The SCAR GPS Campaigns in the context of global reference system realization and geodynamic research

Axel Rülke and Reinhard Dietrich

TU Dresden, Institut für Planetare Geodäsie, 01062 Dresden, Germany (ruelke@ipg.geo.tu-dresden.de)

Summary The SCAR GPS Campaigns have been carried out under the umbrella of the Scientific Committee on Antarctic Research (SCAR) annually since 1995. In an advanced analysis concept we combine the regional solution from the SCAR network with a homogeneously reprocessed global solution. This combination minimizes inconsistencies in the realization of the global reference system in Antarctica. The station coordinates and velocities obtained provide an excellent reference for a broad variety of geoscientific applications. In addition, the obtained results contain valuable information for geoscientific investigations, such as plate kinematics, the stability of the Antarctic Plate or vertical deformations due to glacial isostatic processes. We present the status, introduce an advanced analysis concept of the SCAR GPS network and evaluate the derived accuracies. We discuss in detail the geoscientific implications of the obtained results. We provide an outlook on the contribution of the SCAR GPS Campaigns to the IPY project POLENET in Antarctica.

Citation: Rülke, A., and R. Dietrich (2007), The SCAR GPS Campaigns in the context of global reference system realization and geodynamic research, in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10^{th} ISAES, edited by A.K. Cooper and C.R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 146, 4 p.

Introduction

In 1995 the SCAR GPS Campaigns were carried out for the first time under the umbrella of the Scientific Committee on Antarctic Research (SCAR). Since then the campaigns have been repeated every year and are organized today under the new title SCAR Epoch Crustal Movement Campaigns by the Geoscience Standing Scientific Group (GSSG) of SCAR. The main goals of the campaigns are the realization of the International Terrestrial Reference System (ITRS) in Antarctica for a broad field of Global Navigation Satellite Systems (GNSS) applications, such as mapping, ground truthing for satellite missions, airborne surveys or ship operations on the one hand and the investigation of geodynamic phenomena on the other hand.

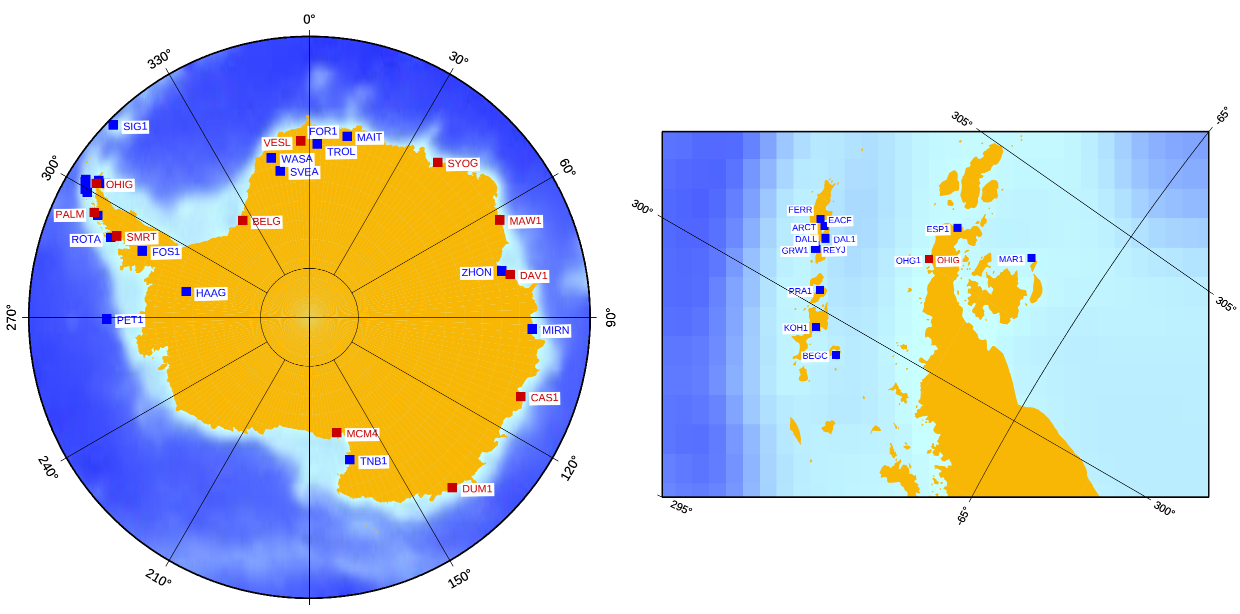

Figure 1. Site distribution of GNSS sites in Antarctica. The red squares are permanent observing stations. The blue squares symbolize campaign stations of the SCAR GPS network. (right: detail Antarctic Peninsula region)

