Installation and First Evaluation of the King Edward Point Geodetic Observatory, South Georgia

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Abstract

During February 2013 the King Edward Point (KEP) Geodetic Observatory was established in South Georgia through a University of Luxembourg funded research project in collaboration with the National Oceanography Centre and the British Antarctic Survey. 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 has been a key location for a number of global monitoring networks, e.g. seismic, magnetic and oceanic. However, no geodetic monitoring station had been established previously despite the global network of Global Navigation Satellite System (GNSS) stations is lacking observations from this region.

In this presentation we will present a first evaluation of the observations from the KEP Geodetic Observatory for the period from 14 February to 14 April 2013. We calculate multipath characteristics and positioning statistics from precise point positioning (PPP) and discuss the installation in terms of benefits for studies of tectonics and glacio-isostatic adjustment processes. The meteorological data is evaluated by comparison to the data from the existing KEP meteorological station and a widely used numerical weather model.

Introduction

Over the last two decades information from geology, geophysics, seismology and satellite altimetry has lead to a good understanding of the tectonic evolution of the Scotia Sea [e.g. Barker, 2001]. It is believed that the northern edge of the Scotia plate forms a left lateral transform with the South American plate, which has a transform rate of approximately 7 mm/yr [e.g. Thomas et al, 2003]. However, due to a lack of subaerial exposure, the Scotia and South Sandwich tectonic plates have remained geodetically under-sampled (Figure 1). Hence, to this day there is an incomplete understanding of the tectonics and potential glacio-isostatic adjustment of South Georgia and the associated shelf areas including that of Shag Rock [Smalley, et al. 2007].

The new King Edward Point (KEP) Geodetic Observatory aims at filling this gap for regional studies but also globally for sea level studies and the International Terrestrial Reference Frame (ITRF) (Figure 2). The observatory consists of the continuous GNSS station KEPA with auxiliary equipment for power, communications and meteorology (Table 1). It includes a network of benchmarks both at KEPA and KEP, allowing to geodetically link the GNSS station with other geophysical sensors, in particular the tide gauge.KEPA is located on the highest point of Brown Mountain, which lies south of KEP research station across King Edward Cove. 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 (Figure3b).

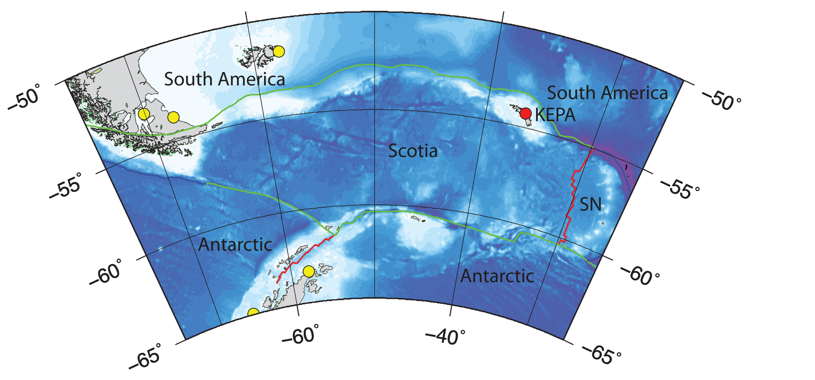

Figure 1: Tectonic plates in the South Atlantic Ocean (Plate Project, Institute of Geophysics, University of Texas at Austin): transforms/fracture zones (green), ridges (red) and trenches (blue); existing continuous GNSS stations (yellow circles) and KEP geodetic observatory (red circle); SN: the South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

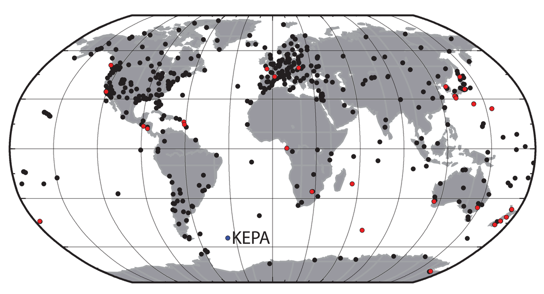

Figure 2: Global network of International GNSS Service (IGS) stations contributing to ITRF2008, (black dots), stations using a Trimble NetR9 receiver (red dots) and KEPA.

