The Contribution of the Geodetic Observatory O'Higgins to the Realization of a Geodetic Reference Frame in Antarctica

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On the development of O'Higgins

Since 1948 O'Higgins is a permanently manned Antarctic military base managed by the Chilean Army, located near the northern end of the Antarctic Peninsula on a small offshore island. At the end of the eighties the Federal Republic of Germany developed a combined SAR receiver and geodetic VLBI antenna to be placed in the neighbourhood of the Weddell Sea to collect radar data of the European Remote Sensing Satellites (ERS). The project was managed by the Bundesamt für Kartographie und Geodäsie (BKG), the German Aerospace Research (DLR) and the German Institute for Polar and Marine Research (Alfred-Wegener-Institute) under BKG's leadership.

The location of the receiver/radiotelescope was selected to fit both ERS and VLBI requirements (stable foundation on bedrock, temporarily free of ice). An already existing station with some logistics was desirable. By a kind agreement of the Chilean Government the installation of the scientific observatory at O'Higgins and the hosting the German crew during periodical visits, could be realized.

The first SAR image from ERS-1 was received successfully on October 9, 1991, the first VLBI experiments were performed during January/February 1992. The SAR receiver system is operated by DLR, which in addition is responsible for the management and logistics of the German part of O'Higgins. The responsibility for all geodetic observations and the care and integration of further geodetic equipment is in the hands of BKG (Reinhold, et al. 1996). Both DLR and BKG organize combined sessions (mostly) twice a year lasting for up to eight weeks each. From the beginning of the geodetic activities at O'Higgins BKG contributed also to GPS-campaigns, organized by the Scientific Committee for Antarctic Research (SCAR).

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Since January 1992 the VLBI equipment at O'Higgins participated in internationally scheduled VLBI experiments. Some results will be presented within this paper. Since February 1995 O'Higgins is involved in the International GPS Service for Geodynamics (IGS) with a Turbo Rogue permanently operating GPS receiver. At the same time an underwater pressure tide gauge has been installed. In order to be able to relate the different observing systems to each other a precise geodetic control network has been established.

The VLBI equipment

The VLBI equipment is the most important geodetic tool of the station as VLBI is the only method for precisely connecting terrestrial stations with the celestial reference frame and for estimating all parameters of Earth with respect to this frame. The construction of the VLBI-antenna is able to resist wind speeds up to 300 km/h, the surface of the reflector and the subreflector can be heated to keep the system operationable even during heavy snowing.

Icing of the antenna is excluded by a special layer. The vertical axis of the telescope is conventionally set parallel to the local vertical. The second axis is tilted against the vertical axis by 45°, and the collimation axis is again tilted against the second axis by an angle of 45°. Keeping the vertical axis fixed the collimation axis is describing a cone when the second axis is rotated (Figure 1).

The radiation from the extragalactic radio sources (quasars) enters the feedhorn and is observed in the operational frequency bands from 8.0 to 8.6 GHz (X-Band) and from 2.0 to 2.3 GHz (S-Band) and gets separated in different conductors. The necessary electronic amplifiers are cooled down to a minimum temperature of 20 K by liquid Helium. The received signal stream is amplified by about 30 dB and transformed to a more convenient frequency region by mixing with intermediate frequencies in the range of 0 to 500 MHz.

The local oscillator of the receiver, the different converters, sampler and formatter are all phase-locked to the stable 5 MHz frequency of an H-maser. The electronics for VLBI (data acquisition rack, recorder, time and frequency rack, H-maser, and the controlling computer) are placed in a container. The time and frequency system consists of a Cesium standard, H-Maser, and a GPS time receiver. The VLBI data are stored on magnetic tapes.

