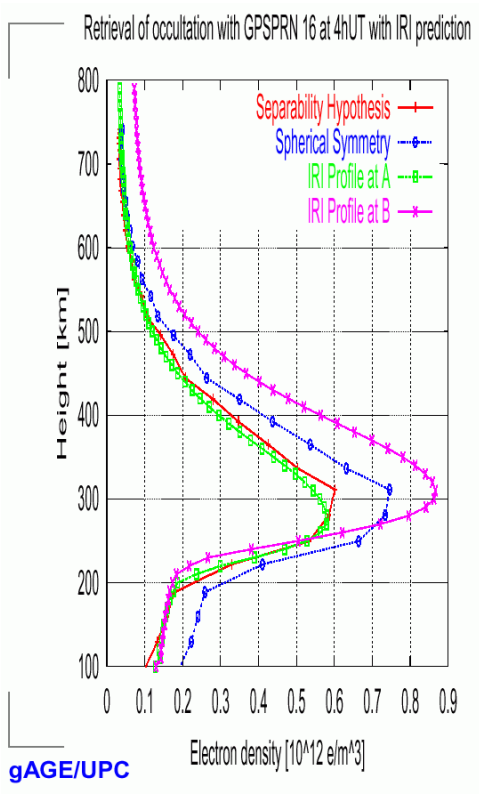
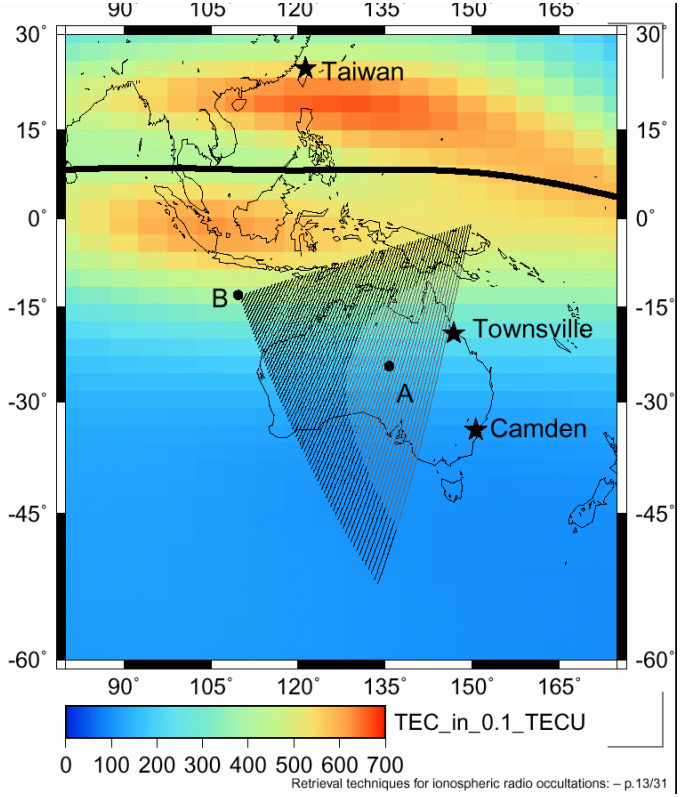
Ionospheric weather models: Electron Density Reconstruction

