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The Spatial Structure of the Oncoming Solar Wind at Earth and the Shortcomings of a Single Solar-Wind Monitor at L1

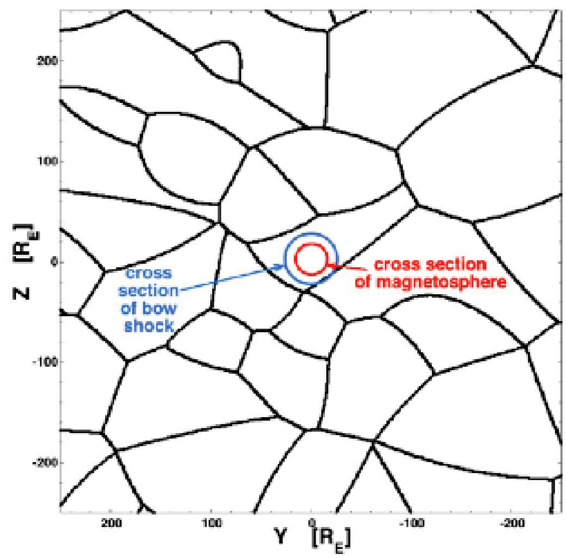

Figure 1: A visualization of the solar wind structure from dusk to dawn in the X=0, ZY cut-plane through the Earth's magnetosphere. The nominal shape of the magnetosphere is shown in red and the bow-shock position is in blue. Regions outlined in black represent individual flux-tubes. Optimal space weather forecasts occur when the L1 spacecraft is in the flux-tube that impacts the nose of the magnetosphere.

In a recent paper ACE/SWEPAM solar-wind flow-vector measurements and the properties of the ACE, Wind, and DSCOVR L1 orbits are used to estimate how well measurements of an upstream solar-wind monitor represent solar-wind properties hitting the Earth. The mesoscale (R_E to 100's of R_E) size of the solar-wind magnetic field structure approaching Earth is visualized in a Y-Z (GSE) plane upstream of Earth. The visualization is created with a modified Voronoi diagram generated to represent some statistical properties of the solar wind: (1) the Parker-spiral average alignment of solar-wind magnetic flux tubes, (2) observed variations in the orientation of individual flux tubes about the Parker-spiral direction, and (3) the observed variability of the diameters of individual flux tubes. (Note: A 2-D Voronoi diagram can be generated by drawing the boundaries about the sample of points on a plane that are closer to a given point than to any other point).

This paper visualizes and then discusses the magnetic-field vector structure and motional-electric-field structure of the oncoming solar wind, including variations of the clock angle of the solar-wind magnetic field. Using this visualization, two-spacecraft transverse-to-radial correlations of solar-wind magnetic fields are discussed, as well as a case of spacecraft on two sides of Earth seeing an extended period of very different solar-wind properties.

Solar-wind visualization is also used to discuss and quantify some shortcomings of using a single solar-wind monitor at L1 to determine the temporal properties of the solar wind that will hit the Earth. Those shortcomings are (1) the aberration of the solar wind, (2) the directional variability of the solar-wind velocity vector, and (3) the orbit of the monitor about the L1 point. ACE is in a Y=±40 R_E, Z=±25 R_E Lissajous pattern about L1, while DSCOVR is in a tilted ~90 R_E x 45 R_E semicircular orbit about the same center. This paper finds median monitor-to-streamline distances of just under 40 R_E, with the result that a single L1 monitor is usually not within the flux tube that hits the Earth. The 3 main contributions to the differences are: (1) aberration of the solar wind (10-23 R_E); non-radial velocity vector (14-47 R_E); and the L1 orbit (0 – 70 R_E).

This study shows that using a single spacecraft to study solar-wind driving of the magnetosphere system will not obtain the highest correlations, and that simulations of the reaction of the system to solar wind driving will not be the most accurate. It is suggested that a study could determine the optimum number of spacecraft in orbit about L1 to provide needed improvements in forecasting, or consideration could be given to placing solar wind monitors closer to Earth.

This study is in press for the ISROSES special issue of the Journal of Atmospheric and Solar-Terrestrial Physics. The item was submitted by J. E. Borovsky of the Space Science Institute in Boulder, CO. Address comments and corrections to jborovsky@spacescience.org. See the ACE News Archives for more ACE News items.