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How can Thermospheric Neutral Density (TND) estimates from CHAMP and GRACE accelerometer observations be used to improve empirical models?

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An accurate estimation of the Thermospheric Neutral Density (TND) is important to compute drag forces acting on Low-Earth-Orbit (LEO) satellites and debris. Empirical thermospheric models are often used to compute TNDs (along-track of LEO satellites) for the Precise Orbit Determination (POD) experiments. However, recent studies indicate that the TNDs of available models do not perfectly reproduce TNDs derived from accelerometer observations. In this study, we use TND estimates from the Challenging Minisatellite Payload (CHAMP) and Gravity Recovery and Climate Experiment (GRACE) missions and merge them with the NRLMSISE00 from the Mass Spectrometer and Incoherent Scatter family. The integration is implemented by applying a simultaneous Calibration and Data Assimilation (C/DA) technique. The application of C/DA is advantageous since it uses model equation to interpolate and extrapolate TNDs that are not covered by CHAMP and GRACE. It also modifies the model's selected parameters to simulate TNDs that are closer to those of CHAMP and GRACE. The C/DA of this study is implemented daily using CHAMP- and/or GRACE-TNDs, while using the Ensemble Kalman Filter (EnKF) and Ensemble Square-Root Kalman Filter (EnSRF) as merger. Compared to the original model, on average, we found 27% (in the range of 2% to 56%) improvements in the estimation of TNDs. In addition, the results of the C/DA are compared with the TND outputs of the JB2008 model along the CHAMP and GRACE orbits, whose results indicate that the daily C/DA outputs are 60% closer to the observed TNDs (that are not used for the C/DA). Overall, our assessment indicates that EnSRF results in more realistic TND simulation and prediction compared to those derived from EnKF. We show that the improved TND estimates of this study will be beneficial for Precise Orbit Determination (POD) studies.

Keywords: Thermosphere, Calibration and Data Assimilation (C/DA), NRLMSISE00, Ensemble Kalman Filter (EnKF), Ensemble Square-Root Kalman Filter (EnSRF)