Is the relation between the solar wind dynamic pressure and the magnetopause standoff distance so simple?

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Motivation

- We know: Rsub ~ $Pd^{-1/N}$ (e.g., N=6 in Beard, 1960; N=6.6 in Shue et al., 1998)
- However, $Pd = \rho * V^2$
- Is it possible that Rsub ~ $\rho^{-1/N} V^{-2/M}$, where $M \neq N$?
- We check it using global MHD simulations

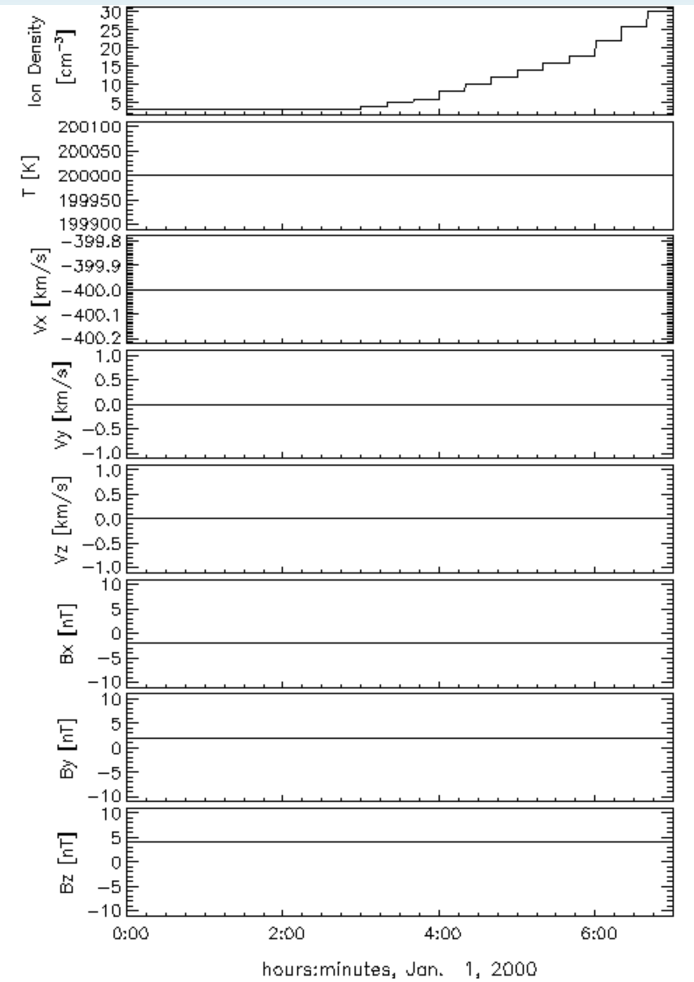
Rsub – Magnetopause Standoff Distance

Pd – Solar Wind Dynamic Pressure

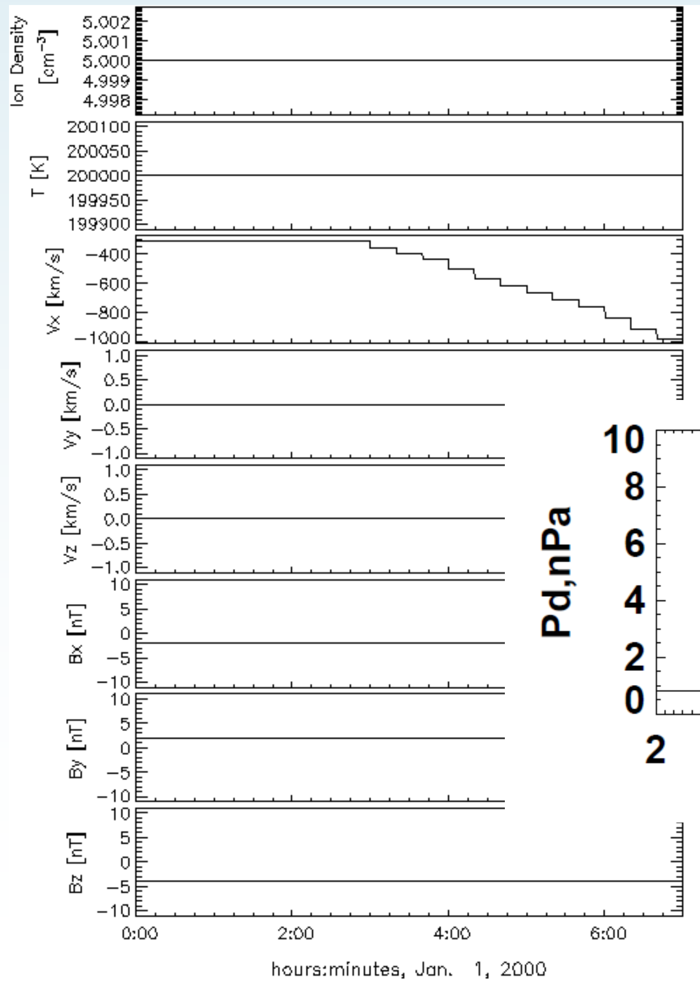
MHD model – Noncoupled SWMF (BATS-R-US) using CCMC (ccmc.gsfc.nasa.gov) runs on request