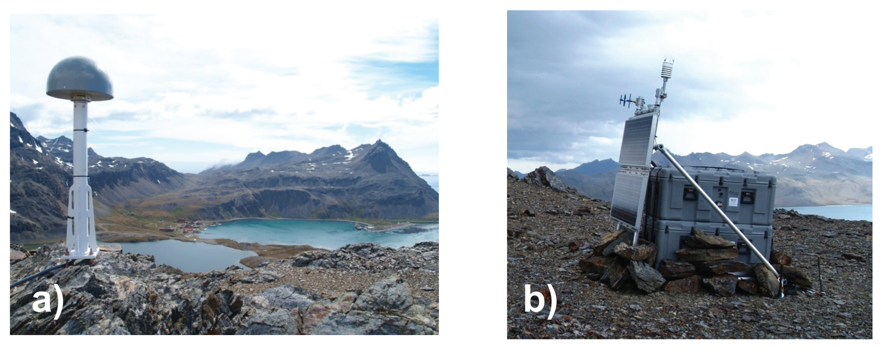

Figure 3: a) GNSS antenna on 1-metre mast. b) aluminium pipe frame with electronics and auxiliary equipment.

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

KEPA Data Quality

The standard tool within the IGS for the analysis of GNSS data quality is Teqc [Estey & Meertens, 1999]. Teqc allows the computation of a number of quality control metrics of which the most important ones include code-multipath on L1 and L2, denoted as MP1 and MP2, and the number of observations per cycle slips. The latter ratio can be expressed in terms of cycle slips per observations in 1000, leading to a number close to zero for the optimal case. Estey & Meertens [1999] describe the computation of the MP1 and MP2 metrics in detail and here we use the root-mean-square value after fitting a moving average to the absolute multipath values.

The computed MP1 and MP2 metrics only partly reflect the multipath environment at a particular site as their values also dependent on the stability of receiver clocks and any receiver observation filtering. Hence, using a highly stable external atomic clock, generally reduces the multipath metrics. Also, within the IGS data providers are encouraged to disable any receiver observation filtering. For this reason we assume that none of the data used in this study have been filtered. Currently Trimble NetR9 receivers operate at 27 stations within the global IGS tracking network (Figure 2). Furthermore, CON2 and PHIG, two sites installed and operated by Unavco Inc., use the same receiver and the same 1-metre antenna mast as KEPA. All available data from these sites have been used in this study for the period from 14 February to 14 April 2013.

