Night-side magnetopause: simultaneous observations of ARTEMIS and MMS

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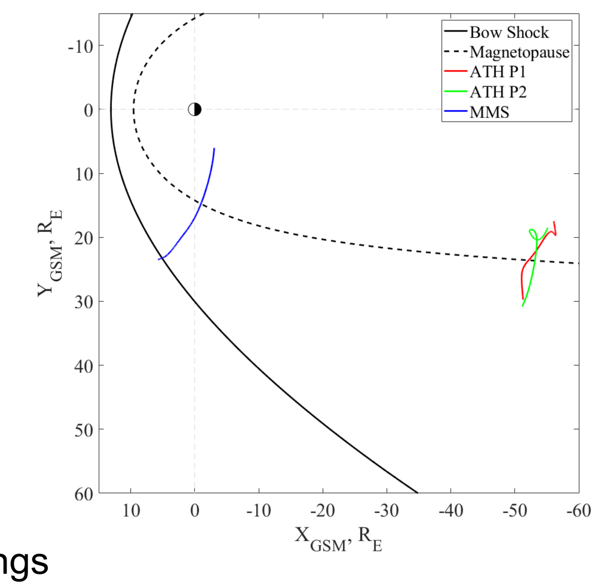
Introduction

The structure of the night-side magnetopause determines properties of magnetosheath (MS) plasma transport to magnetosphere. To investigate spatially and temporally variable magnetopause configuration we consider dataset of the magnetopause crossings by MMS and ARTEMIS spacecraft. Almost simultaneous observations at two radial distances allow us to compare characteristics of the near-Earth magnetopause (probed by MMS) and magnetopause around the lunar orbit (probed by ARTEMIS). We have estimated spatial gradients of magnetic fields and plasma characteristics (ion temperature, plasma number density, and ion bulk velocity) for MMS and ARTEMIS magnetopause crossings. Comparison of scales of these gradients show the magnetopause thickening with the radial distance.

Datasets

We have analyzed ARTEMIS and MMS magnetic field and plasma measurements for 2017-2019 years when spacecraft of both missions cross the magnetopause on the same flank within ~ one day interval.

Example of the day when both missions cross the magnetopause.



Brief summary:

- 6 time periods
- 94 MMS crossings
- 139 ARTEMIS crossings (75 P1 + 64 P2)

Data analysis methods

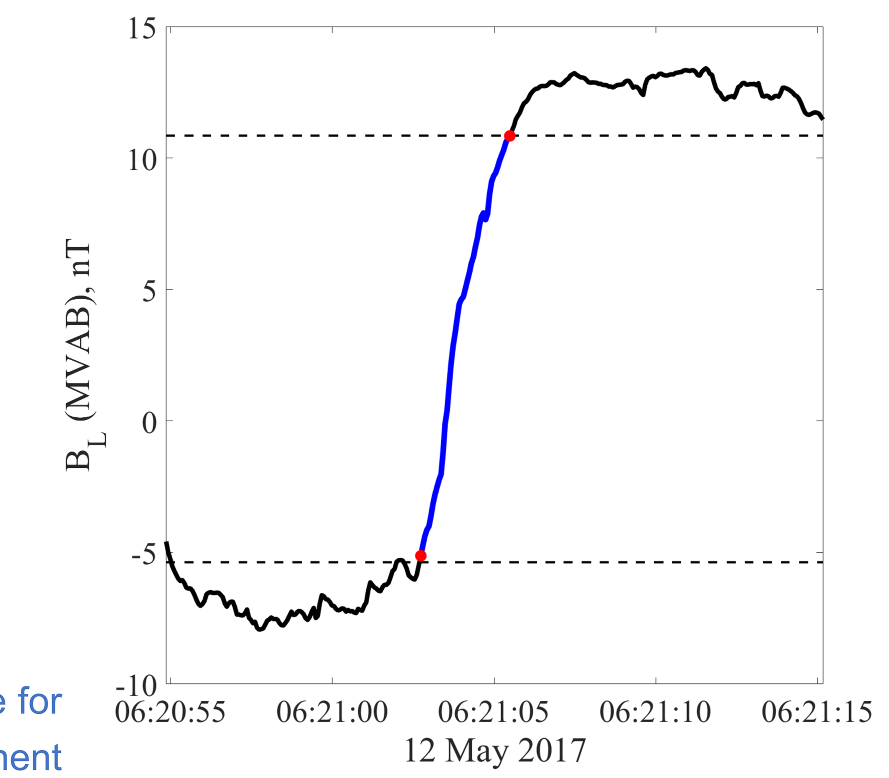
Single-spacecraft (MMS and ARTEMIS)

