ANALYSIS OF SHORT-TERMS HEIGHT CHANGES OF THE HANS GLACIER USING QUASI-CONTINUOUS GPS OBSERVATIONS

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1. INTRODUCTION

During the XXVIII Polar Expedition of the Institute of Geophysics of Polish Academy of Science the quasi-continuous GPS monitoring was conducted on the point established on the glacier surface. The aim of the investigation was to determine the glacier velocity and its height changes. In the paper we are trying to analyze the variations of geometrical heights of the glacier received from GPS observations.

2. METHODOLOGY AND TECHNICAL GUIDELINES OF SURVEYING EXPERIMENT

Two frequency geodetic GPS receivers were used during the surveys to ensure the high accuracy of results. The GPS accuracy is of the 1 to 3 cm in horizontal and 2 to 5 cm in height level. The precision of determination describe many factors: Position Dilution of Precision (PDOP), signal reflections on the way from satellite to antenna (mainly from the glacier surface and from the ablation pole), atmospheric conditions during the surveying session (wind, snowing, raining), land topography (close to high mountains), high activity of ionosphere on these latitudes.

To receive good results of experiment besides choosing proper equipment very important thing was to establish optimal way of GPS observations: survey technology, length of the sessions, survey intervals. Dr. Szpunar (2006) in his doctoral thesis had written about selection of these parameters. Choose of observation technology and length of survey sessions was a result of many years authors experience and literature studies (Vieli et al., 2004). To the most important factors which influence on the final decision we could list:

- **Approximate daily glacier surface motion (15-30 cm - depends on season of the year)**
- **Expected accuracy of determination of the position (a few cm)**
- **Ability to supply receiver for the period of time at least few days**
- **No possibility for the GPS receiver to work in RTK mode (high mountain standing between the rover and reference station)**

In this connection the static technology was chosen as an optimal one with 30 minute observation session. The choice guaranties that the glacier velocity will not disrupt the data. The intervals between next sessions were set on every 3 hours to quasi-continuous motion monitoring with minimum electricity consumption.

Photo 1. Measurement point.

3. **PROGRESS OF SURVEY INVESTIGATION**

Leica System 1200 receivers were used to conduct the experiment. It turned out that in very hard arctic conditions they were very good. The unique technology solution which has been applied in the receivers guaranties high quality of satellite observations and certainty of collecting the GPS data in extreme conditions. The surveying equipment consisted of: Leica GX1230 GPS receiver, Leica AX1202 antenna, Leica RX1210T control panel. Satellite antenna was fixed to the ablation pole. The rest stuff were put to the special box on glacier.

The experiment lasts 9 months (15/09/2005 – 30/06/2006) what gives a good data for analysis of the glacier behavior in different seasons of the year. In that period were a few breaks of collecting the data. The main reason was very fast changes of atmospheric conditions which makes impossible to prevent the equipment. The breaks were insignificant and in the context of period of the survey they did not disturb the results. The breaks also did not influence the post-processing the data. Big number of observations gives us the possibility to build the phenomenon’s model with high accuracy, even with the 1 cm level but using a good filter of eliminations of surveys noise.

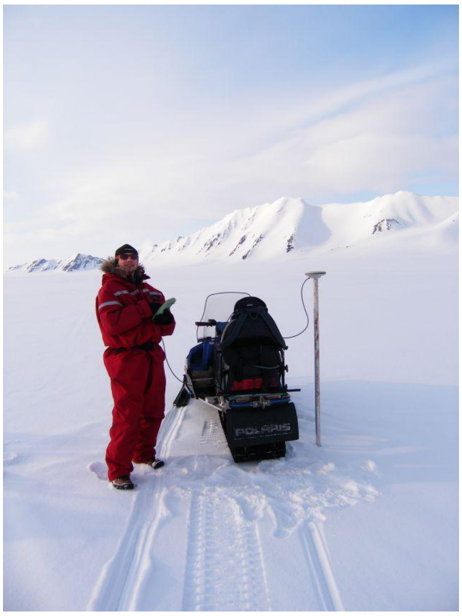

Photo 2. GPS survey.

