SCIENTIFIC EXPEDITIONS TO SVALBARD, ORGANIZED BY THE FACULTY OF GEODESY AND CARTOGRAPHY, THE WARSAW UNIVERSITY OF TECHNOLOGY (WUT)

A. Pachuta, J. Walo, A. Adamek, M. Woźniak, M. Rajner, K. Węzka, D. Próchniewicz
Warsaw University of Technology

1. INTRODUCTION

The Svalbard Archipelago (Fig.1), with an area of 92 000 km^2 and the largest island of Spitsbergen, lies between 80˚48’ and 76˚28’ North and 10˚28’ and 28˚50’ East. The islands cover an area of c. 64 000 km^2.

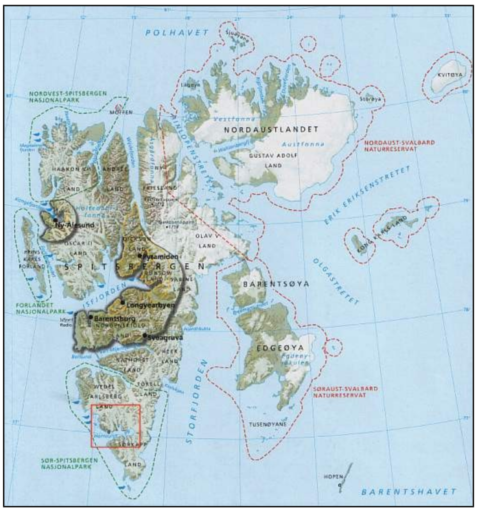

Fig. 1. The Svalbard Archipelago

The history of geodetic involvement in Spitsbergen explorations dates back to 1934, when two officers of the Military Institute of Geography, S.Zawadzki and S.Zagrajski took part in a pioneering expedition. In 1988, the first expedition involving students was organized. The next one occurred almost 15 years later, as late as 2003, thanks to the initiative of the National Club of Polish Geodesy Students affiliated with the Association of Polish Surveyors. The three expeditions that followed were the sole initiative of students and employees of the Faculty of Geodesy and Cartography, WUT

Below is a list of the most important geodetic expeditions to Spitsbergen:

- **1934 – S. Zagrajski, S. Zawadzki – the Military Institute of Geography**
- **1957 – Jerzy Jasnorzewski, Jerzy Fellman**
- **1984 – Jan Cisak, Szymon Barna – the Institute of Geophysics, the Polish Academy of Sciences (Polish acronym : PAN)**
- **1987 – Stanisław Dąbrowski, Zdzisław Kurczyński - the Institute of Geophysics, the Polish Academy of Sciences**
- **1988 – students and staff's Faculty expedition – led by Andrzej Pachuta, scientific advisors – Ryszard Preuss, Artur Gustowski, Jaroslaw Kutyna, Dariusz Osuch, Piotr Wypych**
- **2003 – All-Poland Students' Expedition – 12 people – chaired by Artur Adamek, scientific advisor – Zdzisław Kurczyński**
- **2004 – students and staff's expedition of the Faculty of Geodesy and Cartography WUT, – led by Artur Adamek, scientific advisor – Marek Woźniak**
- **2005 - – students and staff's expedition of the Faculty of Geodesy and Cartography,WUT – led by Kinga Węzka, scientific advisor – Janusz Walo**
- **2006 - students and staff's expedition of the Faculty of Geodesy and Cartography,WUT – led by Kinga Węzka, scientific advisor – Andrzej Pachuta**

All the expeditions involving students chose the region of the Hornsund Fiord in the southern part of the island as the main area of exploration. Above the fiord is located the Polish Polar Station owned by the Institute of Geophysics, PAN. The subject of geodetic research work done by exploration organizers or co-organizers from the Faculty of Geodesy and Cartography, WUT covered, among others: glacier movements, geodynamic research around the Hornsund Fiord, investigating fuel tanks subsidence, compiling planimetric and contour maps of the Hornsund station area, analysis of observation results from the newly established permanent GPS station. The article presents synthetically the results of research and geodetic field work carried out during the last expeditions.

