Supplement of The Cryosphere, 10, 159–177, 2016
http://www.the-cryosphere.net/10/159/2016/
doi:10.5194/tc-10-159-2016-supplement

Supplement of

Geodetic mass balance record with rigorous uncertainty estimates deduced from aerial photographs and lidar data – Case study from Drangajökull ice cap, NW Iceland

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Supplement

Further details on data gap interpolations

In four cases we adopt other approaches than the ones described in Sect. 2.3, to fill in data gaps. In these cases the approach of working with elevation changes relative to LiDAR DEM was abandoned and instead we worked with incomplete DEMs produced by adding the relative elevation change to the LiDAR DEM. DEMs of the northernmost tip of the ice cap (~1.5% of its area) could not be produced from the 1975 and 1985 photographs. In 1985 it was due to clouds and in 1975 the area was covered with single photographs (without stereoscopic coverage). We could therefore map the 1975 outlines of glacier, which were almost identical to the 1994 outlines in this area. First inspection of our data indicated that the net volume changes in the periods 1975-1985 and 1985-1994 was comparable. We therefore assumed the elevation in both 1975 and 1985 was the same as in 1994 and adopted the 1994 glacier margin for the year 1985 in this area. In the case of the 1985 data an area at the northeast margin of the glacier was also missing due to cloud cover (~2% of the glacier area). A year later this area was photographed and we used these photographs to produce a DEM. It was bias corrected towards the 1985 DEM, using the overlapping area of the 1985 and 1986 DEM. The glacier margin of 1986 was adopted as the glacier margin in 1985 in this area.

The aerial photographs of 1975 did not cover the lowermost part of Leirufjarðarjökull outlet glacier in the northwestern part of the ice cap (Fig. 1c). The front of this outlet surged in the 1990s (Björnsson et al., 2003). The glacier front was therefore at similar location in 2011 as in 1960. The surge makes piecewise linear interpolation constrained with the 1975-2011 elevation change from other parts of Drangajökull, invalid as well as extrapolation of the 1975-2011 elevation change using data from the upper part of Leirufjarðarjökull. We therefore plotted the elevation change from of Leirufjarðarjökull as function of elevation for two periods, which were not affected by surges: The period 1960-1985, for which the whole elevation range of the outlet was covered, and the period 1960-1975, for which the middle and upper part of Leirufjaðarjökull was covered. We derived piecewise linear interpolation of the elevation change as a function of the 1960 elevation for the period 1960-1985 for 100 m elevation intervals. The same was done for the 1960-1975 data for elevation above 500 m a.e. To extrapolate the 1960-1975 piecewise interpolation over the missing part in 1975 we assumed that 2/3 of the lowering for the interval 300-400 m a.e. occurred in the period 1960-1975, supported by the trend in elevation change at other parts of Drangajökull. Having estimated the elevation change at 400 m a.e. and 500 m a.e., linear interpolation was applied in between. For approximating the location of the glacier front in 1975 we used glacier margin digitized from a Landsat image from 1972 (http://earthexplorer.usgs.gov). The bedrock assumed to have appeared at the glacier front in 1960-1975 due to the retreat of the glacier was extracted from the 1994 DEM.

Reference

Björnsson, H., Pálsson, F., Sigurðsson, O. and Flowers. G. E.: Surges of glaciers in Iceland. Annals of Glaciology, 36, 82-90, 2003.