4. POST-PROCESSING OF OBSERVATIONS AND ANALYSIS OF THE RESULTS

The Leica GeoOffice v.2 software was used for post-processing of satellite data which were collected. The coordinates and heights are the results of that study. The glacier surface velocities and vertical motions have been determined as a result of that data.

The results are presented in the figures. The first four figures present the data in the period of two months the fifth one presents one month data and the last - one week. The trend lines were put in the figures - moving average – as a calculated from 24 determinations of the position for two months data and 8 determinations for one month. We can notice that the glacier height decrease in average 1 to 2 cm per day. Some changes are visible in period of one month and 5 cm amplitude. The last figure presents survey results in period of one week. The height value is oscillating in 10 cm range and the main cause is because of the satellite constellation in that time (the same constellation is every one sidereal day). But this specific set of satellites doesn’t have wrong influence for the period of long time observation. The chosen technology let us monitoring the glacier velocity with an accuracy 1-2 cm what for analysis of long time data is enough.
Height jump change visible in figure 3 probably is connected with water delivery which created hydraulic cushion of the glacier.

Photo 3. ASTRO – reference station.

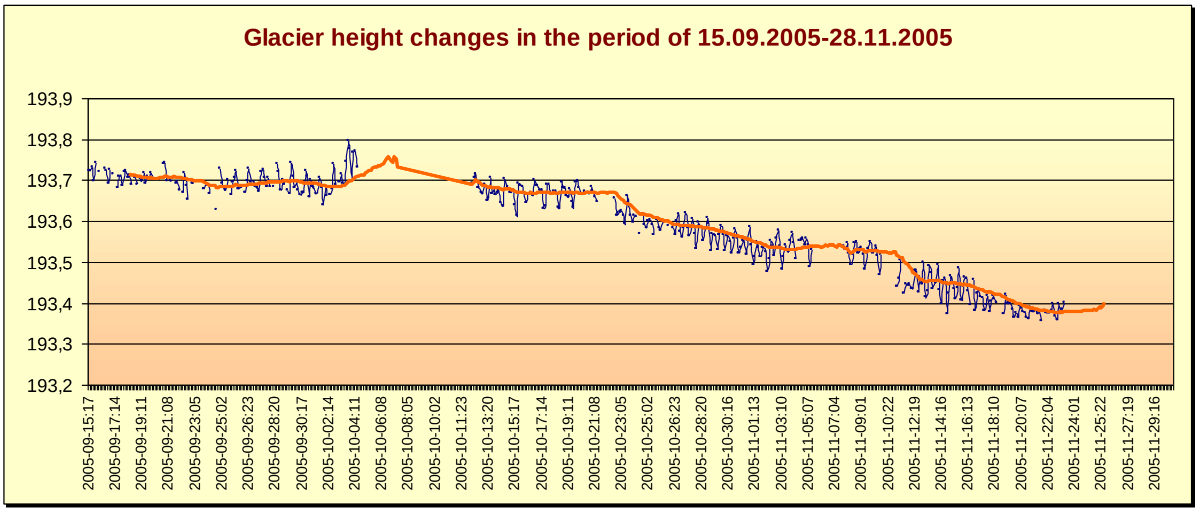

Fig. 1. Glacier height changes in the period of 15.09-28.11.2005.

