Recent Activities at the King Edward Point Geodetic Observatory, South Georgia, in Support of TIGA Objectives

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Abstract

In 2013 the King Edward Point (KEP) Geodetic Observatory was established in South Georgia, Southern Atlantic, in support of geoscience applications. South Georgia Island has been a key location for the seismic, geomagnetic and oceanic global monitoring networks. However, no geodetic permanent monitoring station had been established there despite the lack of observations from this region within the International GNSS Service (IGS) network of Global Navigation Satellite System (GNSS) stations. Currently, the observatory consists of two state-of-the-art GNSS stations (KEPA 42701M001 and KRSA 42702M001) with local benchmark networks, allowing the height determinations from the GNSS antennas to be transferred to the tide gauge (Global Sea Level Observing System 187) and forming a height reference within the International Terrestrial Reference Frame.
In this study, we will present an evaluation of the GNSS observations from the KEP Geodetic Observatory for the period from February 2013 to December 2013. We calculate multipath and positioning statistics and compare these to those from IGS stations. We report on the benchmark network and tide board installation, as well as, on the results from the two levelling campaigns carried out to date. For the future it is envisaged that the stations will contribute to the TIGA objective of monitoring vertical land movements at tide gauges, and that KEPA will contribute to the IGS network.

Introduction

During February 2013 and March 2014 the King Edward Point (KEP) Geodetic Observatory was established in South Georgia, South Atlantic Ocean (Figure 1) and additional surveys were carried out. With its remote location, South Georgia is one of few islands in the Southern Hemisphere, which can be employed to densify the global geodetic infrastructure and counteract the hemisphere imbalance in its observations (Figure 2).
The primary objective of the observatory is to measure crustal movements close to the tide gauge at KEP (Global Sea Level Observing System 187) and to provide a long-term vertical datum. It consists of two continuous GNSS stations KEPA (DOMES 42701M001) and KRSA (DOMES 42702M001) with local benchmark networks to geo-reference the tide gauge to the International Terrestrial Reference Frame (Figure 3). Noteworthy is that the Scientific Commitee of Antarctic Research (SCAR) established the campaign GPS station GRY1 near KEP research station and observed it for two days during 1998 [Dietrich et al., 2001].
As there is an incomplete understanding of the tectonics and potential glacio-isostatic adjustment of South Georgia and the associated continental shelf [e.g. Smalley, et al. 2007], the KEP Geodetic Observatory will also benefit studies on these regional processes (Figure 1). After the November 17, 2013 M_W 7.8 South Scotia Ridge earthquake, KEPA 1Hz data was applied to the seismological interpretation of the earthquake sequence [Ye et al., 2014]. Furthermore, the GNSS data can be applied to monitoring the ionosphere and the water vapour content of the troposphere [Teferle et al., 2014].