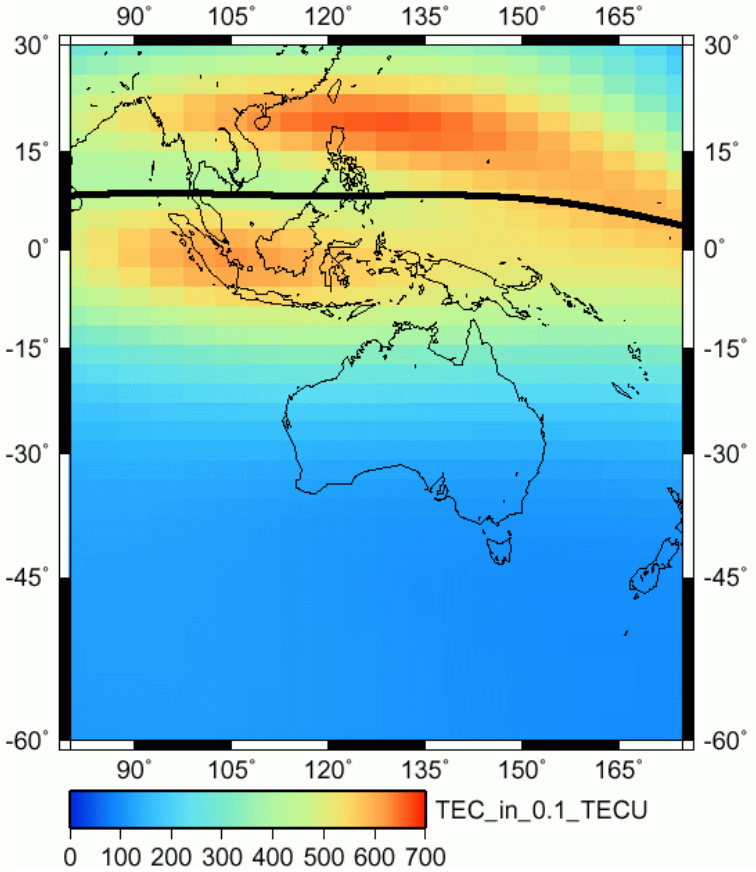


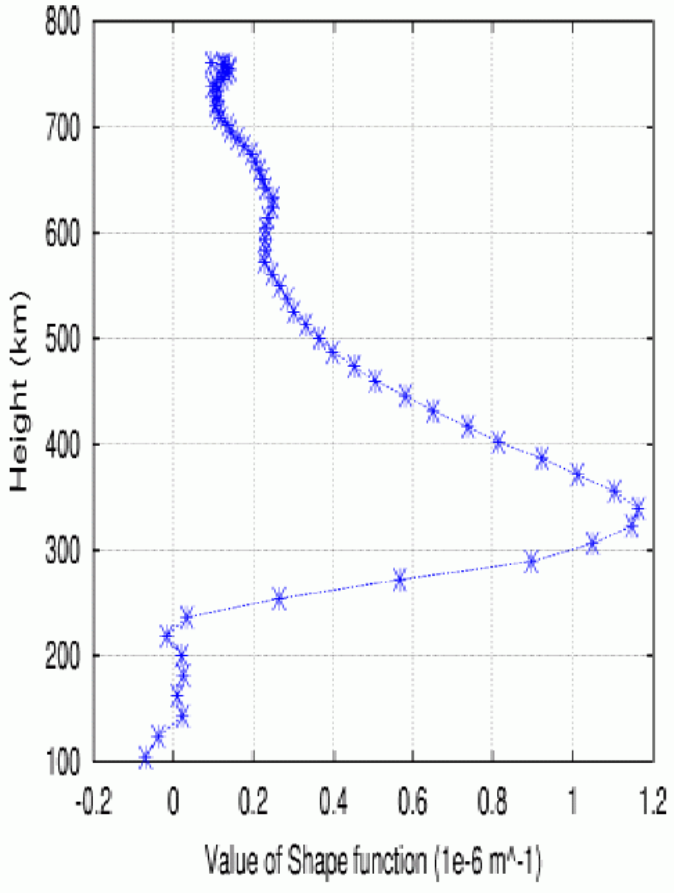


Anna Belehaki (1), Ivan Galkin (2) and Manuel Hernandez-Pajares (3)
(1) Ionospheric Group, IAASARS, National Observatory of Athens, Greece
(2) University of Massachusetts Lowell,USA
(3) UPC-IonSAT Research Group, IGS Associate Analysis Center, Spain

