# Estimating volumetric loss of Nigardsbreen, 1966-2013, using aerial photos and photogrammetry

**The loss of ice on Nigardsbreen, Norway between 1966 and 2013 has been estimated using photogrammetry on four aerial photographs from 1966 to create a 2 m resolution DEM and coregistering it to a LiDAR DEM from 2013.**

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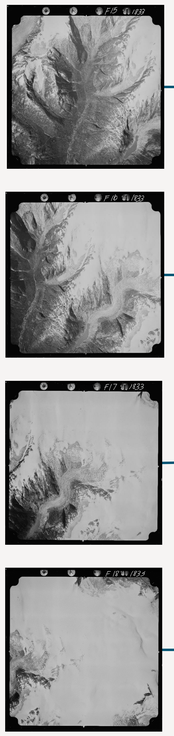
Four aerial photographs of Nigardsbreen from 1966 was used to create a 2 m resolution DEM. The DEM was then coregistered to a 1m resolution LiDAR DEM from 2013. The results show that the mean elevation loss was -9.3 m over the area analyzed and at the glacier terminus the elevation loss has been more than -70 m and the total loss of ice over the period was 11 827 635 m³.

Aerial photographs



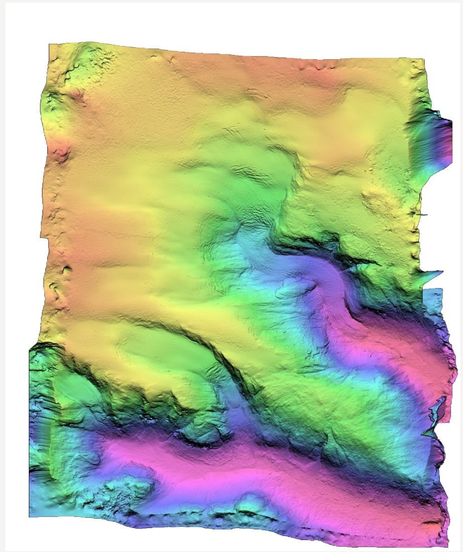
**Inner orientation (lens):**
To correct for distorions produced by the lens the following parameters were adjusted for in PCI Geomatica Orthoengine:
- Focal length
- Radial distortion
- Principal point of symmetry (PPS).
- Principal point of autocollination (PPA).

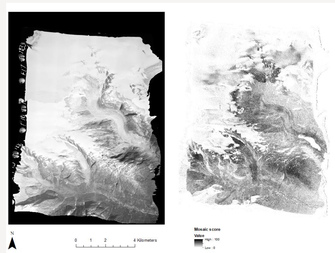
**Relative orientation (overlap):**
To account for the relative overlap between the photos, 10 tie points (TP) collected manually before autocollection of more than 1000 TP's. After autocollection they were refined to filter out TP's with high RMSE. Mean RMSE: 3.

**Exterior orientation (pixel vs ground coordinates):**
To reference the pixels on the photos with ground coordinates,10 ground control points (GCP) was collected. Mean RMSE: 6

**Creating 1966 DEM:**
Created epipolar pairs → DEM from stereo images: NCC (normalized cross-correlation) was used to extract the DEM with + medium smoothing to remove some noise.

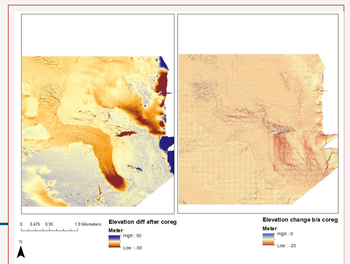
1966 DEM



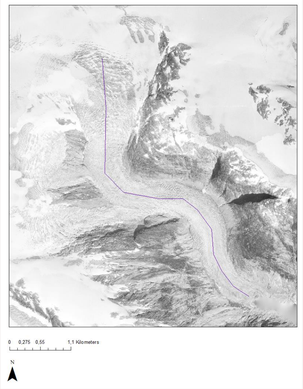


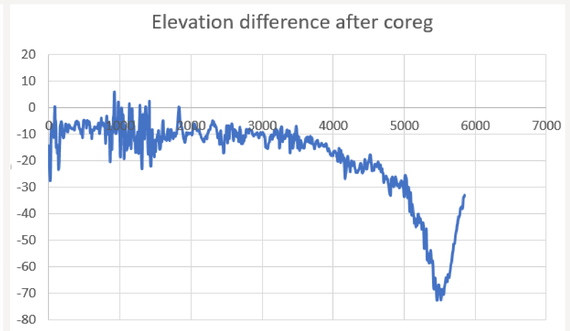
**Mosaic score and imagery of 1966 DEM**: Each pixel is given a value from 0-100 depending on how well the NCC algorithm could recognize similar features in multiple images. High value equals good correlation between the images. The general trend is that snow-covered areas and lakes have low scores due to lack of contrast, while clean ice and non-snow-covered areas have high scores.

**Coregistration:**
When coregistering the 1966 DEM to the 2013 DEM the unstable features of the imagery like the lake and glacier was excluded so the DEM shift would be based on the difference or error on the stable terrain. Coregistration was done following the method by Nuth & Kääb (2011).




**Coregistration results:** The left image shows the difference in elevation between the reference lidar DEM from 2013 and the coregistered 1966 DEM. The mean elevation loss of the glacier was -9,3 m . The right image shows the change in elevation before and after coregistering. The mean difference was -13.6 m before coregistration and 1.4 m after coregistration.






The graph shows elevation change along a transect (image) of Nigardsbreen between 1966 and 2013 (mean error on stable terrain 1.4 m)

**Total loss off ice:** By excluding non-glaciated areas using a shapefile and applying zonal statistics in ArcMap the loss thruout the glacier was calculated. By multiplying the resulting number by 4 (resolution x 2) the total loss of ice in m³ was calculated, which was 11 827 635 m³ or about 0.012 km³ between 1966 and 2013.

**REFERENCES**
**Nuth, C.,** Kääb, A. (2011) Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change. *The Cryosphere.* Vol 5, p 271-290

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