EXAMINING EFFECTS OF CRUSTAL FIELD ON THE MARTIAN MAGNETOTAIL CURRENT SHEET.
K. E. Woods[1] and Y. Ma[2], [1]Pennsylvania State University, Department of Meteorology and Atmospheric Science, [2]University of University, Los Angeles, Department of Earth, Planetary, and Space Sciences

Introduction: No global magnetic field currently exists on Mars, but strong crustal magnetic fields remain in specific regions of the planet. These crustal fields complicate the interaction with the solar wind and the resulting induced magnetosphere, including the magnetotail and current sheet within. The Martian magnetotail contains two lobes, one with positive B_X components and one negative, and, between them, a thin current sheet. In the absence of crustal fields, these lobes would have a fairly vertical separation. However, studies have shown that twisting in the tail region is approximately 45 degrees either clockwise or counterclockwise depending on the sign of the interplanetary magnetic field (IMF) B_Y [2], confirming the effect of crustal fields.

It is unknown how the fields specifically affect the shape of the current sheet, so in this study, we will use both MAVEN observations and numerical model results to help us further understand these phenomena. The crustal field regions are located specifically in the older Martian southern hemisphere in mid to high latitudes [7], and with the rotation of Mars, the crustal fields that are facing toward the Sun would change with both local time and seasons. Using data from the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, we analyzed the structure of the current sheet in the magnetotail and how it changes under different conditions and with different tail distances.

Methodology: Here, we use MAVEN data from December 31, 2014 through December 31, 2018 and compared it to corresponding MHD model results explained in more detail in the next section. For MAVEN data, the selection criteria are as follows: X is less than -1.0 R_M in the tail region, solar wind conditions are available, and the IMF B_Y component is larger than B_Z. We split up the data based on the sign of IMF B_Y and we also split up the data based on crustal field orientations: Day, Dusk, Night, and Dawn. In addition to selecting the data, we also averaged it before plotting. In our high resolution plot, we created 3600 small bins each with area $0.01R_M^2$. Each bin was then averaged, because in some areas, there were many more data points than in others. This ensured fair comparison.

The coordinate system used is MSO. In this system, the x axis points from Mars toward the Sun, the y axis is antiparallel to the orbital velocity of Mars, and the z axis completes the system using the right-hand-rule [3].

Model Description: The model that was used here is a time-dependent multispecies single-fluid magneto-hydro-dynamic model that uses the BATS-R-US code from the University of Michigan [3]. Results of the model have been compared with both MGS [3] and MAVEN observations under quiet [4] and disturbed solar wind conditions[5,6]. The model's grid structure is nonuniform and spherical, and changes with location compared to the inner and outer boundaries. Typical values are assumed for the solar wind conditions. More details of the model can be found in Ma et al. (2014). There is a possibility that this can pose problems for the outcome of the plots if there is any variation within the pressure or direction of the solar wind. However, this model does tend to replicate observational data well, so it is used here confidently.

Results:

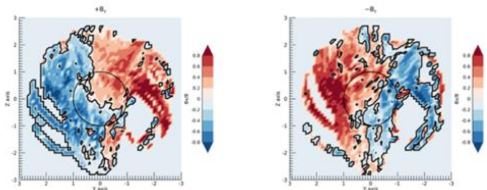

Figure 1: Plots for averaged IMF $+B_Y$ and $-B_Y$ conditions. These plots include all crustal field orientations.

Figure 1 shows that under different upstream conditions, there is a corresponding tilt in the separation of positive and negative B_X/B results. The plots show Bx/B, and the contour lines show where the current sheet can be found – where B = 0, the crossover from the negative magnetic field values to positive magnetic field values. When we split each of these plots up into their subsequent orientations: Day, Dusk, Night, and Dawn, we saw some noticeable changes. These can be seen in Figure 2.

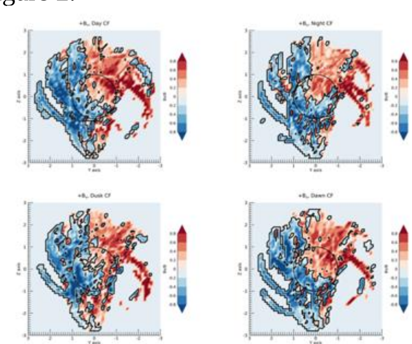

Figure 2: Plots for only IMF $+B_Y$ conditions separated into four averaged crustal field orientations: Day, Dusk, Night, and Dawn.