We simulate the magnetospheric response to increases in the dynamic pressure by varying separately the solar wind density or velocity both for the Northward & Southward IMF (totally 4 runs)

North/South IMF, density increase



North/South IMF, velocity increase

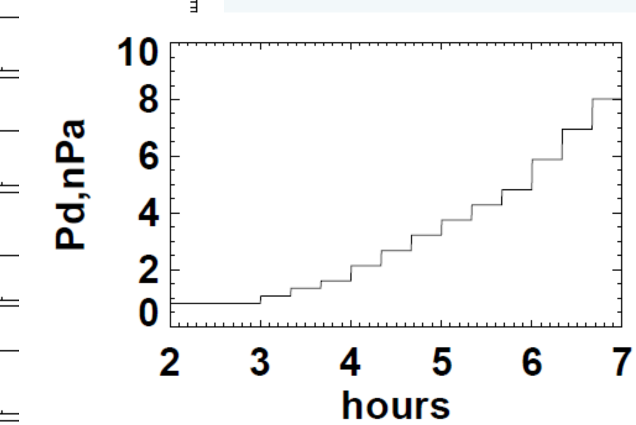


Constant IMF:

Bx=-2 nT

By=+2 nT

Bz=+/-4 nT



We get different Rsub for exactly the same Pd and Bz!

