SPECTRE (www.noveltis.fr/spectre): a web Service for Ionospheric Products

Jeansou, E.(1), Crespon, F.(1,2), Garcia, R.(2), Helbert, J.(1), Moreaux, G.(1) and Lognonné, P.(2)

(1) NOVELTIS, Parc Technologique du Canal, 2 rue de l'Europe, 31520, Ramonville, France

(2) Institut de Physique du Globe de Paris, Département de Géophysique Spatiale et Planétaire, 4 avenue de Neptune, 94107, St Maur des Fossés, France

Funding:
French Ministry of Research (RTE)
ESA (SWENET program)
French Space Agency (CNES)

ABSTRACT:

The dense GPS networks developed for geodesic applications appear to be very efficient ionospheric sensors because of interaction between plasma and electromagnetic waves. Indeed, the dual frequency receivers provide data from which the Slant Total Electron Content (STEC) can be easily extracted to compute Vertical Total Electron Content (VTEC) maps. The SPECTRE project, Service and Products for ionospheric Electron Content and Tropospheric Refractivity over Europe, is currently a pre-operational service providing VTEC maps with high time and space resolution after 3 days time delay (http://www.noveltis.fr/spectre and http://ganymede.ipgp.jussieu.fr/spectre). This project is a part of SWENET, SpaceWeather European Network, initiated by the European Space Agency. The SPECTRE data products are useful for many applications. We will present these applications in term of interest for the scientific community with a special focus on spaceweather and transient ionospheric perturbations related to Earthquakes. Moreover, the pre-operational extensions of SPECTRE to the californian (SCIGN/BARD) and japanese (GEONET) dense GPS networks will be presented. Then the method of 3D tomography of the electron density from GPS data will be presented and its resolution discussed. The expected improvements of the 3D tomographic images by new tomographic reconstruction algorithms and by the advent of the Galileo system will conclude the presentation.

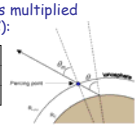
MODEL:

The combination of the pseudo-ranges P1 and P2 and the phase data L1 and L2, respectively at F1 (1575.42 MHz) and F2 (1227.60 MHz) gives the ionospheric delay:

$$D_{iono} = (L1-L2) - <(L1-L2)+(P1-P2)>$$

The integrated TEC along ray path, or slant TEC (STEC), is multiplied by the obliquity factor F_{ob} to have the vertical TEC (VTEC):

$$F_{ob} = \cos^{-1}(\theta_m) \quad \theta_m = \sin^{-1}\left[\left(\frac{R_E}{R_E + R_{iono}}\right)\cdot\sin(\theta)\right]$$



The modelling of the GPS ionospheric combination has to account for electronic errors (Differential Code Biases, DCB) of two types:
- Station (P1-P2) DCB, or Inter-Frequency Bias (IFB)
- Satellite (P1-P2) DCB or Transmitter Group Delay (TGD)

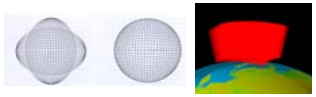
Thus, for a station-satellite observation, one has:

$$D_{iono} = \frac{VTEC}{F_{ob}} + IFB + TGD$$

The VTEC and the biases are estimated jointly with a least-square method. In order to solve the non-uniqueness on the estimated IFBs and TGDs, one has to choose a reference station and fix its bias to 0. So the IFB and TGD estimates are relative to the reference station IFB. Moreover, we introduce a spatial correlation and a time correlation (Kalman filter) to improve the estimation stability.

EXTENSION TO 3D MODEL (under development):

The estimation of IFB and TGD provided by 2D model are used as inputs. The 3D grid is a local cubed sphere in order to allow fast computation of length of ray path in each cell.
[Garcia et al., GJI, 2005]



The modelling match to the sum of each cell weighted by the length of the ray in the corresponding cell.

