THE EVOLUTION OF THE GIANT PROGRAM

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1. HISTORICAL BACKGROUND

GIANT is the acronym for the Geodetic Infrastructure of Antarctica program of the Scientific Committee for Antarctic Research (SCAR). SCAR was formed at The Hague in February 1958. It evolved from a Special Committee on Antarctic Research which was established by the International Council for Science (ICSU) to co-ordinate the scientific research of the twelve nations who were active in Antarctica during the International Geophysical Year in 1957-58. The ongoing objective of SCAR is to promote scientific collaboration in Antarctic research.

At the first SCAR meeting in 1958 Cartography, as it was known then, was part of Working Group 2 (along with Geology, Glaciology and Morphology). At the III SCAR meeting in September 1959 Cartography met as a Working Group in its own right. The following year at IV SCAR in September 1960, a Permanent Working Group on Cartography was established . The Chief Officer was General Laclavére from France. The name was subsequently changed at V SCAR in October 1961 to the Working Group on Geodesy and Cartography. The Working Groups Chief Officer was B P (Bruce) Lambert from Australia. Since then the Chief Officer position has been held by Australian representatives from the National Mapping Division. In 1988, at XX SCAR in Hobart, the name of the group was changed to the Working Group on Geodesy and Geographic Information (WG -GGI) to better reflect its total scope of activity.

From its inception the working group encouraged compatible 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 and geodetic computations. The essential role of Geodesy within the working group at that time was the provision of control for exploration and mapping. This has since evolved to include the monitoring of the current tectonic motion of the continent and its linkage to other continents.

Since the formation of the WG-GGI at V SCAR in 1961 group meetings were usually held at the time of the SCAR meetings and all activities were the responsibility of the Chief Officer. At the XX SCAR meeting in Hobart in 1988 the modus operandi was changed from this single responsibility in producing a growing number of products, with a greatly increased work load. A more distributed arrangement was identified, which was reinforced at a special meeting hosted by Germany in Frankfurt in June 1990 as an alternate venue to the SCAR meeting that year. At the subsequent XXII SCAR meeting at Bariloche in 1992, Drew Clarke from Australia was elected Chief Officer and the operational aspects of the WG-GGI was completely reviewed changing from a focus on mapping standards and individual national activities, to a theme based structure with distributed project responsibilities. The Geodetic Infrastructure of Antarctic program was identified as GIANT at the meeting. Since that time the overall WG-GGI program has further evolved into two major umbrella streams each with an overall coordinator:

- Geodesy (GIANT)
- Geographic Information

This structural grouping proved successful and both streams initiated projects and produced products which were increasingly became available through the web site as Internet technology developed.

Event	Location	Date
AGS 98	Santiago University, Santiago	July 1998
AGS 99	Polish Academy of Science, Warsaw	14-16 July 1999
AGS 01	Arctic and Antarctic Institute, St Petersburg	
AGS 02	Land Information New Zealand, Wellington	
AGS03	University Lviv Polytechnic, Ukraine	15-17th September 2003

Table 1 List of SCAR Antarctic Geodesy Symposia

The concept of a business meeting at the time of the SCAR week working of working group meetings directly before the main SCAR meeting, and a specialist interperiod meeting was developed. This commenced with the USGS hosting a workshop in Flagstaff immediately before the Boulder IUGG meeting in 1995. This approach was further developed when Chile proposed and hosted a specialist Antarctic Geodesy Symposium (AGS) in Santiago immediately before the Concepion XXV SCAR. There have now been four AGS symposia as in Table 1 above culminating in this fifth AGS03 event in Lviv Ukraine. This series of meetings has provided an important continuity of face to face contact whilst focussing on program milestone for individual projects in the GIANT program.