The following comprises some parameters of the antenna:

– diameter of cassegrain radio telescope antenna (main reflector)	9 m
– diameter of subreflector	1,38 m
– focal length	3,6 m

As in other geodetic VLBI equipment the O'Higgins VLBI system is a Mark III type which operates simultaneously in S- and X-band subdivided into 28 separated bands of 2 MHz width each. The frequency reduction to 2 or 4 MHz and the mixing of the originally observed frequency band with the local oscillator frequency are performed independently in each of the 28 channels. The sampling frequency is 4 MHz, this means two samples within a reduced period (Kovalevsky 1995).

VLBI activities at O'Higgins

The first successful VLBI recordings at O'Higgins have been performed in January/February 1993. Besides contributing within IERS to the development and maintaining of ICRF and ITRF and the estimation of EOPs the geodetic VLBI experiments run within the framework of the project DOSE (Dynamics of the Solid Earth), which was initiated by NASA and is executed in worldwide cooperation. Since 1992 O'Higgins was involved in 41 international experiments (status: August 1997).

An important condition for VLBI is the close cooperation between the participating observatories, based on a sophisticated scheduling which is substantial for high precision results. The schedule (made by NASA) combines the operating telescopes at different regions of the earth to radiointerferometers pointing at identical extragalactic radio sources simultaneously.

VLBI results

The VLBI data processing yields station coordinates and station velocities in the ITRF, the coordinates of the observed radio sources in the ICRF, polar motion, the offsets of the earth rotational velocity and offsets from the conventional theory of nutation. After ceasing the optical astrometric methods for earth orientation VLBI is the only tool to relate ITRF to ICRF. BKG has set up a team for processing VLBI data in cooperating closely with the VLBI group of the University of Bonn (Geodetic Institute).

	Coordinates and velocities in mm	σ [mm]	correlation matrix X	Y	Z	X vel	Y vel	Z vel
X	1525833.069	3.2	1.000					
Y	-2432463.886	3.6	-0.136	1.000				
Z	-5676174.545	3.8	-0.227	0.145	1.000			
X vel	0.013	1.8	-0.571	-0.026	-0.187	1.000		
Y vel	0.018	1.9	-0.025	-0.512	0.262	0.020	1.000	
Z vel	-0.004	0.9	-0.271	0.431	-0.324	0.496	-0.858	1.000

Table 1: Free network station coordinates for O'Higgins from the global solution VLBI-ifag95.01, velocities are given in m/year

The applied software is CALC/SOLVE/GLOBL (Caprette et al., 1990), developed at the Goddard Space Flight Center (GSFC-NASA). In the framework of the GPS campaign SCAR95 (cf. next chapter) special emphasis has been laid on a comparison of the VLBI results (station coordinates) with those resulting from the GPS Antarctic reference net-

