Potential Contributions to Geoscience from GNSS Observations of the King Edward Point Geodetic Observatory, South Georgia, South Atlantic Ocean

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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 will present an evaluation of the GNSS observations from the KEP Geodetic Observatory for the period from February to August 2013. We calculate multipath and positioning statistics and compare these to those from IGS stations. The on-site meteorological data is compared to those from the nearby KEP meteorological station and global numerical weather models, and the impact of these data sets on delay and integrated water vapour estimates will be evaluated. 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 the 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 observations (Figure 2).

The primary objective of the observatory is to measure crustal movements close to the tide gauge at KEP and to provide a long-term vertical datum. It consists of the continuous GNSS station KEPA (DOMES 42701M001) with auxiliary equipment for power, communications and meteorology (Table 1). The observatory also supports networks of benchmarks, 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. 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).

As there is an incomplete understanding of the tectonics and potential glacio-isostatic adjustment of South Georgia and the associated continental shelf [e.g. Barker, 2001; Thomas et al, 2003; Smalley, et al. 2007], the KEP Geodetic Observatory will also benefit studies on these regional processes (Figure 1). Furthermore, can the GNSS data be applied to atmosphere research, monitoring the ionosphere and the water vapour content of the troposphere.

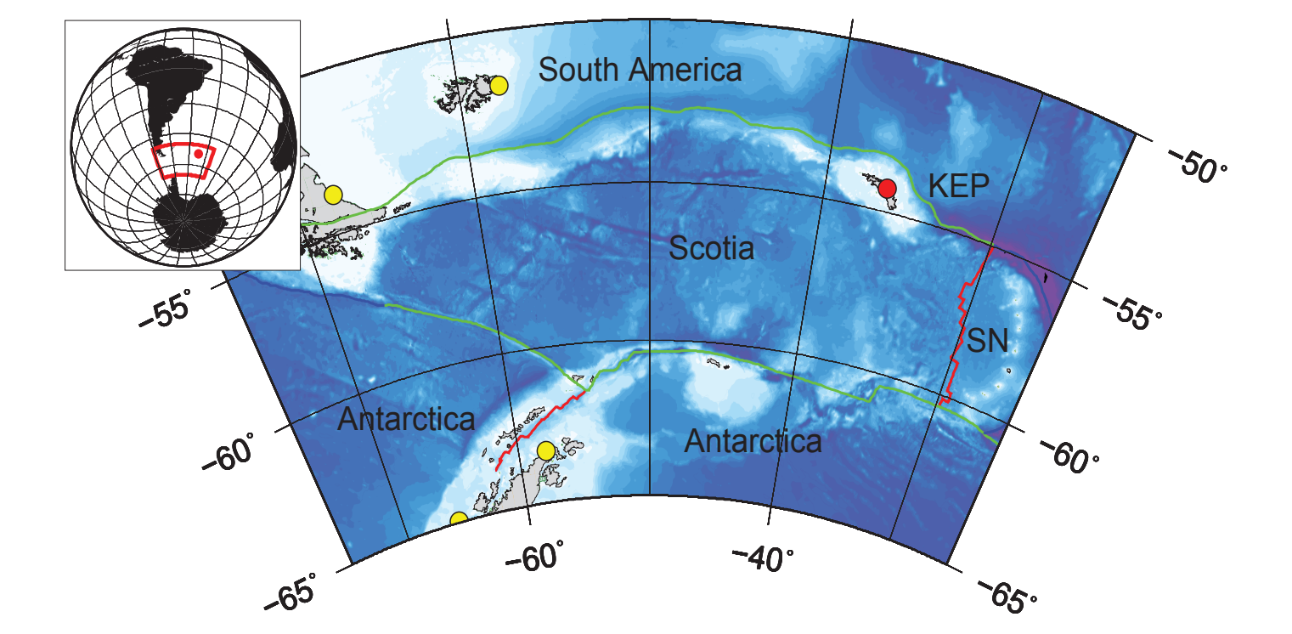

Figure 1: Location of King Edward Point (KEP) and tectonic plates in the South Atlantic Ocean (University of Texas at Austin): transforms/fracture zones (green), ridges (red) and trenches (blue); existing continuous GNSS stations (yellow circles) and KEP geodetic observatory (red circle); SN: the South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