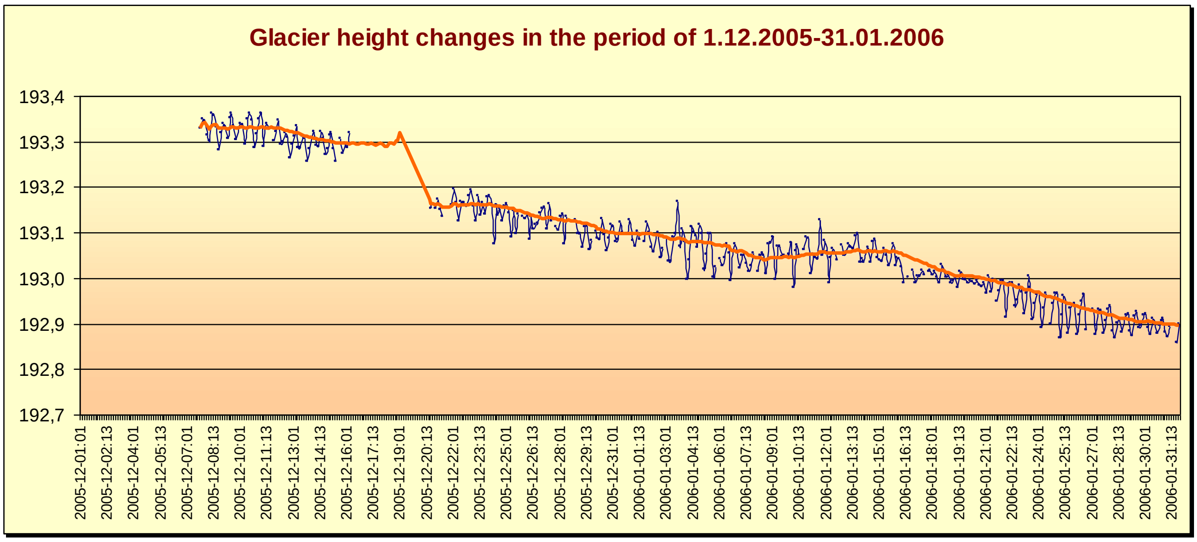

Fig. 2. Glacier height changes in the period of 1.12.2005-31.01.2006.

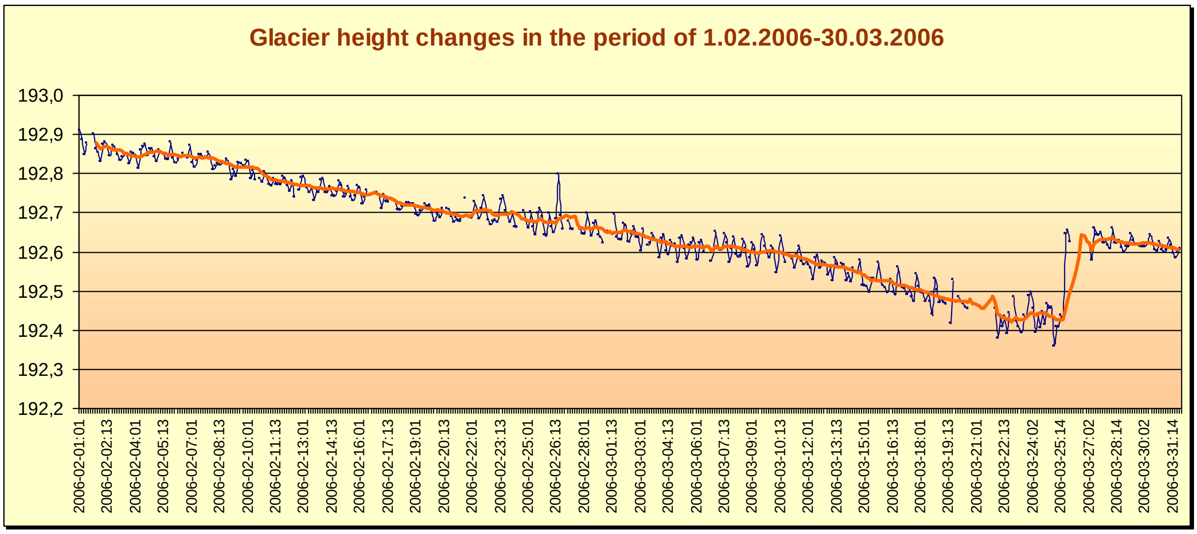

Fig. 3. Glacier height changes in the period of 1.02-30.03.2006.

