Talking about grain size (in different languages)

Maria W. Hörhold¹, Stefanie Linow²

¹Institute for Environmental Physics, University of Bremen, m_hoerhold@iup.physik.uni-bremen.de
²Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, stefanie.linow@awi.de

...in the field

- on the ground: an ice matrix with an ice phase which is continuously increasing in size and connectivity, and which shows a distinct anisotropy
- at different sites in Antarctica: grain size depends on wind, temperature, accumulation rate; very different age scales result in different microstructure

...from space

- in satellite images: different backscatter ($\sigma^0$) or brightness temperature ($T_B$) signatures, depending on liquid water content and firn microstructure
- at different sites in Antarctica: grain sizes depend on climatological conditions

How can we describe grain size?

...in the field / lab

From 3D Image Analysis (Computer Tomography):
- ice in air matrix (close to the surface), air in ice matrix (larger depths)

Snow grains can be described using:
- mean chord length in different directions
- surface area per volume
- specific surface (SSA)
- curvature as measure of elongation / roundness
- Euler number as measure of connectivity

...in models

As input for radiative transfer models:
- spheres of different size, depending on depth / age and temperature conditions at different sites
- homogeneous layers of scatterers
- ice in air (close to the surface), air in ice (larger depths)

Grain growth with depth / age:
- Arrhenius-type growth parametrization, but growth rates and initial radii are often not well-defined

Conclusions

Common grain size definition:
- snow and firn can be represented by the effective radius $R_{\text{eff}}$
- $R_{\text{eff}}$ is calculated from the SSA
- the SSA is easy to measure in the field and lab by different methods; this allows a comparison with different data sets

Application of $R_{\text{eff}}$:
- parametrization of grain growth → improved microstructure model as input for radiative transfer models

Outlook:
- SSA and $R_{\text{eff}}$ can be used to derive correlation length (application in microwave scattering / emission models)

References

Armbruste, J. & Sych, T., MAVI - Modular algorithms for volume images, Fraunhofer Institut für Techno- und Wirtschaftsmathematik, Kaiserslautern, 2005
Paterson, W. Physics of Glaciers Butterworth-Heinemann, 1994
Zwally, H. & Li, J. Seasonal and interannual variations of firn densification and ice-sheet surface elevation at the Greenland summit, Journal of Glaciology, 2002, 48, 199-207

Envisat ASAR image, example from Dronning Maud Land, Antarctica

Multilayer configuration of polar firn for radiative transfer modeling

SSA and $R_{\text{eff}}$ comparison

Problem: different measurement techniques and grain size definitions

Our solution: using the effective radius $R_{\text{eff}}$

The effective radius $R_{\text{eff}}$

- measurements of two independent parameters (SSA and chord length) at six different polar sites
- clear relationship between measured chord length, radius of a sphere with similar surface area and measured SSA:
  - $R_{\text{sphere}} = \sqrt[3]{\frac{6}{\text{SSA}_\text{sphere}}} \cdot \rho_{\text{ice}}$
  - $\text{SSA}_\text{sphere} = \frac{9}{4} \cdot l_{\text{sphere}} \cdot \rho$

Application of $R_{\text{eff}}$

- from measured grain sizes, a simple parametrization of grain size is developed:
  - grain sizes at the surface depend on temperature and accumulation rate

Result of parametrization (solid line) and measured grain radii (dots)