2. INVESTIGATION OF THE HANS GLACIER DYNAMICS

Spitsbergen is characterized by extreme variability of its atmospheric conditions. The main task of our polar expeditions to Spitsbergen was to carry out geodetic research work, the aim of which was to define the character of the Hans Glacier movements. It is one of the twelve glaciers around the Hornsund Fiord (Fig.2). It is situated near the Polish Polar Station.

Fig. 2. The Hans Glacier

The Hans Glacier is about 16 km long and covers an area of 57 km^2. The glacier tongue is up to 2.5 km wide and finishes with the calving glacier toe 1.5 km wide. The glacier rests on the valley walls and its main current rests on the fiord bed. It is a medium size Spitsbergen glacier . The World Glacier Monitoring Service (WGMS) included the Hans Glacier in its data base covering 60 chosen glaciers. The glacier is one of the better investigated and monitored Arctic glaciers.

The traditional method of investigating glacier movements is to determine the changes in the position of characteristic glacier points, on which special wooden staffs have been placed, called ablation staffs. The movement size of ablation staffs is generally identified with the surface movement of a glacier. Theses staffs (11) are evenly placed along the entire glacier. They are deeply planted into its surface so that they could survive at least a couple of seasons. As most part of the glacier belongs to the ablation zone, the staffs melt in (sink in) deeper in the ice every year.

Fig. 3. The progress of ablation staffs measurements by the RTK technique

The measurements of ablation staffs placed along the longitudinal profile were made by the quick static and RTK methods. The measurement analysis reveals changes in the direction of movement vectors, which are thought to be the result of the glacier substratum. If the deformation movement prevails, the movement direction remains constant. Besides the studies on the longitudinal profile, an additional crosswise profile was established (Fig.4) at the height of the fourth ablation staff. In 2005 and 2006, three RTK measurements were made on the new, especially placed ablation staffs.

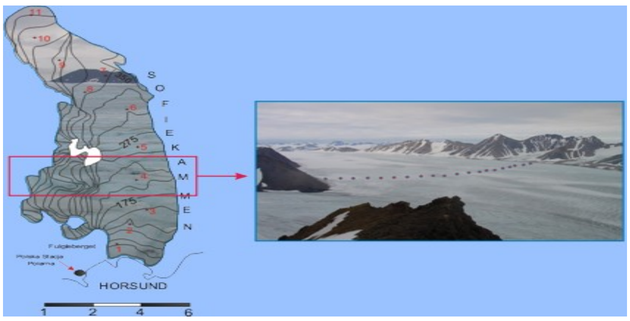

Fig. 4. Longitudinal and crosswise profiles

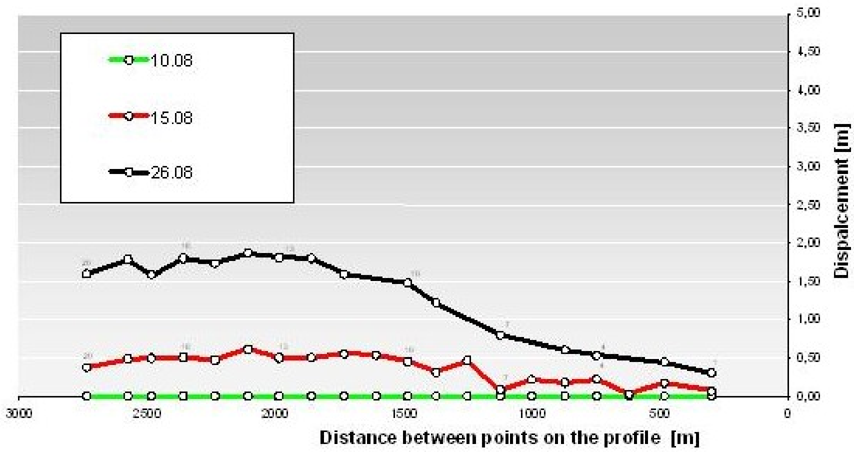

Fig. 5. Displacement of points on the crosswise profile in 2005

By means of determined displacements (Fig.5) the velocity of the glacier movement was calculated, reaching as much as 10 cm a day. In 2006, these points on the Hans Glacier, where the first series of measurements were made the year before, were additionally marked out by the RTK method. Determined again, the heights enabled to define the change in the glacier diameter at the fourth section. The obtained value of the change reached 2 metres (Fig.6), which may reveal a tendency for the glacier to change its ice volume.

