Preliminary results on new Radio Occultation Ionospheric Sounding Techniques applied to COSMIC/FORMOSAT-3 data

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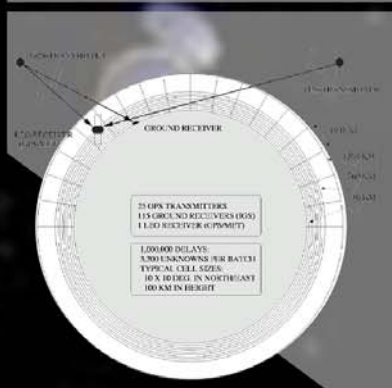
PREVIOUS WORK: USING IONOSPHERIC CARRIER PHASE AS MAIN DATUM

•The GNSS occultation dual-frequency carrier phase data can be used to estimate the electron density **without any apriori solution**: (1) In a global framework combined with ground GNSS data (i.e. in a 3D voxel model), or (2) using just the single occultation data, with the classical Abel transform inverse.

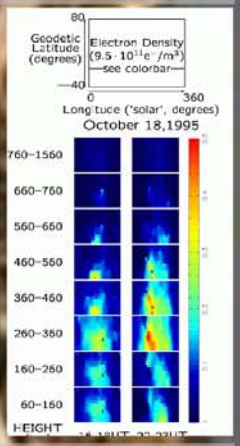
•Pros of Abel with LI vs. 3D voxel models are (I) the high vertical resolution and (II) low computational burden, but with the cons of (I) assuming spherical symmetry and (II) neglecting sounder topside ionospheric content.

•An improved Abel transform approach, including the TEC information and modeling the topside electron content, was proposed by the authors some years ago.

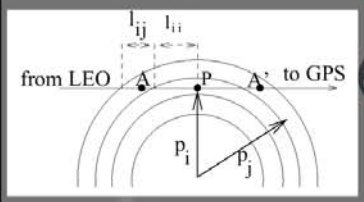


3D VOXEL MODEL

When estimating electron density in a 3D Voxel model (regional/global) different kind of data are mixed: occultation and ground GPS data.



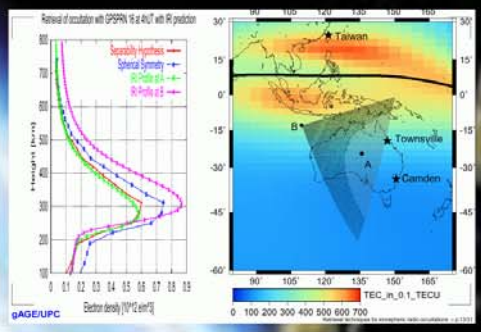
CLASSICAL ABEL APPROACH VS SEPARABILITY CONCEPT



Separability approach:
VTEC to describe the horizontal variability of electron density (Ne). The new estimated value is the "shape function" (F) instead of the electron density.

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

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



Comparisons with ionosonde data (GPS/MET, CHAMP, SAC-C) confirm the electron density estimation (Ne) improvement:

a RMS reduction of 25-35% (20% in disturbed ionosphere) in Solar Minimum, and 35-50% in Solar Maximum.

The improvement in Ne estimates reaches up to 40% in E layer and ~ 50% in Es layer.

CONCLUSIONS

• Procedures to retrieve electron density profiles with high resolution and low computational burden (developed during previous LEO GPS occultation missions such as GPS/MET, SAC-C and CHAMP), have proven its validity with COSMIC constellation data as well.

• In particular we have illustrated as main points:

- The similarity in the results obtained from ionospheric carrier phase combination vs. the L1 bending angle procedure.
- The use of the improved Abel transform, modeling the horizontal gradients, is significant even in COSMIC data which corresponds to Solar Minimum.

• Moreover, it has been illustrated:

- The need to properly model the clock rate in the bending approach.
- The better suitability of bending approach, regarding to the ionospheric carrier phase combination one, in front of phase cycle slips.

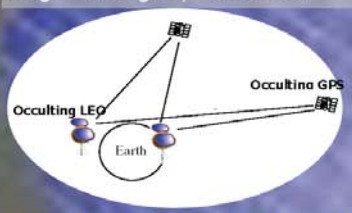
USING BENDING ANGLE FROM DOPPLER L1 PHASE EXCESS AS MAIN DATUM

• To compute accurate radio occultation inversion, it is necessary to remove the drifts of the GPS transmitter and receiver clocks from the raw phase data.

•The recent availability of the COSMIC/FORMOSAT-3 constellation provides an excellent opportunity to make a first test of all these aspects, some of them previously studied with data coming from former GNSS LEO missions.

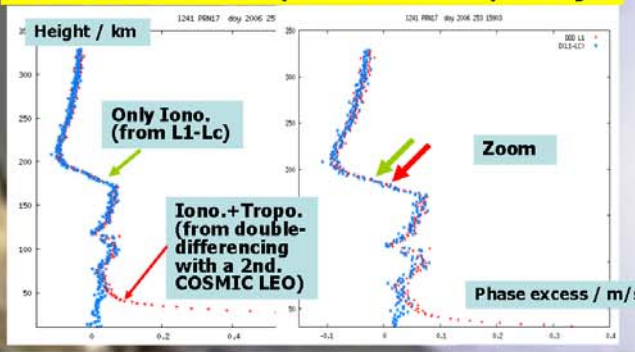
Crucial issue: the clocks drifts have to be removed either by (i) subtracting the ionospheric-free combination of carrier phases, or (ii) by working in double-differences regarding to a fiducial site. With the COSMIC LEO network completely deployed, a double differencing coverage is provided, hence the use of a second COSMIC LEO as reference receiver has been performed.

Otherwise, a completely unrealistic result (several orders of magnitude higher) is obtained.

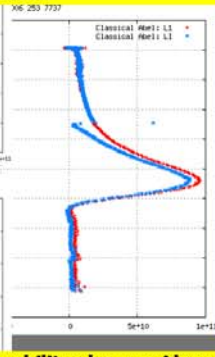


Alternative approach:
The linear combination of observables, Lc, has been used to remove the clock drift.

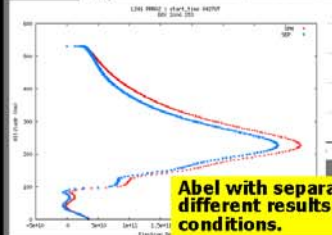
Both clock calibrations are equivalent for the ionospheric region



Abel tranform inverse from LI and from L1 bending are quite equivalent.



Under carrier phase cycle slips, the bending approach –red curve-, not based on consecutive differences of carrier phase as in the case of the LI method –blue points-, is less affected by cycle slips.



Abel with separability also provides significantly different results under present Solar Minimum conditions.

See more details in:

- Garcia-Fernandez, M., M. Hernandez-Pajares, M. Juan, and J. Sanz, Improvement of ionospheric electron density estimation with GPSMET occultations using Abel inversion and VTEC information, Journal of Geophysical Research, Vol. 108, No. A9, 1338, doi:10.1029/2003JA009952, 2003.

- Hernandez-Pajares, M., J. M. Juan, and J. Sanz, Improving the Abel inversion by adding ground data LEO radio occultations in the ionospheric sounding, Geophysical Research Letters, Vol. 27, 2743–2746, 2000.

- Hernández-Pajares M., J.M. Juan, J. Sanz and J.G. Sole, Global observation of the ionospheric electronic response to solar events using ground and LEO GPS data, Journal of Geophysical Research-Space Physics, Vol.61, p.1237-1247, 1998.