International Council for Science

SCAR report

No 20
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SCIENTIFIC COMMITTEE ON ANTARCTIC RESEARCH

at the

Scott Polar Research Institute, Cambridge, United Kingdom

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Report of the

SECOND ANTARCTIC GEODESY SYMPOSIUM 1999

Warsaw, Poland, 14–16 July, 1999

INTRODUCTION

This second SCAR Antarctic Geodesy Symposium was held at the Scientific Centre of Polish Academy of Sciences, Warsaw. It was attended by up to 30 participants, which included representatives of ten SCAR countries. (See list of attendees below)

Professor Linsenbarth hosted a reception for participants at the Instytut Geodezji i Kartografii followed by a technical tour of the facilities.

The program was a blend of background of Polish Antarctic activities related to Geodesy. This included Professor Guterch who also outlined Arctic activities, Professor Birkenmajer with a history of Polish Polar research including his extensive work in the Antarctic peninsula and with Geographical names for geological mapping in the area. Professor Sledzinski outlined his experiences with the 1958 expedition to Dobrowolski in the Bunger Hills including his pendulum absolute gravity observations at that site.

The program continued with presentations on the recent geodetic activities in Antarctica and a proposal for Physical Geodesy Database (Dr Alessandro Capra) and an impressive Internet distributed GIS system for Antarctica (Nengchen Chen, China). Of particular note was the attendance of Dr Alexander Yuskevitch the new Russian representative to the SCAR WG-GGI replacing Dr Soudakov.

Participants gave an indication of their plans for activities for the next summer season 1999/2000.

The second day presentations were rounded of with a technical tour to the Borowa Gora fundamental geodetic observatory where a prototype portable Absolute Gravity meter was demonstrated by Dr Zanimonskiy. A Polish barbecue followed an impressive display of the new JAVAD GLONASS/GPS receiver in the evening.

It was a very successful event well hosted by the Polish Institute of Geodesy and Cartography.

Whilst every effort has been made to secure the final versions of the papers presented at AGS99 there were a number which could not be provided. Where this is the case we have published the abstract provided to us before the Symposium.

John Manning, Convenor
GIANT

Polish Polar Research (an outline)

Krzysztof Birkenmajer

Institute of Geological Sciences (Cracow Research Centre), Polish Academy of Sciences, Senacka 3, 31-002 Kraków, Poland

Introduction

Polish scientific exploration of the Arctic started in the 19th century, long before Poland regained its independence in 1918. Several generations of Polish scientists — imprisoned by tzarist oppressors for their patriotic activities and deported to Siberia, especially after unsuccessful upsurges of 1830–31 and 1863, contributed enormously to geographical discoveries and pioneered biological and geological research in the Siberian Arctic and Subarctic. Earth scientists, Aleksander Czekanowski (1833–1876) and Jan Czerski (1845–1892), should be listed among the most famous.

Polish Antarctic tradition goes back to the participation of Henryk Arctowski (1871–1958) and Antoni Boleslaw Dobrowolski (1872–1954) in the famous Belgian Expedition in *Belgica* to West Antarctica (1897–1899) led by Adrien de Gerlache de Gomery. H. Arctowski, a geophysicist and geologist, was in charge of the expedition's scientific program, A. B. Dobrowolski, then a university student, was first employed as a sailor, later – during wintering in Antarctica, turned meteorologist and specialist on snow and ice.

Arctic

Expeditions to Svalbard, 1932–1938

Four Polish expeditions were sent to Svalbard in the Arctic prior to World War II. The first was organized by J. Lugeon, director of the State Meteorological Institute in Warsaw, to Bear Island (Björnöya), in connection with the 2nd Polar Year (1932–1933). Its program included research in meteorology, geomagnetism, aurora borealis, solar radiation and radio noise. The expedition consisted of five men, three of whom, led by C. Centkiewicz, stayed for the wintering.

Experience gained on Bear Island helped to organize in 1934 the first Spitsbergen expedition of seven men (leader S. Bernadzikiewicz) by the Polish Mountaineering Club. Scientific tasks of the 2-month long summer expedition to north-west Torell Land included: trigonometric and photogrammetric surveys, geological studies, botanic and ornithological observations. During theexpedition, S. Zagrajski and A. Zawadzki prepared a detailed topographic map, 1:50,000 scale, covering some 500 square kms, which was used by S. Z. Rozycki as a base for his geological and periglacial studies. His geological monograph of the area (published in 1959) is among classic pieces of geological studies of Svalbard. Numerous peaks were climbed for the first time.

The 1936 expedition to Spitsbergen was an adventurous one. A three-man party Bernadzikiewicz, K. Jodko-Narkiewicz and S. Siedlecki) crossed the island on skis from south to north in six weeks, covering a distance of more than 800 kms. Although no scientific research was made, two of the expedition members, already veterans of the previous Polish expeditions to Svalbard, gained further experience, invaluable for future Polish exploration in the Arctic.

The 4-man expedition to Oscar II Land, north-west Spitsbergen, in 1938 (leader S. Bernadzikiewicz) studied glaciology and geomorphology along eastern coast of Forlandsundet from a summer camp at Kaffiöyra. The most important scientific result was a geomorphological monograph of the area by M. Klimaszewski (published in 1960).

Expedition to West Greenland, 1937

The 7-man expedition to West Greenland (leader A. Kosiba) lasted for three summer months in the area of Arfersiorfik. They carried out photogrammetrical survey, meteorological observations, glaciological, geological, geomorphological and botanic studies.

IIIrd IGY/IGC expeditions to Spitsbergen, 1956–1962

Polish expeditions to Spitsbergen were resumed in connection with the IIIrd International Geophysical Year (IGY: 1957–1958), and continued during the International Geophysical Co-operation (IGC: 1959–1960). The expeditions were sponsored by the Polish Academy of Sciences (PAS). In 1957, a scientific station was built at Isbjörnhamna, Hornsund, south Spitsbergen, which provides a permanent base for Polish expeditions to this day. The leader of the expeditions was S. Siedlecki, a geologist – a veteran of the Polish expeditions to Bear Island (1932–3), Spitsbergen (1934, 1936) and West Greenland (1937).

During six seasons: 1956 (summer, 5 men); 1957–1960 (four summer expeditions, 25–36 participants); 1957/8 (wintering, 10 men); 1962 (summer, 3 men), scientific investigations were carried out mainly around Hornsund, in Wedel Jarlsberg Land, Torell Land and Sörkapp Land, moreover at Van Keulenfjorden (central Spitsbergen). They included: meteorology; geomagnetism; aurora borealis; ionospheric studies; ozone measurements; radioactivity of atmospheric fall-out; geodetic survey; astronomic observations; limnology; oceanography; botany and zoology; glaciology (leader A. Kosiba); geomorphology and periglacial studies (leaders J. Dylik and A. Jahn); geology and palaeontology (leader K. Birkenmajer). More than 300 original scientific papers were published as a result of these expeditions. The geological studies included i.a. geological mapping to 1:50,000 scale of about 800 square kms in Wedel Jarlsberg Land, Torell Land and Sörkapp Land – a direct continuation of S. Z. Rozycki's work from 1934. In 1960, the Polish station hosted scientific excursions of the International Geological Congress (Copenhagen) and the International Geographical Congress (Stockholm).

Poles in Norwegian expeditions to Svalbard, 1962–1990

Several Polish Earth scientists (4 geologists and 1 geomorphologist) participated in the expeditions of the Norwegian Polar Institute to south and central Spitsbergen (between Sörkapp Land and Van Keulenfjorden) and Bear Island, as leaders or members of field parties, in 1962, 1964, 1965, 1966, 1970 and 1990.

Expeditions to Spitsbergen, 1970 to present

After a 10-year break, summer scientific expeditions to the Polish Station at Isbjörnhamna, Hornsund, were resumed. Sponsored by the Polish National Committee on Geodesy and Geophysics, PAS, they were organized by the Wroclaw University in co-operation with the Institute of Geophysics, PAS, from 1970 to 1974 under leadership of S. Baranowski. The scientific research included mainly climatology, glaciology and glacial seismology, geomorphology and periglacial studies, but also geology and palaeontology, zoology and botany, mainly around Hornsund, partly also in Isfjorden. The expeditions of 1974 and 1975 were organized jointly with the institutes of Palaeozoology and of Geological Sciences, PAS (co-leaders G. Biernat and K. Birkenmajer).

In 1978, the Polish Station at Isbjörnhamna was renovated by an expedition of the Institute of Geophysics, PAS (leader J. Szupryczynski). Since then, scientific research is carried at the station on a yearly basis (base commander S. M. Zalewski). It includes mainly geophysical observations (seismicity, Earth magnetism, climatology, glaciology), but also geology and paleontology, geomorphology and periglacial studies, zoology and botany, special environmental research, oceanology etc.

Two Polish summer field stations are in operation in the Hornsund area: the Baranowski Glaciological Station at Werenskiolldbreen, and the Paleontology Hut at Treskelen.

Numerous, separate research expeditions using, at least partly, logistic support of the Polish Scientific Station at Isbjörnhamna, were organized since 1978 by the Institute of Geological Sciences PAS (leader K. Birkenmajer) and the Institute of Palaeobiology, PAS (leaders G. Biernat and H. Szaniawski), the Jagiellonian University, Cracow (leader Z. Czeppe), the universities of Wroclaw (leaders A. Jahn and J. Pereyma) and Silesia (leader M. Pulina), the Academy of Mining and Metallurgy in Cracow (leaders J. Chrzastowski and A. Manecki), the Association of Polish Geodesists (leader C. Lipert), and others.

The University of Torun resumed in 1975, during summer months, glaciological, climatological, hydrological and geomorphological research (leaders J. Szupryczy_ski and G. Wojcik) in Oscar II Land (NW Spitsbergen) at Kaffiöyra – site of the Polish 1938 expedition. Since 1995, their own small station at Kaffiöyra is being used on a yearly basis (leader M. Grzes).

Since 1978, geomorphological and glaciological research has been carried out during summer in central Spitsbergen by the universities of Warsaw (in western part of Nordenskiöld Land, leader A. Musial), Poznan (in inner Isfjorden, leader W. Stankowski), and Lublin (Bellsund and NW Wedel Jarlsberg Land, leader K. Pekala). An important component of these studies is a detailed geodetic/topographic survey of selected areas.

Oceanographic and oceanobiological research was carried out by marine expeditions to south Spitsbergen (mainly Hornsund) in 1977, 1979, 1980 and 1981, organized by the Gdansk University and the Maritime Academy in Gdynia. Training courses in oceanography were carried out by an expedition to Bellsund in 1977, organized by the Maritime Academy and the Academy of Agriculture in Szczecin.

Poland–USA scientific co-operation in Spitsbergen, 1974–1979

A joint research program of the Institute of Geophysics, PAS, and the University of St Louis (USA), concerned palaeomagnetism of Spitsbergen rocks, and seismology. The field work was carried out at Hornsund (1974: leader K. Birkenmajer), Agardhbukta (1977: leader Birkenmajer) and at Isfjorden (1979: leader M. Jelenska).

Geophysical expeditions in 1976 and 1978 on board R/V *Kopernik* (leader A. Guterch), carried out deep seismic sounding of the Earth's crust along western Spitsbergen shelf and adjoining part of Greenland Sea. Institute of Geophysics, PAS (in co-operation with the Geophysical Enterprise in Torun, Poland), and the universities of St Louis (USA), Bergen (Norway) and Hamburg (FRG) were the participants.

Expeditions to Iceland, 1968–1972

Two scientific expeditions, organized by the Geographical Society of Poland in 1968 (leader R. Galon), and by the Lodz University in 1972 (leader S. Jewtuchowicz), have initiated Polish glaciological and geomorphological research in southern part of Iceland. More research and student expeditions followed.

Jan Mayen, Greenland, Alaska, Arctic Canada and Siberia

A brief volcanological study, following eruption of the Beerenberg volcano on Jan Mayen in 1970, was carried out by K. Birkenmajer. He was also one of leaders of geological mapping parties during the Danish NorthEast Greenland expeditions of 1971 and 1976.

In 1973, an expedition from the Wroclaw University (leader J. Cegla) studied geomorphology and periglacial phenomena in Nordre Isortoq, West Greenland, close to the work area of the Polish 1937 expedition.

It should be added that geomorphology and periglacial phenomena were studied individually or within programs of foreign expeditions or institutions in Alaska (by A. Jahn), Arctic Canada (by R. Gajda and A. Jahn), North Norway and Siberia (by A. Jahn), and Kola Peninsula (by K. Pekala and co-workers); geological mapping was carried out by A. Siedlecka and S. Siedlecki on Varanger Peninsula, North Norway; botanic studies in Canadian Arctic by M. Kuc included living and subfossil mosses.

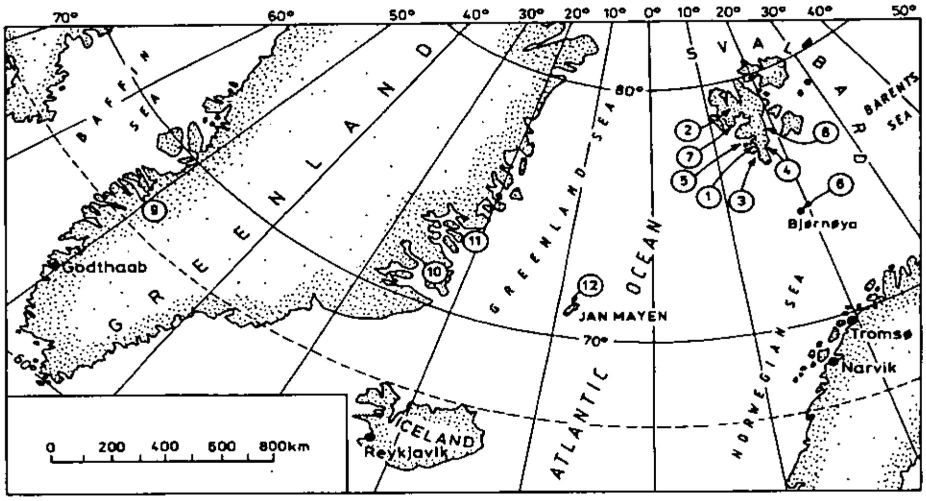

Figure 1. Main areas of Polish scientific research in the Arctic (north of Polar Circle). 1 – W Torell Land; 2 – Oscar II Land; 3 – Hornsund; 4 – E Torell Land; 5 – Bellsund; 6 – Bear Island (Björnöya); 7 – Isfjorden; 8 – Agardhbukta; 9 – Arfersiorfik; 10 – Scoresby Land and Jameson Land; 11 – Kong Oscars Fjord – Clavering Ö; 12 – Jan Mayen

Antarctic

East Antarctica: Bunger Hills expeditions, 1957–1979

The first Polish expedition to Antarctica organized by the Polish Academy of Sciences (PAS) took place during the Austral summer 1958–59 (7 participants, leader W. Krzeminski). On agreement between the Soviet and the Polish Academies of Sciences, the expedition took over the Soviet Oazis Station at Bunger Hills (Knox Coast) in January, 1959, and renamed it the A. B. Dobrowolski Station.

The expedition carried out a time-limited research program in gravimetry, Quaternary geomorphology and geology.

Between 1959 and 1979 no Polish expeditions to the Dobrowolski Station were organized. The station was, however, visited by Polish scientists – members of the Soviet Antarctic expeditions. Individual Polish scientists and scientific teams did also winter in Antarctica at the Soviet Base Molodezhnaya.

The second expedition of 14 men to the Dobrowolski Station in 1978/79 (leader W. Krzeminski), carried out investigations in meteorology and climatology, glaciology, geomorphology and Quaternary geology, moreover astronomical, gravimetric and magnetic observations, and geodetic-photogrammetric survey. Since then, the station has been inactive.

West Antarctica: oceanobiological expeditions, 1974–1976

Three oceanobiological expeditions to Antarctic seas on board Polish research vessels were organized between 1974 and 1976: the reconnaissance cruise in 1974 (R/V *Profesor Siedlecki*) was organized by the Sea Fisheries Institute (SFI), Gdynia; the main expeditions of 1975 and 1976 – by the Institute of Ecology, PAS, in cooperation with the SFI and the Academy of Agriculture in Szczecin. Since 1976, the Polish fishing fleets (fishing companies: *Odra, Dalmor* and *Gryf*) have been operating in the Atlantic sector of Antarctic waters, south of the convergence

West Antarctica: expeditions to King George Island, 1977 to present

In 1977, a second Polish scientific Antarctic station – the H. Arctowski Station at Admiralty Bay, King George Island (South Shetland Islands) was built by an expedition sent by the Institute of Ecology, PAS (leader S. Rakusa-Suszczewski). Since then, the station has been operating on a yearly basis, carrying out a variety of scientific research which includes, i.a.: meteorology and climatology; oceanography and oceanobiology; limnology; terrestrial and marine biota; geomorphology; geology and palaeontology (leader K. Birkenmajer); geodetic and photogrammetric surveys; seismicity and Earth's magnetism. Several institutes of the Polish Academy of Sciences (I. of Ecology; I. of Geological Sciences; of Palaeobiology; I. of Geophysics; I. of Parasitology), the universities of Lodz, Szczecin, Gdansk, Poznan, Warsaw, Bialystok and Cracow, and many scientific institutions at home and abroad cooperate with the station in joint research programs.

West Antarctica: BIOMASS (1981–1987) and ASIZ (1988/9) expeditions

Poland took an active role in the international research project BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks), organizing three expeditions on board R/V *Profesor Siedlecki* to West Antarctic seas, mainly Bransfield Strait, Drake Passage and Scotia Sea: in 1981 (leaders S. Rakusa-Suszczewski and P. Bykowski); in 1983/4 (leaders S. Rakusa-Suszczewski and P. Bykowski); and in 1986/7 (leader S Rakusa - Suszczewski). The fourth expedition on board the same research vessel in 19898/9 (leader S. Radusa- Suszczewski), organized as part of an international research project ASIZ (Antarctic Sea-Ice Zone), worked in the northern part of Weddell Sea.

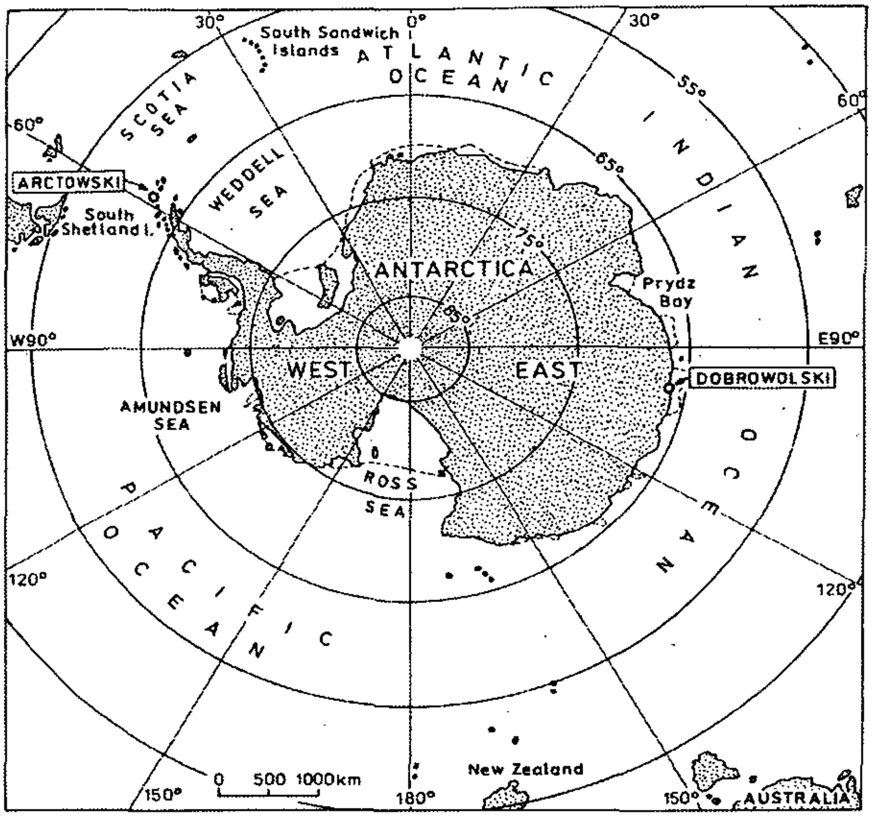

Figure 2. Location of the Polish scientific stations in Antarctica: A. B. Dobrowolski Station (Bunger Hills) and H. Arctowski Station (King George Island)

West Antarctica: geodynamic expeditions, 1979–91

Four marine geodynamic expeditions on board Polish ships were organized by the Institute of Geophysics, PAS (leader A. Guterch). A wide area along west coast of Antarctic Peninsula, between Drake Passage in the north and Adelaide Island in the south, including offshore islands (South Shetlands, Palmer and Biscoe archipelagoes, and Adelaide Island) was surveyed. Deep seismic sounding of the Earth's crust was carried out mainly along transects between Drake Passage and Antarctic Peninsula, crossing Bransfield Strait, several deep-seismic transects were also surveyed farther south, particularly along Gerlache Strait, and between Bismarck Strait and Marguerite Bay.

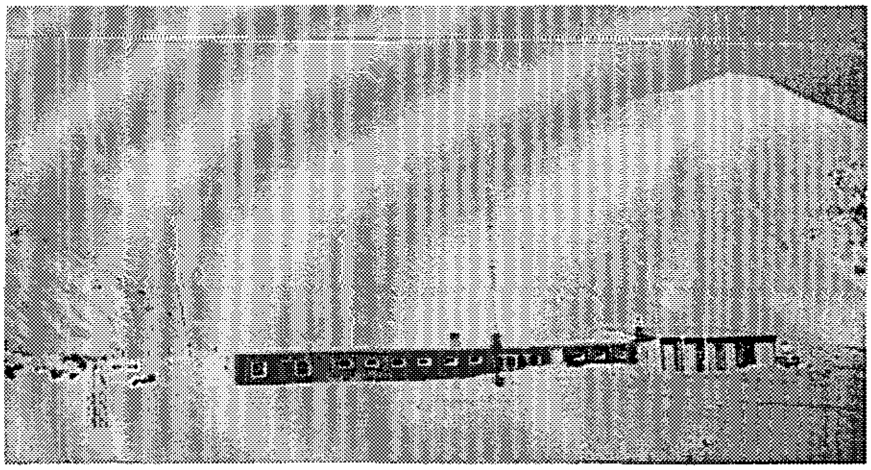

Figure 3. Polish station in Hornsund Fiord

Geological and palaeontological studies (leader K. Birkenmajer) during these expeditions were carried out at many land sites along Antarctic Peninsula (Hope Bay, Paradise Harbour, Adelaide Island), and in the South Shetland Islands (King George Island, Deception Island). Joint Argentine–Polish geological and palaeontological studies on Seymour (Marambio) and Cockburn islands, NE Antarctic Peninsula, were carried out in 1985/6, 1987/8, 1991/2 and 1993/4. A joint project of Brazil and Poland (1984) included study of Tertiary glacial deposits on King George Island.

Selected bibliography

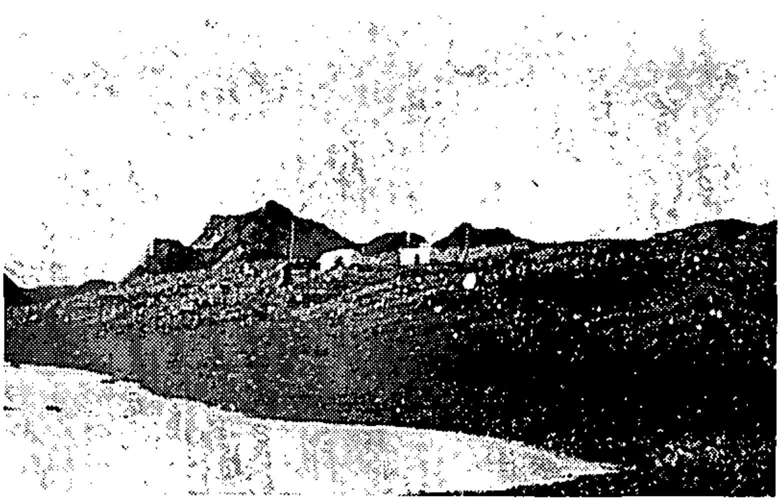

Figure 4. A. B. Dobrowolski Station (Bunger Hils)

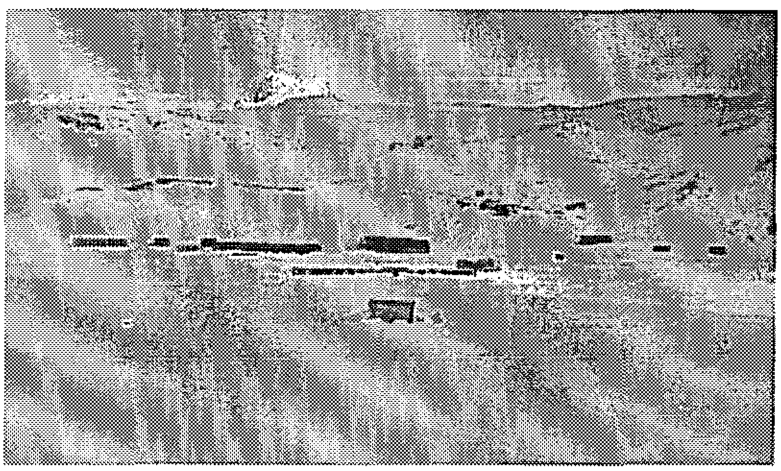

Figure 5. H. Arctowski Station (King George Island)

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A Project for Archiving and Managing Physical Geodesy Data in Antarctica

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[(2)]DISTART - University of Bologna (ITALY)

Abstract

Within the activities of WGGGI (Working Group on Geodesy and Geographic Information) of SCAR (Scientific Committee on Antarctic Research), a "Physical Geodesy" project was planned for the period 1998-2000.

To now a geoid map of Antarctica has been produced by AUSLIG (Australia) showing the geoid-ellipsoid separation between GRS80 and OSU89A. Researchers from different countries have tried to compute a new local and regional high-resolution geoid. The goal of the Physical Geodesy project is the collection and the analysis of data useful for the development of a new high resolution geoid for most of Antarctica. The first phase, the extensive collection of information and data related to geodesy, topography, bathymetry and gravity, was activated in collaboration with Institutions and Specialists Group (BEDMAP, ADGRAV, ADMAP and RAMP).

In order to produce a correct data archiving and management, useful for successive geoid computation, a preliminary plan of DBMS (Data Base Management System) is presented.

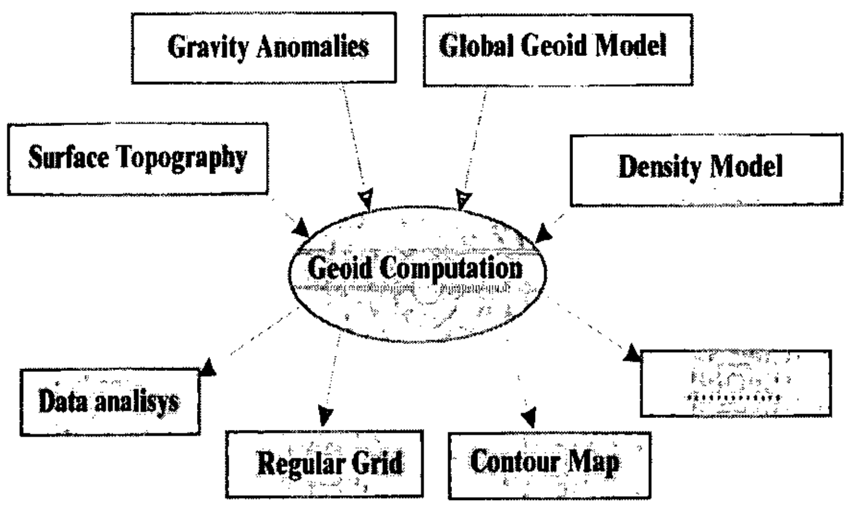

Figure 1. Scheme of Physical Geodesy Program

1 Introduction

A new high resolution geoid has to be obtained starting from a global model of geoid and corrected by the use of geodetic, gravimetric measurements and density model (Figure 1).

The scheme shown in figure 1 represents a classical approach for Gravimetric geoid computation (Barzaghi R., et al. 1993; Reigberg C. 1989; Rapp R.H. et al. 1994; Rapp R.H. 1989; Moritz H., Heiskanen W.A 1967). The uniqueness of the Antarctic continent presents some peculiarities from the point of view of measurement methodologies and instruments. Surface topography determination (DEM generation) has been performed mainly through satellite altimetry surveys due to the poor coverage of classical and other space geodesy techniques, overall for the inner part of Antarctica (generally satellite altimeter is used for sea surface determination in physical geodesy approach).

Moreover density model computation needs for ice thickness determination by the comparison of surface topography and bedrock surface (trough Radio Echo Sounding – RES profiles). The ice thickness variation change locally and in time so it is necessary to take into account also the repetition of surface determination.

The opportunity to undertake this project is strongly connected to the contributions of researchers from different countries who worked on geodesy, geophysics and geology in Antarctica. However, data collection has to be clear and simple for scientists to contribute data. In order to organize different kindd of data, the realization of a Data Base Management System would be the best solution. However gravimetric and topographic measurements show different characteristics, so it is necessary to plan two different DBMS.

A preliminary DBMS was prepared using Microsoft Access for Windows 95, but other software will be studied that may enable the management of a greater quantity of data with stronger facilities.

2 DBMS for Geodetic data.

Several countries and research groups have performed a large number of topographic, gravimetric and tide gauge observations, therefore the first problem is how to collect and organize those data. The data, acquired with different methodologies and generally in different reference systems, must be transformed in the same DATUM in order to perform an homogeneous datasheet.

In Antarctica ice-thickness is changing relatively quickly for many reasons (primarily ice movement and melting), therefore ice topography should be computed periodically.

Regarding this point a closed data exchange should be made with BEDMAP (Bedrock Map Antarctica Project) and RAMP (Radarsat Antarctic Mapping Program).

The DBMS could allow easier data archiving and correct data analysis to establish the level of desired accuracy for high precision topography determination.

The DBMS for geodetic measurements in Antarctica requires some special treatment compared with other kind of DBMS for Geodesy for the following reasons:

1 the atmospheric, climatic and morphologic conditions restrict the taking of classical measurements, especially in the inner part of the Antarctic Continent;
2 space geodesy will constitute the greater part of data;
3 despite of the above consideration, some classical observation will be considered in particular in region close to tide gauges.

Taking into account the above, only some typology of data are available: GPS data (Static - DGPS - Kinematic); DORIS; SAR; Satellite Altimetry; Tide Gauge. Some typology of data are generally not available: Spirit Levelling, SLR and VLBI.

In Fig.2 a scheme of the DBMS for geodesy is shown, showing that each measurement campaign datasheet must be coupled with a Form (Main Form + Sub Form) as Identity Card of the Survey

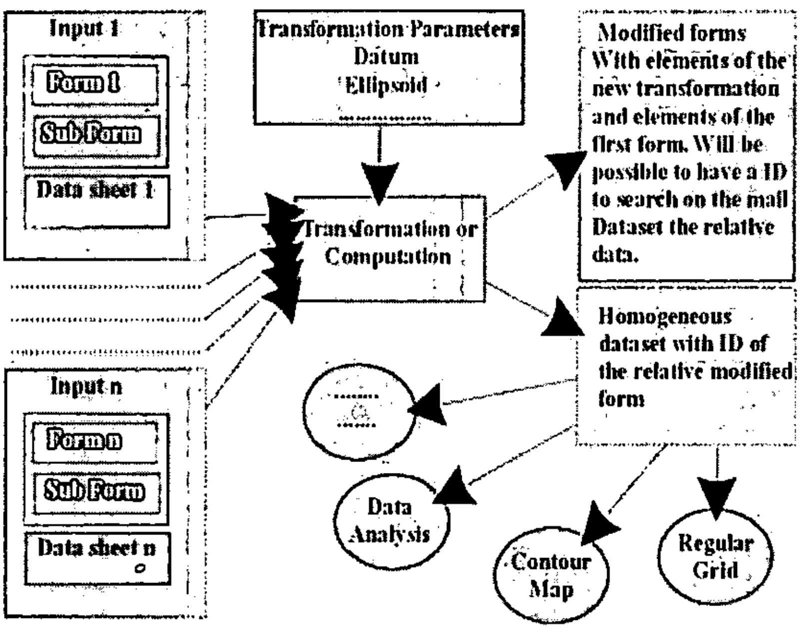

Figure 2. Main Scheme of the DBMS for Geodesy

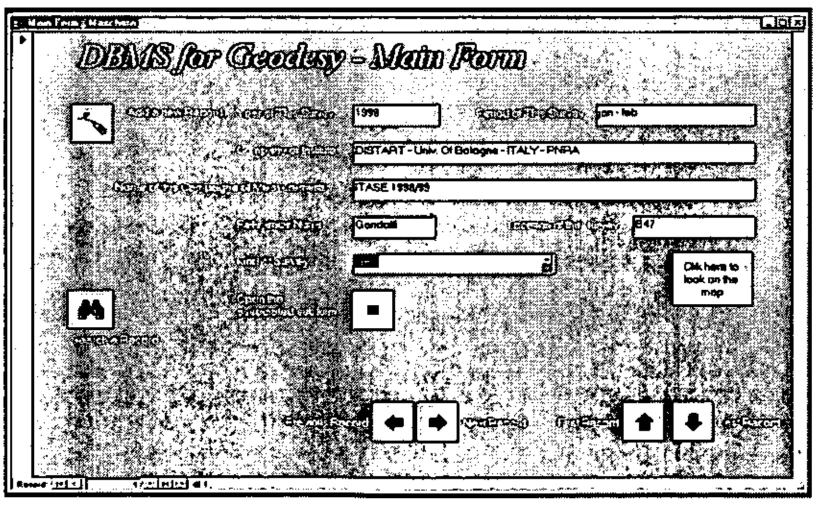

Figure 3. Example of the Main Form

The Main Form (Fig. 3) illustrates some information on Company, Year, Reference, Name of Survey, Location or Region appear. For each kind of survey a particular "Sub Form" permits better understanding of modality, instrumentation, software, reference frame and every kind of information relative to the datasheet. This is only a user facility because the table of the general data contains all the fields of every kind of survey and some of these will be filled. When some data-sets are input, in itsown reference frame, it will be possible to generate a homogeneous data set using transformation parameters and to create an associated table form containing the "history" of each data-set.

