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Intercomparison of LIEDR and NeQuick ionospheric modeling using radio occultation and ionosonde measurements

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ABSTRACT

This paper presents preliminary results of a comparative study of the modeling capabilities of two ionospheric models, LIEDR (Local Ionospheric Electron Density profile Reconstruction) [1,2,3] and NeQuick [4,5,6], by using ionospheric radio occultation (IRO) and vertical incidence sounding (VIS) measurements.

LIEDR is based on a technique [1,2] for constructing a vertical electron density profile, at a given location, by incorporating local digital ionosonde measurements, GNSS-based Total Electron Content (TEC) measurements, and empirical model values of the O^+/H^+ ion transition height (also known as upper ion transition level, UTL). By utilizing this technique, the electron profile is better represented because of the use of independent measurements and additional information about the topside ionosphere. For real-time specification of the local ionosphere, an automated system, also dubbed LIEDR, has been developed [3] and installed at the RMI Geophysical Center in Dourbes (50.1N, 4.6E) where a GNSS receiver, NovAtel GPStation-6 (TM), is collocated with a digital ionosonde, Lowell Digisonde-4D®. The system acquires and processes in real time the concurrent GNSS and VIS measurements and, ultimately, deduces a full-height electron density profile, EDP. At present the nominal time resolution between two consecutive EDP reconstructions is set to 15 minutes and results are promptly displayed (http://ionosphere.meteo.be/ionosphere/liedr).

NeQuick is a quick-run model [4] developed at the International Centre for Theoretical Physics (ICTP) with collaboration of the University of Graz. It has been conceived with the purpose of reproducing the median ionosphere behavior and is particularly designed for trans-ionospheric propagation applications. To provide the three-dimensional (3D) ionospheric electron density distribution for current conditions, various ionospheric electron density reconstruction techniques, based on the NeQuick adaptation to GPS-derived TEC data and ionosonde measured peak parameters, have been developed. These reconstruction techniques rely on the use of effective parameters, such as the effective solar flux index Az, that are defined on the basis of model calculations and experimental data. To move from ionospheric "climate" to ionospheric "weather", the NeQuick can be adapted to either slant TEC (sTEC) data from single/multiple stations [5] or to vertical TEC (vTEC) maps [6]. The effectiveness of these ingestion techniques has been validated in terms of slant TEC and ionospheric peak parameter retrieval capabilities.

In principle, ionosonde-derived values of the ionosphere key parameters, such as the F2-layer critical frequency, f_oF_2, and peak height, h_mF_2, can be utilized in validating IRO-derived peak densities and heights, and, on the other hand, both sets of data can be employed in evaluating the performance of the LIEDR and NeQuick reconstruction of the ionospheric electron density profiles. This could be made possible if selecting the cases when the location of the IRO-deduced profiles is in proximity (within few degrees in latitude and longitude) of an ionosonde.

To put the evaluation concept to test, we have selected all cases of COSMIC IRO that produced vertical electron profiles within 2.5° in latitude and 5° in longitude from the Dourbes ionosonde station in the course of a month, March 2011. The sounding rate back then was once every 15 minutes and we selected only IRO events within 5 minutes from each sounding. Thus, about 2-3 cases per day were identified and used in the analysis. On several occasions, the IRO-derived electron density profiles had the ionosphere peak parameter values matching the corresponding values from the ionosonde. These values have consequently been used to adapt the NeQuick model to the ionosonde-derived f_oF_2 and h_mF_2. All cases from March 2011 were analyzed and a comparison was made between the LIEDR and NeQuick electron profiles. It should be noted that, because LIEDR is built to use ionosonde-derived peak parameters, its output electron density profile is always tied to the values of these parameters. Hence, it was more interesting to assess how the LIEDR and NeQuick profiles compare to the IRO-derived profiles, particularly in the topside ionosphere, above h_mF_2. Here only a couple of examples are presented (Fig.1), a reconstruction of a daytime profile and another of a nighttime profile. For better graphic representation and visual analysis, instead of the electron density N_e, the ionospheric plasma frequency f_p, $f_p[MHz] = 0.898\times10^{-5} N_e^{0.5}[el/m^3]$, is plotted as a function of height.

