Cybercartographic Atlas of Antarctica

Chapter on:

Geodetic Activities and
History of Geodesy in Antarctica

Australia

John Manning
Group Leader, Geodesy Group
National Mapping Division
Geoscience Australia
<JohnManning@auslig.gov.au>

BACKGROUND

The Scientific Committee on Antarctic Research (SCAR) was formed at The Hague in February 1958. It evolved from the Special Committee on Antarctic Research established by the International Council for Science (ICSU) to co-ordinate the scientific research of the twelve nations active in Antarctica during the IGY, the International Geophysical Year in 1957-58.

The main activity of SCAR has been to provide a forum for scientists of all countries with research activities in the Antarctic to discuss their field activities and promote cooperation and collaboration in scientific research amongst Antarctic Treaty Nations. The surveying and mapping activities of SCAR are coordinated through its Working Group on Geodesy and Geographic Information - WG-GGI (www.scar-ggi.org.au/).

From its inception the WG-GGI working group encouraged standardised mapping of the Antarctic continent and established a set of recommendations and standing resolutions as mapping standards. Initially it recommended the use of the Hayford 1924 International spheroid as the basis for mapping projections and positional computations. The initial role of Geodesy within the SCAR WG-GGI evolved from the provision of control for exploration and mapping to the establishment of a single geodetic reference frame for all Antarctic spatial data. Utilising space geodesy techniques it is possible to monitor the internal tectonic motion of the continent and its linkage to other Gondwanaland fragments.

THE USE OF SPACE GEODESY IN ANTARCTICA

In the second half of the 20th century the positioning of geographic features on the Antarctic continent and measurement of baselines to other continental land masses was still only achievable from astronomic observations or local trigonometric surveys within Antarctica. Triangulation chains were difficult to establish due to the need for multi station visibility for angles. The networks, which were established, were usually limited to the immediate vicinity of the base stations, or as small area triangulations based on isolated celestial fixes. It was usually impossible to connect these triangulations by terrestrial survey.

In the early sixties microwave electronic distance measuring equipment (EDM) was introduced to the Antarctic continent, which enabled trilaterations, and large traversing loops rather than pure triangulation to be undertaken, producing systematic but still isolated geodetic networks.

The first application of space geodesy to address this problem and to determine the coordinates of some Antarctic stations in a global reference frame was commenced in 1969 when the global astro-triangulation PAGEOS program occupied Antarctic sites at McMurdo, Mawson, Palmer and Casey. In the early 1970s satellite based microwave positioning proved more useable and firstly Tranet Doppler and then GPS became available on global scale (Manning et al, 1990). The development of positional accuracies achievable from the different geodetic techniques is summarised in Table 1 below.

Period	Technique	Positional Uncertainty
1950s	Positional Astronomy	+- 200metres
1969-70s	Satellite / Stellar photography (PAGEOS)	10 metres
mid 1970s	TRANET Doppler	3-5 metres
late 1980s	GPS	1-2 metre
1990	VLBI	1 decimetre
1995	GPS	1 decimetre
2000	GPS	centimetres

Table 1: Development of positional accuracy of Antarctic sites

THE SCAR GPS PROJECTS

The early Antarctic space geodesy programs were the initiatives of individual countries as part of extensive global programs, and no coordinated international geodetic program 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. However, due to logistic limitations no overall plan was implemented to link the individual networks.

In the late 1980's GPS emerged as a geodetic tool with a potential for Antarctic applications. The XX SCAR meeting, in Hobart, in 1988 endorsed a proposal by Australia to test the developing GPS technique for mapping control and Geodesy applications in monitoring crustal motion. This pilot study was undertaken in two phases: Feasibility observations January 1990 Test observations in January 1991

Despite problems encountered 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 (Govind at al 1990).

With the success of these pilot studies the WG-GGI started an ongoing series of summer GPS epoch surveys headed by Prof Reinhard Dietrich from Germany (Dietrich et al, 2001)**.** All data is archived at the University of Dresden (dietrich@ipg.geo.tu-dresden.de) and can be viewed at:<www.tu-dresden.de/ipg/SCARGPS/database.html>

Despite their success, the GPS campaigns were logistically costly and it was difficult to arrange occupation of all sites at the same time being subject to different logistic arrangements. Consequently in 1993 six permanent GPS sites were installed to provide fundamental fiducial stations to link epoch surveys together.

