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Local ionospheric electron density reconstruction from simultaneous ground-based GNSS and ionosonde measurements

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The purpose of the LIEDR (Local Ionospheric Electron Density Reconstruction) system is to acquire and process data from simultaneous ground-based GNSS TEC and digital ionosonde measurements, and subsequently to deduce the vertical electron density distribution in the local ionosphere. LIEDR is primarily designed to operate in real time for service applications, and, if sufficient data from solar and geomagnetic observations are available, to provide short-term forecast as well. For research applications and further development of the system, a post-processing mode of operation is also envisaged.

In essence, the reconstruction procedure consists in the following. The high-precision ionosonde measurements are used for directly obtaining the bottom part of the electron density profile. The ionospheric profiler for the lower side (i.e. below the density peak height, hmF2) is based on the Epstein layer functions using the known values of the critical frequencies, foF2 and foE, and the propagation factor, M3000F2. The corresponding bottom-side part of the total electron content is calculated from this profile and is then subtracted from the GPS TEC value in order to obtain the unknown portion of the TEC in the upper side (i.e. above the hmF2). Ionosonde data, together with the simultaneously-measured TEC and empirically obtained O+/H+ ion transition level values, are all required for the determination of the topside electron density scale height. The topside electron density is considered as a sum of the constituent oxygen and hydrogen ion densities with unknown vertical scale heights. The latter are calculated by solving a system of transcendental equations that arise from the incorporation of a suitable ionospheric profiler (Chapman, Epstein, or Exponential) into formulae describing ionospheric conditions (plasma quasi-neutrality, ion transition level). Once the topside scale heights are determined, the construction of the vertical electron density distribution in the entire altitude range is a straightforward process. As a by-product of the described procedure, the value of the ionospheric slab thickness can be easily computed.

To be able to provide forecast, additional information about the current solar and geomagnetic activity is needed. For the purpose, observations available in real time – at the Royal Institute of Meteorology (RMI), the Royal Observatory of Belgium (ROB), and the US National Oceanic and Atmospheric Administration (NOAA) – are used. Recently, a new hybrid model for estimating and predicting the local magnetic index K has been developed. This hybrid model has the advantage of using both, ground-based (geomagnetic field components) and space-based (solar wind parameters) measurements, which results in more reliable estimates of the level of geomagnetic activity – current and future.

The described reconstruction procedure has been tested on actual measurements at the RMI Dourbes Geophysics Centre (coordinates: 50.1N, 4.6E) where a GPS receiver is collocated with a digital ionosonde (code: DB049, type: Lowell DGS 256). Currently, the nominal time resolution between two consecutive reconstructions is set to 15 minutes with a forecast horizon for each reconstruction of up to 60 minutes.

Several applications are envisaged. For example, the ionospheric propagation delays can be estimated and corrected much easier if the electron density profile is available at a nearby location on a real-time basis. Also, both the input data and the reconstruction results can be used for validation purposes in ionospheric models, maps, and services. Recent studies suggest that such ionospheric monitoring systems can help research/services related to aircraft navigation, e.g. for development of the 'ionospheric threat' methodology.