The King Edward Point Geodetic Observatory in Support of Sea Level Research

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Abstract

During February 2013 the King Edward Point (KEP) Geodetic Observatory was established in South Georgia, South Atlantic Ocean, through a University of Luxembourg funded research project and in collaboration with the United Kingdom's National Oceanography Centre, British Antarctic Survey and Unavco, Inc. Due to its remote location in the South Atlantic Ocean, as well as, being one of few subaerial exposures of the Scotia plate, South Georgia Island has been a key location for a number of global monitoring networks, e.g. seismic, geomagnetic and oceanic. However, no geodetic monitoring station has been established, e.g. by the International Global Navigation Satellite System (GNSS) Service (IGS) community, despite the lack of such observations from this region. In this study we give details of the establishment of the KEP Geodetic Observatory, i.e. the installation of the continuous GNSS station KEPA on Brown Mountain and the establishment of a new height datum for the tide gauge through a network of benchmarks at the KEP research station. We will present an evaluation of the GNSS positioning results for the period from February to August 2013 and of the survey/levelling work carried out for the height reference. We will discuss the installation in terms of its potential contributions to sea level observations using tide gauges and satellite altimetry, studies of tectonics, glacio-isostatic adjustment and atmospheric processes.

Introduction

During February 2013 the King Edward Point (KEP) Geodetic Observatory was established in South Georgia, South Atlantic Ocean (Figure 1). With its remote location, South Georgia is one of few remaining islands in the Southern Hemisphere, which can be employed to densify the global geodetic infrastructure and counteract the hemisphere imbalance in its terrestrial observations.
The primary objective of the observatory is to measure crustal movements close to the tide gauge (GLOSS No. 187) at KEP research station and to provide a stable, long-term vertical datum. It consists of the continuous GNSS station KEPA (DOMES No. 42701M001) with auxiliary equipment and networks of benchmarks at the installation site and the research station (Figure 2). This allows to geodetically link the GNSS station with the tide gauge and the other geophysical sensors.

The poster is organized as follows: "KEPA and Benchmarks" gives details of the installation of KEPA and of the tide gauge benchmark (TGBM) networks; "Postion Estimates" show the first positioning results for KEPA and compares these to 19 other stations using the same GNSS equipment; and "Vertical Datum" lists the reuslts from the spirit levelling and evaluates the existing chart datum and new height datum for the tide gauge.

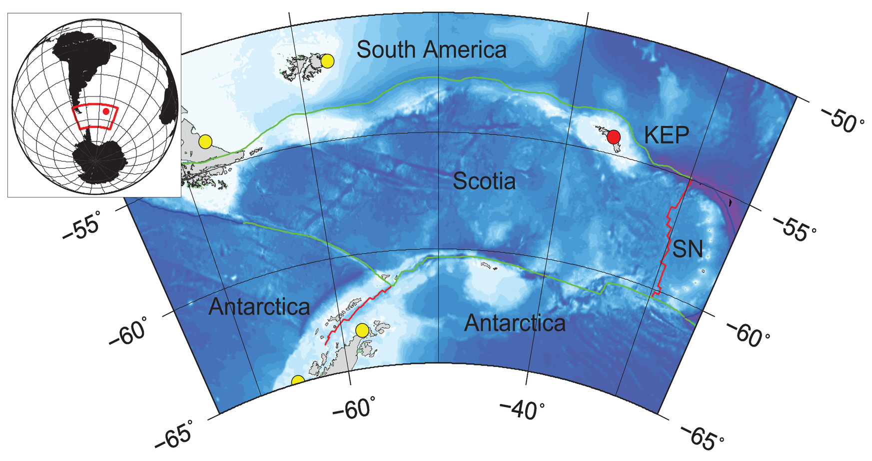

Figure 1: Location of King Edward Point (KEP) and tectonic plates in the South Atlantic Ocean (University of Texas at Austin): transforms/fracture zones (green), ridges (red) and trenches (blue); existing continuous GNSS stations (yellow circles) and KEP geodetic observatory (red circle); SN: the South Sandwich plate.

