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GPS TEC and ionosonde TEC over Grahamstown, South Africa: First comparisons

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Abstract

The Grahamstown, South Africa (33.3°S, 26.5°E) ionospheric field station operates a UMass Lowell digital pulse ionospheric sounder (Digisonde) and an Ashtech geodetic grade dual frequency GPS receiver. The GPS receiver is owned by Chief Directorate Surveys and Mapping (CDSM) in Cape Town, forms part of the national TrigNet network and was installed in February 2005.

The sampling rates of the GPS receiver and Digisonde were set to 1 s and 15 min, respectively. Data from four continuous months, March–June 2005 inclusive, were considered in this initial investigation. Data available from the Grahamstown GPS receiver was limited, and, therefore, only these 4 months have been considered.

Total Electron Content (TEC) values were determined from GPS measurements obtained from satellites passing near vertical (within an 80° elevation) to the station. TEC values were obtained from ionograms recorded at times within 5 min of the near vertical GPS measurement. The GPS derived TEC values are referred to as GTEC and the ionogram derived TEC values as ITEC. Comparisons of GTEC and ITEC values are presented in this paper. The differential clock biases of the GPS satellites and receivers are taken into account. The plasmaspheric contribution to the TEC can be inferred from the results, and confirm findings obtained by other groups.

This paper describes the groundwork for a procedure that will allow the validation of GPS derived ionospheric information with ionosonde data. This work will be of interest to the International Reference Ionosphere (IRI) community since GPS receivers are becoming recognised as another source for ionospheric information.

Keywords: Ionosphere; GPS; TEC; Ionosonde; Plasmasphere

1. Introduction

At our Grahamstown, South Africa (33.3°S, 26.5°E) ionospheric field station we have operated a University of Massachusetts Lowell digital pulse ionospheric sounder (Digisonde) since April 1996. Prior to this date a Barry Research Chirp Sounder was operational at the station for a period of about 27 years, and, therefore, the Grahamstown station has a long archive of bottomside ionospheric information.

Recently, in February 2005, an Ashtech geodetic grade dual frequency Global Positioning System (GPS) receiver was installed at the station, collocated with the Digisonde. The GPS receiver is owned by the Chief Directorate Surveys and Mapping (CDSM), who are based in Cape Town. Although, the primary function of the GPS receiver is to fill a gap in the national TrigNet network (http://www.trignet.co.za/), our relationship with CDSM allows us to utilise the GPS data from this station for research. Fig. 1 illustrates the positioning of the ionosondes and GPS receivers within South Africa. Five real-time GPS stations within Southern Africa are owned by the Hartebeesthoek Radio Observatory (HartRAO) and are also shown in Fig. 1 for completeness. A number of additional stations

