An Abel inversion method assisted by an improved IRI model for ionospheric RO data

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2019.9.23
1. Background

The most significant error of Abel inversion method to retrieve the radio occultation ionospheric observations is brought by the spherical symmetric assumption. The inversion error of F2 layer peak density can reach about 20% with the classic Abel method.

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- The inversion error of F2 layer peak density can reach about 20% with the classic Abel method.
Equatorial ionization anomaly (EIA) artificial wave

The retrieved Ne underestimates the truth in the EIA crest (±10°~30°), while overestimates near the equator (~±10°) and in the north and south of crests (±30°~50°).

(Yue et al., 2010)
2. Improved Abel inversion

The ratio of \( T \) to \( T^{sph} \) (observational field) is considered equal to the ratio of \( T_{mod} \) to \( T_{mod}^{sph} \) (modeled TEC) (Guo et al., 2015, JASTP).

\[
N(r_0) = -\frac{1}{\pi} \int_{r_0}^{r_{LEO}} \frac{dT(r)}{\sqrt{r^2 - r_0}} dr
\]

(Abel inversion)

- Accuracy of \( N_{mod} \) directly influence the result of TEC constraint, as well as the retrieved Ne.

\[
T_{mod} = \int_{r_{LEO}}^{r'} N_{mod} dl
\]

\[
T_{mod}^{sph}(r_0) = 2\int_{r_0}^{r_{LEO}} \frac{rN_{mod}'(r)}{\sqrt{r^2 - r_0}} dr
\]

(Improved approach)

\[
N^*(r_0) = -\frac{1}{\pi} \int_{r_0}^{r_{LEO}} \frac{dT^{sph}(r)}{\sqrt{r^2 - r_0}} dr
\]
3. Improved IRI

International Reference Ionosphere (IRI), describe the variation of electron density by means of a piecewise profile tied to the $F_2$-peak parameters: the peak electron density $N_{mF2}$ (or critical frequency $f_{oF2}$), the peak density height $h_{mF2}$ (or propagation factor $M_{3000F2}$).

- IRI depends on ITU-R maps to get the parameters value.
- The accuracy of peak parameters is crucial for retrieving reliable electron density estimations.
- IRI is welcoming to involve the latest advanced observations to improve their current system.
F$_{2}$ layer: COSMIC EDPs (Electron Density Profiles) → ‘NmF2’, ‘hmF2’ model

Topside: COSMIC podTEC → ‘scale height’ model

IRI

VTEC mean error compared to GIM

‘0’- IRI
‘1’- impIRI

(Wu et al., 2018, JGR)
4. Internal Validation

The occurrence of negative electron densities retrieved by Abel and improved Abel methods.

The number of unreasonable electron densities is largely decreased by about 26% in the day.
Observations EIA artificial wave

Abel

impAbel

Abel - impAbel
5. Validation by ionosonde

Match co-located RO events and ionosonde data within latitude ~2°, longitude ~10°, and 15 minutes. Equinox season.

(Wu et al., 2019, JGR)
6. Validation by GIM

COSMIC Abel retrieved field (~800 km)

GIM VTEC field (~20200 km)

COSMIC POD TEC field (>800 km)
The VTEC mean deviation is decreased from 0.384 to $-0.115$ TECU in 2008, and more than 1 TECU in 2012.
7. Summary

Abel EDPs → impAbel EDPs → New impAbel EDPs

implRI model → new implRI model

RMS: 2.77 2.36 2.31 TECU

(a) Abel

(b) impAbel

(c) 1st iteration

RMS: 2.77 2.36 2.31 TECU
Thanks!