The new table has to contain the initial form, the new reference frame and the transformation parameters associated. When this step is concluded, it is possible to produce regular grid, contour map, data analysis etc..

For a faster selection for local data integration and processing, the Antarctic continent should be divided in sectors to enable each survey to be classified with an associated label of the sector where the survey has been performed. This piece of information should be inserted manually or produced automatically starting from coordinates of input points.

In order to divide coastal regions of Antarctica into sectors, an INDEX map of the 24 planned 1:1.000.000 scale coastal change and glaciological USGS Antarctica Maps should be used. For the inner regions of the continent the limits in longitude of each map tracked to the geographic pole should be used.

Another criteria should be obtained furnishing the division adopted by BAS (British Antarctic Survey) to produce the ADD (Antarctic Digital Database) (Fig 4).

A third criteria should be the selection of sectors delimited in Longitude (10 degrees of amplitude) and in three strips: 60° - 70°, 70° - 80°, 80° - 90° of Latitude South.

Input data is available manually by user or automatically by file (eg. CSV, TXT, XLS, etc.). For Latitude and Longitude only a fixed format was adopted (eg. sexadecimal F13.10)

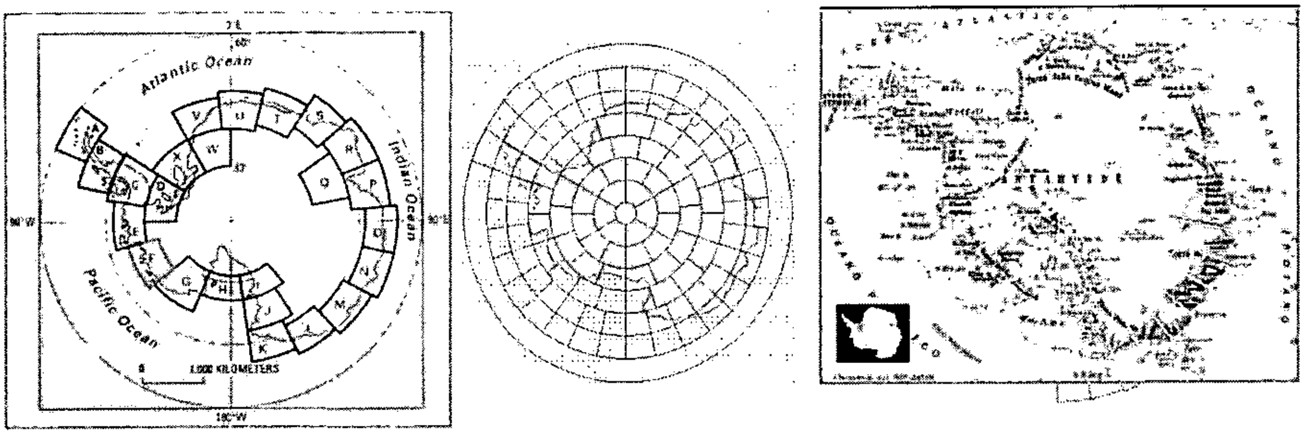

Figure 4. Example of sector sub-division of Antarctica. The map on the left is the sub-division utilized by USGS, on center the sub-division adopted by BAS and on the right another suggested sub-division.

3 DBMS for Gravimetry.

Some consideration and property of DBMS for Geodesy were applied also for DBMS for Gravimetry. Airborne gravimetry, ground gravimetry and satellite gravimetry are considered. At the moment only a first scheme has been drafted and work is still in progress.

4 Data collection

At present the most considerable gap in information relates to gravimetric observation. The Antarctic airborne gravimetry database is in progress (see ADGRAV Project). A collection of information on gravimetric absolute measurements has been made in GIANT Program (Geodetic Infrastructure of Antarctica) of SCAR WGGGI.

Geodetic and Tide Gauge observations are also collected by GIANT and for the most part are already available.

The information for the surface elevation are goals of data set projects like RAMP. While the ice bed elevation model is a goal BEDMAP Project. Within RAMP the Bird Polar Research Centre (BPRC) has created a DEM of the whole of Antarctica. Within BEDMAP, a new topographic model of the bed of the Antarctic ice sheet will be developed, allowing ice thickness determination.

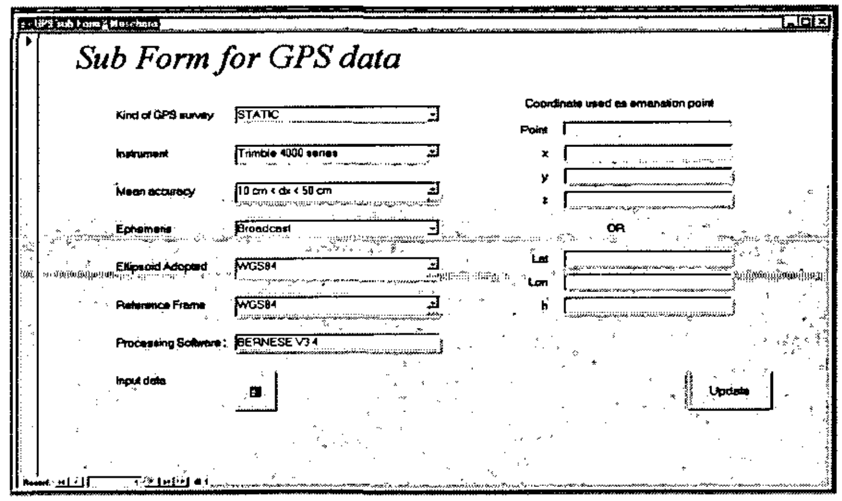

Figure 5. Example of GPS data Sub Form

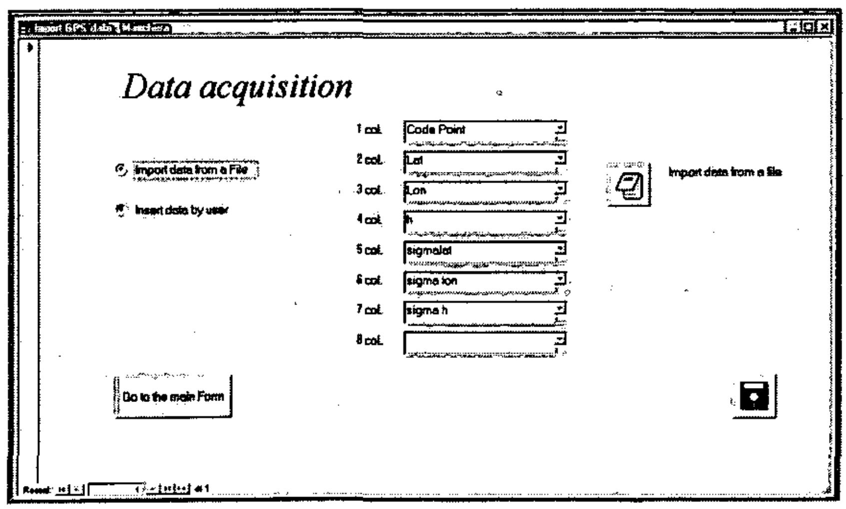

Figure 6. Example of data input panel

Information on the coastline and also of the inner part of continental topography is available on USGS Glaciology and Coastal-change Project and on Antarctic Digital Database (ADD) produced by BAS.

5 Conclusion

The goal of SCAR WGGGI Physical Geodesy Project is the high resolution geoid computation of Antarctica. The first step of data collection was the plan of a DBMS for different kind of data available for the Geoid computation: surface topography, bedrock surface, gravimetric observation and density models. A preliminary DBMS for geodesy and for gravimetry scheme was performed. The work is in progress and it is necessary to better define the DBMS and to start the verification of feasibility through a real data input.

The second phase should be the data collection which will be fundamental to data exchange with research programs like BEDMAP, ADGRAV, RAMP etc.. Moreover, strict interaction with IAG Commission on "Gravity Field and Geoid" is desirable to perform an

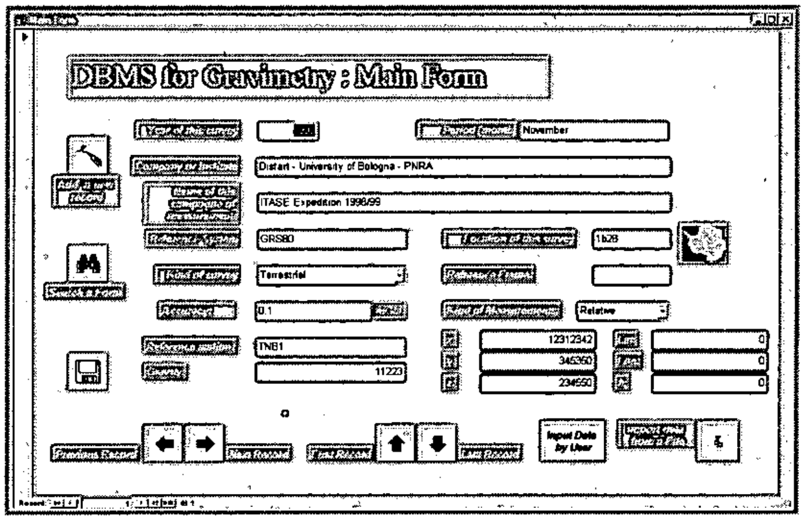

Figure 7 - Example of Gravimetry Main Form

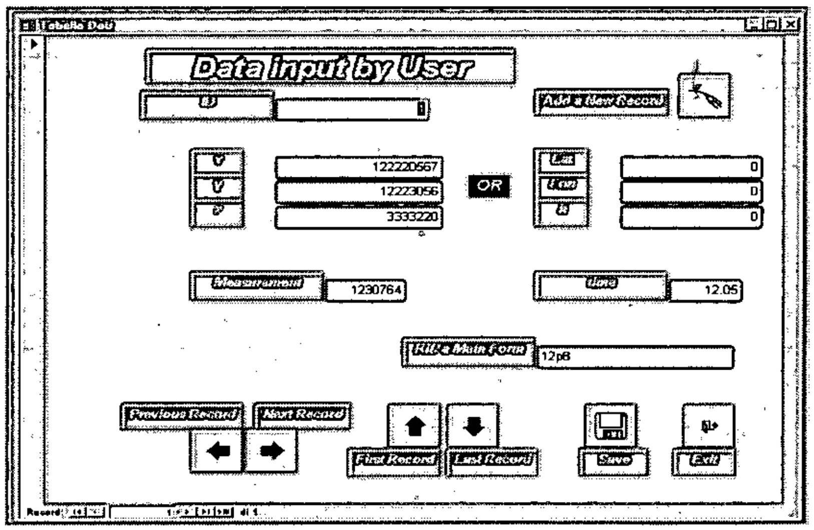

Figure 8 – Example of Gravimetric Data input by user.

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WGGGI Working Group on Geodesy and Geographic Information Web sit address: http://www.scar-ggi.org.au/

ADD - Antarctic Digital Database. Web site address: http://www.nerc-bas.ac.uk/public/magic/add.html

RAMP – Radarsat Antarctic Mapping Program. Web site address: http://polestar.mps.ohio-state.edu/ramp.html

BEDMAP – BEDrock MAPping. Web sit address: http://www.nerc-bas.ac.uk/public/aedc/bedmap/

Antarctic Surveying and Mapping Activities of China and Recent Progress

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Abstract

The Antarctic surveying and mapping activities of China include geodesy, satellite positioning, topographic surveys, photogrammetry and mapping both in the Fildes Peninsula (West Antarctica) and in the Larsemann Hills (East Antarctica). In these regions, Chinese surveyors have set up a coordinate system and a level system, built in some maps of stations, provided the indemnification servings for Antarctic research activities of other academic disciplines. In addition, scientific research on geodesy kinetics and mapping methods have been developed.

In recent years progress in chinese Antarctic surveying and mapping has been achieved. The more important subjects, in brief, are:

a) Zhong Shan permanent GPS satellite tracking site;
b) GPS positioning and navigation of ice sheet research from Zhong Shan station to Dome A zone;
c) Surveying and mapping of Grove Mountains Area;
d) Antarctic internet-based GIS by GEOSTAR;
e) Monitoring crustal movement of the Fildes rift region; etc.

This paper discusses not only above problems but also some future research planning.

Key words: Antarctic, Surveying and mapping, Progress

I. Introduction

It has been 15 years since China entered into surveying and mapping activities in Antarctica. Two scientific research stations, Great Wall station and Zhong Shan Station, have been built by China during these 15 years. These two stations are important bases for Antarctic surveying and mapping activities of China. This paper is organised in two parts. The first deals with the indemnificatory conditions for CHINARE (Chinese National Antarctic Research Expedition) that include the establishment of both stations' coordinate system, plotting basic maps, developing satellite images, satellite navigation, and etc. The second studies the Antarctic scientific research activities correlated with surveying and mapping such as the monitoring of crustal deformation, the changes of sea level, the methods of mapping and the GIS database. Both traditional and modern surveying techniques were utilized by Chinese surveyors, the former were inclusive of theodolite and leveling instrument and the latter included GPS, GIS and RS technology and their integration. Because of the specific nature of surveying, the fieldwork was usually carried out during the Antarctic summer season. Although there were many unfavorable factors such as severe weather, coldness and storms, precise and good quality surveying and mapping results were obtained. In some scientific research fields such as monitoring crustal deformation in large areas, monitoring sea level change, SCAR GPS Campaigns, etc., international cooperation is necessary and important because one country is unable to accomplish these kinds of actual observation activities. If the latest technology is utilized in international cooperation, first-class results can be achieved. Chinese surveyors hope to cooperate honestly with foreign scientists in Antarctic scientific research.

II. Crustal deformation monitoring in the Fildes Peninsula

In order to study crustal movement in Antarctica, China constructed a deformation monitoring network in Fildes Strait region, West Antarctica, which was observed using a DI-20 infrared geodimeter and GPS receivers. China has also participated in SCAR Epoch GPS Campaigns as well. The Fildes peninsula is located between South America Plate and Antarctic Plate, so fault movement was very active. When monitoring crustal movement of the region it is very important to use highly precise geodetic techniques. The shape and structure of this network is shown in Fig.1.

Since the Fildes deformation monitoring network was set up in 1984, we have obtained the observed data of three sessions of the network using a DI-20 infrared geodimeter. Furthermore, the observed data of two other sessions using the GPS positioning technique have been obtained. From data analysis of this network the following conclusions were available:

1) There is some small shear movement trend inthe Fildes fault area;
2) Using the GPS high precise positioning technique in Antarctica is a reliable and valid method to monitor crustal deformation.

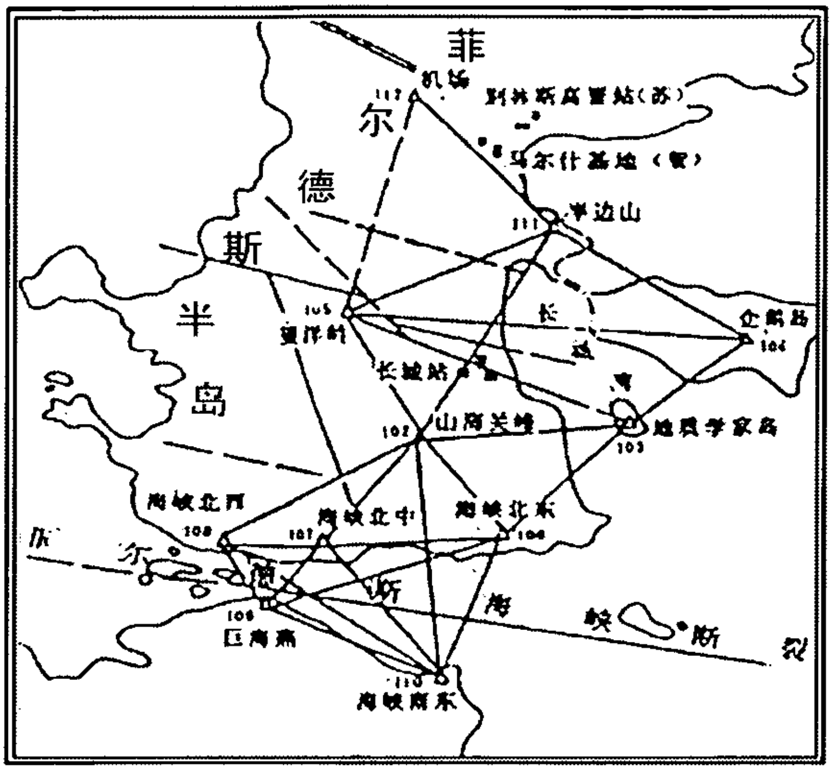

Figure 1. Crustal deformation monitoring network in Fildes Peninsula

III. SCAR Epoch GPS Campaigns

Research on Antarctic plate movement organized by SCAR WG-GGI, was an international project involving several countries. This project has the following objectives: Linking Antarctica with the International Terrestrial Reference Frame (ITRF); Measurement of the relative rates and directions of the Antarctic Plate from adjoining plates; Determination of relative motion of crustal blocks within the Antarctic Plate; Determination of the vertical motion of the Antarctic lithosphere due to changing ice and ocean loadings, etc.

Both China's Great Wall Station and Zhong Shan Station have participated in SCAR Epoch GPS Campaigns which have been carried out from 20 January to 10 February every year since1994. Both stations' monuments, with their permanent copper marker forced into their center, were directly set into bedrock, so the monuments are substantial enough to be stable to the millimeter level. The GPS data and corresponding documentation of each session have been sent to TU Dresden/Germany in time. Now Chinese surveyors are processing GPS data from part of these sessions.

IV. The geodetic network at Larsemann Hills and topographic map

During the first East Antarctica Expedition(1988/1989), the Chinese surveyors set up a coordinate system and a level system based atZhong Shan Station, and some points around the station were surveyed. Zhong Shan station lies in the northeast Larsemann Hills, which cover an area of about 200 square kilometers. The Hills range from south latitude 69.3 deg. to 69.4 deg. and from east longitude 75.97 deg. to 76.44 deg., and half of this area is sea in which there are many islands. It took four years(1988-1992) to establish and survey geodetic network at Larsemann Hills. The network projects a form of the traverse net in which the angles were surveyed using a Wild T2 theodolite and the sides were measured using a DI-20 geodimeter. Its data processing was achieved using the principle of simultaneous adjustment; the statistics and analysis for the adjustment results indicated that the network is of sufficiently good quality to comply with the demands of 1:10,000 scale map work.

At the same time the aerial photograph of the Larsemann Hills was obtained using an ecumenical 120 camera from a small helicopter flying at 3,200 m altitude. Based upon these photograph the Larsemann Hills topographic map and image map of scale 1:10,000 were produced. In addition, the topographic map of the Fildes peninsula area was worked out after the geodetic network of the region had been set up. The topographic maps of Great Wall Station and Zhong Shan Station were surveyed to meet requirements of other research works.

V. Research on Antarctic Geoid using the Earth's Gravity Field

The study of change in the Earth's gravity field is an important part of research into global change. The Antarctic gravity field is related to the change in sea level, ice sheet, climate and global Geoid, and it also restricts these changes.

The Antarctic Gravity Field reflects the nature of matter distribution inside the Earth. In order to analyze the feature of Antarctic Geoid, some recent gravity field models such as OSU91(360 terms), JGMOSU(360 terms) and WDM94(360 terms) have been obtained. The geoid height and mean free-air gravity anomaly of Antarctica (from south latitude 60 deg. to 90 deg.) were computed on the base of WDM94 (see Fig.2 and Fig.3), and the same kind of values were obtained on the base of OSU91 and JGMOSU. To compare the results from WDM94 with the values from OSU91 and JGMOSU, the standard deviation of geoid height is 1.90 m and 2.09 m respectively, and the standard deviation of mean free-air gravity anomaly is 8.97 milligal and 9.32 milligal respectively.

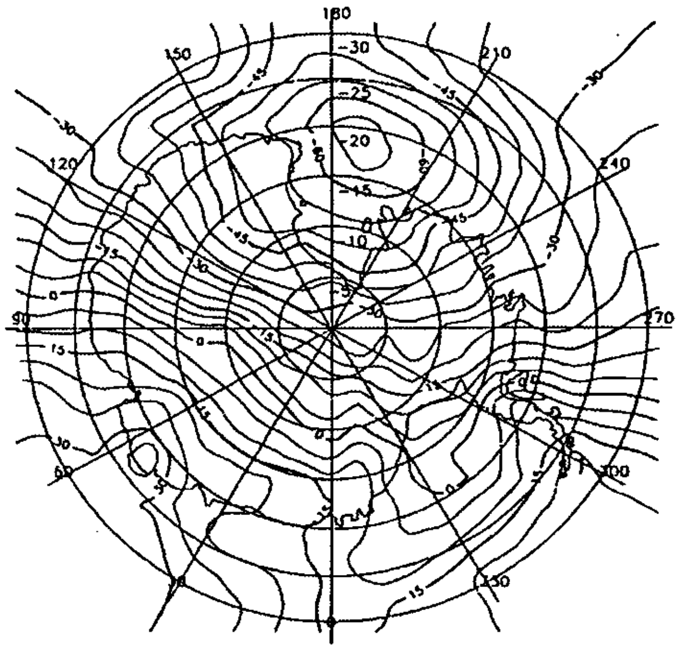

Figure 2. Isoline map of Antarctic geoid height of WDM94 Model (unit: m, isoline interval:5m)

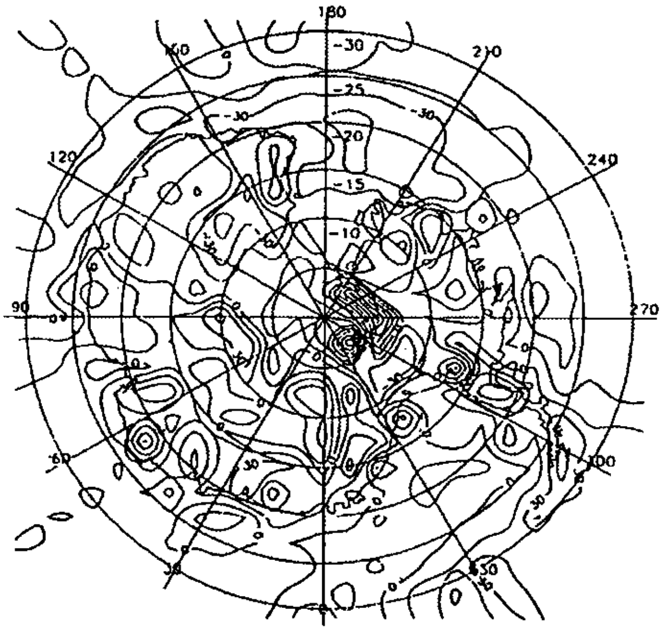

Figure 3. Isoline map of Antarctic mean free-air gravity anomaly of WDM94 Model (unit: mgal, isoline interval:15mgal)

VI. Digital mapping produced with satellite images of the Zhong Shan Station area

Antarctica is covered with ice and snow all year round. The Antarctic weather and environment make surveying very difficult on the ice sheet. Therefore mapping with satellite images is a suitable approach. To make an image map with TM data, some special methods have been introduced:

1) Direction filtering can efficiently remove streaked noise;
2) Image enhancement of different areas using the automatic recognition approach make the image clear, and the details of the ice and snow surface become visible with reasonable contrast.

The precise processing, using control points measured in the field, results in mapping accuracy which can fully satisfy the requirements of the 1:100,000 scale topographic map.

VII. Recent Progress

a) Establishment of a permanent GPS tracking site at Zhong Shan Station

After two years' preparation, China established a permanent GPS tracking site at Zhong Shan Station during 1998/1999 Antarctic summer season. The this site is to develop the research of Antarctic dynamic and related problem. The content of research is as follows:

1) Link of the permanent GPS tracking site to the ITRF
2) Accurate research on GPS satellite orbit in Antarctic area
3) Providing foundationn data for Antarctic plate movement
4) Research on upper ionosphere and meteorology
5) Research on crustal vertical motion.

This site, established according to international IGS standard, will be included into Antarctic permanent GPS tracking sites network.

A double-frequency GPS receiver *Geotracer* sponsored by Spectra Precision AB, was employed to perform continuous operation at this site. This kind of receiver has a superior performance. It can even work well in conditions of -30°C. It is controlled under the GPS-Base software, which ensure it work continuously all the day and store data automatically into computer.

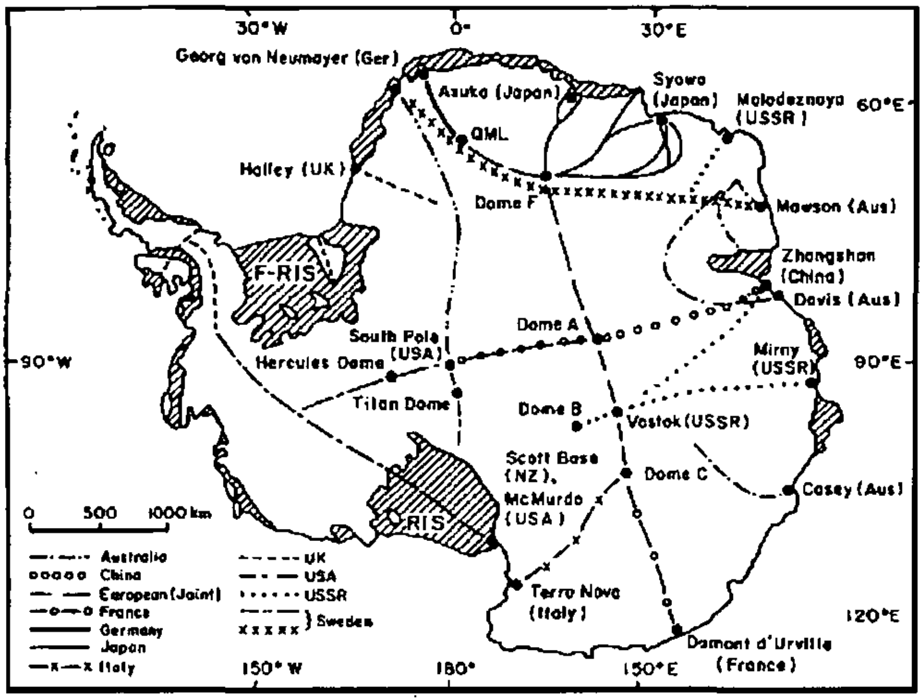

Figure 4. The expedition routes of ITASE project

The receiver was set up at the point previously used in the SCAR Epoch GPS Campaigns at Zhong Shan Station. Since this site was just established, there is problem of not being able to transport data in time, which is hoped to be solved in the near future. Until that time we use compact disc storage and transport data.

b) Navigation and precse GPS positioning during inland ice sheet traverse

As part of the ITASE (International Trans-Antarctic Scientific Expedition) project (see Fig. 4), China has carried out three Antarctic inland ice sheet traverses since 1996.

Every year traverse team departs from Zhong Shan Station and jouney 300 kilometers, 500 kilometers and 1,100 kilometers towards Dome A(82°S, 75°E) respectively. As a member of the traverse team, the surveyor is in charge of explanation satellite images, navigation and precise GPS positioning.

The first traverse was carried out from Jan.18, 1997 to Feb. 1, 1997. The coordinates of the end point of this traverse is 71°54'S,77°59'E, which is 300 kilometers from Zhong Shan Station. On Feb. 3,1998, China's second inland ice sheet traverse team departed from Zhong Shan Station, travelling 500 kilometers towards Dome A to the point (73°22'S, 77°00'E) and back to base on Feb.19, 1998. On the basis of former traverses, the third traverse team pushed forward successfully to Dome A area on Jan. 8th, 1999. The farthest point is (79°16'S,77°00'E) , the elevation of which is 3,900 meters.

According to the route designed, surveyor navigated in the first tractor during advancing on ice sheet. Along the route, there was a mark rod every 2 kilometers for navigation and ice mass balance observation. On every camp point, a double-frequency GPS receiver was employed to collect observation data simultaneously with fixed point at Zhong Shan Station. We could monitor ice mass balance and glacier drift with this differential GPS technique. The mark for high precise positioning was a glass fibre pole, which was 1 meter long, 3 cm in diameter. On top of the pole there was a clear mark for centering

c) Re-observing the Fildes deformation monitoring network in west Antarctica

During the 1998/1999 Antarctic summer season, China re-observed some points of the previous deformation monitoring network in Fildes strait in west Antarctica. The observation marker of these points was strengthened before reusing. Two sets of Turbo Rogue-8000 GPS receivers were employed and five baselines were observed. After the primary calculation, the accuracy index of the baseline vectors were obtained as shown in Table 1. Furthermore, Great Wall Station in west Antarctica participated in the SCAR Epoch 99 GPS Campaign and observed the elevation of the coastline terrace.

d) Developing the Antarctic internet database

The information industry has made progress with the development of network technology in recent years. At the same time, the development of theories of Digital Earth and GIS Visualization have furthered advances in mapping technology, including Antarctic surveying. In order to satisfy the need for rapid access to Antarctic data on the internet, we are developing the Internet GIS of Antarctica by GeoStar software.

Baseline	I			II			II			IV			V		
(mm)	dx	dy	dz	dx	dy	dz	dx	dy	dz	dx	dy	dz	dx	dy	dz
	1.5	15	33	1.1	09	25	1.1	1.0	3.4	1.1	1.6	2.6	1.2	1.6	3.6

Table 1. The accuracy index of rhe baseline vectors from Fildes Strait

This system allows access to the coordinate systems of Great Wall Station, Zhong Shan Station etc. The vector data of maps and the corresponding attribute data can be viewed using popular browsers such as Microsoft Internet Explorer and Netscape Navigator. China's scientific research and Antarctic surveying data can be acquired published and shared on the internet using this system.

e) Surveying and mapping in Grove Mountains

During the 15th CHINARE, in addition to the traverse team extending to Dome A, an additional traverse team comprised of 4 Chinese expeditioners, including a surveyor, travelled to Grove Mountains. It is said that it was the first time man had been to Grove Mountains. The task of this traverse team was to undertake geological research work. The surveyor was in charge of navigation, GPS positioning, surveying and mapping. A Trimble 4000SST GPS receiver was employed to position. Some control points were observed and the map plotting of Grove Mountains will be completed in office in the future.

VIII. The future of Chinese Antarctic surveying and mapping

In the future, China will aim for international advanced levels, cooperate with other countries, carry out international and national Antarctic surveying aspects. The main aims of future development are as follows:

a) Carry out research into tide gauging at Zhong Shan Station and sea-level change in east Antarctica. This project will be put in practice with the help of Australia. At present, both Australia and China have come to a primary agreement about it;
b) Carry out absolute gravity observation and research at Zhong Shan Station. This project will be carried out along with the experts of surveying and mapping from Taiwan, China;
c) Set up an INMARSAT Communication Station at Zhong Shan Station as soon as possible to solve the problem of the data transmission of permanent GPS tracking sites. This project will be carried out cooperating with internal relations departments.
d) Supplement the newest data of Antarctic surveying and mapping data and input them into the database. We will consummate the database continuously in order to meet the need of other objects. This Project will be carried out cooperating with internal relational departments.
e) Continue to participate in SCAR Epoch GPS campaigns in future.

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Present Status of the SCAR GPS Epoch Campaigns

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1 Introduction

The SCAR GPS Epoch Campaigns are a part of the working program of the SCAR Working Group on Geodesy and Geographic Information (WG-GGI), and belong to the main program Geodetic Infrastructure in Antarctica (GIANT), chaired by J. Manning, Australia.

