

SCIENTIFIC EXPEDITIONS TO ANTARCTIC AND SPITSBERGEN WITH THE PARTICIPATION OF SCIENTISTS FROM FACULTY OF GEODESY AND CARTOGRAPHY, THE WARSAW UNIVERSITY OF TECHNOLOGY (WUT)

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1. INTRODUCTION

Professor Czesław Kamela never has been in the Polar Regions, but he was a great advocate of the involvement of employees from Faculty Geodesy and Cartography of Warsaw University of Technology in polar research. Researchers from the Faculty of Geodesy and Cartography Warsaw University of Technology participated in the study of polar inland Spitsbergen and Antarctica. It worth to mention that the first geodesists involved in polar expedition were officers from the Military Geographic Institute – Sylweryusz Zagrajski and Antoni Rogala-Zawadzki (1934).

Below is given chronologically a list of the most important geodetic expeditions to Spitsbergen and Antarctic (primarily by students and staff of the Faculty of Geodesy and Cartography - WUT):

- 1934 – Sylweryusz Zagrajski, Antoni Rogala - Zawadzki – the Military Institute of Geography – first polish polar expedition to Spitsbergen;**
- 1957 – Jerzy Fellman, Jerzy Jasnorzewski, Cezary Lipert – the Spitsbergen expedition during the 3th International Geophysical Year;**
- 1958/1959 – Wojciech Krzemiński, Janusz Śledziński, Zbigniew Ząbek – Polish Polar Station name Antoni Bolesław Dobrowolski – Antarctic;**
- 1978/1979 – Andrzej Pachuta - Polish Polar Station name Antoni Bolesław Dobrowolski in Antarctic;**
- 1980 – Stanisław Dąbrowski, Seweryn Mroczek – summer Spitsbergen expedition - the Institute of Geophysics, the Polish Academy of Sciences (PAN);**
- 1984 – Jan Cisak, Szymon Barna – Spitsbergen expedition organized by the Institute of Geophysics of the Polish Academy of Sciences;**
- 1987 – Stanisław Dąbrowski, Zdzisław Kurczyński – Spitsbergen expedition - the Institute of Geophysics, the Polish Academy of Sciences (PAN);**
- 1988 – students and staff Faculty Geodesy and Cartography expedition – led by Andrzej Pachuta, scientific advisors – Ryszard Preuss, Artur Gustowski, Jarosław Kutyna, Dariusz Osuch, Piotr Wypych;**
- 2003 – Students Spitsbergen Expedition organized by Association of Polish Surveyors – 12 people – chaired by Artur Adamek, scientific advisor – Zdzisław Kurczyński;**

- 2004** – students and staff’s expedition to Spitsbergen of the Faculty of Geodesy and Cartography WUT, – led by Artur Adamek, scientific advisor – Marek Woźniak;
- 2005** - students and staff’s Spitsbergen expedition of the Faculty of Geodesy and Cartography, WUT – led by Kinga Węzka, Zbigniew Malinowski, Marcin Rajner, scientific advisor – Janusz Walo;
- 2006** - students and staff’s Spitsbergen expedition of the Faculty of Geodesy and Cartography WUT – led by Kinga Węzka, Dominik Próchniewicz, scientific advisor – Andrzej Pachuta;
- 2005/2006** – Artur Adamek - member of the Spitsbergen expedition of the Institute of Geophysics, the Polish Academy of Sciences;
- 2006/2007** – Marcin Rajner – member of the Spitsbergen expedition of the Institute of Geophysics, the Polish Academy of Sciences;
- 2008** - Artur Adamek, Kinga Węzka, Maciej Paśnikowski –students Spitsbergen expedition.

Below, there are selected projects carried out by staff and students of the Faculty of Geodesy and Cartography of the Warsaw University of Technology during polar expeditions.

2. SCIENTIFIC GEODETIC EXPEDITIONS TO SPITSBERGEN

The Svalbard Archipelago (Fig.1), with an area of 92 000 km² 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 km².

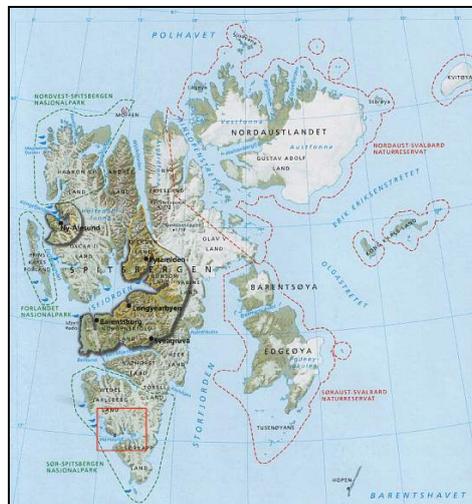


Fig. 1. The Svalbard Archipelago.