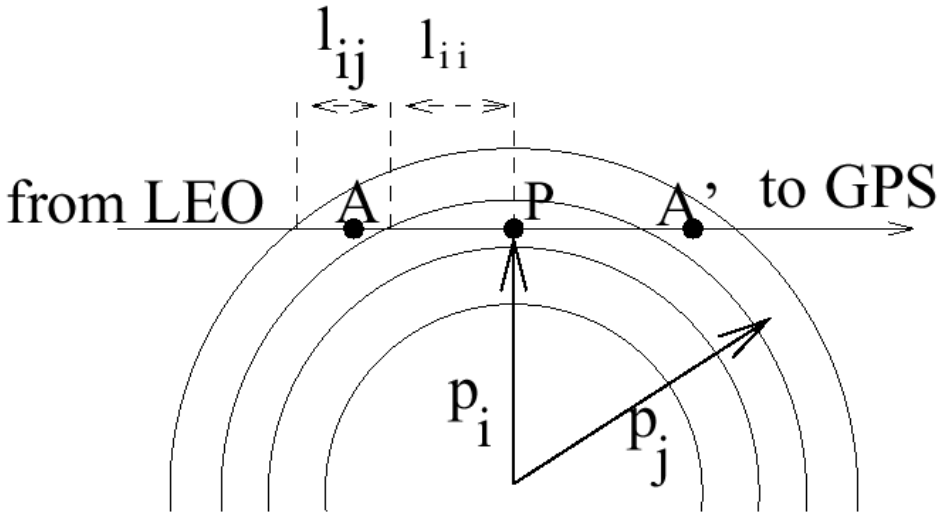
Improved Abel Inversion of GNSS Ionospheric Radio Occultations: Modelling the horizontal Ne gradient from VTEC GIMs

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





Classical Abel Inversion: VTEC is assumed constant in the occultation region (up to few thousands of km)



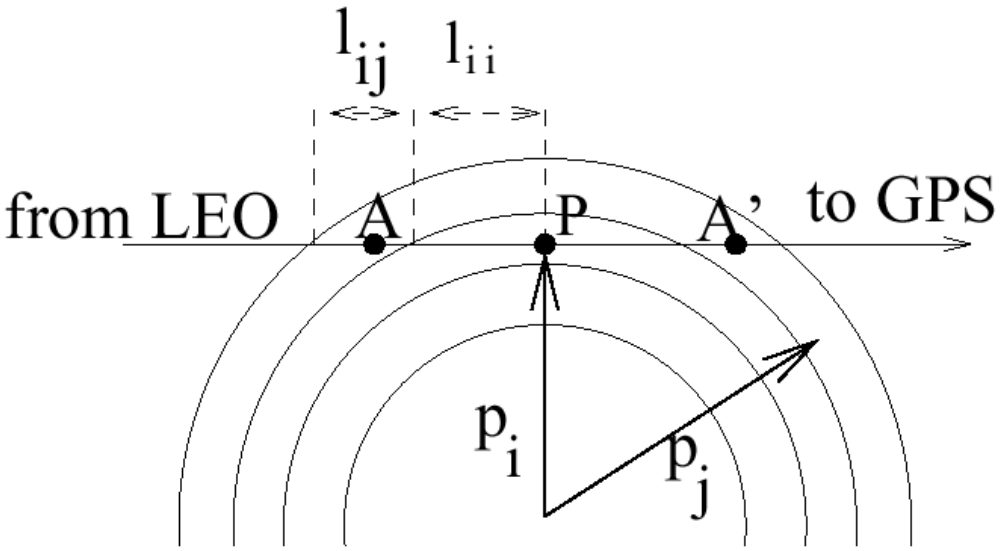
The classical spherical symmetry hypothesis can be formulatted as:

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

Recursive solution starting from the outer ray. STEC corresponding to the impact parameter p_i:

$$STEC(p_i) = 2 \cdot l_{ii} \cdot N_e(p_i) + \sum_{j=1}^{j=i-1} 2 \cdot l_{ij} \cdot N_e(p_j)$$

Improved Abel Inversion



Let's assume a more general hypothesis that just the spherical symmetry:

