Project Details

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Project Title:
Large-Scale Average Trends in Plasma Parameters Across the Heliosphere

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Summary:
Goals and Objectives. The goal of this project is to compile and synthesize historical datasets from in-situ spacecraft into a validated, machine learning (ML)-ready dataset consisting of solar wind parameters spanning the heliosphere. We focus on the fundamental plasma parameters (i.e., density, velocity, temperature, and magnetic field) and those derived therefrom (e.g., plasma beta). Our work has two phases. In Phase 1, we will compile and validate trends in these parameters with distance from the Sun. In Phase 2, we will extend these trends to include not only solar distance but also heliographic latitude. We will publicly release our merged, averaged, and ML-ready data along with our best-fit analytic models for these trends. These analytic models will provide summaries that can be readily utilized for initializing and validating global heliospheric simulations as well as for planning future deep-space missions.

Background. With advances in high-performance computing, global simulations can offer detailed predictions for variations in solar-wind plasma across the heliosphere. Initializing and validating these simulations with data from in-situ spacecraft can be challenging since such measurements are inherently localized. A vast network of in-situ spacecraft spanning the heliosphere would address this issue and revolutionize our understanding of the solar wind, but such a mission is entirely impractical. Nevertheless, many in-situ spacecraft have been sent across the heliosphere. After suitable adjustments for inter-calibration and solar cycle, their data can be taken together to reveal information about the solar wind's large-scale, average expansion -- the background" on top of which transient events (e.g., CMEs and CIRs) develop.

Data and Methodology. We will aggregate publicly available historical datasets from multiple spacecraft, including Parker Solar Probe (PSP), Helios 1 & 2, Mariner 2 & 10, Ulysses, Cassini, Pioneer 10 & 11, New Horizons, and Voyager 1 & 2. Measurements from these spacecraft span three orders of magnitude in solar distance across sixty years. We will pre-average each spacecraft's data to a common cadence. Then, using a well-established technique, we will correct for solar-cycle variations by scaling each average measurement by a time-shifted, contemporaneous, 1-au average value from the OMNI dataset. By binning the scaled, averaged data (first with solar distance and then also with heliographic latitude), we will reveal the large-scale, average trends in the solar wind. For ease of use, we will characterize these trends by using modern machine learning techniques, including non-linear chi-squared minimization and Gaussian processes.

Publication References:

no references