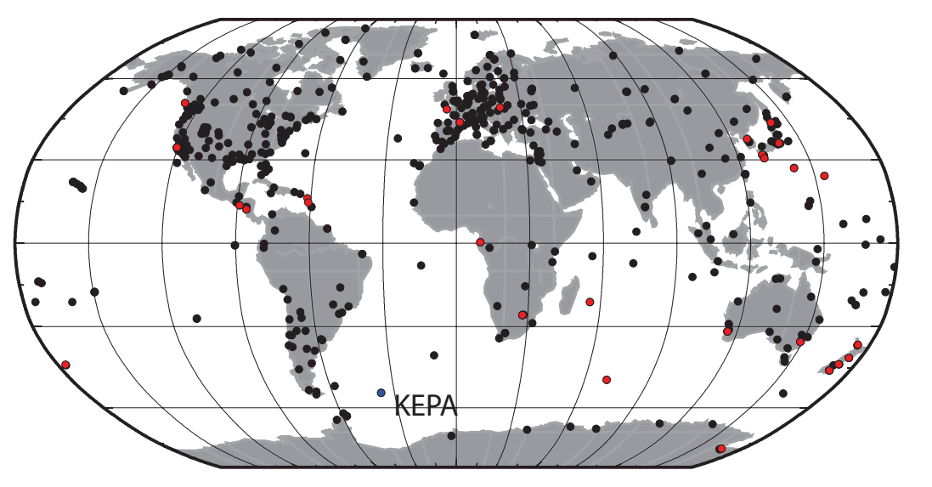

Figure 2: Global network of International GNSS Service (IGS) stations contributing to ITRF2008, (black dots), stations using a Trimble NetR9 receiver (red dots) and KEPA.

