FACTORS CONTROLLING THE POSITION OF THE MARTIAN MAGNETIC PILEUP BOUNDARY.

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Introduction: The magnetic pileup boundary (MPB) at Mars is the position where the dominant ion of the plasma changes from solar wind protons to heavy ions of planetary origin [1]. As such, it is the obstacle to solar wind ions. We investigate the factors that influence the shape and position of the magnetic pileup boundary at Mars in order to better understand the Martian obstacle to the solar wind. Employing MGS data, we determine how the Martian MPB moves in response to factors including solar wind pressure and crustal magnetic fields. We also study the factors affecting the thickness of the MPB. Further, we compare the magnetic pileup boundary to the magnetic barrier at Venus. Direct comparison aids in our interpretation of the physics involved in the solar wind interaction with planets lacking a significant intrinsic magnetic field.

MPB variability: As external influences fluctuate and Mars rotates under the Sun, the MPB moves in and out. Its variability is obvious in Figure 1, which shows the position of the MPB as a function of solar zenith angle. The superposed line is the fit by Vignes et al. [2] to the MGS MPB crossings. The variability can be caused by a number of factors, including changing solar wind dynamic pressure, EUV flux, convection electric field, and position of crustal sources. The entire MPB does not have to move in response to local perturbations.

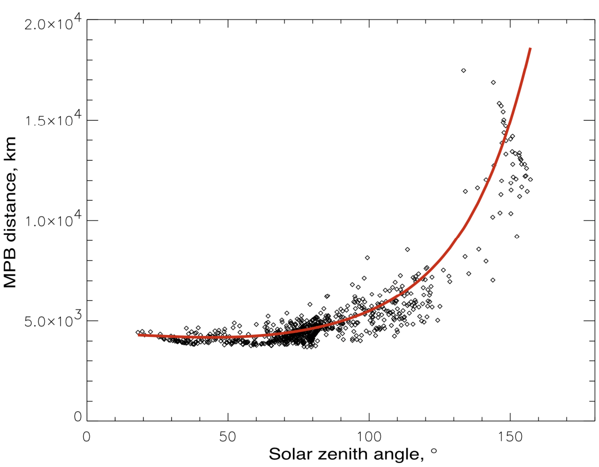

Fig. 1 Distance of observed MPB crossings as a function of solar zenith angle. The fit is that of Vignes et al. (2000).

The strong crustal fields have the effect of pushing the MPB position to greater altitudes [3]. Although there is no MPB crossing by MGS a high southern latitude, there is a trend that the MPB distance is greater and more variable in the southern hemisphere of Mars than in the northern hemisphere (Figure 2).

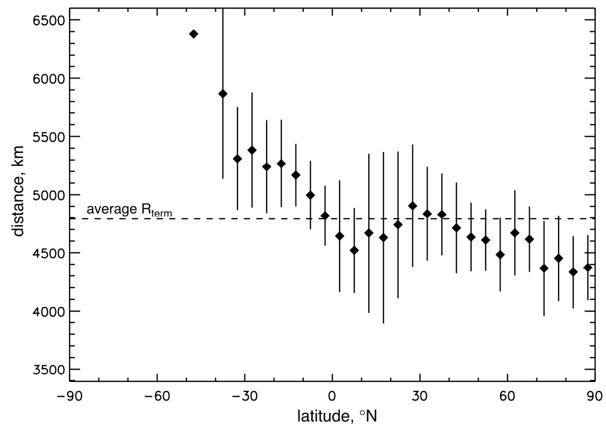

Fig. 2. The average MPB position as a function of planetary latitude. Each MPB position has been mapped to where it would occur in the terminator plane. A single horizontal line will no fit this data.

We have observed the compression of the MPB by strong incident solar wind ram pressure. Using a proxy for the solar wind pressure based on the magnetic pressure in the magnetic pileup region, we found that the MPB is 240 km closer to the planet on average when the solar wind pressure exceeds 1 nPa. (see Figure 3).

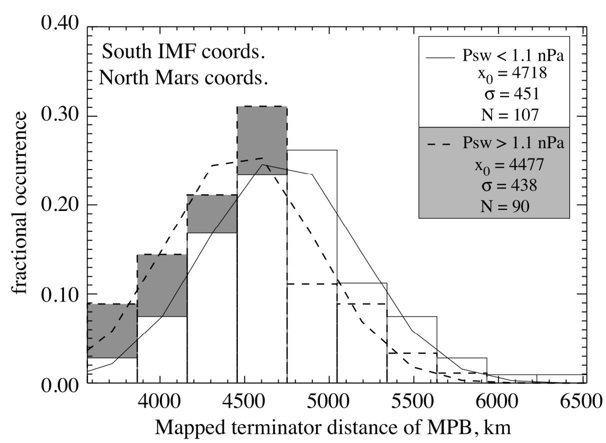

Fig. 3. The gray (white) histogram is the terminator position of the MPB for cases with P_{SW} > 1.1 nPa (P_{SW} < 1.1 nPa). To eliminate other sources of variability, we used only MPB crossings from the northern hemisphere that had southward electric field direction.