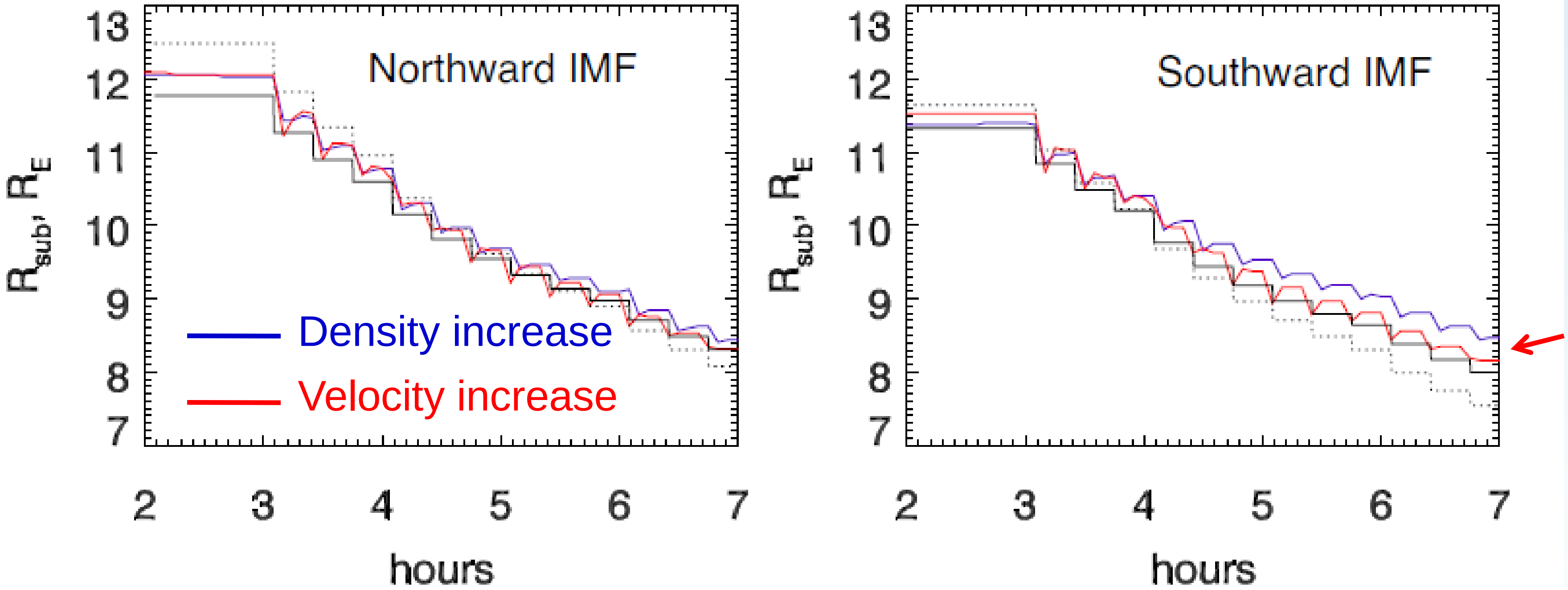
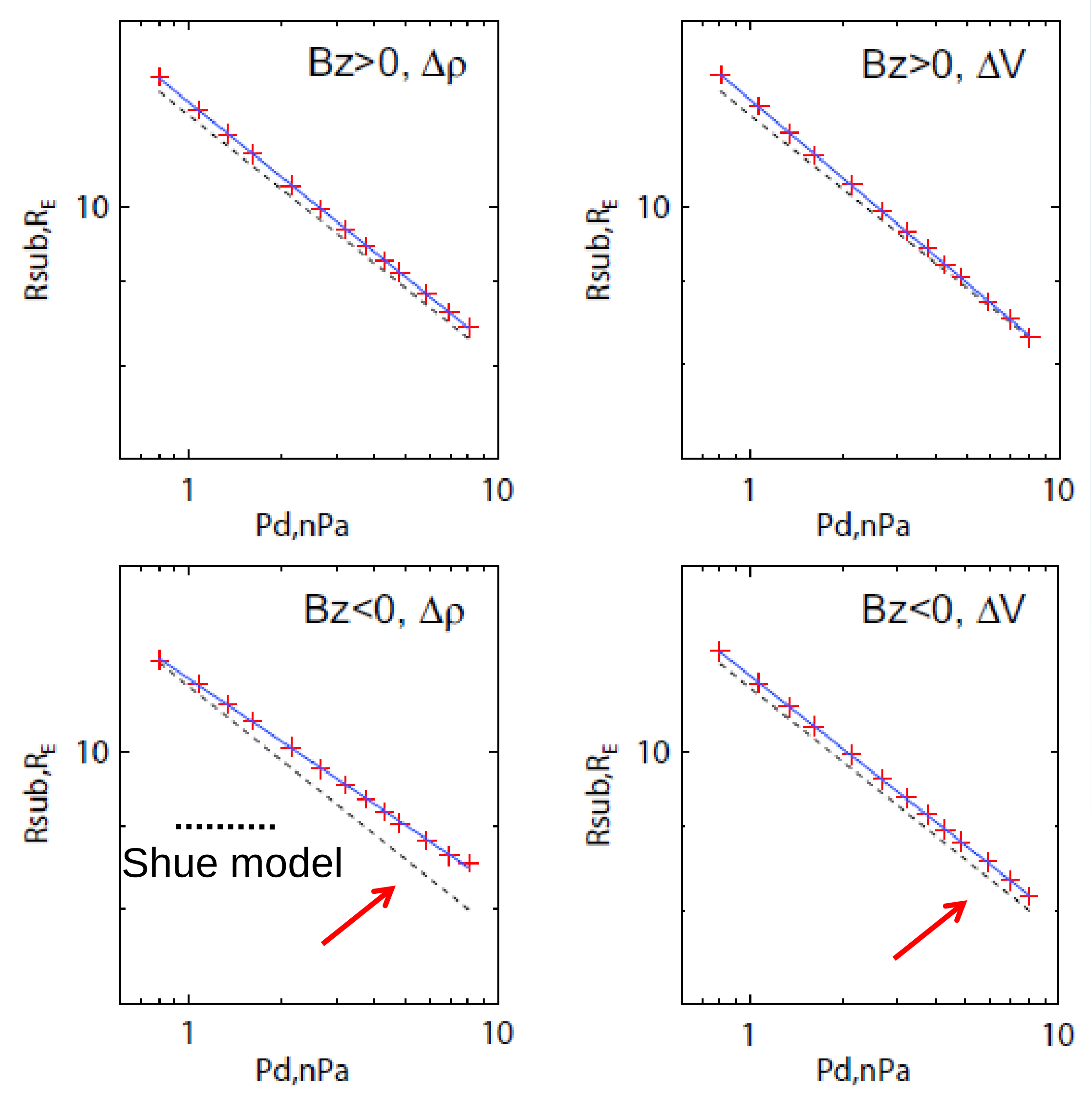