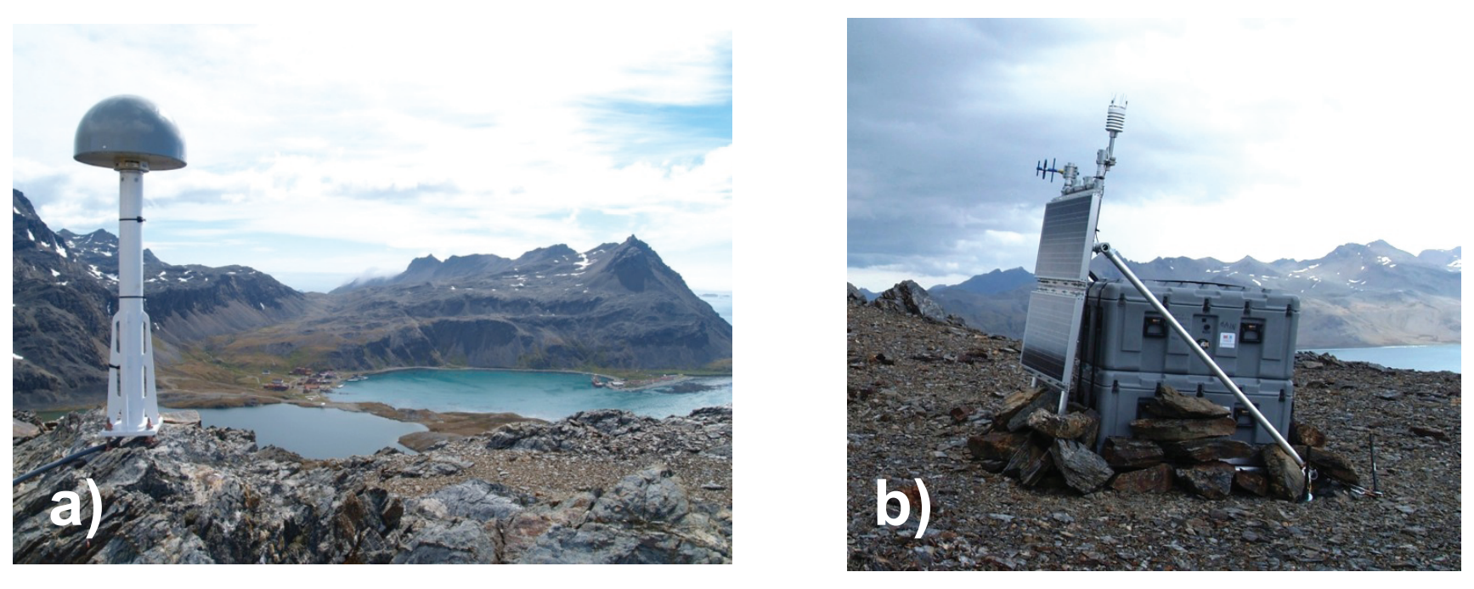

Figure 3: a) GNSS antenna on 1-metre mast. b) aluminium pipe frame with electronics and auxiliary equipment.

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 more stable external clock than the internal one, generally reduces the multipath metrics. Also, within the IGS the default is to disable any receiver observation filtering and we assume that none of the data used in this study have been filtered. 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 10 August 2013, i.e. nearly six months.