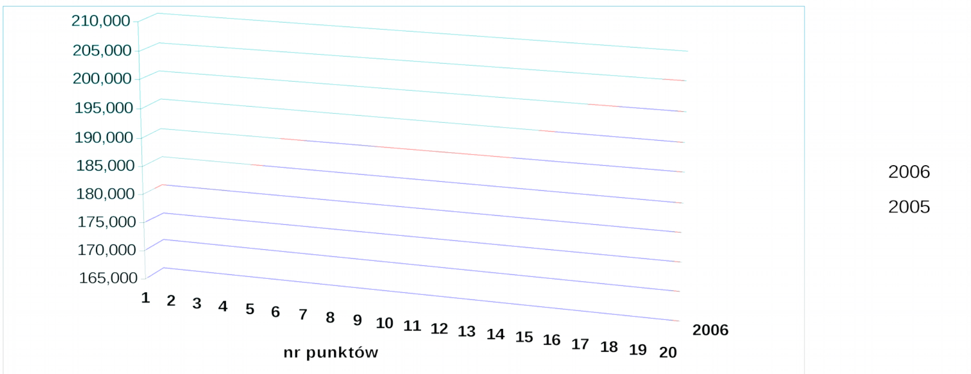

Fig. 6. Changes in the bedding thickness of the Hans Glacier

3. GEODYNAMIC CONTROL NETWORK

In 1988, a control network was established around the Hornsund Fiord, consisting of 7 points placed along both sides of the fiord (Fig.7). The maximum distance between the points is 20 km. In 1988, classical geodetic measurements were made (lengths measured with a Wild Di20 telemeter and angles - with a Wild T2 theodolite). During the last expeditions (2003, 2005 and 2006) measurements were repeated by means of a GPS technology. Length measurements of individual subtenses were observed over 12 hours. For the measurements of local movement of the Earth's crust it would be extremely valuable to analyze and determine the changes in the coordinates of individual points between given measuring periods. However, there is a problem of a uniform reference system that would enable such a comparison. The coefficients of network points

measured in 2005 were determined by tying them up with three reference stations: Ny Alesund (Norway), Tromso (Norway), Hoefn (Iceland). In this way ITRFOO coefficient were obtained. However, a great distance from the reference station (from 200 to 1000 km) made it impossible to define precisely the coefficients of network points in the global system. In 2006, the measured network was tied up with the ASTR point, the coefficients of which had been determined earlier in the ITFR system for the period 2000.00. On the basis of geocentric coefficients crosswise lengths were determined between network points for the measuring periods 2003, 2005 and 2006. Comparing these lengths seems to be the best way to analyze this network with reference to local movements of the Earth's crust as they are not burdened with errors associated with the global reference system.