Figure 1: Permanent GPS stations in Antarctica

This was a significant technological advance as it provided a potential continuous time series of observations and a network of key sites which can then be used as a control framework for subsequent temporary occupations at different times. In 1994 three more permanent GPS trackers were installed.

Since that time Permanent trackers contributing continuous data to IGS have been established at SANAE, in 1999, and other annual down load GPS base stations are operating at Terra Nova Bay, Maitri, Dumont d'Urville and Zhong Shan. Deployment of GPS equipment at unattended remote Antarctic localities for regional densification of geodetic infrastructure is under construction which requires remote power input and regular data retrieval. This technology needs further development.

THE GEODETIC INFRASTRUCTURE OF ANTARCTICA (GIANT) PROGRAM

In 1992 it was decided to develop a coordinated network of GPS geodetic stations using available surveys together with collocation of other techniques such as VLBI, Absolute Gravity, DORIS and tide gauges. This was collectively identified as the

Geodetic Infrastructure for Antarctica (GIANT) program - as described in WG-GGI web site <www.scar-ggi.org.au/geodesy/giant.htm>

The ongoing 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.

Major projects of the Program are:

- Permanent Geodetic Observatories;
- Crustal Deformation Network;
- Physical Geodesy;
- Geodetic Control Database;
- Tide Gauge Data;
- Atmospheric Impact on GPS Observations in Antarctica;
- Remote Geodetic Observatories; and
- New Geodetic Satellite Missions

The status and progress reports of these projects are discussed annually. Details of the most recent WG / GIANT meetings in both Siena, Italy and St. Petersburg, Russia can be found at <http://www.scar-ggi.org.au/meetings/prevmeet.htm>.

The techniques covered by the Permanent Geodetic Observatories project are:

- Continuous GPS
- DORIS
- VLBI
- Tide gauges
- Absolute Gravity
- PRARE
- GLONASS

The status of the elements listed above is shown on the Permanent Observatories web page at <www.scar-ggi.org.au/geodesy/perm_ob/sites.htm>

CURRENT STATUS OF THE GEOID

Another element of the Physical Geodesy project of the GIANT program is the computation of an Antarctic Geoid to provide the connection from ellipsoidal heights, (such as from GPS heights) and heights above sea level. Australia produced early versions of the Antarctic Geoid based on GEM and OSU gravity data sets, which are available on the AUSLIG web site <www.auslig.gov.au/geodesy/antarc/antgeoid.htm>. An accurate definition of the geoid in Antarctica continues to be hampered severely constrained by the scarcity of gravity information, especially across the inland of the continent. .

In 1996 NIMA produced a new global Gravity data model as EGM96, however it still suffers from lack of gravity coverage in Antarctica. A grid of geoidal separation values

that can be used to interpolate a separation value for any location south of 60 degrees latitude are available on the WG-GGI webs site for individual interpolation.

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

International Terrestrial Reference Frame (ITRF)

Antarctica is important in global geodesy. Global Geodesy models have heavily relied on observations from Northern Hemisphere sites and the results do not always fit 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 to make their data available to the global data base of the International GPS Service (IGS) on a daily basis.

The continuous GPS sites in Antarctica have been used in ITRF 2000 primary determinations (Altimimi 2001) and the epoch surveys have also been provided as an input by Dietrich (2001) as densification of the official IERS reference frame. This results in a network of official published IERS coordinates (with velocities) for Antarctic rock sites which can be used by any scientists as the basis for positions that are well defined in the Global reference frame

Velocities for Antarctic ITRF sites are given in Table 2 and Figure 2.

ID	LATv	LONv	HGTv
7400	0.0163	0.0189	0.0047
ART1	0.0161	0.0068	0.0001
BEL1	0.0105	0.0119	0.0347
BELG	0.0105	0.0119	0.0347
BRAZ	0.0125	-0.0039	0.0016
CAS1	-0.0096	0.0026	0.0037
DAL1	0.0142	0.0077	0.0019
DALL	0.0142	0.0077	0.0019
DAV1	-0.0048	-0.0015	0.0043
DUM1	-0.0081	0.0116	-0.0009
ELE1	0.0141	0.0062	0.0024
ESP1	0.0097	0.0142	0.0102
FOR1	0.0058	-0.0009	0.0079
FOR2	0.0058	-0.0009	0.0079
FOS1	0.0107	0.0129	0.0007
GOUG	0.0185	0.0202	-0.0017
GRW1	0.0162	0.0086	0.0075
KERG	-0.0031	0.0060	0.0050
KOUR	0.0120	-0.0045	0.0026
LPGS	0.0114	-0.0017	0.0011
MAC1	0.0304	-0.0108	0.0001

