SPECTRE

Ionospheric tools and products over dense GPS network.

P-E. Godet[1]
R. Garcia[1]
F. Crespon[1,2]
E. Jeansou[2]
J. Helbert[2]
G. Moreaux[2]
P. Lognonné[1]

[1] Institut de Physique du Globe de Paris. Etudes Spatiales et Planetologie, 4 ave de Neptune, 94107 Saint Maur des Fossés, France.

[2] NOVELTIS, Parc Technologique du canal, 2 ave de l'Europe, 31250 Ramonville Saint-Agne, France.
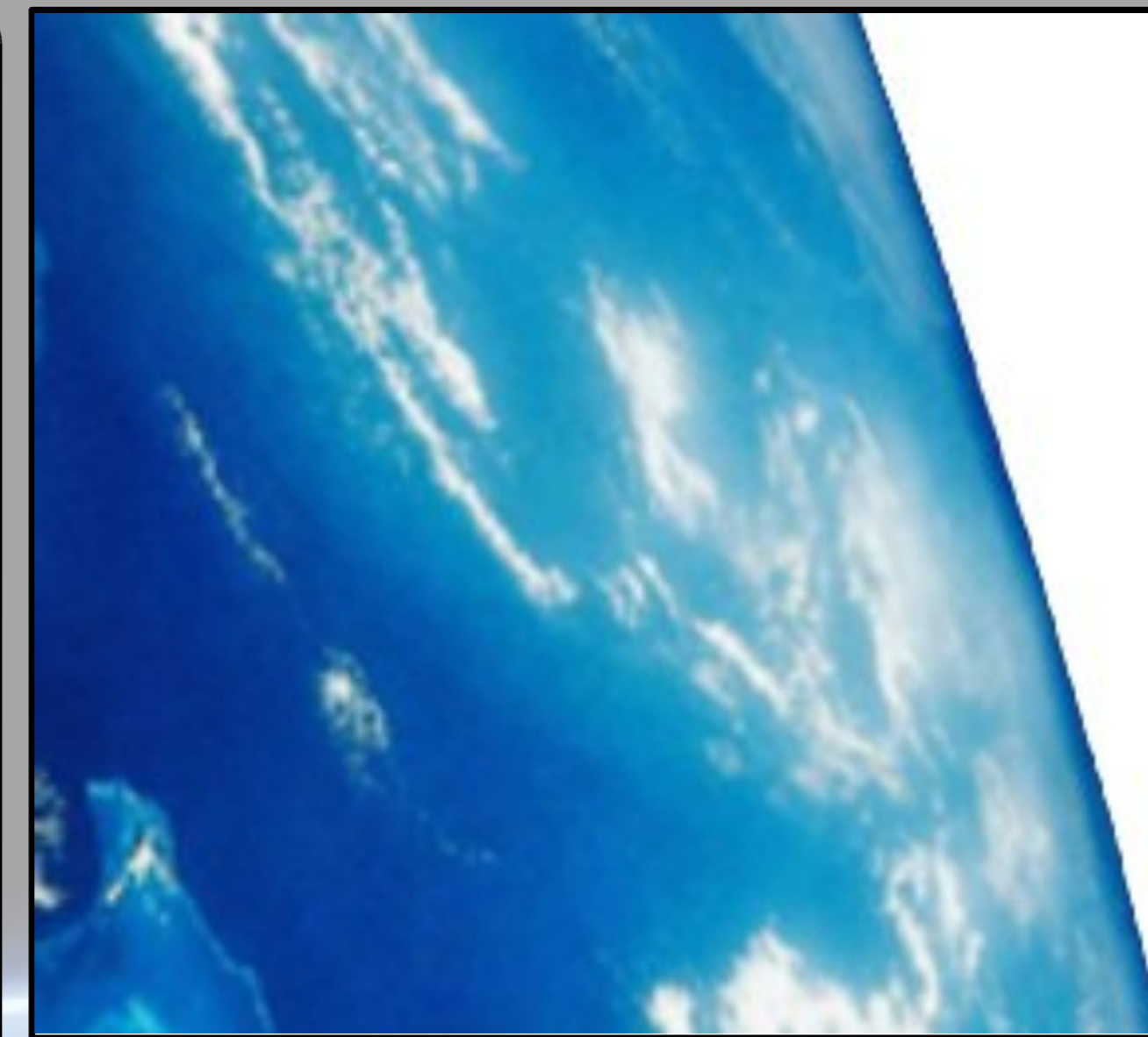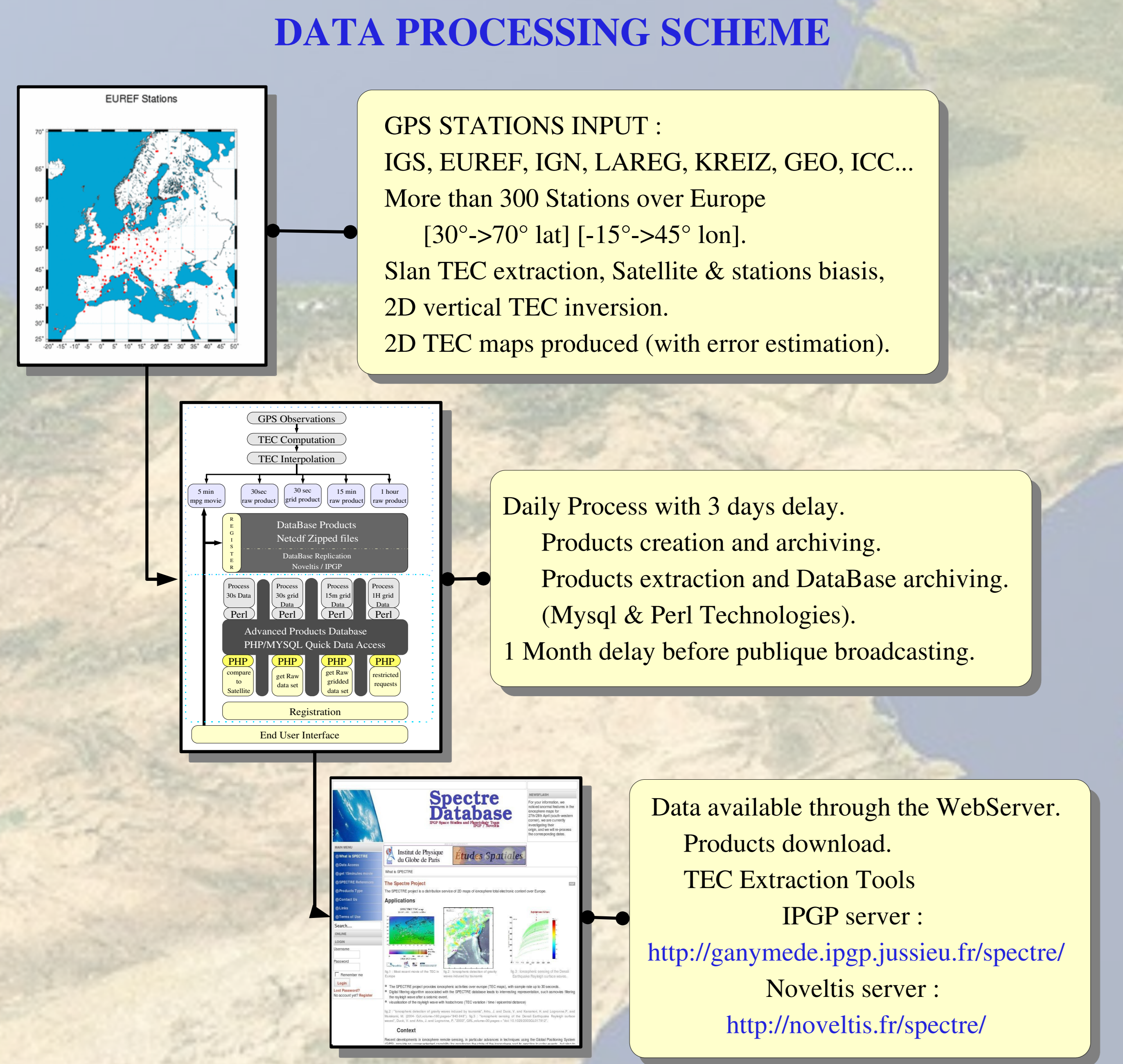
ABSTRACT :

