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A MODEL OF SPACE DEBRIS METAL INJECTION INTO THE MESOSPHERE-LOWER THERMOSPHERE

Abstract

Meteors are a significant source of mesosphere-lower thermosphere (MLT) metals, including Fe, Mg, K, Na and Al. These MLT metals serve as tracers for atmospheric motion and are thought to interact with high-altitude cloud formation and stratospheric ozone depletion. However, meteors may not be the only significant source of MLT metals. Reentered space debris is an understudied source of MLT aluminum with the potential to match and outpace meteoric aluminum influx, considering the increasing reentry frequency. Quantifying anthropogenic metal influx into the MLT region is a crucial first step to understanding the environmental consequences of space debris disposal via reentry. This paper presents the first public model of debris-borne metal injection in the MLT region, coupling 1) a description of the space debris population and material composition, 2) a temporal and spatial distribution of reentries and 3) an ablation model. First, reentry objects are categorized by kind, such as rocket body or satellite, and by mass. Material composition for each debris category is estimated from representative objects. Second, historical reentry predictions from 2002 to 2021 are used to create a spatial and temporal distribution of reentry locations. This reentry distribution is sampled to determine if and where a reentry occurs and the kind of reentry object. Third, an ablation profile along the object's reentry trajectory is computed using a debris reentry ablation model. Combining all three components creates a temporal and global model of ablation emissions over altitudes between 100 and 50km. The predicted aluminum injection in the MLT region for 2021, 2002 and 2011 are presented. These years represent the highest, second highest and lowest number of reentries per year respectively. This debris metal injection model represents the first step towards modeling the consequences of human space activity in the MLT region. Future work includes embedding this model into a global 3D model of the MLT region to understand the global distribution of debris-borne metals.