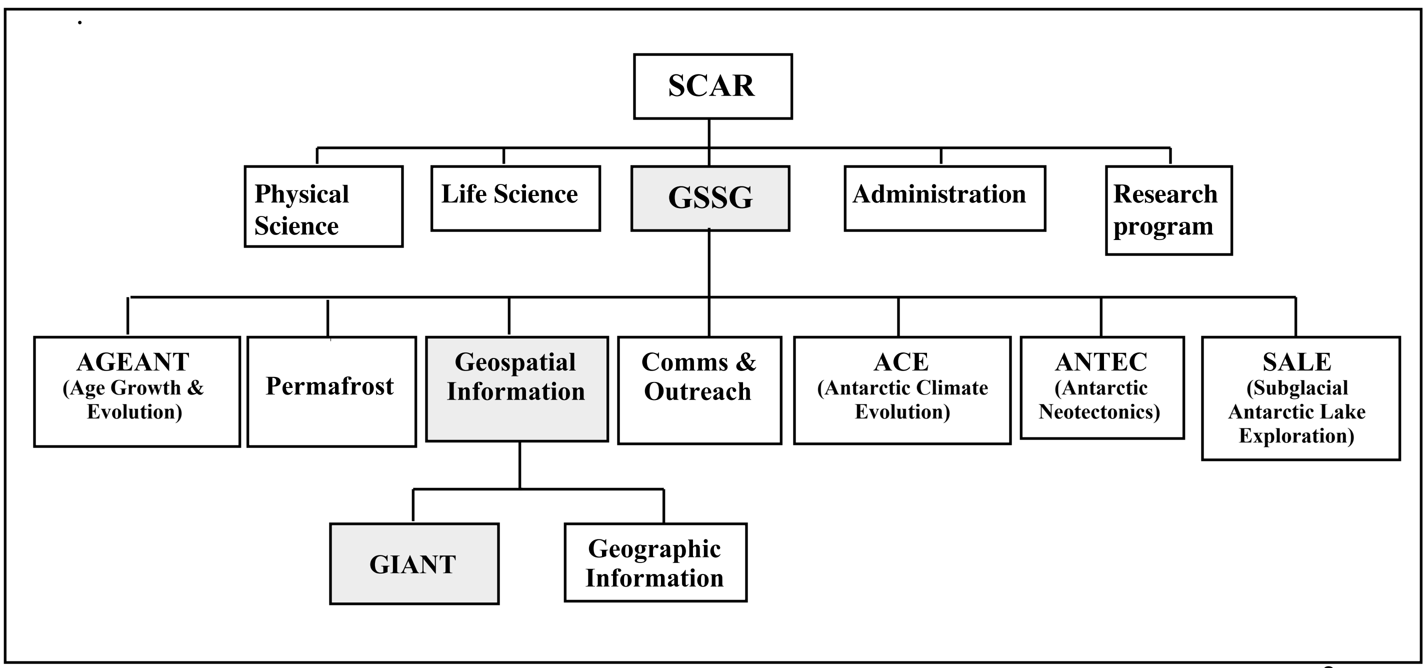

Figure 1: Structure of the Geoscience Standing Group (GSSG)

At the XXVI SCAR meeting in Shanghai in 2002 the long standing and successful WG-GGI (including GIANT) was merged with other SCAR working groups to form the Geoscience Scientific Standing Science Group (GSSG) and as such lost its direct reporting stream to the SCAR Executive Committee. The WG-GGI was renamed the Geospatial Information Group of Experts (GIG) with the intention to broaden its scope to also include Geophysical network information. In the new structure GIANT continues as the coordinating program for SCAR Antarctic Geodesy but as a sub program within GIG, which in turn is a sub group of GSSG. GIANT continues also to contribute expertise and resources to the SCAR Antarctic Neotectonics (ANTEC) program. It is cross linked with the International Association of Geodesy regional sub commission on Antarctica as the GIANT convener is also the co chair of the IAG sub commission on Antarctic Geodetic networks.

2. TECHNICAL BACKGROUND : *The progression to space geodesy*

Until the 1960s the positioning of geographic features on the Antarctic continent and measurement of baselines to other continental land masses was still only achievable by local triangulation surveys within Antarctica and astronomical astronomic observations. Triangulation chains were difficult to establish due to the need for multi station visibility for angle observations. The networks which were established were limited to the immediate vicinity of the base stations, or as small local area triangulations in isolated mountain areas. It was impossible to connect these local triangulations.

Optical and microwave electronic distance measuring (EDM) techniques were introduced to the Antarctic continent in the mid sixties, which enabled trilaterations, and large traversing loops, rather than pure triangulation to be undertaken, producing expanded but still isolated geodetic networks. This remained unchanged until the advent of man made satellites, although several over snow survey traverse connections between mountain features were carried out using EDM techniques.