The main goals of the SCAR GPS Epoch Campaigns are:

- establishment and maintenance of a precise geodetic reference network in Antarctica, linked to the International Terrestrial Reference Frame (ITRF);
- utilization of the Antarctic geodetic network for geodynamic research;
- linking Antarctic tide gauges to the ITRF;
- providing reference for other GPS applications in Antarctica

The status report presented here gives an overview of activities since 1995, including the field campaigns and the data analysis.

2 Field campaigns

The GPS campaigns take place every year from 20 January, 0:00 UT until 10 February, 24:00 UT. The main observation standards were:

- provide daily data sets of 24 hours starting at 0:00 UT
- use only dual frequency geodetic GPS receivers
- data sampling interval 15 seconds (if possible)

Special attention should be paid to stable mounting of the GPS markers. The campaign data were completed by the data of the permanent tracking sites of the International GPS Service (IGS) at the southern hemisphere.

3 Database

All data and station documentation sheets were collected and filed at the Institut für Planetare Geodäsie (Technische Universität Dresden) in Germany. An overview with the participating stations, as they exist in the data base, is shown in Table 1. The data are available for all participants (see also http://www.tu-dresden.de/ipg/...SCARGPS/database.html).

4 Data analysis

The data analysis carried out several research groups with different software packages (see Table 2). The groups provided individual solutions, which were intercompared and finally combined (Dietrich *et al.* 1996, 1998 and 1999). The final coordinates are summarized in Tables 3, 4 and 5.

5 Future work

The SCAR GPS Epoch Campaigns will be continued. The next campaign will be the SCAR GPS 2000 Campaign ("The Millenium Campaign") carried out in the well-tried schedule.

(see also http://www.tu-dresden.de/ipg/SCARGPS/...database-html).

6 Acknowledgements

Thanks are directed to all individuals and agencies, who supported the field projects, and in particular to the SCAR Working Group on Geographic Information, which acted as a scientific focus.

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4-ID	Station name	Station owner	95	96	97	98	99
ARCT	Arctovski	Poland					x
ART1	Base Artigas	Uruguay	x	x	x	x	
BEL1	Belgrano	Argentina	x				
BELG	Belgrano	Argentina				x	
CUR1	Curitiba	Brazil	x	x			
DAL1	Jubany/Dallmann	Argentina/Germany	x	x	x	x	
DALL	Jubany/Dallmann	Argentina/Germany				x	x
DUM1	Dumont d'Urville	France	x	x			
ELE1	Elephant Island/Gibbs Island		x			x	
ESP1	Esperanza	Argentina	x	x		x	
FAL1	Falkland	U.K.	x			x	
FOR1	Forster	(Germany)	x			x	
FOR2	Forster	(Germany)		x			
FOS1	Fossil Bluff	U.K.	x	x		x	
GOUG	Gough Island	South Africa				x	x
GRW1	Great Wall	China	x		x	x	x
GRY1	Grytviken	U.K.				x	
HAAG	Haag Nunatak	U.K.		x			
HAR1	Hartebeesthoek	South Africa	x	x		x	
KOH1	Kliment Ohridski	Bulgaria				x	
KOTA	Kottas Berge	Germany				x	
MAR1	Marambio	Argentina	x	x		x	
MON1	Montevideo	Uruguay	x	x	x	x	x
NOT1	Notter Point		x			x	
OHG1	O'Higgins	Chile/Germany	x	x	x	x	
PAL1	Palmer	U.S.A.	x	x		x	
PALM	Palmer	U.S.A.				x	x
PET1	Peter 1					x	
PRA1	Arturo Prat	Chile	x	x		x	
PUN1	Punta Arenas	Chile	x	x		x	
RIG1	Rio Grande	Argentina	x				
ROT1	Rothera	U.K.	x	x		x	
SAN1	Santiago	Chile	x				
SAN2	Santiago	Chile				x	
SIG1	Signy	U.K.	x			x	
SMR1	San Martin	Argentina	x			x	
SPR1	Punta Spring	Chile	x			x	
SYO1	Syowa	Japan	x				
SYOG	Syowa	Japan		x			x
TNB1	Terra Nova Bay	Italy		x		x	
TROL	Troll	Norway			x		
VER1	Vernadsky	Ukraine				x	
VESL	Sanae	South Africa				x	x
WASA	Wasa	Sweden			x		
ZSS4	Zhong Shang	China			x	x	x

Table 1: List of stations (except IGS stations in Antarctica)

analysis group	software package	
TU Dresden	Bernese 4.0	DRES
Alfred Wegener Institut für Polar- und Meesresforschung	GAMIT/GLOBK	AWI
Universität Hannover	GEONAP	HAN1
	GIPSY (only SCAR98)	HAN2
TU Braunschweig	GEONAP	BRAUN
Universität Karlsruhe	Bernese 4.0	KARL
Bundesamt für Kartographie und Geodäsie, Außenstelle Leipzig	Bernese 4.0	BKG
	GIPSY (only SCAR95)	

Table 2: Analysis groups and software packages

Station	X [m]	Y [m]	Z [m]
ART1	1541244.888	-2555205.107	-5618169.091
BEL1	1105999.505	-763743.179	-6214256.054
CAS1	-901776.158	2409383.435	-5816748.400
CUR1	3763751.645	-4365113.755	-2724404.761
DAL1	1548376.241	-2544409.313	-5621096.404
DAV1	486854.554	2285099.323	-5914955.690
DUM1	-1940883.765	1628483.397	-5833718.005
ELE1	1723594.793	-2520204.027	-5581225.272
ESP1	1560034.354	-2401882.729	-5679860.022
FAL1	2108106.688	-3353898.454	-4982108.736
FOR1	2061522.345	431615.727	-6000314.514
FOS1	757185.446	-1904739.716	-6019724.318
GRW1	1536965.609	-2554125.238	-5619825.330
MAC1	-3464038.464	1334172.738	-5169224.370
MAR1	1527541.626	-2321657.478	-5721839.997
MAW1	1111287.169	2168911.289	-5874493.584
MCM4	-1311703.251	310815.130	-6213255.059
MON1	2909133.028	-4355451.274	-3627801.381
NOT1	1451912.100	-2436397.927	-5693758.656
OHG1	1525852.229	-2432401.839	-5676185.034
PAL1	1192924.638	-2450915.581	-5747042.584
PRA1	1493161.963	-2550156.726	-5633379.124
PUN1	1239165.387	-3582438.932	-5112279.292
RIG1	1429883.030	-3495363.303	-5122698.810
ROT1	909255.078	-2264721.336	-5873063.044
SIG1	2189251.369	-2235016.417	-5539523.685
SMR1	927077.483	-2195046.496	-5896519.285
SPR1	1342651.571	-2427390.456	-5724115.522
SYO1	1766182.606	1460336.746	-5932285.465

Table 3: Coordinate solution of GPS Campaign 1995. ITRF94, Epoch 1995.1

Station	X [m]	Y [m]	Z [m]
ART1	1541244.8961	-2555205.1265	-5618169.0662
CUR1	3763751.6459	-4365113.7733	-2724404.7605
DAL1	1548376.2543	-2544409.3337	-5621096.3999
DUM1	-1940883.7739	1628483.3884	-5833718.0912
ESP1	1560034.3819	-2401882.7559	-5679860.0569
FOR1	2061522.3675	431615.6997	-6000314.5371
FOR2	2061809.1568	432116.1018	-6000155.3854
FOS1	757185.4696	-1904739.7371	-6019724.3396
HAAG	291442.3589	-1405571.0472	-6194871.8855
HAR1	5085401.1354	2668330.0526	-2768688.8948
MAR1	1527541.6521	-2321657.5012	-5721840.0266
MON1	2909133.0165	-4355451.2657	-3627801.3451
OHG1	1525852.2555	-2432401.8589	-5676185.0570
PAL1	1192924.6678	-2450915.6097	-5747042.6130
PRA1	1493161.9834	-2550156.7499	-5633379.1254
PUN1	1239165.3983	-3582438.9522	-5112279.2946
ROT1	909255.1049	-2264721.3571	-5873063.0645
SYOG	1766207.8522	1460290.3467	-5932297.6961
TNB2	-1623858.4689	462478.2106	-6130048.9489

Table 4: Coordinate solution of GPS Campaign 1996. ITRF94, Epoch 1996.1

ID	X	Y	Z	Latitude	Longitude	Height	
ART1	1541244.896	-2555205.117	-5618168.998	-62° 11' 4.22670"	-58° 54' 9.07794"	33.199	
BEL1	1105999.550	-763743.192	-6214256.133	-77° 52' 29.34815"	-34° 37' 36.66144"	245.780	
BELG	1106002.319	-763742.205	-6214255.841	-77° 52' 29.29203"	-34° 37' 36.29529"	245.855	
CUR1	3763751.628	-4365113.766	-2724404.733	-25° 26' 54.12861"	-49° 13' 51.43709"	925.743	(•)
DAL1	1548376.266	-2544409.340	-5621096.389	-62° 14' 26.56946"	-58° 40' 40.05011"	41.204	
DALL	1549109.860	-2544290.071	-5620947.204	-62° 14' 16.33434"	-58° 39' 52.36269"	39.400	
DUM1	-1940883.795	1628483.375	-5833718.110	-66° 39' 54.30245"	140° 0' 6.95389"	-1.270	(•)
ELE1	1723594.819	-2520204.050	-5581225.251	-61° 28' 50.60016"	-55° 37' 52.87166"	124.094	
ESP1	1560034.400	-2401882.736	-5679860.029	-63° 23' 42.31747"	-56° 59' 45.89582"	27.207	
FAL1	2108106.693	-3353898.478	-4982108.712	-51° 41' 53.46884"	-57° 50' 54.29718"	63.230	
FOR1	2061522.361	431615.725	-6000314.518	-70° 46' 40.58154"	11° 49' 30.23133"	152.925	
FOR2	2061809.126	432116.131	-6000155.372	-70° 46' 27.21400"	11° 50' 12.43407"	128.849	
FOS1	757185.484	-1904739.738	-6019724.320	-71° 18' 48.04863"	-68° 19' 15.03479"	158.838	
GOUG	4795578.561	-835299.505	-4107634.065	-40° 20' 55.80310"	-9° 52' 50.58484"	81.276	
GRW1	1536965.671	-2554125.265	-5619825.284	-62° 12' 58.70636"	-58° 57' 44.03432"	37.037	
GRY1	3000185.672	-2219035.702	-5155263.134	-54° 17' 0.91785"	-36° 29' 16.23765"	35.492	
HAAG	291442.336	-1405571.018	-6194871.875	-77° 2' 17.16996"	-78° 17' 8.98390"	1173.005	(6)
HAR1	5085401.141	2668330.117	-2768688.881	-25° 53' 22.95275"	27° 41' 10.22749"	1406.837	
KOH1	1453260.382	-2554435.086	-5641770.093	-62° 38' 29.75432"	-60° 21' 49.44990"	43.613	
KOTA	1706640.101	-293453.132	-6119455.228	-74° 18' 0.17576"	-9° 45' 23.32905"	1423.309	
MAR1	1527541.667	-2321657.484	-5721840.003	-64° 14' 41.79116"	-56° 39' 25.05650"	230.305	
MAW1	1111287.170	2168911.280	-5874493.617	-67° 36' 17.15922"	62° 52' 14.57703"	59.159	
MON1	2909132.991	-4355451.249	-3627801.307	-34° 53' 17.95004"	-56° 15' 35.57635"	158.116	
NOT1	1451912.141	-2436397.943	-5693758.668	-63° 40' 27.08258"	-59° 12' 29.51780"	64.653	
OHG1	1525852.270	-2432401.847	-5676185.033	-63° 19' 17.42174"	-57° 53' 59.42388"	30.428	
PAL1	1192924.682	-2450915.592	-5747042.575	-64° 46' 25.62303"	-64° 2' 47.76826"	40.556	
PALM	1192671.794	-2450887.590	-5747096.064	-64° 46' 30.32720"	-64° 3' 4.04817"	31.050	
PET1	-17156.097	-2306572.281	-5926530.158	-68° 51' 48.65086"	-90° 25' 34.15257"	32.408	
PRA1	1493161.993	-2550156.759	-5633379.111	-62° 28' 39.28245"	-59° 39' 0.97384"	81.197	
PUN1	1239165.405	-3582438.933	-5112279.261	-53° 37' 38.69692"	-70° 55' 10.20087"	23.990	
RIG1	1429883.021	-3495363.286	-5122698.800	-53° 47' 7.74264"	-67° 45' 5.45214"	31.252	(5)
ROT1	909255.120	-2264721.346	-5873063.048	-67° 34' 18.16563"	-68° 7' 30.73446"	32.065	
SAN1	1769699.647	-5044612.982	-3468259.922	-33° 8' 58.69358"	-70° 40' 7.06740"	722.057	
SAN2	1769697.537	-5044611.423	-3468263.246	-33° 8' 58.82240"	-70° 40' 7.12433"	722.059	
SIG1	2189251.401	-2235016.423	-5539523.676	-60° 42' 27.82172"	-45° 35' 33.54552"	48.593	
SMR1	927077.525	-2195046.516	-5896519.282	-68° 7' 46.74474"	-67° 6' 11.67628"	26.198	
SPR1	1342651.609	-2427390.469	-5724115.520	-64° 17' 43.19402"	-61° 3' 6.83674"	49.074	
SYO1	1766182.595	1460336.748	-5932285.491	-69° 0' 24.60111"	39° 35' 6.14562"	42.238	(•)
SYOG	1766207.837	1460290.362	-5932297.705	-69° 0' 25.04677"	39° 35' 1.48042"	50.021	(•)
TNB1	-1623858.481	462478.179	-6130048.980	-74° 41' 55.69762"	164° 6' 10.58315"	72.270	(•)
TROL	1974137.150	87507.435	-6045350.408	-72° 0' 43.32124"	2° 32' 17.10393"	1313.527	(7)
VER1	1163330.339	-2412201.153	-5769273.189	-65° 14' 46.16095"	-64° 15' 12.30495"	19.879	
VESL	2009329.722	-99741.466	-6033158.466	-71° 40' 25.66908"	-2° 50' 30.41721"	862.372	
WASA	1815176.279	-432905.860	-6079084.411	-73° 2' 34.22900"	-13° 24' 50.52273"	466.396	(7)
ZSS4	531102.201	2190269.924	-5946719.112	-69° 22' 15.78604"	76° 22' 11.46260"	40.681	

(5) coordinates in epoch 1995.1
(6) coordinates in epoch 1996.1
(7) coordinates in epoch 1997.1
(•) there are no observations in epoch 1998.1.
the coordinates were extrapolated from data analysis of the campaigns in 1995 and 1996

Table 5: Coordinate solution of GPS Campaign 1998. ITRF96, Epoch 1998.1

Multi-Disciplinary GPS Support in Antarctica

Bjorn Johns

University NAVSTAR Consortium – UNAVCO. www.unavco.ucar.edu

UNAVCO is funded by the U.S. National Science Foundation to provide GPS equipment, technical support, and data archiving services to Antarctic scientists participating in (or collaborating with) the United States Antarctic Program. Over 20 projects per year are supported, and represent various scientific disciplines including geology, geophysics, glaciology, biology, volcanology, and atmospheric sciences. GPS precision requirements range from sub-centimeter to meter level. Applications include crustal deformation, ice sheet dynamics, surveying, mapping, and vehicle and instrument positioning. Static, continuous, rapid static, kinematic, and real-time RTK and DGPS techniques are used to support these diverse GPS applications. From supporting these efforts, UNAVCO offers significant resources to the Antarctic GPS community, including a substantial geodetic GPS equipment pool, support infrastructure, and Internet based documentation.

Support Provided

GPS equipment and technical support (including training and data processing) are available year-round. During the austral summer, project support is provided from a UNAVCO "satellite" facility at McMurdo Station. An engineer is available to provide training and technical support, and manage the equipment pool of over 20 dual frequency geodetic GPS receivers, RTK and DGPS equipment, data processing software, and ancillary equipment.

McMurdo Differential GPS System

In 1997 UNAVCO installed a differential GPS broadcasting system as infrastructure at McMurdo Station. The system broadcasts standard RTCM SC-104 version 2.1 corrections, providing centimeter level RTK corrections in the vicinity of McMurdo Station and meter level DGPS corrections throughout McMurdo Sound. A repeater provides DGPS coverage in Taylor Valley, the most visited of the Dry Valleys. The differential corrections are broadcast continuously during the summer, and as requested during the winter. System information, available equipment, specifications, and operational documentation are available in the McMurdo DGPS Station section of the UNAVCO web page (Figure 1).

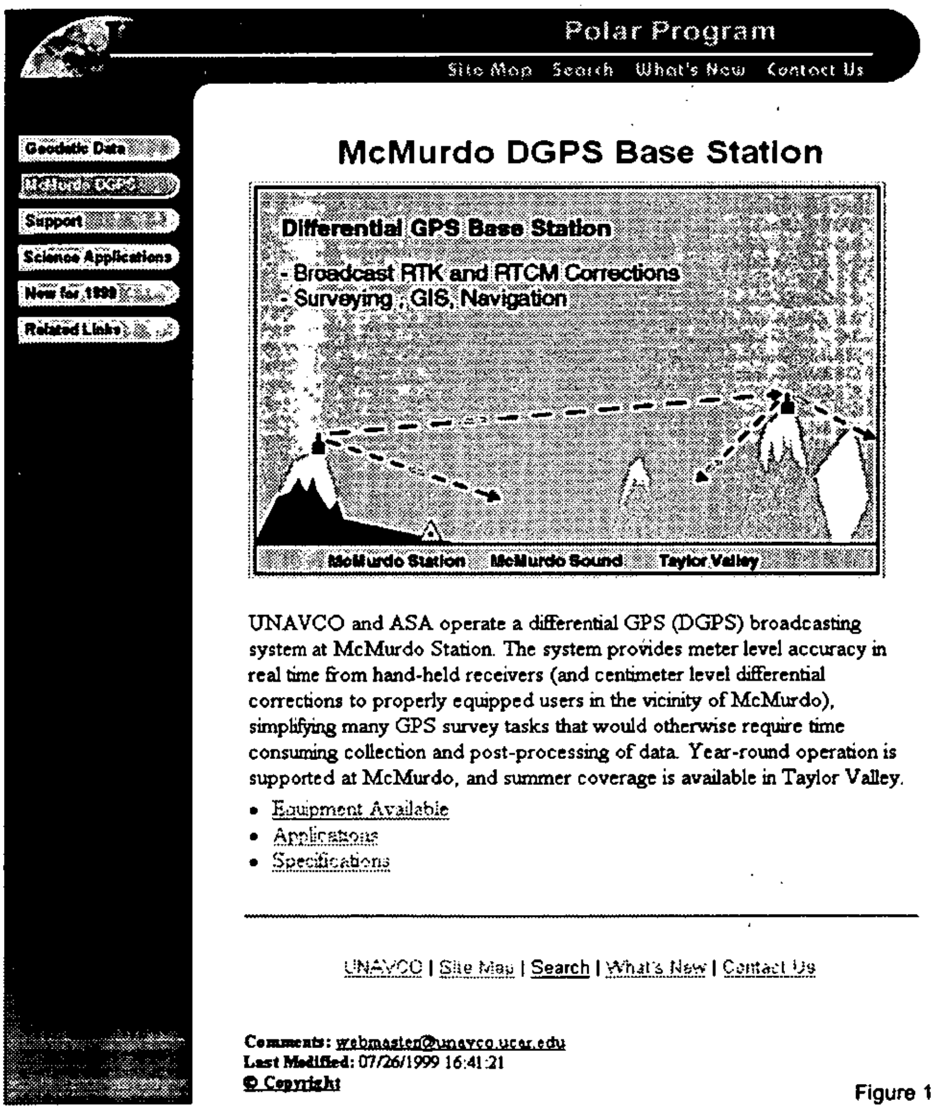
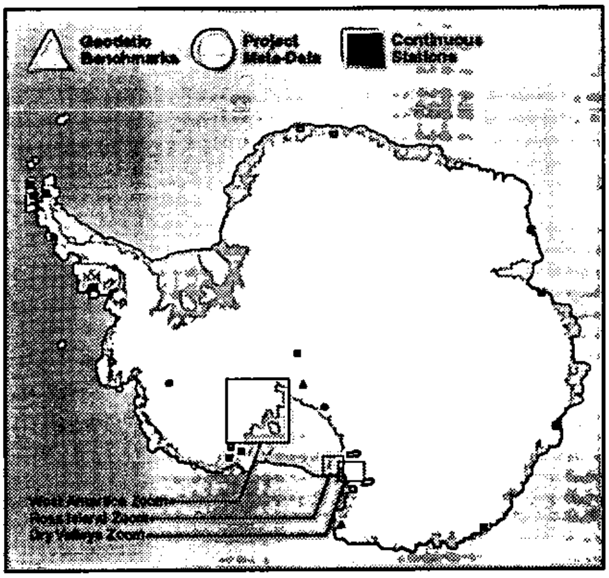


Figure 1. McMurdo Differential GPS Station

Geodetic Data and Meta-Data



Click on index above for detailed information.

Figure 2. Web Geodetic Data Index

Research applications of this system include mapping/ GIS work, locating diving and other research sites on the McMurdo Sound sea ice, and positioning scientific sample and instrument locations in McMurdo Sound and Taylor Valley. The system also provides a valuable asset for McMurdo Station operational applications, including the annual ice runway layout, construction surveying, and search and rescue vehicle navigation.

Internet Based Data and Meta-Data Archiving

All GPS data handled by UNAVCO are archived, both locally at McMurdo Station and at the UNAVCO Facility archive after the field season. The Geodetic Data section of the UNAVCO Polar Program web page (Figure 2) is the central access point for data from UNAVCO supported Antarctica GPS projects. Graphical access to geodetic benchmark data, project meta-data, and continuous stations has recently been added.

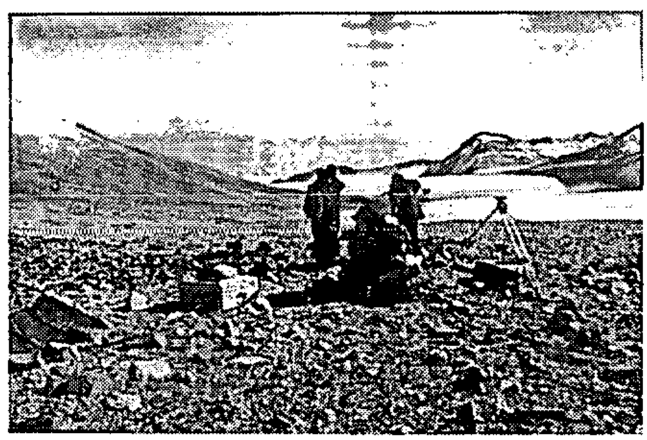
Project GPS data are stored in the UNAVCO data archives, ensuring data safeguarding and future accessibility. Data from Geodetic Benchmarks (Figure 3) collected to geodetic standards are archived by site name, and precise site coordinates and site descriptions are readily available. As this database of precise GPS coordinates continues to grow, future projects benefit by having pre-established geodetic control in their field study areas. Project Meta-Data from UNAVCO supported GPS projects are archived both graphically by project location and by field season, following the SCAR, NSF, and NASA data interchange (DIF) format (Figure 4). Information is also provided for GPS Continuous Stations, with direct links to available information about U.S. NSF sponsored sites, and a link to the SCAR maintained index of international sites.

Other GPS Resources

Many other GPS activities supported by UNAVCO also provide relevant information and resources to Antarctic GPS users as well as the broader GPS community. The UNAVCO facility has supported the installation of over 150 continuously operating GPS stations worldwide and currently monitors the operation of 194 stations. These include stations from the NASA Global GPS Network and various NASA and NSF funded regional networks. From supporting these efforts, UNAVCO offers experience in remote, autonomous GPS site design and support to the GPS science community. Areas of design and field experience include year-round solar powered autonomous

Geodetic Benchmarks

USGS Benchmark VABM-7



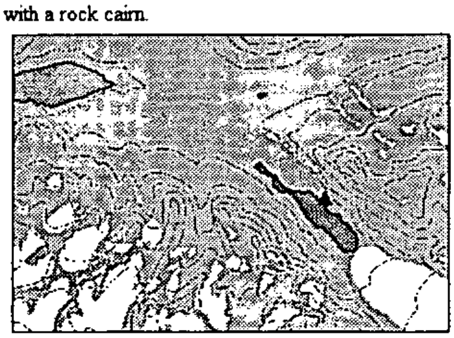
Site Description	Mark is in a boulder on the west side of Victoria Upper Lake, 2.7 km from Upper Victoria Glacier and about 20 meters from lake shore. It is marked with a rock cairn.  *Image Courtesy of USARC.*
Coordinates	77 18 47.7613 S 161 33 21.741 E 347.89 (~401.09 m MSL) ITRF-94
Source	Baseline tie to McMurdo Station MCM4.
Raw Data	UNAVCO Archive

Figure 3. Benchmark Example

GPS sites and data relay stations; data telemetry via radio modem, microwave links, cellular and land line telephone modems to internet sites; various antenna monumentation methods; low power, low cost L1 autonomous TDMA systems for remote, high density applications; automated GPS download software; and power management strategies. UNAVCO and JPL are collaborating on a VSAT demonstration project to test a low power (~20W), environmentally robust remote satellite data retrieval system. Recent efforts of support include facilitating collocation and integration of various sensors including GPS receivers, seismometers, and MetPaks, in cooperation with JPL, IRIS, NOAA, and individual investigators working in Antarctica and other remote locations. Much information from these activities, including continuous station documentation, data management software, antenna/monumentation multipath considerations, equipment specifications, etc. are readily available on the UNAVCO homepage.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Geodetic Data
McMurdo DGPS
Support
Science Applications
New for 1999
Related Links

Meta-Data Summaries
(1998/99 Season)

I-157 Kamb

Data Set Name:
I-157 1998/99

Investigator:
PI: Barclay Kamb
POC: Hermann Engelhardt
Institution: California Institute of Technology
Email: engel@caltech.edu
Web Site: http://skua.gps.caltech.edu

Data Type:
Kinematic GPS

Dates:
12/98-1/99

Location:
Name: Ice Stream D
Coordinates: 81 04 56 S 140 02 48 W
Radius: 20 km

Data Center:
Name: UNAVCO
URL: www.unavco.ucar.edu
Email: archive@unavco.ucar.edu or polar@unavco.ucar.edu
Phone: (303) 497-8000

Summary:
GPS support was requested to measure ice stream velocities at the UPD hot water drill site. A strain grid was laid out and surveyed by UNAVCO during the LC-130 recovery effort in early December. This grid included both lateral and longitudinal components to measure both shear and elongational strain in the vicinity of the drill site. The survey was repeated in late January, providing the desired velocity information. In addition, the field team was provided with a geodetic receiver to

Figure 4. Meta-Data Example

The SCAR Geodetic Infrastructure of Antarctica

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Background

The scientific exploration of Antarctica has been the composite result of many nations research, not just the activities of a single individual nation. Contemporary scientific research in Antarctica began in earnest during the second International Geophysical Year in 1957/58. At that time the Scientific Committee for Antarctic Research (SCAR) was formed to coordinate and promote cooperation in scientific research through discipline based scientific working groups. In 1958 SCAR established a working group on Geodesy and Cartography to promote a joint approach to the positioning and mapping needs of Antarctic field scientists.

Geodetic Survey

Traditionally the positioning of geographic features on the Antarctic continent and measurement of baseline distances to neighbouring southern continental land masses was only achievable from astronomical observations or local trigonometric surveys on exposed rock. But with the advent of artificial geodetic satellites it was possible to begin to apply space geodesy techniques to the problem of linking the isolated geodetic surveys together and the measurement of intercontinental baselines.

Period	Technique	Baseline accuracy
1950s	Positional Astronomy	1 kilometre
1969-70s	Satellite/Stellar photography (PAGEOS)	10 metres
mid 1970s	TRANET Doppler	2-3 metres
late 1980s	GPS	1 metre
1990	VLBI	1 decimetre
1995	GPS	1 decimetre

Table 1. Approximate accuracies on Antarctic baselines

In 1969 the American Pageos global campaign of using ballistic cameras to photograph balloon satellites against a stellar background was extended to Antarctica with several rock sites occupied during that winter (Reece and Brownd 1977). This passive Pageos satellite project was soon followed in the early 1970s by the introduction of the active microwave Tranet Navstar navigation systems employing Doppler techniques for post processed positions (Anderle 1977). This technology was subsequently utilised in Antarctica for Geodesy, Glaciology, and mapping for more than a decade, when it began to be replaced by the application of the developing Global Positioning System in 1988.

SCAR Working Group on Geodesy and Geographic Information

The Scientific Committee for Antarctic Research (SCAR) was formed at the Hague in March 1958 to coordinate the scientific research of nations active in Antarctic during the third International Geophysical Year (IGY) 1957-58. The SCAR objective was to coordinate cooperative Antarctic scientific research and a series of specialist working Groups were established to meet this objective. It was soon realised that scientific researchers needed maps and positions to assist them in their field activity and to document their work in a largely unknown continent. Six months later the SCAR Working Group on Geodesy and Cartography was created to facilitate this work. In 1988, the name was changed to the Working Group on Geodesy and Geographic Information (WG -GGI) to better reflect its total scope of activities.

The early Geodesy objectives of the WG-GGI were to provide a control base for exploration and mapping using celestial techniques or limited area survey triangulations. It was not possible to measure accurate baseline between continents or to connect widely separated local triangulations with the technology available at the time.

With advent of artificial geodetic satellites these connections became possible using space Geodesy techniques. The first Antarctic space geodesy programs were the initiatives of individual countries as part of more extensive global programs, and no coordinated international geodetic program yet existed on the Antarctic continent. In 1976 the SCAR WG-GGI began to look at the possibility of linking the individual national geodetic networks by Doppler techniques and work commenced on gathering the extent of each nations geodetic networks with view to a joint approach, but due to logistic limitations no overall plan was implemented.

The positional accuracies achievable from the developing geodetic techniques are summarised in Table 1.

The SCAR GPS Campaigns

Despite the early GPS work by Counselman (1981) producing promising potential for accurate geodetic survey, it was not until the late 1980's that GPS emerged as a geodetic tool with a potential for Antarctic. The XX meeting of SCAR in Hobart 1988 endorsed a proposal by Australia to test the developing GPS technique for mapping control and Geodesy applications in monitoring crustal motion.

SCAR 1990 GPS Campaign

Australia arranged the initial GPS geodetic quality field observations in Antarctica, drawing on non-geodetic applications for ice surface motion the previous year (Allison 1989). The data gathered in the January 1990 campaign consisted of data from five different receiver types. It included data from the Cooperative International GPS network (CIGNET) program which was observing in the Southern Hemisphere at the same time. This resulted in a network of stations in Antarctica, Australia, and New Zealand (Table 2).

Station	Observing Authority	Receiver Type	Location
McMurdo	USGS	WM102	S77 51 E166 41
Davis	AUSLIG	Trimble 4000SLD	S68 34 E77 58
Law	AUSLIG	Trimble 4000SLD	S69 23 E76 23
Mawson	AUSLIG	WM102	S67 36 E62 53
Dovers	AUSLIG	WM102	S70 14 E65 51
Hobart	U. TAS	MiniMac	S47 48 E147 26
Orroral	AUSLIG	TI4100 Gesar	S35 38 E148 56
Yaragadee	AUSLIG	TI4100 Gesar	S29 02 E115 21
O'Higgins	IFAG	TI4100 Navigator	S63 19 E57 54
Punta Arenas	IFAG	TI4100 Navigator	S53 09 E71 00
Wellington	DOLIS	Trimble 4000SLD	S41 16 E174 47

Table 2. GPS observational sites 1989/90

Initial computation was carried out using the Berne precision software to produce the first intercontinental GPS baseline measurements from Antarctica. (Govind *et al* 1990). The results showed acquisitions problems with the design of the equipment and difficulty was encountered with ionospheric instability from the high level of solar sunspot activity. However the trial clearly showed that baseline accuracies in the order of one metre over intercontinental distances were possible even with the low number of GPS satellite available at the time

SCAR 1991 GPS Campaign

The second phase of the pilot study was undertaken the following summer in January 1991, and was synchronised with the first seven days of the first GPS IERS and Geodynamics Experiment 1991 (GIG 91) global campaign. Data from the sites listed below were processed using the GAMIT software and the results indicated that precisions of the order of 1 part in one hundred million were achievable (Morgan and Tiesler 1991): Mawson; Dovers; Georg Von Neumayer (ice station); O'Higgins; Terra Nova Bay; McMurdo.