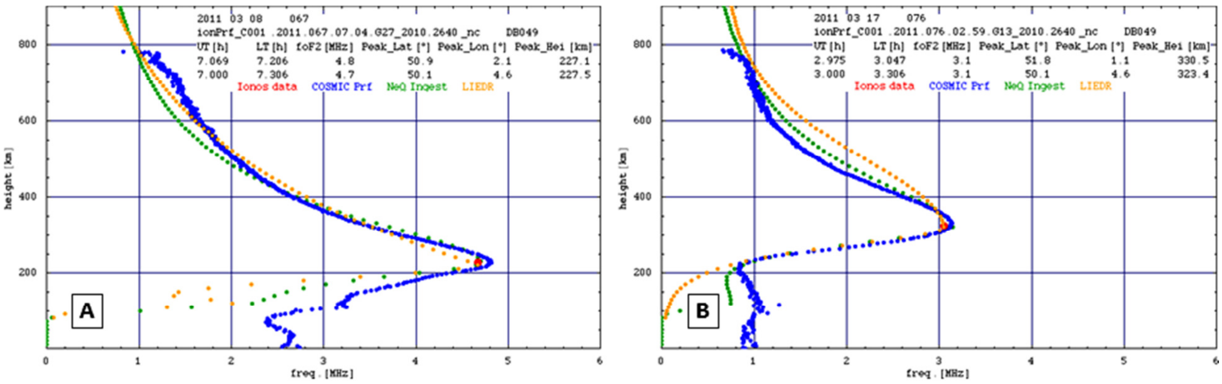

Figure 1. Ionospheric plasma frequency profiles above Dourbes as reconstructed with LIEDR (yellow), NeQuick (green), and COSMIC IRO (blue) for March 08, 2011 (panel A) at 07:00 UT (day) and for March 17, 2011 (panel B) at 03:00 UT (night). The ionosonde-derived peak frequency and height denoted with a red circle.

Further on, we have compared the LIEDR and NeQuick modeling results using Dourbes ionosonde data from March 2011. For the purpose, the ionospheric peak characteristics, obtained from automatically scaled ionograms at 15 minutes time intervals, have been ingested into NeQuick.

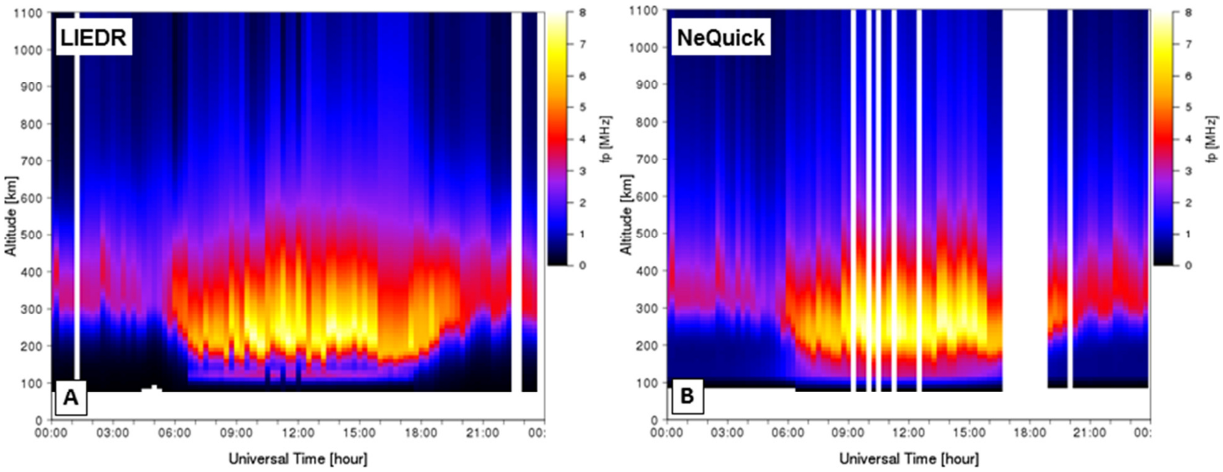

Figure 2. Vertical profiles of the ionospheric plasma frequency above Dourbes as reconstructed via LIEDR (panel A) and NeQuick (panel B) for March 17, 2011.

The resulting electron density profiles were then compared with those from the LIEDR calculations using the same peak values. Automatically-scaled data have been used in order to emulate a near-real-time ingestion procedure. As an example, the reconstructed vertical electron density distribution over Dourbes for the equinox day of March 17, 2011, is plotted (Fig.2) as ionospheric plasma frequency (color-coded, scale on the right) as a function of time and height. The example shows a good agreement between the models, underlying the importance of the ingestion procedure for improving the NeQuick performance.

The preliminary results show that the concept of using IRO and VIS measurements for evaluating the LIEDR and NeQuick performance is worth implementing. In doing so, it seems reasonable to assume [7] that the IRO-derived topside electron density profile is realistic, taking into account the fact that in the IRO procedure the errors accumulate from higher to lower altitudes. The use of the numerous IRO-VIS coincidence events for possible model validations is also envisaged; for example, by validating the modeled topside electron density profiles with the help of topside sounder data and, at the same time, verifying the suitability of the Chapman curve as a topside profiler [8]. Additional efforts will be spent also on evaluating the possibilities of using these particular IRO events as "ground truth" data for the overall improvement of both models.

Key words: LIEDR, NeQuick, GNSS, Ionosonde, Ionospheric Radio Occultation

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