

## **Science gaps in understanding the near-Earth solar wind at mesoscales**

Olga P. Verkhoglyadova (JPL, California Institute of Technology), Panagiotis Vergados (JPL, California Institute of Technology), Justin S. Boland (JPL, California Institute of Technology), Jamie M. Jasinski (JPL, California Institute of Technology), Gary P. Zank (CSPAR, University of Alabama in Huntsville), Nicholeen Viall (GSFC) and Cate Heneghan (JPL, California Institute of Technology)

Parker Solar Probe and Solar Orbiter observations provided important information on solar wind streams or flux tubes up to distances of  $\sim 0.5$  AU from the Sun, proving their solar corona origin and general magnetic field alignment with Parker's model. However, the overall mesoscale properties of the solar wind near Earth remain unresolved. There is growing evidence that approximately 25% of the ambient solar wind is not oriented along the Parker spiral at 1 AU. Solar wind ion composition may change across the flux tubes. The relative abundance of different types of solar wind discontinuities that can bound flux tubes remains unknown. Uncertainty in ambient solar wind structure may account for CME arrival time errors of up to 10 hours at Earth and Mars. Incorporating realistic solar wind plasma and magnetic field properties at L1 into space weather forecasting models is critical for predicting the geo-effectiveness and time evolution of individual Solar Energetic Particle (SEP) events. The Panel on the Physics of Sun and Heliosphere for the 2024 Decadal Survey stated that mesoscale observations could reveal how large-scale solar wind variability cascades down to smaller scales, thereby affecting microphysical processes that are important for understanding and predicting solar wind behavior. HelioSWARM will address the long-standing puzzles of microphysical processes. However, the key properties of mesoscale solar wind turbulence (at  $<0.001$  Hz) that is ultimately injected into the inertial range is largely unexplored, i.e., turbulence spectrum, evolution of large-scale fluctuations, turbulence cascade, stationarity, and homogeneity. These properties are crucial for comprehensive understanding of SEP acceleration at interplanetary shocks and transport. We will outline several key science questions of mesoscale solar wind structuring and magnetic field turbulence at L1 that need to be addressed by multi-point measurements to improve space weather forecasting and to complement science goals of existing space missions.