COST296 WP3 Short-Term Scientific Mission
ICTP 2007
Scientific Report

Benoît Bidaine - B.Bidaine@ulg.ac.be

January 2008

1 Introduction

Name of the scientist: Mr Benoît Bidaine
From: University of Liège (ULg)/National Fund for Scientific Research (FNRS), Belgium
Responsible scientist: Prof. René Warnant

Travel to: Aeronomy and Radio propagation Laboratory (ARPL) of the International Centre for Theoretical Physics (ICTP), Trieste, Italy
Responsible scientist: Prof. Sandro Radicella

Period: December 10^{th} to 21^{st}, 2007

2 Purpose

Mr Benoît Bidaine is starting a Ph. D. Thesis dedicated to the improvement of the ionospheric correction derived from the NeQuick model for Galileo users [1]. This work results from collaboration between the University of Liège (ULg) and the Royal Meteorological Institute of Belgium (RMI) which has a long experience in the mitigation of ionospheric effects on GNSS.

The Aeronomy and Radio propagation Laboratory of the ICTP has developed the NeQuick ionosphere model in collaboration with the University of Graz; the ICTP is continuously working on the improvement of the NeQuick model.

The goal of the STSM of Benoît Bidaine to ICTP is to develop collaboration between ULg, RMI (experienced in GNSS navigation) and ICTP (experienced in ionosphere modelling) in order to evaluate and possibly improve the ionospheric correction provided by the NeQuick model for GNSS users.

3 Work carried out

3.1 Plan

The main topic which was investigated during the mission is related to the validation of the NeQuick model using different data sets. The discussions were based on former work ([2, 3]) dealing with the comparison of the first version of the model recommended by the ITU-R [4] and its second version recently published [5]. In addition the NeQuick formulation and its physical behaviour were discussed considering the bottomside and topside representations and the interaction between both. This will constitute the basis for future investigation of ingestion techniques using NeQuick as well as the ionospheric correction algorithm for Galileo single frequency users.

3.2 Data

The first approach chosen for NeQuick validation concentrates on the electron density profile formulation. To this extent we replace the CCIR maps of f_oF_2 and $M(3000)F_2$ used in the model by measured values of these parameters using ionosondes. We can then compare the results with two kinds of measurements: vertical TEC computed by GPS and electron density profiles from ionosondes. Consequently we need to be aware of these data characteristics in order to validate them and choose which to use for what purpose.

During the mission we first focused on issues related to their production process such as differences between auto-scaled and manually scaled data for ionosondes or vertical TEC computation for GPS measurements. Then we envisaged their respective accuracies and the influence on the results eg the uncertainty of few TECu for GPS TEC leads to more robust conclusions in high solar activity.

In the following step we discussed the effects to take into account for data validation or filtering (geomagnetic active periods, unrealistic values in digisonde data, unrealistic values in TEC data, etc.). We highlighted the distinction between data quality issues and subsets constitution eg regarding ionospheric disturbance. On the one hand, outliers or « spikes » ie data points with big derivatives and sign inversion must be identified and possibly removed. On the other hand one must talk about ionospheric more than geomagnetic disturbance where the second can be an explanation for the first but not only. Finally we defined methods to perform these validation and filtering (use geomagnetic indices, use moving average, remove only problematic data or a continuous set of data including problematic ones eg all a day or sufficiently long periods).

3.3 Formulation

As mentioned before, we investigated the two versions of NeQuick concerning several topics such as

- bottomside parameters computation eg the use of digisonde TEC or other,
- topside evolution eg the new shape parameter k formula determination based on topside soundings.

The mission was then the occasion to discuss many questions gathered since the beginning of Benoît Bidaine's work about NeQuick (internship at ESA in 2006) and to identify several details to modify in NeQuick code.

