ICE VOLUME CHANGES OF ARIEBREEN, SPITSBERGEN, DURING 1936-1990-2007

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Introduction

Ariebreen (77º 01' N, 15º 29' E) is a small valley glacier (ca. 0.36 km^2 in August 2007) located at Hornsund, Spitsbergen, Svalbard, ca. 2.5 km to the west of Hornsund Polish Polar Station. Many Svalbard glaciers have experienced a significant recession at least since the 1930s, and most likely since the end of Little Ice Age in the early 20th century (Werner, 1993). It has manifested as thinning and retreating of ice fronts, though a simultaneous thickening at the uppermost elevations in many locations has been reported (Bamber et al., 2004; Nuth et al., 2007). Moreover, the thinning rate of western Svalbard glaciers has shown an acceleration during the most recent decades (Kohler et al., 2007).

The main aims of this contribution are to determine whether Ariebreen follows such retreat pattern and to quantify the retreat it has experienced, in terms of area, thickness and volume changes, to estimate the average mass balance equivalent to the ice volume change during the period under investigation, and to estimate the volume of ice presently stored in Ariebreen. The main tools to accomplish this will be the analysis of digital terrain models (DTM) of the glacier surface corresponding to different dates, and the radio-echo sounding of the ice body to determine the present ice volume. The latter is described in a separate contribution to this workshop (Navarro et al., 2008).

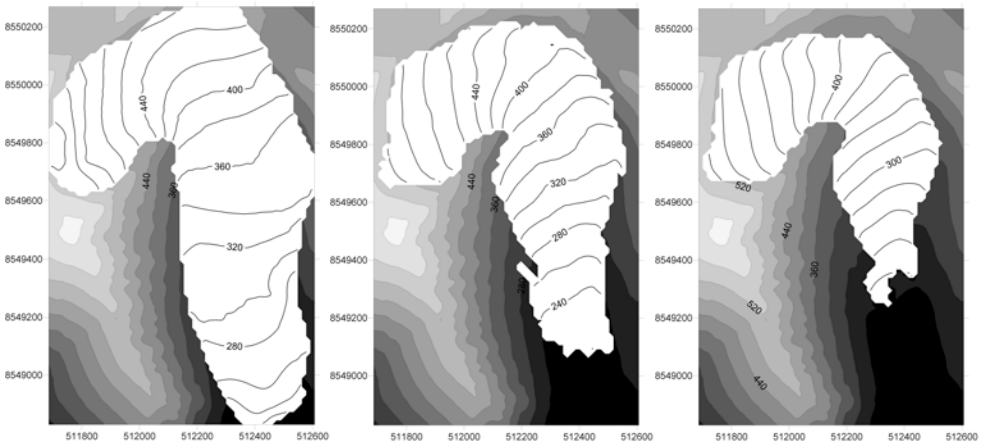

Figure 1. Surface topography of Ariebreen in 1936 (left), 1990 (centre) and 2007 (right).

Construction of DTMs and estimation of ice volume changes 1936-1990-2007 and total volume (2007)

The volume changes 1936-1990 and 1990-2007 were estimated by subtracting the DTMs for the corresponding years, constructed on a common (for each pair) grid 5 m x 5 m. The total volume in 2007 was estimated from the ice thickness map constructed from the radar data.

The DTM for 1936 (Figure 1, left) was constructed from the sheet B12 (Torellbreen, Spitsbergen) of the 1:100 000 Svalbard topographic map (Norsk Polarinstitutt 1953), which is a photogrammetric compilation from aerial photographs taken in 1936. The errors in the DTM for 1936 are the most prominent ones, because of the uncertainties inherent to the original map and the poor coverage of the source data, limited to the glacier boundary and a few contour levels. We have taken as an estimate of the vertical accuracy of the individual data points the value of ±12.49 m for Wedel Jarlberg Land (where Ariebreen is located) obtained by Nuth et al. (2007).

The DTM of the glacier surface in 1990 (Figure 1, centre) was extracted from the DTM of Werenskiold area constructed by Kolondra (2002) from infrared false colour aerial photographs taken in August 1990. The vertical accuracy for the original 1990 DTM was estimated by its author as ±0.5 m. However, for our reconstruction of the glacier surface on the same common grid 5 m x 5 m as 1936 DTM, a standard deviation of ±2.08 m resulted for the interpolation error of the vertical coordinates by kriging.

The DTM of Ariebreen for 2007 (Figure 1, right) was based on our own geodetic measurements made in August 2007 with a Leica TCR-1105 total station. A total of 646 points were measured, of which 192 corresponded to the glacier boundary. The resulting DTM for 2007, with the same regular grid 5 m x 5 m as the 1990 DTM, showed a standard deviation of ±2.42 m for the interpolation error of the vertical coordinates by the kriging method.