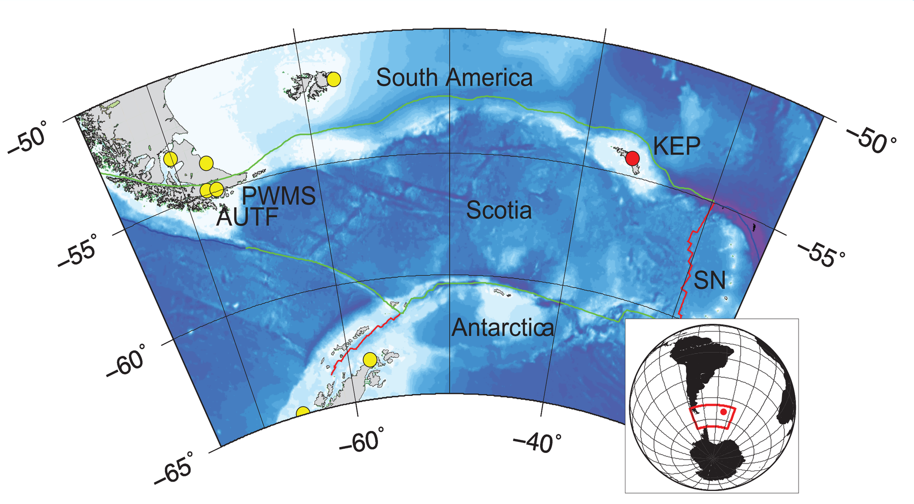

Figure 1: Location of King Edward Point (KEP) and tectonic plates in the South Atlantic Ocean (University of Texas at Austin): transforms/fracture zones (green), ridges (red) and trenches (blue); existing continuous GNSS stations (yellow circles) and KEP geodetic observatory (red circle); SN: the South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

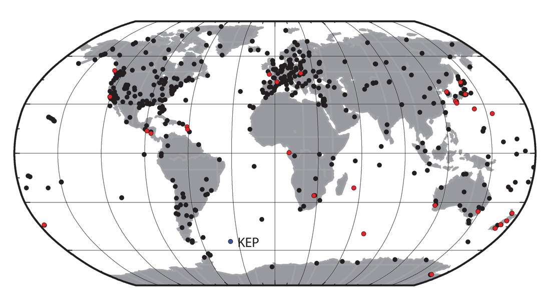

Figure 2: Global network of International GNSS Service (IGS) stations contributing to ITRF2008, (black dots), stations using a Trimble NetR9 receiver (red dots) and KEP.

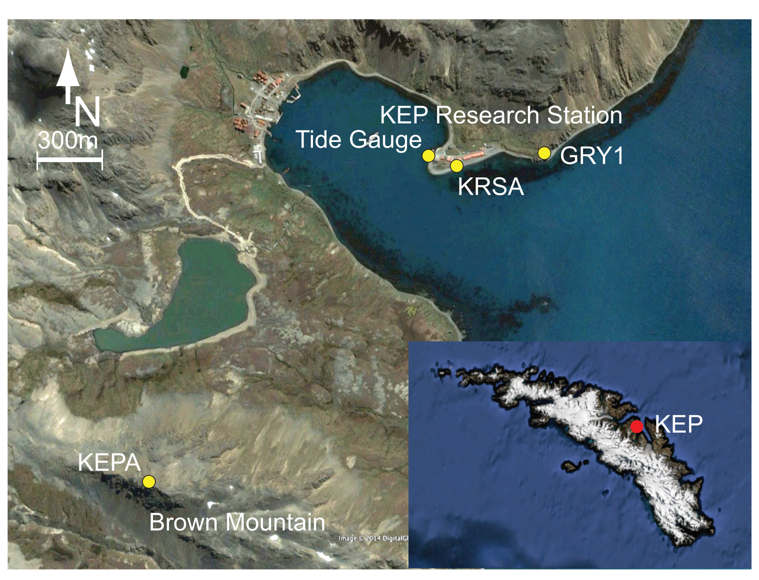

Figure 3: Map of surroundings of KEP Research Station. Locations of KEPA and KRSA continuous, and GRY1 SCAR campaign GNSS stations, and of the tide gauge. Imagery from Google Earth.

GNSS Installations

KEPA, the primary GNSS station, is located on the highest point of Brown Mountain (320 m), which lies southwest of KEP (Figure 3). This ensures a clear horizon for the GNSS measurements in the extremely mountainous (up to 3000 m) surroundings. The antenna and 1-m mast are bolted onto a rock outcrop (Figure 4a) with an aluminium pipe frame housing the auxiliary equipment and enclosures approximately 30 m away (Figure4b).
KRSA, the secondary station, is located at KEP Research Station close to the tide gauge and other sensors (the geomagnetic and seismological stations - not shown) (Figure 3). Its purpose is to monitor relative motions between KEPA and the research station which is located on gravel deposits. Being located at sea level KRSA suffers from large sky obstructions to the northeast from Mt Duse (670 m). The antenna is mounted on a 1.5-m mast, which it bolted onto a 1-m concrete pillar (Figures 5a and 5b). Although the pillar is purpose-built, it sits on 1x1 m concrete foundations which has supported other instrumentation in the past and has therefore been assumed to be “as stable as it gets”, considering the lack of bedrock. The receiver and electronics are housed in a Pelican case directly at the station. Further details on both GNSS stations are in Table 1.

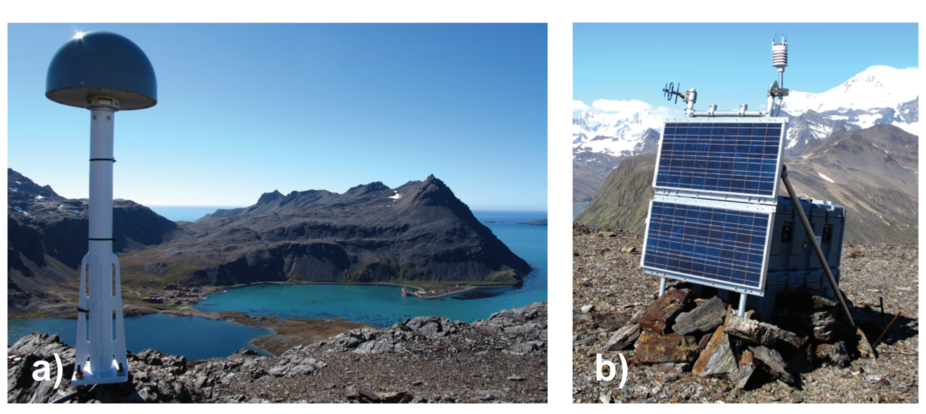

Figure 4: a) KEPA GNSS antenna on 1-m mast with view northeast towards KEP Research Station and Mt Duse; b) KEPA aluminium pipe frame with electronics and auxiliary equipment.

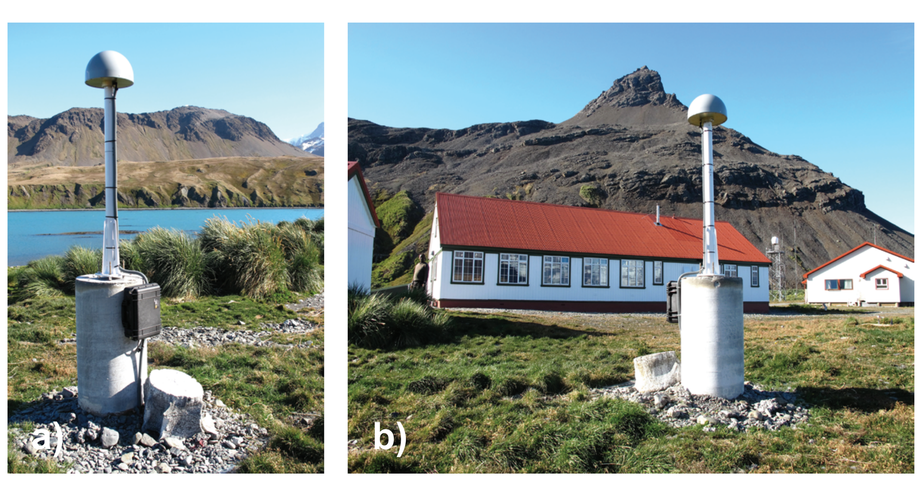

Figure 5: a) KRSA GNSS antenna on 1.5-m mast, concrete pillar and equipment case with view southwest towards Brown Mountain; d) KRSA station with view northeast towards Mt Duse.

