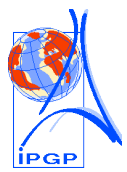




SPECTRE service

Continuous 2D monitoring of the ionosphere by GPS data, 3D tomographic developments, database evaluation and applications.

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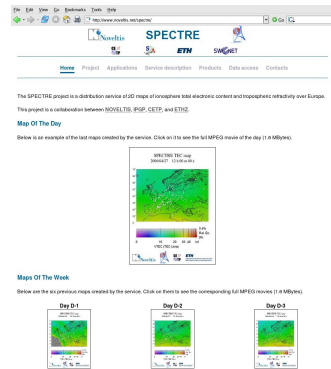


Abstract:

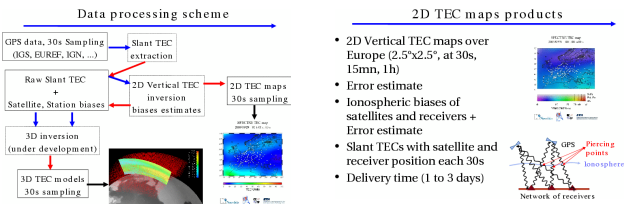
The SPECTRE service (Service and Products for Electron Content and Troposphere refractivity over Europe from GPS data) is a result of a 4 years joint effort of IPGP research institution and Noveltis Company. The post-processed GPS data, the final ionospheric products and some data extraction tools are freely available to the scientific community through our web sites (<http://ganymede.ipgp.jussieu.fr/spectre> or www.noveltis.fr/spectre) and for non-scientific applications, please contact Noveltis company. In particular, a specific tool has been developed for extracting the Vertical TEC values along the orbit of DEMETER satellite. An evaluation of the 2D products database is presented by comparison with two hour sampling JPL and CODE products. The model parametrization, the inversion method and the resolution of 3D ionospheric tomography are presented and discussed. Then, some scientific applications taking advantage of the high time resolution of SPECTRE products are described. Some examples of ionospheric perturbations associated to acoustic and gravity waves created by earthquakes and tsunamis are presented and discussed. The extension of the service above dense GPS networks in active seismic regions (mainly Japan and California) has been experimented, and the related difficulties are presented.



<http://ganymede.ipgp.jussieu.fr/spectre>



<http://www.noveltis.fr/spectre>



3D tomographic developments

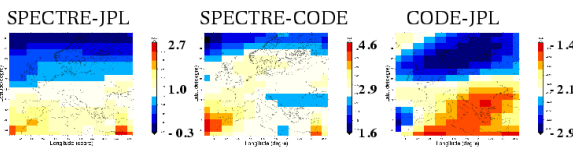
- Originality of the tomographic method:
 - One tomographic model per epoch (30 s sampling)
 - Different inversion procedures for TEC absolute values and perturbations
 - Parametrisation with cubic sphere blocks allowing a fast computation of the forward linear problem
- Sparse matrix inversion method
- Model error and resolution computation

3D tomography developments

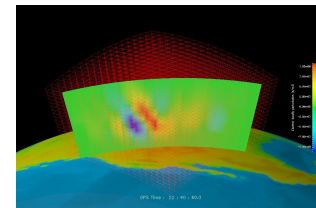
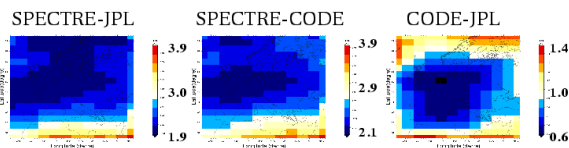
- Electron density perturbations:**
 - Filtered Slant TEC data at HF
 - A priori: the altitude of maximum infrasound-electron density coupling
 - dNe parametrization
 - Linear inverse problem
 - Minimum Norm constraint to recover the perturbation structure
- Electron density absolute values:**
 - Slant TEC data
 - A priori: receiver and satellite biases (from 2D inversion) + IR2003 model (including SPIM)
 - Log(Ne) parametrization
 - Linearized by using dNe/Ne
 - Minimum gradient constraint to recover the electron density absolute values (IR1 gradients)

Comparison with JPL and CODE 2h sampling ionospheric products over 1 year

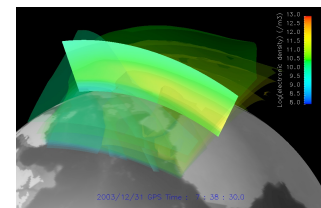
Average:



Standard deviation:



Ionospheric Perturbation above California associated to the infrasonic waves created by the seismic surface waves coming from the Denali earthquake (great circle cut and 3D grid).



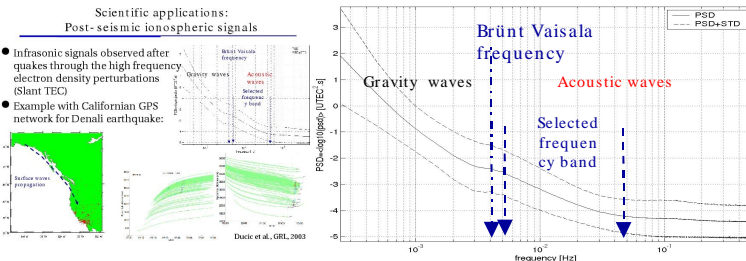
Logarithm of electronic density above Europe on 31th december 2005 (N-S cut and isosurfaces). 3D tomography under development

Conclusions and prospect:

The SPECTRE project has demonstrated that GPS data can be used to infer the electron density structure of the ionosphere both for absolute electron content variations and ionospheric perturbations. The comparison of TEC estimates with JPL and CODE products indicates a larger dynamic range for our estimates. Moreover, the high rate of our products and the possibility to recover Slant TEC estimates corrected for station and satellite biases open new scientific applications of these data (ionospheric seismology, high frequency space weather). The 3D tomography of electron density and ionospheric perturbations is currently under development. Despite intrinsic limitations due to the uneven sampling of GPS rays, the actual code is able to invert a fine 3D structure (10 000 model points) in near real time (less than 30 s). The SPECTRE products can be extended to other areas of dense GPS receivers (California and Japan) once the problems related to computation time, mass memory and data availability and quality (Crespon et al., submitted) will be solved. New scientific applications are opened by such high rate ionospheric sounding: ionospheric seismology (Ducic et al. 2003.; Garcia et al., 2005) and tsunami detection (Artru et al. 2004, Occhipinti et al., submitted).

References:

- Artru, Farges and Lognonné, 2004, Geophys. J. Int., v. 158, 1067-1077
- Crespon, Garcia, Durand and Morel, 2006, "High Frequency noise and aliasing in GPS data: a warning for geoscience applications", submitted to Geophys. Res. Lett.
- Ducic, Artru and Lognonné, 2003, Geophys. Res. Lett., v. 30(18), doi:10.1029/2003GL017812
- Garcia, Crespon, Ducic and Lognonné, 2005, Geophys. J. Int., v. 150, 651-664
- Lognonné et al., 2006, Planet. Space Science, v. 54, 528-540
- Occhipinti, Lognonné, Kherani and Hébert, 2006, "Chasing tsunamis in the ionosphere", submitted to Geophys. Res. Lett.

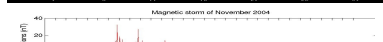


Scientific applications: H.F. TEC variations during magnetic storms

DST index during November 2003



High frequency variations (periods < 6h) of DST index



High frequency variations (periods < 6h) of average TEC at latitudes above 60°N

