

The influence of Space Weather and of the ionosphere on GNSS

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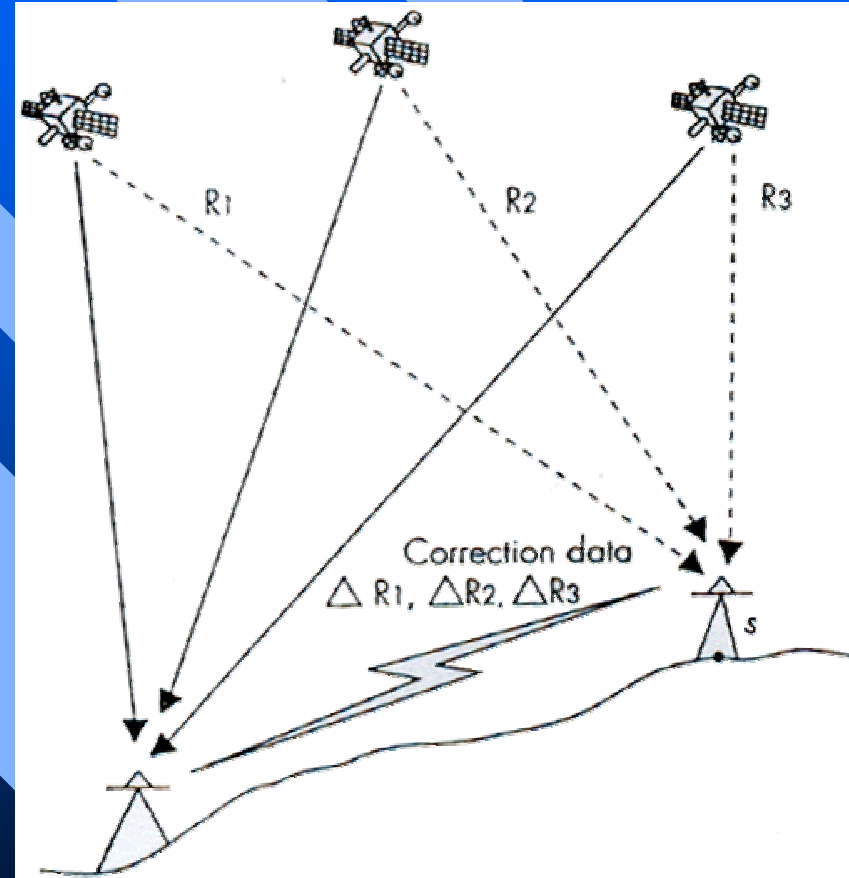
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Differential Positioning and Navigation

- 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

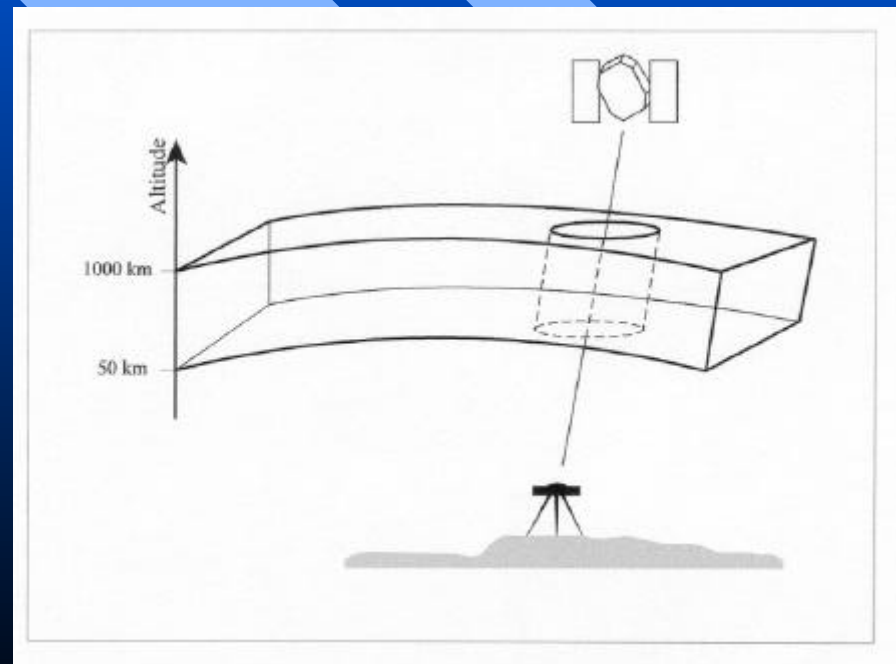
- uses code measurements
- distances up to 1000 km

■ 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 $1 \text{ TECU} = 10^{16} \text{ el/m}^2$.