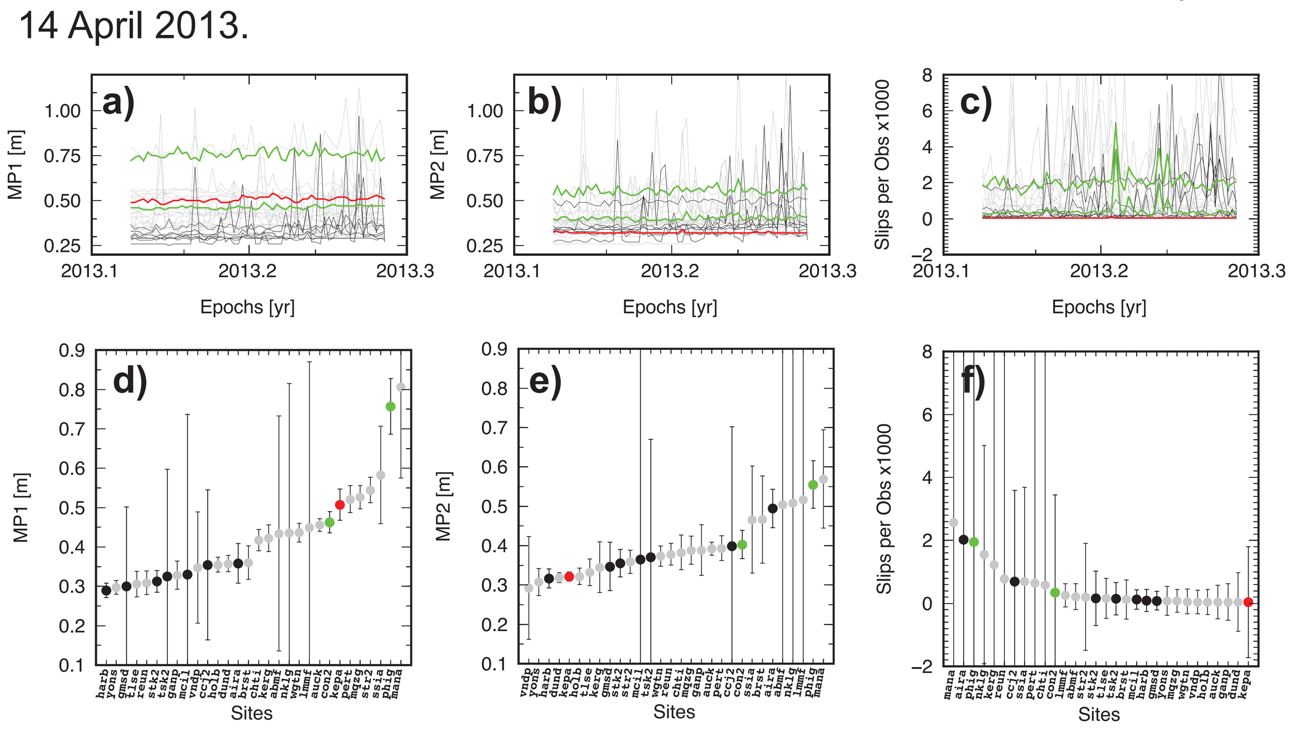

Figure 4: Time series (a-c) and statistics (d-f) of quality control metrics MP1, MP2 and slips per observations in 1000 for 30 stations using a Trimble NetR9 receiver for the period 14 February to 14 April 2013. Shown are IGS stations using internal receiver clocks (grey colour) and external atomic clocks (black colour), CON2 and PHIG (green colour) and KEPA (red colour). The statistics presented are the mean values and their uncertainty is three times the standard deviation.

From Figure 4 it can be seen that the KEPA data quality as indicated by the three metrics varies. Whereas the mean MP1 value for KEPA is one of the highest, its mean MP2 value is among the lowest. Although at different levels, both appear to remain fairly constant over the two-month period and show not spikes, which does not hold true for most other sites. It can also be seen that, as expected, the metrics for sites using external frequency standards are generally lower. The metrics for CON2 and PHIG indicate large amounts of multipath, which might be attributed to the 1-metre mast used at these two sites and KEPA. Using the cycle slips per observations in 1000 metric KEPA outperforms all other stations, confirming the undisturbed environment of KEPA on top of Brown Mountain.

Position Estimates

Using 17 IGS stations, CON2 and PHIG, and KEPA daily position estimates were obtained using the Bernese GNSS Software v 5.2 in precise point positioning (PPP) mode [Teferle et al., 2007]. We use the final satellite orbit and clock as well as the Earth rotation products from the IGS COD analysis centre, which are also based on the Bernese GNSS software, avoiding effects arising from the use of different software and model implementations during product generation and user application in PPP. In order to investigate the multipath effects on the position estimates three processing streams were applied using elevation cut off angles of 3, 10 and 15 degrees, respectively.