Figure 2. Left panel (runs 1-2), right panel (runs 3-4). Blue and red lines correspond to density (runs 1,3) and velocity increases (runs 2,4) in the noncoupled SWMF model. Results of the empirical (Shue et al., 1998) (black solid) and (Lin et al., 2010) (black dotted) models are shown for comparison.

Rsub (Pd) in 4 runs (red crosses) & Shue et al.'s model



We get a significantly weaker decrease in Rsub in the run with density increase for Southward IMF than in the other 3 runs

Explanation:

If we increase the SW velocity rather than the density for southward IMF we get stronger increase in the magnetopause & M-I Region 1 currents

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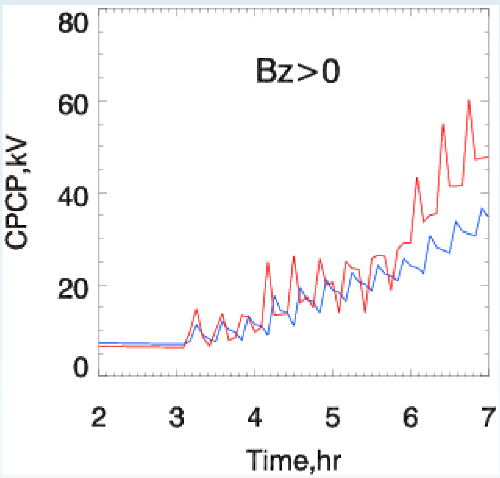
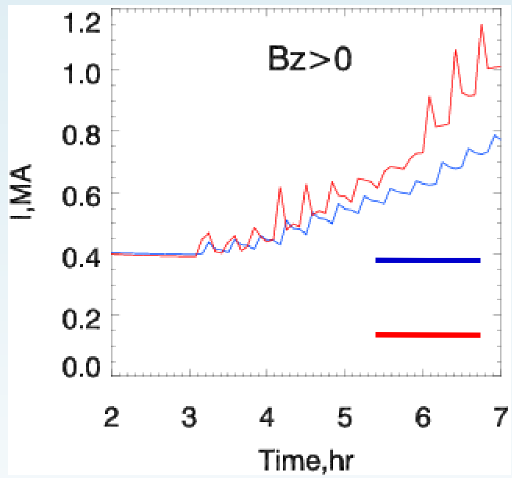
Rsub is less for the velocity increase

"N" (power degree) is smaller for the velocity increase than for the density increase in the Southward IMF case

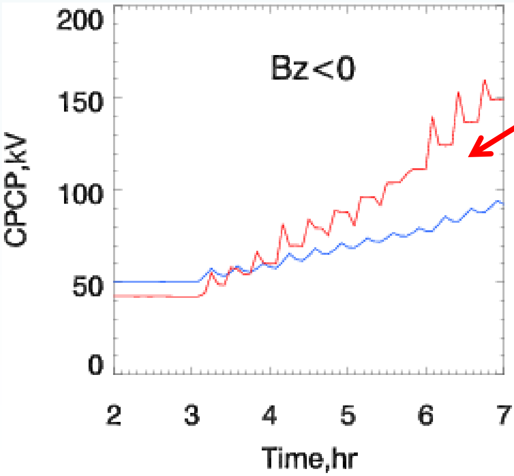
Cross Polar Cap Potential & Total Field Aligned Current