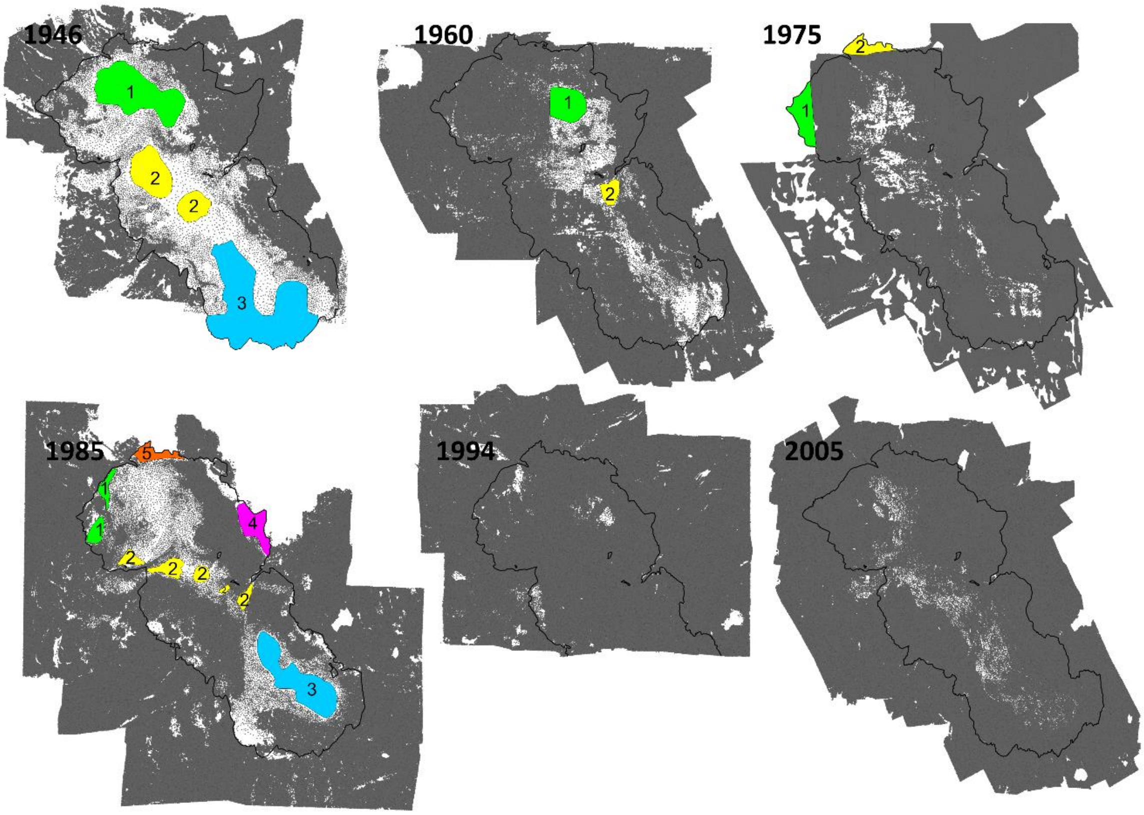

Figure s1. The photogrammetric point clouds coverage. Areas within the glacier but outside the numbered color coded areas were interpolated with kriging interpolation (see Sect. 2.3 for details), while specific data gap interpolation was carried out for the remaining glacier parts (see Sect. 2.3 and the Supplement main text). Patches with same color and number for given DEM are considered as single area in the uncertainty estimate of the interpolated areas (see Sect. 2.7). Patches number 3 in 1946 and 1 and 1975 were assigned the uncertainty ±15 m, patches 1 and 2 in 1946 ±10 m but others ±7.5 m.

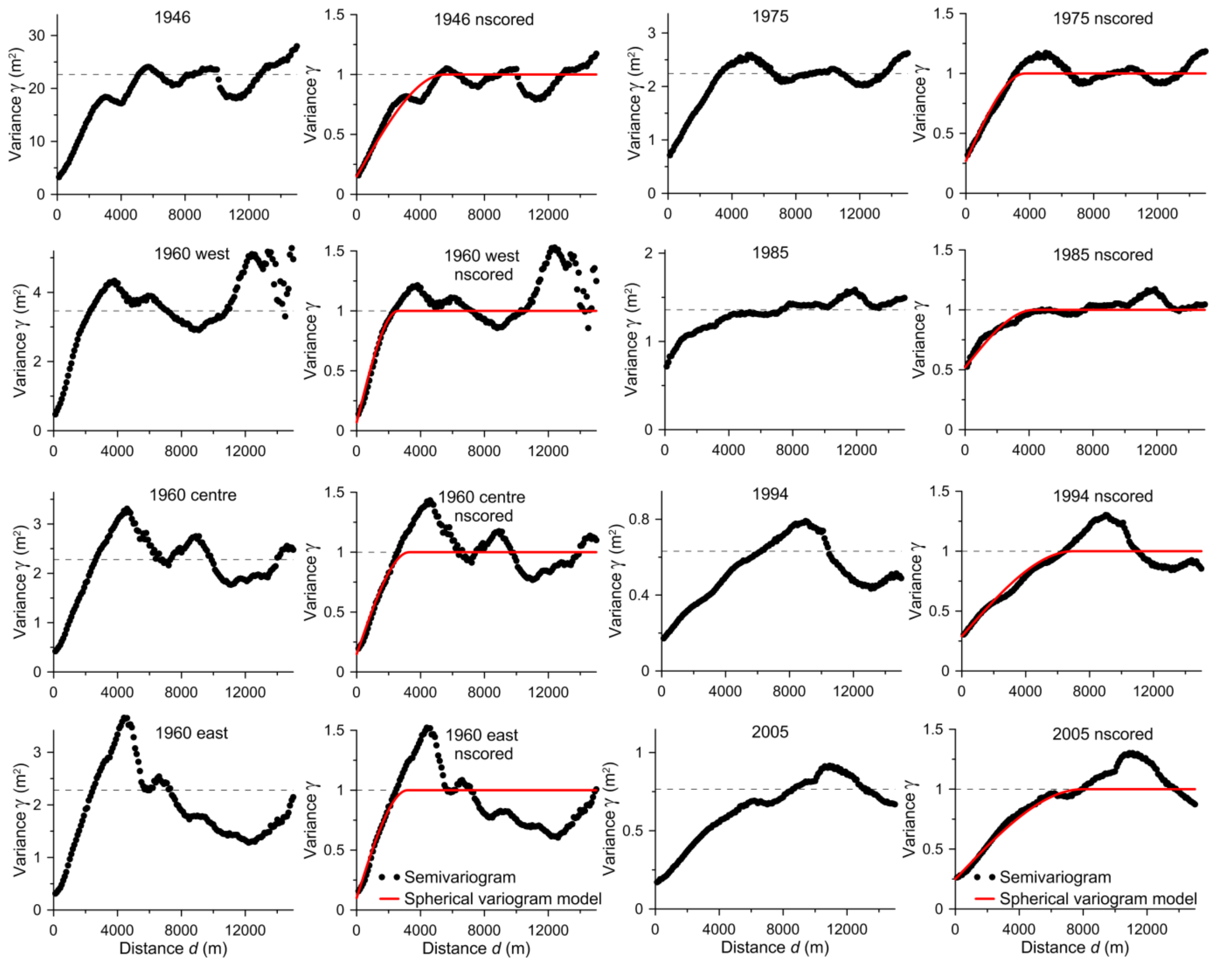

Figure s2. Semivariograms produced for the derived errors in the photogrammetric DEMs (from ice and snow free areas after and outlier and high slope areas were masked out) before and after nscoring the error data (see Sect. 2.2). The graphs with the nscored data also show the derived spherical variogram model (in red) used in the SGSims.