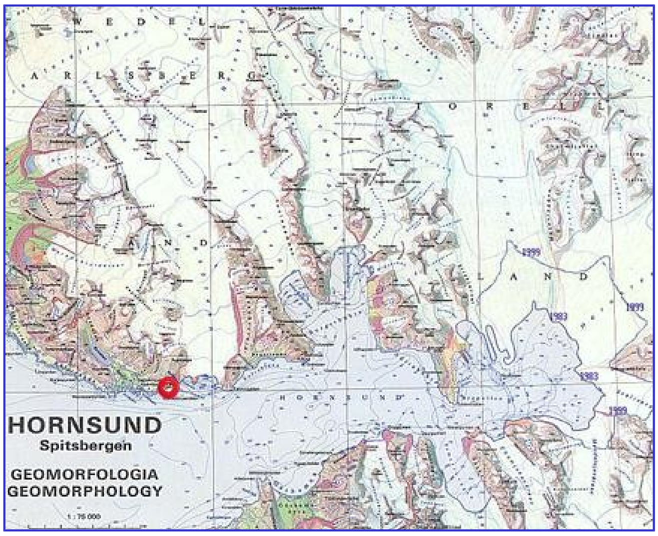

Fig.7. Geodynamic testing network

4. PERMANENT STATION

The study contains a preliminary analysis of GPS observation results collected in 2006 by the permanent station set up in October 2005 near the Polish Polar Station. The aerial was placed in the astronomical point, at which Doc. Jerzy Jasnorzewski (1959) and Dr. Jan Cisak (1984) set out the latitude and longitude from astronomical observations (CISAK and DĄBROWSKI, 1990). The localization of the permanent station antenna is shown in Fig. 8.

Fig. 8. View of the astronomical point before and after installing the antenna

Bernese v.4.2 software was used for processing satellite observations, the same processing strategy applied for each observation day. The calculations were made in the OGPSP calculating service (http://ogsp.gik.pw.edu.pl, LIWOSZ, 2005).
The 2006 observations were processed at weekly intervals – 52 days in total (DOY 006 – 362).Three stations working within the IGS network were assumed to be reference stations, namely TOMSO (TROM), HY ALESUND (NYAL) and KIRUNA (KIRU).
Fig. 9 shows mutual location of the stations. The observations used to determine station coefficients were made at 30- second intervals, which yielded 2880 measuring periods a day for a single point.

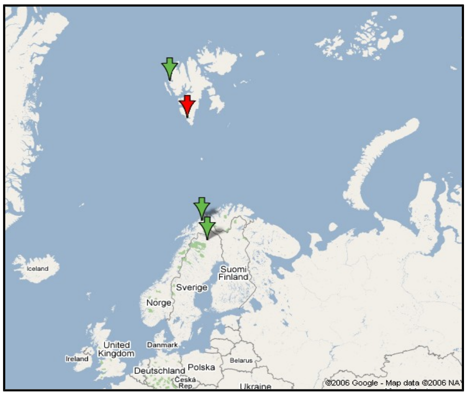

Fig. 9. Location of IGS and ASTR stations (Source: Google Map)

Analyzing the determination of ASTRO station coefficients, one should underline a reasonably high determination accuracy and result coherence despite considerable distance from the assumed reference stations. Mean coefficient errors for given observation days in the great majority of cases did not exceed 1 mm. The inner coherence (short term) for coefficients X and Y was also at the level of about 1 mm, for coefficient Z - at the level of about 8 mm. Great internal incoherence was observed in the case of the initial (DOY 6-62) and final (DOY 300-362) days of the year – for X and Y: 5-8 mm, for z: up to 4 cm (especially when determined with reference to the station in KIRU and TROMSO). However, on the basis of a single- year analysis of data one cannot talk about a seasonal phenomenon yet, least of all provide hypothetical origins of this phenomenon.
Analyzing the obtained data in view of their long-term changes, one can observe some trends in coefficients changes. Coefficient X, especially, displays an almost linear trend decreasing its value by c.20 mm a year. Coefficient Y also shows a slight linear tendency, increasing its value by c.4 mm a year. However, it is so small a change that with a comparatively short measurement period a trend like this cannot be explicitly said to exist. A distinctly smaller value can be observed for coefficient Z at the beginning of the year and a bigger one – at the end of it. The changes are quite significant but they may overlap with lower internal cohesion of measurement results.
The trends observed in coefficient changes may stem from the imperfect models used for determining constituent vectors (the model of plate movements, ionosphere) and also from local movements of the Earth's crust. Precise explanation of how they originated requires careful analysis of data over a longer period of observation.

5. STUDYING VERTICAL MOVEMENTS OF FUEL TANKS FOUNDATIONS

To monitor the behavior of tanks foundations of the fuel station located in permafrost an appropriate control network was set up. It was established in 2004 with a view to carrying out measurements by means of precise leveling. All subsidence measurements are always made with reference to the same Horr benchmark, 8.594 m above sea level and fixed into a rock near the building of the Polish Polar Station.
A systematic height measurement of points (24 benchmarks) installed on the spot foundation under the fuel tanks is to control object safety, constituting a set of data used for analyzing the behavior of engineering objects located exactly in such geotechnical conditions.