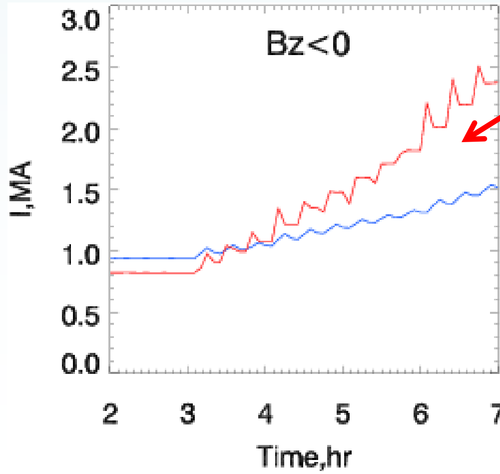




Density increase

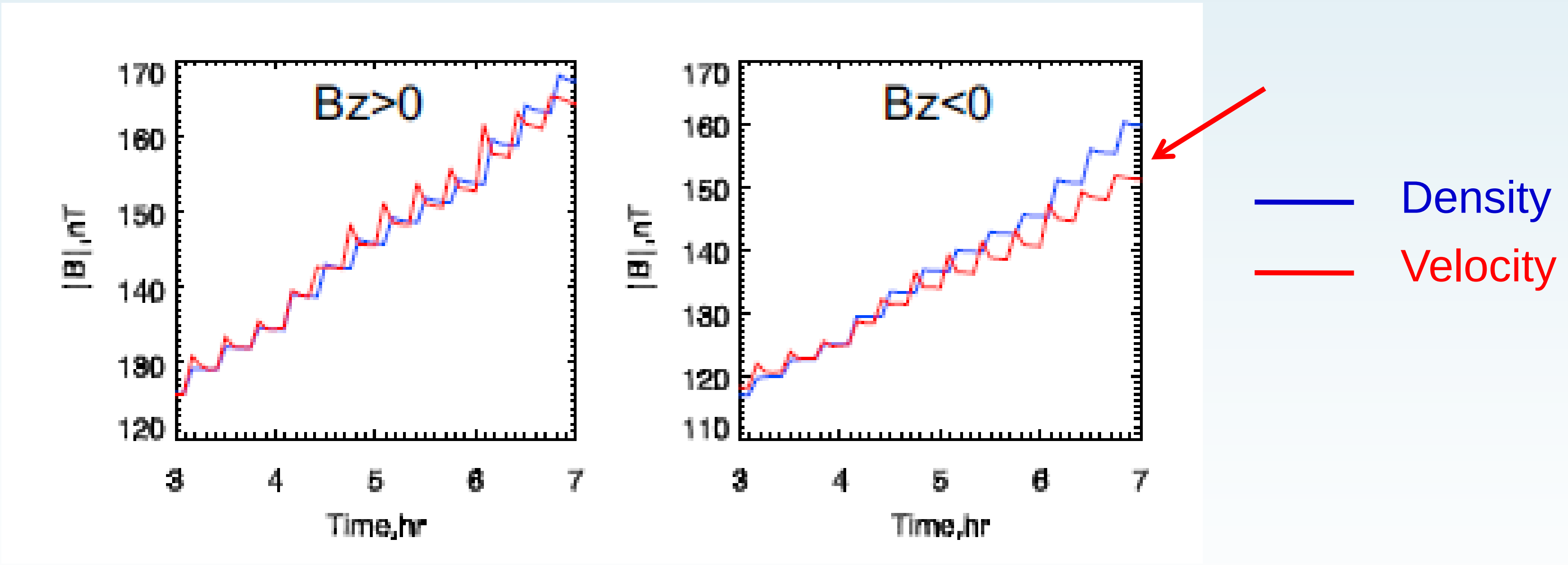
Velocity increase





The differences in the CPCP & Total FAC between the density and velocity runs

We also obtain the differences in |B| at geosynchronous orbit (in subsolar point)



Similar results for different MHD models: power law index N in $Rsub \sim Pd^{-1/N}$

Model	1	2	3	4
Density/Northward	6.53	6.51	5.95	6.40
Velocity/Northward	6.23	6.19	5.92	6.30
Density/Southward	7.80	7.82	6.32	7.98
Velocity/Southward	6.69	6.16	5.83	6.38

Models:
1 – non-coupled SWMF (BATSRUS)
2 – non-coupled SWMF with a higher conductivity 10 S (instead of 5 S)
3 – SWMF CIMI
4 – LFM-MIX

Conclusions

- The magnetopause reacts differently to the density and velocity increases for the same solar wind dynamic pressure and IMF Bz (especially for Bz<0)
- The magnetopause comes closer to the Earth in the runs with velocity increase than in the runs with density increase
- A suggestion for developers of empirical models to use $Rsub \sim \rho^{-1/N} V^{-2/M}$, where $M \neq N$

These results have been recently published in Geophys. Res. Lett.
https://doi.org/10.1029/2019GL086474 (in open access)
This presentation contains figures and the table published in that paper.