The volume changes between any two years were estimated computing, by Simpson's method, the volume resulting from the subtraction of the DTMs for the corresponding years, constructed on a common grid. The total ice volume in 2007 was estimated from the ice thickness map retrieved from the radar data. The ice thickness data were also subtracted from the 2007 glacier surface DTM, constructed on the same grid, in order to determine the subglacial bedrock map. The ice thickness and subglacial relief maps are shown in another contribution to this workshop (see Figure 2 in Navarro et al., 2008).

Results, discussion and conclusions

The area, average ice thickness and ice volume of Ariebreen in 1936, 1990 and 2007, together with their changes during the periods 1936-1990, 1990-2007 and 1936-2007, are shown in tables 1 and 2, while Figure 2 shows the ice thickness changes experienced by the glacier during the mentioned periods.

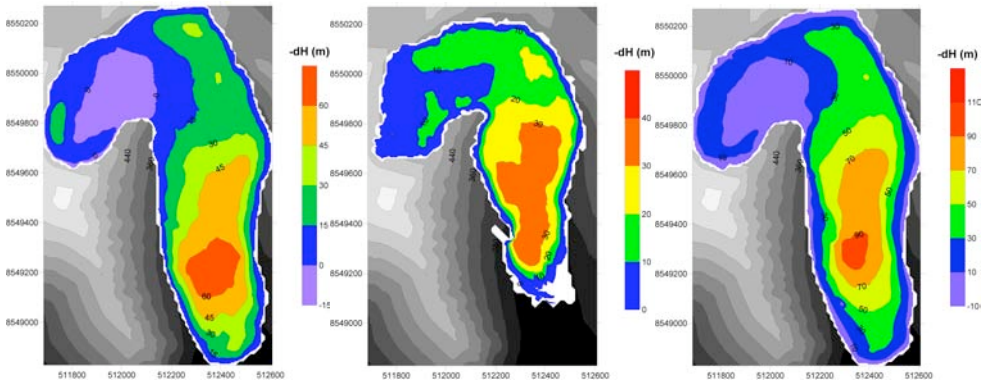

Figure 2. Thickness change of Ariebreen 1936-1990 (left), 1990-2007 (centre) and 1936-2007 (right).

Notice the distinction between the change in average thickness (Table 1) and the average thickness change (Table 2), resulting from the computation over different areas, the latter being that of the start of the period, which is larger and then results a smaller average.

Quite remarkable changes are observed for all parameters in Table 1 and 2. The largest percent change corresponds to the ice volume (that has decreased by 69±29% during the full period analysed), as this figure combines the effects of both changes in area –mainly due to ice front retreat– and changes in ice thickness. The changes in ice volume during the periods 1936-1990, 1990-2007 and 1936-2007 are equivalent to average annual mass balances of –0.44±0.27, –1.00±0.27 and –0.57±0.24 m/y w.e., respectively, computed considering an ice density of 900 kg/m3 and an average area for each period.

Table 1. Glacier area, average ice thickness and ice volume of Ariebreen in 1936, 1990 and 2007, and changes for the periods 1936-1990, 1990-2007 and 1936-2007.

	1936	1990	2007	Change 1936-1990	Change 1990-2007	Change 1936-2007	% Change 2007/1936
Area (km^2)	0.689 ±0.040	0.504 ±0.038	0.363 ±0.009	−0.185 ±0.055	−0.141 ±0.039	−0.325 ±0.041	−53 ± 6
Average thickness (m)	50.22 ±12.83	37.70 ±3.61	22.29 ±1.68	−12.52 ±12.82	−15.41 ±3.98	−27.93 ±12.94	−56 ± 26
Volume (km^3)	0.0346 ±0.0098	0.0190 ±0.0024	0.0108 ±0.0008	−0.0156 ±0.0096	−0.0082 ±0.0022	−0.0238 ±0.0100	−69 ± 29

Table 2. Average thickness change of Ariebreen for the periods 1936-1990, 1990-2007 and 1936-2007.

	1936-1990	1990-2007	1936-2007
Average thickness change (m)	−22.65 ±12.66	−16.22 ±3.19	−34.52 ±12.72

The above data show that Ariebreen has followed the general recession pattern observed in Svalbard, manifested as thinning and retreating of ice fronts, though a simultaneous thickening at the uppermost elevations, an also shows the acceleration in thinning rate observed in western Svalbard glaciers during the most recent decades.

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