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Investigations of Coastal Erosion by Means of Laser Scanner VZ-1000 in Vestpynten, Spitsbergen

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Abstract

The erosion of a coastal bluff was investigated using a Riegl VZ-1000 laser scanner. The bluff is located at Vestpynten (Spitsbergen), where the local road is threatened by erosion of the bluff. The bluff is approximately four meters high. The coastal bluff was scanned three times during the 2012-2013 field season. The resulting point clouds were used to illustrate the change of the surface of the coastal bluff and to calculate the material losses over time. Results can be used when one considers coastal protective measures for the studied area. Recommendations and suggestions regarding routines during field survey and data processing are presented.

Introduction

Due to increasing interest in Arctic coastal regions, coastal erosion is becoming an attactive topic. This paper is a part of Nina Ganicheva's master thesis (2014) and a continuation of the master thesis written by Antonia Linzbach. The work describes the processing of 3D Laser measurements from an eroding bluff in Svalbard, in order to investigate the erosion pattern at the site as a basis for the design of an appropriated shore protection suggestion, as well as to evaluate the applicability of 3D laser measurement systems in Arctic environments. This technology is assumed to be of interest due to its precision, comparably easy set up and the possibility to conduct measurements in inaccessible areas. The measurements were done at Vestpynten, Spitsbergen (Position 78.25209N 15.41691E) in 2012 and 2013, where several infrastructures are located closely to an eroding bluff (Figure *1*, Figure *2*).

Field work

The data collection was conducted with the RIEGL® 3D terrestrial laser scanner. The initial raw data consists of two scanning positions located closely to each other, where scanning was conducted during two years: 24th of August 2012 and 8th of August 2013.

The scans have recorded point clouds of a section of approximately 360 meters in length of the eroding bluff and are accompanied with three to four digital photographs each. The recorded data contained some gaps and smaller white spots where no data was recorded. In this work a zone with a length of 118 meters was analyzed.

Figure 1: Zoom of the map, showing the location of Vestpynten on Spitsbergen (Norsk Polarinstitutt 2011).

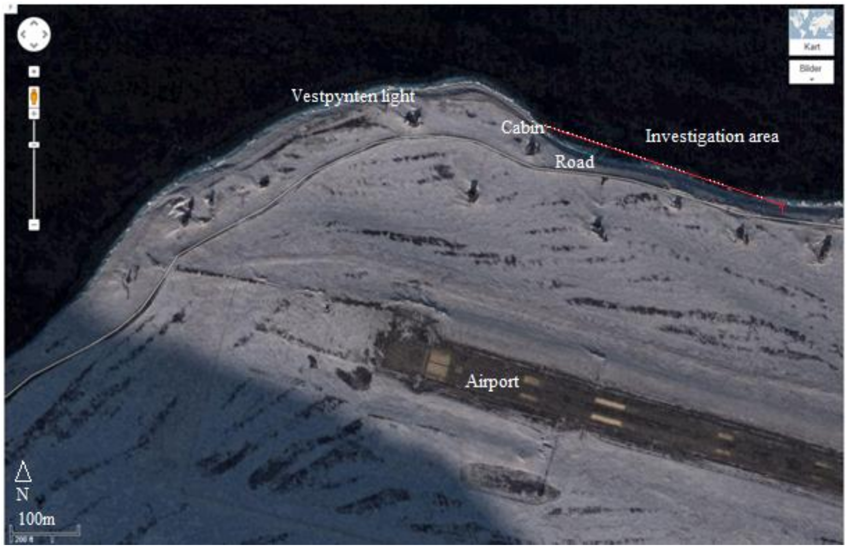

Figure 2: Satellite picture of Vestpynten with indicated investigation area and infrastructures (Google 2013).