	KEPA (DOMES 42701M001)	KRSA (DOMES 42702M001)
GNSS Equipment	Trimble NetR9 Trimble Choke Ring TRM59800.00 SCIS Robot antenna calibration by NGS, USA	Trimble NetR9 Trimble Choke Ring TRM59800.00 SCIS Robot antenna calibration by Geo++, Germany
GNSS Data/Archive	1s and 15s GPS, GLONASS, Galileo and BDS daily download, Unavco Inc., TIGA	1s and 15s GPS, GLONASS, Galileo and BDS hourly download, University of Luxembourg
Power System	12V DC from 2 solar panels with 80 Watts 20x deep-cycle lead-gel batteries	27 V DC from mains power at research station RCV internal battery is used as UPS
Communications	Intuicom EB-1 900 MHz Ethernet radio bridge Uptime: 5 hours on/off VSAT communication link @ KEP	Phoenix Contact DSL/Ethernet link Uptime: permanent VSAT communication link @ KEP
Weather Sensor	Vaisala WXT-520 weather station (dedicated)	KEP Automatic Weather Station

Table 1: Equipment details for continuous GNSS stations KEPA and KRSA.

KEPA Data Quality and Position Estimates

Using Teqc [Estey & Meertens, 1999] the data quality for KEPA has been evaluated for the period 14 February 2013 to 31 December 2013 and compared to 27 IGS stations using Trimble NetR9 receivers (Figure 2) and two sites installed and operated by Unavco Inc. in Antarctica, which use the same receiver and the same 1-m antenna mast as KEPA. Figure 6 shows the MP1 and MP2, as well as the cycle-slips per 1000 observations time series for KEPA and the 29 other stations.
Using 17 IGS stations, the two Unavco sites, and KEPA daily position estimates were obtained using the Bernese GNSS Software v 5.2 in precise point positioning (PPP) mode. We use the final satellite orbit and clock, as well as the Earth rotation products from the IGS analysis centre CODE. Figure 7 shows the position time series for KEPA and Table 2 compares the WRMS of the position residuals of all 20 stations. Further details of the analysis can be found in Teferle et al. [2014].

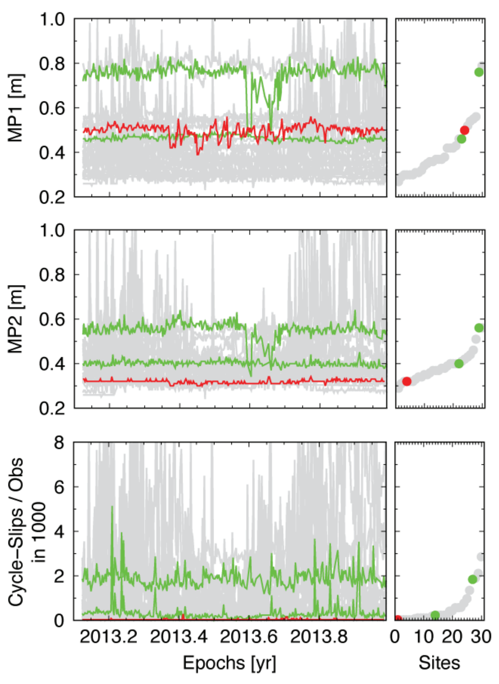

Figure 6: Time series and cumulative distributions of MP1, MP2 and slips per observations in 1000 for 30 stations using a Trimble NetR9 receiver for 14 February to 31 December 2013. Shown are IGS stations (grey colour), Unavco sites (green colour) and KEPA (red colour).

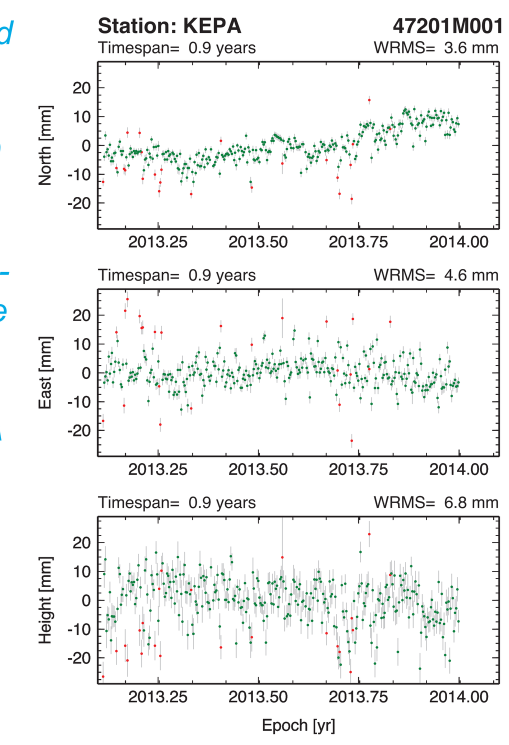

Figure 7: PPP position time series for KEPA for 14 February to 31 December 2013. Position outliers are indicated by the red circles and uncertainties are three times the daily standard error from the GPS processing.