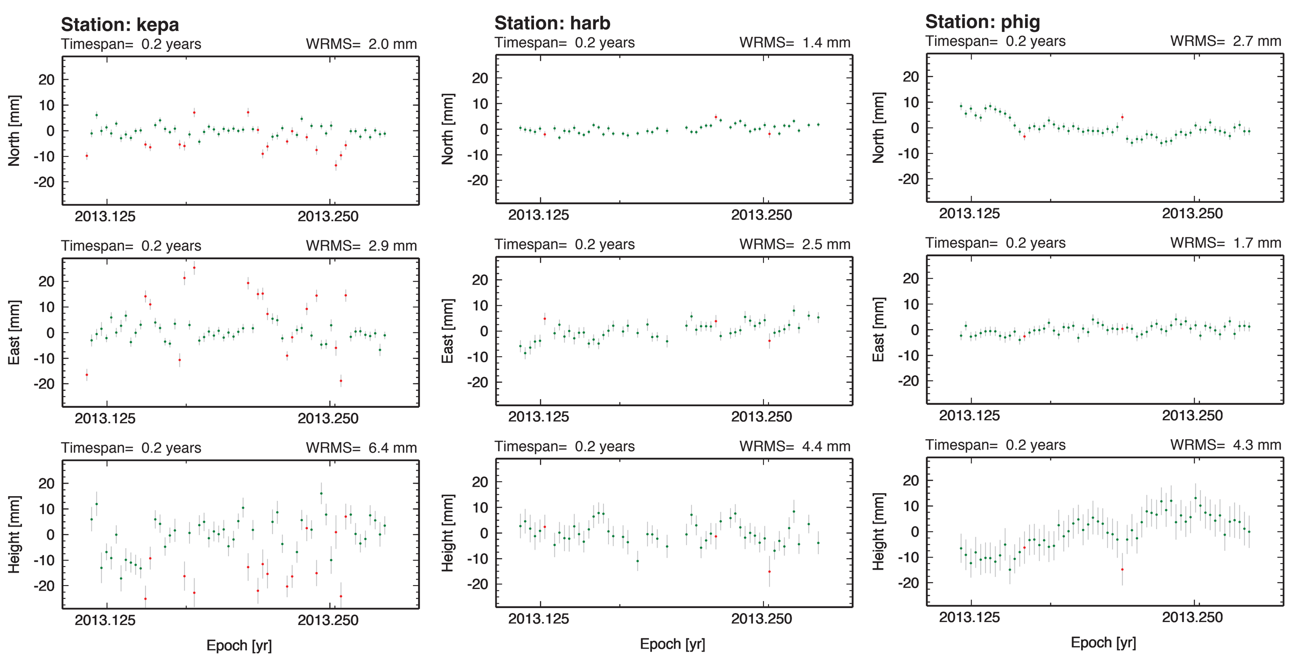

Figure 5: Example position time series for KEPA, HARB and PHIG from PPP using a 10 degree elevation cut off angle for the period from 14 February to 14 April 2013. HARB has one of the lowest MP1 and MP2 metrics due to the use of an external atomic clock whereas PHIG has one of the highest, possibly due to the 1-metre antenna mast. Position outliers are indicated by the red circles and uncertainties are three times the daily standard error from the GPS processing.

From both Table 2 and Figure 5 it can be seen that the position time series for KEPA with outliers show a larger than average scatter as indicated by the WRMS values. For the time series without outliers, i.e. the cleaned time series, the WRMS statistics for KEPA agree well with the others. However as indicated by Figure 5, the number of outliers for KEPA is much larger than for the other stations. Nearly 27% of position estimates have been removed for KEPA in contrast to 1-3% for the other stations. Table 2 also suggests that, except for the Up component time series (with outliers), there is little dependency of the WRMS statistic on the elevation cut off angle.

	North (with outliers)	East (with outliers)	Up (with outliers)	North (without outliers)	East (without outliers)	Up (without outliers)
3 degrees elevation cut off						
19 stations	1.9 ± 0.5	3.0 ± 0.8	5.7 ± 1.6	1.7 ± 0.5	2.9 ± 0.8	5.3 ± 1.5
KEPA	3.8	7.0	12.1	1.9	3.1	6.1
10 degrees elevation cut off						
19 stations	1.9 ± 0.5	3.0 ± 0.8	5.7 ± 1.6	1.7 ± 0.5	2.8 ± 0.8	5.3 ± 1.5
KEPA	3.7	7.5	9.8	2.0	2.9	6.4
15 degrees elevation cut off						
19 stations	1.9 ± 0.4	3.2 ± 0.8	6.5 ± 1.7	1.8 ± 0.4	3.1 ± 0.8	6.1 ± 1.6
KEPA	3.8	8.3	9.2	2.1	3.2	6.3

Table 2: Weighted root-mean square (WRMS) statistics for KEPA and 19 other stations for the North, East and Up position component time series for the period of 14 February to 14 April 2013. The WRMS values were computed with respect to a linear trend for both time series with outliers and those without outliers. The uncertainties of the mean WRMS values are the standard deviations.

Troposphere Estimates

Atmospheric water vapour is a primary greenhouse gas and plays an important role in weather forecasting and climate monitoring. GNSS signals experience a propagation delay, which is related to the amount of water vapour in the lower atmosphere. Hence GNSS observations can be processed to estimate this delay with millimetre-level accuracy and together with meteorological data (air temperature and pressure) can be used to compute the amount of atmospheric water vapour on various temporal and spatial scales. We use the observations of the weather stations of the KEP geodetic observatory and KEP research station, denoted as BAS, together with NCEP/NCAR reanalysis [Kalnay et al., 1996] gridded data to verify the observations and to evaluate the impact of these data sets on the integrated water vapour (IWV) estimates.