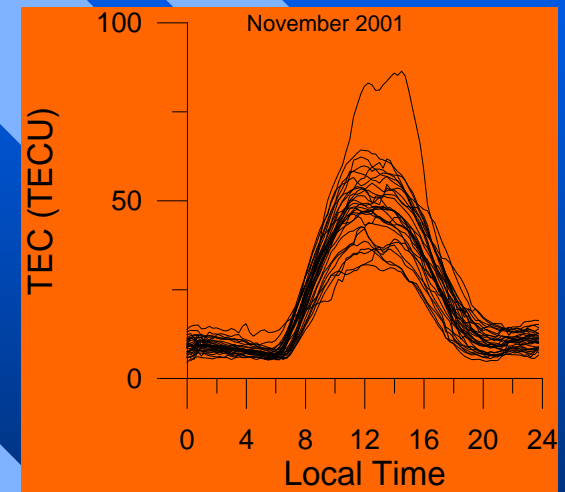
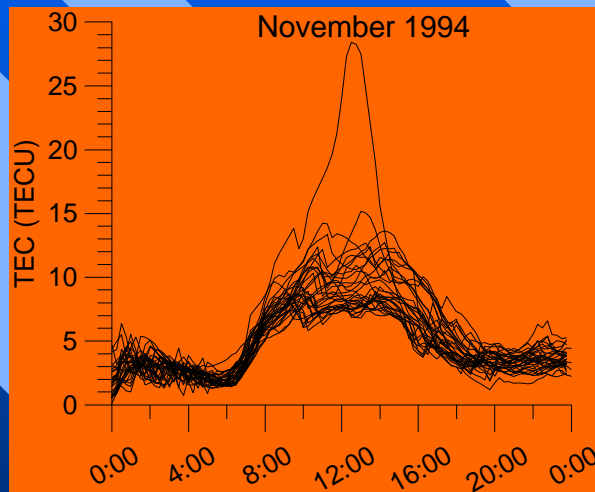
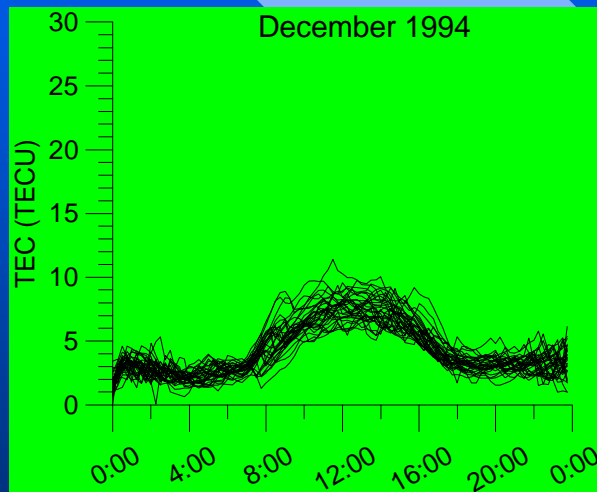


The Total Electron Content (TEC)