Data

The International GNSS Service (IGS) operates a GNSS network of more than 500 globally distributed stations (Dow et al., 2005). In Antarctica these permanent observing stations represent a backbone network (red squares in Figure 1). In order to densify the permanent network of the IGS, more than 30 additional stations were established and observed by 20 participating countries in the frame of the SCAR Epoch Crustal Movement Campaigns (blue squares in Figure 1). Most sites are located in coastal areas with a high density of stations on the Antarctic Peninsula and the South Shetland Islands. The data and their documentations are archived in the SCAR GPS database, which is maintained in Dresden (SCAR, 2007).

Analysis

In a joint effort the groups of TU Dresden and TU Müchen/GFZ Potsdam reprocessed a global GPS network of about 200 individual sites from 1994 to 2006 (Steigenberger et al., 2006) with the Bernese GPS Software 5.0 (Dach et al., 2007). For this processing a state-of-the-art strategy was implemented, which contains also new modeling approaches. To allow for the atmospheric influence on the GPS signals, the 2nd- and 3rd-order ionospheric effects were considered consistently (Fritsche et al., 2005) and the isobaric hydrostatic mapping function (IMF) based on numerical weather data (Niell, 2000) was used (Vey et al., 2006). The phase center variations of satellite and receiver antennas were corrected using an absolute model (Schmid et al., 2007). The normal equation files obtained from this reprocessing contain homogeneous time series of all estimated parameters, such as satellite orbits, Earth rotation parameters, station coordinates and troposphere parameters from 1995 to 2006.

The homogeneous results, such as satellite orbits and Earth rotation parameters from the reprocessing project were used as input information for the processing of the Antarctic GPS network from 1995 to 2006. The modeling refinements were introduced in a similar way as for the global processing. On the normal equation level the regional solution of Antarctica was combined with the global solution in a way, that corresponding parameters of a specific station, such as station coordinates and troposphere parameters, are stacked. This leads to an optimum combination of both solutions.

The daily normal equation files obtained were combined and station coordinates and velocities were estimated. We considered discontinuities in the station coordinate time series which may be caused by hardware changes or tectonic events.

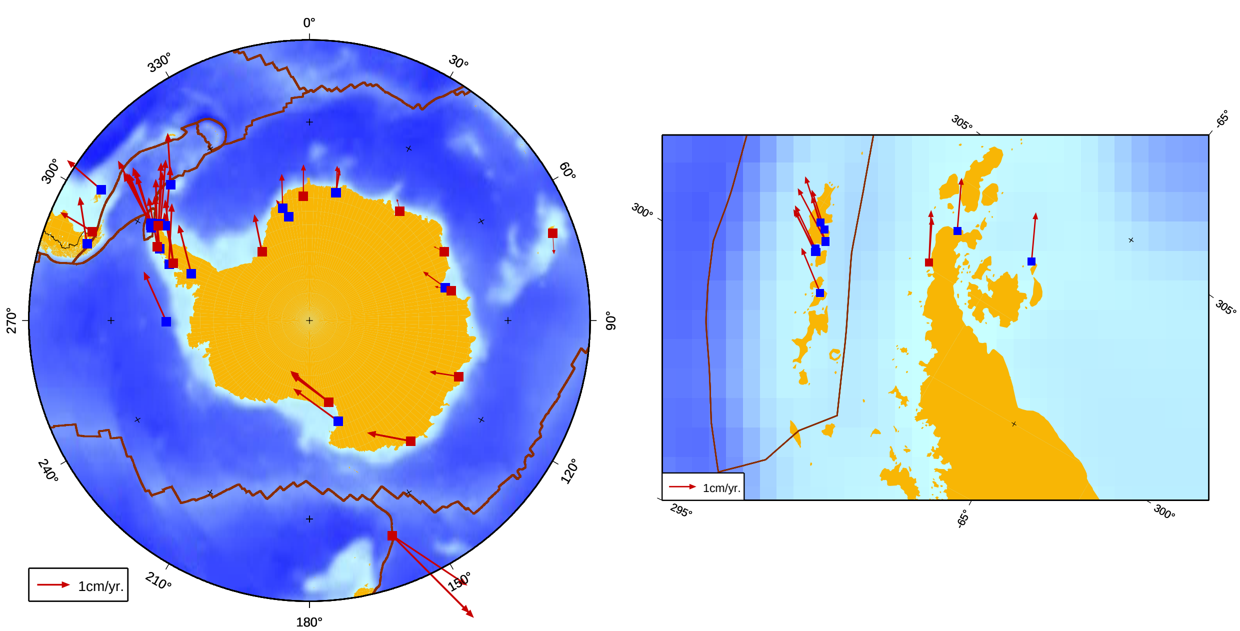

Figure 2. Horizontal station velocity field for Antarctica and in detail for the South Shetland Islands (right). The brown lines symbolize the plate boundaries (Bird, 2003).