- Minimum Variance Analysis on MF (**MVAB**) *(normal direction)*
- DeHoffmann-Teller analysis (**dHT**) *(magnetopause velocity)*
- Minimum Faraday Residue (**MFR**) *(normal direction + magnetopause velocity along normal vector)*
- Composite Method (**COM**=MFR+MVAB) *(normal direction + magnetopause velocity along normal vector)*

Multi-spacecraft (MMS)

- Curlometer *(currents)*
- Timing *(normal direction + magnetopause velocity along normal vector)*

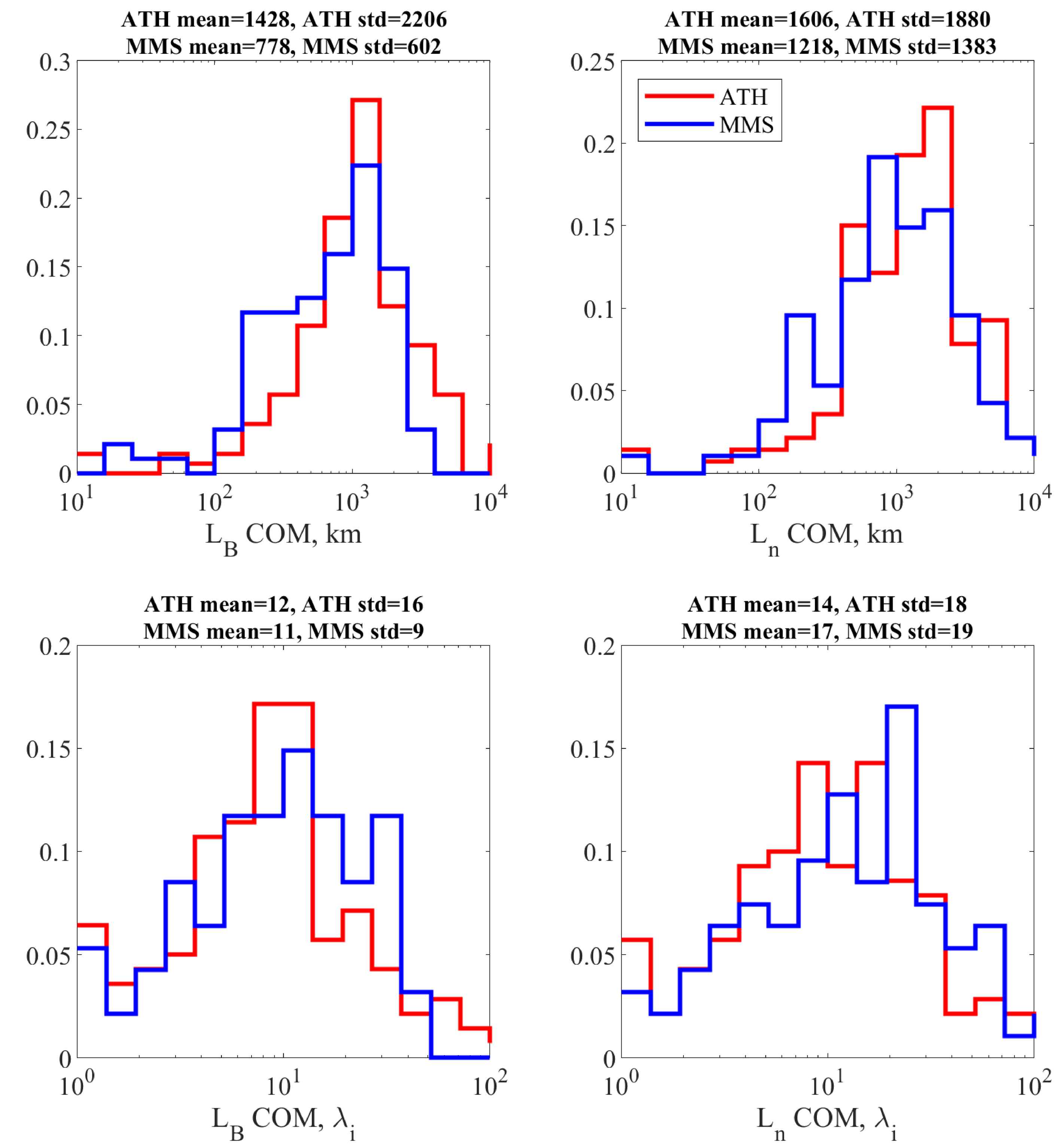
We have analyzed spatial structure of the magnetopause current sheet and transition regions of ion velocity, plasma density and ion temperature. To estimate spatial scale of these layers we find the time interval of 76% variation of considered characteristic, and then multiply duration of this period to the magnetopause velocity estimated from methods mentioned above.



