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Geodetic glacier mass balance and its uncertainty based on a spatial statistical analysis: application to the Western Svartisen ice cap, Norway

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Geodetic mass balance results can deviate significantly from field based measurements. To determine if such differences are real or methodological there is a need to improve uncertainty estimates of the elevation differences derived using geodetic methods. Though such uncertainty estimates are often made at individual points in space it is most useful to provide uncertainty estimates for spatially averaged areas, e.g. drainage basins, for which data may be spatially correlated. This paper describes a methodology that takes into account the spatial auto-correlation of the elevation differences when calculating spatial averages. The methodology is applied to the Western Svartisen ice cap in Norway. A spatial statistical assessment is made of the photogrammetrical bedrock elevations surrounding the glacier and this is further applied to indicate the uncertainty in the elevation differences of the glacier surface. It is shown that the spatially averaged uncertainty is not only dependent on the standard error of individual elevation differences but it also depends strongly on the size of the averaging area and the scale of the spatial auto-correlation. To further assess the validity of the method when applying bedrock statistics to glacier surfaces, concurrent photogrammetrical and laser scanning data for bedrock and a range of glacier surfaces are used to evaluate the dependency of the spatial statistics on the surface type. We conclude that the elevation error and uncertainty assessment determined from bedrock statistics can, in this case, also be applied to glacier surfaces of the sizes of the Svartisen drainage basins. The geodetic mass balance, and its uncertainty, for Western Svartisen was determined to be -2.6$\pm$0.8 m w.e. for the period 1968 to 1985, and -2.0$\pm$1.6 m w.e. for the period 1985 to 2002.