Compressions and Rarefactions in the Solar Wind

Dr. Heather Elliott/Southwest Research Institute

In this talk we examine the dynamic interaction between the fast and slow solar wind as the wind flows away from the Sun. We examine the dynamic interactions by sorting the compressions and rarefactions using the running average of the solar wind speed-time profile. We use this sorting to study how dynamic interactions affect the radial evolution of the solar wind temperature (T) - speed (V) distribution from 0.29 AU to 5.4 AU. We also use the compression and rarefaction sorting to examine the Kp geomagnetic index and solar wind speed relationship.

The solar wind temperature and speed are generally well correlated at ~1 AU, except in Interplanetary Coronal Mass Ejections where this correlation breaks down. Using measurements at 1 AU, we found that both the compressions and rarefactions T-V curves are linear, but the compression curve is shifted to higher temperatures. By separating compressions and rarefactions prior to determining the radial profiles of the solar wind parameters, the importance of dynamic interactions on the radial evolution of the solar wind parameters is revealed. Although the T-V relationship at 1 AU is often well described by a single linear curve, we find that the T-V relationship continually evolves with distance. Beyond ~2.5 AU the differences between the compressions and rarefactions are quite significant and affect the shape of the overall T-V distribution to the point that a simple linear fit no longer describes the distribution well.

Many forecasts of the Kp geomagnetic index rely on the upstream solar wind speed since the speed strongly correlates with the Kp index. However, the distribution of Kp and solar wind speed measurements is quite broad. To understand how common certain combinations of Kp and speed are, we plot the percentage of points in 2-dimensional Kp and speed bins using a color scale. Using these color Kp-solar wind speed distributions for compressions, rarefactions, and Interplanetary Coronal Mass Ejections (ICMEs) separately, we find that much of the variability in the Kp-solar wind speed distribution is attributable to the dynamic interaction between the fast and slow wind. We compare three different criteria for identifying compressions and rarefactions, and find that density criteria provide greater separation between compressions and rarefactions than dynamic pressure or speed-time slope criteria. However, the speed-time slope provides enough separation to be useful given that the solar wind speed has a long autocorrelation time, and can be predicted using solar observations (e.g. expansion factor models). To ensure our work can easily be incorporated into forecast models, we provide the Kp-speed distributions files for all three methods of identifying compressions and rarefactions. We describe a method to extend forecast lead times by estimating compression strength with a speed-time profile obtained from solar wind speed predictions based on solar, coronal, and/or heliospheric imaging observations.