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INVESTIGATION AND PREDICTION OF TWO-LINE ELEMENT ERRORS FOR OBJECTS IN THE IONOSPHERE

Abstract

With both the development of the US Space Surveillance Capabilities and the increase in the number of deployed satellites, the space-track TLE catalog that currently covers more than 20,000 objects keeps on building up. However, the uncertainty of the public database remains of the order of 1 km for Low Earth Orbit (LEO) objects. In this paper, the error of the public TLE data is characterized using accurate ephemeris data from more than 20 LEO satellites as truth data with altitudes between 500 km and 900 km.

First, we observe daily and yearly fluctuations of the TLE errors that come from gravitational effects. Second, at a given altitude, the satellite drag varies by several orders of magnitude depending on the solar activity and night/day effects. The F10.7 solar flux, and the K_p, a_p geomagnetic indices are used in current ionosphere models (e.g. NRL MSISE-00, ISO 14222). While the F10.7 solar flux gives a near real-time indication of the solar activity, only one value is available every day. The K_p index is available at a 3-hour rate but incorporates long-lasting effects that occur in the magnetosphere, such that is should be considered as an indirect indicator of the solar activity. Higher frequency and higher accuracy solar indicator are therefore needed.

The TLE error is primarily correlated with the ground track of the satellite and luni-solar terms, which allows to correct the error by a factor 2 to 3. We further incorporate the error on the satellite drag models by using a set of solar activity indicators based on time series of the F10.7 flux, and instrument data from the ACE spacecraft that measure the properties of the solar wind plasma in near real-time. The models are built on a set of polynomial regressions and multi-layer perceptrons (MLP) neural networks. Incorporating these effects allows to reduce the mean TLE error to accuracy approaching 100 m for the LEO objects. These improved TLEs pave the way to more accurate orbit determination and more accurate predictions of future collision risks based on accurate orbit propagators.