SCAR 1992 GPS Campaign

A major observational SCAR GPS campaign was implemented in January 1992. Its objective was to produce definitive baselines between rock sites in Antarctica and intercontinental ties between Gondwanaland continental

Site Location	Country	Lat	Long	Receiver Type	Start	End
Amundsen Scott	USA	90 00 S		Ashtech LD XII	01-Jan	21-Jan
Buenos Aires	Argentina	34 36 S	58 27 W	T141OO (7 chnl)	01-Jan	21-Jan
Byrd	USA	80 01 S	119 32 W	Ashtech LD XII	01-Jan	21-Jan
Casey	Australia	66 17 S	110 32 E	Trimble 4000 SST	01-Jan	21-Jan
Davis	Australia	68 35 S	77 58 E	Trimble 4000 SST	01-Jan	21-Jan
Deception Island	Argentina	62 59 S	60 42 W	Trimble 4000 SLD	01-Jan	21-Jan
Dumont D'Urville	France	66 40 S	140 01 E	Ashtech LD XII	21-Feb	26-Feb
Gnangara	Australia	31 47 S	115 52 E	Ashtech LD XII		
Grunenhogna	South Africa	72 02 S	02 48 W	Trimble 4000 SST	01-Jan	21-Jan
Hartebeesthoek	South Africa	25 53 S	24 42 E	Rogue	02-Jan	21-Jan
Heard Is	Australia	53 01 S	73 24 E	Trimble 4000 SST	23-Feb	26-Feb
Kerguelen Island	France	49 21 S	70 12 E	Ashtech LD XII	06-Jan	22-Jan
Mawson	Australia	67 36 S	62 52 E	Trimble 4000 SST	01-Jan	21-Jan
Mc Murdo	USA	77 51 S	166 41 E	Ashtech LD XII	01-Jan	21-Jan
Nordenskioldsbasen	Sweden	73 03 S	13 24 W	WM102	01-Jan	21-Jan
O'Higgins	Germany/Chile	63 19 S	57 54 W	Trimble 4000 SST	01-Jan	21-Jan
Orroral	Australia	35 38 S	148 56 E	Trimble 4000 SST	21-Feb	26-Feb
Port Kembla	Australia	34 29 S	150 55 E	Trimble 4000 SST	16-Jan	20-Jan
Rio Grande	Argentina	53 43 S	67 45 W	Trimble 4000 SLD	01-Jan	12-Jan
Smithfield	Australia	34 40 S	138 39 E	TI 4100/7chnl	01-Jan	21-Jan
Sydney	Australia	33 50 S	151 16 E	Ashtech LD XII	16-Jan	21-Jan
Syowa	Japan	69 00 S	39 35 E	Trimble 4000 SST	01-Jan	21-Jan
Tahiti	France	17 27 S	149 34 W	Rogue	01-Jan	21-Jan
Terra Nova Bay	Italy	74 42 S	164 06 E	Trimble 4000 SST	01-Jan	16-Jan
Thevenard	Australia	32 09 S	133 39 E	Trimble 4000 SST	16-Jan	20-Jan
Tidbinbilla	Australia	35 24 S	148 59 E	Rogue	01-Jan	21-Jan
Townsville	Australia	19 18 S	146 52 E	Trimble 4000 SST	01-Jan	26-Feb
Ushuaia	Argentina	54 49 S	68 19 W	Trimble 4000 SLD	17-Jan	21-Jan
Wellington	New Zealand	41 16 S	174 47 E	Trimble 4000 SST	01-Jan	21-Jan
Yaragadee	Australia	29 03 S	115 21 E	Rogue	01-Jan	21-Jan

Table 3.
GPS observational sites 1992 field campaign

fragments. The project involved twelve nations in the observation of twenty-eight stations in three phases for sites located in Antarctica and on the surrounding southern continents and islands shown in Table 3. The campaign was successful and processed in GAMIT at the University of Canberra.SCAR 1993 and 1994 GPS Campaigns

SCAR 1993 and 1994 GPS Campaigns

Despite their success, the GPS campaigns were logistically costly and it was difficult to arrange occupation of all sites at the same time with differing nations being subject to different logistic arrangements. Consequently in 1993 permanent GPS sites were installed to provide fundamental fiducial stations to link epoch surveys together. The permanent stations were: Mcmurdo; Mawson; Amundsen-Scott (ice station); Casey; Davis; Macquarie Island.

This was a significant technological advance as it provided a potential continuous time series of observations and a network of key sites to used as a control framework for temporary occupations at different times. In 1994 permanent GPS trackers were also installed at: O'Higgins; Syowa; Kerguelen.

SCAR 1995 GPS Campaigns

In 1995 Germany took over coordination responsibility from Australia for the summer epoch campaigns beginning with the GAP95 survey, principally focused on the geodynamics of the Antarctic Peninsula (Fig.1).

Results of the GAP95 campaign are published in Dietrich (1996). Germany has continued to coordinate the ongoing summer epoch campaigns. The sites occupied in each phase are summarised in Table 4.

4-ID	Station name	Station owner	95	96	97	98	99
ARCT	Arctowski	Poland					x
ART1	Base Artigas	Uruguay	x	x	x	x	
BEL1	Belgrano	Argentina	x				
BELG	Belgrano	Argentina				x	
CUR1	Curitiba	Brazil	x	x			
DAL1	Jubany/ Dallmann	Argentina/ Germany	x	x	x	x	
DALL	Jubany/ Dallmann	Argentina/Germany				x	x
DUM1	Dumont d'Urville	France	x	x			
ELE1	Elephant/Gibbs Islands	U.K.	x			x	
ESP1	Esperanza	Argentina	x	x		x	
FAL1	Falkland	U.K.	x			x	
FOR1	Forster	Germany	x			x	
FOR2	Forster	Germany		x			
FOS1	Fossil Bluff	U.K.	x	x		x	
GOUG	Gough Island	South Africa				x	x
GRW1	Great Wall	China	x		x	x	x
GRY1	Grytviken	U.K.				x	
HAAG	Haag Nunatak	U.K.		x			
HAR1	Hartebeesthoek	South Africa	x	x		x	
KOH1	Kliment Ohridski	Bulgaria				x	
KOTA	Kottas Berge	Germany				x	
MAR1	Marambio	Argentina	x	x		x	
MON1	Montevideo	Uruguay	x	x	x	x	x
NOT1	Notter Point		x			x	
OHG1	O'Higgins	Chile/Germany	x	x	x	x	
PAL1	Palmer	U.S.A.	x	x		x	
PALM	Palmer	U.S.A.				x	x
PET1	Peter I					x	
PRA1	Arturo Prat	Chile	x	x		x	
PUN1	Punta Arenas	Chile	x	x		x	
RIG1	Rio Grande	Argentina	x				
ROT1	Rothera	U.K.	x	x		x	
SAN1	Santiago	Chile	x				
SAN2	Santiago	Chile				x	
SIG1	Signy	U.K.	x			x	
SMR1	San Martin	Argentina	x			x	
SPR1	Punta Spring	Chile	x			x	
SYO1	Syowa	Japan	x				
SYOG	Syowa	Japan		x			x
TNB1	Terra Nova Bay	Italy		x		x	
TROL	Troll	Norway			x		
VER1	Vernadsky	Ukraine				x	
VESL	Sanae	South Africa				x	x
WASA	Wasa	Sweden			x		
ZSS4	Zhong Shang	China			x	x	x

Table 4.
GPS sites occupied in SCAR Epoch campaigns 1995-1999

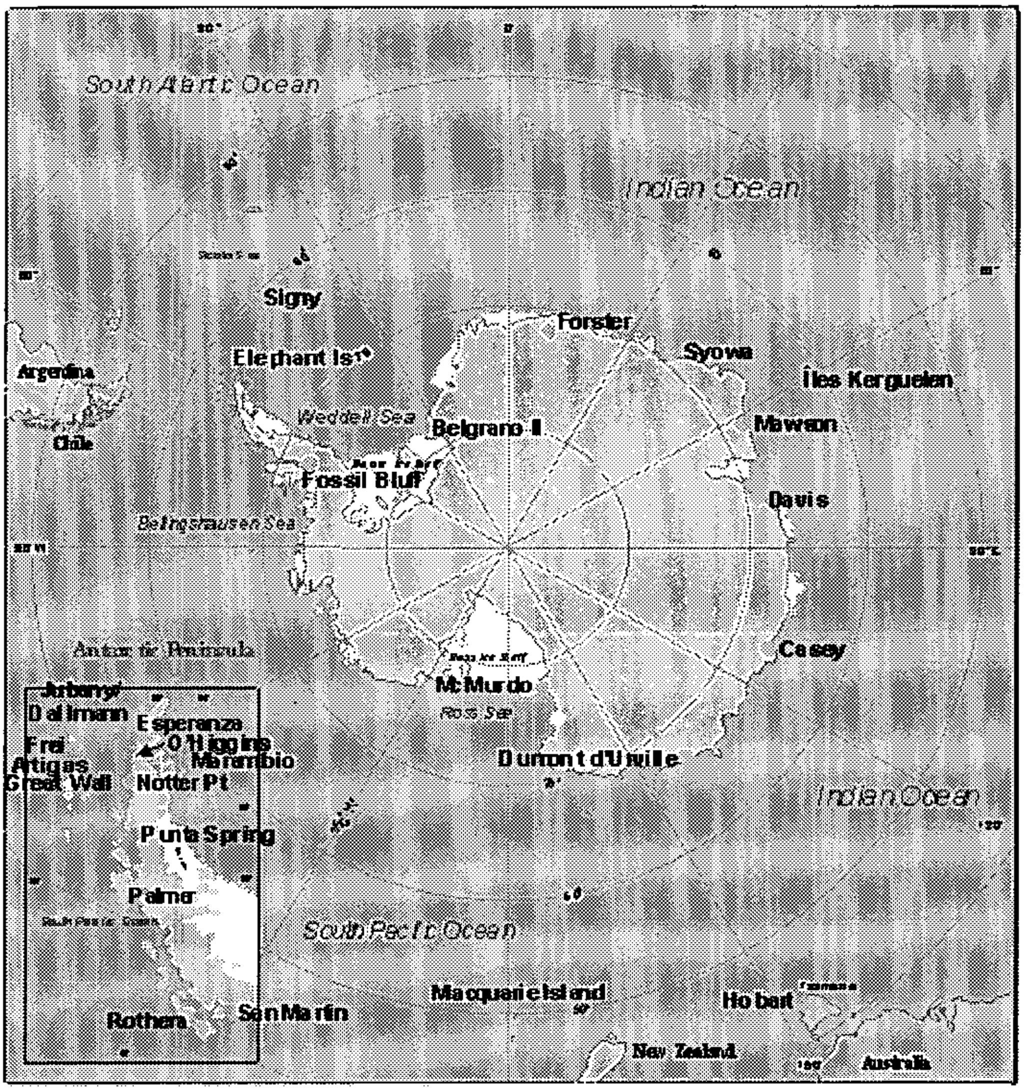

Figure 1. GAP95 Observational Sites

The Geodetic Infrastructure of Antarctica (GIANT) Program

At the XXII SCAR meeting in 1992, a proposal for a Geodetic infrastructure of Antarctica (GIANT) program was endorsed. The objective was to establish a precise network of points on rock sites across Antarctica, connected by space geodesy techniques which would enable existing all data on local geodetic datums to be directly related to produce a common geographical spatial data infrastructure. This was collectively identified as the Geodetic Infrastructure for Antarctica (GIANT) program.

GIANT program objectives:

The GIANT program objectives are to:

- Provide a common geographic reference system for all Antarctic scientists and operators.
- Contribute to global geodesy for the study of the physical processes of the earth and the maintenance of the precise terrestrial reference frame
- Provide information for monitoring the horizontal and vertical motion of the Antarctic.

This geodetic infrastructure will enable earth science investigators involved in individual disciplines (such as geodynamics, oceanography, geophysics, glaciology and geodesy.) to monitor temporal changes in horizontal and vertical positions, including sea level, relative to a fixed geocentric reference system traceable over a period of decades. The geodetic network will provide the spatial framework for use by scientists based on rock sites and as a reference platform for moving ice cap studies.

Implementation and development of the GIANT program has continued since 1992 and there are now seven key elements in the GIANT Program. These elements are summarised below for the current period 1998 to 2000.

1. Permanent Geodetic Observatories

Project Leaders: John Manning, Australia, Hans Werner Schenke, Germany

Goal: To develop an infrastructure of permanent geodetic stations to bring all individual geodetic networks to a common datum, and to provide geodetic information for the global monitoring of natural earth processes.

Key activities:

- Collaborate with other SCAR scientists to identify requirements for space geodetic sites In conjunction with SCAR working groups design an extended network of continuous geodetic observatories;
- for manned stations
- for remote locations
- Support continuation of O'Higgins VLBI for scientific purposes and as an important contribution to the global reference frame
- Establish priorities for on-line satellite data retrieval from ground stations
- Deliver regular space geodesy solutions to IGS and IERS
- Post details of all permanent sites on web site
- Develop and publish GPS base station specifications
- Evaluate accurate local ties between collocated techniques
- Facilitate tide gauge data to Southern Ocean Sea Level Centre

2. GPS Epoch Campaigns

Project Leaders: Reinhard Dietrich, Germany, Andres Zakrajsek, Argentina, Kevin Dixon, UK, Michel Le Pape, France, E Dongchen, China, Hector Rovera, Uruguay, Alessandro Capra

Goal: To densify the geodetic infrastructure established from the permanent observatories. This will includes links to individual geodetic networks, tide gauges and the computation of surface movement vectors within a common Antarctic reference frame.

Key activities:

- Establish guidelines for ground mark monuments
- Co-ordinate annual epoch campaigns
- Arrange orderly data archive and data access from these campaigns
- Undertake GPS connections to Tide gauge benchmarks
- Deliver results to ITRF in conjunction with results from permanent observatories
- Notify results of each campaigns occupations

3. Physical Geodesy

Project Leaders: Alessandro Capra, Italy, Lars Sjoberg, Sweden, Andres Zakrajsek Argentina, Hans Werner Schenke, Germany, John Manning, Australia.

Goal: Collection and analysis of physical geodesy data, for the development of a new high resolution Geoid for the Antarctic.

Key activities:

- The collation of extensive data holdings related to topography, bathymetry and gravity as essential inputs to Geoid computation, includes:
- Data collection and analysis of gravity related data ground/airborne/satellite data.
- Collect relevant data from satellite altimetry
- Collaboration with International Geoid Service (IGES) and International association of Geodesy (IAG)
- Collaboration with SCAR WGs Solid Earth Geophysics, Geology, Glaciology
- Collaboration with BEDMAP, ADGRAV, RAMP as data for Geoid computation
- Participate in the ADMAP meeting and Earth Science in Antarctic, NZ, in 1999
- Preparing data base of information from collated information prior to computation
- Evaluation of EGM96 improvement over OSU91 in Antarctica
- Facilitate computation of improved tidal models
- Prepare for computation of high resolution Geoid model

4. GLONASS Evaluation

Project Leaders: John Manning, Australia, Larry Hothem, USA)

Goal: Evaluate the benefit of GLONASS for global geodesy, Antarctic geodesy and navigation applications in Antarctica.

Key activities:

- Participate in the International GLONASS Experiment (IGES) pilot project with dual frequency GLONASS instruments at IGS collocated sites
- Retrieve data by satellite for analysis
- Analyse GLONASS orbits, reference frame differences and ground positions for geodesy and navigation applications in Antarctica
- Participate in presentation of IGEX results 1999
- Report on use of GLONASS for Antarctic Geodesy and navigation.

5. Differential GPS Base Stations

Project Leaders: Larry Hothem, USA, Hans Werner Schenke, Germany, IHO, Kevin Dixon, UK, Jan Cisak, Poland, Alessandro Capra, Italy.

Goal: To increase the utility of Geodetic GPS base stations by making DGPS corrections available for radio transmission for scientific field and operational use.

Key activities:

- Identify global standards for use in marine DGPS transmission using Geodetic base stations
- Develop options for base station sites for shipping navigation coverage of Antarctic Peninsula.
- Examine DGPS for real time kinematics and aviation applications in Antarctica and combination with geodetic accuracy base stations
- Liaison with COMNAP regarding transmission of GPS corrections at base stations.

6. Remote Geodetic Observatories

Project Leaders: (Larry Hothem, USA, Alessandro Capra, Italy, John Manning, Australia)

Goal: To deploy GPS equipment at unattended remote Antarctic localities for regional densification of geodetic infrastructure, and for scientific studies of surface geodynamics. This requires remote power input and data retrieval. This technology is not quite available at present and needs further development.

Key activities:

- Monitor and report on use of solar, wind and other methods of power generation for data logging information at remote GPS sites
- Monitor developments for remote retrieval of GPS data from remote sites by satellite communication techniques
- Collaboration with non-SCAR researchers

7. Information Access

Project Leaders: John Manning, Australia, All members of GIANT program

Goal: To publicise and distribute results of GIANT activities to the general Antarctic community.

Key activities:

- Prepare general papers on GIANT activities for publication.
- Ensure ready access to data from permanent observatories from host databases
- Establish cross links from WG-GGI web site to individual geodetic sites
- Develop DIFs for geodetic data in conjunction with JCADM
- Establish newsletter/newsgroup communication for information distribution on Web
- Monitor web posting of photo identifications on web sites
- Continue interaction with representatives on SCAR working Groups
- Develop IAG Commission X sub Commission on Antarctic Geodetic networks
- Publish WGS84-ITRF information paper and circulate within SCAR (SCAR Bulletin)
- Arrange an Antarctic Geodesy Symposium (AGS99) in Europe at the time of IUGG

Current Activities of the GIANT Program

The activities of the GIANT Program are reviewed every two years by the Working Group during the SCAR meetings. An interperiod symposium or business meting is also usually held. Work has coninued in alldefined elements since the SCAR meeting in Concepion in July1998. The WG-GGI website (www.scar-ggi.org.au/geodesy/giant.htm) has been populated with details of the current status of Antarctic Geodetic observatories illustrating:

- Permanent GPS installations
- Permanent Tide Gauge installations
- Absolute gravity fundamental sites
- DORIS sites
- VLBI sites

These are shown below as extracts from the WG-GGI web site(Figs 2–6).

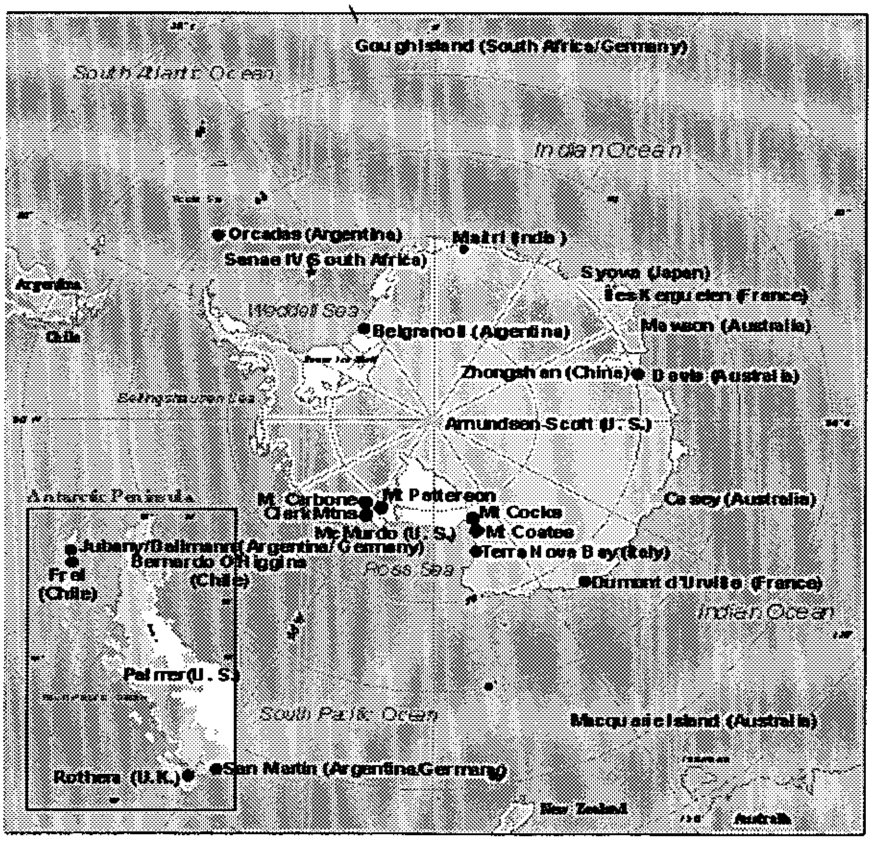

Figure 2. Permanent GPS installations

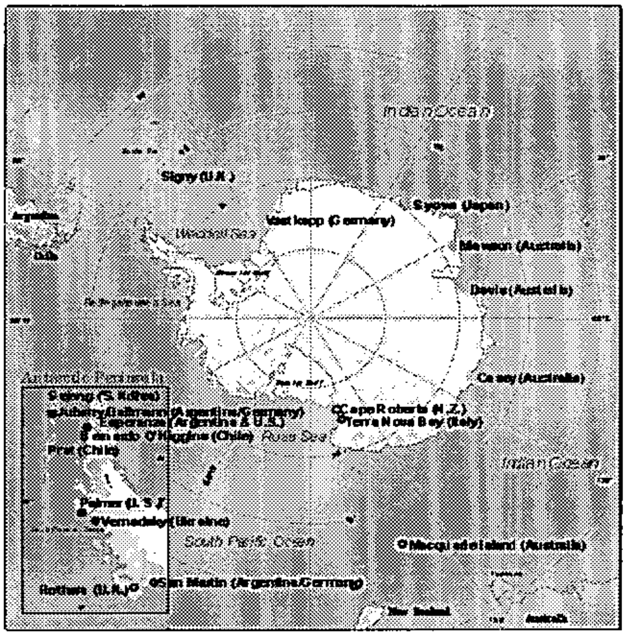
Figure 3. Tide Gauges

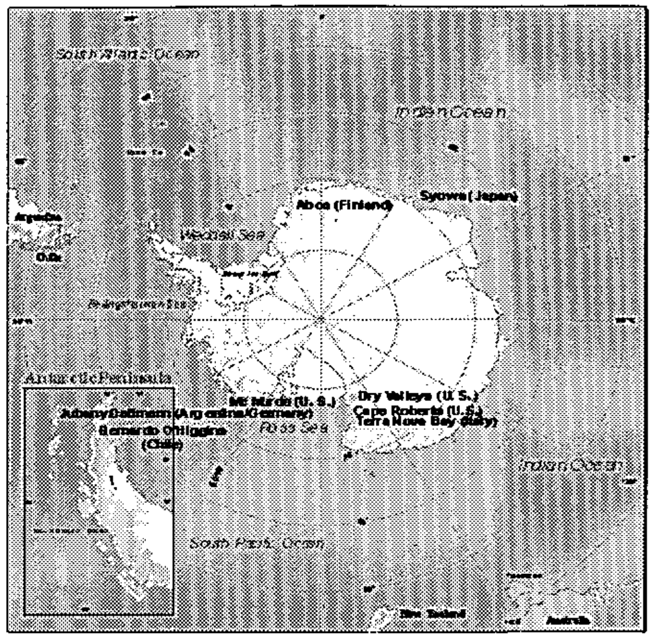
Figure 4. Absolute gravity sites

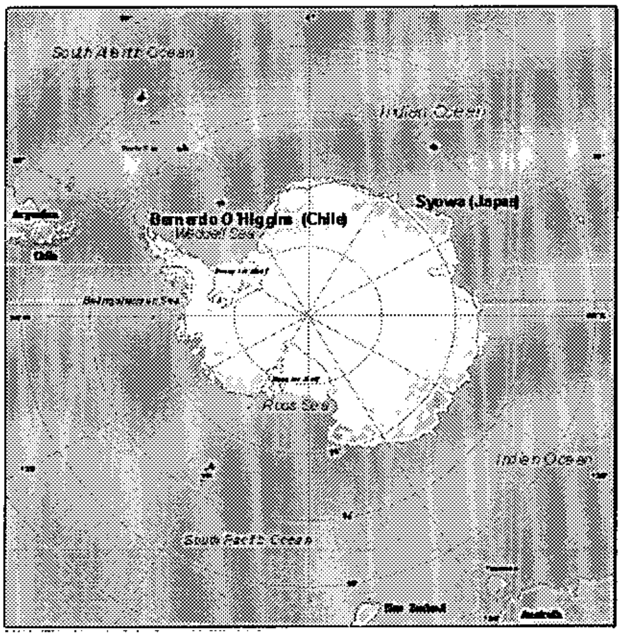

Figure 5. DORIS sites

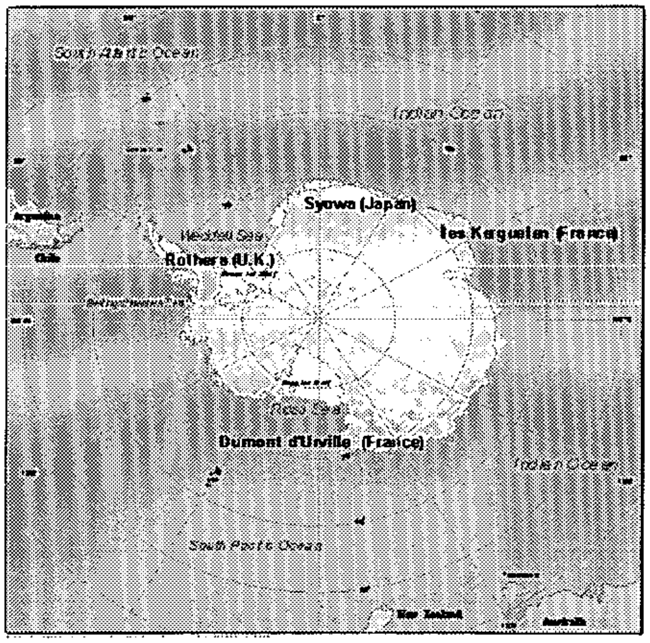

Figure 6. VLBI sites

The current activities of GIANT can be summarised as :

Permanent sites

Antarctica is important in a global geodesy sense. Global Geodesy models have heavily relied on observations from Northern Hemisphere sites and the results do not always fit in the Southern Hemisphere or represent the best global picture. Antarctic geodetic observatories provide data to rectify this imbalance with some continuous GPS sites using satellite data retrieval systems to make their data available to the IGS database. Data is available from other sites only by annual manual downloads. The status of the permanent observatories is shown in Figure 2 as extracted from the WG-GGI web site

Epoch campaigns

Germany coordinated the GPS Epoch campaigns for the past five years of summer epoch camapigns 1995 to 1999. The objective has been to densify the ITRF reference frame points beyond the fiducial network of permanent GPS stations. Details of the 1995 campaign are given in Dietrich *et al* (1997) and the sites occupied that time are shown in Figure2 above. The complete list to sites occupied during the five year period is summarised in Table 4 . Dat is available through Dr Dietrich at University of Dresden (Dietrich@ipg.geo.tu-dresden.de)

Geoids

An accurate definition of the geoid is severely constrained in Antarctica by the lack of gravity information, especially across the inland of the continent. . Australia produced early versions of the Antarctic Geoid based on GEM and OSU gravity data sets, which are available on the AUSLIG web site http://www.auslig.gov.au/geodesy/antarc/antgeoid.htm. The current situation with the geoid in Antarctica remains hampered by the continuing lack of ground gravity data. A grid of geoidal separation values initially from the OSU91A geopotential model and subsequently from the recent EGM96 that can be used to interpolate a separation value for any location south of 60 degrees latitude are available on the AUSLIG webs site for individual interpolation

These enable GPS users to refer their observed elevations (ellipsoidal values) to a nominal sea level surface, although the values are limited by the amount of data used in the Antarctic region

The gathering of geophysical data to improve the Antarctic Geoid is a major undertaking. Data collection is being undertaken cooperatively with other groups through the newly formed SCAR Neo Antarctic Group of Specialists (ANTEC) and the BEDMAP, ADGRAV and RAMP projects.

GLONASS

GLONASS observations undertaken in collocation with GPS at McMurdo in January /February 1999. Results seminar will be held as part of ION 99 conference in Nashville in September. Report on Antarctic applications will be prepared following this seminar.

DGPS applications

The current DGPS standard for base stations used by the United States Coastguard base stations is the specification recommended for use in the GIANT Program. Details are available on the web site (www.navcen.uscg.mil/dgps/dgeninfo/dgpsant.htm). The WG-GGI has investigated the establishment of DGPS transmission base stations along the Antarctic Peninsula . With three sites distributed as below then DGPS accuracies of better than two metre would be made available to all shipping along the Eastern side of the Peninsula a significant safety measure. The recommended sites are : King George Island; Palmer; San Martin or Rothera.

This would also produce a significant benefit for aviation in the region and could be used by scientists for field work with hand held receivers. Eventually this DGPS transmission network would be extended through liaison with COMNAP to other manned stations around the continent during shipping or aviation activities.

The current DGPS standard for base stations used by the United States Coastguard base stations is the specification recommended for use in the GIANT Program. Details are available on the web site (www.navcen.uscg.mil/dgps/dgeninfo/dgpsant.htm).

Remotely operating GPS sites

At present there is a technological limitation on operating and maintaining remote placed continuous GPS equipment to be self powered and able to transmit data back to manned bases or directly by satellite to global data centres. Technological developments are continuing and ANTEC has arranged a special seminar at Pasadena USA in August to discuss the state of the technology for remote power and data transmissions for remote sites.

Antarctic research symposia

There have been a number of recent Antarctic Geodesy events held including:

- AGU San Francisco December 1998
- EUG10 Strasbourg March 1999
- EGS 99 The Hague April 1999

There will be an Antarctic Symposium arranged in conjunction with ANTEC during the European Geophysical Symposium in Italy in April2000 and a splinter GIANT meeting may be held at that time to incorporate Scandinavian and Russian geodesists.

Group of Specialists on Antarctic Neotectonics (ANTEC)

At the SCAR XXV meeting in Concepcion, Chile, Prof. Dalziel, IUGS Delegate, presented to Delegates a joint recommendation from the Working Groups on Geology, on Solid-Earth Geophysics, and on Geodesy and Geographic Information, that SCAR should establish a new Group of Specialists on Antarctic Neotectonics (ANTEC). The presentation highlighted some unique aspects of the Antarctic continent such as:

- It lies at the centre of a lithospheric plate that, unlike any other, is almost entirely surrounded by spreading ridges and, furthermore, has been essentially in a polar position for the last 100 million years;
- It appears to lack the intra-plate seismicity that characterises all other continents;
- It includes at least one intra-plate rift system, stretching from the Ross Sea to the Weddell Sea, that has unique characteristics including possible implications for the stability of the West Antarctic Ice Sheet.; and
- It is covered by the only extant continent-scale ice sheet, which applies unusual stresses to the crust.

The presentation emphasised the current development of new technologies that are making possible new studies in geodynamics and neotectonics. These provide an opportunity for earth scientists and allow Antarctica to be placed more precisely in the global framework. (*SCAR Bulletin* 133, April 1999). The WG-GGI has strong representation in ANTEC as shown in Table 5.

Member	Country	Field of Expertise	Email Address
Dr Terry J Wilson (Convenor)	USA	Tectonics	wilson.43@osu.edu
Dr Robin E Bell	USA	Gravity, Geology	robinb@ldeo.columbia.edu
Dr Alessandro Capra	Italy	Geodesy, Gravity	alessandro.capra@mail.ing.unibo.it
Dr Reinhard Dietrich	Germany	Geodesy	dietrich@ipg.geo.tu-dresden.de
Dr Jesus M Ibañez	Spain	Seismology	ibanez@iag.ugr.es
Dr Tom S James	Canada	Glacial rebound	james@pgc.nrcan.gc.ca
Mr John Manning	Australia	Geodesy, Remote sensing	johnmanning@auslig.gov.au
Dr Andrea Morelli	Italy	Seismology	morelli@ingrm.it

Table 5. Members of the ANTEC Group of Specialists

Collocation with other geodetic techniques

GPS is a major technique in use in Antarctica but for global observations collocation with other techniques is important such as DORIS, Absolute Gravity, Tide Gauges, and VLBI

The first Antarctic VLBI experiment was observed at Syowa in 1991 (Kurihara *et al* 1991) using a temporary configuration. A permanent installation was established by Germany at the Chilean base of O'Higgins in 1993 and has participated in a number of southern hemisphere campaigns. (Bosworth 1993), (Seeger 19994). Japan refurbished the antenna at Syowa as a permanent installation in 1998 and experiments between other sites in Australia and South Africa are continuing, whilst O'Higgins continues to be operated during the summer months.

Absolute gravity sites have been established in Antarctica by Finland, Italy, Japan, and by the USA in the McMurdo region. A super conducting Gravimeter has been in operation for four years at Syowa.

Permanent recording tide gauges have been deployed at a number of sites including Mawson, Syowa, Cape Roberts, Davis and Casey and O'Higgins.

