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Numerical wave propagation through ice-covered regions

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Modelling seismic waves in ice-covered polar regions can be a cumbersome process. The local topographical variations and the thickness of the ice sheet are often small compared to the seismic wavelengths of interest which, due to numerical limitations, often makes waveform modelling in these regions computationally intensive. It is thus of great interest to quantify the importance of the ice sheet and its topography on the recorded wave field and to see whether it is possible to model the wave field in an accurate manner without directly accounting for the ice sheet.

In this study we model wave propagation in NW-Greenland using the spectral-element method. We do this on four separate meshes containing different levels of complexity ranging from no topography to a mesh with a fully implemented ice sheet. By modelling the same earthquake on each mesh and recording the wave field on a grid of receivers, we can recover the effect that each level of complexity (topography and ice sheet implementation) has on the recorded wave field. The misfit between the recorded wave fields can then be measured as a function of frequency, with the fully implemented ice sheet as a reference, estimating when it is safe to ignore the ice sheet while maintaining confidence in the results. The modelled periods of seismic waves were between 11 and 120 s, recorded on receivers with up to 1100 km epicentral distances.

The results show a significant effect of both topography and the direct effect of the ice sheet. Their combined effect results in about 2% difference in phase velocity along the ray path. The misfit due to the ice sheet could be decreased by lengthening the shortest modelled period while the misfit due to the topography remained significant through the period changes. Computational time can be reduced by a factor of 50 with minimal loss in accuracy by replacing the ice sheet with bedrock of equivalent thickness.