Anisotropic radar reflections in ice-sheets: Potential mechanisms and implications

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Introduction

Polarimetric ice-penetrating radar measurements aim to retain anisotropic features from within the ice. Recent studies ([1], [2]) in Antarctica showed that especially in deeper ice, the formation of flow induced aligned crystal orientation fabric (COF) can be a main mechanism for a polarization-dependent response in the radar data. As aligned crystal significantly alters the flow behavior of ice, this is an important implication for ice-sheet modeling. In this study we also investigate the effect of anisotropic inclusions (e.g. air bubbles) which may act as strain markers within the ice.

Observation

Circular radar profile (airplane on the ground)

(1a): Backscattered power of circular radar profile shown in (1c); (1b), (1e): The sinusoidal pattern exhibits a 180°-symmetry. In the upper 400 – 900 m (~5-10μs TWT) it is maximal in the direction of minimal surface strain. From 900 m down to ~1300 m (~15μs TWT) the pattern shifts by 90°; (c) the depth averaged attenuation corrected profile shows changes in reflection power of ~3–5 dB. A 45° symmetry pointing to birefringence is not dominating.

Method

We use volume scattering models to estimate both, the effect of deformed air bubbles and varying COF. For the airbubbles we use an adapted model based on the radiative transfer equations [3]. This includes the full angular dependency, varying orientation distributions and first order multiple scattering. For the COF we plan to implement a random medium model for a (non-tilted) biaxial medium (work in progress).

Results and Outlook

The model outcomes with respect to deformed airbubbles reproduce the observed symmetry, but seem small in magnitude. To classify the effect, a comparison with the volume scattering for COF is necessary.

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References

[1]: Eisen et al., Direct evidence for continuous radar reflector originating from changes in crystal-orientation fabric, The Cryosphere, 1, 1-10, 2007
[3]: Tsang et al., Radiative transfer theory for active remote sensing of a layer of small ellipsoidal scatterers, Radio Science, Volume 46, No. 3, 1981