Table 2: Mean WRMS statistics and standard deviations for KEPA and 19 other stations for 14 February to 31 December 2013. All values are in mm.

	North	East	Up
19 stations	2.1 ± 0.5	3.2 ± 0.9	6.1 ± 1.5
KEPA	3.6	4.6	6.8

Table 2 indicates that the position time series for KEPA show larger than average WRMS values which is attributed to the apparent multipath effects at KEPA. A preliminary double-difference solution seems to be less affected by the multipath.

Benchmark Networks and Levelling Results

Two benchmark networks were installed: one at KEPA on Brown Mountain and a second one at KEP Research Station. The KEPA network provides a precise reference of the current GNSS antenna ARP in case the monument should get damaged or destroyed (not discussed further). The network at KEP Research Station provides the height connection of the KRSA antenna ARP to the tide gauge as well as allows stability monitoring of the KRSA monument and of the whole area. Figure 8 shows this benchmark network which incorporates two benchmarks used by the United Kingdom Hydrographic Office (UKHO).

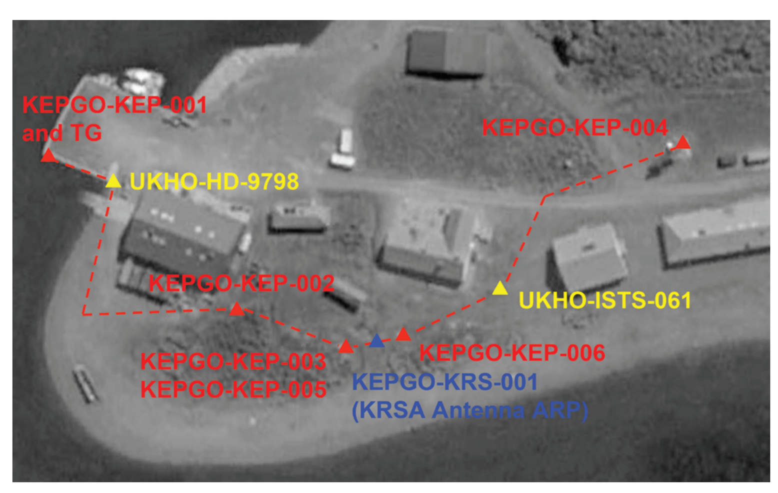

Figure 8: Benchmark network at KEP Research Station: tide gauge (TG) and KEP Geodetic Observatory (red), KRSA antenna and monument (blue) and UKHO (yellow). UKHO-ISTS-061 is the International Satellite Tracking Station Number 061 and was established in 1967/68.There are five benchmarks at the KRSA antenna and monument, only the one for the antenna ARP is shown. Imagery from Google Earth.

Table 3 and Figure 9 indicate that the areas not adjacent to the jetty have been stable to within 3 mm from 2013 to 2014, whereas the benchmarks on the jetty and tide gauge indicate subsidence in the range of 7-9 mm over the same period.

Table 3: Levelling results for benchmarks observed during the 2013 and 2014 campaigns. The analysis assumes that KEPGO-KEP-004 has been stable over the previous year and its height has been computed to be 3.76 m using KEPA and additional campaign GPS observations in 2013, 2013 levelling data and EGM2008 Geoid separations. Uncertainties are 1-σ.

