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# Monitoring the ionosphere using new GNSS.

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## ABSTRACT

Local variability in the ionosphere Total Electron Content due to different types of ionospheric "disturbances" can strongly degrade the performances of GNSS-based high accuracy positioning. In this context, the University of Liege developed the so-called GPSTECMON software: based on GPS dual frequency measurements performed at a single station, GPSTECMON monitors the Total Electron Content and detects the occurrence of ionospheric disturbances which can pose a threat to GNSS high accuracy applications. Then, the reconstructed information on the ionospheric activity is exploited to offer different services to GNSS users through an operational web site (http://www.gnss-ulg.be). At European mid-latitudes, the most frequent disturbances are Medium-Scale Travelling Ionospheric Disturbances (TIDs).

At the present time, ionosphere monitoring using GPS dual frequency L1/L2 measurements has different weaknesses:

- ***Limited TEC accuracy:*** it ranges from 2 to 5 TECU; this is mainly due to the fact that the "classical" dual frequency TEC reconstruction techniques need code measurements to solve phase ambiguities; multipath, noise and hardware biases affecting code measurements limit the accuracy of the reconstructed TEC. In practice, an uncertainty of 5 TECU on TEC corresponds to an uncertainty of about 80 cm on the computation of the ionospheric error on the L1 carrier. Therefore, increased TEC accuracy is highly desirable.
- ***Limited TEC spatial resolution:*** it depends on the number of satellites in view; in Liege (Belgium), the number of GPS satellites in view ranges from 8 to 15 with an average of 11. A proper modeling of local variability in TEC due to TID's or to geomagnetic storms requires an increased spatial resolution.
- ***Observational bias in the detection of irregularities:*** GPS-based detection of moving structures like TIDs is limited due to satellite orbital motion. Indeed, most of GNSS satellites and, in particular, GPS satellites are placed on Medium Earth Orbits (MEO) at an altitude around 20 000 km. This means that they have a velocity with respect to the ionosphere. TIDs are moving structures and therefore have also a velocity with respect to the ionosphere. In practice, TID detection will be affected by the relative velocity between the TID and the satellite. For a given TID, the fact that the satellite has a velocity which is parallel, anti-parallel (worst case) or perpendicular to the TID velocity has an influence. For example, if the TID has

a velocity which is anti-parallel and of the same order of magnitude than the satellite velocity, there is a high probability that the TID will not be detected. In other words, the study of ionospheric disturbances using GPS satellites has an “observational bias” which makes their modelling more difficult.

The availability of new GNSS emitting new and more accurate signals and also the combination of the different GNSS will allow the development of improved data processing strategies for ionosphere monitoring and, as a consequence, improved services for GNSS users. The paper analyses the added value of new GNSS for ionosphere monitoring with respect to the above mentioned weaknesses encountered with GPS dual frequency data. In particular, the paper discusses the use of satellites with geostationary or inclined geosynchronous orbits to remove the orbital bias in the detection of ionospheric irregularities.

**Key words:** GNSS, Beidou, Ionosphere, Irregularities, Travelling Ionospheric Disturbances.