With the advent of man made satellites, space geodesy was applied to address the problem of intra continental connection and to accurately determine the coordinates of some Antarctic stations in a global reference frame. In 1969 the global astro-triangulation PAGEOS program occupied Antarctic sites at McMurdo, Mawson, Palmer and Casey, photographing passive satellites against a star background. In the 1970s active microwave positioning from satellites proved more useable than the PAGEOS optical photographic approach and firstly Transit Doppler and later GPS became available on global scale. The improvement in positional accuracies achievable from the different geodetic techniques is summarised in Table 1 below.

Period	Technique	Baseline accuracy
1950s	Positional Astronomy	+- 200metres
1969-70s	Satellite/Stellar photography (PAGEOS)	10 metres

mid 1970s	TRANSIT Doppler	3-5 metres
late 1980s	GPS	1-2 metre
1990	VLBI	1 decimetre
1995	GPS	1 decimetre
2000	GPS	Several centimetres
2003	GPS, enhanced VLBI	Sub centimetre

Table 1: Positional accuracy progression in Antarctica sites

The early Antarctic space geodesy programs were the initiatives of individual countries as part of more 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 nation's geodetic networks with view to a joint approach, but due to logistic limitations no overall plan was implemented to link the individual networks.

In the late 1980's the application of the GPS military navigation system emerged as a civilian geodetic tool with a potential for Antarctica. The XXth meeting in 1988 endorsed a proposal by Australia to test the developing GPS technique for mapping control and potential applications in monitoring crustal motion. This pilot study was undertaken in two phases:

- Feasibility observations January 1990
- Test observations in January 1991

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 1990

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 feasibility studies the WG-GGI initiated an ongoing series of summer GPS epoch surveys. These were coordinated by Reinhard Dietrich from Germany (Dietrich 1996), (Dietrich, 2001) and the sites occupied are shown in Figure 4**.** All epoch data is archived at University of Dresden as an ongoing collection for science research (Dietrich@ipg.geo.tu-dresden.de).

Despite their success, the GPS campaigns were logistically costly and it was difficult to arrange the simultaneous occupation of all sites, 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 (1995)

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

- O'Higgins
- Syowa
- Kerguelen

Since that time permanent GPS trackers contributing continuous data to world data bases on a daily basis have been established at SANAE (1999) and Palmer. Other annual download GPS base stations are operating at Terra Nova bay, Maitri, Dumont Durville, Cape Roberts, Belgrano and Zhong Shan.(see figure 5)

The technology to power GPS equipment at unattended remote Antarctic observatory sites during the sunless winter is under current development with varying degrees of success. Ideally this requires remote power and satellite data retrieval strategies. The Australian National University has deployed 4 stations in the vicinity of the Prince Charles Mountains in East Antarctica and continues development for regular satellite downloads from some of those sites. Japan is trialling a remote site on an island some 30 km from Syowa and USGS is trialling annual download from remote sites at Finger Point, Mt Fleming and Cape Roberts (collocated with a remote operating tide gauge). This remote operation technology is not quite proven and needs further development to be ready for the international polar year in 2007.

3. THE GEODETIC INFRASTRUCTURE OF ANTARCTICA PROGRAM

At the XXII SCAR in 1992 the results of the SCAR GPS Antarctic Project 1990-92 were assessed and it was decided to extend the GPS projects to develop collocation network of other techniques such as VLBI, Absolute Gravity, DORIS and tide gauges. This was collectively identified as the Geodetic Infrastructure for Antarctica (GIANT) the coordinating program for Geodesy.

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.

Since 1992 the GIANT program has been revised and endorsed at each major SCAR conference on a two yearly basis. The components of the current program are:

3.1 Geodesy program (GIANT)

There are nine projects in the program as shown at www.scar-ggi.org.au/geodesy/giant.htm and are summarised below as:

1. Permanent Geoscientific Observatories

Project Leader: Australia - Mr John Manning

Goal: To develop an infrastructure of permanent geoscientific (ie. seismologic, geomagnetic, geodetic and gravimetric) stations to bring all individual networks to a common datum, and to provide geoscientific information for the global monitoring and analysis of natural earth processes

2. Epoch Crustal Movement Campaigns

Project Leader: Germany - Prof Reinhard Dietrich

Members: Italy, Chile, Japan, China, Australia, USA

Goals:

1. To densify the geodetic infrastructure established from the permanent observatories; and
2. To develop a deformation model for surface movement vectors within a common Antarctic reference frame.

