

# Modeling Orbital Decay of Low Earth Orbit Objects Using CTIPe Atmospheric Density

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We evaluate the effectiveness of the Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) model in predicting orbital decay of low Earth orbit (LEO) objects, including satellites and space debris. LEO objects experience significant variations in orbital decay due to atmospheric drag in the thermosphere, which is influenced by thermospheric density distribution and variations. Since direct global observations of thermospheric density are challenging, thermospheric models like CTIPe are utilized to assess thermospheric conditions under varying solar activities.

To model orbital decay, we develop a linear regression model using thermospheric density at 300 km altitude from the CTIPe model as the explanatory variable and the orbital decay rate of the CHAMP satellite (~400 km altitude) as the target variable. The regression coefficients are derived using six geomagnetic storm cases from 2002–2003. Training data include 15-day periods before and after each storm onset (Dst index minimum). Two prediction models are constructed: (1) a model that does not distinguish between storm and quiet periods and (2) a model that differentiates storm phases from quiet conditions.

The experimental results indicate a generally linear relationship between CTIPe-derived thermospheric density and CHAMP orbital decay. However, distinguishing storm periods affected the model's effectiveness, and in some cases, CTIPe overestimated atmospheric density. The best-performing model achieved an R-squared value of 0.77 for orbital decay estimation based on CTIPe density. While the linear regression approach proved useful, its general applicability remains limited due to the small number of test cases. Additionally, the altitude discrepancy between CTIPe density (300 km) and CHAMP satellite (400 km) contributed to estimation challenges. Future research will explore alternative thermospheric models to enhance orbital decay prediction across a broader altitude range.

Keywords: Orbital Decay, CTIPe Model, Space Debris, Magnetic Storms, linear regression