3-D modelling of the Fimbul Ice Shelf face: An internal and external geometry perspective

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SUMMARY

This research presents the development of a baseline three-dimensional (3-D) model of the Fimbul Ice Shelf (FIS) geometry, utilizing high-resolution data acquired via Drone-based Ground Penetrating Radar (DGPR). The primary aim was to establish a methodological framework for D-GPR application in a dynamic Antarctic ice shelf environment, ultimately upgrading input variables for current ice sheet models, facilitating accurate four-dimensional (4-D) modelling, and providing enhanced visualisation of ice shelf dynamics. A scoping review confirmed D-GPR as the optimal approach for baseline surveying due to its powerful subsurface scanning, enhanced safety, and fast acquisition times in crevassed terrain. The resulting baseline survey utilized the Zond Aero LF GPR (optimized for 50 MHz antenna operation) flown at a fixed height of 5 m AGL, and at a speed of 4 m/s using Adaptive Bank turns.

The post-processing pipeline incorporated advanced enhancement techniques, validating the effectiveness of the Block-matching and 3-D filtering (BM3D) algorithm for noise reduction while preserving fine layering. A comparative assessment of feature extraction methods demonstrated that conventional techniques, such as the Continuous Wavelet Transform (CWT) and the Hough Transform, were inadequate for the fine-scale, high-density layering present in the D-GPR data. This necessitated the development of novel feature extraction concepts (Horizontal Layer Extraction and Basal Crevasse Tip Extraction) which successfully converted features into georeferenced *.las point clouds. The extracted features were integrated into a final 3-D model, enabling the accurate visualization of basal crevasse geometry. The model revealed that basal crevasses near the T-intersection had propagated through 81% of the ice shelf thickness, reaching a peak propagation of 89% in the Western grid area. These measurements quantify the serious risk posed by the high penetration percentage of the basal crevasses. Final discussion identified crucial lessons for future expeditions, emphasizing that sub-centimetre accuracy required for robust 4-D analysis must incorporate angular bias corrections (pitch, roll, and heading) and implement the Time-Depth Conversion (via Kovacs formula) to account for non-constant velocity profiles across the variable snow, firn, and ice layers. This research establishes a vital D-GPR methodological baseline for the long-term monitoring and understanding of ice shelf stability.