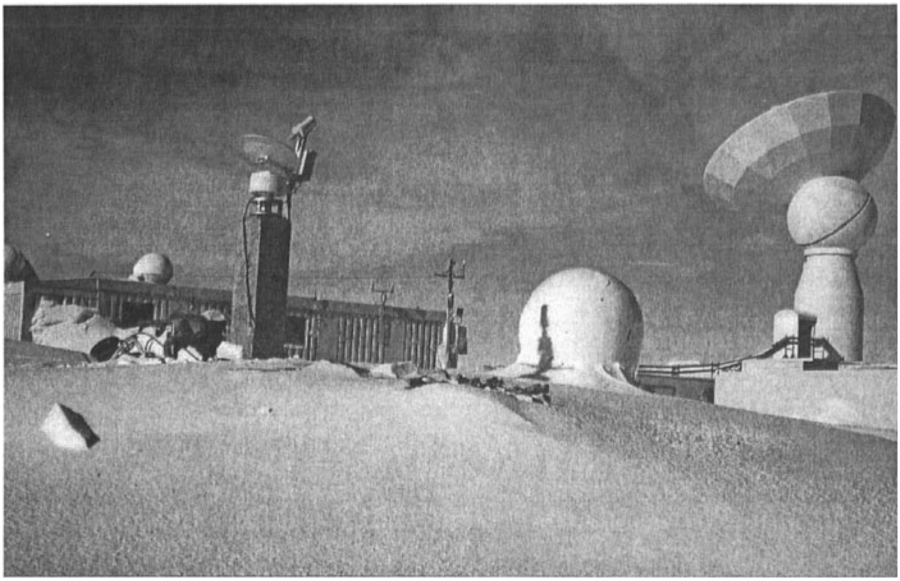

Figure 1: View on the geodetic observatory O'Higgins. From left to right: 2 radoms of INMARSAT antenna, PRARE test installation on pillar K4, radom of TURBO ROGUE antenna, VLBI antenna

work. For this comparison all available global VLBI data (collected since 1984) have been mixed with the data of 14 VLBI experiments at O'Higgins (1993: 7 experiments, 1994: 3 experiments, 1995: 4 experiments).

The combined data (in total 562 experiments of 28 stations) resulted in a parameter set of a free network solution (cf. Table 1). The solution (VLBI.ifag95.oh01) was finally related to the global coordinates of ITRF94 (epoch 1993.0) by a least squares transformation (7-parameter transformation), minimizing the residuals between the BKG-solution and the ITRF94 coordinates at the epoch in question.

results (epoch 1995.1)	x [m]	y [m]	z [m]
VLBI.ifag95.oh01	1525832.989 ± 0.003	-2432463.652 ± 0.003	-5676174.527 ± 0.003
GPS.scar95.all Trimble GPS receiver centered to VLBI	1525833.000 ± 0.007	-2432463.664 ± 0.007	-5676174.534 ± 0.011
ITRF94 VLBI solution	1525832.983 ± 0.010	-2432463.638 ± 0.012	-5676174.503 ± 0.016

Table 2: Comparison of results from VLBI and GPS (transformed with NUVEL 1 A to the epoch 1995.1 of the GPS SCAR95 campaign)

The coordinates of the geodetic reference point of the VLBI antenna can be compared with the results from the SCAR95 GPS campaign (cf. next chapter). The last line (Table 2) contains the coordinates of the VLBI antenna published by the IERS Central Bureau. The results are in good agreement with each other.

GPS-activities at O'Higgins

In order to improve the geodetic connection of O'Higgins with its environment as well as to establish a reference network in Antarctica German geodesists created such a network, observed and processed the collected data (Dietrich, 1996). These German activities have been integrated in the program of SCAR WG-GGI.

Within this network (25 stable marked stations in Antarctica and 12 additonal stations) there is a subset of about 12 stations on the Antarctic Peninsula, which are of specific interest for O'Higgins: Repeated observations in future will enable to detect differential motions in this district. The observations within this network have been performed in 1995. A final coordinate set was ready in 1996. The precision of the final solution is in the order of 1 cm for the horizontal components and 2 cm for the vertical component of the coordinates related to the frame of ITRF94 and the epoch 1995.1. A comparison of the GPS with VLBI results for O'Higgins with VLBI was given in the last chapter and is confirming the precision estimates. The first repetition of the observations is scheduled for 1998. Permanent GPS observations at O'Higgins started in 1995. By these O'Higgins is participating in the IGS. Data transmission from O'Higgins is performed by a satellite link using the INMARSAT system.

Sea level monitoring

In 1995 an underwater tide gauge system was installed at O'Higgins. The tidal data will allow investigations of local features of the ocean tides. A second item will be analyses of long term sea level changes induced by postglacial continental uplift as well as by the melting of polar ice through possible changes of the global climatic behaviour. The latter item is also of common interest.

The direct collocation of space geodetic equipment and sea level monitoring will be an important feature of the station. The space geodetic observations yield "absolute" coordinates, this means coordinates related to the centre of the Earth's mass. The sea level observations can directly be related to the geodetic systems due to the short distance. So the sea level recordings at O'Higgins are more or less directly connected to the Earth's centre.