Our analysis has not revealed a dependence of the MPB position on the direction of the convection electric field. However, our method of determining the convection electric field direction yields high uncertainties. Our analyses cannot rule out the possibility that such an asymmetry exists.

MPB properties: The MPB is the position across which the dominant ion changes [1], the electrons cool [2], the magnetic field strength increases[4], magnetic field draping becomes well-defined[5], and wave activity decreases[6]. Generally at Mars, these changes occur abruptly. The average MPB thickness (i.e. the vertical distance over which the changes occur) is 300 km on the dayside.

In the southern hemisphere, the MPB thickness has a different distribution than in the northern hemisphere. The effect of the crustal fields is to make the MPB thicker on average (see Figure 4). This may be understood in terms of the diversion of the shocked solar wind flow around a mini-magnetosphere that protrudes into the flow. The increased flux to the sides of the crustal field will serve to thicken the MPB there. The MPB may be thinner directly above the crustal fields, however. Confirmation of this will have to await further data. It is difficult to deconvolve all of the known influences with the current data set.

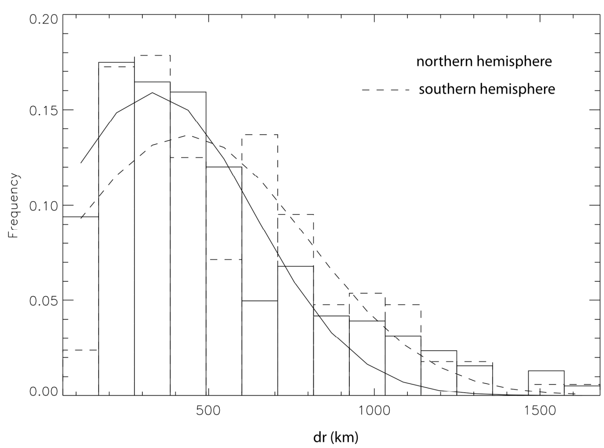

Fig. 4. The thickness of the MPB is shown for northern hemisphere crossings and southern hemisphere crossings. The distribution is broader and has a higher central value in the southern hemisphere.

Venus comparison: The magnetic barrier is a region in between the shocked solar wind and the ionosphere at Venus [7]. It comprises a mix of ionospheric and solar wind plasmas. This must be true because the IMF penetrates the barrier. Some plasma must carry it through. Magnetic pressure dominates in this region (83% of upstream solar wind pressure).

Breus et al. [8] called it the “topside ionopause.” Photochemical processes produce the transition from solar wind to planetary plasmas. High P_{sw} modulates the region. On the other hand, Perez-de-Tejada[9] attributes the “intermediate transition” at Venus to an expansion of the plasma flow. Expansion is to compensate for losses to friction as the flow encounters the ionopause. Wave bursts at plasma frequency are located at the transition layer

The MPB (Mars) and the Magnetic Barrier (Venus) both are the obstacle in the gasdynamic description of the interaction [7]. The top altitude of the MPB is higher than the top of the magnetic barrier at Venus in terms of planetary radii. Both are depressed to lower altitudes and have higher peak magnetic fields with increasing solar wind pressure. A stronger asymmetry with electric field direction is observed at Venus than Mars.

The magnetic field strength builds over a short distance at Mars, and remains high over an extended distance before reaching the ionopause. There is a region of sustained high magnetic field that is sometimes up to 1000 km thick between the MPB and the ionosphere proper. In contrast, the magnetic field builds over an extended distance at Venus and achieves its maximum close to the ionopause.

Summary: Both Mars and Venus have a region in which magnetic pressure dominates that separates the planetary plasma from solar wind plasma. This boundary is the effective solar wind obstacle in the gasdynamic approximation. The MPR covers a larger part of the solar wind interaction region at Mars than at Venus.

The Martian MPB has variability of ±400 km at the terminator (or .12 R_{Mars}). We have verified that solar wind pressure and crustal fields modulate its postion. There is no evidence that electric field direction is important, although these results are not conclusive. Solar wind pressure plays a role at both Mars and Venus. Crustal magnetic fields play a role only at Mars.

The MPB thickness has a variability of ~300 km (or .09 R_{Mars}). The MPB is thicker on the nightside, under low solar wind pressure, and in the southern hemisphere.

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