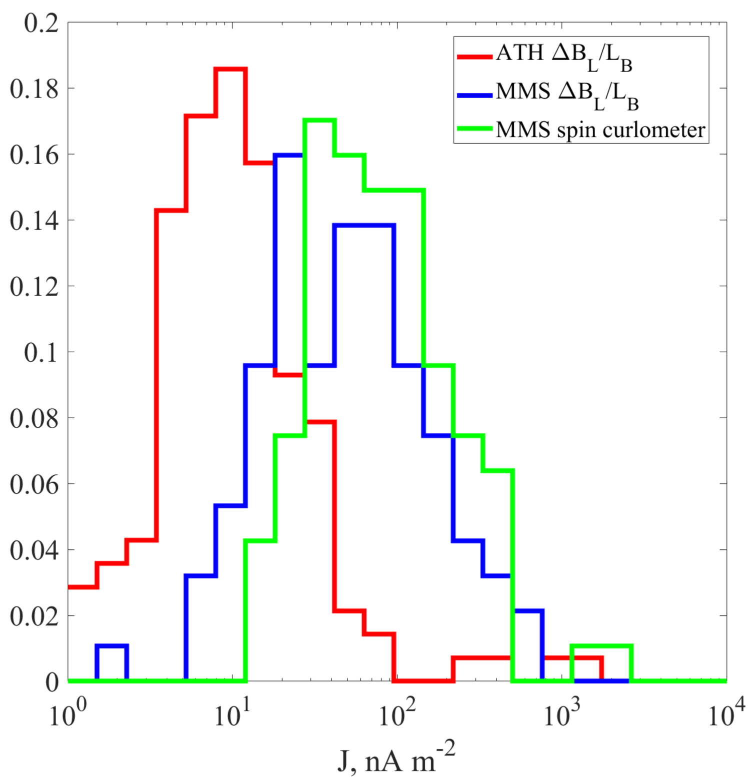
Example of thickness estimate procedure for magnetic field B_L-component

Distributions of layer thicknesses

Histograms of magnetopause layer thicknesses for ARTEMIS and MMS missions have similar shapes, but due to more elongated distribution "tails" the mean thicknesses values (in km) are larger on lunar orbit, while thicknesses normalized to MS ion inertial lengths can be larger in the middle tail flanks.



