SIRGAS

TOWARD A SIRGAS SERVICE FOR MAPPING THE IONOSPHERE'S F2 PEACK PARAMETERS

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GESA

UPC

gAGE

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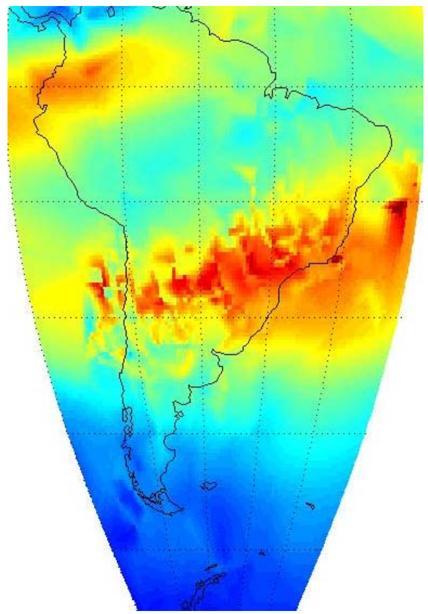
Introduction

✓ *As part of a regular service in the framework the IAG Sub-Comission 1.3b (SIRGAS), La Plata National University computes hourly maps of vertical TEC for South America.*

✓ *They are based on dual-frequency GPS observations from the SIRGAS Continuously Observing Network, and are computed using the La Plata Ionospheric Model (LPIM)[1].*

✓ *The service is operational since June 2006 and its products are available at www.sirgas.org.*

✓ *The present work is aimed to develop and validate a new SIRGAS ionospheric product: 4-D (λ, φ, h, t) maps of the electron density distribution based on the ingestion of dual-frequency GPS data into a physical model of the Earth's ionosphere.*



Outlook of the presentation

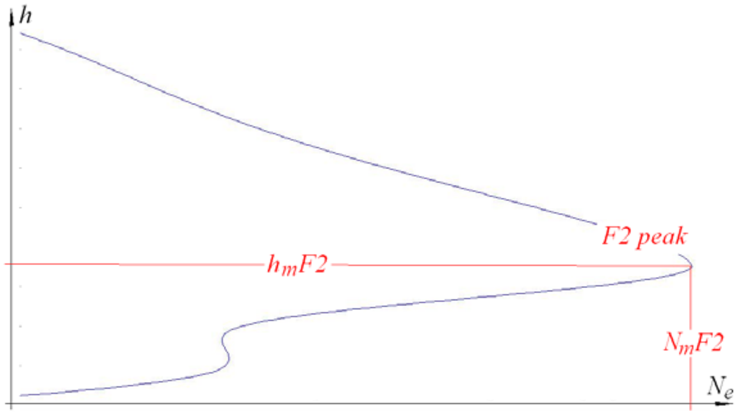
1. The physical model (NeQuick)
2. Adaptation of NeQuick for GPS-data ingestion
3. Data ingestion procedure
4. Results
5. Validation

1) Brunini et al, 2008. South American regional maps of vertical TEC computed by GESA: a service for the ionospheric community, JASR, 42, 737-744.

The physical model (NeQuick)

- ✓ Among other applications, NeQuick[1] is used by Galileo for single frequency operation.
- ✓ It is an empirical model of the Earth's ionosphere that allows computing the electron density (N_e) at any given location and time (λ , φ , h, t).
- ✓ NeQuick is driven by 2 parameters: the electron density (N_mF2) and the height (h_mF2) of the F2 peak:

$$N_{eNQ} = F(\varphi, \lambda, h, t \mid N_m F2, h_m F2)$$



- ✓ N_mF2 and h_mF2 can be measured (with ionozonde where available) or computed from a global database (the ITU-R –formerly know as CCIR– database).
- ✓ The ITU-R database[2] provides monthly mean values based on observations collected between 1954 and 1958 by a world-wide network of ~150 ionozondes concentrated in USA and Europe.
- ✓ These monthly mean values can be significantly deviated from the actual values and produce large errors in the NeQuick electron density distribution.

1) Radicella & Leitinger, 2001. The evolution of the DGR approach to model electron density profiles, JASR 27 (1): 35-40.

2) CCIR Atlas of Ionospheric Characteristics, Comité Consultatif International des Radiocommunications, Report 340-4, International Telecommunications Union, Geneva, 1967.

