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Editorial: Magnetosheaths

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Editorial on the Research Topic
Magnetosheaths

The magnetosheath plays a crucial role in transferring solar wind mass, momentum, and energy into the magnetosphere. Its properties determine the nature of the coupling that occurs at the magnetopause boundary, in particular for the dayside magnetic reconnection that ultimately drives geomagnetic storms and substorms. Processes occurring at the inner and outer boundaries of the magnetosheath, namely the magnetopause and bow shock, establish conditions within the magnetosheath, including the response to solar wind structures such as shocks and coronal mass ejections (CMEs). Conditions within the magnetosheath favor the occurrence of many types of instabilities on scales ranging from the kinetic to magnetohydrodynamic (MHD), and the resulting waves such as Kelvin Helmholtz (KH) also play a role in the global interaction.

The papers presented in this research volume cover a wide range of research topics related to the terrestrial magnetosheath. Several papers revisit old problems with new data sets, revealing the details of magnetic field line draping, the plasma depletion layer, turbulence, and transients such as magnetosheath jets, while another reports new results from global hybrid simulations for an interplanetary shock interacting with the magnetopause. Magnetopause currents are explored with more realistic boundary conditions and magnetosheath fields, and new methods such as machine learning are applied to the inner boundary of the magnetosheath. One paper proposes a new technique for remotely detecting magnetosheath boundaries in soft X-rays, while another describes an alternative theoretical approach connecting the magnetotail to the dayside magnetopause.

The subsolar magnetosheath plays a crucial role in the solar wind-magnetosphere interaction. Michoette de Welle et al. present results for the spatial distribution of the magnetic field amplitude and plasma density from the subsolar bow shock to the magnetopause based on large data sets from several spacecraft. In particular, they consider the dependence of the magnetic pileup region and plasma depletion layer outside the magnetopause on the interplanetary magnetic field (IMF) orientation, with a view towards its implications for magnetopause reconnection. They find higher densities at the magnetopause in the quasi-parallel magnetosheath, with density profiles that become more symmetric in the middle of the magnetosheath with decreasing IMF cone angle. On the other hand, they find higher magnetic field strengths in the quasi-perpendicular magnetosheath, and profiles that become more symmetric towards the magnetopause.

The presence of a radial IMF causes the dayside magnetosheath to become turbulent and may affect the rate of energy transfer. Pi et al. study the subsolar magnetosheath magnetic field, plasma parameters and pressure profiles from the bow shock to the magnetopause. They report that the north-south IMF orientation does not have any significant effect on the field magnitude, density, and fluctuation level. Furthermore, they demonstrate that a radial IMF does not change the magnetic field or density profile, but does enhance magnetic field and density fluctuations downstream from the bow shock. The density fluctuations decrease slowly toward the magnetopause, while the magnetic field fluctuations remain unchanged throughout the magnetosheath. They note that the temperature increases by a factor of two, but that the temperature anisotropy does not change, when the IMF rotates toward a radial orientation.

Rakhmanova et al. investigate and compare the spectral slopes of the plasma turbulence from kinetic to MHD scales in the solar wind and behind the quasi-perpendicular bow shock for different solar wind plasma and IMF conditions. They demonstrate that processes within the magnetosheath, rather than at the bow shock, determine the nature of turbulence in the magnetosheath Correlations between the properties of turbulence within the magnetosheath on kinetic scales and solar wind velocity and temperature imply that the small-scale processes that exist within high-speed and high-temperature plasmas do not depend upon bow shock conditions, or are re-established rapidly behind the bow shock. They therefore conclude that kinetic scale turbulence in the solar wind plasma can contribute to magnetospheric disturbances, especially during the interaction of the magnetosphere with high-speed solar wind originating in coronal holes.

Pöppelwerd et al. study magnetosheath jets, which are known to occur primarily behind the quasi-parallel shock. Using Cluster observations from the subsolar region, they present a new list of magnetosheath jets and their occurrence rate according to criteria presented by Archer and Horbury (2013), Koller et al. (2022) and Plaschke et al. (2013). Their list complements those previously reported from Time History of Events and Multiscale Interactions During Substorms (THEMIS), Magneospheric Multiscale (MMS), and Cluster observations. When spacecraft conjunctions occur, these lists can enable researchers to study the temporal evolution of jets.

Moissard et al. present results from a global hybrid particle-in-cell (PIC) simulation which surprisingly indicates the acceleration of an interplanetary shock as it propagates through the magnetosheath. The interplanetary shock, in front of a magnetic cloud, in a solar wind with a low Alfven Mach number of 4.5 accelerates northward and southward over the magnetopause and decelerates around the flanks. Pending a supporting observational study, these results may have important consequences for the transfer of solar wind energy into the magnetosphere.

Semenov et al. connect the dayside magnetosheath to the magnetotail with a new theoretical approach to the steady Dungey cycle. It involves the Birkeland current loops associated with electric fields that drive the ring current particles to the dayside magnetopause and then back to the tail. Solved elegantly using the Stokes theorem, the proposed approach provides an explanation for the magnetic flux transfer between the dayside and nightside which must be incorporated in 3D-simulations of reconnection in the magnetospheric system.

Tsyganenko et al. present first results from an empirical model for the magnetic fields and electric currents near the dayside magnetopause. Their model consists of magnetospheric and magnetosheath modules. It invokes new modelling methods that give more realistic boundary conditions and field distributions within the magnetosheath. By employing models for the standoff distance and curvature/flaring of the boundary as a function of the solar wind and IMF Bz, they derive the spatial patterns of dayside magnetic field draping and Chapman-Ferraro currents for different IMF clock angles and their response to the Earth's dipole tilt angle. They discuss results for magnetosheath flux pile-up and dayside magnetopause erosion during periods of northward and southward IMF, respectively.

Aghabozorgi Nafchi et al. employ machine learning to construct a new empirical model for the magnetopause location based on a large database of spacecraft crossings. This model does not rely on predefined assumptions concerning the magnetopause location or functional dependence on control parameters such as the solar wind dynamic pressure and IMF orientation. They find that their model agrees well with observations.

The locations of the magnetopause, cusps, and bow shock can be identified in images of the soft X-rays emitted when exospheric hydrogen neutral atoms exchange electrons with high charge state solar wind ions (e.g. O^{7+}). Gong et al. present the results of global MHD simulations for an extreme magnetic storm and calculate the expected soft X-ray images from these simulations. The authors identify magnetopause positions within the MHD simulations and compare them with those estimated from the images. The results demonstrate that when the magnetopause lies within the Soft X-ray Imager's (STX) field-of-view, the method accurately reconstructs subsolar magnetopause locations with errors less than 0.5 Earth radii (R_E), which satisfies the scientific requirements for the forthcoming Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission.

Many of the articles in this volume consider the response of terrestrial dayside features to variations in the solar wind, and frequently emphasize the spatial and temporal errors that arise when propagating features observed near the Sun-Earth L1 libration point to the bow shock and magnetopause. This problem is particularly acute for transient solar wind features, which may never arrive at Earth or arrive at unexpectedly early or late times. More work is needed on this Research Topic.

As a final note, while this Research Topic of papers focusses on the magnetosheath near the Earth, magnetosheaths are observed in the magnetic environments of all planets with a magnetic field, in front of transient solar wind structures such as fast CMEs, and upstream of the heliosphere. They are also associated with astrophysical objects The articles collected in this research volume pave the way toward further improvements in our understanding of the coupling processes in all of these magnetosheaths.

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