Data processing

The collected data was processed with RISCANPro, the standard software of the scanner system. The VZ-1000 has an integrated GPS, inclination sensor and compass to facilitate the registration of scan positions. However, the compass was detected to not give exact directions; this might be due to the high latitude of the site (78°N). Nevertheless, for any kind of comparative analysis the different scans need to be fit to each other, first by manually doing a coarse registration, in order to avoid the incorporation of unrecognized deviations between the scans. All scans of one site should always be registered and adjusted to only one designated reference scan and at least four mutual points in the corresponding scans need to be registered. (Linzbach 2013)

After the coarse registration the Riegl Multi Station adjustment (MSA) tool can be applied to the scanner images for automatic fine adjustment using a best-fit iterative least-squares iterative method. MSA replaces, together with the manual coarse registration, the need for artificial reflector points as they are required in other laser measurement methods. (RIEGL Laser Measurement Systems GmbH 2011).

After the scanned coastal sections point clouds were superimposed on each other with different colours, the studied zone was divided into six sections of different length (Figure *3*). This decision helped to simplify the analysis of a long section. Small sections were compared separately. In order to detect the volumetric change, the “measure volume and surface tool” of the RISCAN Pro software was used. To prepare the data for these measurements, a reference plane was incorporated into the scanner-images. The reference plane was set co-planar to the X-Z-Axis to create a vertical wall behind the bluff, and the same reference plane was used for all scans (Figure *4*). The relative volumetric changes between the scans of 2012 and 2013 were then calculated via subtracting the measured volume of 2013 from that of 2012. Moreover, the obtained bodies are suitable for illustrative comparisons; they show differences on the eroding surfaces and illustrate the dimension of erosion (Figure *5*).

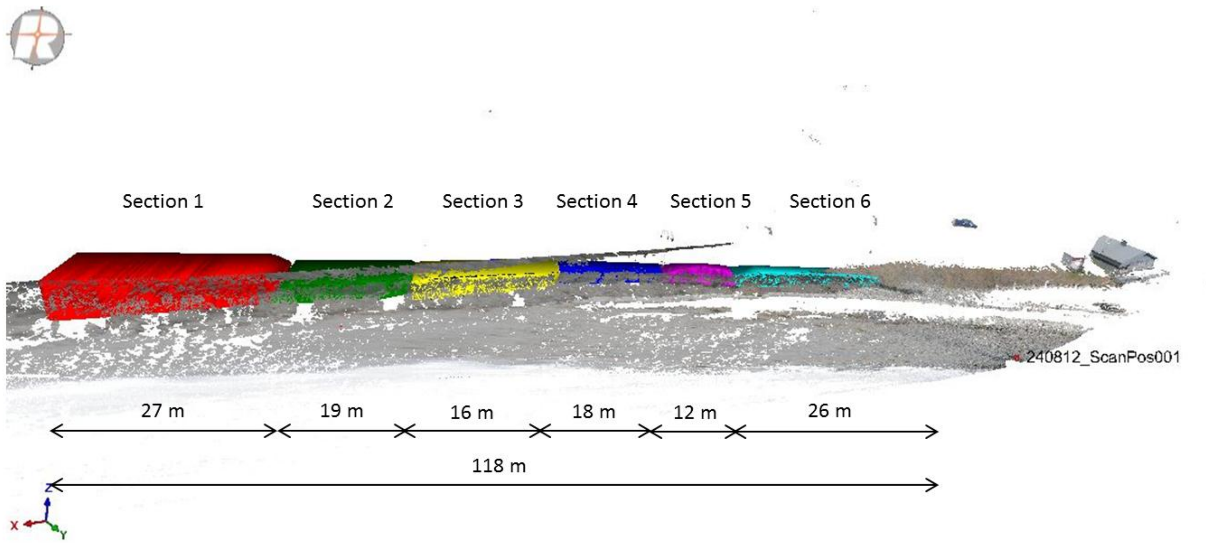

Figure 3: The division of the scanned bluff into six sections.

