Changes Of Glacier Extent: Using Gis To Integration Maps, Remote Sensing Material And Field Surveying. Petuaniabukta, Central Spitsbergen Case Study

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INTRODUCTION

There is a strong evidence that glaciers are retreating in many regions of the world (IPCC, 2001). Recent studies shows that this process is also likely to accelerate in the future (Paul 2004). This have significant implications as glaciers are perceived as one of the key indicators of global climate change (i.e. Dyurgerov, 2000; Oerlemans, 2005; Ding, 2006). Furthermore their melting have strong impact on water circulation salinity, water resources and hydropower potential and it is also a factor in rising of the sea level (Church 2001, Svendsen, 2002; Khalsa, 2004).

Because of this significance there is a strong need for more detailed assessments of this process and large number of glaciers are being measured and monitored all over the world. This task however presents numerous challenges. One of them is that most of the glaciers lie in the remote mountainous regions and it is very difficult to perform reliable and constant in situ observations and monitoring. This is why remote sensing methods are being employed studies like Khalsa (2004) study of Tien-Shan and Trabant (1999) measurements of Alaska glaciers. Often data on glaciers exists in different forms ranging from topographical maps in various projections and scales, aerial photos and field measurements to satellite imagery like in the case of Swiss glacier inventory (Kääb 2002) that is a part of USGS-led Global Land Ice Measurements from Space and Ding (2006) study of chinese glaciers, and Geographic Information Systems offer a possibility to integrate various data sources into one comprehensive and reliable analysis.

STUDY AREA AND DATA TYPES

Study area is localated in central Spitsbergen – in the area of the north part of Billefjorden – Petuniabukta ***(figure 1)***. Different types of data were used for analyzing changes of 13 glaciers during last 50 years.:

1) topographical maps 1:100 000
2) monochromatic aerial photography from 1961 year in scale 1:50 000
3) colour aerial photography from 1990 year in scale 1:15 000
4) Aster image from 2002 year – pixel ground resolution c.a. 15 m
5) Field measurement using differential LEICA GPS A500 (accuracy 1-3 cm) or hand Garmin GPS (accuracy 2 – 3 m)

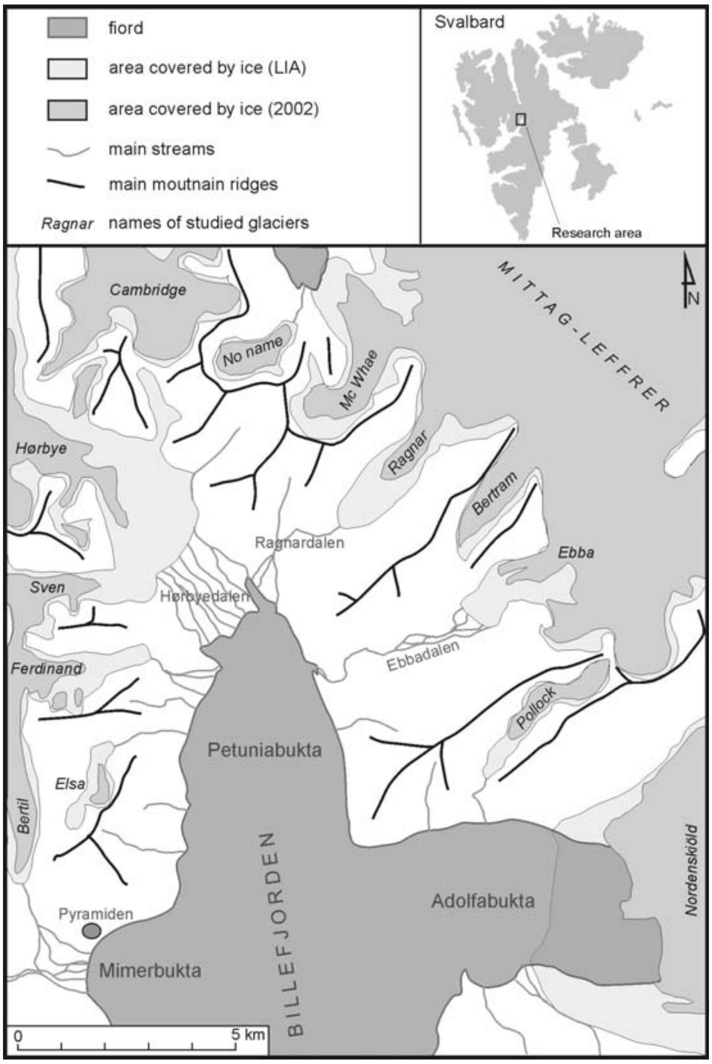

Figure 1: Study area with glaciers.