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Adaptation of NeQuick for GPS-data ingestion

✓ NeQuick was parameterized as a function of N_mF2

$$N_{eNQ+} = N_{eNQ0} + \frac{\partial N_{eNQ}}{\partial N_m F2} \cdot \Delta N_m F2$$

where N_{eNQ0} is the electron density computed using the ITU-R value of N_mF2.

✓ The correction ΔN_mF2 was further parameterized as a time dependent expansion with geographical dependent coefficients:

$$\Delta N_m F2(\lambda,\mu,LT) = a_0(\lambda,\mu) + \sum_{i=1}^{I}\left\{a_i(\lambda,\mu)\cdot\cos\left(k\cdot\frac{2\cdot\pi}{24}\cdot LT\right) + b_i(\lambda,\mu)\cdot\sin\left(k\cdot\frac{2\cdot\pi}{24}\cdot LT\right)\right\}$$

μ being the 'modip' latitude.

✓ Finally, the geographical dependent coefficients a_i and b_i were parameterized by means of a spherical harmonics expansions

$$a_i(\lambda,\mu) = \sum_{l=0}^{L}\sum_{m=0}^{M}\left\{u_{lm}\cos\left(m\cdot\lambda\right) + v_{lm}\sin\left(m\cdot\lambda\right)\right\} P_{lm}(\sin\mu)$$

which gives 12.514 coefficients u_{lm} and v_{lm} for $I=24$, $L=15$, and $M=9$.

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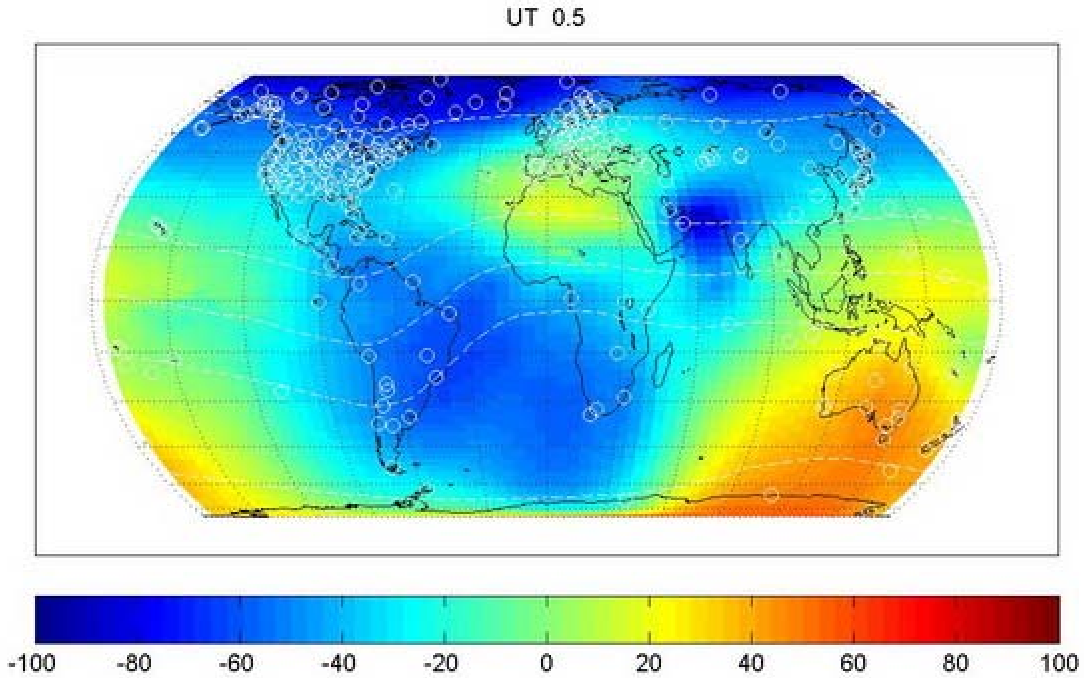
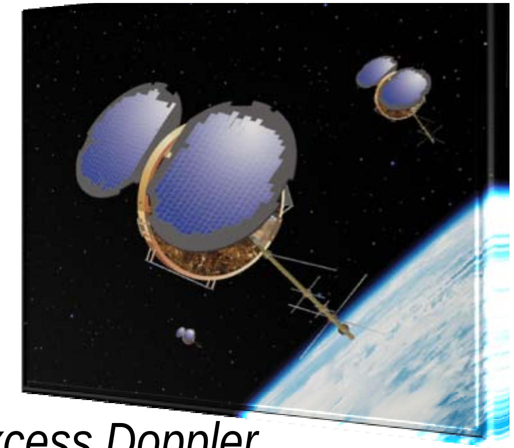
GPS-data ingestion into NeQuick