The history of geodetic involvement in Spitsbergen explorations dates back to 1934, when two officers of the Military Institute of Geography, A. Rogala-Zawadzki and S. Zagrajski took a part in a pioneering expedition (Zagrajski et al., 1936). The first employee of our department involved in the expedition to Spitsbergen was in 1957 Jerzy Fellmann, who later became a dean of the Faculty Geodesy and Cartography WUT. He took a part in geodetic exploration of a Werenskiold glacier face (Fellmann, 1982). In 1988, the first expedition from Faculty Geodesy and Cartography (WUT) involving stu-

dents was organized. The next one occurred almost 15 years later, as late as 2003, thanks to the initiative of the National Club of the Polish Geodesy Students affiliated with the Association of Polish Surveyors (Polish acronym SGP). The three expeditions that followed were the sole initiative of students and employees of the Faculty of Geodesy and Cartography (WUT). All the expeditions involving students were placed in the region of the Hornsund Fiord in the southern part of the island as the main area of exploration. In that fiord is located the Polish Polar Station owned by the Institute of Geophysics, PAN. The subject of geodetic research work, performed by exploration organizers or co-organizers from the Faculty of Geodesy and Cartography (WUT), covered, among others: glacier movements, geodynamic investigation around the Hornsund Fiord, monitoring fuel tanks subsidence, compiling planimetric and contour maps of the Hornsund station area, analysis of observation results from the newly established permanent GPS station (Pachuta et al., 2007).

2.1. Investigation of the Hans Glacier dynamics

Spitsbergen's nature is characterized by extreme variability of its atmospheric conditions. The main task of our polar expeditions to Spitsbergen was to carry out a 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 km². The glacier tongue is up to 2.5 km wide and finishes with the calving glacier toe of 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 recognized and monitored Arctic glaciers.

The traditional method of glacier movements investigations 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. These 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.

Observations of ablation staffs placed along the longitudinal profile were executed by the GPS quick static and RTK methods. The measurement analysis reveals changes in the direction of the 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) on the height of the fourth ablation staff. In 2005 and 2006, three RTK measurements were performed on the new, especially placed ablation staffs.

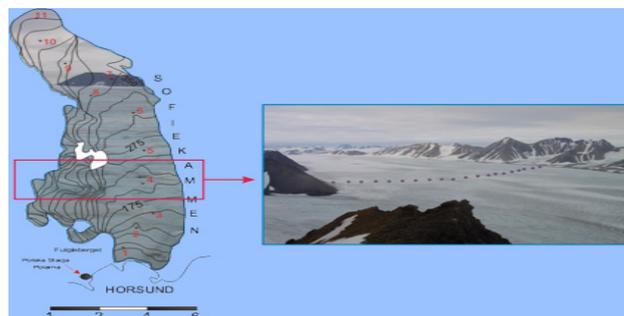


Fig. 4. Longitudinal and crosswise profiles.

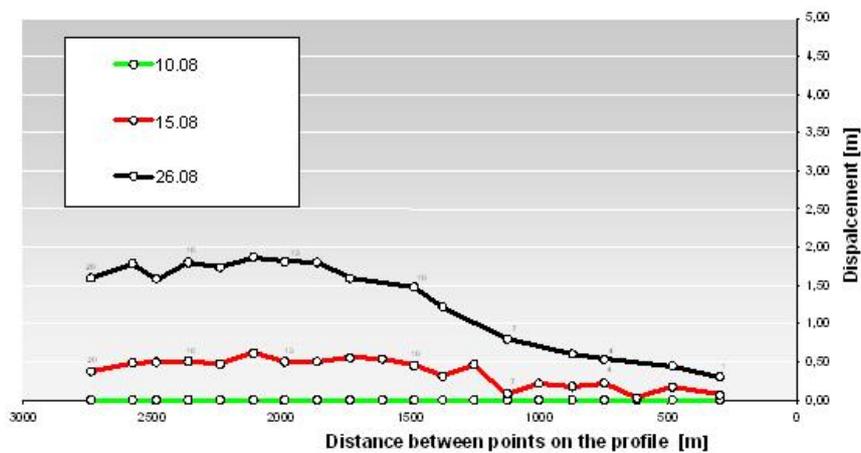


Fig. 5. Displacement of points on the crosswise profile in 2005.

