

## **Long-term observations of snow spatial distributions at Hellstugubreen and Gråsubreen, Norway: An investigation in winter balance, time stability, probing reliability, and reduced survey designs**

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Snow accumulation is the most spatially heterogeneous component of glacier mass balance calculations, yet it exhibits robust time stability in spatial distributions. This investigation examines the characteristics of time stability, the reliability and representativeness of snow probing locations, and the scope for reducing the snow measurement surveys at two glaciers. The Norwegian Water Resources and Energy Directorate's (NVE) long-term snow distribution archives at Hellstugubreen and Gråsubreen cover 48 and 44 years respectively, and provide a unique opportunity to investigate snow distributions on two proximate glaciers, allowing inter-comparisons. Throughout, data years are categorised into quarters, thus exposing variable snow spatial distribution patterns relative to overall precipitation levels.

Stability maps and statistics are computed on a cell-by-cell basis on a 30 m x 30 m grid. Results find strong spatial heterogeneity in snow distributions, and increasing time stability with snow levels at both glaciers. Good time stability is also found at low precipitation levels at Gråsubreen. Overall, Hellstugubreen is more time stable than Gråsubreen. Reliability maps of representative probing locations are used to reduce survey designs, allowing resampling and reconstructions of winter balances. One index site for glacier-wide winter balance and one probing location per 50 m elevation interval are used. These calculations are done for all compiled data years, or combined quarters of data years based on the winter balances.

Winter balance reconstructions produce records within <0.10 m w.e. and <0.15 m w.e. of official winter balances at Hellstugubreen and Gråsubreen. Mean percentage errors are <6.2 % and <13.7 % respectively. The most accurate winter balance reconstructions use one probing per 50 m elevation interval, and quartered data years. Using centreline only probings underestimates winter balance, most dramatically at Hellstugubreen. Several strongly irregular snow spatial distribution years are found, creating inconsistent results. These years are considered to be affected by localised irregular wind conditions.