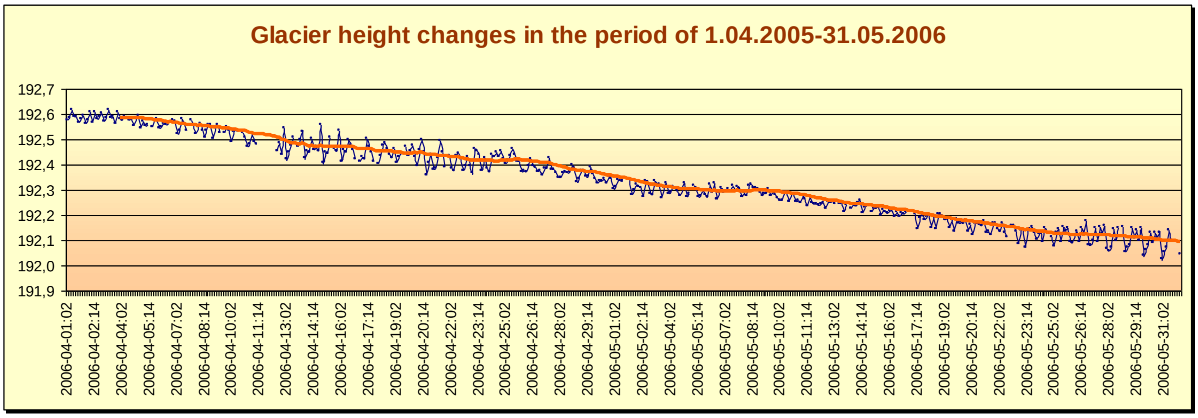

Fig. 4. Glacier height changes in the period of 1.04-31.05.2006.

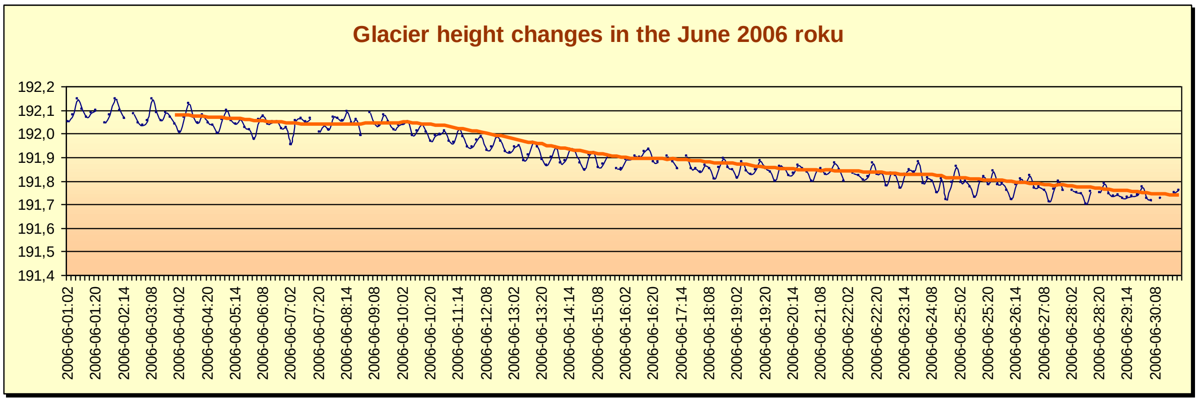

Fig. 5. Glacier height changes in the June 2006.