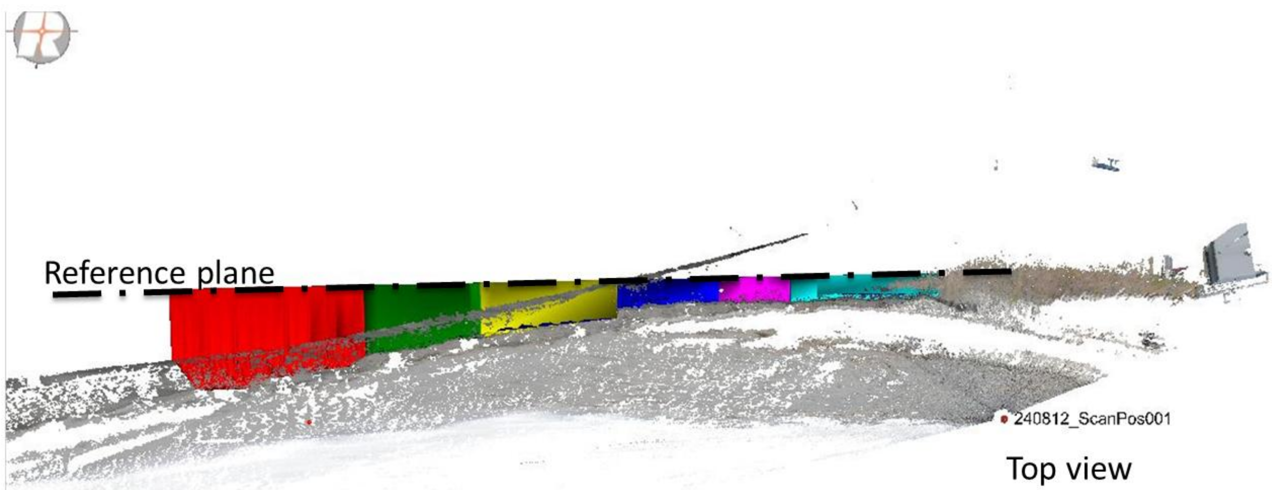

Figure 4: Segmentation of the studied zone (six sections) and reference plane (top view).

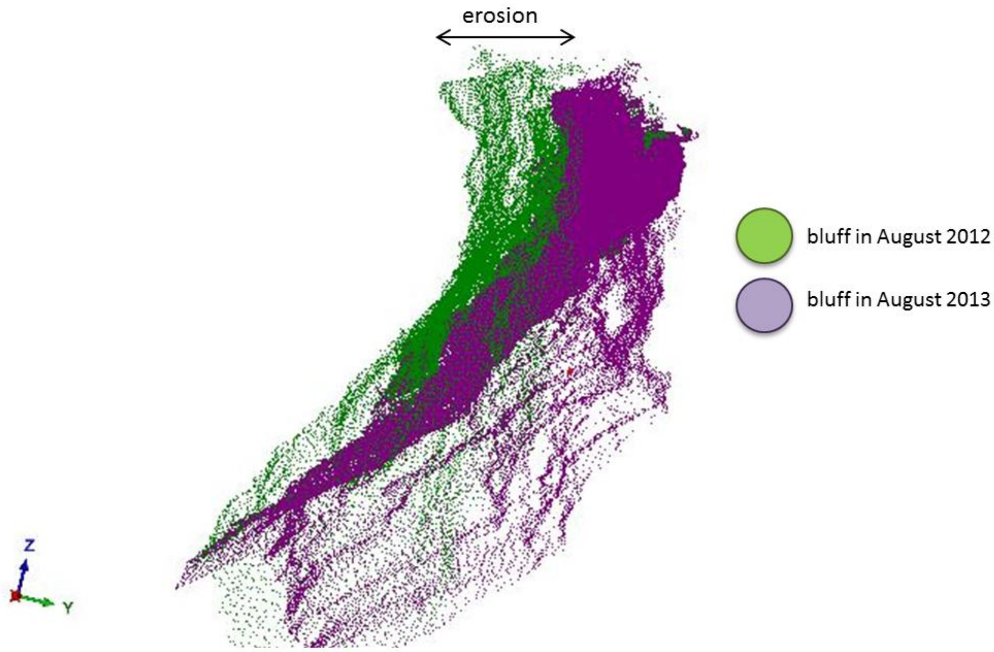

Figure 5: Profile of the scanned coastal bluff (pointcloud section 3, 16m length), comparison of the recorded pointclouds of 2012 and 2013.