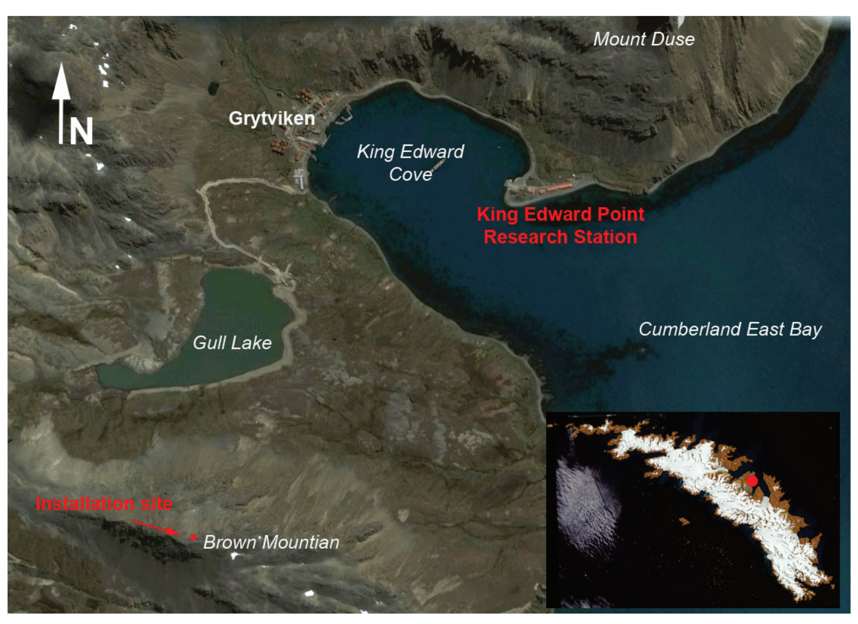

Figure 2: KEP research station surroundings with installation site on Brown Mountain. Inset shows South Georgia with the location of King Edward Cove (Image from Google Earth).

KEPA and Benchmarks

KEPA is located on the highest point (approximately 330 m altitude) of Brown Mountain, which lies south of KEP at a distance of 1.9 km. The location ensures that satellite signals are not obstructed by any of the mountains surrounding the research station. The GNSS antenna and monument are bolted onto a rock outcrop (Figure 3a) with an aluminium pipe frame housing the auxiliary equipment and enclosures approximately 30 m away (Figure 3b). The equipment includes the GNSS receiver, solar power and communication systems, as well as, the weather station (Table 1). The data from the weather station is fed into the GNSS receiver which merges it with its own observations. The data is retrieved daily via the satellite link of the research station and an Ethernet radio bridge to KEPA. The first positioning results for KEPA are shown in box "Position Estimates".

The UK Hydrographic Office maintains the local chart datum through four benchmarks located in Grytviken and the KEP research station. Figure 4 shows the locations of the official tide gauge benchmarks (TGBM) UKHO-HD-9798 and UKHO-ISTS-061 within the vicinity of KEP, as well as, the newly established ones which are numbered as KEPGO-KEP-001 to 004. All TGBMs, including the tide gauge (TG), were levelled and their height differences were derived with a precision of less than 1 mm. Following the installation of KEPA, GPS surveys of KEPGO-KEP-003 and UKHO-ISTS-061 established their ellipsoidal heights and using the geoid heights from EGM2008, orthometric heights were computed for these two TGBMs. The ellipsoidal and levelled height differences between UKHO-ISTS-061 and KEPGO-KEP-003 are -0.3045 m and -0.3053 m, respectively, and demonstrate the high level of consistency of the results. The box "Vertical Datum" provides the results for the TGBMs and evaluates the different references.

