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M-INGESTION: SIMULTANEOUS INGESTION OF IONOSONDE AND GNSS DATA INTO THE NEQUICK IONOSPHERIC MODEL

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Summary: The steady increase in volume and quality of ionospheric measurements allows for potential improvements in the existing ionospheric models. In particular ionosonde and Global Navigation Satellite Systems (GNSS) data provide complementary information for original developments regarding the NeQuick model, a quick-run empirical model of the electron density supplying flexible solutions for various applications. Indeed NeQuick is often used to investigate radiowave propagation issues: among others it has been implemented within the Galileo Single Frequency Ionospheric Correction Algorithm.

The model is particularly suited to be used within an optimization procedure called ingestion. In this framework, an "effective ionization level" Az plays the role of solar activity input in order to fit a specific dataset eg of slant Total Electron Content (TEC). However larger discrepancies can then obviously be observed towards other parameters eg the F2-layer critical frequency foF2. This draws the interest for a multiple ingestion - or m-ingestion - scheme implying an adaptation towards several datasets by defining several effective parameters.

In our study, we perform m-ingestion of ionosonde and GNSS data providing us with slant TEC. In fact it allows us to constrain the electron density profile slab thickness. For the purpose, a high solar activity period (year 2002) was analysed based on collo-cated digisonde and EUREF GNSS observations at a mid-latitude site, Dourbes (50.1°N, 4.6°E). In this way, we can gather some clues on expected ionospheric effects on Galileo applications during the next solar activity maximum.

1 INTRODUCTION

Ionospheric models often use solar activity indices as standard input. These indices are based on solar observations and do not necessarily account perfectly for the solar activity in EUV radiations inducing the ionisation in the Earth atmosphere. Hence different "effective" indices have been developed from the combination of ionospheric models and experimental data. They allow to drive a model towards measured values by adapting it to a specific data set, a reconstruction technique usually referred to as data ingestion[1]. NeQuick, a quick-run empirical model of the electron density developed at the Aeronomy and Radiopropagation Laboratory of the Abdus Salam International Centre for Theoretical Physics (ICTP) and at the Institute for Geophysics, Astrophysics and Meteorology of the University of Graz[2], has often been used in this framework in combination with Total Electron Content (TEC) data[3]. At a given time and for a given ray path, the TEC value obtained from the integration of NeQuick electron density profile depends monotonously on its solar flux input. The latter is then usually called effective ionization level Az and is computed by minimising the mismodelling between the model and a subset of TEC values. For example the ingestion scheme defined for NeQuick in the context of the Galileo Single Frequency Ionospheric Correction Algorithm will produce daily Az values using slant TEC (sTEC) data for entire days[4].

sTEC ingestion leads to better results in terms of TEC but not necessarily regarding other parameters such as the F2-layer peak characteristics. We attribute this to an inadequate representation of the slab thickness from NeQuick[5]. The latter parameter is defined as the vertical TEC (vTEC) divided by the F2-layer peak electron density NmF2 related itself to the F2-layer critical frequency foF2. Adapting NeQuick simultaneously to foF2 and TEC data through a multiple ingestion - or m-ingestion - technique would then allow us to cope with NeQuick weakness in terms of slab thickness.

2 M-INGESTION

To carry out m-ingestion, we introduce three effective parameters:

- two related to the F2-layer peak characteristics (we double up the solar flux input to allow using two different Az);
- a third one (α) used for the adaptation to vertical or slant TEC, defined as a coefficient of the F2-layer thickness parameter (B2bot).

To illustrate this principle, we can ingest ionosonde (critical frequency foF2 and propagation factor M(3000)F2) and GNSS (sTEC) data at a mid-latitude location (Dourbes, Belgium) presenting collocated ionosonde and GPS receiver. In particular we use manually-scaled digisonde data and GIM-levelled GPS sTEC data[6] from July 26th, 2002 (high solar activity). For this situation, we compute one triplet (Az_{foF2}, $Az_{M(3000)F2}$, α) per hour corresponding to the digisonde sampling rate at that period.

To demonstrate the interest of m-ingestion, we compare in figure 1 foF2 and vTEC daily profiles for different uses of NeQuick 2.