DORIS beacons are operational at Syowa, Kerguelen, Rothera and Dumont Durville. To date Satellite Laser Ranging has not been undertaken in Antarctica, but there are plans to incorporate it in the future.

Conclusion

The GIANT program can make a significant contribution to the work of earth scientists in Antarctica such as in the ANTEC program. GPS and other precise geodetic observations have been made over a number of years and already provide a reference framework for geodynamics. These current movement velocities are available at a number of for comparison with long term geophysical records. An extended network of GPS sites is being developed in conjunction with ANTEC for occupation when the technology permits to contribute contemporary velocities to give a better. understanding of the crustal motion both within Antarctica and in relation to the southern hemisphere land masses.

The geodetic infrastructure also provides the base linkages to consolidate individual geodetic networks into a single geodetic datum so that all spatial data dependent on geodetic positions can readily be integrated into an Antarctic Spatial Data base

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Antarctic Neotectonics

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2 Department of Geological Sciences - Ohio State University

1. Introduction

Antarctica is characterised by a unique combination of active processes. Active crustal deformation (uplift, faulting) and active volcanism are widespread in West Antarctica and may occur beneath the ice sheet in East Antarctica where subglacial mountains and basins are present. Antarctica is also undergoing active glacial loading and unloading, which induces isostatic motions and applies unusual stresses to the crust. The association of glaciation with rifting and rift-flank uplift is unique. Active tectonic processes may influence the stability of the Antarctic ice sheets. The high-elevation Transantarctic Mountains may be characterised by unusually ancient landscapes preserved in the long-lived polar desert environment. The Antarctic continent appears to lack the intraplate seismicity that characterises all other continents and, coupled with abundant evidence suggesting rapid deformation, presents an unusual geodynamic paradox.

2. ANTEC Group of Specialists

At the SCAR XXV meeting in Concepcion, Chile, Prof. Dalziel, IUGS Delegate, presented to Delegates a joint recommendation from the Working Groups on Geology, on Solid-Earth Geophysics, and on Geodesy and Geographic Information, that SCAR should establish a new Group of Specialists on Antarctic Neotectonics (ANTEC). The presentation highlighted some unique aspects of the Antarctic continent such as:

- It lies at the centre of a lithospheric plate that, unlike any other, is almost entirely surrounded by spreading ridges and, furthermore, has been essentially in a polar position for the last 100 million years;
- It appears to lack the intra-plate seismicity that characterises all other continents;
- It includes at least one intra-plate rift system, stretching from the Ross Sea to the Weddell Sea, that has unique characteristics including possible implications for the stability of the West Antarctic Ice Sheet.; and
- It is covered by the only extant continent-scale ice sheet, which applies unusual stresses to the crust.

The presentation emphasised the current development of new technologies that are making possible new studies in geodynamics and neotectonics. These provide an opportunity for earth scientists and allow Antarctica to be placed more precisely in the global framework. (*SCAR Bulletin* 133, April 1999)

Delegates agreed that a Group of Specialists on Antarctic Neotectonics (ANTEC) should be established with the following Terms of Reference:

The preparation of an Implementation Plan that should include, but not be limited to:

- Identification and coordination of additional sites where permanent geodetic control is essential for geodynamic research purposes,
- Identification and coordination of additional sites where permanent seismic stations should be installed for addressing the structure beneath Antarctica (lithosphere and asthenosphere).
- Encouraging and coordinating installation of instruments at such permanent sites, and in regional networks of instruments (GPS, gravity, seismic) for focused studies,
- Facilitating the sharing of instrumentation,
- Ensuring that protocols for data collection, archiving and distribution best serve the needs of the research community.

The Promotion of scientific research opportunities and directions by:

- Holding workshops and symposia to identify promising research directions in neotectonics and geodynamics of Antarctica.
- Encouraging studies in relevant geoscience areas, such as stress determinations, micro faulting, geochronology (taking advantage of developments in high precision traditional techniques and the emerging cosmogenic radionuclide methods), landscape evolution, and petrology.

ANTEC membership was subsequently approved by the SCAR Executive Committee (see previous page).

3. Science Objectives

The goal of the ANTEC program is to improve understanding of the unique character of the neotectonic regime of the Antarctic plate. Within that goal, specific objectives and the questions which they should address were identified at the inaugural meeting of the group in March 1999 as:

Differentiate between glacial and tectonic kinematic signals

- Which tectonic features are active?
- What rebound patterns are resulting from mass load changes?
- Are glacio-tectonic features active (or were they active in the Neogene) ?

Map the deep structure of the Antarctic lithosphere and asthenosphere

- How are the mechanical properties and properties of the lithosphere distributed?
- Are there mantle plume signatures?

Document seismo-tectonic features of the Antarctic plate

- Is the continent truly aseismic?
- Do patterns of seismicity / aseismicity relate to ice-mass loads?
- What kinematics and dynamics are indicated by the seismicity?

Better understand nature of coupling between tectonics, climate and erosion

- What is the distribution of active faulting?
- Age and evolution of landscape patterns?
- Rates of uplift and denudation?
- Relation of uplift to active and post-glacial faulting?
- Active rift basins?
- Links between active volcanism, postulated mantle plumes, uplift and tectonism?

4. Strategies for Antarctic Neotectonic Research

ANTEC is developing strategies to take advantages of recent advances in technology and increasing availability of continent-wide space imagery and geophysical data. To progress its objectives four principal areas of research have been identified with a further need for technical development and general co-ordination. The principal research areas are:

Geodesy and Remote Sensing (Contacts: Bell, Capra, Dietrich, Manning)

Responsibilities include:

- Co-ordination of data collection and exchange for existing permanent GPS stations and for regional GPS epoch based networks.
- Integration of predicted horizontal and vertical motions due to tectonics and glacial rebound in planning for new permanent stations.
- In collaboration with other groups plan location of new stations inland from coastal regions taking into account crustal block boundaries and model predictions from rebound related uplift patterns
- Facilitation of the application of new satellite remote sensing data and techniques (gravity, laser altimetry, and radar interferometry) to Antarctic neotectonic research.

Seismology (Contacts: Ibanez, Morelli)

Responsibilities include:

Assessments and Compilations of:

- Current operational status of permanent seismic stations
- Availability of station data
- Locations and results of seismic studies of deep structure
- Known earthquakes within Antarctica

Formulate plans for:

- Improving availability of data from permanent seismic stations
- Systematic study of existing data archives to improve earthquake detection and develop cumulative data set
- Develop data base of focal mechanisms and stress data
- Workshop to establish science objectives of future seismological research and, based on these, identify optimum localities for new permanent seismic stations and target areas for regional temporary seismic instrument deployments.

Neotectonic Geology and Glacial Rebound (Contacts: Wilson, Bell, James)

Responsibilities include:

- Provide framework for planning optimum geodetic station configurations to isolate rebound and tectonic signals.
- Improve integration of relative sea level geodetic data into rebound modelling.
- Encourage collaboration between researchers investigating ice sheet mass balance, sea level change, and tectonics.
- Provide neotectonic framework for planning geodetic and seismologic station arrays and regional target areas for instrument deployment campaigns.
- Promote compilation and integration of results in the following areas:
    - Structural geology/Tectonics: active and Neogene faulting; kinematic and dynamic interpretations of faults and fractures; integration of active fault studies from outcrop geology & geophysical data (offshore & onshore); Neogene and younger basin analysis.
    - Volcanology: distribution of active and Neogene volcanism; petrologic evidence for mantle processes.
    - Landscape evolution: tectonic geomorphology; timing and rates of uplift; landscape surface ages; raised beach levels.

An additional two general areas were also identified for specific action:

Technological Development (Contacts : Wilson, Manning, Ibanez)

Responsibilities include:

- Address urgent need for solving problems related to power and communications for continuously operating geodetic and seismologic instruments
- Arrange Technological Development workshop to bring together all parties involved in developing improved power & communications for continuous GPS & seismic stations

General Co-ordination (Contact: Wilson)

In order to promote completion of research focused on neotectonic issues, ANTEC should:

- organise appropriate symposia at relevant national & international scientific meetings, and make sure these are widely advertised
- organise science planning workshop to encourage interdisciplinary and co-operative research
- organise thematic publications, possibly including continent wide map(s) (e.g., the ANTOSTRAT volumes published in AGU Antarctic Research Series)
- Consider how to foster 'Information clearing house' on relevant activities currently in progress

More detailed research plans will be developed for each area with the overall ANTEC activities made available on the ANTEC web site: <http://www.scar-ggi.org.au/geodesy/antec/antec.htm>

3. Geodesy and Remote Sensing

5.1 Geodesy

The Geodesy component will use existing data to build on the work of SCAR WG-GGI Geodetic Infrastructure program (GIANT) to provide best three dimensional movement vectors at existing permanent GPS, VLBI and DORIS base stations. This will provide a framework to extend observations for a more complete general coverage of the continent. It will facilitate a comparison of contemporary surface geodynamics with the long term geological record.

Existing sites

The results from existing continuous GPS sites are available from the International Earth Rotation Service (IERS), Figure 1, has been complied from International Terrestrial Reference Frame (ITRF) information contained in Sinex files available on the web site:

<http://lareg.ensg.ign.fr/ITRF/>

Meta data details of existing permanent stations already compiled by SCAR WG-GGI; information available on their web site:

http://www.scar-ggi.org.au/geodesy/perm_ob/sites.htm

Details of recent SCAR GPS epoch campaigns, co-ordinated by Germany, and resultant velocities are published in "The Geodetic Antarctic Project GAP95 – German Contributions to the SCAR 95 Epoch Campaign" (Dietrich 96).

Results from these epoch surveys will be further collated with those from the permanent sites and made web accessible.

New Geodetic sites

The existing SCAR network of GPS permanent base stations is principally built on coastal rock sites at manned stations as a geodetic infrastructure for homogeneous spatial data. But there is a current technical limitation in providing power and arranging data retrieval at unmanned remote sites for continuous GPS observations required for accurately monitoring movement.

This technological limitation is being addressed by researchers such as Carol Raymond and, Andrea Donnellan as described at the NASA JPL web site. Coupled with satellite phone technology these developments should enable GPS data to be observed through the Antarctic winter and brought out from remote sites by satellite communication, while other data can be downloaded annually for retrospective processing.

When the technology permits new continuous operating GPS stations inland from coastal regions will be established taking into account logistics, continental coverage, crustal block boundaries and model predictions for rebound-related uplift patterns and the needs of a geodetic infrastructure for the spatial data community. This will provides a framework for more intense epoch based studies looking at specific problems such as the TAMDEF survey near McMurdo.

Whilst the technology is being developed sites the location of sites to best study the continental geodynamics and relationships with internal motion of blocks within Antarctic are being identified such as shown in figure 2. with the aim to better understand the contemporary geodynamics on Antarctic land mass.

5.2 Remote Sensing

There is an acute lack of gravity in Antarctica. Despite a recent focus on establishing absolute gravity sites to help to tie relative gravity networks together, there is still a need for both aerogravity to infill between ground sites and satellite gravity sensing for long wave length data. A primary task is to assemble an upgraded gravity data s et suitable for integrating with new aerogravity and satellite borne gravity data.

There is need to collaborate closely with other research projects such as RAMP, BEDMAP, ADMAP, and ANTOSTRAT for neotectonic research and to arrange for ground truthing and calibration of satellite imagery and remotely sensed geophysical data such as:

- SAR interferometry, SAR stereo, ERS Tandem Mission, RADARSAT Antarctic Mapping Mission
- Laser altimetry from 'ICESAT'
- Gravity data from CHAMP and GRACE missions

6. Conclusion

Antarctica presents a unique neotectonics system for research. The newly established ANTEC Group of Specialists will use new technologies and approaches to integrate studies in geodynamics and neotectonics to place Antarctica more precisely in a global framework.

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8. Web sites

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GIANT - http://www.scar-ggi.org.au/geodesy/giant.htm

IERS - http://hpiers.obspm.fr/

ITRF - http://lareg.ensg.ign.fr/ITRF/

NASA JPL - http://geodynamics.jpl.nasa.gov/antarctica/

TAMDEF - http://www-bprc.mps.ohio-state.edu/GDG/tamdef.htm

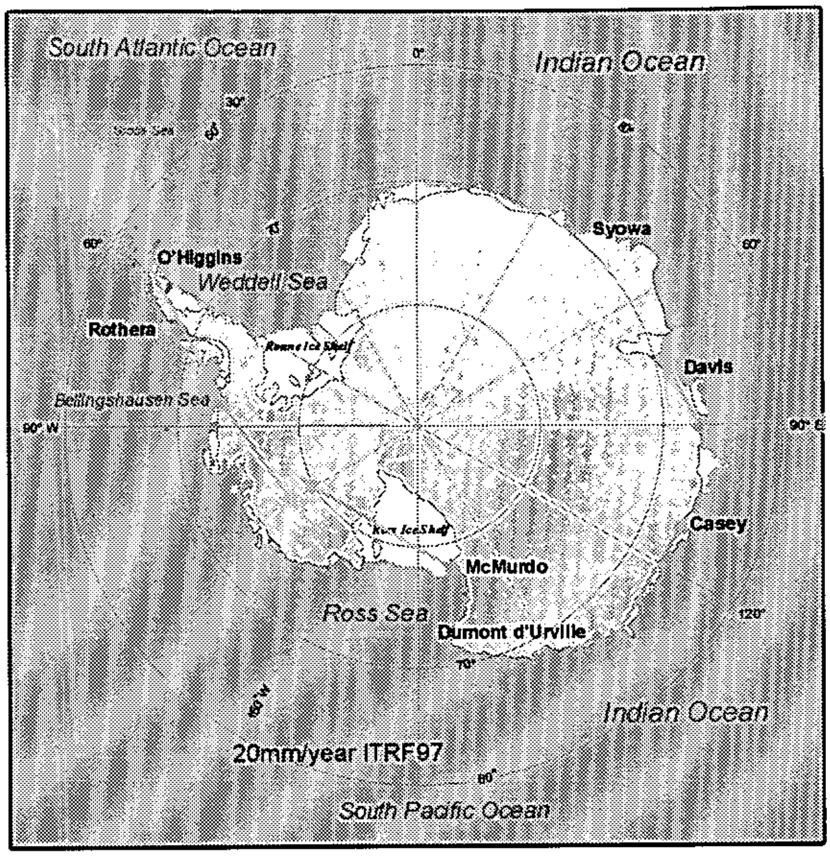

Figure 1. ITRF velocities

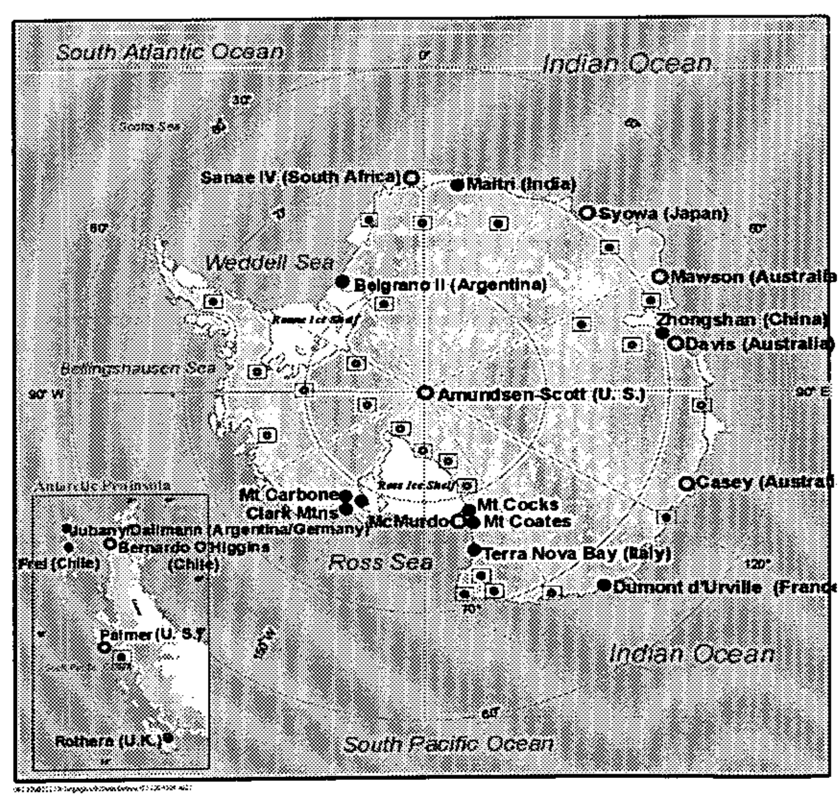

Figure 2. Existing GPS and proposed sites

Permanent GPS - manual download

Permanent GPS - satellite link

Proposed site

GeoStar and GIS of Antarctica

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Abstract

The impact of Antarctica, especially the Geographic Information System (GIS), on our future becomes more profound each day. It is urgent that we construct a GIS to enable the access, sharing and publishing of Antarctic data on the Internet. The rapid advance in network and component technology has been the most important characteristic of software development in recent years. This paper will present the features and functions of GeoStar software and the characteristics of Antarctica data. Moreover, we will introduce the Internet-based Geographic Information System of Antarctica, which includes facilities for data management, acquisition, spatial query, mapping and show etc, and which can access and manage multi-data source such as GeoFile, GeoDB, ARC/Info, MapInfo, DXF and MGE, and link with databases including Sybase, SQL server, Oracle, dBase, Access, FoxPro and Informix, which are able to access, share and publish Antarctica data on the Internet and can manage multi-scale maps.

Keywords

GIS, Antarctica, Internet GIS , GeoStar,DGI,DHM.

Introduction

This paper presents a new Geographic Information System-GeoStar software. The main advantages of the software compared to similar software are: (1) an object-orientated spatial data management platform which is highly efficient; (2) integration of the Vector, Image and DEM databases; (3)bcomponent GIS; (4) Internet GIS which provides the means to access, publish and share GIS data on the Internet. This paper explores how we can collect data ,construct the GIS database and publish distributive geographic information(DGI) of Antarctica on the Internet using GeoStar software.

The World Wide Web (WWW) is at present the most widespread electronic medium for the ordinary user. The enormous body of information on the Web is one of its great advantages. Another is the distributed nature of the information. However, GIF-format or JPEG-format images are the only forms of returned spatial data on WWW which makes manageing these images, eg. zooming in and out, pannning, online map production, modeling and analysis services, time-consuming work

Java, being robust, secure, easy to use, easy to understand, and automatically downloadable on a network, is an excellent language basis for database applications. What is needed is a way for Java applications to talk to a variety of different databases. JDBC (Java Database Connectivity) is a Java API for executing SQL statements. It consists of a set of classes and interfaces written in the Java programming language. JDBC provides a standard API for tool/database developers and makes it possible to write database applications using a pure Java API.

Distributed Geographic Information of Antarctica

1. The actuality and importance of Antarctica data sharing.

The need to access, publish and share Antarctica data on the Internet increases each day with the rapid development of scientific research and groundwork, surveying and mapping in Antarctica. The present GIS data of the Antarctic topographic database is almost isolated: information and data is acquired, stored and analysed to meet the needs of an individual project or program, resulting in data redundancy and inefficiency of data collection and storage. The development of the GIS application is based on a concrete independent and close platform. Moreover, they use conflicting data languages, so are unable to share data. The increasing need for Antarctic information has furthered the advance of scientific research in Antarctica. In addition, people are demanding more and more information on the Internet, especially spatial information of Antarctica.

Compared with the traditional GIS, the Internet GIS has the following benefits:

Firstly, Internet technology transfers GIS, previously only for professional use, to the public information system. In other words, it make GIS available to everyone.

Secondly, accessing data on the Internet can reduce the cost of data distribution, improve the extent to which geographic data is shared and avoid repitition of data collection.

Thirdly, Internet-based GIS technology can construct a geographic information service network through the information highway.

2. The structure of Antarctica data.

An integrated Internet based GIS of Antarctica should contain the following sections:

Web home page data: Generally speaking this is the format of HTML. It includes hyper text, hyper media, hyper Link etc. Current Internet information only includes the above 3H information without the hyper map information. Basic collection, updating and publishing on Internet are performed but the question is how to organize them in a sensible and efficient way. According to the features of Antarctic web homepage data, we believethat web home page data should include the following four portions: scientific research, groundwork surveying and mapping, station information and online help. In recent years China has obtained more and more Antarctic surveying data with the development of GPS,GIS and RS technology; this includes the observation of crustal distortion of the whole Antarctica by means of GPS, the construction of the place names database by means of GIS, the acquisition of the satellite images of Antarctica by means of RS technology and research into sea level change by means of 3S technology. The above progenies provide the abundant data source for web home pages.

Vector data and attribute data: In 1994 the United States began their "Digital GeoSpatial Data Framework" scheme which is used to establish the GeoSpatial database. China will establish the large-scale GIS in the whole nation in order to avoid repitition of data collection, and will include the Digital Orthograph Map (DOM) ,Digital Elevation Model (DEM) and vector data. In this framework DOM is the dominating portion. DEM is produced together with DOM. The vector data include Geodesy reference points, transportation, water system, boundary, cadastral data and etc (Li, 1998). Scientific Committee for Antarctic Research (SCAR) [Working Group on Geodesy and Geographic Information (WG-GGI)] is responsible for organizing and managing international Antarctic scientific research on the following six research topics [or fundamental geographic datasets]:

1. Antarctic Coastline Data Project
2. Antarctic Hydrographic Data Project
3. Antarctic Ice Bed Elevation Project
4. Surface Elevation Project
5. Names Project
6. Features Project.

We argue that the vector data of Antarctica must include the following information.

1. Water system maps of the coastlines, lakes, rivers, unmelted Ice area and ice shelf data.
2. Island maps, showing boundaries, buildings etc. Island maps and water system maps constitute the framework of the Antarctic geographical region and perform an important role in terrain control; moreover, they are extremely important to Antarctic GIS. Most geographic analysis and applications are referenced to them.
3. Contour maps and elevation data which show the undulation of the topography, and are an important data source of DEM. They are important for the study of the overlay and vicissitude of the Antarctic glacier.
4. Geodesy control points and place names data. The Vector data is stored in afile system and the attribute in a relationship database. The show component of GIS only shows the position and annotations of the points.
5. Metadata is the quantitative and qualitative description of Geographic spatial data (Kong, 1998; Lin, 1998b) and is the data to describe the contents, definition, spatial frame of reference, quality, management etc of spatial data. It is one of the key technologies of geographic spatial data and, primarily, includes information on mark, data quality, spatial reference, space-time, spatial data denotation, system, distribution, metadata reference etc. The metadata of this system includes the mapping region, collector, proprietor, the cover of the map, scale, accuracy, date of collection and updating, data structure and attribute, map projection and location of data etc.
6. Image data are acquired by the means of RS technology. China scientists analyse glacier flow and evolution, and iceberg movelent by monitoring changes in the ice sheet. Data sources have included MSS in 1970s, TM from1989 and radar imaging from1997.

3. The features of Antarctic geographic information

Distributed Geographic Information (DGI) includes geographic information such as map, image, data muster, analysis operation, reporter, etc which can be published in various ways on the Internet by means of network technology. Geographic information of Antarctica also has the distributive characteristics of perpendicular and horizontal distribution.

Perpendicular distribution: One region may have different thematic geographic information based on the same scale. eg, King George Island contains many layers of information: maps of coastline, hydrology, contours, place names, topography, plant distribution etc. (Figure 1). Moreover, different types of information may be collected and maintained by different departments in different ways. Coastline and contour maps etc may be collected by

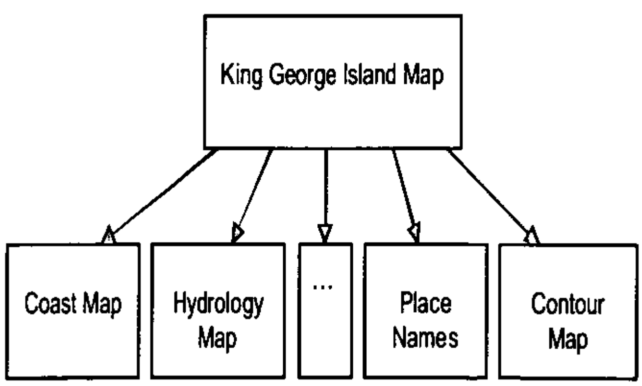

Figure 1. The Layers of King George Island Map

surveyors; plant distribution map by biologists, place names map by means of GPS technology; hydrologic map using RS technology. Organizing the above data efficiently involves organising the Antarctic geographic data through horizontal distribution.

Horizontal distribution: A map of Antarctica showing surface elevation, lakes, ice shelf, station information etc. can serve as the home page (or main map) (Figure 2). Each island name can be used as the keyword of a hyperlink to each Antarctic station home page . The user can query any information from the Antarctica map to the Laser map and from the Laser map to Zhongshan station map by clicking on the hyper link, so performing a multi-scale query.

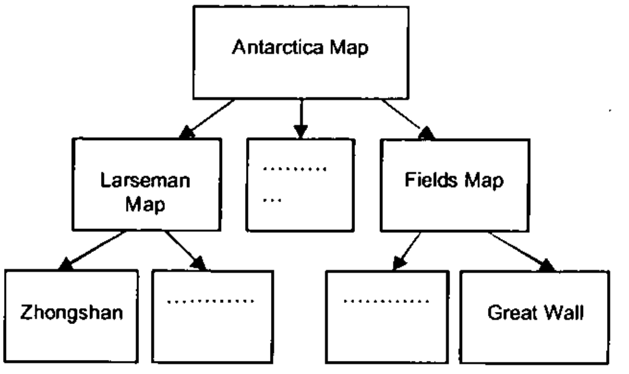

Figure 2 The multi hyper maps

Different scales and different map projections : This is a feature of geographic information of Antarctica. Table 1 shows that Antarctic maps adopt different projections, and therefore are on different scales. It also indicates the heterogeneity of data source, as different maps use different data formats.

Map Name	Projection	Scale	Format
Antarctica	Oblique Azimuthal Equi-distant	1:17250000	Arc/Info
Larsemann	Gauss-Kruger	1:10000	MapInfo
Fields	Gauss-Kruger	1:10000	MapInfo
Zhongshan	Cylindrical Equirectangular	1:2000	GeoStar
GreatWall	Cylindrical Equirectangular	1:2000	GeoStar

Table1. The comparison of maps

GeoStar Software:

1. The Characteristic of GeoStar.

GeoStar, which contains almost all of GIS functions, is an important scientific and technological research project in China during "8th five years" and "9th five years". GeoStar is an enterprise GIS software for managing large-scale spatial data. It can simultaneously manipulate graphics data, attribute data, image data and DEM. It can also be linked with various kinds of commercial DBMS, such as SQL Server, Sybase, Oracle, Informix, etc through ODBC. In addition, it can exchange data with currently popular GIS software and Chinese spatial data through its data-exchanging modules.

The core module of GeoStar is the platform of spatial data management, which is responsible for receiving, processing, querying, indexing and transferring spatial data. A set of API functions has been extracted and used by high level systems for data collection, spatial query, spatial analysis and other applications. A common spatial database can be shared by all modules.

The major characteristic of GeoStar is that it can integrate vector data, attribute data, image data and DEM. The integration is used mainly for professional large spatial databases, vector data, attribute data, image data and DEM and can be stored in different databases respectively and distributed through the integrated interface. The four kinds of data can be manipulated in cooperatively, such as zooming in and out, seamless roaming and performing spatial queries.

GIS of Antarctica:

1.Comparision of existing GIS of Antarctica on Internet

There are two traditional approaches to constructing client-side access to distributed spatial data search and access systems on the Internet: the Web client-to-server gateway approach and the Client-side plug-in approach. (Peng, 1997).

2.Model of GIS of Antarctica

The GIS of Antarctica, constructed as the distributed hyper map model (DHM) is distributed on the Internet, and constitutes the Web server, Client, multi-JDBC data acquisition server and multi-database server (Figure 3). This model address five fundamental features:

- Vector Graphic Data.
- Task separation.
- Computing distribution.
- Servers and Clients distribution.
- Inter-operability of mutli-data source

Using this model, the spatial data in clients are vector graphic data. All operations, for example zooming in and out, panning, online map production, modeling and analysis services are performed by the clients' machine, without the server . This new method undoubtedly reduces the burden on network transportation and the server.

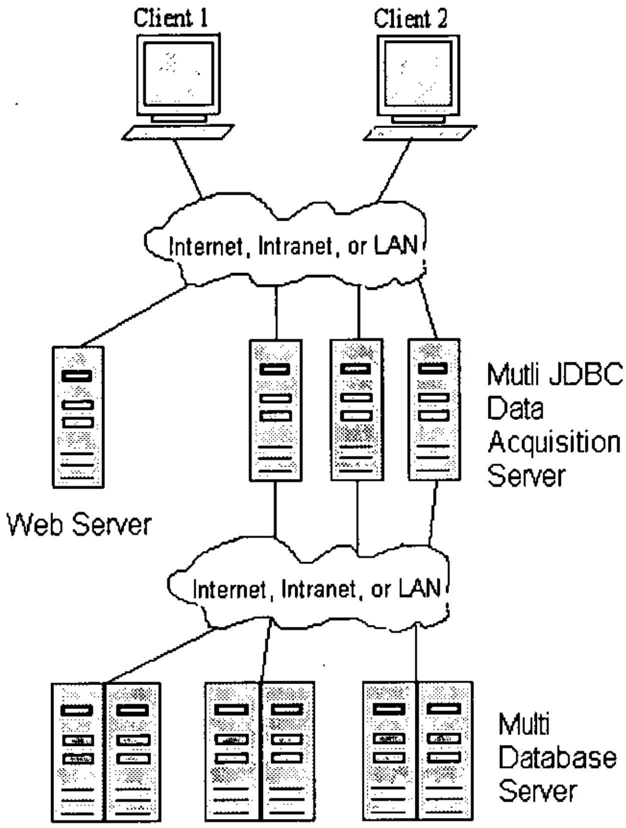

Figure 3 Distributed Hyper Map Model

3. Features and Functions of GIS of Antarctica.

This system includes many features.

- The tasks of Web server, Clients, multi-JDBC data acquisition server and multi-Database server are completely separate. The Web server manages Web services, providing classes that the system needs to run. The Multi-database server is responsible for data services, such as data computing and operating. The multi-JDBC data acquisition server provides the interface between the multi-database server and the clients' machine. Other tasks are performed by clients' machine, including show, query, mapping production and analysis.
- Computation is distributed on the Internet. Some is finished on the clients' machine, that which is relative to database management is performed on the multi-database server.
- The multi-database server and multi-JDBC data acquisition server are distributed on the Internet.
- This model provides the inter-operability of multi-data source. Only through the WWW, can users use multi spatial data sources, such as ArcInfo, MapInfo, MGE, DXF, GeoDB (Microsoft SQL server, Sybase) and GeoFile. The vendors of GIS data can use any GIS software. All GIS information can be published on the Internet.

This system includes many functions.

- It will be available on all platforms and operation systems equipped with the JAVA Virtual Machine. Users can start up this system with any WWW browser after which it has no relationship with the browser.
- This system can be operated expediently. Without installation, users can start this system when they know its IP.
- Users can analyze map features and descriptive attribute information for query, spatial analysis, thematic map production, distance analysis and tabular manipulation etc.
- This system provides a printing function. All kinds of results including mapping and tabular manipulation can be printed on the clients' side printer independent of the Server and the detailed printer type of the Client side.
- This system runs simultaneously in multi-languages.
- The system produces multi-scale graphics to be visually manipulated, users can acquire multi-data source on Internet and perform multi-media and explicatory functions.
- Security. Users can access data, but can not save information on the clients' side

Conclusion and future work

From figures 4, 5 and 6 we can come to the following conclusions:

- Internet based GIS of Antarctica is the best combination of GIS and Internet for access, sharing and publishing of Antarctic data online and can contribute to distributed computing and inter-operability of Geographic information.
- The distributed hyper map model is very effective for Internet based GIS of Antarctica.
- The characteristics are multi-distributed data sources, distributed component, distributed computing and inter-operability.

Internet based GIS of Antarctica is at the development stage and still has many problems to be solved, eg. the visualization of spatial information, software inter-operation, spatial analysis etc.

Acknowledgements

This Project is sponsored by Professor Deren Li, Professor Dongchen E, Professor Jianya Gong. They have given me much help during the design and implementation of this system. This project has been finished by all members of GIS Research Center of Wuhan Technical University of Surveying and Mapping and all members of Chinese of Antarctic Center of Surveying and Mapping. Here I express my gratitude to them.