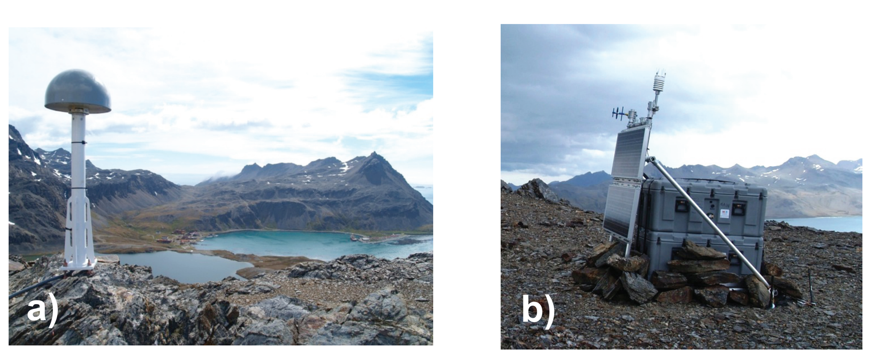

Figure 3: a) GNSS antenna on 1-metre mast. b) aluminium pipe frame with electronics and auxiliary equipment.

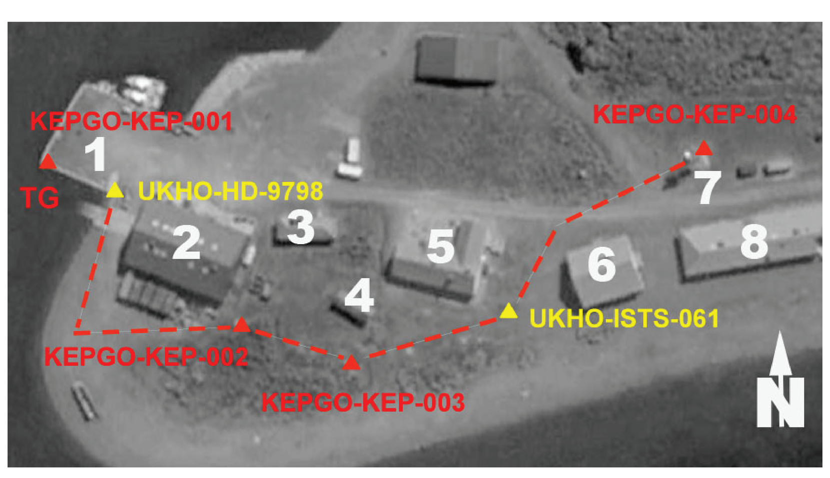

Figure 4: Network of TGBM at KEP research station. Existing TGBM (UKHO- HD-9798 and UKHO-ISTS-061) are in yellow and new TGBM (KEPGO-KEP-001 to KEPGO-KEP-004) in red. Dashed line shows the path of levelling work carried out during February 2013: from the tide gauge on the jetty (1) past the boatshed (2), over the grass area south to the food (3) and coal (4) stores, between Discovery House (5) and Carse House (6) and to the satellite tower (7).

Table 1: KEPA equipment details.

GNSS Equipment	
Receiver	Trimble NetR9
Antenna/Radome	Trimble Choke Ring TRM59800.00 SCIS
12V DC Power System	
Solar Panels	2x 80 Watts
Batteries	20x Deka Solar photovoltaic lead-gel
Communications	
Radio link	Intuicom EB-1 900 MHz Ethernet radio bridge
Satellite link	VSAT communication link @ KEP
Other Sensors	
Weather station	Vaisala WXT-520

Position Estimates

Using 19 global GNSS stations and KEPA we obtained daily position estimates applying the Bernese GNSS Software v 5.2 in precise point positioning (PPP) mode. We used the final satellite orbit and clock, as well as, the Earth rotation products from the IGS analysis centre CODE, which are also based on the Bernese GNSS software. This avoids effects arising from the use of different software and model implementations during product generation and user application in PPP. Figure 5 shows the KEPA position time series for the first six months and Table 2 summarizes the results obtained.