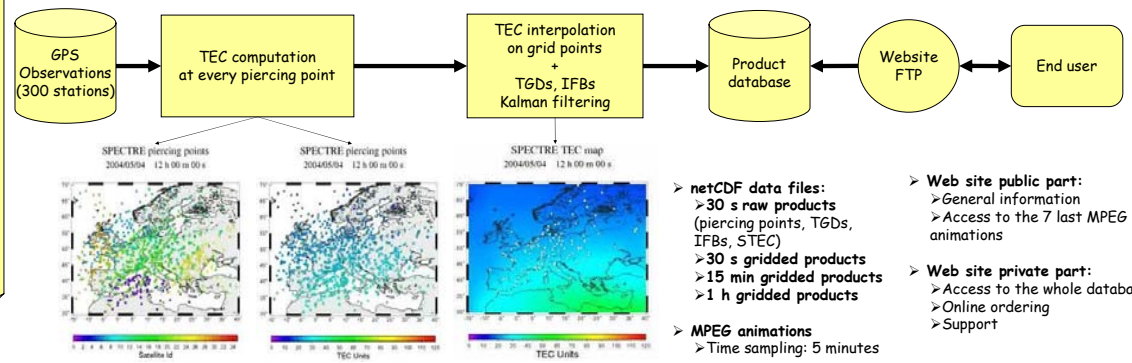
$$D_{iono} = \sum_k l_k * p_k$$

The SPECTRE service

SPECTRE is a pre-operational service:
- Based on the software developed by IPGP
- Consolidated by NOVELTIS:
  - Automation
  - Archiving procedures
  - End-user interface for data ordering

Products:
- Are computed daily on a routine basis
- Are available with a 3 days delay
- Are archived in our database (data since April 2004)
- Can be ordered through our web site (www.noveltis.com/spectre)

Products availability:
For any information: spectre@noveltis.fr



- **netCDF data files:**
  - **30 s raw products** (piercing points, TGDs, IFBs, STEC)
  - **30 s gridded products**
  - **15 min gridded products**
  - **1 h gridded products**
- **MPEG animations**
  - Time sampling: 5 minutes
- **Web site public part:**
  - General information
  - Access to the 7 last MPEG animations
- **Web site private part:**
  - Access to the whole database
  - Online ordering
  - Support

Extension of SPECTRE:

This service is going to provide TEC products for two other dense GPS networks: the GEONET of Japan and the SCIGN of California.

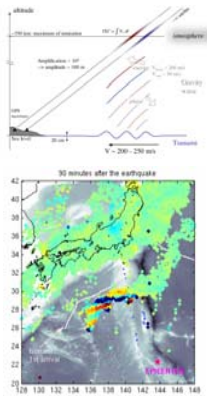
In order to set a pre-operational service like for the Europe we have to use a cluster to implement SPECTRE.

SCIENTIFIC APPLICATIONS

The service SPECTRE provide to scientists several ionospheric products that are useful to study the dynamic of the ionosphere. Thus, the service SPECTRE is an efficient tool to develop research in various domain like ***Spaceweather*** and ***Ionospheric Sismology***.

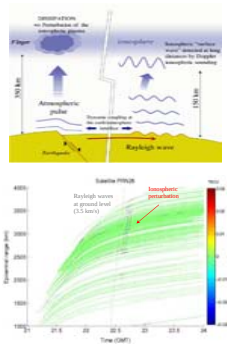
(Free data access for scientific applications: http://ganymede.jussieu.fr/spectre)

Tsunamis



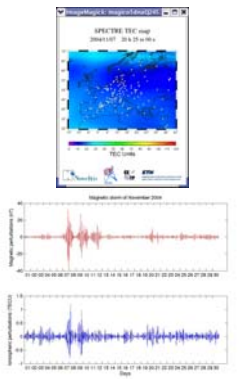
TEC variations 90 min after the Volcano Islands earthquake (M=7.6, 2000/03/28)

Earthquakes



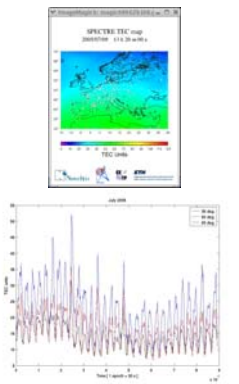
Ionospheric seismogram over California after the Denali earthquake (Alaska, 2002/11/03) filtered between 4.8 mHz and 5.8 mHz. [Ducic, GRL, 2003] [Garcia, GJI, 2005]

Magnetic Storms



TEC perturbations (period < 6h) over european high latitudes (>60°N) for the magnetic storm of November 2004.

Daily variability



2D TEC maps and dynamic of the ionosphere for several latitudes (35°N, 50°N and 65°N) at longitude 15°E for july 2005.

CONCLUSION

- Service SPECTRE is now fully operational for Europe providing (3 days delay):
  - **30 s raw products** (piercing points, TGDs, IFBs, STEC)
  - **2D TEC maps products (2.5°*2.5°) at 30 s,15 min and 1h.**
  - **Web site:** www.noveltis.fr/spectre
- Current scientific applications:
  - **Spaceweather**
  - **Ionospheric sismology**
- **Free data access for scientific applications:** http://ganymede.jussieu.fr/spectre
- Extension under development:
  - **3D tomography**
  - **Set up service for GPS networks of California and Japan**