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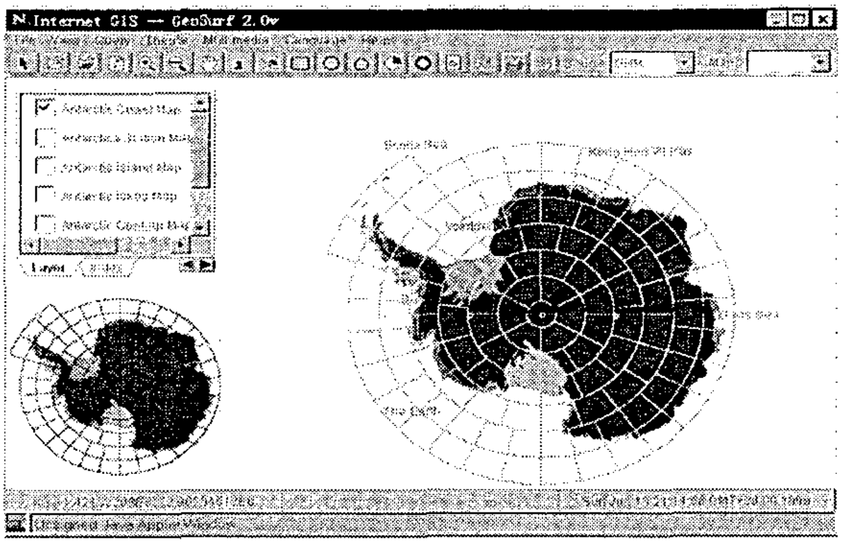

Figure 4. The Map of Antarctica

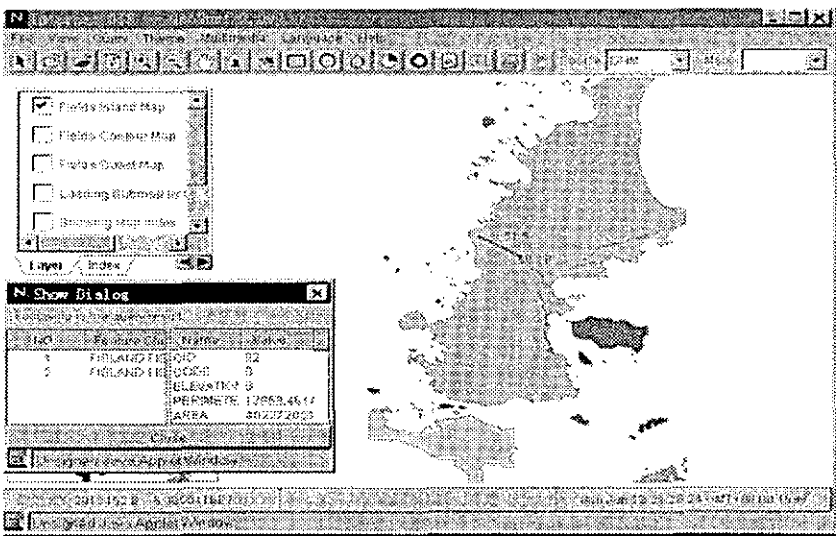

Figure 5. The map of Fields

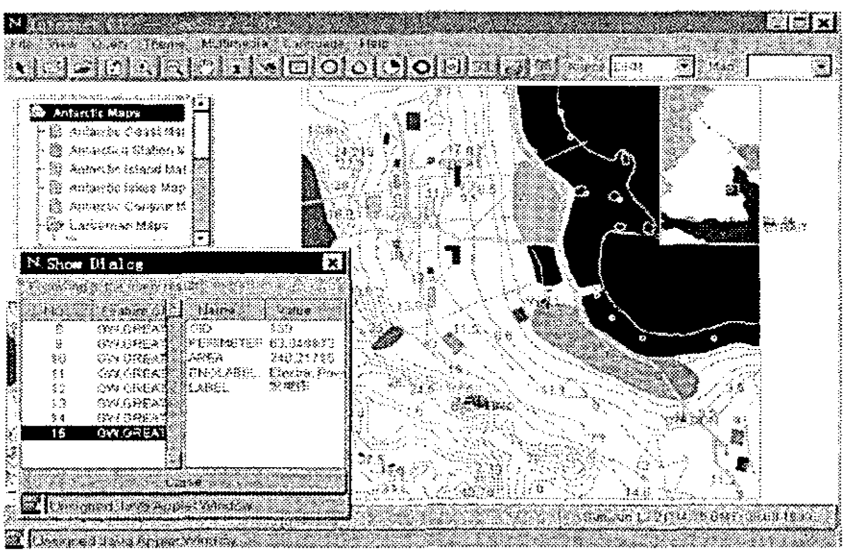

Figure 6. The map of Great Wall Station

Polish Geodetic Activity in the 1998/99 Antarctic Summer Season

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Summary

The paper presents Polish activity in the field of geodesy in the Antarctic summer season 1998/99. The main task: participation in the SCAR EPOCH 99 GPS CAMPAIGN and several additional tasks, such as measurement of the local GPS network, measurements for producing a 1:50000 map of Admiralty Bay, precise measurements of the boundaries of the Site of Special Scientific Interest No 8 located near Arctowski Station, supporting measurements for mapping the area of Turret Point on King George Island and neighboring Penguin Island, etc.

Introduction

Henryk Arctowski is Poland's full-year medium-sized Antarctic station, located in Admiralty Bay on King George Island, South Shetlands. The station was established in 1977, and since then has been maintained by The Department of Antarctic Biology of Polish Academy of Sciences. As a result of its establishment Poland became a signatory of the Antarctic Treaty and subsequently the station became the centre of continuous scientific activity. The principal role of the station is to serve as an ecological and earth sciences observatory.

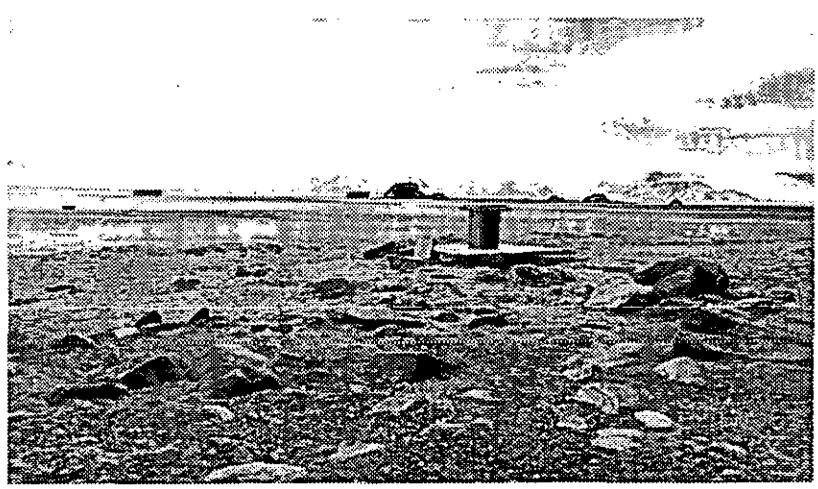

Figure 1. Geodetic pillar at Arctowski Station

Due to the co-operation between Department of Antarctic Biology and Institute of Geodesy and Cartography the author had the chance to join the summer party of the XXIII Polish Antarctic Expedition to Arctowski Station (December 1998 to March 1999).

The main goal of joining the expedition to include the main geodetic point of Arctowski into the GPS network of *geodetic infrastructure of Antarctica* developed in the GIANT program by participation in SCAR EPOCH 99 GPS CAMPAIGN.

The additional tasks were:

- Measurements of the local GPS network related to the main point.
- Measurements for producing the 1:50000 map of Admiralty Bay.
- Precise measurements of the boundaries of the Site of Special Scientific Interest No 8 located near Arctowski Station.
- Supporting measurements for making a plan of the station area including the existence of plants and the placement of various scientific equipment.
- Supporting measurements for mapping the area of Turret Point on King George Island and neighboring Penguin Island.

SCAR EPOCH 99 GPS CAMPAIGN

When Arctowski Station was established a concrete geodetic pillar was also erected, and used for astronomical determination of the station co-ordinates (figure 1). The same point was used also ten years ago, in 1989, by the team making Doppler measurements at the station.

The pillar itself is of very strong construction, made of reinforced concrete and built on a rocky base about 200m away from the station. Considering that the area is free from obstructions, and the excellent condition of the pillar, it was obvious to use it for the GPS campaign. For SCAR EPOCH 99 purposes we named the point ARCT.

Before taking measurements the brass centering device was fixed on the pillar to ensure automatic centering of the GPS antenna with very high (less then 1 tenth of millimeter) accuracy. All the equipment, i.e. GPS receiver, computer etc. were placed in a waterproof and windproof box near by the pillar. In addition, the power supply line was taken down.

The GPS equipment used, was Ashtech Z-12 GPS receiver with the remote option, which allowed the automatization of the data collection, and the geodetic L1/ L2 antenna.

During the SCAR EPOCH 99 CAMPAIGN period, according to the schedule, between January and February 1999, continuous 24 hour GPS data collection with 15 s interval was maintained. However the data collection started in advance at the beginning of the year and continued with no break until the second half of March.

With the exception of ARCT point, all local network point locations are the hills or rocks surrounding the station and the Admiralty Bay (Figure 2). These are Point Thomas (the rocky hill near by the station), Jeardine Peak, Tower Peak, Mount Wawel (the hill on the east side of the bay) and the rock on the Chabrier Island at the entrance to the bay.

The measurements were taken during 2-4 hour sessions, depending on the distance from the ARCT point, with the same 15 s data collecting interval, so the estimated accuracy of obtained vectors, relative positions of the points, are on the level of a few millimeters

The equipment used was the set of two other double frequency Ashtech Z-12 receivers, the same type as the one operating on ARCT point.

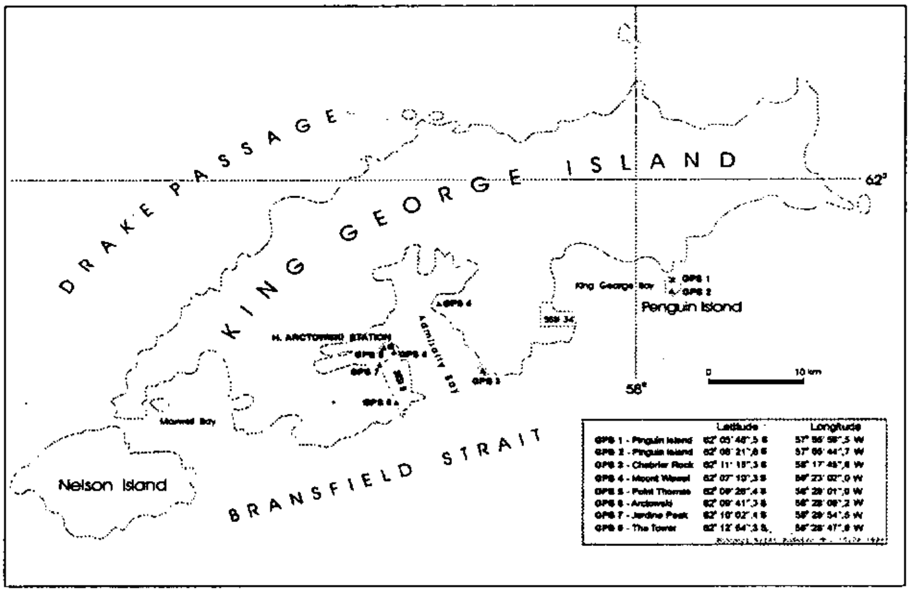

Figure 2. Map to show the location of GPS observation points

The data collected were transferred afterwards to the SCAR EPOCH 99 CAMPAIGN data collecting center at the Institute for Planetary Geodesy in Dresden.

The single point position of ARCT point (62° 09' 41.4"S, 58° 28' 09.3" W) were calculated as an average value of the single point positions from over 3 months continuous data. The accuracy, in the sense of standard deviation, is about 3 m, and the co-ordinates agree very well with the results obtained by the Doppler measurements.

Local GPS network.

Besides the permanent observations on ARCT point, measurements of the local network of 6 points were taken. All points were newly established with brass marks with a cross-shaped cut which were set into the rock. Furthermore two, similarly-marked points on Penguin Island were also set and measured.

The new precise network is expected to be used, among others, in the production of the existing 1:50000 map of Admiralty Bay.

Boundaries of SSSI No. 8

Along with the network measurements, the boundaries of the Site of Special Scientific Interest No 8 were precisely determined. SSSI No. 8 is situated on the west side of Admiralty Bay close to and extending south from Arctowski Station. As the satellite technology and co-ordinate systems in geodesy make a standard it became necessary to determine the WGS84 co-ordinates for the points defining this protected area.

The boundaries determination have been determined according to the definition within the *Management Plan for SSSI No 8*. The area there is delimited with four

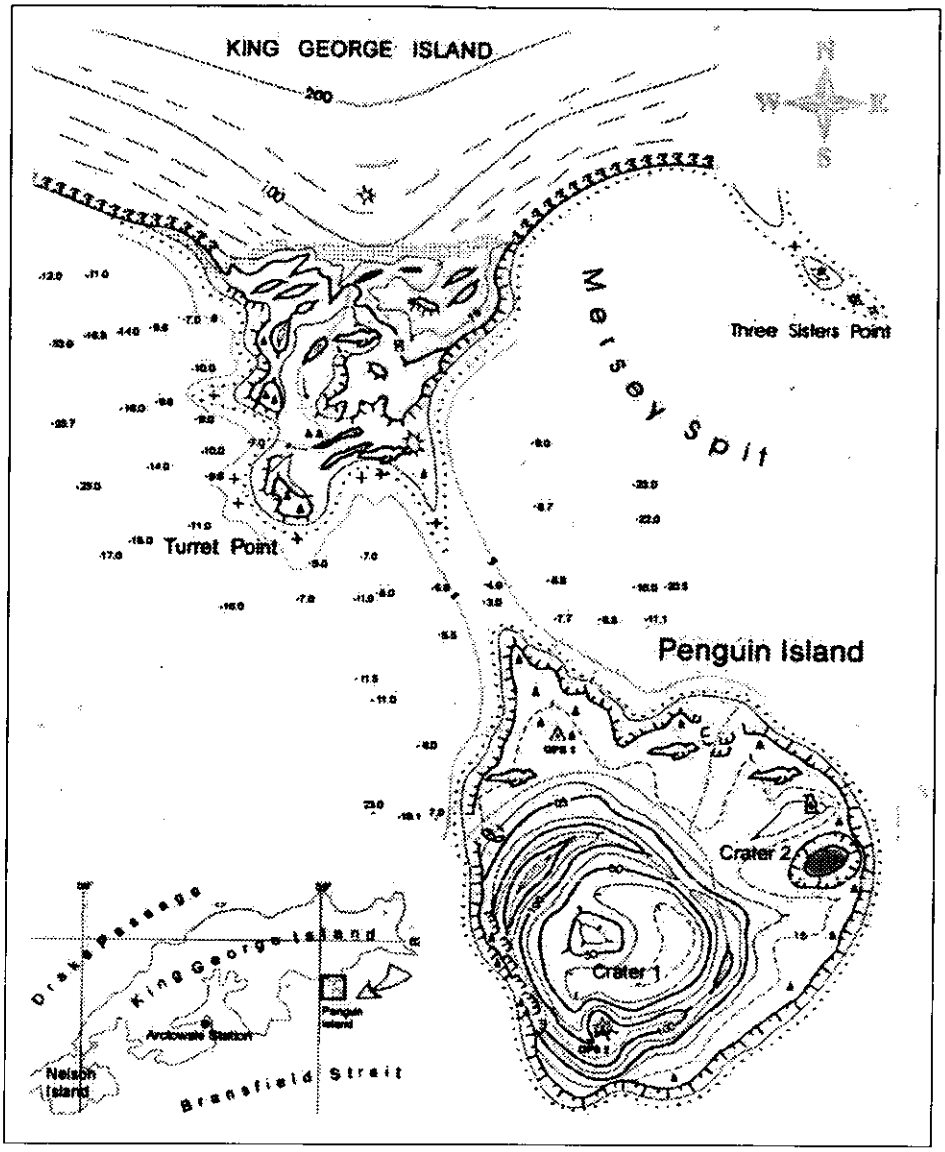

Figure 3. Preliminary measurements of Turret Point and King George Island

points, the co-ordinates of which were determined in relation to ARCT point with decimeter accuracy. In addition, points were measured from three other characteristics in the area.

Additionally, rapid static and kinematic measurements were made to support making a plan of the station area . The purpose of this was to include into this plan the placement of various scientific, in most cases hydro-biological equipment, the extent of plants in the vicinity of the station as well as current placement of penguin rockeries and the nearest moraines.

The precise WGS84 co-ordinates of the lighthouse operating on the shore in front of Arctowski Station were also determined.

Turret Point and Penguin Island mapping

In support of the mapping of Turret Point in the middle-east part of King George Island and on Penguin Island, several GPS sessions were undertaken.

On Penguin Island two new points were established using brass marks with a cross-shaped cut. The points were placed at stable-look, huge rocks protruding from the soft ground of the inactive volcano which made the island, one of them in the middle of the volcano crater.

The measurements, completed using rough bathymetry around Turret Point and Penguin Island, are the basis for mapping activities in that area. Figure 3 presents the very preliminary measurements calculated at the station by Mr Rafal Pudelko.

Polish Geodetic Antarctic Studies. A short historical outline

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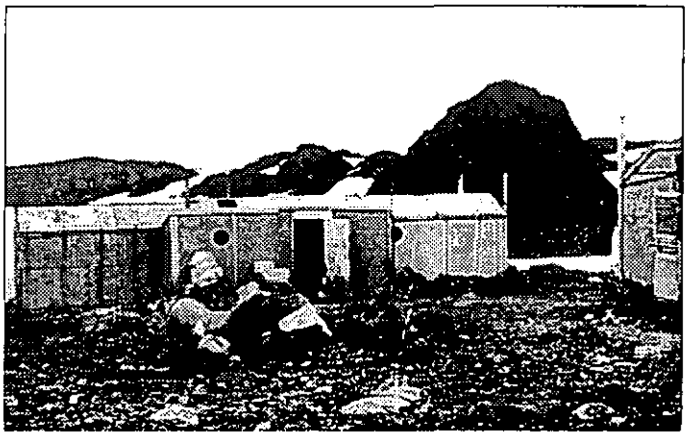

Figure 1. A. B. Dobrowolski Station

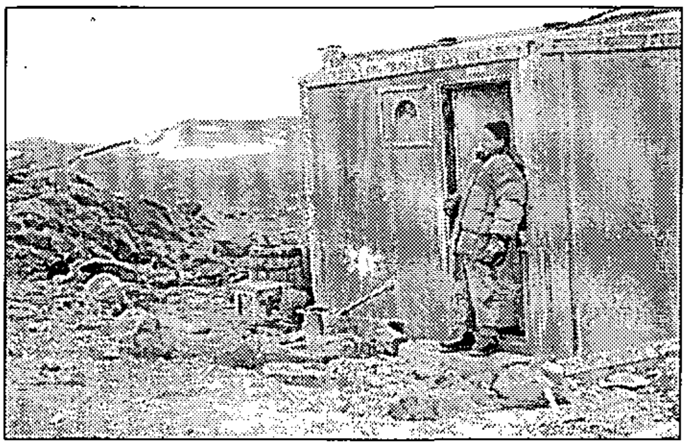

Figure 2. Author in front of the gravimetric pavilion

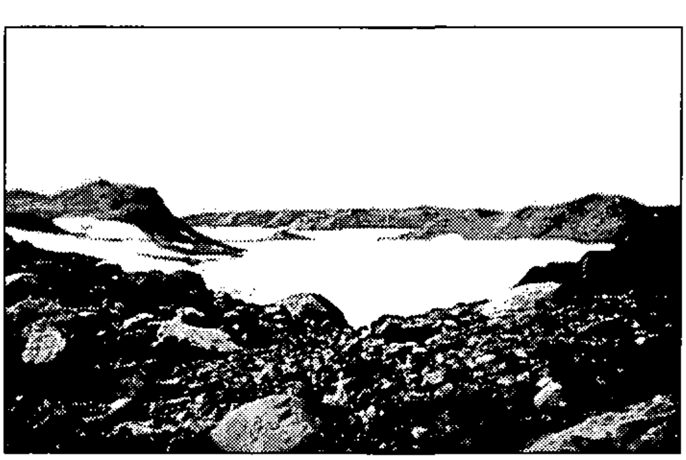

Figure 3. Vicinity of the A. B. Dobrowolski Station (Bunger Oasis)

Active exploration of the Antarctic Continent by Polish scientists began in the late fifties and was focused mainly on different scientific investigations (geophysics, geodesy, biology, ecology etc.) carried out at two Polish Antarctic stations: Station A.B.Dobrowolski located in Bunger Oasis and Station H. Arctowski, Admiralty Bay, King George Island. This short historical outline remembers the main milestone works of Polish geodesists carried out at these two Antarctic stations.

The first Station in Bunger Oasis was taken over by Polish scientists from their Soviet colleagues on 23 January 1959 and was named Station A.B.Dobrowolski. The station is situated in a very specific Antarctic "oasis" where the nunatac stones appear above the ice, very strong winds blow, there is extremely high solar radiation, a very high temperature gradient, big differences between the daytime and night-time temperature; during the summer the day temperature is usually above zero and the humidity is very low.

During the 1958–59 Antarctic summer the first magnetic observations were made by Dr. Wojciech Krzeminski but probably the most valuable achievement of this first expedition to the A.B.Dobrowolski Station was the establishment of the gravimetric point in one of the pavilions of the Station and direct connection of this point to the main Polish gravimetric network. The gravimetric point was embedded in the stone ground and marked by special brass plate. For the measurement of the gravity difference the four-pendulum gravity-meter Askania Werke was used. We should remember that at the time this gravity-meter was commonly recognised as a very precise and sophisticated instrument. The gravity value determined by Z.Zabek and J.Sledzinski for the Antarctic Station ($\phi = 66°16.3'$ S, $\lambda = 100°45.0'$ E, H = 35.4 m) was

$$g_{Ant.} = 982\,424.4 \text{ mGal} \pm 0.4 \text{ mGal}.$$

The next geodetic works in the A.B.Dobrowolski Station were carried out during the third Antarctic expedition organized by the Polish Academy of Sciences from 1978–79. The broad scientific program included the following works: establishment of a geodetic network in the Bunger Oasis, establishment of an astronomical reference point, magnetic observations, photogrammetric surveys aimed at developing maps of the vicinity of the Station to scales 1:500 and 1:5000 (Z. Battke - author of the maps). Also the gravimetric measurements were continued. The

No.	X	Y	–	H	g	Free-air anomaly	Bouguer anomaly
	[m]	[m]	[° ' "]	[m]	[mGal]	[mGal]	[mGal}
ASTRO	5000.00	5000.00	66°16'30.0"	35.26	982 438.41	76.94	73.98
CS	4704.62	5235.25	39.5	59.23	431.42	77.17	72.20
F1	4617.70	4084.38	42.3	52.16			
F2	4905.18	3988.64	33.1	24.91	439.46	74.74	72.65
F3	5382.02	4290.39	17.7	76.16	428.85	76.67	72.60
M	4886.99	4533.26	33.6	48.52	434.12	80.23	73.84
F4	5253.99	4604.34	16 21.8	76.03	428.74	80.00	73.63
F5	5988.78	4223.39	15 58.1	80.16	428.19	81.17	74.45
F6	5785.19	5032.66	16 04.7	63.49	432.14	78.46	74.23
F7	5864.13	5984.15	02.1	50.41	434.73	79.85	74.53
F8	5473.48	5994.72	14.7	80.46	427.66	80.43	73.60
F9	4947.06	5997.41	31.7	55.84	432.35	77.20	72.52
F10	4550.33	6040.11	44.5	29.62	437.95	74.47	72.00
PC	5038.59	5025.10	28.8	38.20	437.60	77.06	73.86
PG1	5461.48	4604.59	15.1	51.05	434.49	78.17	73.89
PG2	5373.71	4788.87	17.9	41.81	436.13	76.91	73.41
PG3	5425.25	4953.83	16.3	45.96	435.40	77.48	73.62
PG4	5594.60	4977.57	10.8	55.60	433.49	78.66	74.01
PG5	5364.95	5175.63	18.2	31.02	438.18	75.62	73.02
PG6	5686.30	5469.55	17.9	84.74	426.56	80.77	73.67
PG7	5592.20	5528.32	10.9	50.12	434.43	77.90	73.70
PG8	5247.25	5308.19	22.0	34.32	437.16	75.55	72.67
PG9	5387.80	5638.50	17.5	40.06	436.57	76.81	73.45
PG10	5225.66	5665.24	22.7	57.21	432.11	77.55	72.76
PG11	4895.34	5723.13	33.4	28.13	438.35	74.61	72.26
PG12	4792.26	5106.24	36.7	11.72	442.40	73.55	72.57

Table 1. Coordinates of geodetic network points, gravity values and free-air and Bouguer anomalies

established geodetic network consisted of 26 points and was measured by Dr. A. Pachuta and Dr. J. Cisak using Wild T2 theodolites and Zeiss EOK distance meters.

The established astronomical point (measured by Dr. J. Cisak) was determined by the Kawrajski method from pairs of stars at equal heights using a Wild T2 theodolite. The result of the determination was:

$$\phi = 66° 16' 34.4''S \pm 1.6''$$
$$\lambda = 100° 45' 00.7''E \pm 0.3''$$

During the third expedition the Station was visited by Dr. Vincent Morgan, a scientist from Australia, who determined the coordinates of the astronomical point by satellite Doppler technique. His result gained from only three satellite passes was:

$$\phi = 66° 16' 30''E$$
$$\lambda = 100° 45' 03''E$$

Magnetic works performed in 1979 by S. Mroczek focused on measurement of the magnetic deviation of navigation devices of two helicopters Mi-2 available at the Station and determination of the magnetic declination in the vicinity of the Station. The value of the declination was determined as

$$D_{Dobrow.} = -89^{0}\,36.4'$$

The time variation of the declination with respect to the measurements from 1958 were also determined.

The programme of gravimetric works included the gravity surveys in the region of the Station Dobrowolski and the gravimetric connection Station Dobrowolski – Mirnyj (Soviet Antarctic station). The gravimetric surveys in the vicinity of the Station were made by using the Canadian gravimeter Sharpe CG-2. For gravimetric connection of the Mirnyj station 4 flights, either by Soviet Mi-8 helicopter or Polish Mi-2 helicopter were carried out. As a result the new value of gravity for the point in Mirnyj was established; the gravity difference was determined as

$$\delta g_{Mirnyj\text{-}Dobrow.} = 34.37 \text{ mGal} \pm 0.05 \text{ mGal}.$$

Hence, for the gravimetric point at Mirnyj:

$$\phi = 66° 33.1' S$$
$$\lambda = 93° 09.5''E$$
$$H = 35.058 \text{ m}$$

the following gravity value referenced to the pendulum point of Station Dobrowolski was achieved:

$$g_{Mirnyj.} = 982\,390.0 \text{ mGal} \pm 0.4 \text{ mGal}$$

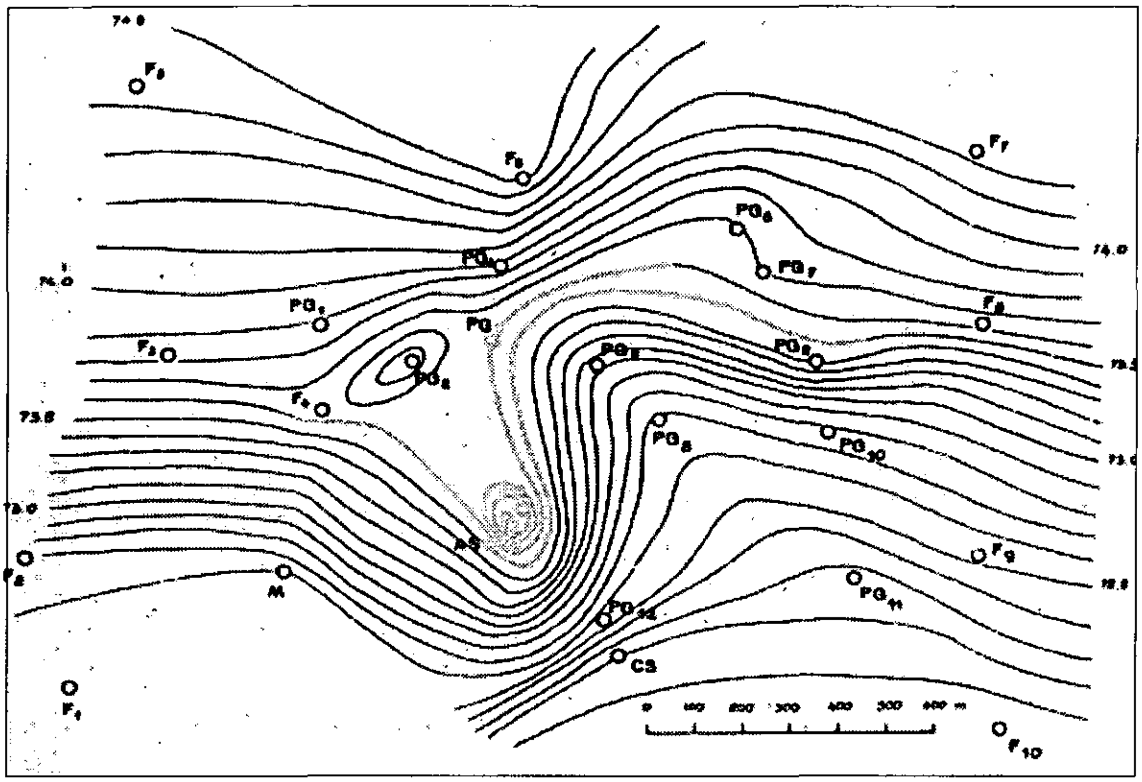

Figure 4. Bouger anomalies

This value agrees well with other determinations performed for Mirnyj by German, American and Soviet scientists. The gravimetric works were undertaken by Dr. A. Pachuta from the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology.

It should be mentioned that Polish geodesists have introduced some Polish names on maps developed during the 1978–79 expedition. We mention only the following: Zatoka Polskich Geodetów (Bay of Polish Geodesists), Beskid, Giewont (peaks of the mountains south Poland), Skala fok (Rock of Seals), Gniazdo Skuy (Nest of Skuy Birds), Czarna Skala (Black Rock), Wzgórze Kaminskiego (Kaminski Hill), Dolina Manczarskiego (Manczarski Valley), Góra Rózyckiego (Rózycki Peak).

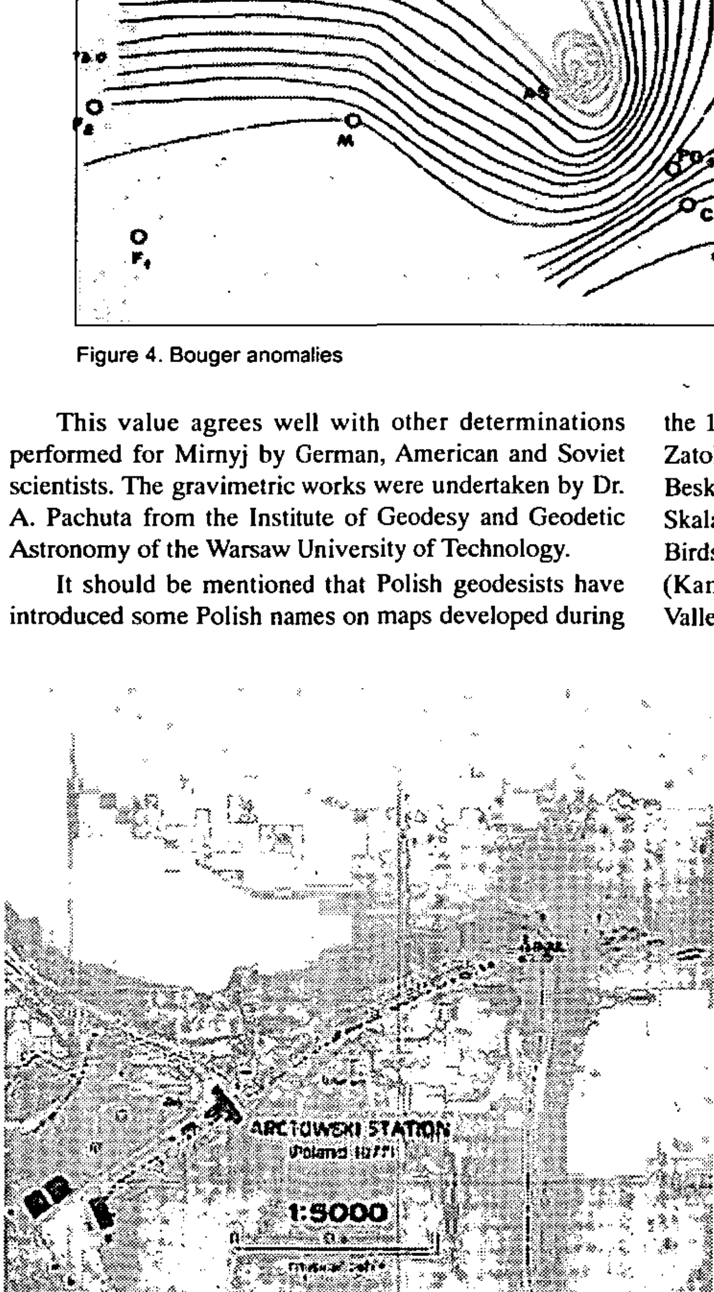

Figure 5. Location of Arctowski Station

Another Polish Antarctic station, Arctowski Station, established in Admiralty Bay, King George Island, South Shetland Islands began its operation on 26 February 1977 and since then has been working permanently (Figs 5, 6 and 7).