METHODS

Data integration

The UTM projections and WGS84 datum was chosen as the main and output projection of this study. Since obtained data was in different reference systems reprojection methods were used where needed. The topographical maps 1:100 000 were scanned and registered to the UTM projection using corner points and crossings of grid lines. The ground control points (GCP) measured with GPS were used to register scanned aerial photographs. Aster image already has an internal orientation so georeferencing was not needed. Satellite imagery, GCPs and aerial photograph fitted well but topographical maps had to be subjected to rectification using several ground control points. The field data acquired in UTM projection were also introduced to resulting database.

Glacier extent measurement

Since there is an almost constant generation of ice-cored moraines and a lot of debris is covering the ice in marginal zone it is almost impossible to unambiguously determine the location of ice-margin. Instead the concept of “clean-ice edge” was used and measured. For each glacier four extents for different time horizons were distinguished and manually digitised:

1) maximum Little Ice Age (LIA) – by using aerial photographs for detection of moraine ridges range and reconstruction in this way former ice-margin position.
2) 1961 – outlined from black and white aerial photography
3) 1990 – pointed out on colour photography
4) 2002 – obtained from Aster image

Apart from this for 3 glaciers the position in the years 2001-2005 were digitised basing on points collected by GPS filed survey.

The final step was the calculation of amount of glacier area extinction in every period of time using GIS tools.

RESULTS

Decadal area changes of studied glaciers varied from about 4000 m^2/year to above 164 400 m^2/year ***(figure 2, table 1)*** and the largest extinction was observed for Nordenskiöld and Hørbye glaciers. Rate of ice-margin recession was usually between 10 to 20 m/year (800 – 1500 m from position of maximum extension) ***(table 2)***. Only the south wing of Nordenskiöld glacier retreated much more – about 3500m.
In the scale of whole research area the glaciated area is smaller by 25 km^2 comparing to Little Ice Age.

Glacier	LIA - 1961	1961 - 1990	1990 - 2005	Sum	Mean
	m^2				m^2/year
Bertil	390 550	223 440	197 450	811 440	9896
Bertram	317 340	129 730	100 430	547 500	6677
Ebba	544 750	402 300	162 290	1 109 340	13529
Elsa	136 600	134 340	142 480	413 420	5042
Ferdinand	685 830	465 760	99 390	1 250 980	15256
Hørbye	2 694 900	1 534 100	1 109 370	5 338 370	65102
Mc Whae	283 430	684 350	408 120	1 375 900	16779
Nordenskiöld	9 340 600	3 915 850	231 360	13 487 810	164485
Pollock	427 400	69 690	48 630	545 720	6655
Ragnar	502 420	445 190	215 760	1 163 370	14187
Sven	935 730	184 460	81 320	1 201 510	14653
Unnamed	136 250	114 140	80 300	330 690	4033

Table 1: Changes of area of the studied glaciers in the Petuniabutka area.