- ✓ *Dual-frequency GPS observations from a global network of 311 stations.*
- ✓ *Slant TEC calibrated with the La Plata Ionospheric Model (LPIM).*
- ✓ *Estimation by Least Squares of the 12.524 coefficients u_{lm} and v_{lm} constrained to minimize the square of the difference between LPIM and NeQuick slant TEC.*
- ✓ *The movie shows the $\Delta N_m F2$ correction as a percentage of the $N_m F2$ value compued form the ITU-R database (one plot per hour).*



- *FORMOSAT-3/COSMIC constellation*
  - *Constellation Observing System for Meteorology Ionosphere and Climate*
  - *6 Satellites launched in April 2006: alt=800km, Inc=72deg, eccentricity=0deg*
  - *Quasi-operational GPS limb sounding with global coverage in near-real time*
  - *Climate Monitoring & Geodetic Research*



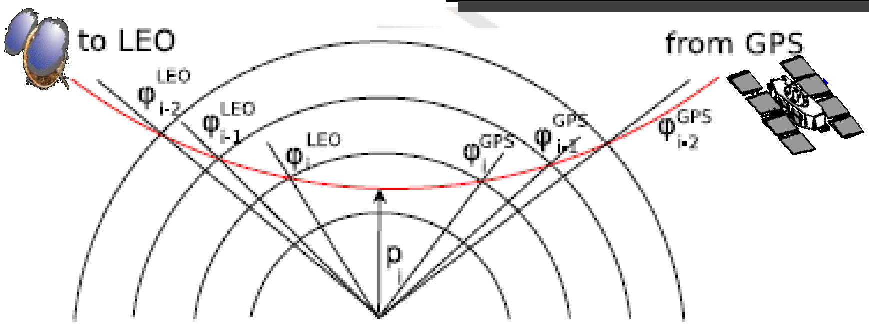
- *Improved Abel inversion applied to bending angles derived from L1 excess Doppler*

Separability hypothesis:

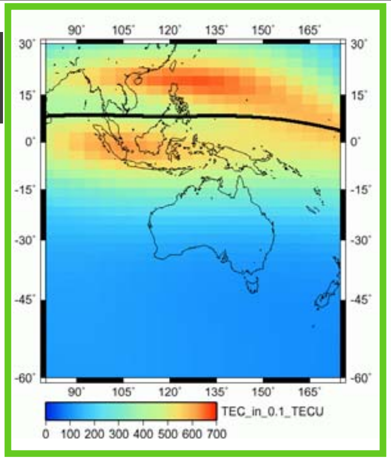
$$N_e(LT, LAT, H) = VTEC(LT, LAT) \cdot F(H)$$

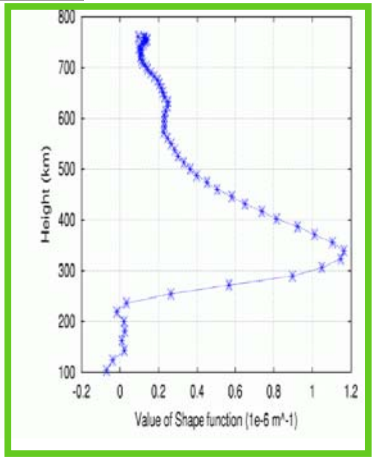
vs. Classical hypothesis:

$$N_e(LT, LAT, H) = \Phi(H)$$



- *Recursive solution starting from the outer ray.*
- φ_i *: bending angle of the ray with impact parameter* p_i*.*