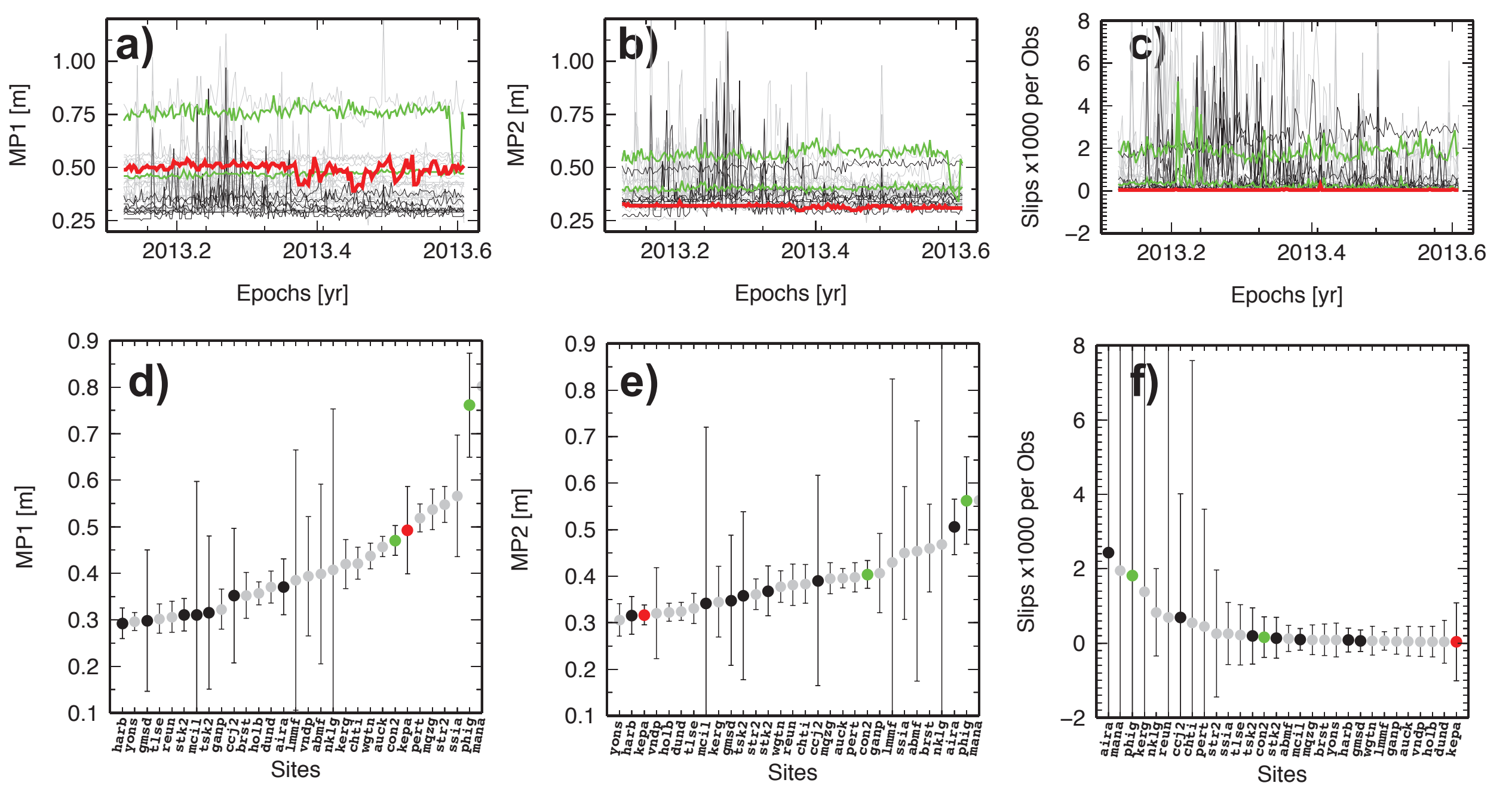

Figure 4: Time series (a-c) and statistics (d-f) of quality control metrics MP1, MP2 and slips per observations in 1000 for 30 stations using a Trimble NetR9 receiver for the period 14 February to 10 August 2013. Shown are IGS stations using internal clocks (grey colour) and external clocks (black colour), 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 largest, its mean MP2 value is among the smallest. Although at different levels, both appear to remain fairly constant over the first three months and show no spikes, which does not hold true for most other sites. From May 16, 2013 onwards is a clear change in their patterns, which corresponds with the time of the first snow cover at KEPA, showing a clear sensibility of the MP1 values to the local environmental conditions. 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 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 [e.g. Teferle et al., 2007]. We use 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, avoiding effects arising from the use of different software and model implementations during product generation and user application in PPP. Figure 5 shows example position time series for KEPA and HARB and Table 2 summarizes the results obtained.