Results of data processing

The scanner images were divided into six sections, for more precise marking and measuring, of which the volumes in respect to a reference plane (fixed for all scans Figure *3*, Figure *4*) were then determined. The measured volumes [in m^3] of the sections of the bluff are given in Table 1 and Table 2. The volumetric changes are utilized as a basis to determine the retreat of the free face of the bluff and the development (accumulation) of the scree slope (Figure *6*).

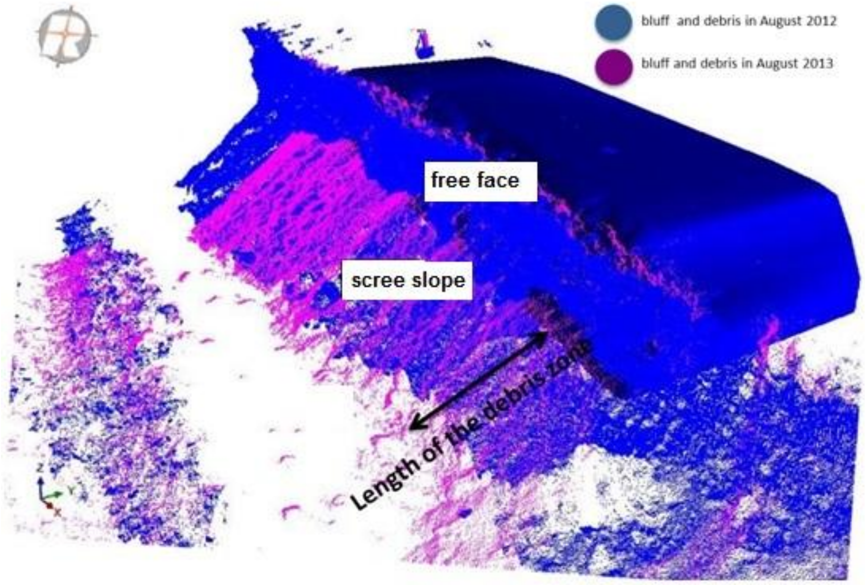

Figure 6: Comparison of free face and scree slope for 2012 and 2013.

The obtained results for the free face and scree slope are given in Table 1 and Table 2.

Table 1: Parameters of free face in the studied sections

Number of the section		1	2	3	4	5	6	Total Length [m]
Length of the section [m]	**August 2012**	27	19	16	18	12	26	118
	August 2013	27	19	16	18	12	26	118
Height of free face of the section [m]	**August 2012**	2,36	1,8	2,5	1,63	1,7	1,7	
	August 2013	2,36	1,8	2,5	1,63	1,7	1,7	
Volume of free face area of the section [m^3]	**August 2012**	1197	476	449	162	100	196	
	August 2013	1136	429	389	145	94	195	
Volume difference [m^3]		-61	-46	-60	-16	-6	-1	"-" means loosing of the volume
Rate of bluff crest recession [m/year]	=Volume difference/Height /Length	0,96	1,37	1,50	0,57	0,30	0,04	The maximum rate of bluff crest recession is 1,50 m/year

Table 2: Parameters of scree slope in the studies sections

Number of the section		1	2	3	4	5	6	Total Length [m]
Length of the section [m]	**August 2012**	27	19	16	18	12	26	118
	August 2013	27	19	16	18	12	26	118
Volume of the area with scree slope of the section [m^3]	**August 2012**	440	247	234	186	90	160	
	August 2013	448	254	237	191	98	173	
Volume difference of areas with scree slope [m^3]		+8	+7	+3	+5	+7	+13	"+" means gaining of the volume

From the obtained values in Table 1 and Table 2, one can conclude that within the monitored period (August 2012 - August 2013) the volume of the free face of the bluff has been decreased, while in the debris part the volume has increased.