	Distance [m] from	Campaign 2013		Campaign 2014		Difference (2014-2013)	
Benchmark	KEPGO-KEP-004	Height [m]	SD [m]	Height [m]	SD [m]	Height [m]	SD [m]
KEPGO-KEP-004	0	3.7600		3.7600		0.0000	
UKHO-ISTS-061	68	3.0757	0.0003	3.0749	0.0001	-0.0008	0.0003
KEPGO-KEP-003	140	2.7704	0.0006	2.7676	0.0002	-0.0027	0.0007
KEPGO-KEP-002	174	2.8145	0.0007	2.8124	0.0002	-0.0022	0.0007
UKHO-HD-9798	205	1.3465	0.0010	1.3396	0.0003	-0.0069	0.0010
KEPGO-KEP-001	235	1.3229	0.0012	1.3154	0.0003	-0.0075	0.0012
TG	235	0.6560	0.0012	0.6469	0.0005	-0.0091	0.0013

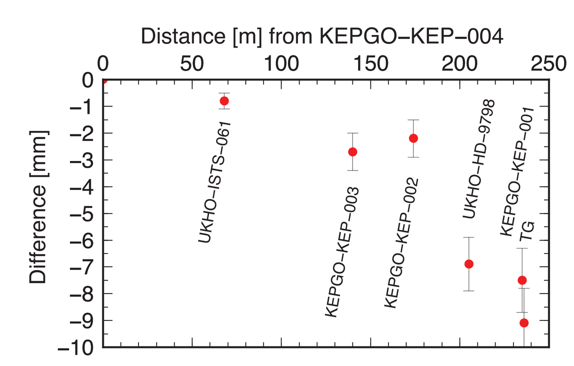

Figure 9: Height differences for benchmarks observed during the 2013 and 2014 levelling campaigns. Analysis assumes KEPGO-KEP-004 has been stable over the previous year. Uncertainties are 1-σ.

Conclusions

The new King Edward Point Geodetic Observatory and its continuous GNSS stations KEPA and KRSA have been introduced and an initial evaluation of KEPA has been performed. Teqc data quality metrics indicate a high level of L1 code-multipath whereas L2 code-multipath and the number of cycle slips per observations are very low. The initial position estimates from precise point positioning indicate a larger than average scatter in the daily solutions which has been attributed to the apparent multipath. Future investigations will show to which extent more precise network solutions can improve the position time series or whether modifications at the station are required.
The benchmark network at KEP Research Station was introduced. It geo-references the tide gauge via the GNSS stations to the International Terrestrial Reference Frame and allows precise stability monitoring. The leveling campaigns in 2013 and 2014 indicate that 7-9 mm of subsidence may have occurred at the jetty and tide gauge over the last year. This indicates that regular precise leveling campaigns are required. The KEP Geodetic Observatory is located in the geodetically under-sampled South Atlantic Ocean. Considering this and the hemisphere imbalance in geodetic networks, the GNSS stations have the potential to make an important contribution to future sea level and other geophysical studies as well as the IGS and the International Terrestrial Reference Frame.

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References

Dietrich R. et al. (2001): ITRF coordinates and plate velocities from repeated GPS campaigns in Antarctica – an analysis based on different individual solutions. J Geodesy 74(11-12): 756-766.
Dow et al. (2009): The International GNSS Service in a changing landscape of Global Navigation Satellite Systems. J Geodesy 83:191-198.
Estey, L. H. and C. M. Meertens (1999). TEQC: The Multi-Purpose Toolkit for GPS/GLONASS Data. GPS Solutions 3(1): 42-49.
Smalley, R., Jr., et al. (2007): Scotia arc kinematics from GPS geodesy. Geophysical Research Letters, 34: L21308.
Teferle F. N. et al. (2014): The King Edward Point Geodetic Observatory, South Georgia, South Atlantic Ocean: A First Evaluation and Potential Contributions to Geosciences. IAG Symposia, in press. Download at: http://hdl.handle.net/10993/17029
Ye L. et al. (2014): Complementary slip distributions of the August 4, 2003 Mw 7.6 and November 17, 2013 Mw 7.8 South Scotia Ridge earthquakes. Earth and Planetary Science Letters, in press.

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