Results

As the main result for all stations at least one set of coordinates at a specific epoch and one corresponding velocity vector with their validity intervals are obtained. The velocity field for Antarctica is shown in Figure 2. Using the station position $\mathbf{X}(t_0)$ at a specific epoch t_0 (e.g. 2000.0) and the velocity vector $\dot{\mathbf{X}}$ the station position at an epoch t can be computed with

$$\mathbf{X}(t) = \mathbf{X}(t_0) + (t - t_0)\dot{\mathbf{X}} \tag{1}$$

Thus, the obtained reference system realization can be used as a reference for a variety of practical and scientific applications. For evaluation the results are compared to existing realizations of the ITRS, such as ITRF2000 (Altamimi et al., 2002) and ITRF2005 (Altamimi et al., 2007).

The results can be used directly for geoscientific investigations, such as the estimation of plate rotation poles and the assessment of the stability of the Antarctic plate (Dietrich et al., 2004). Figure 3 shows spherical distance changes within the Antarctic Plate which illustrate that the observations confirm a coherent motion of the Antarctic Peninsula and East Antarctica with an accuracy of about 1 mm/yr. In contrast the South Shetland Islands are separating from the Antarctic Peninsula with about 7 mm/yr.

Over a period of more than 10 years, the reference frame obtained also provides reliable vertical station motions for Antarctica with an accuracy of a few mm/yr, which will help to evaluate vertical deformations by glacial isostatic models (Ivins and James, 2005).

Outlook

The SCAR GPS Campaigns represent an excellent basis for the IPY project POLENET. In the frame of POLENET a large number of GNSS stations in Antarctica will be established and existing stations will be reobserved. Thus, the POLENET project will densify the existing network, will improve the geodetic reference for Antarctica and will expand the potential of geoscientific interpretations.

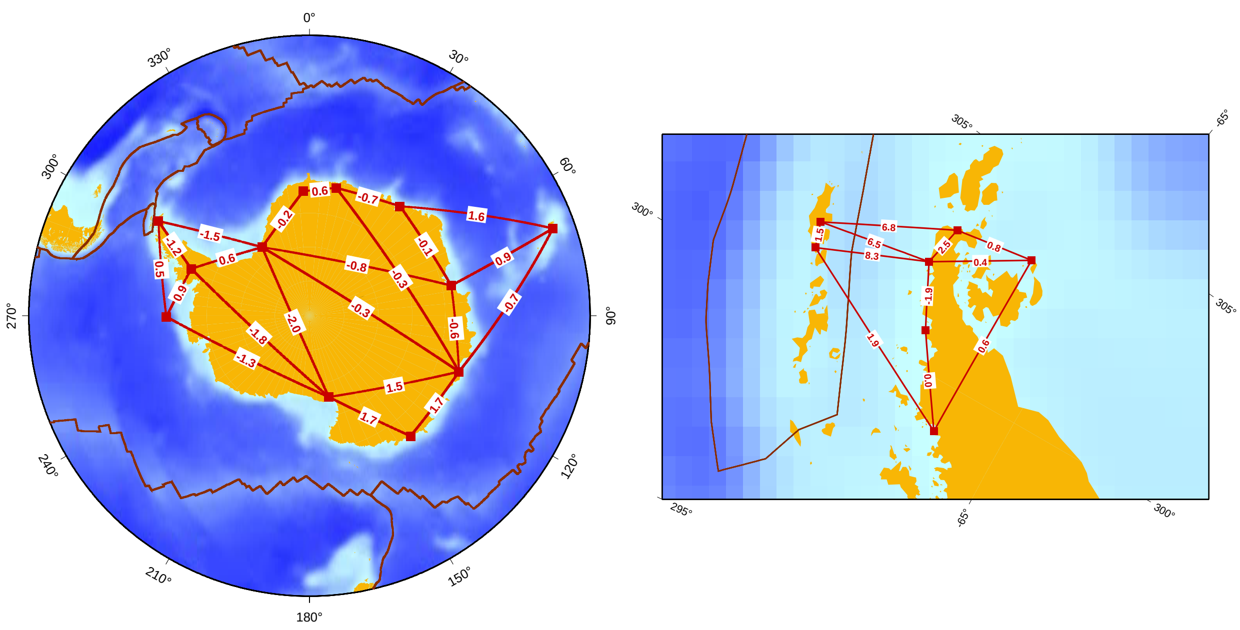

Figure 3. Changes of spherical distances within GPS stations in Antarctica in mm/yr. While the entire Antarctic Plate is rather stable, an opening of the Bransfield Strait with about 7 mm/yr could be observed.

