Ionosphere Tomography using ØRSTED GPS Occultation Data and Comparisons with Ground-Based Radar Observations

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1 Abstract

Data from the Turbo-Rogue GPS receiver onboard the ØRSTED satellite are used to derive satellite-to-satellite Total Electron Content (G.B. Larsen et al., 2000). The observed Total Electron Content (TEC) has been used to calculate electron density profiles using ionosphere tomography. The tomographic solution is limited to the plane of ØRSTED’s orbit. Since a substantial amount of occultations does not take place in the exact anti-velocity direction but with some azimuth deviation angle, the solution considers the first 10° at each side of the orbital plane. The grid used for the tomographic solution along the satellite orbit of ØRSTED has a resolution of 9° in latitude, 120 km in height, and 5° in longitude parallel to ØRSTED’s orbit. A Kalman filter is employed to enforce smoothness with time. The electron density is then estimated for six different layers with heights ranging from 6560 to 7400 km (from the center of the Earth).

A different method to derive electron density profiles from individual occultations is based on the Abel transform (G.B. Larsen et al., 2000). The Abel transform assumes spherical symmetry which limits the accuracy of the derived profiles. Electron density profiles obtained with the tomographic approach are compared with electron density profiles derived using the Abel transform. To obtain high accuracy profiles, only occultations with small azimuth angles have been used.

To validate both methods, the derived electron density profiles are compared with ground-based electron density observations.

2 Comparisons

Figure 2.1 gives an example of the tomographic solution for November 23, 1999. (A detailed description of the tomographic method can be found in Rius et al. 1997, and Raffini et al., 1998.) TEC observations from 12 to 18 UT (3.6 orbits) including 46 occultations have been used as input to the calculations. In obtaining the tomographic solution the inclination of the ØRSTED orbit has been set to 90°. 0° corresponds to ØRSTED’s ascending node, which was at 216° in the Earth centered inertial system. The position of the sun is at 242° in the Earth centered inertial system and at a latitude of -22°. This gives local time (LT) values of about 10:15 LT on the ascending side, and 22:15 LT on the descending side. The four plots give electron density values for the different longitudinal planes parallel to ØRSTED’s orbit. The upper two plots represent solutions at +7.5°, and +2.5°, closer to the sun, while the lower two represent solutions for planes shifted by -2.5°, and -7.5°. Heights extend from approximately 180 km to 1000 km. Electron density values at longitudes closer to the sun show higher values at both, day- and nightside, as expected. The disappearance of the lower F-region can be seen on the descending side.

The quality of the tomographic solution depends on the amount of evenly distributed data in time and space. Because of the particular spatial distribution of ØRSTED and the GPS con-
Figure 2.1: Tomographic solution for November 23, 1999. TEC observations from 12 to 18 UT (3.6 orbits) including 46 occultations have been used as input for the retrieved electron density distributions.
Figure 2.2: Electron density profile on November 23, 1999 (upper panel) and February 12, 2000 (lower panel). Dashed lines indicate ionosonde electron density observations, solid lines give the electron density obtained by using the Abel transform and symbols represent the tomographic solutions of the different longitudinal planes (positive closer to the sun).
stellation, there is lack of data at certain times.
When occultations are too sparse for a full tomographic inversion, individual occultations can be analyzed by adding constraints. Assuming a spherically symmetric ionosphere, one can obtain the electron density profile by solving an Abelian integral equation.
Electron density profiles obtained from the tomographic solutions are compared to profiles derived using the Abel transform and ground-based electron density observations. This is done by comparing results where the latitude of the tomographic solution is closest to the latitude of the tangent point of the ray at a height of 300 km. Figure 2.2 shows two comparisons for November 23, 1999, 15:38 UT and February 12, 2000, 7:42 UT. Dashed lines indicate ionosonde electron density observations, solid lines give the electron density obtained by using the Abel transform and symbols represent the tomographic solutions of the different longitudinal planes (positive closer to the sun).

3 Summary
The comparisons have shown that both the tomographic solution, as well as electron densities derived using the Abel transform, agree quite well with ground based observations. It has been found that the major reasons for discrepancies between the tomographic solution and results obtained by applying the Abel transform are due to using input data from several orbit revolutions of ØRSTED and the smoothing procedures employed. While performing the tomographic inversion using just one occultation as input results in close agreement with the profile derived using the Abel transform, the tomographic inversion using occultations from 3.6 revolutions can occasionally lead to physically unrealistic profiles. Once more observations for each revolution of the ØRSTED satellite become available, occultation data from one revolution may be enough to perform the tomography. The quality of the tomographic results strongly depends on the distribution of the input data. Data gaps could be filled by using a global ionospheric model. Discrepancies between profiles obtained with the Abel transform and ground-based observations are found to be related to the assumption of spherical symmetry. A relative maximum or minimum in electron density at the tangent point will result in a negative or a positive bias respectively.

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References:

