PRIME [SH]

Non-Deterministic Magnetosheath Modeling

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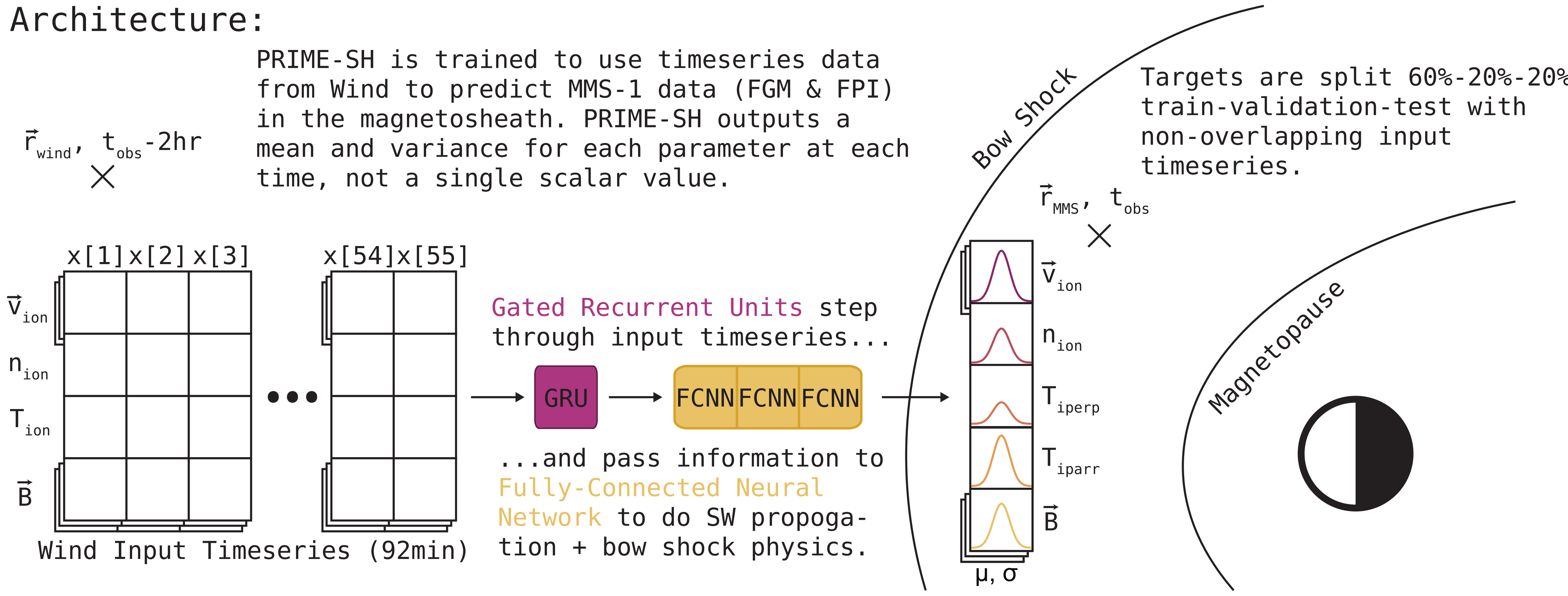
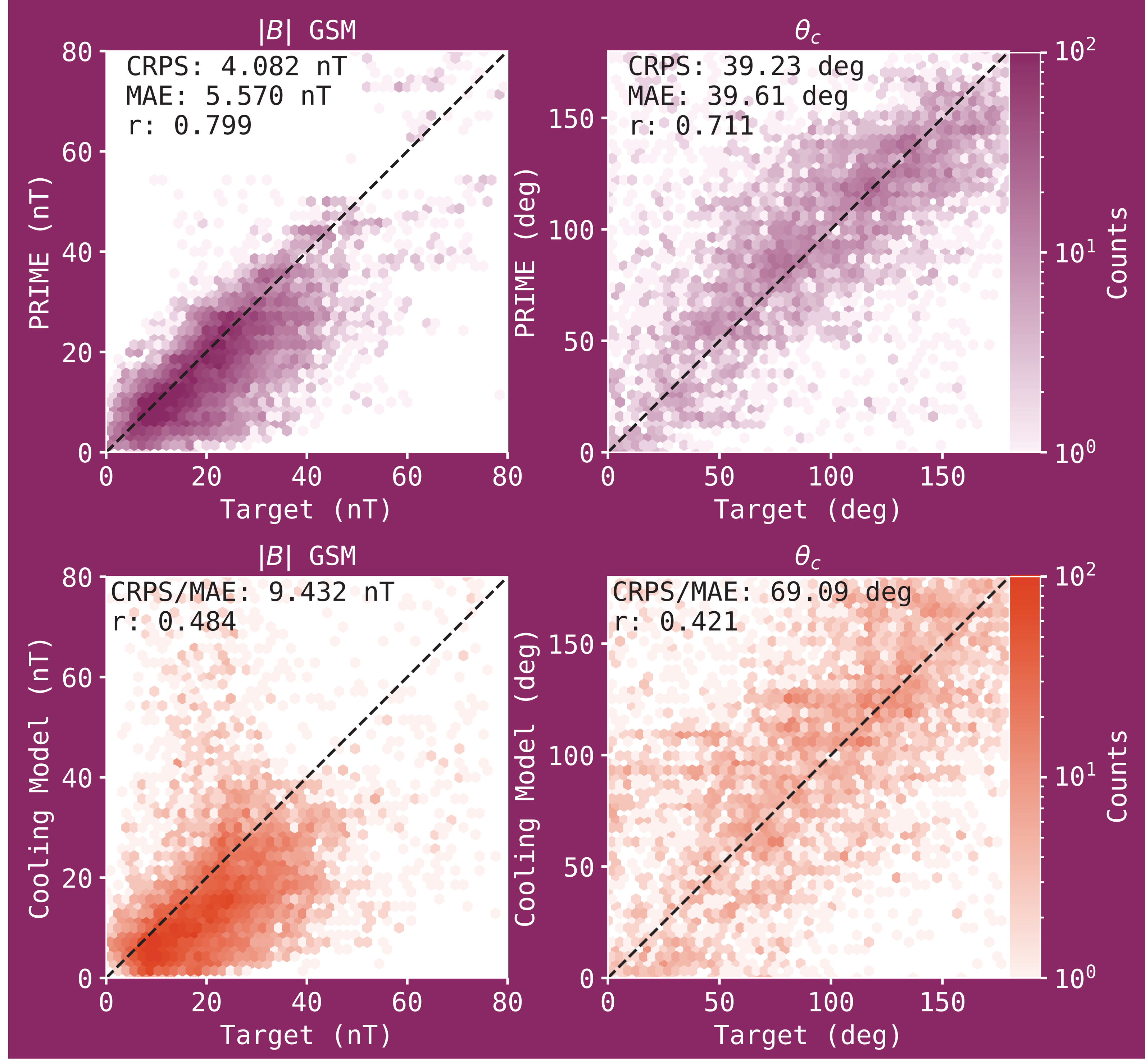
PRIME-SH is a magnetosheath prediction algorithm adapted from the Probabilistic Regressor for Input to the Magnetosphere Estimation (PRIME) solar wind propagation architecture, trained to predict MMS-1 data given input from the Wind spacecraft at L1. PRIME-SH can predict magnetic field and plasma conditions anywhere in the dayside magnetosheath given solar wind conditions at L1, and do so more accurately than analytical models. Furthermore, PRIME-SH reliably estimates its own uncertainty. PRIME-SH can be used to assemble high resolution maps of the magnetosheath with physically consistent streamlines, a stagnation point, field line draping, and mass/momentum/energy conservation. It also can be used to study kinetic physics that MHD models cannot reproduce, such as temperature anisotropy.