SPECTRE is a result of a 4 years joint effort of IPGP research institution and Noveltis Company. Technologies have been developped for providing final ionospheric products and data extraction tools from the dense GPS networks developed for geodetic applications. This operationnal service is freely available to the scientific community through the web site.
The SPECTRE data products are used for many applications for the scientific community with a special focus on spaceweather and transient ionospheric perturbations related to Earthquakes.
Quick extraction tools of the vertical TEC values permitted the evaluation of the 2D products database by comparison with JPL and CODE products, and permits various correlation with all kind of satellite measurement.

SCIENTIFIC PURPOSE

Recent developments in ionosphere remote sensing, particulary the Global Positioning System (GPS), provide an unprecedented capability for monitoring the state of the ionosphere in reaction to solar events and Earth geophysical events. The ionosphere is indeed a natural amplifier of ground measurements, and vertical velocity is amplified as it reaches the ionosphere. This amplification can be used to detect, monitor, and characterize ionosphere state disturbances. SPECTRE operates the extraction of the Total Electron Content (TEC) of each ground based GPS stations and proceed to the TEC mapping of the dense GPS network area.

DATA PROCESSING SCHEME

EUREF Stations

GPS STATIONS INPUT :
IGS, EUREF, IGN, LAREG, KREIZ, GEO, ICC...
More than 300 Stations over Europe
[30°->70° lat] [-15°->45° lon].
Slan TEC extraction, Satellite & stations biasis,
2D vertical TEC inversion.
2D TEC maps produced (with error estimation).

Daily Process with 3 days delay.
Products creation and archiving.
Products extraction and DataBase archiving.
(Mysql & Perl Technologies).
1 Month delay before publique broadcasting.

Spectre Database

Data available through the WebServer.
Products download.
TEC Extraction Tools
IPGP server :
http://ganymede.ipgp.jussieu.fr/spectre/
Noveltis server :
http://noveltis.fr/spectre/

DATA APPLICATIONS

SPECTRE VALIDATION

Comparison with the Ionospheric products of JPL Service and CODE Service.
1 Year data (2H sampling rate).

Average | Standard Deviation
CODE - JPL
SPECTRE - CODE
SPECTRE - JPL

The comparison of TEC estimates with JPL and CODE products indicates a larger dynamic range for our estimates.

TEC PROFILE

20 000 Km — GPS Satellites
1336 Km — Topex, Jason
710 Km
450 Km — Demeter, Champ-C
300 Km
100 Km

Altitude / Electron Density #/cm³

Electro-Magnetic Correlation

Comparison beetween ground-based magnetic data from the CLF station and the SPECTRE TEC for this location.

(30 days data, 1 minute sample rate)

(1 day detail)

A correlation can be observed with a 14h30 delay between the two signals.

Post-Seismic Waves Investigation

Special feature of the SPECTRE Service is the hodochron layout. This data processing shows the propagation of post seismic waves in the ionosphere. By filtering the signals between 4.8mHz and 5.8mHz we can observe the waves of 200s period which disturb the ionosphere.

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Epicentrale distance(Km) / time (hour)

(ionospheric waves for the 8 October 2005).
Post seismic waves can be observed for major Earthquakes in close Areas. Theses kind of signals are too weak in Europe to be seen.

JASON / SPECTRE Correlation

The Jason satellite displays TEC DATA used for the altimetry correction. Theses data have been recolted and compared to the SPECTRE Data.

TEC Comparisons between JASON and SPECTRE (orbits over Europe)

(Jason traces over Europe and SPECTRE TEC).

The SPECTRE dynamic seems to have a larger dynamic range. Test have been made for the Topex satellite, but the TEC is not available for the land area.
(only water-area).

DEMETER/SPECTRE Correlation

The scientific objectives of DEMETER are the survey of the Earth electromagnetic environment, and the ionospheric perturbations linked to the seismic activity. (TEC is measured in-situ).

TEC compaison between DEMETER and SPECTRE over Europe. (low disturbance day)

TEC comparison between DEMETER SPECTRE over Europe. (high disturbance day)

PRODUCTS LIST

SPECTRE is fully operational for Europe providing with 3 days delay :
The maps extensions are -15° West to 40° East and 30° North to 70° North,

- 30s TEC Data (piercing points, TGDs, IFBs, STEC).
- 30 s 2D TEC maps products (2.5°*2.5°).
- 15m 2D TEC maps products (2.5°*2.5°).
- 1H 2D TEC maps products (2.5°*2.5°).
- TEC movies, 5min sampling rate.

Time resolution of 30s is pass filtered to produce the 15 minutes and 1 hour maps.
The Data are free for the scientific applications. For any other use, please contact Noveltis.

TOOLS LIST

- **Registration** Get Raw products.
- **Registration** Comparison with the Demeter Satellite TEC Data.
- **Registration** Comparison with Jason satellite TEC Data
- **Registration** Comparison with Topex satellite TEC Data
- **Restricted** Hodochrone layout
- **Restricted** Comparison with IAGA electro-magnetic files.
- **Restricted** TEC Time-series Profiler (1day / 2 weeks).
- **Restricted** Others Advanced tools in progress.

CONCLUSION AND PROSPECTS

The SPECTRE project has demonstrated that GPS data can be used to infer the electrondensity 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 avalaibility and quality (1 second sample rate objective instead of 30seconds) 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:
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HOW TO ACCESS THE SPECTRE SERVICE :

http://ganymede.ipgp.jussieu.fr/spectre/
http://www.noveltis.fr/spectre/