

A WARNING SYSTEM FOR TRAVELLING IONOSPHERIC DISTURBANCES USING SKYWAVE DOPPLER FREQUENCY AND ANGLE-OF-ARRIVAL MEASUREMENTS

A. Belehaki¹, B. Reinisch², I. Galkin³ and the Net-TIDE team⁴

¹National Observatory of Athens, Palaia Penteli, Greece

²Lowell Digisonde International, LLC, Lowell, MA, USA

³University of Massachusetts Lowell, Space Science Laboratory, Lowell, MA, USA

⁴ The Net-TIDE team (<https://sites.google.com/site/spsionosphere/network>)

Travelling ionospheric disturbances (TIDs) constitute a threat for operational systems using ground-based HF and trans-ionospheric VHF-UHF radiowave propagation. TIDs can impose disturbances with amplitudes of up to ~20% of the ambient electron density, and a Doppler frequency shifts of the order of 0.5 Hz on HF signals. Therefore, their identification and tracking is important for the reliable operation of critical systems using the ionosphere as an essential part or for systems for which the ionosphere is fundamentally a nuisance.

The Net-TIDE project has developed a warning system for real-time identification of TIDs using skywave Doppler frequency and angle-of-arrival measurements archived in a Digisonde-to-Digisonde (D2D) format. Data are collected from network-coordinated HF sounding between pairs of European DPS4D and processed in real-time for the calculation of the angles-of-arrival and Doppler frequencies of ionospherically reflected high-frequency (HF) radio signals. In the Net-TIDE methodology, the ionosphere is represented by a moving undulated mirror, to relate HF signal parameters to TID characteristics, using the Doppler-Frequency-Angular-Sounding (FAS) technique.

The raw data (D2D skymaps and ionograms) are deposited in near real time via Internet in corresponding databases at the Lowell GIRO Data Center (LGDC). During this initial phase of the project, all data are processed in real-time for the calculation of the angles-of-arrival and Doppler frequencies of ionospherically reflected high-frequency (HF) radio signals. A new database, TIDBase has been set up at LGDC for the ingestion of the new type of skymap data files, "DOP", containing the D2D skymap data. TIDBase also stores the results of the FAS analysis providing information on the reference time, the location of the TID, the observation metadata (location of instruments, operating frequency, expected maximum group path of 1E signal), extracted time series of the RF signal characteristics, the derived TID characteristics, and the uncertainty/quality flags.

Visualization of the TID amplitude, velocity, wave period, and propagation direction at all reflection points in the network provides a near real-time comprehensive picture of TID activity over Europe. The NET-TIDE identification and warning service, provides the user with an

overview of the evolution of perturbation within the last 3 hours displaying the time plots of group path, Doppler frequency, and arrival angles. The TID wave amplitudes measured at different links and frequencies will of course be different and therefore appropriate reference levels are needed to facilitate the assessment of the importance of the perturbation from the user side.