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Ionospheric Profile Retrievals using 1D-Var with COSMIC-2 Bending Angles

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This paper describes, and validates, a technique of retrieving ionospheric profiles using a 1D Variational (1D-Var) assimilation system using bending angles derived from FORMOSAT-7/COSMIC-2 data. Traditionally when assimilating slant total electron content (STEC) observations into ionospheric data assimilation models an estimate of the Differential Code Biases (DCBs) are required. These can be estimated by the data provider or, alternatively, DCBs are commonly estimated during the assimilation step in many models by including them in the state vector. However the uncertainty in the DCB estimation, and its impact on the final analysis, is often overlooked. To overcome the challenge of DCB estimation in this work the derivative of STEC with respect to the impact parameter, a, (dSTEC/da), has been assimilated. This quantity is to a good approximation the L2 minus L1 bending angles, plus a term including the electron density at the LEO satellite. Using a simple "Vary-Chap" model with a 1D-Var retrieval code assimilating the STEC derivative, ionospheric profiles are reconstructed. These retrievals are compared to the Level 2 F7/C2 products and validated against ionosonde observations. The study looks at all COSMIC-2 retrievals within 200 km of an ionosonde with "well"-scaled ionograms from 2020, resulting in a comparison of over 10,000 occultations.

It is shown that the using a single layer Vary-Chap profile this 1D-Var retrieval has an ~11% absolute error in specification of NmF2, compared to a 3% error from the Level 2 F7/C2 profile. However, a four layer Vary-Chap model has only a 0.9% error across the entire study. Whilst the F2-peak is an important parameter and a good indicator of how well the 1D-Var retrieval is working, the reason behind using the Vary-Chap layers is to reconstruct the full ionospheric profile. To assess the bottomside performance all of the ionospheric profiles (from the ionosonde, COSMIC-2 and the 1D-Var) are interpolated onto the same altitude grid, at 1 km resolution, and the root mean square error (RMSE) at each altitude is then calculated. The resulting RMSE altitude profile is shown in Figure 1.

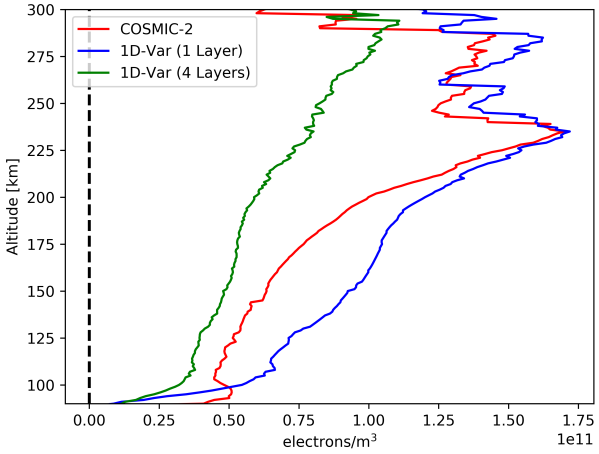

Figure 1. Root mean square error (RMSE) altitude profiles for COSMIC-2 and the 1D-Var retrieval with only an F2 layer (blue) and F2+F1+E+Topside layers (green) compared to ionosonde observations.

This shows that the 1D-Var retrieval with one-layer (F2) performs very similarly to the COSMIC-2 profiles throughout the bottomside. Above 225 km there is no statistically significant differences in the results. However the four-layer (F2+F1+E+Topside) 1D-Var retrieval shows an excellent performance throughout the altitude range, with an improvement over COSMIC-2 by approximately 40%.