Comparison of Ion Temperatures in the Magnetosphere as a Function of the AE Index Using TWINS ENA Data

Evan Aguirre, Amy M. Keesee, and Earl E. Scime, Department of Physics, West Virginia University

Presented here is a parametric study of the effects of substorm activity on ion temperatures. We have taken 3+ years of ACE Solar Wind Data and sorted by IMF activity, quiet time (<100 nT), moderate (100 < AE < 300 nT), and high activity (>300 nT). IMF polarity and solar wind speed, low (<400 km/s) and high (>400 km/s).

The temperature in each parametric bin are calculated using the methods of Scime et al. [2002,2005] and Keesee et al. [2008,2011] using ENA data supplied by the TWINS spacecraft. The results presented here show the global ion temperatures in an Earth centered 40 Re x 40 Re region projected onto the equatorial plane. The region within 5° of Earth’s limb is excluded from our analysis because of high collisionality that violates assumptions made in the projection and temperature calculation. A modeled magnetospheric boundary is typically used, but is ignored in certain cases to allow us to see effects that would be cutoff by the modeled boundary. The global and local features are discussed including some instrumental artifacts of the TWINS spacecraft.

### Methods and Observations

Up to 3 years of data from Jan 1, 2011 to Dec 31, 2013 are used in this study. An interval of choice is scanned for all sub-intervals that fit our desired solar wind parameters. Each sub-interval must have a minimum time of constant activity based on the number of instrument sweeps (ranging from 5 to 40) that we choose. Ion temperatures are calculated using a Line of Sight projection technique with spatial resolution of 0.5 Re x 0.5 Re in GSM coordinates and fitting the distributions to a standard Maxwellian distribution. The magnetospheric boundary used for most of our analysis is based on the Shue et al. [1997] model. This boundary is then neglected so that the reconnection effects near the boundary can be visualized more fully. These effects are primarily seen during a southward IMF and greater than 400 km/s solar wind speed.

### Instrumental Issues

Throughout the course of our study we noticed a cool spot on the dusk-side close to the magnetospheric boundary. It is almost every image. A similar cutout has been observed in the flux plots, and is believed to be due to the field of view being partially blocked by the instrument, as seen in the figure to the right. The lower left figure shows a plot of our projected ion temperatures, with the cutout visible. The lower right figure shows a plot of 12 keV flux, also with the cutout visible. This persistent block of ENA flux in the dusk region will make it difficult to draw conclusions about observations there.

A second issue with the TWINS instruments is accurately matching the signal between the two instrument heads. We have found this to be a particular issue with TWINS 2, though it is sometimes visible in TWINS 1. The voltages on the two heads are set at different levels, which can affect the sensitivity of each head. The effects of this can be seen in both figures to the right. In the flux plot, higher values are observed in one head (the inner, upper hemisphere and outer, lower hemisphere) while the other head indicates lower flux values. This also affects our ion temperatures measurements, as can be seen in the ion temperature plot, with higher temperatures in a shape similar to what is seen in the flux view.

### Energy Flux Plots

As an additional insight we decided to plot the flux versus energy during different activity levels. There are 19 levels of flux energy ranging from 2 keV to 60 keV. Of the 160 x 160 spatial bins we chose 4 bins at random during activity levels of moderate and high activity with a southward IMF. For moderate activity the spectrum tends to roll over at low energies. For high activity, the spectrum tends to increase at decreasing energies. This may be due to increased oxygen that typically populates the lowest energy bin when converting velocities to energies under the assumption that they are all hydrogen. Below are the relevant plots with the spatial indices (x,y) where x and y are converted to earth radii with the origin at Earth.

### Discussion

The most interesting observation we saw during our study was the overall lower temperatures during the high activity compared to the moderate and quiet activity. During the sub-storm expansion phase we see higher temperatures, most notably in the dawn-side for moderate activity. For high activity, after the buildup of the substorm, the temperatures cool off.

It is known that during a southward IMF magnetic reconnection occurs at the nose of the magnetopause and during a northward IMF it occurs at the polar cusps. As shown in the top center plots, heating is observed on the dawn-side for intervals of southward IMF. The absence of heating on the dusk-side could be due to a prevalence of reconnection toward one side, or a difference in viewing geometry. However, the instrumental cutout could also play a role in the absence of heating, so these results are inconclusive.

We also know that the Parker spiral angle changes with regards to solar wind speed. Although we do not go into a quantitative derivation of the Parker spiral angle, studies (Rager [2008] and Smith & Bieber [1990]) have shown that the angle depends in some form on the solar wind velocity. The difference in the Parker spiral angle during a fast solar wind could help us explain the heating that we see along the magnetospheric boundary.