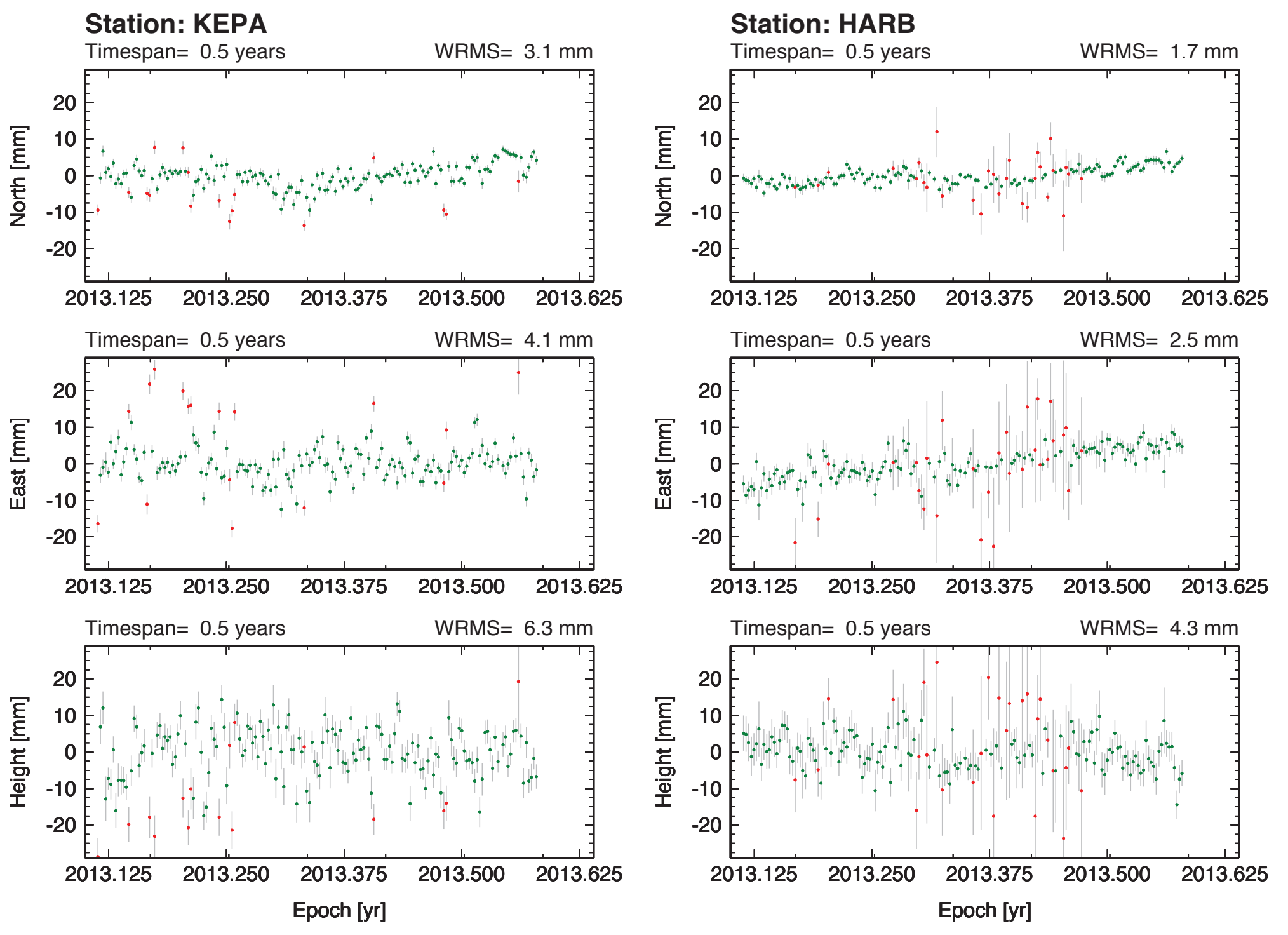

Figure 5: Example position time series for KEPA and HARB from PPP using a 10 degree elevation cut-off angle for the period from 14 February to 10 August 2013. HARB has one of the lowest MP1 and MP2 metrics due to its environment and the use of an external clock. Position outliers are indicated by the 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 component time series for the period of 14 February to 10 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 Table 2 and Figure 5 it can be seen that the position time series for KEPA show a larger than average scatter as indicated by the weighted root mean square (WRMS) values. The larger scatter is attributed to the apparent multipath effects at KEPA. The source for it has been identified as the rock surface shown in the foreground at the right-hand side of Figure 3a. Although a preliminary double-difference solution seems less affected by the multipath, ways to improve the data quality are being investigated.

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.