4 Main results obtained

4.1 Data

We moved forward in the validation process of currently owned data (Dourbes digisonde and EUREF station, 2002)

- examining cumulative distributions of f_oF_2 and ITEC differences between auto-scaled and manually scaled data (95% of f_oF_2 differences below 1.9 MHz);
- identifying problematic situations in auto-scaled data (ionograms corresponding to spikes in auto-scaled data showing gaps in F trace);
- highlighting remaining problems in manually scaled data (ionograms corresponding to spikes in manually scaled data showing cut F traces);

- defining an adaptative moving-average filter to eliminate outliers.

We chose and required data sets to be used in NeQuick validation considering that

- ionosonde manually scaled data are preferred;
- years of interest must at least contain high solar activity level periods (cf. GPS TEC uncertainty).

Therefore we selected San Fernando and Roquetes IGS stations (corresponding to El Arenosillo and Roquetes digisondes) for which TEC data were available at ICTP for 2000 and 2004. We also planned to compare TEC data for Brussels IGS station (also available at ICTP for 2000 and 2004) with corresponding data computed with the same method as the one used in Dourbes comparison [3]. This will allow us to discuss consistency between conclusions for the different locations.

In order to study ionospheric disturbance effects, we defined rules to constitue three subsets in each data sets using monthly medians and quartiles of f_oF_2.

4.2 NeQuick validation

We confirmed the list of relevant tests to be performed including

- TEC statistics refining the time scale (year, month, day);
- TEC splitting by integrating digisonde electron density profiles and subtracting the obtained bottomside contribution to GPS TEC to represent topside contribution;
- equivalent thicknesses comparison.

Furthermore we highlighted the interest of using using absolute values (instead of relative; cf. GPS TEC uncertainty) and we intended to repeat the tests for the three subsets defined here above. We also stated that focusing on specific hours such as daily minimum/maximum or 5 and 12 UT could bring interesting conclusions. Results should be obtained by the end of February 2008.

5 Future collaboration with host institution

Considering Benoît Bidaine's Ph.D. objectives, other travels to ICTP will take place in the next four years. A possible involvement in NeQuick 2 official testing is also expected. Joined contacts with ESA have also to be taken into account in the framework of Galileo single frequency algorithm assessment and potential evolution.

6 Projected publications/articles

A publication will be submitted to the *Annales of Geophysics* in the following months.

References

[1] Prieto-Cerdeira, R., Orus, R., Arbesser-Rastburg, B. "Assessment of the Ionospheric correction algorithm for GALILEO Single Frequency Receivers". In *Proceedings of the 3rd ESA Workshop on Satellite Navigation User Equipment Technologies NAVITEC 2006* [CD-Rom], Noordwijk, The Netherlands, 2006.

[2] Bidaine, B., Prieto-Cerdeira, R., Orus, R. "NeQuick: In-Depth Analysis and New Developments". In *Proceedings of the 3rd ESA Workshop on Satellite Navigation User Equipment Technologies NAVITEC 2006* [CD-Rom], Noordwijk, The Netherlands, 2006.

[3] Bidaine, B., Warnant, R. "Assessment of the NeQuick Model at Mid-latitudes Using GPS TEC and Ionosonde Data". In *Proceedings of the 1st Colloquium Scientific and Fundamental Aspects of the Galileo Programme* [CD-Rom], Noordwijk, The Netherlands, 2007.

[4] ITU-R. *NeQuick software* [on line]. Rec. P.531, 2002. Available on http://www.itu.int/ITU-R/study-groups/software/rsg3-p531-electron-density.zip. (cited September 2th, 2007)

[5] Nava, B., Coïsson, P., Radicella, S. M. "A new version of the NeQuick ionosphere electron density model" [on line]. *Geophysical Research Abstracts*, Vol. 9, 07642, 2007. SRef-ID: 1607-7962/gra/EGU2007-A-07642. Available on http://www.cosis.net/abstracts/EGU2007/07642/EGU2007-J-07642.pdf. (cited September 8th, 2007)