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 executed 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 m (Fig.6), which may reveal a tendency for the glacier to change its ice volume.

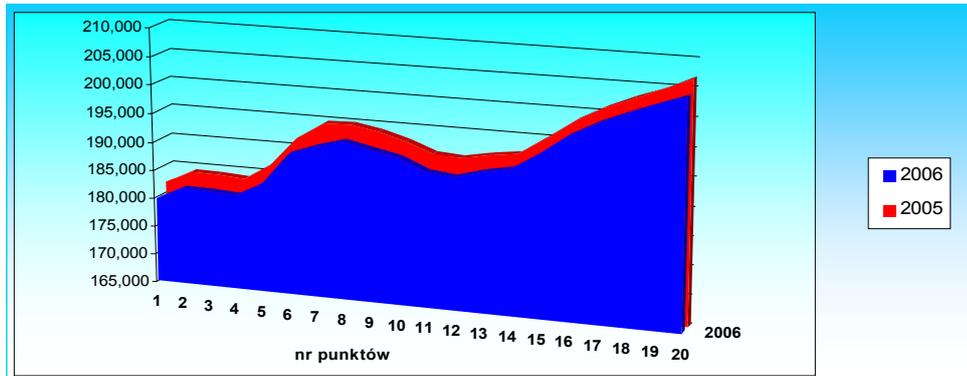


Fig. 6. Changes in the bedding thickness of the Hans Glacier.

2.2. 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 equal to 20 km. In 1988, classical geodetic measurements were performed (distances measured with a Wild Di20 telemeter and angles with a Wild T2 theodolite). During the three last expeditions (2003, 2005 and 2006) such kind of measurements were repeated by means of the 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 measurement 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 coefficients 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 observed network was tied up with the ASTR point, the coefficients of which had been determined earlier in the ITFR system for the moment of 2000.00. On the basis of geocentric coefficients crosswise lengths were determined between network points for the measurement 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.

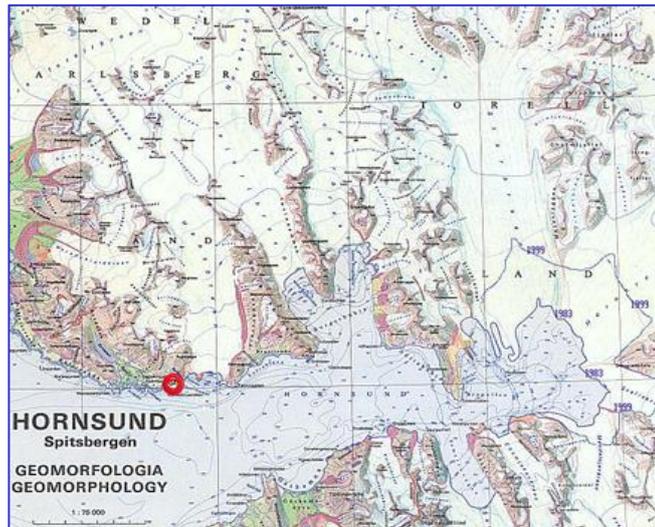


Fig. 7. Geodynamic testing network.

2.3. 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 Dr. 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 GPS satellite observations, the same processing strategy applied for each observation day. The calculations were performed 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.

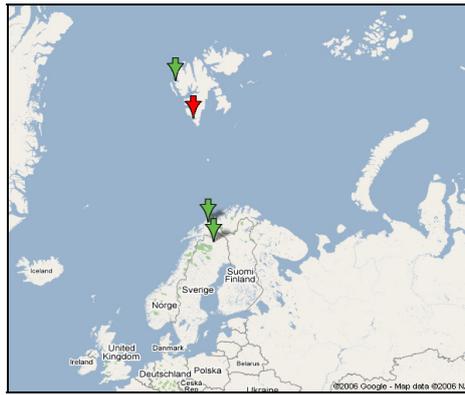


Fig. 9. Location of IGS and ASTRO stations (Source: Google Map).

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 say 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.

2.4. Studies of 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 were always performed 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 determination 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.