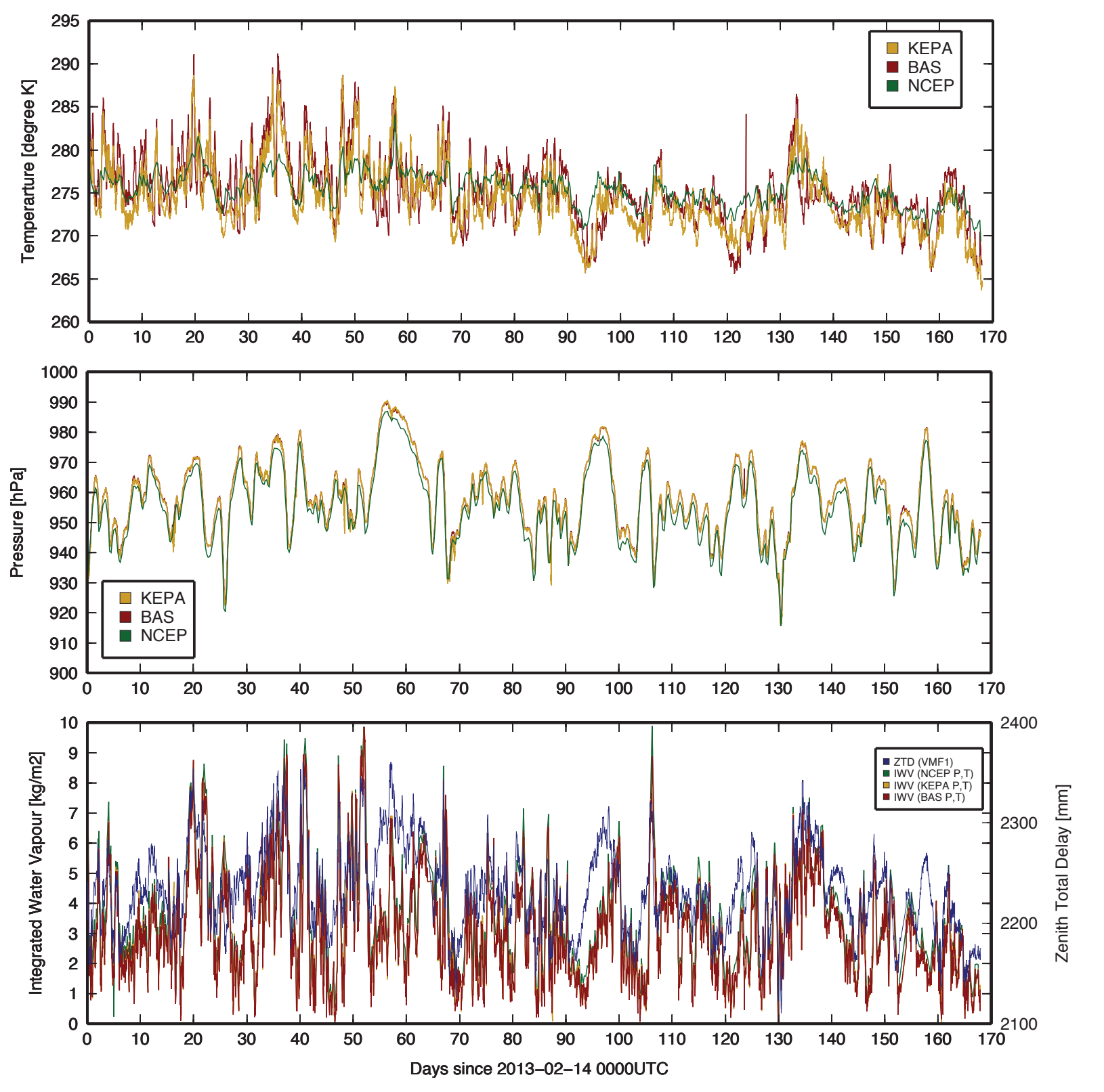

Figure 6: Time series of air temperature and pressure from KEPA and BAS weather stations and NCEP/NCAR reanalysis gridded data, zenith total delay and integrated water vapor for the period from 14 February to 10 August2013.

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

	Temperature [°K]	Pressure [hPa]	IWV [kg/m^2]
KEPA - BAS	2.3	0.9	0.1
KEPA - NCEP	2.7	3.2	0.4
BAS - NCEP	3.2	3.3	0.4

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.

Discussion and 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 L1 code-multipath whereas L2 code-multipath and the number of cycle slips per observations are 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. Further tests will show to which extent more precise network solutions improve the position time series. 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.

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 a number of future studies and the terrestrial reference frame. Although the primary objective is to measure crustal movements close to the the KEP tide gauge and provide a long-term vertical datum for sea level studies, the information obtained will also benefit satellite altimetry calibrations. 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 visco-elastic response due to glacial-isostatic adjustment cannot be ruled out. It is hoped that this and future installations will help to improve our understanding of the geophysical processes affecting this region.

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