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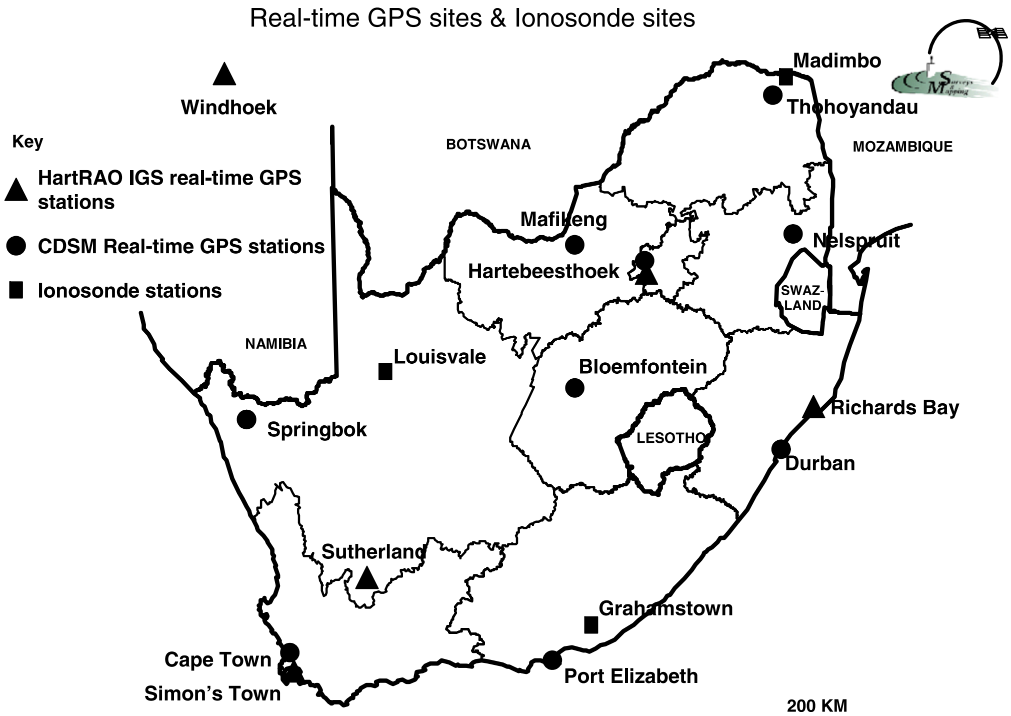

Fig. 1. A map of South Africa depicting the real-time GPS and ionosonde sites. The data used in this study were collected at the Grahamstown site.

not shown operate within Southern Africa on a non real-time basis.

Recently, there has been a move within the ionospheric community to use the Total Electron Content (TEC) parameter to characterise the ionosphere. By making use of the ionospheric induced delays on radio signals from GPS satellites orbiting the Earth at 20,200 km, the ionospheric and plasmaspheric TEC can be quantified on a global scale. It has been found that by using the GPS derived TEC values in an inversion method similar to medical tomography, the electron density profiles at any desired location can be derived. Therefore, GPS can provide a cost effective method for characterising the ionosphere, and supplementing ionosonde measurements where needed. Several groups, including but not limited to Breed et al. (1997), Lunt et al. (1999), Hernández-Pajares et al. (1999), Belehaki et al. (2004), and Cilliers et al. (2004), have been researching both the derivation of TEC and the use of ionospheric tomography in this field.

The aim of this paper is to present, for the first time, the results from the comparisons between ionosonde TEC (ITEC), and GPS derived TEC (GTEC) for the Grahamstown station. These results provide the groundwork for a method to validate ionospheric information derived from GPS measurements with ionosonde measurements.

2. TEC data availability

For this study four months of Grahamstown GPS and ionosonde data were used. These four months were March, April, May, and June of 2005, and correspond to a low solar activity period, as well as the autumn and beginning of winter months in the Southern Hemisphere. GTEC is defined as the total electron content derived from GPS measurements, and covers an altitude range up to 20,200 km, the height of orbit of the GPS satellites.

The Grahamstown GPS receiver records measurements at 1-s intervals from all satellites within radio sight of the station, and stores the data in hourly files. To determine the TEC from these measurements, the data was re-sampled at 60-s intervals and spliced into daily files. The TEC value for each 60-s sample was then determined by the use of an Adjusted Spherical Harmonic Analysis method. This procedure will not be described here since the emphasis of this paper is on the results rather than the technique, however, the reader is referred to De Santis et al. (1991) and Schaer (1999) upon which the procedure was based, and Opperman et al. (2006) for details specific to the determination of TEC from the South African GPS network. The determination of GTEC as used in this study makes allowance for the differential clock biases of the GPS receiver and satellites.

ITEC is the total electron content determined from the electron density profile derived from ionosonde measurements, and covers an altitude range up to 1000 km. The electron density profile up to 1000 km is derived from a combination of the inverted bottomside ionogram (up to the height of the F2 peak) and a modelled topside profile (Reinisch and Huang, 2001). The TEC value is calculated as an integral over the entire profile from 0 to 1000 km.