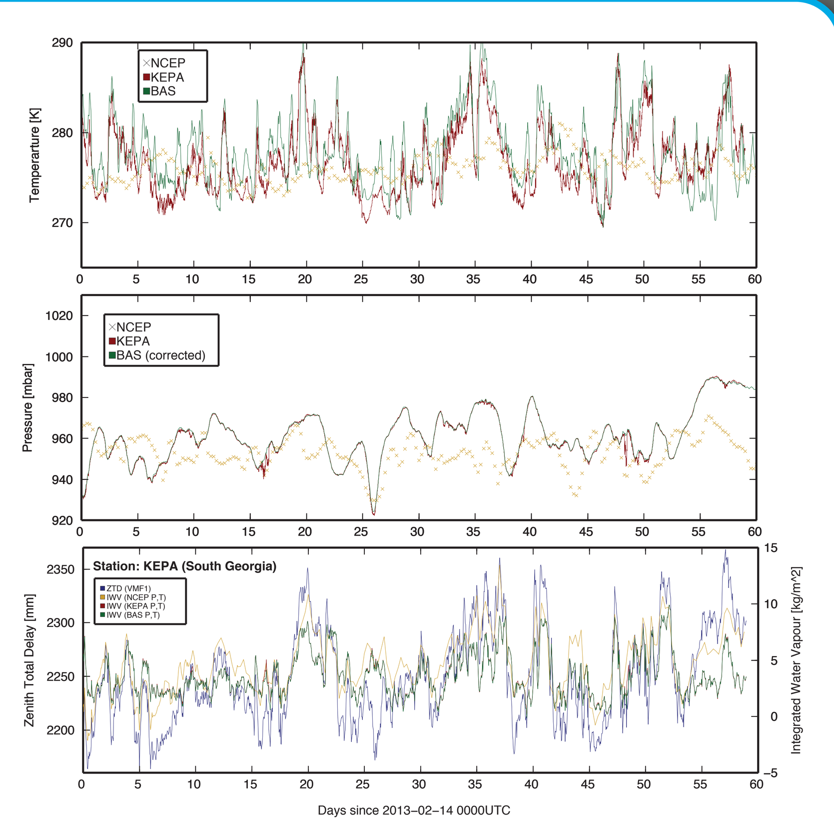

Figure 6: Time series of air temperature and pressure from KEPA and BAS weather stations and NCEP/NCAR reanalysis gridded data, zenith total delay and integrated water vapor for the period from 14 February to 14 April 2013.

Table 3: Statistics for the differences in air temperature and pressure data sets from KEPA and BAS weather stations and NCEP/NCAR reanalysis gridded data and the integrated water vapour estimates from the Vienna Mapping Function (VMF1).

	Min	25th %ile	Median	75th %ile	Max	RMS
Temperature (all values in °K)						
KEPA - BAS	-6.2	-2.6	-1.9	-0.3	10.2	2.6
KEPA - NCEP	-7.6	-2.0	0.7	3.6	12.3	4.1
BAS - NCEP	-7.2	-0.9	1.9	4.9	14.8	4.8
Pressure (all values in hPa)						
KEPA - BAS	-13.3	-0.5	-0.2	0.1	1.2	1.0
KEPA - NCEP	-34.5	-1.0	9.8	17.0	34.0	14.7
BAS - NCEP	-34.3	-0.5	10.5	18.6	39.7	15.5
Integrated Water Vapour from ZTD using VMF1 (all values in kg/m^2)						
KEPA - BAS	-0.12	-0.01	0.01	0.05	1.79	0.13
KEPA - NCEP	-4.58	-1.97	-0.78	0.52	4.72	2.02
BAS - NCEP	-4.55	-1.95	-0.91	0.49	4.68	2.03

Table 3 and Figure 6 show the exellent agreement for the air temperature and pressure observations from the KEPA and BAS weather stations. With the required accuracies for IWV estimates of 1-5 kg/m^2 and 0.25-2.5 kg/m^2 for forecasting and climate monitoring applications [Barlag et al., 2004], respectively, the performance of both weather stations needs to monitored and compared to gridded values such as those from NCEP/NCAR reanalysis.

Conclusions

The new King Edward Point Geodetic Observatory and its KEPA GNSS station have been introduced and an initial evaluation has been performed. The data quality metrics indicate a high level of code-multipath on L1 whereas multipath on L2 and the number of cycle slips per observation are low. Initial position estimates from precise point positioning indicate a larger than average scatter in the daily solutions which can be reduced to average levels through adequate outlier detection. However, more tests are needed to identify the source of the problem and if more precise network solutions are also affected. The meteorological observations from the KEPA and BAS weather stations show excellent agreement and fulfill the GNSS meteorology requirements for forecasting and climate monitoring applications.

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