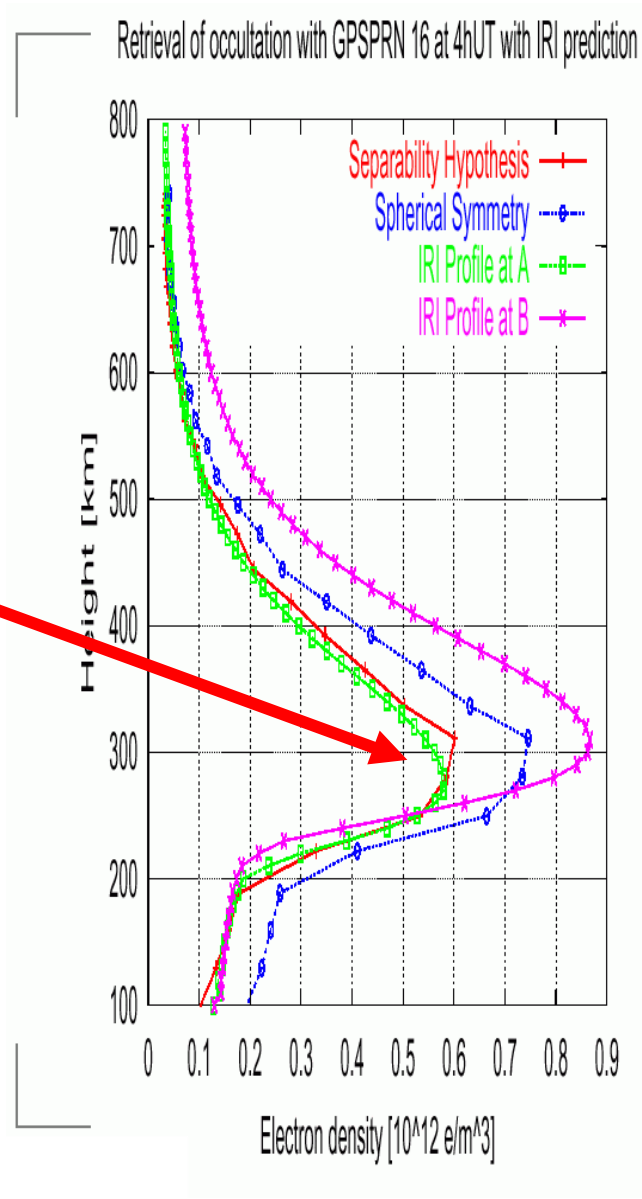
$$N_e(LT, LAT, H) = VTEC(LT, LAT) \cdot F(H)$$

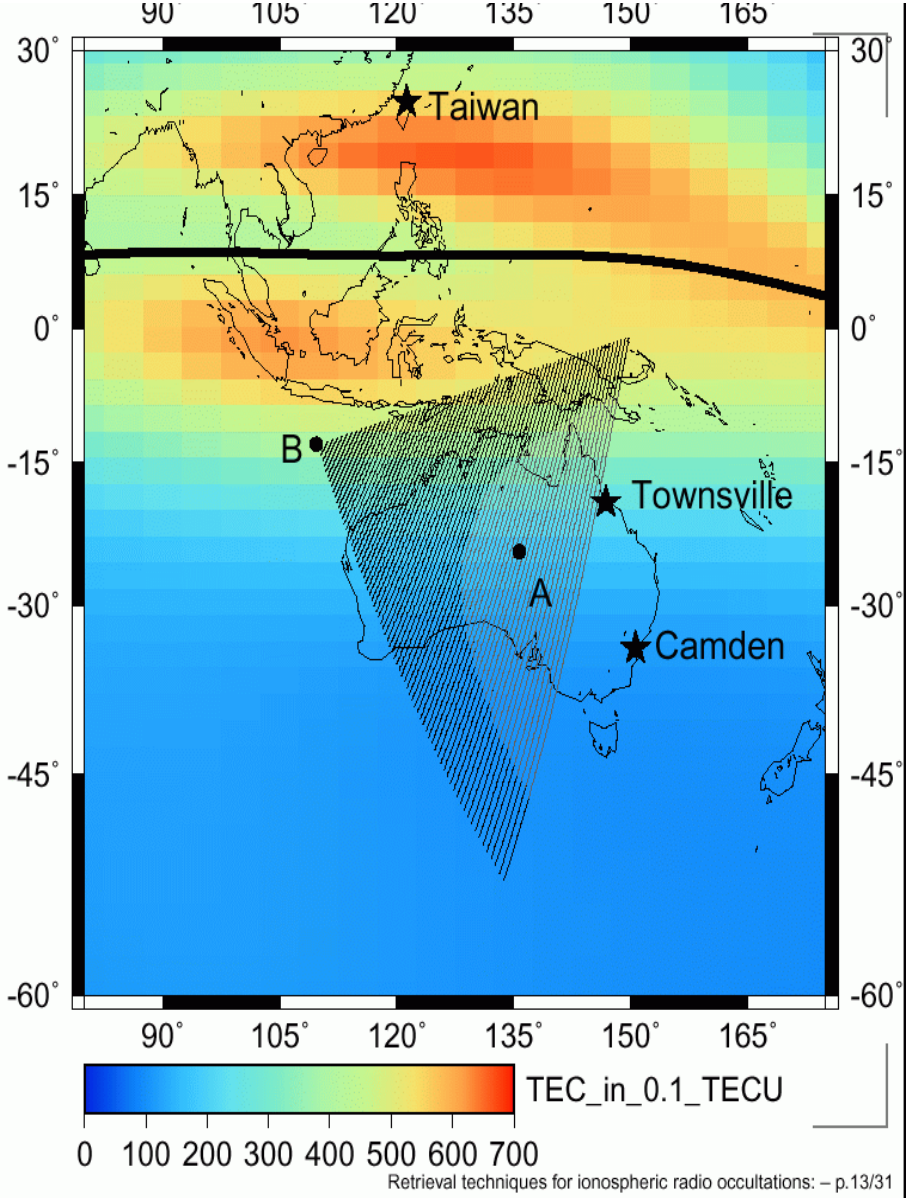
Starting from the outer ray, the STEC corresponding to the impact parameter p_i can be modeled by:

$$STEC(p_i) = 2 \cdot l_{ii} \cdot VTEC(LT_{ii}, LAT_{ii}) \cdot F(p_i) +$$
$$\sum_{j=1}^{j=i-1} l_{ij} \cdot \left[VTEC(LT_{ij}, LAT_{ij}) + VTEC(LT'_{ij}, LAT'_{ij}) \right] \cdot F(p_j)$$

Benefits of separability hypothesis

With the TEC (computed from ground GPS data) modelling the horizontal variation, the electron density at tangent point A (green) is estimated from the GPS occultation data better (red) that assuming spherical symmetry (blue).





Results with GPS/MET data during 11 days in Solar Cycle minimum (1995)

The improvement in f0F2 estimation is very clear using the improved Abel transform vs. the classical one: a reduction in the RMS of about 25% to 35%, at low and mid-high latitude (20% in disturbed ionosphere).

Table 1. Table of foF2 Errors With Respect to Ionosonde Measurement[a]

		N.comp	Sep.Hyp. RMS: MHz [%]	Sph.Symm RMS: MHz [%]
		Quiet Ionosphere		
Low	Day	177	1.2 [16.2]	1.6 [21.4]
latitudes	D&D	10	0.5 [9.7]	0.8 [14.5]
0° ± 30°	Night	100	1.1 [27.6]	1.3 [31.7]
Middle and high	Day	2054	0.7 [11.6]	1.1 [17.8]
latitudes	D&D	908	0.8 [19.1]	1.1 [25.9]
±30° ± 90°	Night	1122	0.6 [17.6]	0.8 [23.9]
		Disturbed Ionosphere		
Europe	Day	105	0.9 [17.7]	1.6 [31.2]
	D&D	94	0.7 [18.2]	1.2 [30.8]
	Night	32	0.4 [16.1]	0.8 [34.9]

[a]The error is Absolute RMS in MHz and Percentual relative RMS difference in brackets. The number of comparisons is also given.

Separability: improvement in E layer estimation

The improved Abel can provide reliable estimates of the NmE value as well (not just NmF2 values).