From the MAVEN observations, it seems that when the strong crustal fields are located on the dayside, the Day plot is most similar to the original data that can be found in Figure 1. As the data transitions from Day to Dusk, the clear separation becomes a lot choppier. The negative components seem to dominate in the central region that is enclosed in the circle. The Night current sheet is very curved, more so than any of the other orientations. Lastly, Dawn seems to return to what the overall averaged data shows, but the positive components of Bx still seem to dominate here.

An analysis for the negative IMF By condition was done in a similar way. It is important to note that the differences for each orientation did not mirror each other. The Day data did look similar to the overall averaged data, and the Dusk separation line also became steeper and less clear. However, the Night plot showed no curvature, and instead this feature was found slightly in the Dawn plots, showing that the patterns in the different upstream conditions should be investigated separately and not treated as one pattern.

After this analysis of only MAVEN data, we compared it to the model described previously. The model seems to have a more vertical tilt than the MAVEN data, but the general trends are the same. We used summer model data only because the original model plots were not representing the data well due to seasonal effects that are discussed in the next section. This change made comparison easier and showed that the model from Ma et al. accurately represents data received from MAVEN.

Lastly, we investigated the variation of tail current sheet configuration with tail distance. As the strength of the crustal field drops rapidly with distance from the planet, we expect its effect on tail configuration will also drop off with increasing distance.

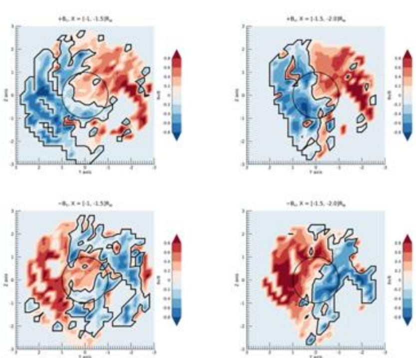

Figure 3: Low resolution plots showing change in current sheet with distance. The top row shows IMF +By conditions and the bottom row is with -By conditions. The left two plots are closest to Mars, and the right plots are farther down the tail.

As you can see, in the region closest to Mars, the current sheet is positioned horizontally, meaning it has a very complicated and heavily influenced configuration. As the distance increases, the sheet becomes almost vertical, showing that there is little influence from crustal fields. So, the biggest impact is close to Mars, as was predicted. This same analysis was done for the model, but we noticed that there were only slight differences as distance increased instead of drastic ones like we see in MAVEN observations.

Discussion: There are significant differences in the shape of the current sheet with different orientations of the crustal magnetic field on Mars. This was seen in both positive and negative IMF By conditions, but with different effects. In addition to this, we have seen that there is a change in this shape with increasing distance from Mars down the tail, as the effect from the crustal fields become less dominant. However, there is a lot more to be explored. Martian seasonal effects should be considered. These could potentially give some more insight as to how the crustal field can change shape due to conditions other than the regular Day, Dusk, Night, and Dawn crustal field orientations. Currently, the seasonal regions do not appear to be evenly distributed, but with more work on this topic, better analyses can be made.

Also, as MAVEN collects more data, it will be of interest to split the data into smaller distance regions from Mars so that we can see the changes with distance with more precision. At this point in time, there are not enough data points to adequately complete this investigation.

Acknowledgements: All figures were made using IDL software.

References: [1] Brain D. A. (2006) *Space Science Reviews, 126*, 77-112. [2] Dibraccio G. A. et al. (2018) *Geophysical Research Letters, 45*, 4559-4568. [3] Ma Y. J. et al. (2014) *Geophysical Research Letters, 41*, 1-7. [4] Ma et al. (2015) *Geophysical Research Letters*, 9113-9120.[5] Ma et al. (2017) *Geophysical Research: Space Physics.* 122. [6] Ma et al. (2018) *Geophysical Research Letters.* 45. [7] Nagy A. F. et al. (2004) *Space Science Reviews, 111*, 33-114.