Improving thermospheric drag modeling with EUV images: an FDL-X 2023 project

Tom
Berger
University of Colorado at Boulder, Space Weather Technology, Research, and Education Center
Shresth Malik, University of Oxford, Dept. of Computer Science
James Walsh, University of Cambridge, Dept. of Engineering
Giacomo Acciarini, University of Surrey, Astrodynamics Group

Oral

ccurately estimating spacecraft location is of crucial importance for a variety of safety-critical tasks in low-Earth orbit (LEO), including satellite collision avoidance and re-entry. The major source of uncertainty in LEO trajectory calculations is the variable drag force imposed by changes in thermospheric density in response to space weather. Current empirical and physics-based models, as well as many machine learning (ML) approaches, rely on daily solar irradiance and geophysical activity proxy indices as inputs, limiting their ability to capture the dynamic complexity of the system response to transitory solar flares and geomagnetic storms. NASA's Solar Dynamics Observatory (SDO) has been continuously capturing data since 2010, providing high resolution extreme ultraviolet (EUV) and magnetic field images that have recently been pre-processed into a ML-ready dataset (SDOML). In this work, based on a previously developed ML thermospheric density model (Karman), we process the SDOML images via a sigma-variational autoencoder to include embeddings of 12 EUV and magnetic field channels at a nominal 6- minute cadence. The model uses these as base-level irradiance drivers instead of the proxy indices, greatly improving temporal resolution and enabling accurate nowcasting of the short-term density response to solar flares. We validate the model against CHAMP, GRACE, and GOCE thermospheric density measurements to show that it achieves mean absolute percentage error values comparable to or better than existing empirical models such as JB08 and MSIS.

This work has been enabled by Frontier Development Lab (FDL.ai) a public/private partnership between NASA, Trillium Technologies and commercial AI partners Google Cloud and Nvidia.

Presentation file
wednesday-berger-thomas.pdf
YouTube link
View recording
Meeting homepage
4th Eddy Cross-Disciplinary Symposium
Download to PDF