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Monitoring the ionospheric positioning error with a GNSS dense network

Gilles Wautelet, Sandrine Lejeune, and René Warnant
Royal Meteorological Institute of Belgium, Brussels, Belgium (gilles.wautelet@oma.be)

Local variability in the ionospheric Total Electron Content (TEC) can seriously affect the accuracy of GNSS real-time applications. In relative positioning, users have to compute the vector (called baseline) linking their receiver to a reference station for which the position is accurately known. As long as the ionosphere remains quiet (i.e. a background ionosphere with no local disturbance), the accuracy of relative positioning using phase measurements is of a few cm.
The SoDIPE-RTK software developed at the Royal Meteorological Institute of Belgium allows to compute the part of the positioning error only due to the ionosphere (referred later as "ionospheric error") for a given baseline. In practice, baselines considered in this paper are not larger than 40km in order to ensure a successful ambiguity resolution process for both L1 and L2 carriers. More precisely, data analysed in the frame of this work are baselines belonging to the Belgian GPS dense network called Active Geodetic Network (AGN). SoDIPE-RTK has been applied on the whole network during typical ionospheric conditions: quiet, active and stormy. Active conditions refer to disturbed ionosphere due to the occurrence of Traveling Ionospheric Disturbances (TID's) while stormy conditions are relative to extremely disturbed plasma during the occurrence of powerful geomagnetic storms. From this dataset, we extract some descriptive statistics like average, standard deviation, extrema... of the ionospheric error. As expected, this term is centimeter-level during quiet conditions while maximum values are reached during stormy conditions. For a 10km baseline, one can observe ionospheric errors of about 15cm during the occurrence of a winter medium-scale TID (MSTID) and up to 1m during geomagnetic storms.
Moreover, the availability of a dense network allows to study the influence of baseline orientation on ionospheric error magnitude. We have analysed two specific cases of moving ionospheric structures: a winter MSTID and an "ionospheric wall" (TEC depletion) caused by an extreme geomagnetic storm. In both cases, equatorwards direction of propagation was clearly visible on polar plots. Indeed, baselines oriented parallel to the direction of propagation of disturbances are more affected by TEC gradients than others. SoDIPE-RTK is therefore a tool which allows not only to assess the effect of ionospheric disturbances on relative positioning but also to monitor propagation patterns of such disturbances while run through a GPS dense network.
Finally, we propose a service dedicated to GNSS relative positioning users based on SoDIPE-RTK. Every 15 minutes, each AGN baseline is mapped in a given color ranging from green (quiet conditions) to red (extreme conditions). This easy-to-use application allows registered users to access to local information about current ionospheric conditions on the field.