The influence of Space Weather and of the ionosphere on GNSS

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Differential Positioning and Navigation

- Two receivers are observing the same satellites.
- One of them is fixed and has a well-known position.
- Depending on distance, the error sources are common.
Differential applications considered

- **DGPS** : m-accuracy
  - uses code measurements
  - distances up to 1000 km

- **RTK (Real-Time Kinematic)** : cm-accuracy
  - uses phase measurements
  - short distances (10 km)
  - needs ambiguity resolution
The ionospheric error

- Depends on wave frequency and on the ionospheric Total Electron Content (TEC).

- The TEC is measured in TECU with $1 \text{TECU} = 10^{16} \text{el/m}^2$. 
The Total Electron Content (TEC)

- The TEC depends on many parameters: local time, season, geomagnetic latitude, geomagnetic activity, solar activity, ...

- The TEC is very variable in space and time.

- As a consequence, the TEC is difficult to model.
The Klobuchar Model

- Based on monthly mean behaviour of the TEC.

- In practice, removes 60 to 90% of the effect
  ➔ Not always satisfying.
DGPS and the ionosphere

- The TEC depends on geomagnetic latitude and on local time.

- This dependency creates large- and medium-scale gradients (100 km to 1000 km).
  - up to 30 TECU/100 km at magnetic equator (6 m L1 vertical)
  - regularly >10 TECU/1000 km in Europe (>1.6 m L1 vertical)

- These gradients will affect DGPS applications.
RTK and the ionosphere (1/3)

- TEC gradients usually small on short distances
- Sometimes small-scale ionospheric disturbances
  - Travelling Ionospheric Disturbances (TIDs)
  - scintillations
These disturbances give strong variations in the TEC in space and time (even on short time intervals and short distances).
These gradients can affect the ambiguity resolution process.

There are 2 possible consequences:

- The ambiguity is fixed to a wrong integer
- The ambiguity cannot be solved

In both cases, this problem can result in a severe degradation of the computed positions.
Travelling Ionospheric Disturbances

- Depend on solar activity (which is very high since 1999).

- Have a clear seasonal behaviour (more TIDs during the winter between 10h00 and 16h00 local time)
Scintillations

- Depend on solar activity (which is very high since 1999).

- Are strongly related to Space Weather and, in particular, to geomagnetic storms (Kp index).

- Severe geomagnetic storms are the origin of strong scintillations which severely degrade RTK solutions.

- No correction for these phenomena.
The ROB and the RMI intend to collaborate to set up an « ionosphere » service for GPS users (RTK).

This service will be mainly based on the measurements collected at the RMI - Centre de Physique du Globe of Dourbes (Philippeville).
Royal Meteorological Institute
Centre de Physique du Globe at Dourbes
Section: Ionospheric Profiles

http://www.meteo.be/CPG/index.htm
At Dourbes, the following measurements are available:
- GPS data (ROB)
- geomagnetic data (RMI)
- ionospheric sounding (RMI)

These measurements will be used to detect and to predict the presence of ionospheric disturbances.
In practice, a near real-time assessment of the ionospheric activity effect on DGPS and RTK will be published on the Web using colors (mid-2003).

In addition, we will try to predict the occurrence of severe scintillations 24 hours in advance for RTK users using forecasts of the Kp geomagnetic index (end 2003).