Current sheet (left) and plasma density transition region (right) thickness distributions for ARTEMIS (distant tail) and MMS (middle tail) missions in absolute values (top panels) and normalized to magnetosheath ion inertial lengths λ_i (bottom panels).

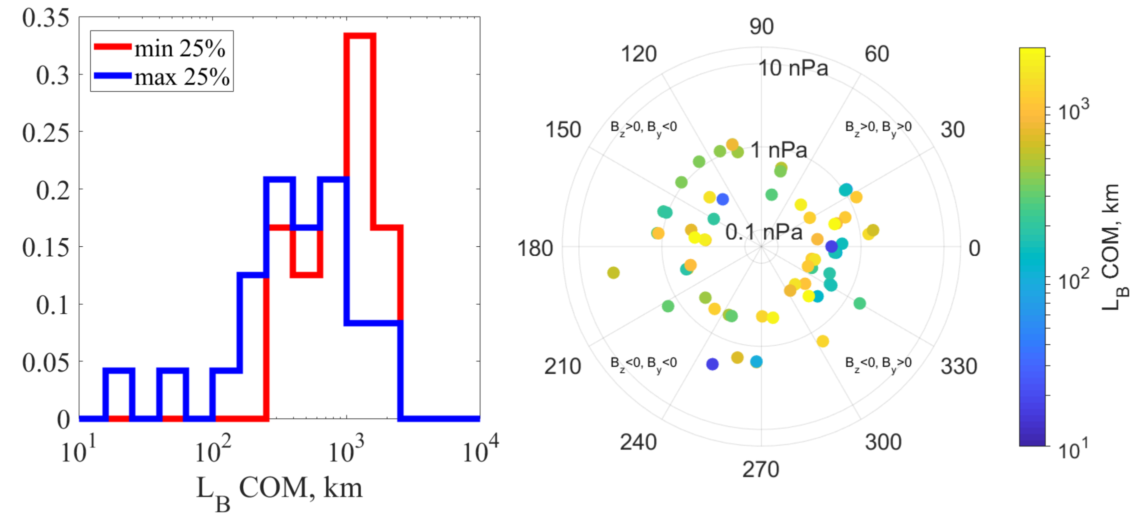


Due to decrease of the magnetic field magnitude with radial distance and (less important) due to thickening of the magnetopause current sheet, the current density magnitude increases from MMS to ARTEMIS orbit by about factor ~ 5. Here we present mean current density values estimated as $J_{CS} = \Delta B_L/L_B$ and results of curlometer method for spin-averaged MMS magnetic field.

Current density magnitude distributions for both missions.

We investigate dependence of the magnetopause current sheet spatial scale on MS full pressure (magnetic + plasma + dynamic) for MMS mission. Histogram of 25% of cases with the minimum pressure values corresponds to greater thicknesses in comparison to histogram of 25% of cases with maximum pressure values. We get similar dependence for plasma parameters transition regions.

