Modeling the spatial variation of ice-sheet radar attenuation

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Knowledge of the spatial variation of ice-sheet attenuation rates is poor but is needed to accurately infer englacial and basal properties from ice-penetrating radar data. Radar-attenuation rates depend on the spatial variation of temperature and soluble impurity concentrations (in Antarctica, primarily acid and sea-salt chloride).

Because temperature and impurity-concentration data are measured only at the surface or in ice cores or boreholes, models of their spatial variation are required to predict attenuation rates in ice sheets. Here we evaluate several methods for modeling the spatial variation of attenuation rates, using an example of their application along a flowline that crosses through the Vostok ice core in East Antarctica. We use radar-layer depths and temperature and velocity outputs from a thermomechanical ice-sheet model to extend impurity-concentration and borehole-temperature data from Vostok along the flowline. The simplest possible model is a uniform, depth-averaged attenuation rate everywhere along the flowline, the next model uses spatially-varying temperatures and uniform impurity concentrations, and subsequent models use radar-layer depths the ice-sheetmodel outputs to also estimate the spatial variation of impurity concentrations, along with spatially-varying temperatures. We find that models that include the spatial variation of temperature can have large differences in roundtrip attenuation (> 10 dB) compared to models that simply use a uniform attenuation-rate field. Models with progressive improvements for modeling the spatial variation of impurity concentrations introduce only small (< 3 dB) changes in the roundtrip attenuation.

This work shows that an attenuation-rate model tied to an ice-core site can be satisfactorily extended spatially using available radar-layer depths and a temperature model.