Tectonic deformation models for South Shetland Islands, Bransfield Strait and the Antarctic Peninsula from GPS surveys

M. Berrocoso, M. E. Ramírez, A. Fernández-Ros, A. Pérez-Peña, and J. M. Salamanca

Laboratorio de Astronomía, Geodesia y Cartografía. Departamento de Matemáticas. Facultad de Ciencias. Campus de Puerto Real. Universidad de Cádiz. 11510 Puerto Real (Cádiz-Andalucía). España (manuel.berrocoso@uca.es)

Summary The region defined by the South Shetlands Islands, the Bransfield Sea and the Antarctic Peninsula represents one of the most interesting geodynamic regions in Antarctica due to the convergence of several tectonic plates. Using GPS we present a tectonic displacement model for this region. The boundaries of some of these plates are still uncertain, especially those ones related to the plates bounding Deception Island Volcano. After the 1998 volcanic crisis on Deception Island, an extensional radial process was observed around the island. After this period, the displacement vectors for this island seem to migrate trending to the modulus and direction of the Antarctic Plate. These unexpected displacement patterns for Deception Island and the rest of the islands in the archipelago, has motivated the extension of the RGAE geodetic network. At present this network consists of 12 stations distributed along the South Shetland Archipelago and the Antarctic Peninsula.

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Introduction

The region defined by the South Shetland Archipelago, the Bransfield Sea and the Antarctic Peninsula is dynamically complex due to its tectonic configuration. In fact, some major plates converge, the Antarctic and the South American plates, and there area several minor plates that also interact: the Scotia, the Phoenix and the South Shetland plates (Figure 1).

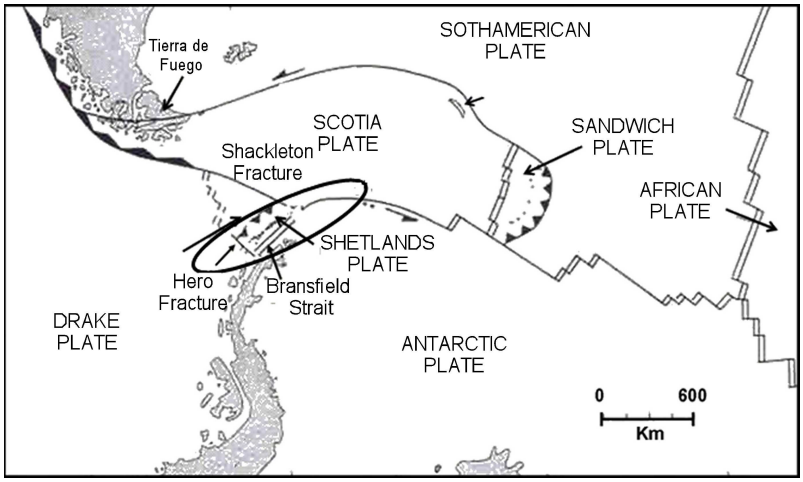

Figure 1. Geodynamical setttings of the South Shetland Islands and the Antarctic Peninsula.

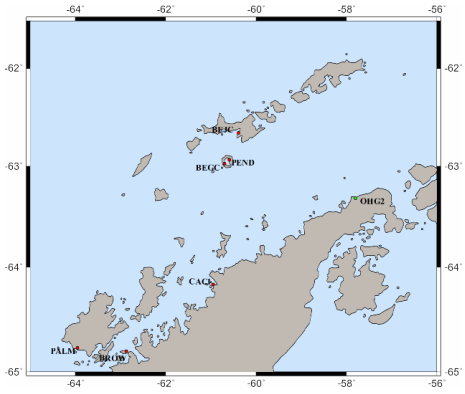

Figure 2. RGAE geodetic network until December 2006.

The seismicity for the Bransfield Strait is characterized for the present of shallow events, which reveals active subduction with back-arc expansion. The South Shetland microplate was originated by the opening of the Bransfield Rift. It is bounded by the Schackleton and Hero Fracture Zones to east and west, respectively, bounded by the Bransfield Trench to the north and by the Bransfield Rift to the south (González Ferrán, 1991). On the other hand, the volcanism of the area is associated to the spreading center of the Bransfield Basin, which is related to Deception, Penguin and Bridgeman islands as well as some submerge volcanic vents (Gracia et al., 1996).

The RGAE Spanish Antarctic Network was firstly surveyed during the 1987-88 Spanish Antarctic campaign. For that time it consisted just of two geodetic stations: BARG, near the Argentinean Base on Deception Island, and BEJC, near the Spanish Base Juan Carlos I on Livingston Island.

Although the first objectives of these observations were the establishment of a frame to reference other geophysical measurements and the update of the existing Cartography, they also provided an approach to the

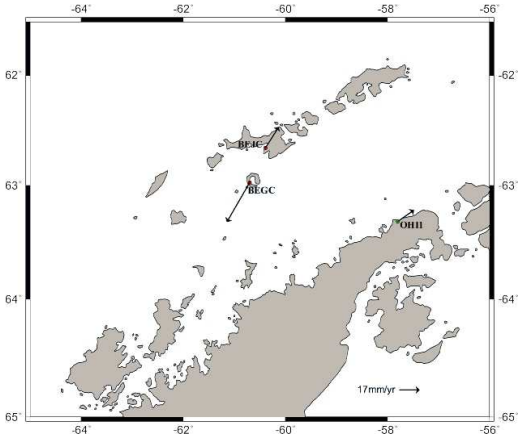

Figure 3. Displacements for the period 1995/96 to 1999/00

tectonic behaviour of the area (Berrocoso 1997). Through the years new stations have been added to the network. The distribution of the network up to December 2006 is shown in Figure 2.

On the other hand, several stations from the RGAE geodetic network have been considered in order to monitor the volcanic deformation and local displacements on Deception Island Volcano. In particular, during the last years two important seismic crises were detected on Deception Island, in December 1991 and December 1998, respectively. During this period, it was observed an extensional radial process in every geodetic station on the island. In fact, the deformation models for that period reflect that the volcanic crisis in 1888 forced the island not to follow the expected direction of the Bransfield Rift axis (Fernández-Ros 2006) as it is shown in Figure 3.

Data acquisition and processing

The data and results we present cover the period 1999/00 to 2004/05. Just the stations BEGC on Deception Island, BEJC on Livingston Island and the IGS geodetic station OHI2 at the Antarctic Peninsula were considered since the remaining stations in the network have not been surveyed during the last campaigns.

Data processing was made by using the BERNESE GPS Scientific Software v4.2 (Beutler et al. 2001), considering 24 hours sessions, a 10º elevation mask and a 30 s sampling rate. The basic options for the data processing are given in Table 1 and they have been decided according the special characteristics of the network.

Table 1. Data processing options

Ambiguity Fixing	In the final solution.
Antenna Phase Corrections	IGS Phase Center Variation files
Cut Off Angle	10°
Sampling Rate	180 sec for the final parameter estimation.
Orbits	IGS Final Orbits.
Earth Orientation Parameters	IGS final products
Mapping Function	Niell Model
Troposphere Parameters	Hourly

OHI2 IGS station was set as the fixed site in the processing. The displacement rates for the other stations between two epochs t_1 and t_2 are given by $\bar{x}_{t_2} = \bar{x}_{t1} + vt$, where t is the time between both epochs t_1 and t_2 in years.

Results

The obtained displacement models are illustrated in Figure 4. According to these models and the estimated values given in Table 2 for BEGC station on Deception Island, it can be observed how the displacements for the Deception Island trend in modulus and direction to the mean velocity of OHI2 IGS station at the Antarctic Peninsula. This fact suggests the different tectonic behaviour of Deception Island from Livingston Island, which follows the direction of the Bransfield Rift axis (Dietrich et al. 2001).

Table 2. Displacements for BEGC geodetic station at Deception Island

Campaigns	**cm**
1999/00 to 2001/02	5.17
2001/02 to 2002/03	4.07
2002/03 to 2003/04	2.22
2003/04 to 2004/05	2.07
2004/05 to 2005/06	1.89
Mean velocity for OHI2	1.79