One of the first geodetic works was the establishment of the reference astronomic point. located near the lighthouse. However, the unfavourable weather conditions and very short nights during the 1977–78 summer expedition only allowed Dr J. Jasnorzewski to determine the astronomic coordinates with very low accuracy:

$$\phi = -62^\circ\ 09'\ 51'' \ \pm 12''$$
$$\lambda = 3^h\ 53^m\ 51^s \ \pm 0.8^s$$

This accuracy was well improved about ten years later by J.Cisak, M.Dobrzycka. They obtained:

$$\phi = -62^\circ\ 09'\ 39'' \ \pm 2''$$
$$\lambda = 301^\circ\ 31'\ 32'' \ \pm 2''$$

They also determined the coordinates of the reference point at H. Arctowski Station by carrying out the Doppler observations in the frame of the Intercosmos Doppler Observation Campaign ICDOC. The coordinates of this point determined from 311 satellite passes related to the WGS72 system are:

$$\phi = -62° \, 09' \, 41''$$
$$\lambda = 301° \, 31' \, 49''$$
$$H = 30.60 \text{ m}$$

The broad geodetic programme of the 1978–79 expedition and subsequent expeditions also included photogrammetric works aimed at preparation of maps of various parts of the vicinity of the Station H. Arctowski (Fig 8). We mention the following maps: the map of the Admiralty Bay Station H. Arctowski area at the scale 1:25000 (Dr. K. Furmanczyk, Dr. A. Marsz), maps at scales 1:5000 and 1:50000 of the vicinity of the Station of H. Arctowski (Dr. Z. Battke). map of a special protected area "Lions Rump" (Dr. J. Cisak and Dr. Z. Battke), map of the vicinity of the Spanish station at the Livingstone Island at the scale 1:5000 (Dr. P. Madejski). All the maps worked out by the geodesists were also used for the aims of biological studies (determination of the location of flora and fauna) as well as for geomorphologic and ecologic studies.

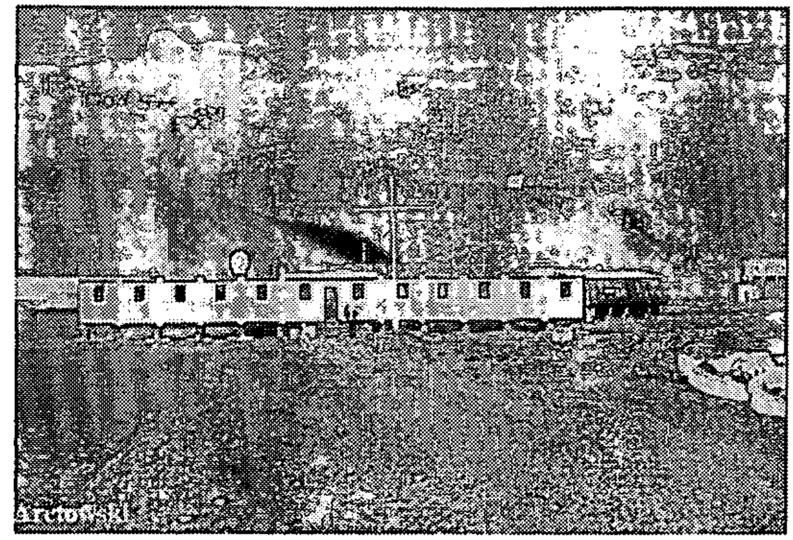

Figure 6. The main building of Arctowski Station

Figure 7. Arctowski Station in winter

More than 1000 scientists have worked at the Station H. Arctowski since 1978. The scientists from other countries who have visited and worked at the station came from: Argentina; Brazil; Belgium; Canada; former Czechoslovakia; Germany; Monaco; New Zealand; Peru, former Soviet Union; Spain; United Kingdom and USA. Long-term projects were jointly undertaken in 1990–91 by Polish and Dutch scientists. Almost 20,000 tourists have visited the Station since 1976.

It should be stressed that permanent activity of the Antarctic Station H. Arctowski was lead successfully by the Institute of Ecology of the Polish Academy of Sciences, now is organized by the Department of Antarctic Biology of the PAS and personally by the Director of this Department Prof. S. Rakusa-Suszczewski. His personal engagement is gratefully acknowledged.

When speaking about Polish exploration in the Antarctic we must not forget the activities of two Polish geodesists who died ten and eighteen years ago.

Dr. Wojciech Krzeminski was the young boy scout who took part in the Warsaw uprising during WWII. Wounded he was than taken prisoner in Nazi Stalag IXB in Zeltchen near Dresden. From 1945–46 he was a soldier of the Polish Army in Italy and in England, returning to Poland in 1947. From 1947–52 he was student of the Faculty of Geodesy and Cartography of the Warsaw University of Technology. He began to work in 1951 and his whole work was focused on magnetic surveys as well on selected problems of the geodetic metrology. He was a head of the First Polish Antarctic Expedition of 1958–59 and the Polish Antarctic Expedition 1978–79. He was very active on an international level in the framework of the scientific organizations of International Association of Geodesy of the International Union of Geodesy and Geophysics, SCAR, KAAPG and others. He died on 9 April 1981.

Dr. Jerzy Jasnorzewski graduated from Warsaw University of Technology, Faculty of Geodesy in 1932, began work at the Astronomical Observatory in Cracow and than at the Warsaw University of Technology. He specialised in geodetic astronomy, geodetic instruments and geodetic metrology. He took part in two polar expeditions to Spitsbergen and to Station H. Arctowski in Antarctica where he established reference astronomic stations. From 1959 he worked for 10 years as a Deputy Director of the International Bureau des Poids et Mesures in Sèvres. He died on 14 May 1989.

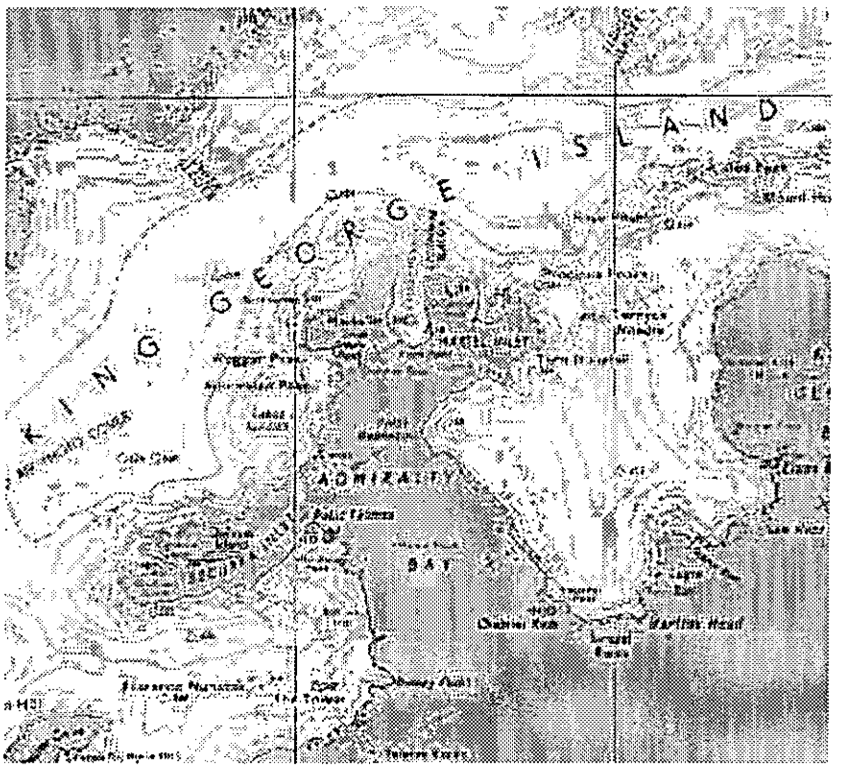

Figure 8. 1:50 000 map of the vicinity of the H. Arctowski Station

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Topographic and Geodetic Works executed by the Federal Service of Geodesy and Cartography

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Map drawing on the Antarctic Continent coincided with its opening by the First Russian Antarctic Expedition under the leadership of Bellinsgauzen and Lazarev when, in 1820, our compatriots came the shelf glacier of the Antarctic coast and for the first time carried out a sea inventory.

1969 was marked by the creation of a two-volume edition of the Atlas of the Antarctic Continent which contains detailed characteristics of the nature of the Continent. The experts of "Roscartographiya" also took part in this work (this Atlas could be named the "Cartographical Encyclopedia of the Antarctic Continent"). The specialists of the State Enterprise "Aerogeodeziya" have taken part in Antarctic expeditions since 1970. The activities were carried out by geodetic land parties from our organisation, comprising 20 Soviet Antarctic Expeditions and 9 Russian Antarctic Expeditions.

These activities can roughly be divided into four stages:

Stage 1 (1970 - 1974)
Stage 2 (1975 - 1984)
Stage 3 (1985 - 1990)
Stage 4 (1991 - to the present).

Stage One – acquaintance with Antarctic conditions, choice of the most effective methods of geodetic activities, checking and use of new technical means in Antarctic conditions. Some special geodetic activities of that period were performed in the eastern part of the Antarctic Continent:

1) Radiogeodetic measurements for definition the length of the space basis about 1400 Kms between stations Novolazarevakaya and Molodezhnaya. The radigeodetic system used was the aircaft radio range-finder (RDS). The whole basis was divided into 3 lines, each of which was measured by a method of internal crossing of the range.The result processing of measurements was carried out with the use of the computer in stationary conditions. The basis length was equal 1377332 m with mistake of measurement ±2 m.
2) The basis measurement between two points of class 1 with the help of the "Quartz" laser range-finder for standardization the aircraft radio range-finder. The basis length was equal 10730,016 m with mistake of measurements -6.9 mm, relative mistake 1:1555000.
3) Linear - angular measurements of a geodetic figure consisting of 7 points and 13 sides (10 triangles). The calculated mistake of the angle was 1.≤44, mistake of the side was 5.44 mm. Results of the work are in the Catalogue of coordinates and heights of the points at Molodezhnaya station.
4) Astronomical definitions of the points of classes 1 and 3. The mistakes for class 1 were for latitude – 0".16, for longitude – 0".09. The astronomical definitions of class 3 were used for creation the topographical maps of the scales 1:100000 and 1:200000.
5) The general square of area was about 200,000 km^2. Map production was carried out by a way of aerotopographical surveying by stereotopographical method. The air photography was made from the plane IL-14 with Russian cameras (focus 100 mm and 50 mm). Synchronously with air photography it was the registration of RDS reading, radio altimeter and pressure altimeter.

Astropoints of class 3 with mistakes of measurements ±2 m were used as a geodetic basis for topographical surveying. The measurement processing was carried out on the computer established permanently at station Molodezhnaya.

Construction of spatial photogrammer nets was carried out on a stereoproector, reduction on a photoreducer, transformation on Seg-V and relief drawing on a stereometer.

In total for the first work period 28 sheets of maps of the scale 1 :100 000 and 52 sheets of the scale 1:200 000 were produced .

Stage Two. Geodetic land activities were carried out mainly in the western part of the Antarctic Continent. This period is characterized by the variety of kinds of geodetic undertakings, which concern:

1. Production of topographical maps of the scales 1:100,000 and 1:200,000. The main aim was development of territory in the interests of science and search of minerals. These activities were a continuation of those begun in eastern Antarctica. Horizontal survey control was carried out using RDS and elevation control through air leveling. 49 sheets of topographical maps of the scale 1:100 000 and 46 sheets of the scale 1:200 000 were published. The whole square of territory measured 146 000 km^2.
2. Definition the force of gravity on the 9 basic gravimetric points with accuracy of 0.25 mgal.

3. Gravimetric surveying of the scale 1:1000,000 with the help of Russian gravimeters. Surveying was performed with density 1 point per 100 km^2.
4. Production of the topographical plans of the scale 1:2,000 on areas of the Soviet Antarctic stations: Molodezhnaya, Mirnyi, Novolazarevskaya. Plane table measurement was achieved with contour interval of 1m. The whole square of the surveying measured 12.5km^2.

Stage Three. Mapping, not only of the physical surface of the Antarctic Continent, but also under the ice, both the underwater part and separate elements of glacial cover. A feature of this stage was the creation of the whole complex of topographical and thematic maps of the scales 1:500,000 and 1:1000,000 based on space photographs and using radar-tracking and seismic sounding. Mapping was done on the territories in the east and west of the Continent.

During this period work on producing topographical plans of the scale 1:2,000 and maps of the scale 1:10,000 on areas of Soviet stations were continued: Novolazarevskaya, Molodezhnaya, Bellinsgausen, Russkaya. Surveying on the scale 1:2,000 was undertaken in an area of 12.3 km^2 and on the scale 1:10,000 in an area of 11.8km^2. Creation of the complex of the intercommunicated topographical and thematic maps was completed in an area of 400,000 km^2. For producing topographical maps we used IL-14 and IL-18 airplanes, and MI-8 helicopters .

For determination of the coordinates of the points of sounding, the RDS-2 radio system and SMA-761 satellite dopler equipment was used .

The complex of maps included:

- topographical map of physical surface including glacial surface,
- thematic map of radical relief displaying terrestrial surface without glacial cover.
- thematic map on which horizontals show the thickness of glacial cover.

Stage Four. This stage is characterized by a reduced the volume of land activities, the most important of which are:

1) Dopler observation for artificial satellites of the Earth at first on five Antarctic stations, anb then only on two. The supevision was carring out all the –year-round for construction net of space triangulation and for making more exact the elements of satellite's orbits and also the coodrinates of ground points.
2) Updating of topographical surveying of the scale 1:2,000 on the territory of Russian stations: Bellinsgausen, Novolazarevskaya and Mirny.
3) Selective routs of barometrical leveling.
4) Producing the digital maps with method of digitalization of all creating maps of the scale 1:100,000 and 1:200,000.

In perspective we want to update plans of the scale 1:2,000 for all Antarctic stations and to digitalize all topographical maps of the scale 1:100,000 – 1:1 000,000. We plan also to use GPS-technology for executing the geodetic base instead of astronomical measuring.

"Aerogeodesiya" geodetic activities and maps of the Antarctic Continent with their informative data and accuracy have received high recognition not only in our country, but also among foreign experts.

The received cartographical materials can be effectively used for measuring the physical condition of glacial cover, its thermodynamic processes, for studying the questions about environment, climate, water resources, perspectives in development of the oil and gas shelf areas, construction of the Antarctic stations, field bases, air stations, moorings etc.

With technical plans the choice of a technique and technology of producing the topographical maps on the scale of 1:100,000 and 1:200,000, and also complex of topographical and thematic maps on the scale of 1:500,000 and 1:1000,000 is determined.

It should be noted that during the land activities of each stage, wide use of the most perspective and highly effective means and methods ensured high accuracy and efficiency of mapping of the different territories of Antarctica.

In the organizational plan the following questions are solved:

- organization of the field stations (bases) on shelf glaciers;
- preparation of ice take off and landing strips for airplanes;
- organization of the field camps, ground radiometric and barometric stations on continental ice and in mountains;
- guaranteeing the safe production of works in coastal and continental areas, on shelf glaciers and in mountains;
- the most efficient use of the IL-14 and AN-2 planes, MI-8 helicopters, aircraft technics and guarantee of works by a radio communication.

The State Enterprise "Aerogeodesiya" has accumulated enormous experience in the production of a wide spectrum of topographic, geodetic and cartographical activities in the extreme conditions of Antarctic Continent. We recommend that any organization, at home or abroad, requiring the highly accurate, reliable and operative realization of any kind of geodetic and topographical undertaking on the Antarctic Continent contact our organisation.

Atmospheric Influences on Astrogeodetic Measurements in the Polar Regions

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Abstract

The paper outlines the author's research both independent and joint into atmospheric influences on the results of angular and electronic distance measurements in polar regions and, in particular, in Antarctica. A short description of the structural peculiarities of the atmospheric boundary layer is given. Special attention was given to thermal stratification and its influences on the results of astrogeodetic measurements. Investigation into astronomic refraction was conducted on the basis of aerological data. An integral of refraction was computed at different zenith angles for several Antarctic and Arctic stations. Refractive anomalies were calculated by means of refraction tables. The results of the theoretical and experimental investigations of the terrestrial vertical refraction in polar regions are given. Analysis of atmospheric influences on the electronic distance measurements were carried out by means of the refraction index calculation for light-and radio waves. The data of aerological soundings and meteorological gradients in the lowest atmospheric layers were used as initial materials. It should be noted that microwave distance measurements in central Antarctica ensure reliable accuracy because of the minimal air humidity. As regards the electronic distance measurements to satellites the existent models do not quite ensure reliable results for laser and microwave distance measurements due to peculiarities of the meteorological parameter distributions in atmospheric lower layers in the polar regions and, in particular, central Antarctica.

1. Introduction

The aim of the study was to determine the extent of atmospheric influence on the results of angular and electronic distance measurements in the polar regions. It should be noted that satisfactory precision of accounting of atmospheric influences is provided on the whole at the angular and electronic distance measurements to objects, located both in and outside the atmosphere, at zenith distances of less than 70°. Achievement of the precise results at large zenith distances, and especially in the near horizontal zone, is possible only in reliable representation of atmospheric stratification and first of all the boundary and lowest layers. It is accounted for by a heterogeneity of atmospheric structure and its dynamics and first of all by peculiarities of an air temperature and humidity distribution with a height.

2. Some peculiarities of the vertical distribution of air temperature and humidity

In the polar regions, according to long-term monthly mean aerological sounding data, it has been established that the vertical distribution of air temperature in the boundary layer is characterized mainly by stable thermal stratification. In Antarctica two zones, distinguished by meteorological peculiarities, should be marked out:

- Antarctic coast zone - meteorological data of Mirnyj station characterizes most of the Antarctic coast situated as effected of the gravity wind;
- Central Antarctica – the most representative is the Vostok station.

The mean capacity of the ground inversion layer amounts 240m over coast and in Central Antarctica – 720m. The ground inversion intensity makes up in average 2.8 and 17.1°C per year accordingly and its recurrence reaches 75 and 98% [2]. The vertical temperature gradient in the lower 100-metres layer of the continent centre reaches the extremal values on the terrestrial globe ~ 40-50°C/100m. Depending on analysis of skewness A_t and excess E_t coefficients of air temperature in the atmospheric boundary layer it follows that the vertical temperature distribution in the central region of Antarctica does not correspond to normal law both in winter and in summer. An inversion creation in the lower 200-metres layer of Antarctic coast is connected with the gravity wind. Above this layer an ordinary decrease of temperature is observed. The ground inversion is destroyed with weakening of the gravity wind in summer, however, the value of the vertical temperature gradient is not large and it approaches an isothermal gradient. A mean capacity in the central Arctic (Pole region) makes up 1.19km in January and 0.64km in July.

As regards vertical distribution of air humidity in Antarctica, a typical feature is a vividly expressed inversion character due to the temperature inversion. The value variation of air humidity at the Antarctic coast in winter is small in a height– from 1.4 mb at the surface to 0.5 mb at a height of 3km and in summer it decreases uniformly from 4 mb to 1.2 mb. On the whole, the vertical distribution of air humidity is in keeping with the air temperature distribution. In winter, the air humidity in Central Antarctica is extraordinarily small owing to the lowest near surface air temperature and its value makes up 0.08 mb only. It increases to 0.012 mb at a height of 600m and slow decrease of it is observed then. In summer, the air humidity changes from 0.3 mb to 0.4 mb within the altitude range from 0 to 3km and it is similar to humidity values of a wintry period in Arctica.

It should be noted that an intensive ground inversion of temperature prevents, to a great extent, the development of turbulent heat and water exchange in the lower layers of the atmosphere of the polar regions, especially of central Antarctica.

3. Contribution of the lower atmospheric layers in the formation of refractive quantities

Proceeding from stratification peculiarities of the atmospheric lower layers in the polar regions the investigations for the establishment of representation of these layers with the object of reliable determination of atmospheric corrections were realized by carrying out the angular and electronic distance measurements at the low lines of large lengths. Atmospheric models constructed on the basis of the long-term monthly mean aerological sounding data on a number of Arctic and Antarctic stations were used as initial materials [13]. The computation programs of astronomic refraction angle ρ and atmospheric correction ΔS into laser distance measurements to satellites by these models had been worked out. A spherical model of atmosphere was founded in the both cases.

The calculation results are presented for two Antarctic stations only - Mirnyj and Vostok. Such a selection was conditioned because the data obtained by the models of Mirnyj station are representative for corresponding models of the most of coastal Antarctic and Arctic stations which we had analysed. The Vostok station data describe in general the Antarctic Plateau (Central Antarctica). For the Mirnyj station the contribution of the lowest and boundary layers of atmosphere in the formation of the quantities ρ and ΔS is preliminary like in the both models and it gives at zenith distance 75° - 5 and 17% accordingly; it is somewhat greater in winter because in the lowest layer 0.04-0.2km the temperature inversion by intensity 1.2° is existed there and an isothermal stratification takes place practically in summer. This contribution increases in geometric progression at the large zenith distances and exceeds 20% and 40% accordingly at Z=89.8°.

At Vostok station there is a more contrasting picture (Table 1). The contribution of the boundary layer in the summer model is inkeeping with the winter model contribution of Mirnyj station and it is slightly greater owing to the more intensive inversion.

The quantities of astronomic refraction and the contribution of the lowest and boundary layers considerably increase in winter. Thus, an atmospheric influence on the quantity r increases in ~1.5km layer in comparison with the summer period and the refraction component amounts to 70% in the near horizontal zone. The lowest 300-metres layer causes the most considerable contribution. The latter makes up 14% at zenith distance 75∞ and exceeds 50% at Z=89.8∞ which is provoked by superintensive inversion in this layer. As to DS corrections, an influence of ground inversion shows to a lesser extent here.

4. Analysis of temperature inversion influence on the astronomic refraction angles

In order to estimate an influence of the temperature inversion on the quantity of common astronomic refraction in the lowest atmospheric layers we made up three atmospheric models for the Vostok station [12]. Model 1 presents aerological sounding data at the isobaric surfaces and model 2 was completed by meteorological parameters at standard altitudes in the 4-6km layer. Model 3 was completed by one-time sounding data every 100m in the lower semi-kilometer layer.

It should be noted that the difference of refraction angles makes up only 0.02" at Z=75° therefore the representation of atmospheric stratification at Z<75° may be very generalized. However, the difference of refraction angles increases essentially at the large zenith distances and it amounts to 40' in the horizon. If we take into consideration that the near-ground layer is presented in model 3 only every 100m then, beyond all manner of doubt, by a more detailed and objective reflection of this layer a still more refraction angles could be obtained and first of all, the lover near-surface layer several tens metres

Z°	Layer: 3,42 km -			Layer: 3,42 km -		
	5,0	11,18	80	3,72	5,0	80
	January			August		
	Contribution, %, ρ / ΔS		ρ" / ΔS, m	Contribution, %, ρ / ΔS		ρ" / ΔS, m
75	19,6 /20,3	67,6 /69,0	159,6 / 5,8	14,4 / 5,3	28,9 /20,7	182,1 / 5,8
88	26,3 /26,5	76,3 /76,9	854,5 /30,8	19,4 / 6,1	37,7 /27,3	1034,6 / 31,1
89,8	46,1	85,5	1625,0	50,8 /21,9	70,1 /52,7	3049,4 / 69,8

Table 1. Vostok station

thick has to be presented in the most detail. Such a representation is necessary not only for the construction "refraction" models on the Antarctic Plateau but also for other regions of Antarctica and Arctica. It follows even from the analysis of the temperature gradients measured in the lower 30-metres layer at the Mizucho station located on the Antarctic Slope [5].

Proceeding from the given peculiarities of atmospheric stratification in Antarctica the seasonal (for January and July) and mean annual models were worked out on the basis of the aerological sounding data at the Mirnyj and Vostok stations [8].

With the aim of using suitability of existent tables for the determination of astronomic refraction in the polar regions the Pulkovo refraction tables of the 4th edition and the Kazan observatory ones were analysed and after 1985 the Pulkovo refraction tables of the 5th edition were examined [4,10, 12 etc.]. The mean monthly data of aerological soundings on the five Arctic and ten Antarctic stations as well as one-time sounding data of different polar stations were used for this purpose. Astronomic refraction was calculated both by aerological sounding data and by refraction tables. On the basis of the analysis of refraction anomalies calculated as differences between refraction angles obtained from the aerological sounding data and by refraction tables it is necessary to mark out the following (by the Pulkovo refraction tables of the 5th edition):

- in summer the refraction anomalies do not exceed 0.3" on absolute value at $Z \leq 70°$ in the Arctic and 0.2–0.3" in Antarctica; during the winter they amount to 0.2–0.3" on the Antarctic coast and 0.3–0.5" in Central Antarctica as well as 0.4" in Arctica. Thus, in summer the refraction tables ensure determination of astronomic refraction to within 0.3" practically on all Antarctica's territory but in winter the account accuracy goes down two times;
- at zenith distances less than 80° the refraction tables allow consideration of the refraction angle to within 1";
- neither refraction tables do not ensure the precise determination of astronomic refraction at $Z>80°$ in polar regions, especialy in Antarctica.

A large number of investigations of astronomic refraction anomalies at the large zenith distances by instrumental method was carried out by the observations of the Sun and bright stars on the southern shore of White Sea, and on Nowaya Zemlya and in other regions [7,9,11]. A principally new technique of astronomic refraction determination in the near horizontal zone was worked out from observations of the upper and lower solar limbs on the same almucantar which allowed the most reliable quantities of astronomic refraction angles (anomalies) in the most difficult zone , from an observations standpoint, to be obtained[21].

5. Some results from the terrestrial vertical refraction studies

On the basis of hourly mean monthly values of global solar radiation, albedo, pressure and air humidity at the three Antarctic and two Arctic stations the coefficients of vertical refraction were determined [16]. Their pronounced dependence on the latitude is observed in daily variations; in summer the coefficient changes from 0.1 to 0.5 at Mirnyj station and its levelling takes place at Vostok. In annual variation the refraction coefficient increases approximately three to four times from summer to winter in all polar regions. Its dependence on earth albedo has been ascertained. Thus, at Mirnyj station located on the surface covered by snow and ice (albedo ~ 80%) the refraction coefficient is almost twice that at the Novolazarewskaya station where the albedo does not exceed 30%. The "periods of quiet images" and corresponding them the coefficients of normal refraction have been established. Therefore, at the Novolazarewskaya station these periods begin at Sun heights averaging nearly 7°, moreover they shift in time from the near midnight intervals in summer to the near midday ones in winter. The values of normal coefficients exceed essentially the common ones. The evening "periods of quiet images" comparatively with the morning ones are shifted in time to sunset, moreover the coefficients values are less approximately by 10% in the morning period. At the high-latitude stations these periods come at Sun heights of ~10-15°. A refraction coefficient asymmetry is observed here less in both time and quantity.

Turbulence characteristics and vertical refraction coefficients for January have been determined by hourly observations of temperature and wind speed at seven levels of the lower 30-metres atmospheric layer at the Mizucho station [5]. A determination technique of vertical profile of the temperature by measured wind profile has been approved as well. The difference between calculated and measured air temperatures does not exceed 0.2° for the period from 5 to 20 o'clock. During the night period with increase of temperature inversion these differences amount to 1° at the upper bound of the 30-metres layer[15].

Numerous experimental investigations of vertical refraction influences on the accuracy of trigonometric levelling were carried out during the summer periods of 1978-1981 on the four parts of the Barents and Kara coasts of northern and southern islands of Nowaya Zemlya. Both the single and reciprocal simultaneous measurements of zenith angles were fulfilled on to geodetic points outlying in average at a distance 10-12km. By the results of meteorological observations the vertical gradients of temperature γ_t and air humidity γ_e were determined and the mean integral gradients $\bar{\gamma}_t$ and $\bar{\gamma}_e$ were calculated. The transition periods from normal air stratification to inversion one and conversely were investigated. A correlation degree between meteorological and mean integral gradients was analysed[14].

Region	t, °C	P, mb	e, mb	e', mb	δ_e	$\delta N / \delta e$	δ_N
Summer (January) / Winter (July)							
Central Antarctica	-32.6 / -67.6	633.4 / 621.7	0.29 / 0.00	0.47 / -	-0.18 / -	6.37 / 8.74	1.1 / -
Antarctic coast zone	-1.6 / -20.4	990.4 / 988.6	3.67 / 0.94	3.97 / 0.65	-0.30 / +0.29	4.99 / 5.77	1.5 / 1.7
Antarctic Peninsula	+0.9 / -8.4	990.8 / 993.5	5.39 / 2.78	4.73 / 2.26	+0.66 / +0.52	4.90 / 5.26	3.2 / 2.7

Table 2. Accuracy characteristics of refraction index determination for ultra-short waves

On the basis of comparison of measured and calculated coefficients of vertical refraction for the mentioned periods it was established that the change rate of isothermal layer with a height is almost half as much as in the middle latitudes and it makes up about 35 metres an hour [19]. It should be noted that in summer over the mountain stone plots and particularly over a stony tundra considerable turbulence develops in the lower ground air layers in the hours close to midday. Under such conditions the technique of accounting of vertical refraction by the fluctuation of images of aperture sights was approved, so doubling the accuracy of trigonometric levelling [3].

The realized investigations allowed us:

- to elaborate a calculation technique of refraction coefficients for a certain period and a concrete region;
- to establish the most suitable periods of geodetic measurements from the standpoint of refraction influence in polar regions;
- to work out new methods of determination and accounting of the vertical refraction [1,20].

6. Distribution of the electromagnetic wave refraction index

The principal error of distance measurements by microwave and laser rangefinders and radionavigation systems is caused by the propagation inconstancy of refraction air-index both in space and in time. The nature of refraction index propagation in polar regions has some peculiar properties in comparison with the middle and low latitudes. Refraction index modules for light N_S waves and ultra-short N_R ones were calculated for standard heights levels up to 3km from the earth surface for each month of the 11 polar stations [6]. The ratio $N_R < N_S$ predominates in polar regions, and in particular in Antarctica, in contrast to another regions where the refraction index of ultra-short waves is much greater. The most stable difference $\Delta N = N_R - N_S$ is observed in Central Antarctica and its annual amplitude (A) does not exceed 3 units of N. At the Antarctic coast zone the value ΔN is positive in January and February only and A£12. In Arctic regions the ratio $N_R > N_S$ is being observed from June till September and annual amplitude of ΔN amounts to 30 units of N. A daily variation of refraction index both light- and ultra-short waves is not large, a maximal amplitude falls in the autumn period in Arctica and in the spring period in Antarctica (according to data fromMirnyj station) and it does not exceed 6-8 units of N.

On the basis of the distribution analysis of quantities N_R and N_S it follows that the change of refraction index is in general close to the linear law in summer. In winter a deflection of linear regularity is insignificant in coastal Antarctica and the Arctic but it is highly essential in central Antarctica and amounts to 30 units of N in the lower semi-kilometer air layer. The quick decrease of refraction index *in height* caused by superintensive temperature inversion (it amounts to 45 units of N in the lower 300-metres atmospheric layer in July – August at the Vostok station) gives an error into the results of laser distance measurements to satellites from 6cm at the zenith point to18cm at Z=75° in comparison with the Marini-Murray model [22].

7. The degree of influence of air humidity on microwave distance measurements

For the establishment of the influence degree of air humidity both by the ground microwave distance measurements and GPS observations* in polar regions the following investigations were realized [17,18]. After the meteorological parameters of separate stations the ensemble-averaged values of_atmospheric pressure P, temperature t and water vapour pressure e were calculated for the three Antarctica's regions (Table 2):

- Central Antarctica (according to data from Vostok station, the altitude above sea-level is equal 3488 m);
- Antarctic coast zone (11 stations, the average altitude makes up 28 m);
- Antarctic Peninsula (24 stations, the average altitude amounts 12 m);

* Taking into consideration that the network of GPS permanent stations is now in Antarctica and yearly GPS campaigns acquire more and more prevalence (Ukrainian station "Academician Vernadskyj" participated in 1998), two VLBI stations are working permanently and SLR stations are getting ready for permanent observations and it becomes evident that problem of detail investigation of the atmospheric influence peculiarities on the results of such observations is exceptionally topical in this region.

It should be noted that water vapour pressure in Antarctica is much lower than in other continents. At the same time to measure it directly is very complicated and sometimes impossible. Using mean-statistical humidity characteristics for the determination of refraction index at microwave radio distance measurements may cause a refraction index error from $2\cdot10^{-6}$ in Central Antarctica to $25\cdot10^{-6}$ at the Antarctic Peninsula and may increase the relative error of line measurement from 1:500 000 to 1:40 000.

