

## ESTABLISHING OF FOUR SITES FOR MEASURING COASTAL CLIFF EROSION BY MEANS OF TERRESTRIAL PHOTOGRAMMETRY IN THE KONGSFJORDEN AREA, SVALBARD

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### Abstract

Four sites for measuring coastal cliff erosion in the Kongsfjorden area on Svalbard (79° N, 13° E) were established in the period August 2<sup>nd</sup> to 8<sup>th</sup> 2002. The sites were chosen to compromise different kinds of material and exposure. Both cliffs in unconsolidated material and cliffs in bedrock were chosen. Photos were taken at distances ranging from 7 to 15 metres from the cliff walls with a Hasselblad camera. Both the camera positions and some established fixed points were surveyed. At site 1 and 4 a number of bolts were also drilled in to the cliff and surveyed. These are used as control points for the photogrammetric orientation of the photos. At the other two sites only the camera position and direction were measured. At each site photographs were taken from two to three different camera positions to get three-dimensional coverage of the cliffs.

The photos were scanned and digital terrestrial photogrammetry was applied to construct digital terrain models of the cliffs. The plan is to photograph the sites again in two years time and to construct a new set of digital terrain models. The erosion rate can be found by simply taking the difference between these two sets of terrain models. Due to the short distance between camera and cliff, the accuracy is in the millimetre range.

### The study area

The Kongsfjorden area is situated at the western coast of Spitsbergen, the largest island of the Svalbard archipelago (see Fig. 1). The area has continuous permafrost with measured depths ranging from 130 to 150 near the shores of Ny-Ålesund (Orvin 1944; Liestøl 1976). The mean annual air temperature in Ny-Ålesund is -5.8°C (1975-2000 data obtained from Ketil Isaksen at the Norwegian Meteorological Institute). The tidal range is about 2m. The shores of the area are made up of a mixture of cliffs in unconsolidated material, cliffs in bedrock and glacier fronts terminating in the sea. The selected sites consist of low cliffs in bedrock and unconsolidated material, both with stony beaches in front (Ødegård et al. 1987). The geology of site 1, 3 and 4 is lime- and dolostone (Carbon and Perm) while site 2 is in an area of gneiss (upper Proterozoic). The unconsolidated beach material is of Quaternary origin (Hjelle 1993). The area has earlier been subjected to some related research activities concerning coastal processes e.g. cryogenic weathering of cliffs (Ødegård and Sollid 1993).

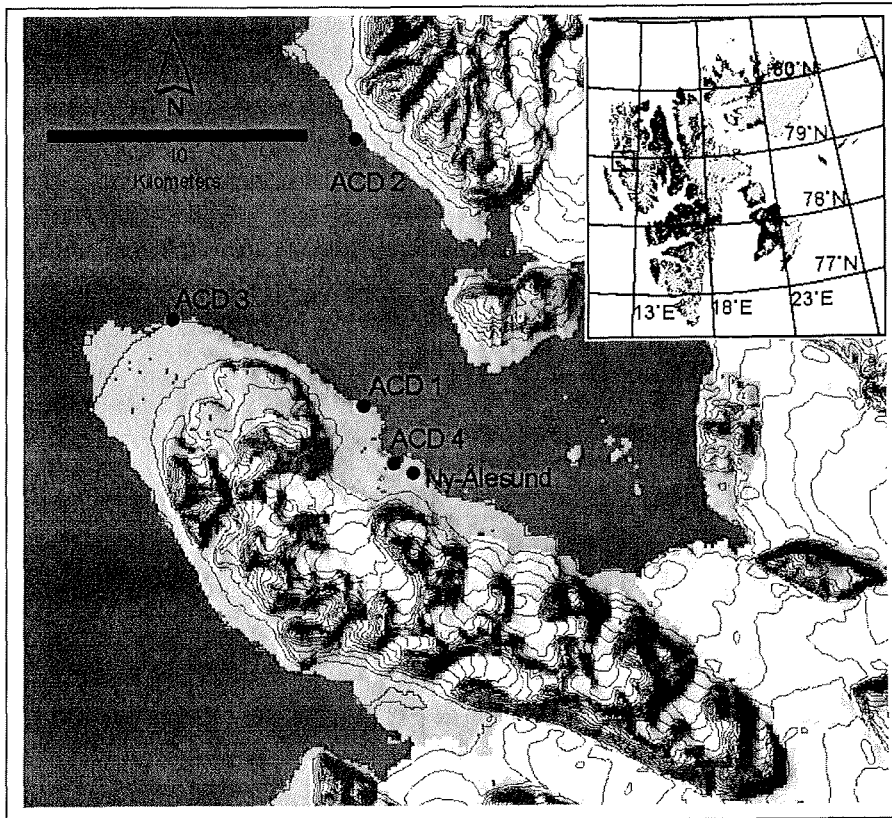


Figure 1. Map of the site locations in the Kongsfjorden area.

