antarctica
- the mean annual temperature is -44.6°C, the accumulation rate is 0.065 m w.e./year

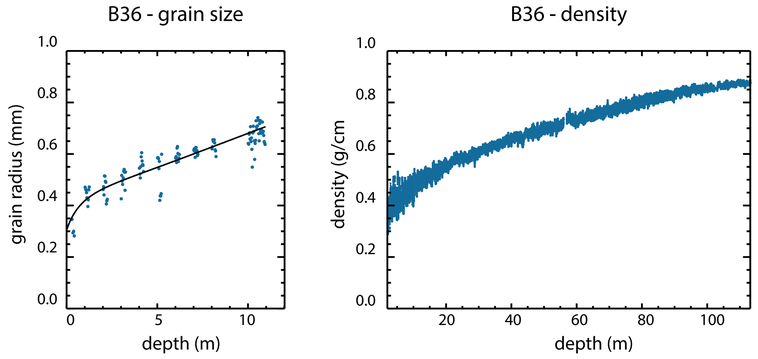


Figure 1: Measured grain size (Computer Tomography) and measured high-resolution density (Gamma-absorption)

Parametrization of grain size variability

- density variability in polar firn is connected to grain size variability via the snow metamorphism process
- we use density and grain size from CT measurements from 5 antarctic sites to parametrize grain size variability as a function of density variability
- this allows us to reconstruct grain size using
  1. modeled mean grain size based on annual mean temperature and accumulation rate
  2. grain size variability derived from density measurements

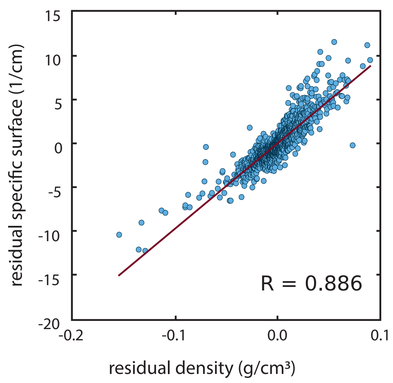


Figure 2: Measured residual specific surface vs. measured residual density (Computer Tomography) of 5 antarctic sites with regression line, correlation coefficient = 0.886

- strong linear relationship between residual (detrended) specific surface and residual density of the analyzed firn cores
- reconstructed specific surface variability based on density measurements

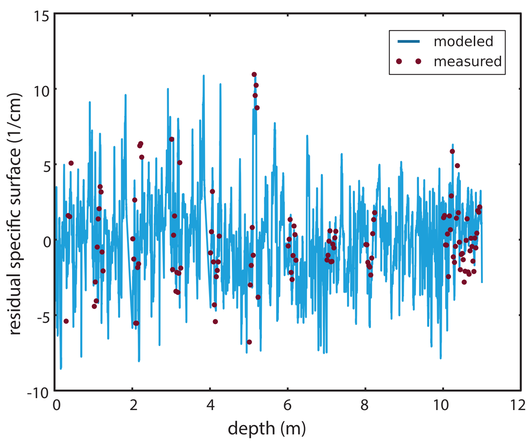
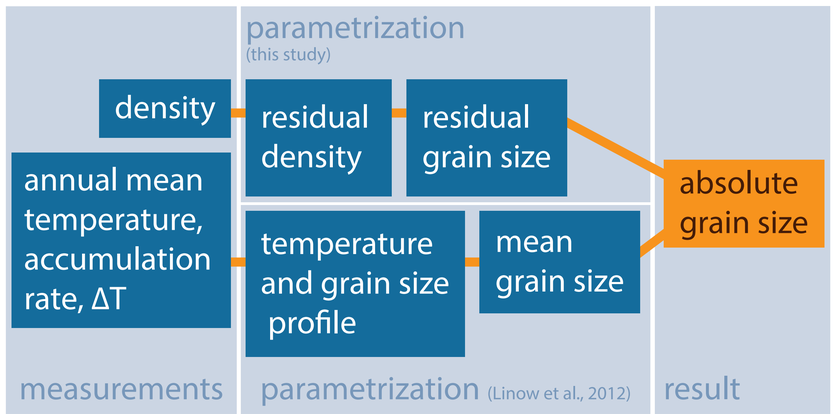


Figure 3: Measured (red dots, CT) and modelled (blue line, from high-resolution density data) residual specific surface over depth



Sensitivity of the MW signal to variability

- we examine the influence of microstructure variability on the MW signal under different assumptions:
  1. mean profile
  2. mean profile + random noise
  3. parametrization of variability
- we use microwave data from AMSR-E and SSM/I to analyse the influence of layering on the microwave signal
- models: MEMLS and DMRT/ML

Results (B36)

- MEMLS:

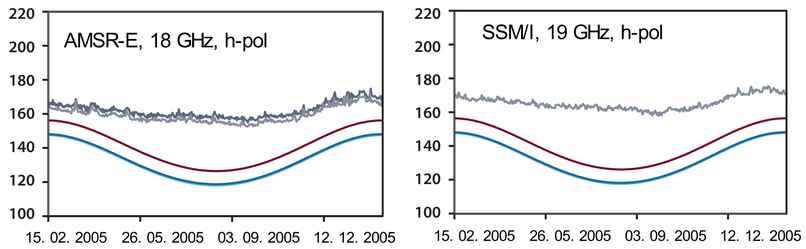


Figure 5: Measured brightness temperatures of different channels compared to model runs (MEMLS)

- DMRT-ML:

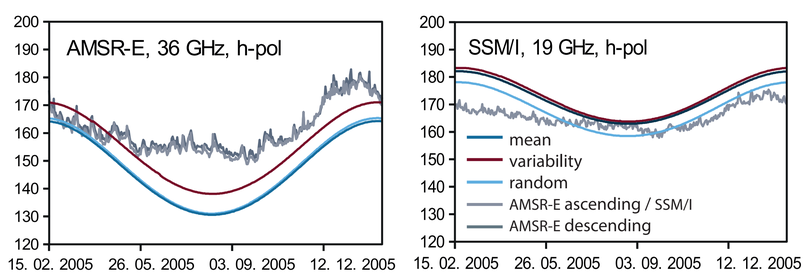


Figure 6: Measured brightness temperatures of different channels compared to model runs (DMRT-ML)

- bias = $[\Sigma(T_{B,modeled} - T_{B,satellite})^2 / n]^{0.5}$ depends on the profile type, for DMRT-ML also on frequency

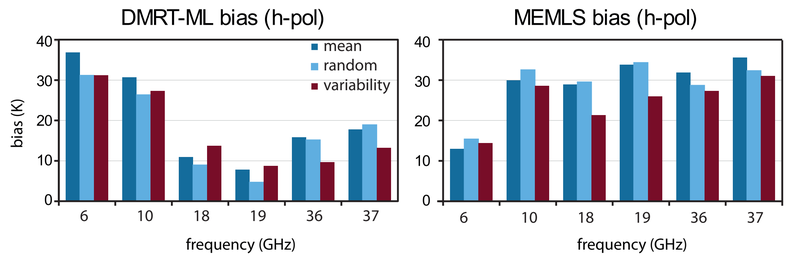


Figure 7: Comparison of the bias between modelled and measured brightness temperatures for different firn profile types

Conclusions

- we can show that grain size variability is coupled to density variability, and are able to reconstruct grain size from measured density profiles
- first sensitivity studies with MW models show improved results when a realistic variability is used
- future studies will extend this analysis

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