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Optimising common-midpoint surveys for estimation of ice and soil moisture

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Acquisition of ground penetrating radar (GPR) common mid-point (CMP) gathers is time-consuming, but necessary because interpretation of CMP data provides subsurface velocity:depth model. The accuracy of this model is particularly important when velocities are to be used to infer subsurface physical properties such as water content. We therefore investigate the smallest range of source-receiver offset, x, (relative to depth, z) that delivers adequately-resolved velocity and zero-offset two-way time, such that an accurate velocity:depth model may be picked. We use a synthetic CMP gather, with offset range = 0-50m, for reflections at 5-25m depths in a 0.1m/ns velocity overburden. The synthetic GPR pulse is a mixed-phase 50MHz Berlage wavelet. A semblance-based velocity anlaysis was applied to subsets of synthetic data, with resolution judged by the width of semblance peaks in both velocity and time. Temporal resolution is controlled by inclusion of sufficient near-offset traces, and velocity resolution by far-offset traces. Negligible improvement in resolution of either variable was found for minimum offset $<$ (x / z) = 1.5, and maximum offset $>$ (x / z) = 2.5. Consequences of using a mixed phase wavelet are evident: the highest semblance response is associated with the high-amplitude 2nd lobe of the GPR wavelet. The velocity-time pair picked from the semblance plot is therefore ideal for imaging, but is systematically biased relative to true subsurface values; those values would be derived from first break times, which are not expressed in the semblance unless the wavelet is zero-phased. Bias in velocity leads to over-estimates in subsurface water content. For the glaciological case, if a GPR wavelet propagates in dry and wet ice at 0.168 m/ns and 0.145 m/ns respectively, the error in the estimate of water fraction may be as much as 15%, if the chosen zero-offset time is delayed by 20 ns with respect to the first break.