### Technique and precision

The camera set up used at the sites is shown in Fig. 2. At all sites a fixed point for global reference was established. A bolt was drilled into the bedrock and its position measured by GPS. The positions of the camera stations were measured by GPS and surveyed from the fixed point to create both a global and a local reference. The photos were acquired with a stereo overlap as seen in Fig. 2 by using a Hasselblad camera with a 60 mm lens. At two of the sites bolts to be used as photogrammetric control points were drilled into the cliff wall as well. At the sites consisting of unconsolidated material no control points were established. The distances between the camera stations and the cliff wall varied between 7 and 15 metres for the four sites. The distance between the camera stations was approximately half of the photo distance. The coordinate system is transformed in a manner to simulate the geometry of aerial photogrammetry. The z-axis is pointing out of the cliff and the xy-plane is parallel to the cliff wall and also the line between the photo stations (Fig. 2). The camera was mounted on top of the theodolite with a special device (Fig. 3). This makes it possible to measure the exact position of the camera and to ensure that the photo stations are on line parallel to the cliff wall. The camera positions are also used in the photogrammetric orientation of the scenes. For the scenes from the sites of unconsolidated material this set up also gives the

opportunity to measure the photo angle used for exterior orientation of the scenes. This is important since no control points are available.

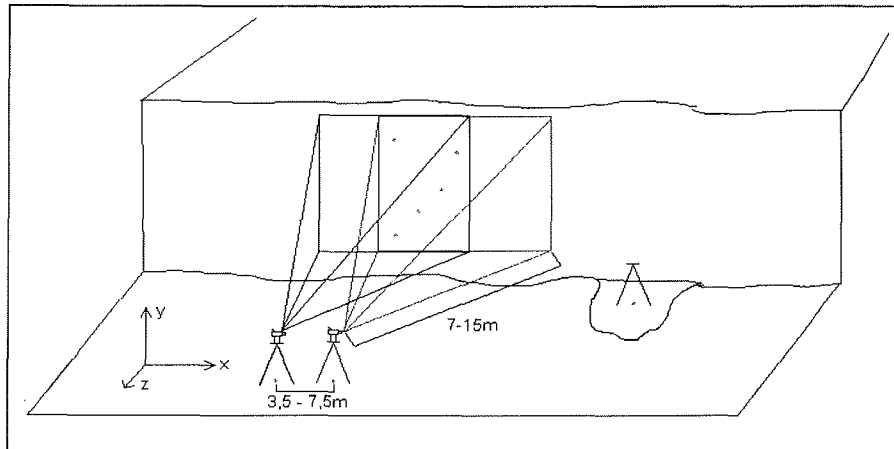


Figure 2. The set up of camera and fix points at the sites.

The photos were scanned at a resolution of  $11\ \mu\text{m}$  (2,300 dpi) and imported into the Z/I Imaging digital photogrammetric workstation software. After the photo pair or triples have been used to create a photogrammetric stereo model it is possible to automatically generate a high precision digital terrain model (DTM). The Match-T algorithm (Krzystek 1991) in Z/I Imaging utilizes cross-correlation to detect the same points in the different photos of the stereo model and then measures the elevation by measuring the y-parallax. Photo distances in the range of 7-15 m gives a scale of 1:117 to 1:250. With the above mentioned scanning resolution the XY-resolution is in the order of 1.2 – 2.5 mm. The accuracy of elevation measurements done by photogrammetry is about 0.20-0.40‰ of the photo distance. This gives an elevation accuracy (Z-direction) of 1.4 – 2.8 mm for the 7 m photo distance and 3.0 – 6.0 mm for the 15 m photo distance. To be able to use the Z/I software the coordinate system had to be rotated and all coordinates up scaled by a magnitude of 100, both to simulated aerial photography which is the normal input to the software.

