Development of Space Weather related services for real time GNSS applications.

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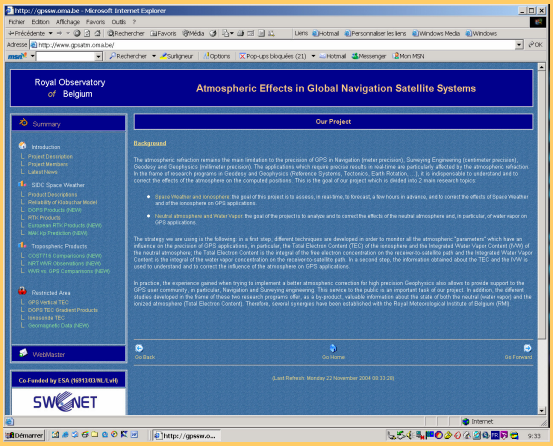
The Project

In the frame of the SIDC Space Weather Pilot Project, the Royal Observatory of Belgium, the Royal Meteorological Institute of Belgium and the Geophysical Institute of the Bulgarian Academy of Sciences are developing new services for the users of GPS. The goal of these services is to assess in near real-time and to forecast the influence of Space Weather and ionospheric conditions on the precision of different types of GPS applications :

- ***Code-based single frequency applications without DGPS corrections :*** these applications rely on the Klobuchar model to correct the measurements for the ionospheric error. The Klobuchar model (the official correction model broadcast by GPS satellites) can predict the ionosphere Total Electron Content (TEC). When Space Weather conditions are active, the predicted TEC can differ from the real TEC. When large discrepancies appear, the accuracy of the application can be strongly degraded. Our product compares the predicted and the measured TEC at Brussels and "translates" the discrepancies in terms of positioning error.

- ***Code-based single frequency applications with DGPS corrections :*** DGPS is a technique which allows a mobile user to measure its position with a meter-level precision in real-time by making use of differential corrections broadcast by a reference station. The distance between the mobile user and the reference station should not be larger than 1000 km. The positioning precision can be strongly affected by Space Weather conditions and by the resulting ionospheric activity. The service provides information about the DGPS positioning error related to the ionospheric activity depending on distance with respect to Brussels.

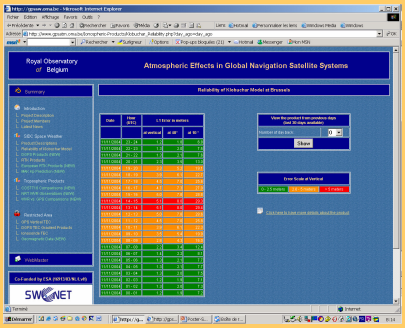
- ***Real-Time Kinematic (RTK) :*** RTK is a technique which allows a mobile user to measure its position with a cm-level precision in real-time by making use of differential corrections broadcast by a reference station. The distance between the mobile user and the reference station is of the order of 10 km. The positioning error is mainly affected by the small-scale gradients in the ionosphere. The SIDC project provides information about the small-scale gradients in the ionosphere over Belgium and surroundings using a system of colours (green, orange, red and black) which assesses the influence of the detected small-scale ionospheric activity on RTK positioning conditions.

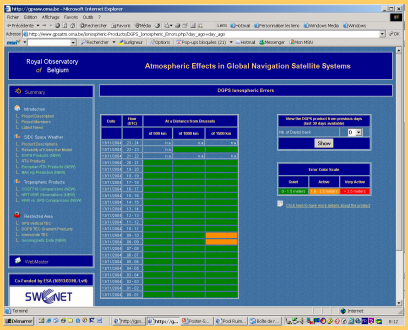


The Products (http://www.gpsatm.oma.be)

1. The Klobuchar product

The Klobuchar model broadcast by GPS satellites allows to predict the vertical TEC at a given time and location in order to correct GPS measurements for the ionospheric effect. When Space Weather conditions are active, the predicted TEC can strongly differ from the real value of the TEC. Our service compares the Klobuchar predicted TEC and the measured TEC at Brussels on an hourly basis : the first two columns indicate the date and the hour (in UTC) for which the information is available (for example, 00-01 represents the model error between 00h00 and 00h59 UTC). Columns 3 to 5 show the difference between predicted and measured TEC "translated" in terms of positioning error on the L1 carrier (in meters) for different satellite elevations (vertical, 40° and 10°). Let us mention that, if we fix the elevation mask angle at 10°, the mean satellite elevation at Brussels ranges from 30° to 50° and the mean daily elevation is about 40°.





2. The DGPS product

Navigation with DGPS technique is affected by ionospheric residual errors which increase with the distance between the user and the reference station. These residual errors depend on 3 parameters :

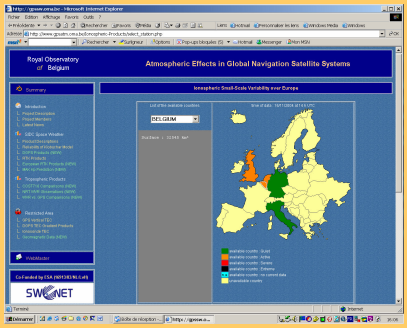
- the ionosphere Total Electron Content (TEC) ;
- the TEC gradients between and around the reference station and the user location ;
- the geometry of the observed constellation (the satellite distribution in the "local" sky).

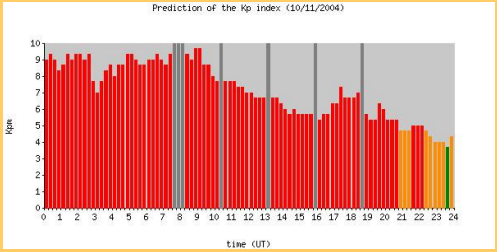
Based on these 3 parameters, our service computes on an hourly basis the mean DGPS positioning error (on the L1 carrier) due to the ionosphere for different distances with respect to Brussels (which plays the role of reference station). The distances considered are : 500 km, 1000 km and 1500 km.

3. The RTK product

Our RTK product gives information about the detected ionospheric small-scale activity over Belgium and surroundings. In practice, the effect of these disturbances on Real Time Kinematic applications is assessed using a system of colours :

- **green : low ionospheric variability – no degradation of RTK precision due to the ionosphere ;**
- orange : the ionosphere is active – small degradations of the RTK precision are expected ;
- **red : severe to extreme ionospheric activity – strong degradations of RTK precision are expected ;**
- black : extreme ionospheric variability – positioning with RTK is severely degraded or is even not possible.





4. Forecasts of degraded RTK positioning conditions using the MAK model

Based on a model developed by the Geophysical Institute of the Bulgarian Academy of Sciences, the so-called, Muhtarov Andonov Kutiev (MAK) model, we are forecasting the Dourbes (Belgium) K local geomagnetic index. Based on these forecasts and on the observed relationship between local geomagnetic activity and RTK positioning error, we issue warning messages when the positioning conditions are expected to reach red or black conditions (see point 3) during the next few hours.