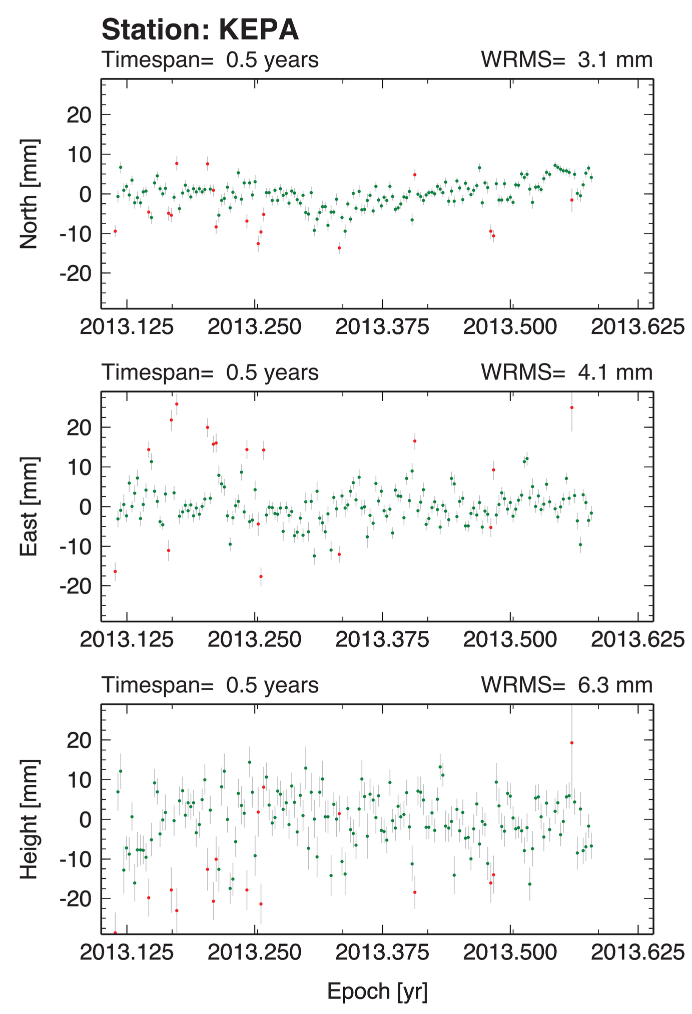

Figure 5: PPP position time series for KEPA for the period from 14 February to 14 August 2013. Position outliers are indicated by the red circles and uncertainties are three times the daily standard error from the GPS processing.

Table 2: WRMS statistics for KEPA and 19 other stations for the North, East and Up position components in time series for the period of 14 February to 14 August 2013. The uncertainties of the mean WRMS values are the standard deviations. All values are in mm.

	North	East	Up
19 stations	1.7 ± 0.5	2.8 ± 0.8	5.3 ± 1.5
KEPA	3.1	4.1	6.3

From Figure 5 and Table 2 it can be seen that the position time series for KEPA show a larger than average scatter for the North and East components (1-σ level) as indicated by the weighted root mean square (WRMS) values. The larger scatter is attributed to multipath effects at the site. The source for these have been identified as the rock surface shown in the foreground at the right-hand side of Figure 3a. Ways to reduce the impact of the multipath on the position estimates are being investigated.