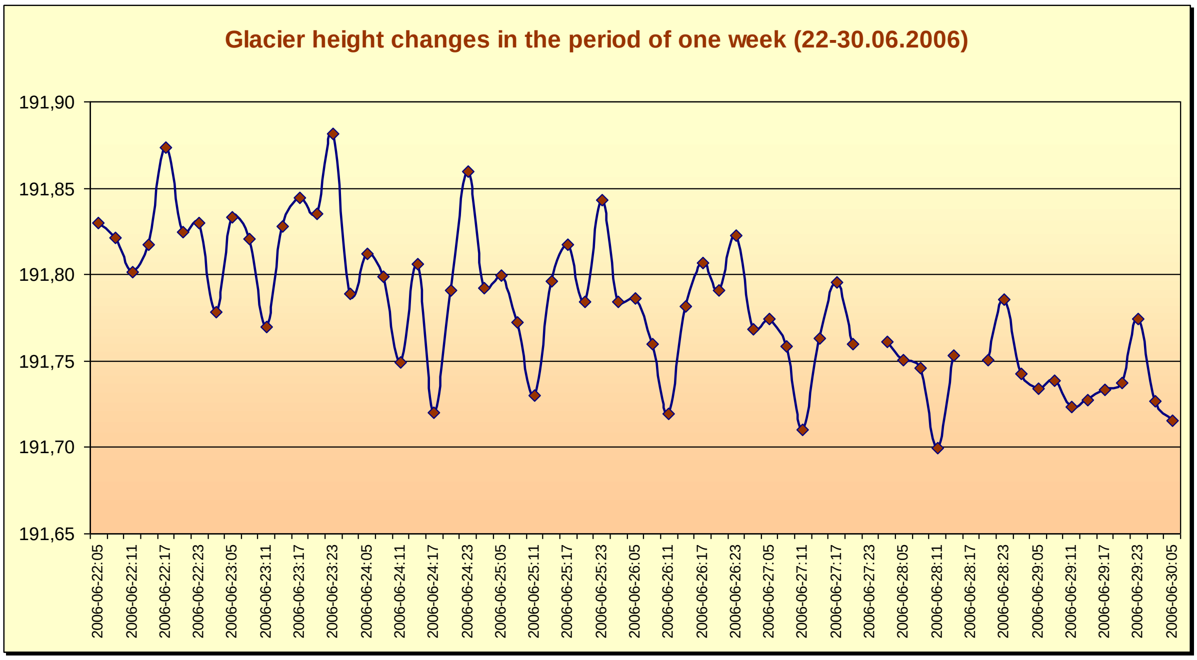

Fig. 6. Glacier height changes in the period of one week (22-30.06.2006).

5. SUMMARY

The analysis of the measurement results exemplifies very valuable information about the glacier behavior which glaciologists need to understand phenomena occurring on the glacier in different seasons. Beside the experiences collected during this experiment it will be the background to design similar investigations from survey technology and methodology point of view. Basing on these results and experiment analysis we can draw some conclusions:

- **In the period of the experiment the glacier surface felt down as much as 2 meters. This is the natural tendency and consequences of flowing down the glacier to the fiord and his ablation.**
- **In the figures we could notice wavy nature of the phenomenon of the glacier surface which probably is connected with topography of the fiord bottom, ocean tides affected on the glacier front and some processes connected with the ablation water delivery to the glacier bed. This problem requires a detailed study based on environmental data.**
- **The results of determined heights were periodically disrupted by atmospheric conditions (snowing, wind).**
- **The GPS data used to follow the vertical velocity of the glacier surface let us to monitor the glacier with height accuracy. Also the automation of the survey and post-processing is possible.**
- **There are some disadvantages of using this monitoring technology in surveys: one point of observations, influence of atmospheric conditions on the results of surveys, periodically hard access to equipment and not good enough way of installation of the satellite antenna on the glacier (ablation pole).**

REFERENCES

JANIA, J.: ***Glaciology,*** **PWN 1997 Warsaw, (In Polish).**

PACHUTA, A., ADAMEK, A., WOŹNIAK, M.: ***Investigation of movement of the Hans glacier by GPS methods in the Hornsund fjord on Spitsbergen,*** **Reports on Geodesy, No. 2 (73), pp. 285-290, 2005.**

SZPUNAR, R.: ***Satellite movement monitoring in quasi-real time*****. Doctor Thesis, Warsaw, 2006, (In Polish).**

VIELI, A., JANIA, J., BLATTER, H., FUNK, M.: ***Short-term velocity variations on Hansbreen, a tidewater glacier in Spitsbergen*****. J. Glaciol., Vol. 50, No. 170, pp. 389–398, 2004.**

WALO, J., PUCZKO, D., ADAMEK, A., WĘZKA, K., MALINOWSKI, Z., RAJNER M.: ***Monitoring of Hans Glacier movement dynamics (Horsund Sw Spitsbergen, Svalbard),*** **Reports on Geodesy, No. 1 (76), pp. 173-180, Warsaw 2006.**