Table 2: Positions and velocities for Antarctic ITRF sites

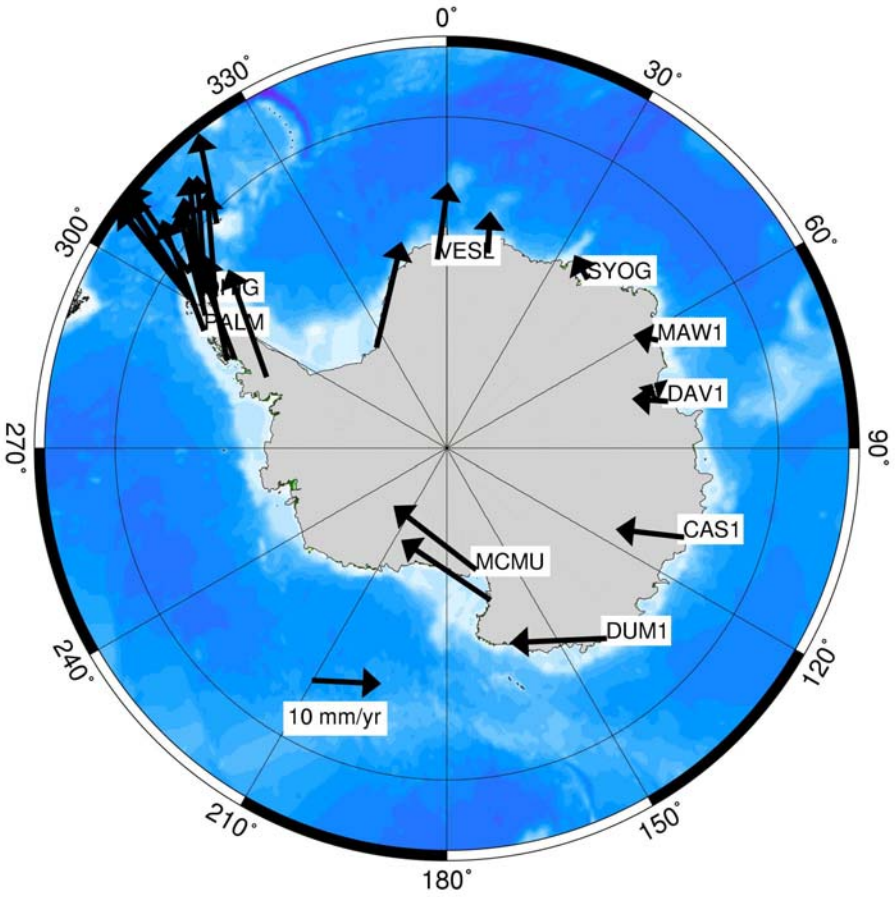

Figure 2: Velocities for Antarctic ITRF sites

ANTARCTIC GEODESY SYMPOSIUMS (AGS)

The first of these symposiums was held in Santiago, Chile in 1998. The idea of the symposiums is for each of the host countries to be able to showcase their current research and results from Antarctic geodesy activities.

Three symposiums have now been held - with the proceedings from the last 2 being published as a SCAR Report.

- Abstracts from the papers at the first AGS - AGS'98 - are available at <www.scar-ggi.org.au/geodesy/ags98/abstracts.htm>

- Full proceedings from the second AGS - AGS'99 - are available at either <www.scar-ggi.org.au/geodesy/ags99/docs.htm> or <www.scar.org/Publications/reports/Rep%2020/Rep20contents.html>

- Full proceedings from the third AGS - AGS'01 - are available at either <www.scar-ggi.org.au/geodesy/ags01/docs.htm> or <www.scar.org/Publications/reports/Report%2021/report_21_contents.htm>

ONLINE GEODETIC CONTROL DATABASE

The result of one of the GIANT projects from the 2000-2002 work plan was the creation of an online database of geodetic control. The need for this type of system was recognised many years ago. Now technology is able to deliver this type of information to anyone with access to the Internet.