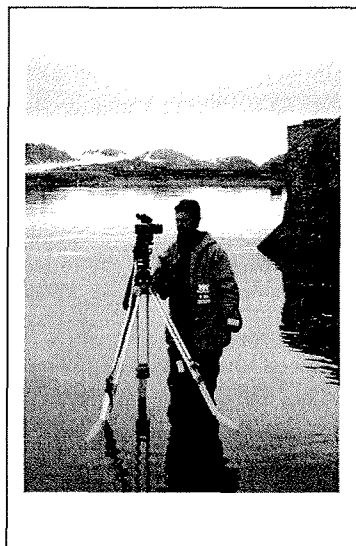


Figure 3. Camera on theodolite.

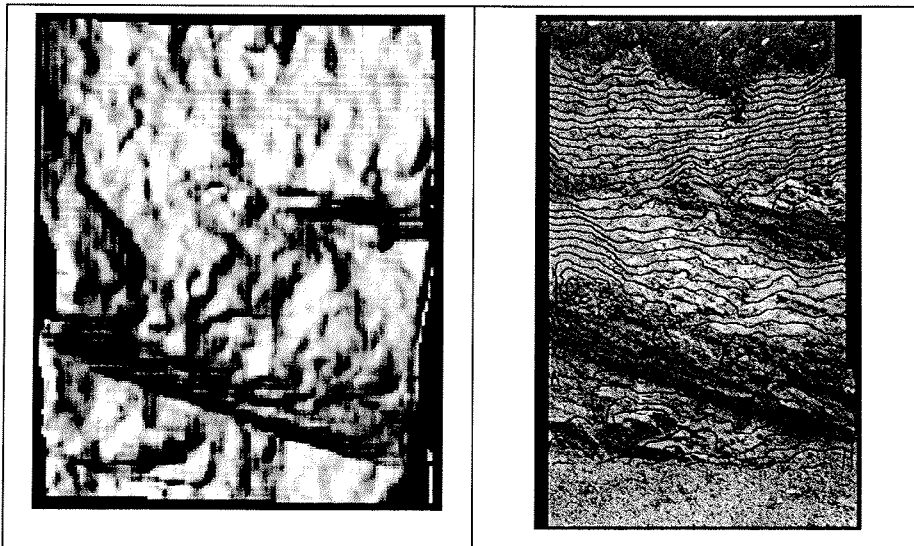
### Results

The automatically generated DTM for site 4 is shown in Fig. 4, both as a shadowed relief of the digital terrain model and as contour lines on top of the orthophoto of the cliff wall. The height and width of the area covered by the model is 3.3 m and 2.8 m respectively. When investigated the three-dimensional model follows the terrain quite nicely. But all the points in the generated digital terrain model are laying some centimetres above the surface. This error is probably due to the theodolite-camera centre offset. The position of the theodolite is

taken to be the projection centre of the photos and used in the photogrammetric calculations. Hence the theodolite-camera centre offset has to be determined to determine the exact position of the projection centre. Some photos of an indoor house wall with known and marked points have been taken at the Agricultural University of Norway. By the use of bundle adjustment of these photos in the Z/I-Imaging software it should be possible to calculate the offset between the camera centre and the theodolite.

### Preliminary conclusion and future work

The method of close up digital terrestrial photogrammetry seems suitable for creating accurate digital terrain models of coastal cliffs and hence promising for calculating erosion rates in the order of millimetres to centimetres. The plan is to acquire a new set of photos of the same sites in 2004 to generate new terrain models that will enable the erosion rate calculations. André (1997) reports a rock wall retreat in the range 0 to 1.58 mm/year in the same area. The coastal cliff erosion rate is unknown but believed to be higher than the rock wall retreat rate and hopefully greater than the accuracy of the technique used.



**Figure 4.** Two representations of the digital terrain model; a shaded relief to the left and contours with 5 cm equidistance on an orthophoto to the right. The size of the model area is 3.3 m by 2.8 m (height and width respectively).

### Acknowledgements

The fieldwork was financially supported by the INTAS-project *Arctic coasts of Eurasia: dynamics, sediment budget and carbon flux in connection with permafrost degradation* (INTAS-2001-2329) and the Norwegian Research Council on behalf of the Norwegian Polar Committee .

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