Discussion

Erosion can be divided into four categories, according to the rate of erosion these are (Alfred Wegener Institute 2011):

- Stable or aggrading
- Slow erosion (0-1 m/y)
- Moderate erosion (1-2 m/y)
- Rapid erosion (2-10 m/y)

According to the erosion data obtained in this work (Table *1*) it can be concluded, that there is a slow to moderate erosion at Vestpynten’s coastal zone in 2012-2013. The erosion consists of a decreasing free face of the bluff with a scree slope located directly beneath, where the eroded material accumulates. Geomorphologically, this type of erosion is called a Richter denudation slope. The material accumulation in 2013 compared to 2012, which is mainly found at the lower part of the bluff (scree slope) and some small overhangs at the top of the bluff can be explained by the build up of cracks which lead to overhanging material at the top and accumulation of loose material on the foot of the bluff. This assumption should be validated by further monitoring. Overall, the surface confirms the presumption that the erosion on Vestpynten is a combination of material loss from the instable free face and accumulation of the eroded material on the scree slope with possible subsequent evacuation of material from the prelocated beach by waves.

In regards to the data collection it should be acknowledged that the recording of data seems to include some inaccuracies when scanning large sections such as the approximately 300 meters of coast which were recorded in the scans. The approximately 118 meters of the bluff closest around the scanning point were recorded with decent quality, while those areas further away contained many gaps in the recorded pointclouds, where the laser ray was not properly reflected. Moreover, it has to be considered that certain weather conditions limit the applicability of 3D Laser measurement systems; snow accumulations cannot be distinguished from other ground constituents, and thus might falsify measurements. Low temperatures might also damage the measurement device. For the precise position logging of the scanned areas, it has to be considered, that the device integrated compass has a decreased precision with high latitudes. When the compass is used, corrections have to be adhered. Regarding the processing software, it was also found that an incorporated scale for the created views/illustrations is lacking.

Conclusions

Formation of scree slope can be considered as a process leading to stabilization of the shore line at the present research site; nevertheless one should consider actions of nature forcing in order for further discussion regarding coastal dynamics in this area.

The conducted 3D laser scanner measurements and results were found to be a successful research method for the assessment of erosion rates/volumes. However, certain conditions, such as cold temperatures, possible measurement falsifying snow accumulations, and decreased compass precision with high latitudes, must be considered. Moreover, scales have to be fitted manually into all software created illustrations.

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References

RIEGL Laser Measurement Systems GmbH. (2011a). RIEGL VZ-1000. Technical documentation and user instructions.RIEGL Laser Measurement Systems GmbH. 348 p.

Alfred Wegener Institut. 18. April 2011. http://www.awi.de/de/aktuelles_und_presse/pressemitteilungen/detail/item/arctic_coasts_on_the_retreat_international_studies_describe_current_state_of_the_arctic_coasts/?cHash=5e5c7cacd22d08808636025dcc0398fe (Last retrieved 22. January 2013).

Finseth, J., Sessford, E., Hormes, A., & Tangen, H. (2012). Erosion and geohazard protection of a coastal cultural heritage in Svalbard; "Fredheim". *Port and Ocean Engineering under Arctic Conditions*. Espoo POAC. 1-11.

Google. (2013). *Google earth*. Retrieved February 23, 2013, from http://maps.google.no/

Linzbach, Antonia (2013) Coastal erosion on Vestpynten, Svalbard; Engineering measures for shore protection. *LWR Degree Project* p.49.

Norsk Polarinstitutt. (2011, September 16). *Norsk Polarinstitutt*. Retrieved January 23, 2013, from http://placenames.npolar.no/stadnamn/Vestpynten+lykt?ident=15818

RIEGL Laser Measurement Systems GmbH. (2011a). RIEGL VZ-1000. Technical documentation and user instructions.RIEGL Laser Measurement Systems GmbH. 348 p.