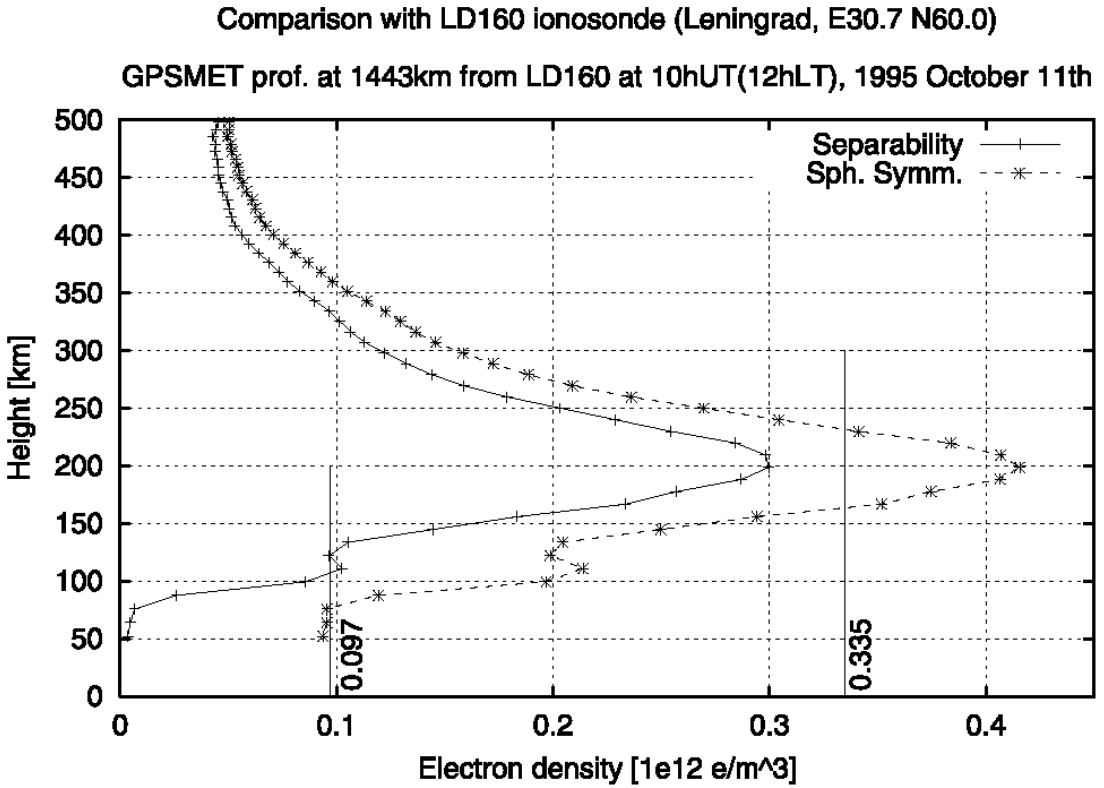


Figure 6. Effect of accumulative errors on the computation of the E layer electron density. The errors in the estimation of the upper layers strongly affects the lowermost layers. This particular example corresponds to an occultation of the GPSMET with the PRN20 at 11 October 1995 (day of year 284), 1000 UT (1200 LT), at E43.3 N44.9, compared with the corresponding NmF2 and NmE values obtained with the Leningrad Ionosonde.

Separability: improvement in E layer estimation

Table 2. Table of foE Errors With Respect to Ionosonde Value[a]

	N.comp	Sep. Hyp. RMS: MHz [%]	Sph. Symm. RMS: MHz [%]
E layer	135	0.4 [17.1]	0.7 [28.5]
Es layer	35	0.5 [16.2]	1.0 [30.4]

[a]The error is Absolute RMS in MHz and Percentual relative RMS difference in brackets.

The improvement in foE estimates reachs to a reduction of 40% in E layer and near 50% in Es layer

References & bibliography

- Garcia-Fernandez, M., Hernández-Pajares, M., Juan, J. M., & Sanz, J. (2005). Performance of the improved Abel transform to estimate electron density profiles from GPS occultation data. GPS Solutions, 9(2), 105-110.
- Hernández-Pajares, M., Juan, J. M., & Sanz, J. (2000). Improving the Abel inversion by adding ground GPS data to LEO radio occultations in ionospheric sounding. Geophysical research letters, 27(16), 2473-2476.