- 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

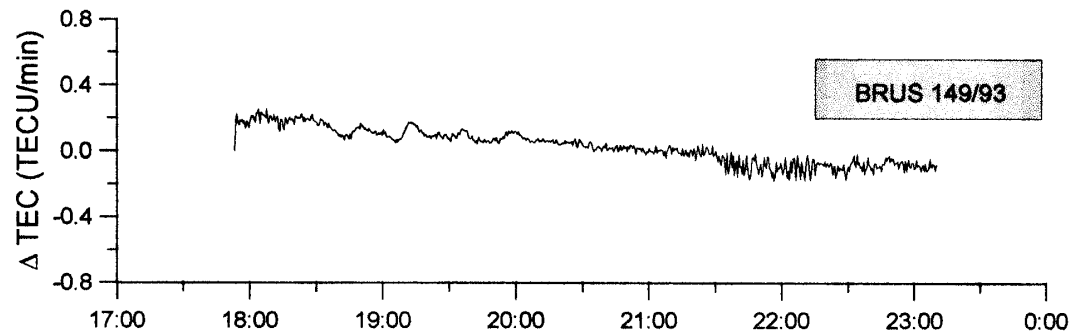
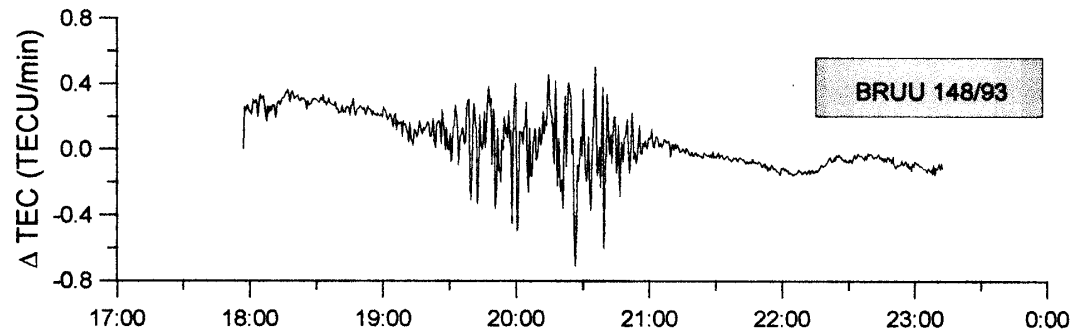
- The TEC depends on geomagnetic latitude and on local time.
- This dependency creates large- and medium-scale gradients (100 km to 1000 km).
 - up to 30 TECU/100 km at magnetic equator (6 m L1 vertical)
 - regularly >10 TECU/1000 km in Europe (>1.6 m L1 vertical)
- These gradients will affect DGPS applications.

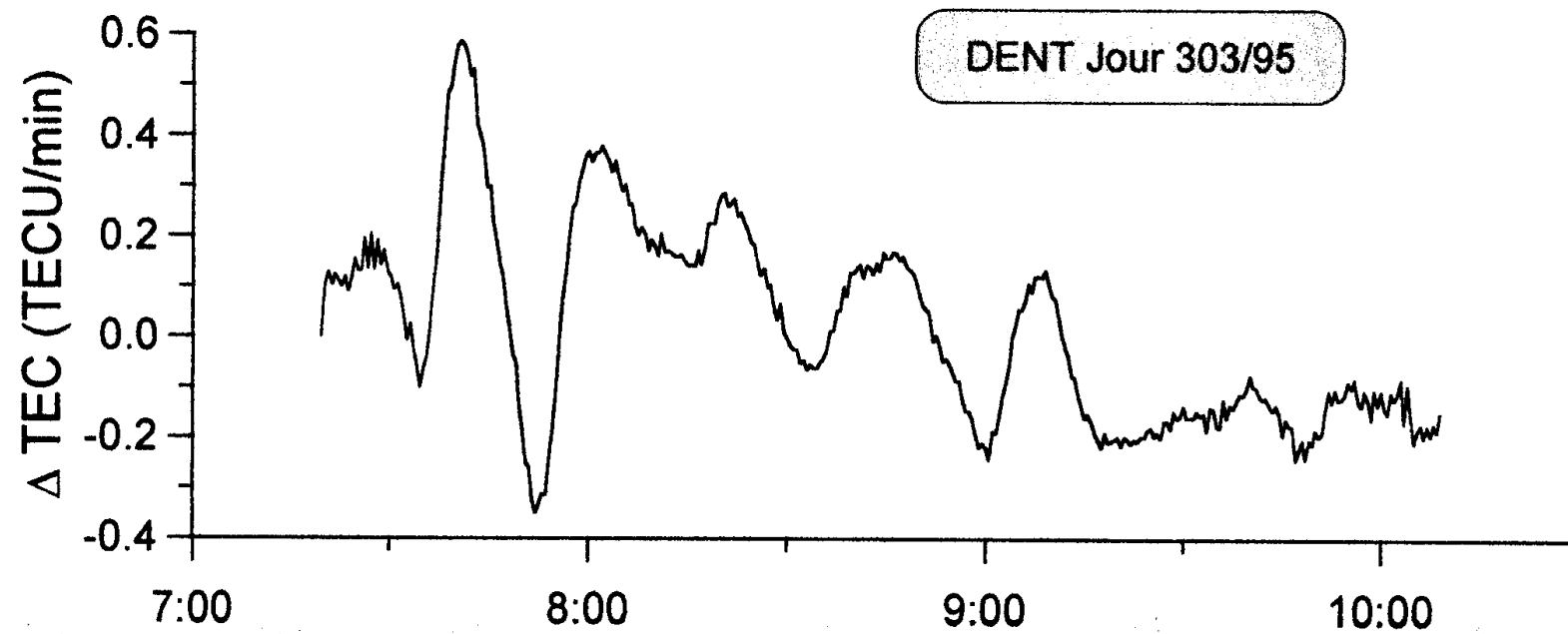
RTK and the ionosphere (1/3)

