Geophysical Research Abstracts, Vol. 8, 09552, 2006
SRef-ID: 1607-7962/gra/EGU06-A-09552
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Measurements of snow water equivalent using multiple-offset ground-penetrating radar

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Ground-penetrating radar (GPR) measurements of snow water equivalent depend on accurate information of the radar wave propagation velocity in the snow cover, as well as on the relationship between the dielectric constant and snow density. This paper evaluates a simplified procedure to derive snow water equivalent from GPR travel time data only, using multiple-offset GPR antennas arranged in an array. The dielectric constant and the depth of the snow cover are determined by multi-channel measurements using several combinations of transmitter and receiver antennas in the array, based on basic common-mid-point principles. This set-up enables continuous determination of both snow cover depth and snow density along the measurement profile, which reduces the uncertainties due to spatial variation of snow density. The measurement system is evaluated using manual snow depth and snow density measurements at two sites in northern Sweden during winter 2004/2005. Results show that the spatial variation of both snow depth and snow density were improved with the multi-offset measurements compared to the use of a single channel measurement.