Proceeding from the assumption that is necessary to determine air humidity accurately which should ensure the calculation accuracy of refractive index to within $2\cdot10^{-6}$, it is possible to achieve by means of the measured air temperature with the help of the functional dependence:

$$e'=P/622(a + bt + ct^2)$$

where, a = 2.789, b = 0.192, c= 0.0037 – coefficients obtained from twice measurements daily of water vapour fraction of total mass during three summer and three wintry months at Mirnyj station. Calculation error of humidity δ_e is a difference between initial (mean-statistical) humidity quantity and the calculated one by the above formula. For the establishment of the error influence δ_e on the determination precision of refractive index the differential dependence $\partial N/\partial e$ (in N-units) was obtained for each region for January and July. The error δ_N of the calculated refractive index is determined by product $(\partial N/\partial e)\delta_e$.

The results obtained show that indirect determination of humidity for radiogeodetic measurements ensure the calculation accuracy of refractive index not less than $2\cdot10^{-6}$ on the whole Antarctic territory except for the Antarctic Peninsula. In the Arctic the error δ_e makes up the following depending on year season and region:

- in the western sector of the Russian Arctic the error δ_e makes up 0.4-0.5 mb in summer and 0.3 mb in winter;
- in the central Arctic these values makes up 0.3 and 0.2 mb.

One of the main errors owing to incorrect determination of refractive index n in the line of radio wave propagation consists of replacement integral mean temperature $\bar{t}$ and humidity $\bar{e}$ values by the average ones and $t=(t_1+t_2)/2$ and $e=(e_1+e_2)/2$ from measurements on the last points of the line. The errors due to inequality t and $\bar{t}$, e and $\bar{e}$ were analysed by means of meteorological observation data at the Mizucho station. The high-altitude profiles of temperature and humidity were determined for an arbitrary chosen line with ray height to 30m. The temperature profile was approximated by logarithmic dependence and humidity was calculated after the above formula. The relative errors $\Delta S/S$ obtained by the average monthly (January) values of measured temperatures for the different periods of day and night are given in Table 3.

Thus, for the mentioned conditions the difference $t - \bar{t}$ causes the determination error of refractive index $2\cdot10^{-6}$ at night time and it must be taken into account for precise measurements. The difference $e - \bar{e}$ may be disregarded. The technique calculated from the refraction index determination, on the basis of the investigations carried out, results in an increase in the accuracy of geodetic measurements in the polar regions.

Notation	Local time					
	1	5	9	13	17	21
$\Delta S_t / S \cdot 10^{-6}$	1,8	0,4	0,4	0,3	0,0	1,1
$\Delta S_e / S \cdot 10^{-6}$	0,1	0,0	0,2	0,3	0,0	0,5

Table 3. Relative errors DS / S

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Argentine Participation in Antarctic Surveying Activities from 1901 to 1999: an overview

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First Experiences

José María Sobral was probably the first Argentine to be involved in Antarctic surveying. He took part in the 1901-1903 Swedish Antarctic Expedition (led by Dr. Otto Nordenskjöld), and performed several astronomical-fix determinations as well as other surveying activities in the Antarctic field during the campaign.

Astronomical Observations

From 1904 onwards, astronomical techniques were widely used both for static positioning at relevant sites as well as for expedite navigation purposes by Argentine Antarctic field parties.

Classical Surveying Techniques

Triangulation and leveling works were implemented to support the Instituto Antártico Argentino (IAA) geo-sciences, mainly for glaciological field activities. For several decades the works were typically relying on 1" theodolites, microwave EDMs and geometric/spirit levels. Electronic tacheometers and a laser distance meter were also implemented at a later stage.

Case study: Surface Dynamics of the Northern Larsen Ice Shelf, between the Seal Nunataks and the Jason Peninsula.

US Transit/Doppler Navy Navigation Satellite System(NNSS)

In 1975/76 a joint United States Geological Survey/British Antarctic Survey (USGS/BAS) field party performed geodetic satellite/doppler-based observations at several sites, mainly for Antarctic satellite imagery geocoding purposes. Some of the sites were directly associated with Argentine Antarctic activities (e.g. Matienzo and Marambio bases).

IAA started using the Transit-doppler satellite-system technique in 1982, mostly in a "stand-alone" positioning approach. Translocation techniques were also implemented, depending upon third party's instrument availability. Astronomical observations were still used for azimuth determinations.

NAVSTAR - GPS (NAVigation System with Time And Ranging – Global Positioning System):

IAA's involvement with the use of GPS in Antarctica in began in 1985, at the beginning of the US, Argentina, Chile (USAC) aero-geophysical Antarctic surveying project led by Dr. John L. LaBrecque (Lamont Doherty Geological Observatory). During USAC the IAA made a contribution regarding the decoding of the raw hexadecimal GPS almanac and ephemeris broadcast information in order to optimize the flights due to the limited GPS coverage at that early stage).

At present, several IAA research groups perform their GPS-surveys, mainly based on L1-receivers, typically for geo-referencing purposes.

Precise GPS

During the 1980's, at least two German scientific field parties worked in the vicinity of the Argentine Station Belgrano II. They established a GPS reference station at the base, significantly improving the accuracy of the station coordinates.

In 1993 USGS surveyors performed GPS surveying at Marambio (Seymour) Island, in order to geo-reference Argentine aerial photographs of the Island. A map at 1:10000 scale was produced jointly with Ohio State University.

It was not until the SCAR Epoch95 GPS Campaign (GAP95), that IAA became directly involved with high precision GPS-surveying methods. GAP 95 and its follow-on repeat campaigns (1996 and 1998) represented a dramatic change for Argentine geodesy in several aspects:

- A new site monumentation strategy, aimed at long-term stability, was implemented for the first time at Argentine Antarctic sites.
- Position errors were reduced from "various meters" to "centimeter" levels at 5 locations.

The Argentine geodetic network, undergoing a re-definition process, as well as various other South American countries could greatly benefit from GAP/SCAR GPS Epoch results.

GAP'95/96/98 - SCAR Epoch 95/96/98 GPS Campaigns:

The Antarctic stations Belgrano II, Esperanza, Jubany/Dallmann, Marambio and San Martín were surveyed during the major 1995 and 1998 international GPS Campaigns. Esperanza, Jubany/Dallmann and Marambio sites were also occupied during the 1996 repeat-campaign. GPS instruments were provided by German research institutions at all these locations. Argentine observers participated at Esperanza (ESP1) and Marambio (MAR1).

Long-term GPS monitoring

During the austral winter 1996, IAA performed its first long-term GPS monitoring experience at the ESP1 - GAP95 site using a geodetic receiver provided by the Alfred Wegener Institute for Polar and Marine Research, Germany (AWI).

In February 1997 a continuous GPS station provided by AWI was installed at Jubany/Dallman (Trimble 4000SSi with Trimble Choke Ring antenna).

In February 1998 a continuous GPS station provided by AWI was installed at Belgrano II (Ashtech Z-XII with Ashtech Choke Ring antenna).

In March 1999 a continuous GPS station provided by the University of Memphis, USA was installed at Orcadas (Ashtech Z-XII with Ashtech Choke Ring antenna).

In April 1999, a continuous GPS station provided by AWI was installed at San Martín (Ashtech Z-XII with Ashtech Choke Ring antenna).

Differential Kinematic GPS

In 1987, during the USAC Project, IAA made its first experience in terms of GPS-differential processing (Pseudo-Range only).

More recently, in December 1998 the British Antarctic Survey (BAS) and IAA performed an aero-geophysical survey in the James Ross Island region, based upon precise GPS-navigation. The GPS data set was jointly processed (phase-differential).

Tide Gauges

Argentina performed several Antarctic sea level monitoring activities in the past, specially at Esperanza and Brown stations (mechanical floating devices). At present 3 tide gauges are operating at Esperanza, Jubany/ Dallmann and San Martín stations respectively.

In 1993 a sea level continuous monitoring station provided by the National Oceanic and Atmospheric Administration, USA (NOAA) was installed at Esperanza.

In 1996 a sea level continuous monitoring station provided by AWI was installed at Jubany/Daltmann.

In 1998 a sea level continuous monitoring station provided by AWI was installed at San Martín.

Gravity observations

A gravity link between Rio Gallegos (Argentina) and Marambio station was performed in 1979 by P. Skvarca (IAA) and others in order to have Argentine Antarctic gravity measurements connected with IGNS71 (3 sequential flights / 2 "G" - LaCoste & Romberg instruments).

Field gravity (relative) surveys were performed at some Argentine stations as well as in specific areas of interest, e.g. on a longitudinal traverse along the Northern Larsen Ice Shelf.

IAA also participated in airborne gravity Antarctic surveys during USAC (1985-89) and, more recently, with BAS on James Ross Island.

In December 1997, an absolute gravity value was determined at Jubany/Dallmann by German geodesists, using an FG-5 instrument.

Seismological observations (for geodetic purposes)

At Jubany/Dallmann as well as in Belgrano II, seismological equipment provided by AWI was installed during GAP98 for long-term monitoring. Jubany/ Dallmann was dismantled in April 1999.

Note: In addition to IAA, several other national Argentine institutions (e.g. Instituto Geográfico Militar, Servicio Hidrográfico Nacional) have performed, and continue to perform different types of surveying works in Antarctica, to support their charting and nautical activities.

Field Tests of the Portable Absolute Gravimeter for Remote Applications

Yevgen Zanimonskiy

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Introduction

Today the globe is covered by a non-uniform gravity network. Network density and the accuracy of the gravity measurement attributed to a site may differ by 1–2 orders of magnitude.

The gravity network in certain parts of the world is still poorly developed but this is not always due to the inaccessibility of the area. For example, in less developed countries and countries of the former Soviet Union there are motorways and urban and village infrastructure so that a network may be improved and accuracy increased by the traditional method of connecting sites using relative gravimeters. Poor network development may also be due to the user's conservatism, based on the presence of precise equipment and the checked and formally authorised techniques of measurement and data representation.

However in areas which are difficult to access, such as mountains, deserts, and polar regions, the repeated moving between sites using ground or air transportation can become too technically difficult or too expensive. As a result the international scientific community (J. Manning, 1999) and governmental organisations, interested in an inexpensive and simple way to improve the quality of the networks, could use a specially adapted absolute gravimeter.

Adapting the Absolute Gravimeter for the Field

One problem with adapting the absolute gravimeter to field measurements is its change in status. The existing absolute gravimeters form the group standard, checked at international comparisons in Paris. The field apparatus, offering slightly lower quality, could be considered as a working tool for measurements, used for direct measurements then checked by means of comparison with the standard.

So far the concept of checking or calibration of a ballistic gravimeter, for uniformity of measurements, has not been internationally applied. However, the need to carry out large projects using various devices from widely differing bases has made calibration essential. Certainly, without legislative registration of separate devices, each developer may be tempted to equate his device to the standard. Nevertheless there are unconditional leaders in accuracy, namely the FG-5 gravimeter, which may be used as the standard for calibrating the portable gravimeter.

On the other hand there is a problem of gravitational stability on the sites used for calibration. Variations of unknown origin limit the accuracy of comparison and require preliminary research and regular repetition of measurements.

The requirements of special gravimeters can be formulated as follows:

- Stability of the systematic error at a level of 5-10mGal within 0.5-1 years (gravimeter autonomy "in Large");
- Ability to carry out measurements automatically after installation at unattended remote localities (gravimeter autonomy " in Small");
- Small dimensions and weight;
- Simplicity of service and repair;
- Low cost of the device and complete set of spare parts;
- Invariability with respect to change of temperature and humidity.

Operation and Maintenance of a Gravimeter

Before a long expedition, the gravimeter should be serviced and checked on the control site and the numerical amendments estimated and fixed. The measurements will be carried out according to the schedule:

- The gravimeter is established on the base of the site and a controlled series of measurements made;
- The instrument is switched to automatic data accumulation mode;
- When used outdoors the gravimeter is covered by a cap, protecting the device from atmospheric influences;
- The control data are transferred by radio to the computing centre;

The structurally autonomous absolute gravimeter comprises two parts:

- Primary gauge - ballistic gravimeter
- System of maintenance, power supply, data transmitter and protection .

The system of maintenance is not specific (A. Donnellan *et al.*,1999) and can be made of available modules. Therefore, production depends only upon engineering effort with financial support. Design of the primary gauge is much more complicated.

History of the Ballistic Gravimeter

The concept of an autonomous absolute gravimeter arose during the design, creation and research on a field portable ballistic gravimeter. Initially a ballistic gravimeter was operated in laboratory conditions. The devices, approximately equal in accuracy, were developed in several countries. Recently the best apparatus of this class, i.e. the JILAg and the FG-5 have been made the basis for the international group standard.

Twenty five years ago the Kharkov Institute of Metrology began work on the production of a ballistic gravimeter. Subsequently several devices for various purposes were designed: complicated instruments, automobile-mounted, terrestrial and shipborne devices, all with two advantages; their ability to operate in adverse conditions of external environment and their simplicity of operation. Unfortunately the accuracy of these gravimeters is insufficient for geodetic purposes.

Despite research by several groups worldwide, even the small-sized gravimeters which exist cannot be considered suitable for the field as they need to be connected to the net power supply and are intended for use indoors. It is clear that the unique device of this class, namely the A10 absolute gravimeter could be the device suitable for field work. T.M. Niebauer (1999) announced the extremely high characteristics of the device. The high data rate achieved with the new launching chamber will allow kinematic absolute gravity measurements for use on marine and airborne platforms (J.M.Brown *et.al.*1999). However, despite the great potential of the A10, we consider that, for Remote Geodetic Observatories, special gravimeters should be developed.

Data Accumulation and Errors

It is important to mention that the absence of superfluous tidal variations of gravity in unexplored areas cannot be guaranteed. The amplitude of these oscillations with the periods from 3–24 hours may reach a substantial level (in Borowa Gora observatory it was recorded at the level of 4–6mGal). In coastal areas of Antarctica the obvious problem is caused by ocean tidal loading. The constant component of gravity on the site should thus be estimated by means of continuous measurements, at least for 2–3 days.

To accumulate data to a level of precision of 5-10mGal takes about 3–5 hours. The long time required for these measurements encourages the use of a simpler ballistic gravimeter.

External seismic influences are the main sources of random errors but these errors may be substantially reduced by use of the long period damping system. Besides suppressing external influences, the isolation system also suppresses auto-seismic handicaps by means of a ballistic block. With a symmetrical rise-and-fall method of measurement a source of a handicap is the catapult, launching a test-body. With the free-fall method the mechanism accompanying a test-body in fall is a source of vibration.

The efficiency of such systems can be very high, which is evident in case of a superspring in both the JILAg and FG-5 apparatus. However these highly sensitive mechanical devices with an analogue feedback are not adaptable for field conditions.

A natural feature of remote areas is the absence of artificial seismic handicaps. This fact essentially simplifies the task of data accumulation. Our experience, acquired in

Figure 1. Gravimeter

the process of research and development of a portable ballistic gravimeter, shows that, during the night and holiday periods, it is possible to accumulate data within 5 hours with a random error at the level of 10mGal. In coastal areas, obviously, the influence of the ocean produces an additional effect that increases the seismic background. However, this influence is random and stationary, so an increase in data accumulation time cannot necessarily be expected.

In our portable rise-and-fall gravimeter no long period isolation system is implemented. For suppression of auto-seismic effects constructive and methodical solutions are applied. Firstly, using titanium for the test-body and carriage of the catapult made it possible to launch a body with acceleration of 15-20 g. The electromagnet of the catapult with its energy-storing capacitor provides fast shot-and-stop of the mechanism ensuring its stability during measurement. Only the decreasing oscillations of the reference lever have a negative seismic effect on the measurement.

The larger the frequency and the faster the attenuation of these fluctuations, the smaller the effect on the measurements. This is achieved by means of a more rigid fastening of the ballistic block to the base. The base should be not too small. If it is made of ferro-concrete its volume is should be larger than one cubic meter. A suitable variant could be a solid natural rock with a rather flat and horizontal surface of the size of 0.8 x 0.8m. In mountain areas and on exposed rocks the measurements can be successfully conducted without a preliminary benchmark of the bases. This above-mentioned disadvantage rules out using the gravimenter on small bases designed for relative gravimeters. The best way of fixing the ballistic block system to the base is to use anchor screws; however, securing it with a weight, eg. a set of long life batteries, is a practical solution.

The strong correlation between auto-seismic interference and measurements causes variations of systematic error depending on site characteristics. This apparent disadvantage of a system, on the other hand, offers the opportunity to reduce this error. Firstly, software can allow changes to the length of time interval corresponding to a set of test-body acceleration measurements conducted during a single throw. Averaging the acceleration data obtained at several time intervals reduces the influences of the decreasing oscillations. The operator can manually implement the length of measuring time interval; it can also be done automatically with use of a pseudo-random number generator. Secondly, it is possible to control the total time of free movement. Averaging the results obtained in various auto-seismic conditions provides an additional randomisation of the systematic errors.

Gravimeter Testing and Calibration

Up-to-date experiments and analysis demonstrate the value of the simple absolute ballistic gravimeter at remote observatories.

Testing of the portable ballistic gravimeter was carried out on five sites of the Polish Gravity Control Network. The majority of data was collected on sites of a small local network at the Borowa Gora observatory with three sites located in the premises and three outdoors. The volumes of the base pillars varied from 1–6 cubic meters. The gravity measurements on outdoor sites were protected against the rain with a tent and were carried out at temperatures above zero.

The gravimeter was tested for more than three years from 1995 to 1998.

The results obtained by several instruments, including the FG-5 and the JILA-6 were used to calibrate the gravimeter as the working tool of measurement. In the beginning the calibration was conducted twice a year and later only once. National holidays (Easter and Christmas) when several days in row are practically free of artificial seismic interference were chosen for calibration. Calibration was focused on determining the numerical factors used for calculating the amendments for influence of residual gas in the ballistic block and on estimating the random error of a gravimeter relative to the absolute value on the site.

The standard time for averaging the results is always 24 hours. The data to be averaged come from either a series of continuous observations covering one day during a holiday period or from two data sets of several hours duration taken on two consecutive nights during the week.

The analysis of data collected from 1996 to 1999, after both hardware and software upgrading, resulted in error reduction from 70 to 15mGal. Further improvement can be expected when the modern stabilised laser is applied.

Conclusion

The experience gathered over last few years shows that the portable ballistic gravimeter of the Institute of Geodesy and Cartography, Warsaw, can be considered as the prototype for an autonomous absolute gravimeter.

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Abstracts

Transantarctic Mountains Deformation Monitoring Network (TAMDEF) South Victoria Land - Initial Results

Larry Hothem, Jerry Mullins and Robert Glover[1]
Ian Whillans, Terry Wilson, and Mike Willis[2]

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TAMDEF is a collaborative GPS campaign initiated in 1996 by Ohio State University scientists in cooperation with the U.S. Geological Survey and sponsored by the National Science Foundation to measure horizontal and vertical deformation in the McMurdo Sound region. An array of 28 GPS stations spans an area approximately 375 km north-south and 300 km east-west with the goal of measuring and attempting to differentiate between causes for the rock motions. The expected signals are:

1 crustal rebound - uplift is predicted for the north end of the study area (from considerations of glacial geology) with more uplift predicted at the south end (based on glaciological theory) due to formerly thicker ice in McMurdo Sound region of the Ross Sea; and, either an eastward or westward tilting depending on whether the ice-age glaciers in East Antarctica or West Antarctica thinned or thickened the most.
2 tectonic - there is evidence for active 'normal' fault motion in specific zones in the mountain front and active spreading is predicted across the Terror Rift.
3 volcanic - subsidence is possibly due to the weight of the volcanic material from the Ross Island volcanoes; and, Mt. Erebus is currently active and there may be episodic inflation or deflation.

In this region of Antarctica, model predictions for crustal rebound toward isostasy reach vertical motion rates of 3 to 20 mm per year. The directions and patterns of these predicted motions are mostly distinct. The design of the deformation monitoring network and the GPS observing campaign strategy was designed to discriminate among them. The GPS surveys form geometrical elements at three spatial scales:

1 Long baselines (100 km) that span the features most expected to show motion according to the hypotheses above - simultaneous tracking time is at least 2 days, often 7 days,
2 Short baseline (10 km) arrays crossing suspected fault zones with inferred neotectonic motions - simultaneous tracking time about 24 hours, and
3 Very short baselines (0.1-0.2 km) at each site to test for local motion due to such processes as frost action - simultaneous tracking time is 0.5-1.0 hours.

All monuments are special stainless steel pins set in the rock that stand about 0.05 m above the rock. Between November 1996 and January 2000, the station arrays were established and repeat measurements completed using dual-frequency late model GPS instruments in combination with choke-ring antennas. Analysis of the measurements from 3 observing campaigns are yielding repeat values in any coordinate ranging generally between 0 and 3 mm for the very short-baseline 'microfootprint' arrays and 2 to 5 mm for the short and long baseline arrays. Scheduled for the 1999-2000 field season is the last of four independent observing campaigns in this phase of the TAMDEF project for the South Victoria Land region.

Absolute Gravity Measurement at Aboa: Effects of Close-Range Ice and Snow Cover

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In January 1994 the Finnish Geodetic Institute made a determination of absolute gravity at the base Aboa ($\varphi = 73°03'S$, $\lambda = 13°25'W$) in Western Queen Maud Land. The JILAg-5 absolute gravimeter was used. The work was a part of the Finnish scientific Antarctic expedition FINNARP-93. I give a brief description of the results. A repeat measurement is planned in coming years, to detect a possible variation in gravity due to vertical motion and large-scale mass transfer. The site is on a small mountain of basaltic rocks with a large solid angle to the surrounding glacier and to the snowy slopes descending towards it. I discuss the gravity effects of mass variations in this near field.

Activity of Polish Surveyors in Spitsbergen

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Polish geodetic activity in Spitsbergen began during the first Polish expedition in 1934, when some of the last existing white spots on the Spitsbergen map were measured. Among the seven members of this expedition were two surveyors. The triangulation network was established and the area of 260 km^2 (Amundsenisen area of Wedel Jarlsberg Land) to scale 1:50 000 was measured using terrophotogrammetry. Contemporary Norwegian maps (sheet B12, C12) contain many Polish names from this time, eg. Kopernikusfjellet, Polakkbreen, Curie-Sklodowskafjellet to name a few.

Polish surveyors were next in Spitsbergen during the period 1957-59, participating in the III International Geophysical Year and the International Geophysical Co-operation (1959-60). During this time the Polish Scientific Polar Station was built in Hornsund Fiord on Spitsbergen. In addition the astronomical point was established and terrophotogrammetric surveys were initiated (changes of the front position of glaciers Hans and Werenskiold, and other topographic works, resulting in the production of two maps of glaciers: Werenskiold 1: 5 000 (3 sheets, 42.3 km^2) and Penck 1: 2 000 (2 sheets, 5 km^2).

Unfortunately, Polish surveying and scientific expeditions to Spitsbergen were interrupted in 1960 for a period of a dozen years and it was only due to the efforts of scientists of Wroclaw University that the next scientific expedition took place. Photogrammetry was not main aim of this search, however, some terrophotogrammetric photos were used to determinate the changes of the front position of glaciers Hans and Werenskiold.

The most important and fruitful period of our activity started in 1978, when the Polish Scientific Polar Station on Spitsbergen was reactivated. The station is still working permanently today, run by the Institute of Geophysics of Polish Academy of Sciences. Many scientific programmes are undertaken also by other regional academic centres not only in the environs of the Polish Polar Station.

Geodetic works are done mainly for specialists other sciences, especially for glaciology. The main topics are:

- Registration of changes of the front positions,
- Determination of surface movement of the Hans Glacier;
- Topographic elaboration (maps of glaciers and their surroundings);
- DTM of glaciers with radar and radio sounding of bedrock;
- Analysis of geometry changes of glaciers (longitudinal profiling by means of GPS techniques and Airborne laser altimetry method;
- Mapping of a macro and mezo cryokarst form on the glacier surface.

The main geodetic and cartographic results (printed) of these activities are shown:

From 1982 we have permanent data on changes of the front position of Hans Glacier (over 100 cycles in different periods) and its surface movement (one week, one day period even - over 30 cycles). We are using the permanent photogrammetric station (autocentering iron ring) to register cyclic observation.

In 1991, together with colleagues from the Norsk Polarinstitutt, Oslo and the Institute of Geography of Academy of Sciences, Moscow, we participated in an international survey programme of a large glacial area. The longitudinal profiles of the Amundsenisen Plateau, Lomonosovfonna and Kongsvegen - Svea Glacier were measured by GPS.

Thanks to co-operation with NASA we have obtained data from airborne laser altimetry surveys over glaciers situated near the Polish Polar Station. Some data were elaborated (Paierl, Mühlbacher and Amundsenisen) and the great reduction in the height of surface glaciers were observed.

The other results of our geodetic activities are published in permanent publications and are presented at scientific conferences, symposiums and workshops in Poland and abroad.

GPS Networks for the Observation of Ice Surface Deformation in Dome C and Talos Dome Areas

G. Bitelli, A. Capra, S. Gandolfi, F. Mancini, L. Vittuari

DISTART - University of Bologna

Accurate topographical surface, surface ice deformation, bedrock topography and internal layering are important physical parameters to modelling the age of ice versus depth. In the framework of EPICA (European Project for Ice Coring in Antarctica), GPS kinematic profiles and a geodetic strain network of 37 stations were carried out at Dome C in 1995 during the 11th Italian Expedition in Antarctica. In order to determine the ice surface deformation, geodetic strain networks were re-measured a second time in January 1999.

During the 1996 ITASE Italian expedition a snow/firn core of 90 m was drilled on the topographic top of Talos Dome. In the same area a GPS strain network of 9 stations was established and surveyed to determine ice deformation around the drilling site. GPS measurements were repeated in December 1998.

Results of Dome C and Talos Dome strain networks made during the 1998-99 Italian expedition and the analysis of ice surface deformations are presented.

Recent Results of GPS Networks for Crustal Deformation Control on Terra Nova Bay Area (Antarctica)

A. Capra, S. Gandolfi, P. Sarti, F. Mancini, L. Vittuari

DISTART- University of Bologna

The Italian geodetic network, located around Terra Nova Bay, Italian base in Antarctica, was monumented in 1990-91 as a reference frame for scientific activities (photogrammetry, cartography, geology) and for the purpose of geodynamics. The network was completely surveyed twice in 1990-91 and 1993-94 and once in December 1998. A geodetic GPS network was also established in 1990-91 for the study of deformation control of the Mount Melbourne volcano. The network has been surveyed four times: 1990-91, 1993-94, 1995 and 1997-98. The resulting coordinate variation was quite small after the fourth repetition, in comparison with method precision.

The results obtained, using two different types of software (Geotracer v. 2.25 and Bernese v.4.0) and different approaches to GPS data solutions (Lc,L1,L3), were significantly different, probably due to the different algorythms and to the modelisation of ionospheric effects. Thus, a new data processing method presenting a different approach has been created using a third type of software, Gipsy. The results of the Gipsy application and a comparison with the other solutions, are presented. A deformation analysis has been made integrating geodetic measurements with geophysical observations.

In addition, analysis of the data acquired from TNB GPS permanent station is presented, along with the results of measurements obtained from long occupation and far away stations (about 1000 km from each other): TNB1 (Italian base), Dome C station (during Dome C Strain Net surveying in January 1999) and Mc Murdo (USA base).

Appendix 1

Antarctic Geodesy Sympoium 1999 Program

Wednesday 14th July 1999

18.00 – 20.00

Icebreaker party at the Institute of Geodesy and Cartography

Adam Linsenbarth – Director of the Institute of Geodesy and Cartography – welcome ceremony and presentation of the Institute.

Thursday 15th July 1999

9.00 – 10.30 *Chairman: Jan Cisak*

Alexander Guterch - President of Polish Committee on Polar Research – geophysicist and organiser of seismic expeditions to Antarctica and Arctic. Prof. Guterch will open the Symposium

Krzysztof Birkenmajer - History of Polish Polar Research

Janusz Sledzinski - "Polish Geodetic Antarctic studies" (Prof. Sledzinski from Warsaw University of Technology was a member of first Polish Antarctic Expedition to A.B. Dobrowolski Station in 1958).

11.00 – 12.30 *Chairman: John Manning*

John Manning – Overview of GIANT program

Reinhard Dietrich - "Present Status of the SCAR GPS Epoch Campaigns"

Alessandro Capra - "A Data Base for Physical Geodesy Data Collection and Analysis"

14.00 – 15.30 *Chairman: Reinhard Dietric*

Larry D. Hothem - "Transantarctic Mountains Deformation Monitoring Network (TAMDEF), South Victoria Land - Initial Results" (oral & poster)

Bjorn Johns - "Multi-Disciplinary GPS Applications in Antarctica - McMurdo DGPS Base, Science Support, and Operational Surveying."

John Manning – SCAR Group of Specialists on Antarctic Neotectonics (ANTEC)

Alessandro Capra - "Local Geodynamics Studies In Antarctica (Terra Nova Bay- Victoria Land)"

16.00 – 17.30 *Chairman: Larry Hothem*

Jaakko Makinen - " Absolute gravity measurement at Aboa: Effects of close range ice and snow cover"

Alessandro Capra - " GPS networks for the observation of ice surface deformation in Dome C and Talos Dome areas"

Alexander Yuskevitch (AEROGEODEZIJA - from St. Petersburg – new Russian member of SCAR WG-GGI) "Topographic and geodetic works executed by Federal Service of Geodesy and Cartography of Russia in Antarctic Continent since 1970"

Symposium Dinner

Guest speaker - *Krzysztof Birkenmajer*

Friday 16th July 1999

9.00 – 10.30 *Chairman: Alessandro Capra*

Nengcheng Chen - "Geostar and Internet Based GIS of Antarctica"

Chunming Chen – "Antarctic Surveying and Mapping Works of China and Recent Progress"

Larry Hothem - "Antarctic Geodetic Activities by U.S. - Underway and Planned (oral & poster).

Fedir Zablotskyj (Ukraine) - "Results of atmospheric influences on astrogeodetic measurements in Polar Regions."

11.00 – 12.30 *Chairman: John Manning*

GIANT Meeting – progress on SCAR WG-GGI projects and reports on activities undertaken during season 1998/99

- Permanent Observatories
- Epoch Campaigns
- Physical Geodesy
- GLONASS
- Differential GPS
- Remote Observatories
- Information Access

14.00 – 15.00 *Chairman: John Manning*

GIANT Meeting – plans for geodetic work next austral summer 1999/2000

15.30 – onwards *Chairman: Jan Cisak*

Technical Tour to the Astro – Geodetic Observatory of the Institute of Geodesy and Cartography in Borowa Góra *(36 km from the Centre of Warsaw)*

Evgenij Zanimonskiy - Ukraine - "Autonomous field and laboratory tests of the portable Absolute Gravimeter" (He proposes to have this presentation during technical excursion to the Observatory.)

Ilari Koskelo – Finland - Javad presentation

Outdoor reception - late into the evening.

Appendix 2

List of Participants at AGS99

Name	E-mail	Country
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SCAR Report

SCAR Report is an irregular series of publications, started in 1986 to complement *SCAR Bulletin*. Its purpose is to provide SCAR National Committees and other directly involved in the work of SCAR with the full texts of reports of SCAR Working Group and Group of Specialists meetings, that had become too extensive to be published in the *Bulletin*, and with more comprehensive material from Antarctic Treaty meetings.

SCAR Bulletin

SCAR Bulletin, a quarterly publication of the Scientific Committee on Antarctic Research, is published on behalf of SCAR by Polar Publications, at the Scott Polar Research Institute, Cambridge. It carries reports of SCAR meetings, short summaries of SCAR Working Group and Group of Specialists meetings, notes, reviews, and articles, and material from Antarctic Treaty Consultative Meetings, considered to be of interest to a wide readership. Selections are reprinted as part of *Polar Record*, the journal of SPRI, and a Spanish translation is published by Instituto Antártico Argentino, Buenos Aires, Argentina.

Polar Record

Polar Record appears in January, April, July, and October each year. The Editor welcomes articles, notes and reviews of contemporary or historic interest covering the natural sciences, social sciences and humanities in polar and sub-polar regions. Recent topics have included archaeology, biogeography, botany, ecology, geography, geology, glaciology, international law, medicine, human physiology, politics, pollution chemistry, psychology, and zoology.

Articles usually appear within a year of receipt, short notes within six months. For details contact the Editor of *Polar Record*, Scott Polar Research Institute, Lensfield Road, Cambridge CB2 1ER, United Kingdom. Tel: 01223 336567 (International: +44 1223 336567) Fax: 01223 336549 (International: +44 1223 336549)

The journal may also be used to advertise new books, forthcoming events of polar interest, etc.

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