3. Physical Geodesy

Project Leader: Italy - Prof Alessandro Capra

Members: Germany, Australia, Russia, USA, Japan, Canada

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

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4. Geodetic Control Data Base

Project Leader: Australia - Mr Glenn Johnstone

Members: Germany, UK, USA

Goal: Maintain the master index for Antarctic positional control, including all levels of accuracy

5. Tide Gauge Data

Project Leader: Japan - Dr Kazuo Shibuya

Members: Australia, China, Germany, New Zealand, Italy, Russia, USA (Amos), UK (Woodworth), other specialists as required

Goal: To consolidate the collection of and access to Antarctic tide gauge information

6. Atmospheric Impact on GPS Observations in Antarctica

Project Leader: Poland - Dr Jan Cisak

Members: Germany, Italy, USA, Australia (IPS), Norway, China, IGS

Goal: To understand the iononspheric and tropospheric impact of the atmosphere on the quality of GPS observations in Antarctica

7. Remote Observatory Technologies

Project Leader: USA - Mr Larry Hothem

Members: Japan (GSI), Australia, Italy, Netherlands (Swartz)

Goal: Identify technology and monitor developments for the deployment of geophysical and geodetic measurement sensors, and ancillary support equipment, at unattended remote (no existing infrastructure for power, shelter and communications) Antarctic localities.

8. Ground Truthing for Satellite Missions

Project Leader: Germany - Prof Reinhard Dietrich

Members: Italy, Australia, USA (U of Texas)

Goal: To ensure new satellite missions are integrated with the Antarctic geodetic system

9. Geodetic Advice on positioning limits of special areas in Antarctica

Project Leader: Chile - Tnt Col Rodrigo Barriga

Members: Germany, Australia, USA

Goal: To provide advice to SCAR, through the Geoscience Standing Scientific Group on the geodetic aspects of protected area definitions.

One of the complex elements in The GIANT program is the development of the ellipsoid to geoid separation values to obtain heights above sea level from GPS or altimeter observations. An accurate determination of the Antarctic geoid continues to be severely hampered by the scarcity of gravity information, especially the interior of the continent. Australia produced early versions of the Antarctic Geoid based on GEM and OSU gravity data sets, which are available on the web site. In 1996 NIMA produced EGM96, a new global Gravity data model which however still suffers from lack of Antarctic gravity data. A grid of geoidal separation values based on EGM96 is available NIMA web site and which can be used to on line interpolate a separation value for any location (http://www.nima.mil/GandG/egm96/intpt.htm)

Whilst these earth gravity models still are inadequate for extensive Antarctic research, long wave gravity models from the CHAMP and GRACE satellite are beginning to become available and will improve the situation. Medium wave length gravity however is also required and this can be produced from airborne gravity. The experience from the successful aero gravity activities of Denmark and the Unites States of America in Greenland and the Artic Ocean offer a technique to dramatically improve this aspect of the Antarctic gravity data set and provide the base for the subsequent computation of the geoid within the GIANT Geoid project. Ultimately terrestrial gravity will be integrated by introduction of precise Absolute gravity at origin sites top produce a continental wide gravimetric framework

GIANT also provides important geodesy input to two other major activities:

- ANTEC, and
- ITRF

3.2 The Antarctic Neotectonics Group of Specialists ANTEC.

This group of specialists was established following the SCAR XXV meeting in Concepcion with three GIANT representatives. The ANTEC objectives are intertwined with the need for a precise geodetic framework over Antarctica in the establishment of remotely operated sites away from the manned coastal stations and the integration with other geodetic techniques.

