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INVESTIGATING THE IMPACT OF UNMODELLED SOLAR EVENTS ON SATELLITE ORBITS THROUGH REALISTIC SIMULATION SCENARIOS

Abstract

Despite the significant improvements achieved in the development and calibration of empirical thermospheric density models, relatively large uncertainties remain in estimating density values during periods of enhanced geomagnetic activity, especially after Coronal Mass Ejections (CMEs) and Corotating Interaction Regions (CIRs). The aim of this paper is to enlighten the lack of sensitivity of the current empirical density models in case of intense solar events drastically modifying thermospheric density over short temporal and then spatial scales. This would be beneficial to improve the prediction of decay rates suffered by LEO objects and to reduce the current level of orbital propagation uncertainties obtained with empirical density models during periods of high to very high geomagnetic activity. Starting from density measurements derived from accelerometric data onboard the Gravity Recovery and Climate Experiment (GRACE) and the Challenging Minisatellite Payload (CHAMP) and taken during intense Solar-driven geomagnetic storms, we build global density enhancement maps with temporal, altitudinal, and latitudinal dependencies for different storm categories. Due to the lack of density measurements outside of the orbital regimes of GRACE and CHAMP, we estimate realistic trends based on theoretical predictions and density model outputs validated by tracking data. Finally, a full set of simulations is carried out to assess the full range of orbital decay rates that orbiting objects could show during periods of intense geomagnetic activity. This is done for different values of Area-to-Mass Ratio (AMR) and different orbital regimes by varying the semi-major axis, inclination, and altitude of perigee. Although extensive research has been done on density anomalies resulting from Solar storms from the point of view of thermospheric modeling, a full study on their impact on a broad range of satellite orbits is still worth being conducted. The results, if properly validated, would be useful for spacecraft operations, thanks to a better understanding of satellite decay caused by a sudden increase in density values. In addition, this research will benefit the tracking and monitoring of the space debris population, while simultaneously contributing to reducing the uncertainties in orbit propagation for collision avoidance purposes, especially in the case of objects with high Area-to-Mass Ratios.