

4D-var estimation of exhaust emissions by North Korean rockets

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In this paper, a four dimensional variation (4D-Var) data assimilation technique is used to characterize ionospheric holes created by North Korean ballistic missiles/rockets launched over South Korea. The ionospheric holes were assumed to be created due to a chain reaction between ions, electrons and neutral molecules (in this case H₂O and H₂) deposited in exhaust plumes. The neutral molecules dispersion model was developed based on advection-diffusion equation, and spherically symmetric diffusion assumed. Synthetic data (slant total electron content; STEC) that were generated using the exact GPS-receiver geometry over the South Korean region were utilized in validating the 4D-var technique. The reconstructed three dimensional structures nearly matched the original assumed ionospheric holes. Furthermore, applying the adjoint optimization technique to the observed STEC data we were able to estimate the amount of rocket emissions.

Keywords: 4D-var, Ionosphere, Rocket, Total Electron Content (TEC)