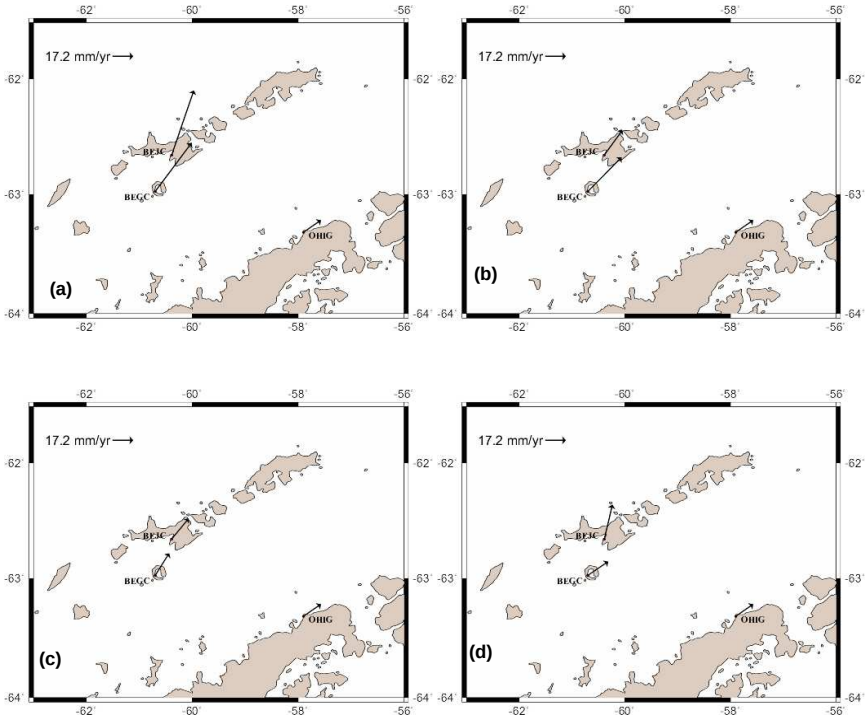

Figure 4. Estimated displacements for the periods: (a) 1999/00 to 2001/02; (b) 2001/02 to 2002/03; (c) 2002/03 to 2003/04; (d) 2003/04 to 2004/05.

In order to achieve a better understanding of this environment, in particular, the behaviour of the South Shetland Archipelago displacements and to define the limits of the active plates and fractures existing in this area, several stations have been included in the RGAE network during the last Spanish Antarctic campaign 2006/07. These new stations have been surveyed this year for the first time.

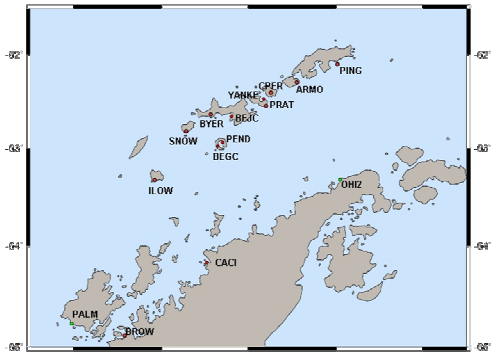

Figure 5. Distribution of the RGAE geodetic network

Nowadays the Spanish Antarctic network consists of the following stations, distributed along the South Shetland Archipelago and the Antarctic Peninsula (Figure 5): BEJC and BYER (Livingston Island), BEGC (Deception Island), ILOW (Low Island), SNOW (Snow Island), LUNA (Half Moon Island), PRAR and YANK (Greenwich Island), CPER (Robert Island), ARMO (Nelson Island), PING (Penguin Island), CACI (Cierva Cove, Antarctic Peninsula), ALBR (Antarctic Peninsula). Other stations are also considered as the ones at the O'Higgins Chilean Base and at the American Antarctic Base Palmer on Anvers Island.

Discussion

The results we have obtained after the processing of the GPS data from some of the stations of the RGAE Spanish geodetic network reveals that the displacements for Deception Island Volcano trends to the mean velocity of OHI2 IGS station at the Antarctic Peninsula. This suggest that the South Shetland Archipelago and in particular Deception Island behaviour is influenced by the interaction of the plates converging in the area and by the volcanic activity on the island. In fact, the estimated displacements from 1999/00 to 2004/05 campaign reveals a migration of the extensional radial process previously detected in the island, originated by the volcanic crisis in December 1998, to the displacement corresponding to the Antarctic Plate. These two different patterns motivated the extension of the geodetic network, which consists of twelve stations distributed along the South Shetland Islands and the Antarctic Peninsula. The surveying of these stations along the following campaigns will provide a deeper knowledge of the tectonic characteristic of the area and the bounds of the converging plates.

Summary

In this paper it is presented the last displacement models obtained from the GPS data processing of some of the stations from the Spanish Antarctic geodetic network, which was designed and established to monitor the tectonic behaviour of the area defined by the South Shetland Archipelago, the Bransfield Sea and the Antarctic Peninsula.

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