VTEC information externally provided

Shape function: New unknown

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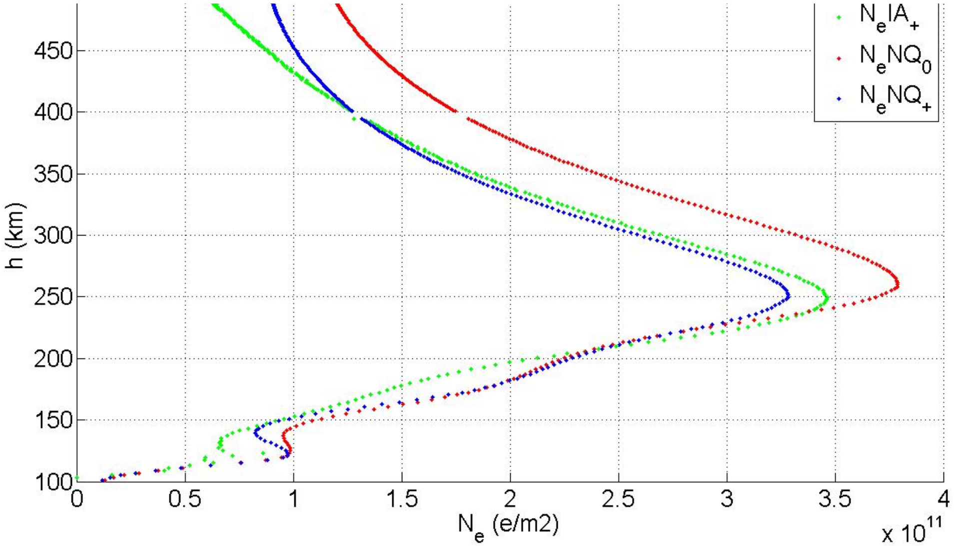
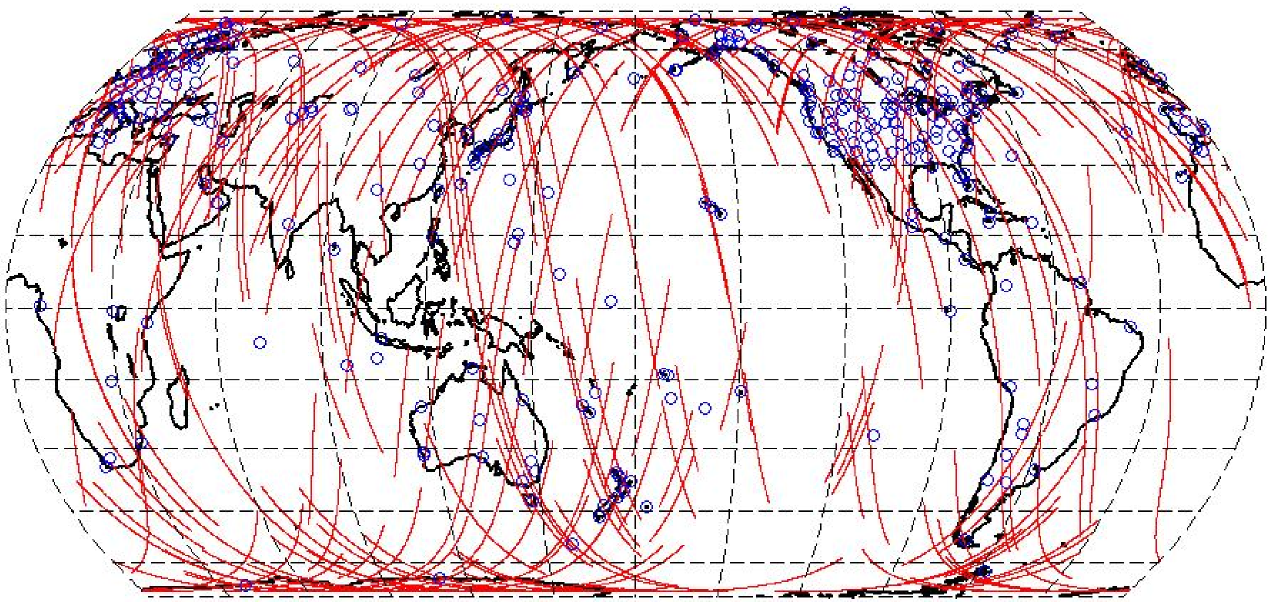
Validation

Electron density profiles computed with NeQuick before (red) and after (blue) GPS data ingestions compared to electron density profiles retrieved from GPS-FORMOSAT-3/COSMIC occultations (green) by Improved Abel inversion[1].





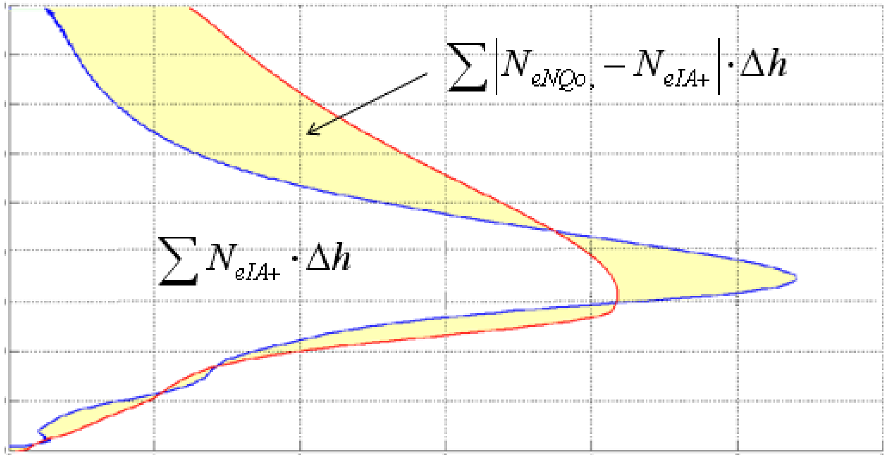
557 profiles for January 6, 2007.