- TEC gradients usually small on short distances
- Sometimes small-scale ionospheric disturbances
 - Travelling Ionospheric Disturbances (TIDs)
 - scintillations

RTK and the ionosphere (2/3)

- These disturbances give **strong variations** in the TEC in space and time (even on short time intervals and short distances).



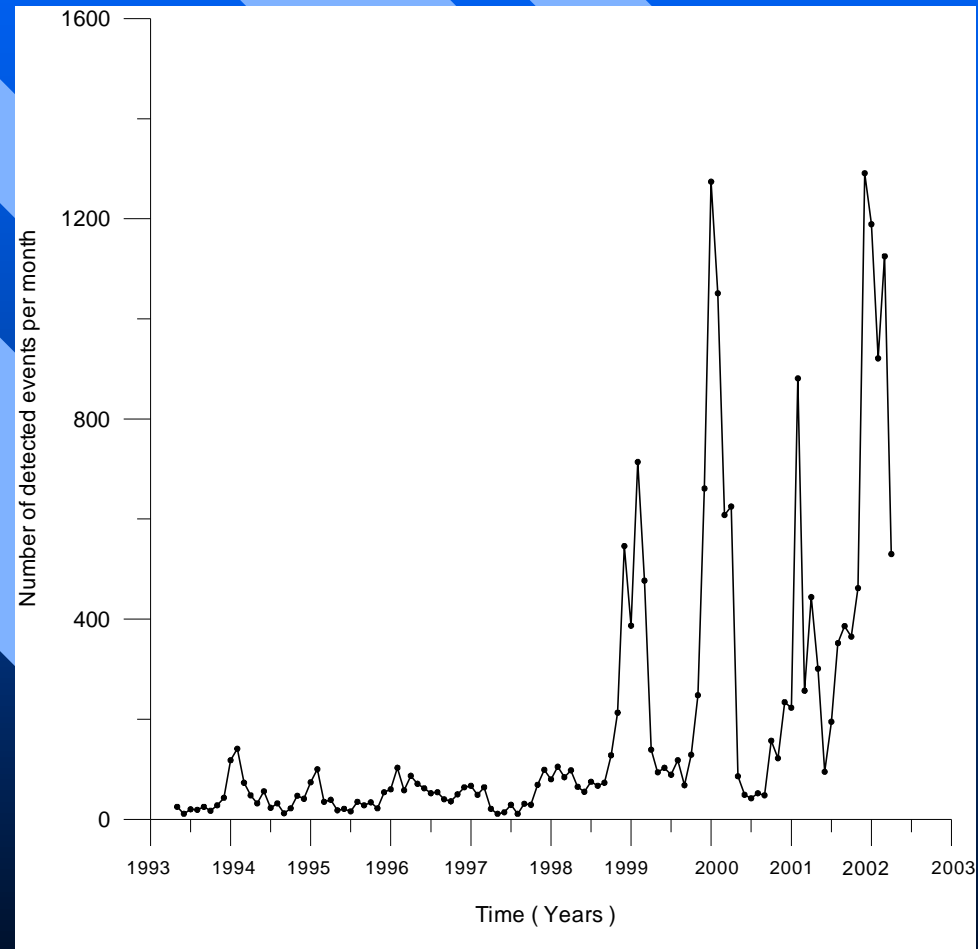


RTK and the ionosphere (3/3)

- 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 – RMI GPS Service (1/3)

- 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>

The ROB – RMI GPS Service (2/3)

- 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.**

The ROB – RMI GPS Service (3/3)

- 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).