Acknowledgments. We would like to thank all individuals and institutions who supported the field projects and provided observation data, in particular A. Zakrajsek, Argentina, J. Manning and G. Johnston, Australia, E. Simões de Fonseca Jr. and S. M. Alves Costa, Brazil, Bulgaria, C. Iturrieta and R. Barriga Vargas, Chile, E. Dongchen, China, C. Vigny, France, H.-W. Schenke and Daniel Schulte, Germany, E.C. Malaimani, India, A. Capra, Italy, K. Shibuya, Japan, T. Eiken, Norway, J. Cisak, Poland, A. Yuskewich, Russia, M. Berrocoso, Spain, E. Asenjo, Sweden, A. Fox, U.K., L. Hothem, USA, K. Tretyak and G. Milinevski, Ukraine, H. Rovera, Uruguay. Furthermore, we thank the SCAR Geoscience Standing Scientific Group which promoted the SCAR GPS Campaigns. The Drawings were made with the Generic Mapping Tools (GMT) (Wessel and Smith, 1991).

References

Altamimi, Z., Collilieux, X., Legrand, J., Garayt, B., and Boucher, C. (2007). ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth orientation parameters. J. Geophys. Res.. (submitted).

Altamimi, Z., Sillard, P., and Boucher, C. (2002). ITRF2000: A new release of the International Terrestrial Reference Frame for earth science applications. J. Geophys. Res., 107(B10). 2214, doi:10.1029/2001JB000561.

Bird, P. (2003). An updated digital model of plate boundaries. GGG, 4(3):1027, doi:10.1029/2001GC000252.

Dach, R., Hugentobler, U., Fridez, P., and Meindl, M., editors (2007). Bernese GPS Software Version 5.0. Astronomical Institute, University of Berne, Switzerland.

Dietrich, R., Rülke, A., Ihde, J., Lindner, K., Miller, H., Niemeier, W., Schenke, H.-W., and Seeber, G. (2004). Plate Kinematics and Deformation Status of the Antarctic Peninsula based on GPS. Glob. Planet. Change, 42:313–321.

Dow, J. M., Neilan, R. E., and Gendt, G. (2005). The International GPS Service (IGS): Celebrating the 10th Anniversary and Looking to the Next Decade. Adv. Space Res., 36(3):320–326. doi: 10.1016/j.asr.2005.05.125.

Fritsche, M., Dietrich, R., Knöfel, C., Rülke, A., Vey, S., Rothacher, M., and Steigenberger, P. (2005). Impact of higher-order ionospheric terms on GPS estimates. Geophys. Res. Lett., 32. L23311, doi:10.1029/2005GL024342.

Ivins, E. R. and James, T. S. (2005). Antarctic glacial isostatic adjustment: a new assessment. Ant. Science, 14(4):541–553, doi: 10.1017/S0954102005002968.

Niell, A. E. (2000). Improved atmospheric mapping functions for VLBI and GPS. Earth Planets Space, 52:699–702.

SCAR (2007). The SCAR GPS database. http://www.tu-dresden.de/ipg/service/scargps/database.html.

Schmid, R., Steigenberger, P., Gendt, G., Ge, M., and Rothacher, M. (2007). Generation of a consistent absolute phase center correction model for GPS receiver and satellite antennas. J. Geod.. doi: 10.1007/s00190-007-0148-y.

Steigenberger, P., Rothacher, M., Dietrich, R., Fritsche, M., Rülke, A., and Vey, S. (2006). Reprocessing of a global GPS network. J. Geophys. Res., 111. B05402, doi:10.1029/2005JB003747.

Vey, S., Dietrich, R., Fritsche, M., Rülke, A., Rothacher, M., and Steigenberger, P. (2006). Influence of mapping function parameters on global GPS network analyses: Comparisons between NMF and IMF. Geophys. Res. Lett., 33. L01814, doi:10.1029/2005GL024361.

Wessel, P. and Smith, W. H. F. (1991). Free software helps map and display data. EOS Trans., 72:441.