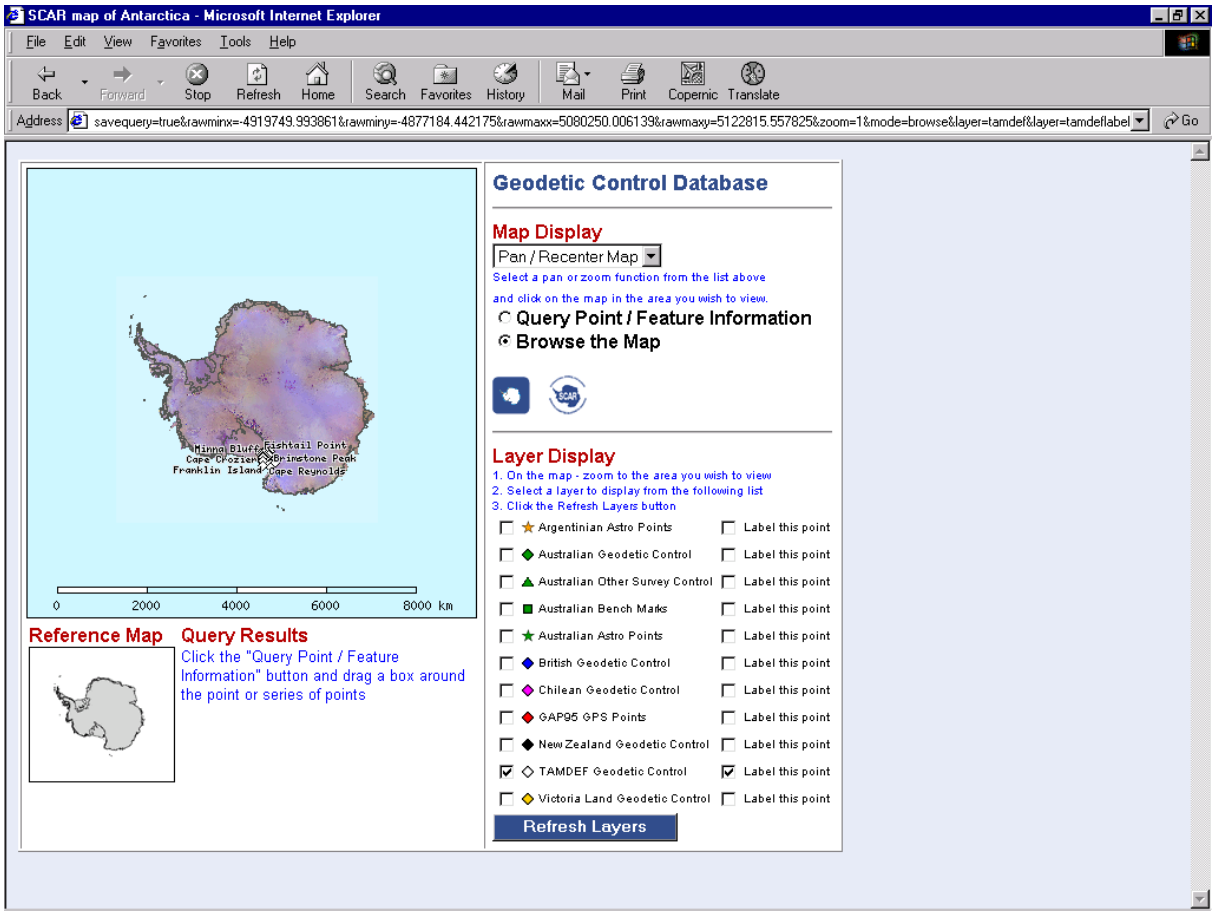

Figure 3: <www.scar-ggi.org.au/geodesy/giant.htm#controldb>

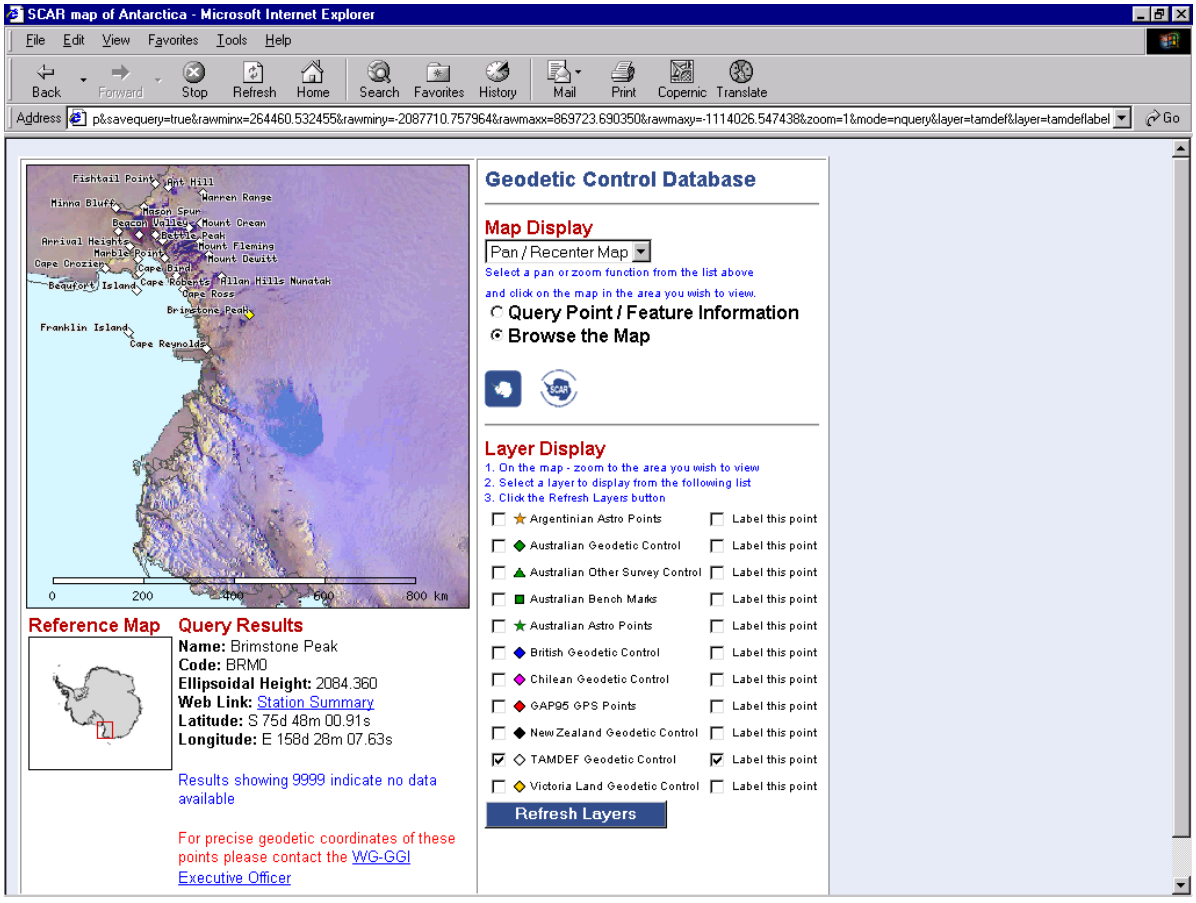

Figure 4: Results from a query on the Online Geodetic Control Database

CONCLUSION

There has been considerable international cooperation in Antarctic Geodesy since SCAR was formed in 1958. The principal coordinating mechanism has been the SCAR working group on Geodesy and Geographic Information and recently thorough its GIANT sub program. The GIANT program is ambitious with many problems of real time intercontinental data communication, from base stations and placement of receivers in remote localities, but progress is being made.

A number of permanent GPS receivers have been installed in Antarctica over the past five years and data is increasingly being retrieved by satellite transmission from these sites. This fiducial network of GPS points augmented by VLBI and other technique forms the basis for an integrated geodetic infrastructure as the basis for all scientific spatial data within a single global reference frame. Ready on-line access to data and results is an objective of the program and details are kept up to date on the WG-GGI web site through the WG-GGI Outreach program.

Geodetic observatory sites in Antarctica are of ongoing importance to global geodesy especially in the determinations of precise orbits and the integration of different observational techniques. These sites have been complimented by summer epoch campaigns to densify the ITRF network across Antarctica with specific regional projects in the Antarctic Peninsula and McMurdo Sound

The application of space geodesy now offers tools to undertake a more comprehensive study of crustal movements within Antarctica and in relation to other fragments of the ancient Gondwanaland. The monitoring of surface geodynamics and the provision of results can make a significant contribution to the work of other Antarctic earth scientists such as is the case with newly formed ANTEC group of specialists concerned with developing a better understanding of the crustal dynamics of Antarctica.

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