3.3 The International Terrestrial Reference Frame (ITRF)

Antarctica is important in the context of global geodesy. In the past global 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 space geodetic observatories have provided data to rectify this imbalance. Some continuous GPS sites make their data available to the International GPS Service (IGS) using satellite data retrieval systems. Data from continuous GPS sites in Antarctica were used in ITRF 2000 primary determinations (Altimimi 2001) and the epoch surveys have also been processed by Dietrich (2001) as densification of the global 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 in the Global reference frame. Through the GIANT program SCAR has accepted the recommendation that all geodetic networks in Antarctic should be computed in the ITFR 2000 reference fame using The GRS80 ellipsoid.

4. CONCLUSIONS

There has been considerable international cooperation in Antarctic Geodesy since SCAR was formed in 1958. The GIANT program was identified in the SCAR 1992 meeting and has evolved as the coordinating program for all SCAR Antarctic geodesy. With advent of man made satellites Geodesy has advance significantly linking isolated geodetic networks and monitoring tectonic motion.

A number of permanent GPS receivers have been installed in Antarctica and data is increasingly being retrieved by satellite transmission from these sites. This fiducial network of GPS points, augmented by VLBI and other techniques, forms the basis for an integrated geodetic infrastructure as the basis for all scientific spatial data. Data from these 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 provide a stable platform for combining summer epoch campaigns, densifying the ITRF network across Antarctica.

The application of space geodesy technology now enables a more comprehensive study of crustal movements within Antarctica and its relationship to other fragments of the ancient Gondwanaland. GIANT is making a significant contribution to the work of other Antarctic earth scientists such as the newly formed ANTEC group of specialists which is concerned with developing a better understanding of the crustal dynamics of Antarctica.

To meet the continual advancing requirement for accuracy for studying Antarctic geodynamics stresses, GIANT will expand the geodetic network to provide a very stable Antarctic reference frame for geodynamics and become involved in aerogravity campaigns to supplement satellite gravity data in order to improve the geoid.

6. REFERENCES

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Figure 2 Tide Gauge Installations