Vertical Datum

Table 3 shows the adjusted heights for the TG and all TGBMs with respect to the UKHO chart datum as defined by the heights of UKHO-HD- 9798 and UKHO-ISTS-061. By introducing both official UKHO TGBM height values the adjusted heights differ by -0.0403 m, which may reflected the accuracy of these or are an indication of instabilities. Assuming that the official TGBM heights are correct to the given centimetre, then this would indicate some instability in these benchmarks. The local inspection and the levelling observations would indeed support the assumption of subsidence of UKHO-HD-9798 by about 4 cm since 2003.
Using the orthometric heights of 2.0151m for UKHO-ISTS-061 and 1.7061m for KEPGO-KEP-003 as references for two alternative datum definitions, new heights for the TG and other TGBMs can be derived. Table 4 shows these with respect to the two possible height datums. The difference in the heights between the two sets is 4 mm, reflecting largley the difference in their EGM2008 information and not their ellipsoidal heights. As the GPS observations at UKHO-ISTS-061 were taken over a longer period than on KEPGO-KEP-003 preference is given to the datum defined by this TGBM using the new observations. This analysis also suggests a datum shift of over 1 m between the UKHO chart datum for South Georgia and this newly established datum.

Table 3: Adjusted heights for TG and TGBMs with respect to UKHO chart datum, i.e. UKHO-HD-9798 with a height of 1.34 m and UKHO-ISTS-061 with a height of 3.03 m. All values are in m.

Benchmark	Height (UKHO-HD-9798)	Height (UKHO-ISTS-061)
UKHO-HD-9798	1.34	1.2997
UKHO-ISTS-061	3.0703	3.03
TG	0.6496	0.6093
KEPGO-KEP-001	1.3165	1.2762
KEPGO-KEP-002	2.8095	2.7692
KEPGO-KEP-003	2.7653	2.7250
KEPGO-KEP-004	3.7546	3.7143

Table 4: TG and TGBM heights with respect to KEPGO height datum, i.e. UKHO-ISTS-061 with a height of 2.0151m and KEPGO-KEP-003 with a height of 1.7061 m. All values are in m.

Benchmark	Height (UKHO-ISTS-061)	Height (KEPGO-KEP-003)
UKHO-HD-9798	0.2848	0.2808
UKHO-ISTS-061	2.0151	2.0111
TG	-0.4056	-0.4096
KEPGO-KEP-001	0.2613	0.2573
KEPGO-KEP-002	1.7543	1.7503
KEPGO-KEP-003	1.7101	1.7061
KEPGO-KEP-004	2.6994	2.6954

Discussion and Conclusions

The KEP Geodetic Observatory is located in the geodetically under-sampled South Atlantic Ocean. Considering this and the general hemisphere imbalance in geodetic networks, the KEPA GNSS station has the potential to make an important contribution to the international terrestrial reference frame as well as studies in various fields of the geosciences. The primary objective is to measure crustal movements close to the the KEP tide gauge and to provide a stable, long-term vertical datum for sea level studies using the tide gauge and satellite altimeters.
South Georgia lies south of the plate boundary between the Scotia and the South American plates. The tectonic processes active are believed to tilt South Georgia Island and its continental shelf. It is believed that large parts of this shelf were covered by ice during the Last Glacial Maximum. Hence, a small viscoelastic response due to glacial-isostatic adjustment cannot be ruled out. It is clear that these processes may impact on the stability of the tide gauge and its observations.
We have presented the new continuous GNSS station and provided an initial evaluation of six months of position estimates. The comparative analysis of these with information from 19 other GNSS stations indicates a larger than average scatter in the daily solutions, which has been attributed to local multipath. Further tests will show to which extent more precise network solutions improve the position time series and how the multipath effects can be reduced.
Using GPS survey and precise spirit levelling data collected during the visit, the existing UKHO chart datum was investigated and a datum for the tide gauge was obtained. The measurements indicate possible instabilities in the UKHO TGBMs and a datum shift of over 1 m between the official chart datum and the new one. The high consistency in the results obtained by this study provide an important step towards establishing a stable, long-term height reference for the tide gauge. Only future repeat surveys will provide a better picture of the stability of the tide gauge and of the benchmarks.

Acknowledgements

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Further Information

Teferle, F. N. (2013), The King Edward Point Geodetic Observatory, Technical Report, University of Luxembourg, pp51. Available at: http://hdl.handle.net/10993/5520.

This poster can be downloaded here:

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