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A REVIEW OF EXISTING METHODS FOR REAL-TIME ATMOSPHERIC DENSITY CORRECTIONS

Abstract

Orbit prediction uncertainties are of utmost importance in Space Situational Awareness (SSA). In low-Earth orbits, atmospheric drag is the major source of uncertainty associated with conjunction assessment and collision avoidance operations. Drag effects are particularly difficult to model because they require knowledge of the thermospheric density, which is highly dynamic and stochastic and depends on external drivers, such as solar and geomagnetic activity. Therefore, real-time estimation and calibration of thermospheric density models have attracted substantial interest over recent decades.

To compute the neutral density for orbit calculations, empirical models of the thermosphere are generally applied because they are fast to evaluate. However, their accuracy is limited as they are based on temporally and spatially averaged density measurements and observations modeled by a closed-form parameterized formulation. Improved thermospheric densities can be computed through calibration of these models using recent data. On the other hand, physics-based models more accurately model the upper atmosphere (in particular during storm conditions) by solving fluid equations on a discretized grid over the volume of interest. This demands considerable computational effort. The number of variables also complicates the estimation of the atmospheric state through data assimilation. Real-time data assimilation is achieved using ensemble Kalman filters and by estimating external drivers. In addition to empirical and physics based data assimilation, various methods have been developed to locally or globally estimate the thermospheric mass density based on object tracking data, accelerometer data or atmospheric measurements.

To motivate this research area and facilitate the development of atmospheric density estimation techniques, this paper summarizes the existing methods and their associated applications in the field of astrodynamics. Frameworks of methods for density correction, the advantages and drawbacks of different methods, as well as potential directions for future efforts are also discussed.