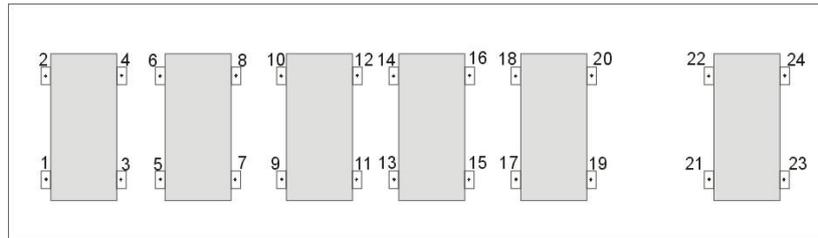


Fig. 9. Positions of benchmarks on the spot foundation of fuel tanks.

Observations in 2006 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 error of benchmark heights determination 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 mechanics specialists, the size of such 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 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 investigations 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.

3. GEODETIC INVESTIGATIONS IN ANTARCTIS

In Antarctica, an area which has about 14 million km, only 0.3% from areas is free of ice. The largest ice-free areas have named oases. Of the dozen or so hotspots on the continent is the largest oasis located in Antarctica name Bunger. Oasis has been discovered by an American pilot Bunger in 1948. Since 1958 in this part of Antarctic is located Polish polar station name Antoni Bolesław Dobrowolski.

3. 1. Determination of gravity acceleration on the A. B. Dobrowolski Station in Bunger Oasis

In 1958/1959 was organized the first Polish Antarctic Expedition to the Bunger Oasis. The leader this was geodesist ass. prof. Wojciech Krzeminski from Institute Geodesy and Cartography. In this expedition also took a part two young scientists from the Faculty of Geodesy and Cartography Warsaw University of Technology - Zbigniew Ząbek and Janusz Śledziński. The most important objective scientific expedition was to determine the gravity acceleration at the point of the gravimetric station AB Dobrowolski.

The value of gravity was defined by a four-pendulum apparatus of Askania – Werke mark at that time. This value was transformed from the main gravimetric point located in Warsaw University of Technology. The pendulum gravimetric point was established in the vestibule of seismic pavilion on A.B. Dobrowolski polar Station (Ząbek, Śledziński, 1960).

3. 2. Gravimetric investigations in Bunger Oasis during expedition in 1978/79

The first independent Polish expedition to the Antarctic set sail from Gdynia Polish ship names *Zawichost* on 19/11/1978 year. Like mentioned expedition in 1959 led the ass. prof. Wojciech Krzeminski from the Institute of Geodesy and Cartography in Warsaw. Among the 14 teams took part in a personal five surveyors. Besides Wojciech Krzeminski they were Seweryn Mroczek and Jan Cisak from the Institute of Geodesy and Cartography, Zbigniew Battke from Polish Army, and Andrzej Pachuta from Warsaw University of Technology. For the study of gravity during this trip was responsible Andrzej Pachuta. The scientific program of the expedition to the Polish Station Dobrowolski in Bunger Oasis in 1978/79 included a reconnaissance surface gravimetric survey of the Station surroundings. The research program expected an use of pendulum data collected by Z. Ząbek and J. Śledziński in 1959 during the First Polish Antarctic Expedition to Dobrowolski Station (Ząbek, Śledziński, 1960). The geodetic network was installed, the elements of which (angles and distances) were determined by a polar method – distances with EOK 2000 and angles with theodolite Wild T2. Altitudes of points were determined with the use of technical or trigonometric leveling. Differences of gravity were measured with the quartz gravimeter Sharpe CG-2 No. 156. The factor (constant) k of the instrument was estimated at Mirnyj station by the tilt method with the use of the apparatus constructed on the base of the theodolite Wild T-4 in Institute of Higher Geodesy and Geodetic Astronomy of Warsaw University of Technology. A geodetic network was set up in the area of about 4 km^2 , composing of 26 points. The gravimetric reductions were introduced to measured values of gravity. Density of subsurface parts of the Earth's crust was evaluated by the Nettleton's method. Free-air and Bouguer's anomalies were obtained and the maps of adequate anomalies were prepared on this ground (Pachuta, 1980). A thickness of the Earth's crust was evaluated by application of Woolard theory and formulae for Bunger Oasis. The Mohorovičić discontinuity occurs there at the depth of about 26 km.

4. CONCLUSIONS

Participation of the Polish surveyors in the study of polar regions is very large. The most active center in this regard is the Faculty of Geodesy and Cartography of the Warsaw University of Technology. In recent years, measurement technologies have changed in comparison to the first works performed in 20 century, but did not change the objective cognitive tests conducted by the surveyors. Surveyors run their own projects but also perform surveying services for representatives of other fields of knowledge. Young geodetic active staff is the guarantor of the continuation of the polar regions studies.

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