- The model standard use (using the monthly smoothed sunspot number as solar activity input) provides good foF2 values but underestimates vTEC significantly. (We also observe a vTEC underestimation when replacing the underlying CCIR maps of foF2 and M(3000)F2 by actual measurements, a procedure called “ionosonde parameters constrain”[7].)
- vTEC is better represented after sTEC ingestion using a daily Az similarly as for the Galileo algorithm but foF2 is then overestimated.
- Finally, for m-ingestion, we obtain exact foF2 values (only one value per hour is available and used to compute Az_{foF2}) and even better results in terms of vTEC than for the previous cases.

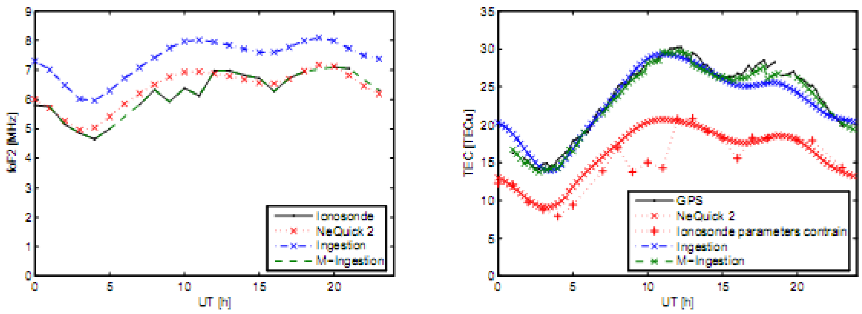

Figure 1: foF2 (left) and vTEC (right) comparison for different uses of NeQuick 2 (Dourbes, July 26th, 2002).

3 CONCLUSION AND PERSPECTIVES

In this study, we investigate a technique referred to as m-ingestion consisting in the simultaneous use, within the NeQuick model, of several effective parameters associated to different data sets and corresponding parameters. We perform tests for a mid-latitude station (Dourbes) with collocated ionosonde and GPS receiver.

We will present results for the whole year 2002 (high solar activity level) providing interesting indications about ionosphere modelling for the next solar maximum, especially for future systems such as the European GNSS Galileo. We will compare several m-ingestion applications using different parameters (eg F2-layer peak height hmF2 in place of M(3000)F2) or providing effective parameters on a daily basis.

REFERENCES

[1] B. Nava, S. M. Radicella, R. Leitinger, P. Coïsson, A near-real-time model- assisted ionosphere electron density retrieval method, Radio Sc., 41, RS6S16, (2006). doi:10.1029/2005RS003386

[2] B. Nava, P. Coïsson, S. M. Radicella, A new version of the NeQuick ionosphere electron density model, J. Atmos. and Sol.-Terr. Phys., 70(15), pp. 1856-1862, (2008). doi:10.1016/j.jastp.2008.01.015

[3] B. Bidaine, R. Warnant, Ionosphere Modelling Based on the NeQuick Model and GNSS Data Ingestion, Proc. 2nd International Colloquium Scientific and Fundamental Aspects of the Galileo Programme [CD-Rom], Padua, Italy, (2009). Available on http://orbi.ulg.ac.be/handle/2268/19132.

[4] R. Orus, B. Arbesser-Rastburg, R. Prieto-Cerdeira, M. Hernandez-Pajares, J. M. Juan, J. Sanz, Performance of Different Ionospheric Models for Single Frequency Navigation Receivers, Proc. Beacon Satellite Symposium 2007, Boston, Massachusetts, (2007).

[5] D. Buresova, B. Nava, I. Galkin, M. Angling, S. M. Stankov, P. Coisson, Data ingestion and assimilation in ionospheric models, Ann. Geophys., 52(3/4), pp. 27-45 (2009).

[6] R. Orus, Lj. R. Cander, M. Hernandez-Pajares, Testing regional vTEC maps over Europe during the 17-21 January 2005 sudden space weather event, Radio Sc., 42, RS3004, (2007). doi:10.1029/2006RS003515

[7] B. Bidaine, R. Warnant, Assessment of the NeQuick model at mid-latitudes using GNSS TEC and ionosonde data, Adv. Space Res., in press. doi:10.1016/j.asr.2009.10.010