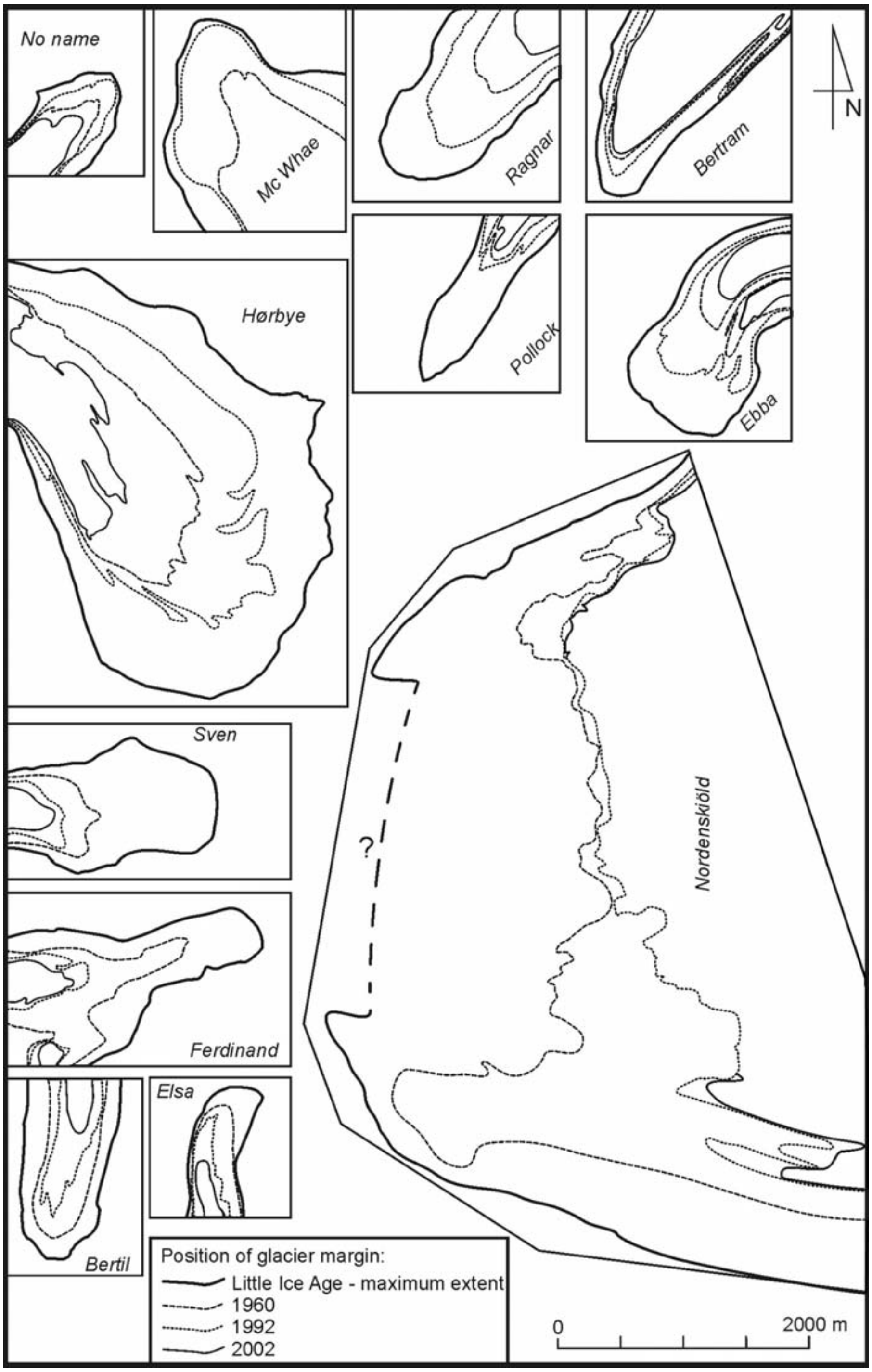

Figure 2. Changes of glacier extents in the Petuniabukta area between LIA and 2002 year.

Glacier	LIA - 1961	1961 - 1990	1990 - 2005	Sum	Mean
	m				m/year
Bertil	161	162	599	922	11
Bertram	316	136	40	492	6
Ebba N	291	502	237	1 030	13
Ebba S	499	199	241	939	11
Elsa	192	105	421	718	9
Ferdinand	551	835	142	1 528	19
Hørbye	460	520	545	1 525	19
Mc Whae	77	388	402	867	11
Nordenskiöld N	820	362	67	1 249	15
Nordenskiöld W	379	2498	651	3 528	43
Pollock	986	139	77	1 202	15
Ragnar	471	603	394	1 468	18
Sven	926	277	81	1 284	16
Unnamed	112	186	196	494	6

Table 2: Retreats of the clear-ice margin of the studied glaciers in the Petuniabukta area.

CONCLUSION

1. All glaciers in the study area are in permanent recession since the LIA maximum
2. GIS allows to integrate data of different type and scale to one system, and make glacier extinctions measurements possible with satisfying accuracy
3. It will be worth in future to obtain detailed elevation model (for example from Aster stereo pair images) to make better and less subjective classifications and measurements

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