The changing ice coverage at the shore and the rocky coast make the cable connection a highly vulnerable part of the tide gauge installation. The sensors have been solidly mounted and fixed to underwater bedrock. Two pressure sensors were in operation until March 1997. Unfortunately the sea level recording is interrupted since this time, probably due to cable problems.

The PRARE Ground Unit

The PRARE system (Precise Range And Range Rate Equipment) is an allweather microwave ranging system (accuracy at the cm level) for the measurement of satellite to ground ranges and range rates (DGFI, 1991). PRARE has been designed and developed mainly at the Institute for Navigation, University of Stuttgart, and was originally dedicated for precise satellite positioning for a number of ESA's satellite missions.

PRARE provides quick information for the determination of satellite orbits, which is important for an efficient application of remote sensing with satellites (e. g. satellite altimetry, SAR). On the other hand PRARE allows the precise determination of the coordinates of ground stations (Dornier, 1991). The installation of a PRARE ground unit was done in 1996 to assist the ERS-2 satellite mission. Since that time the system operates automatically and continuously (with only short interruptions).

O'Higgins geodetic control network

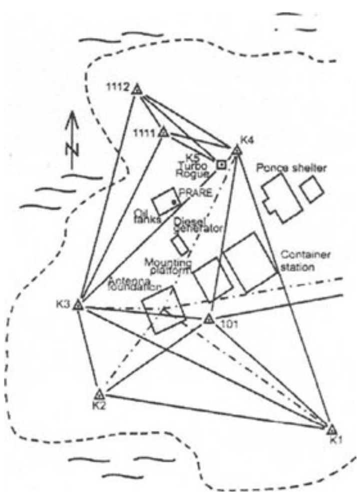

Figure 2: The local control network at O'Higgins

	dX	dY	dZ
K1	19.229	61.825	-10.501
K2	-34.111	9.814	-2.758
K3	-24.123	-15.065	8.215
K4	44.163	-17.916	29.285
K5	39.450	-17.639	28.436
101	8.086	13.987	4.750
1111	20.956	-34.586	36.002
1112	19.931	-48.620	44.347
M	0.000	0.000	0.000

M is the VLBI reference point (no 7245)

Table 3: Local coordinate differences in the control network of O'Higgins in [m]

In order to relate the different geodetic measuring systems of O'Higgins to each other a control network has been installed at the observatory. The observation points are stable monumented to allow the precise surveying of distances and angles and levelling with conventional surveying techniques. Whereas in case of the GPS antennas the corresponding reference point (this is the point to which the coordinates are related after processing the GPS data) is realized and marked by the manufacturer, the reference point of the VLBI antenna must be found from observations: it is the (virtual) crossing point between the vertical axis and the tilted second axis of the telescope. The control network is shown in Figure 2.

The difference between the coordinates of the VLBI reference point and other geodetic points are given in Table 3. Pillar K1 has been used during the SCAR95 GPS campaign in

Antarctica, pillar K4 within earlier SCAR GPS activities. On K5 the Turbo Rogue antenna is positioned. The PRARE antenna has not yet been precisely surveyed within this local network.

Prospects

In January and February 1995 some gravimetric tests have been made on O'Higgins, to get information on the microseismic behaviour. BKG is planning longer recordings for at least some months to determine local tidal parameters for this site (earth tides) as well as absolute gravity observations.

Future activities at O'Higgins focus on continuing the VLBI, GPS, and sea level observations as well as on stabilizing and increasing the precision. Direct observations of a baseline between O'Higgins and Syowa by VLBI are in discussion for 1998. To ensure a valuable contribution to ITRF and to an Antarctic reference network it is necessary to continue the observations over a longer period.

Acknowledgement

The geodetic operations, especially the VLBI campaigns and the realization of the logistic part, have only been possible in and due to the good cooperation with the colleagues from DLR. The support of the Goddard Space Flight Center of NASA in integrating the station O'Higgins into international projects and analyzing the VLBI observations is gratefully acknowledged.

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