Figure 3 Absolute gravity sites

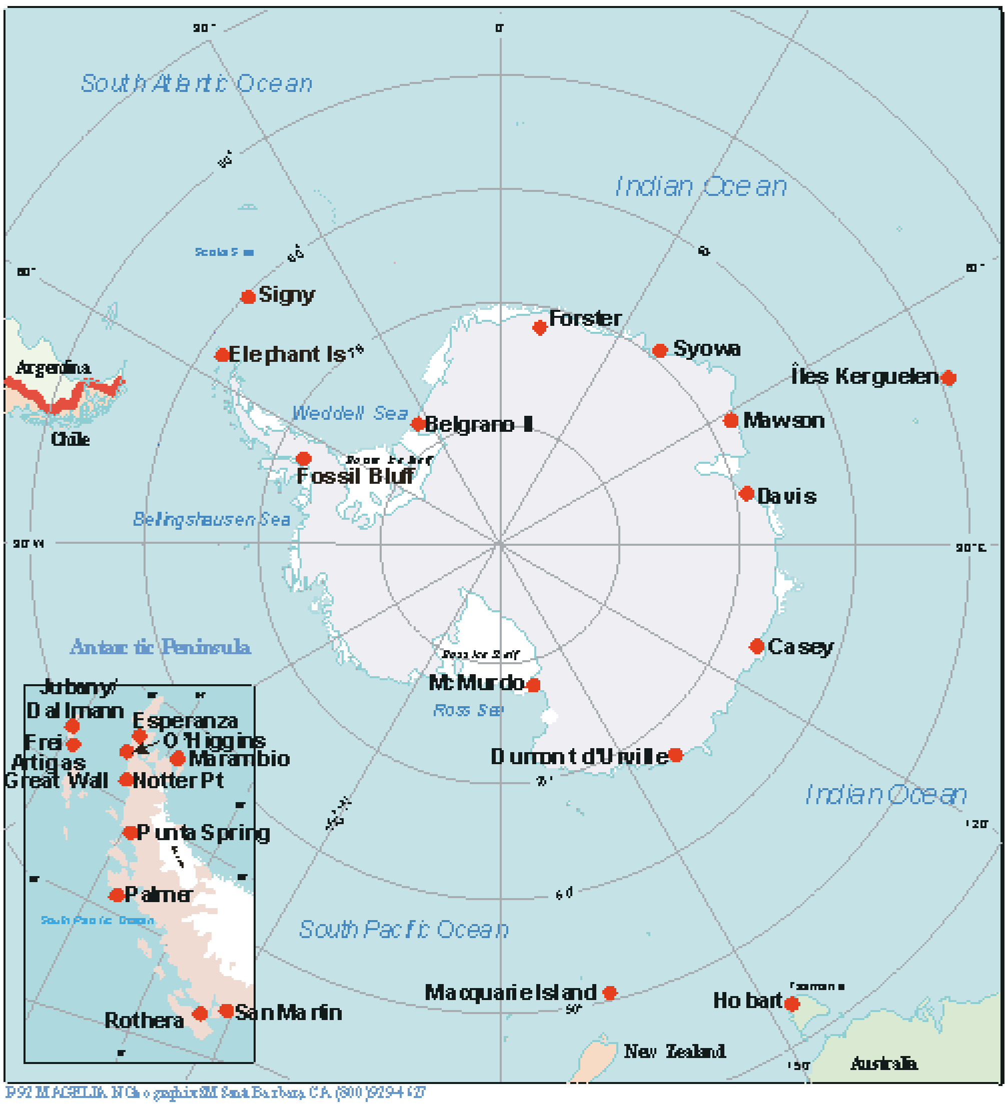
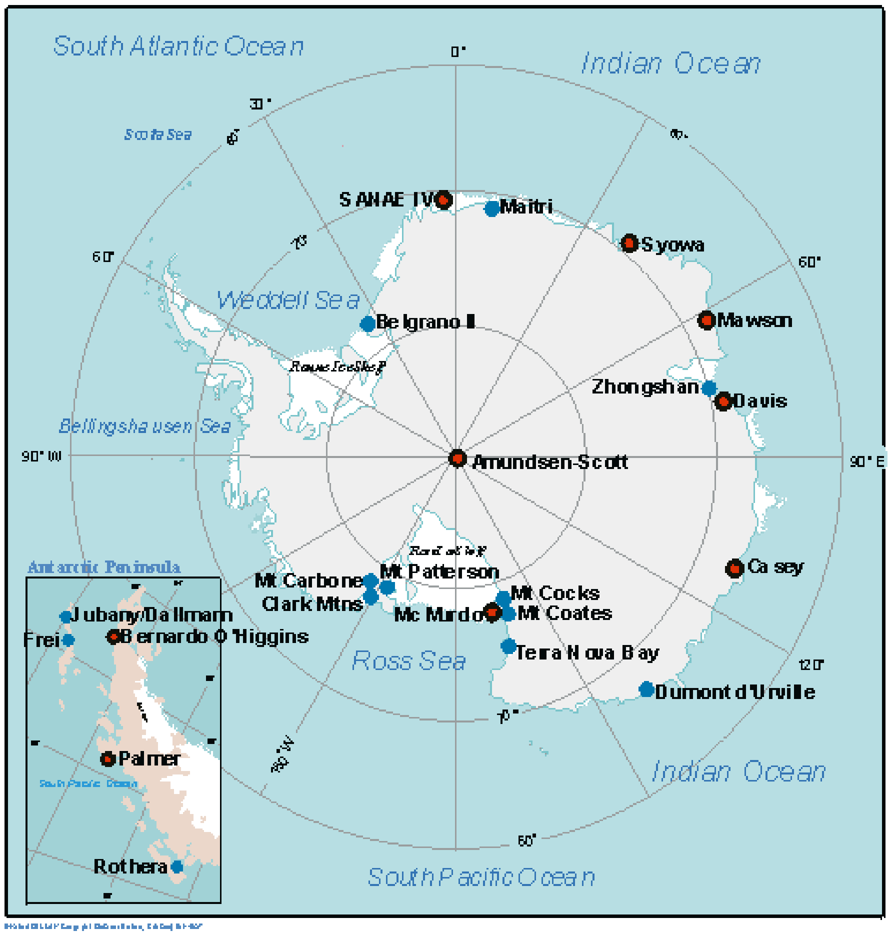


Figure4. GAP1995 Observational Sites

Figure 5 Continuous GPS sites



Permanent GPS - manual download

Permanent GPS - satellite link