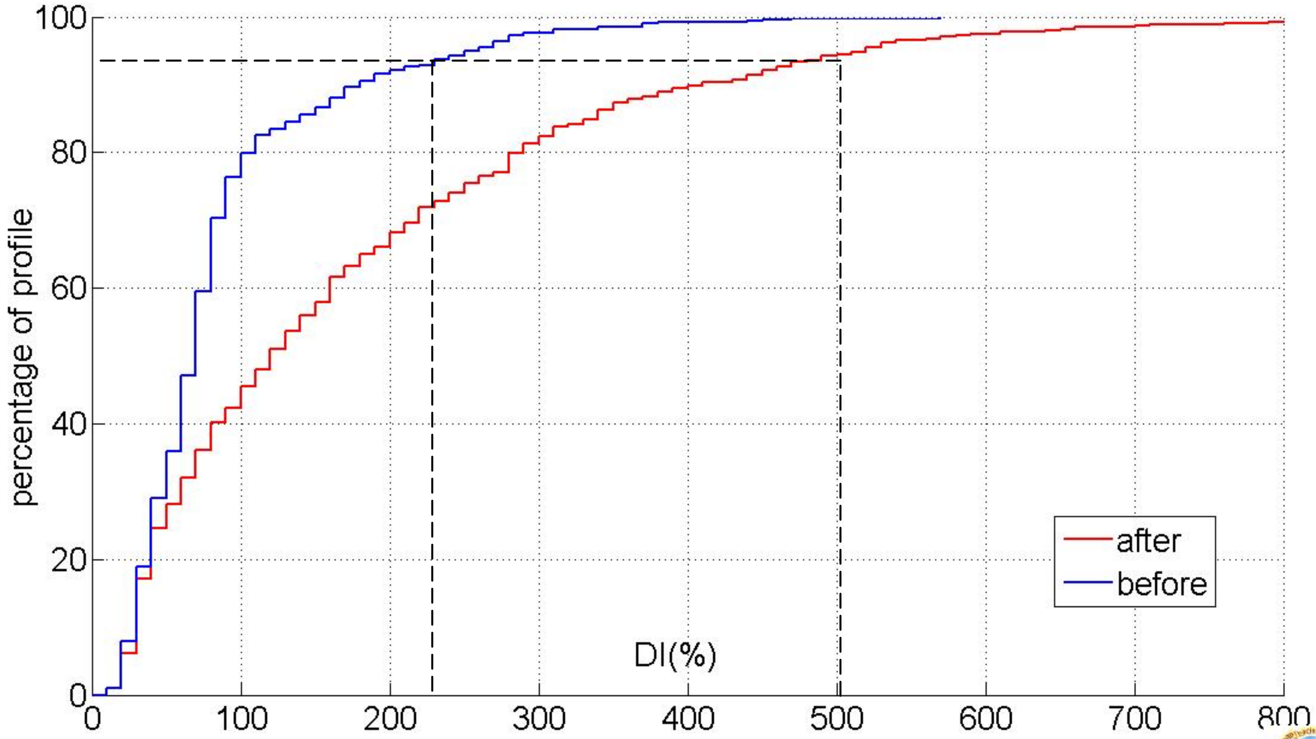
1) Hernández-Pajares et al., 2000. Improving the Abel inversion by adding ground GPS data to LEO radio occultations in ionospheric sounding. GRL 25 (16) 2473-2476.

Conclusions

The agreement between NeQuick and GPS-FORMOSAT-3/COSMIC occultation profiles was evaluated by the so-called 'discrepancy index'

$$\Delta I(\%) = 100 \times \frac{\sum \left| N_{eNQ} - N_{eIA} \right| \cdot \Delta h}{\sum N_{eIA} \cdot \Delta h}$$





Discrepancy indexes are reduced to ~1/2 after data ingestion; e.g.: the 95% percentile is reduced from ~500% to ~225%.