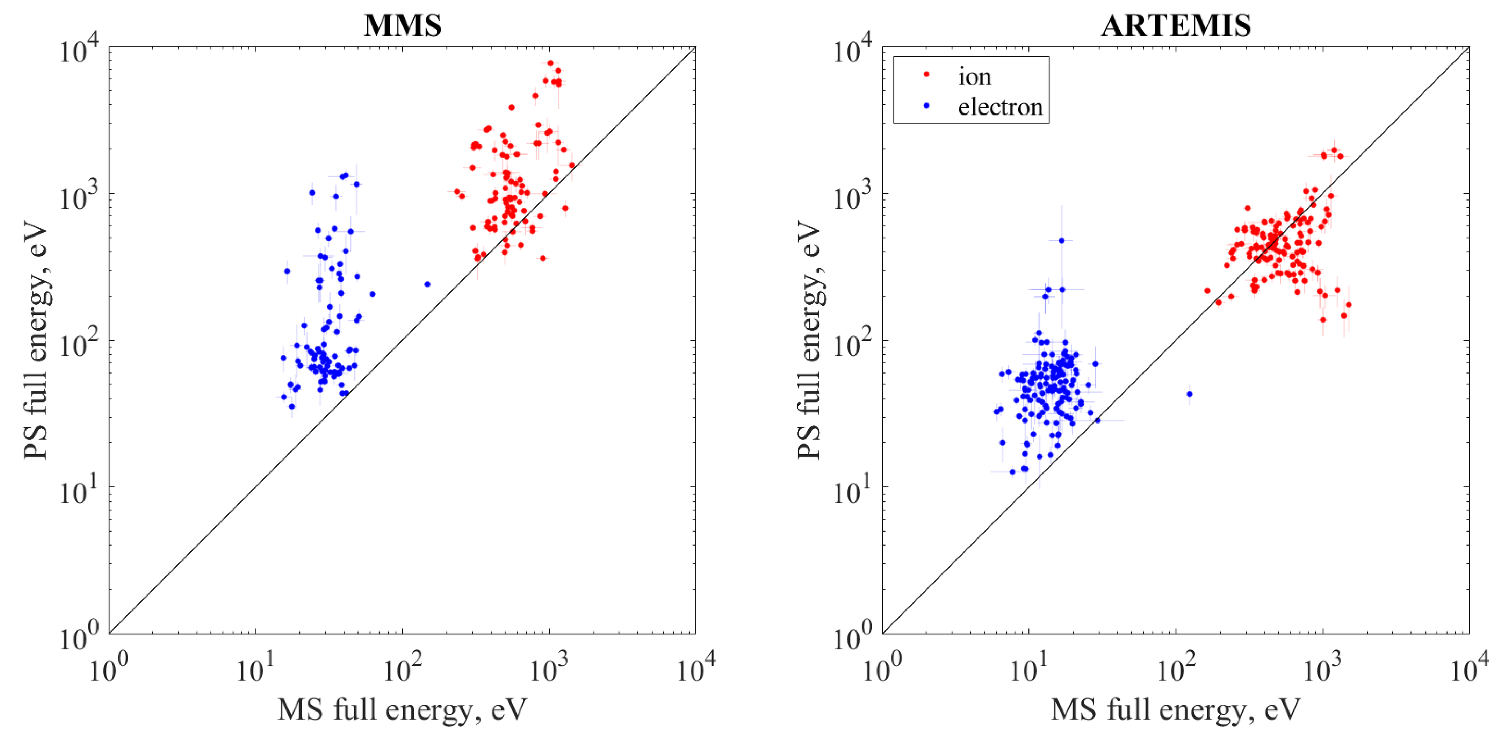
Scatter plot also show that we usually observe thicker layers during periods of small MS pressure and positive IMF B_y. These dependencies require further detailed investigation.



Dependence of current sheet spatial scale on full MS pressure and rotation angle of IMF magnetic field ($\alpha = \operatorname{atan}(B_z/B_y)$).

Energy variation across the magnetopause

On lunar orbit MS and PS ion energies are quite close, i.e. full ion energy conserves for magnetopause crossing, whereas electron energy increases. For the near-Earth magnetopause (MMS) energies of ion and electrons increases from MS to PS. This may indicate on ion diffusive transport (without heating) across the distant magnetopause, while such transport is ineffective in the near-Earth magnetopause.



Plasma sheet full particles energy (kinetic plus thermal) versus their magnetosheath full energy. Blue markers are electrons and red markers are ions.

Conclusions

- There is some thickening of the magnetopause with the radial distance from the Earth.
- The mean value of the current density magnitude about five time larger in middle tail in comparison with the distant magnetopause.
- At lunar distances PS and MS ion energies are very similar, whereas the near-Earth magnetopause separates two ion populations with very different energies.
- The magnetosheath pressure may influences magnetopause thickness in the middle tail.