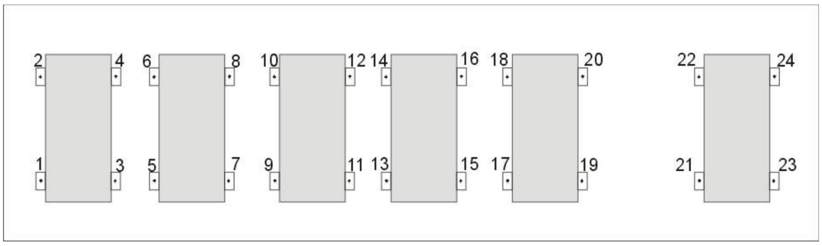

Fig. 10. Positions of benchmarks on the spot foundation of fuel tanks

The 2006 observations were made by means of a Ni004 precise leveler and a set of invar staffs. Before the measurement, the equipment was checked but it did not require any rectification. The measurement was registered and tentatively processed by means of the NWP program on a field computer PSION. The obtained results show that the mean determination error of benchmark heights does not exceed ±0.5 mm. The accuracy of the performed measurements is adversely affected by the substratum, the surface of which is not frozen. Such a substratum does not guarantee the stability of the instrument and staffs during the measurement.
The heights obtained in 2006 compared to the measurement results of 2005 enabled to define height differences between the control benchmarks. These differences range from -4.27 mm to -2.32 mm and point to a slight uniform subsistence of the fuel tanks. However, the size of displacements in 2005-2006 is almost twice as large as that of the 2004-2005 period. According to specialists, the size of vertical displacements of the spot foundation along with the tanks does not pose a direct threat to the safety of the fuel system and tanks operation.
Understandably, the results presented in the this study do not embrace all the experimental research that was done during the expeditions to Spitsbergen, organized by the Faculty of Geodesy and Cartography, the Warsaw University of Technology. Other research that can be named here includes a photogrammetric survey connected with the study of the dynamics of the Hans glacier toe, cooperation with Spanish polar explorers in radar tests of the Arie and Hans glaciers bedding thickness, compiling a planimetric and contour map of the Hornsund Station area, equipment calibration for magnetic measurements, etc.

6. REFERENCE

Adamek A., ***Geodezja ekstremalna (Extreme geodesy),*** **„Geodeta" Information Magazine, No. 12/2004.**

Cisak, J., Dabrowski S , (1990), ***Polish geodetic and cartographic studies in the Arctic and Antarctic regions,*** **Polish Polar Research, 11, 3-4, 1990.**

Czarnecki K., ***Geodezja współczesna w zarysie(Outline of Modern Geodesy),*** **Wiedza i Zycie Publishing House, Warsaw 1994.**

Jania J., ***Glacjologia (Glaciology),*** **PWN Scientific Publishers, Warsaw 1997.**

Kurczyński Z., ***Studenci przemierzają Arktykę (Polish students travel across the Arctic)*** **„Geodeta" Information Magazine, No. 10/2003.**

Pachuta A., ***Pierwsza wyprawa Wydz. GiK PW na Spitsbergen (The first expedition to Spitbergen by the Faculty of Geodesy and Cartography, the Warsaw University of Technology),*** **Przegląd Geodezyjny (Geodetic Review) 1989, No. 4-5 (18-21), Warsaw 1989.**

Pachuta A. , Pachuta K., Adamek A., Walo J., Wozniak M., Kurczynski Z., (2005): ***Zastosowanie metody GPS w badaniach polarnych na Spitsbergenie.*** **Materiały z konferencji „Geodeticke siete a priestorove informacie"(The application of a GPS method in polar research in Spitsbergen. Conference materials, Podbanske, 24-26 October 2005.**

Pałubski A..: ***Wyrównanie i analiza sieci punktów dla otoczenia fiordu Hornsund (Adjustment and analysis of the point network for the Hornsund Fiord area), The Cracow University of Mining and Metallurgy, C*****racow 2003.**