Architecture:

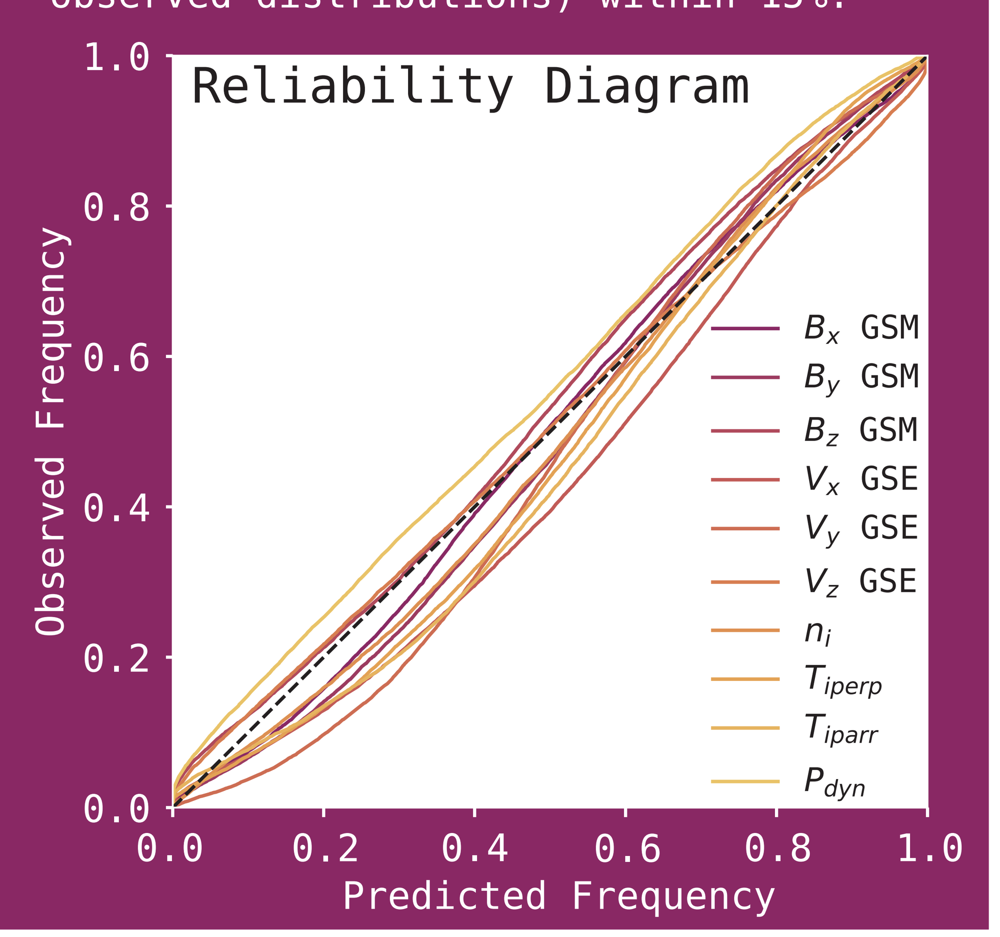


Statistical Validation:

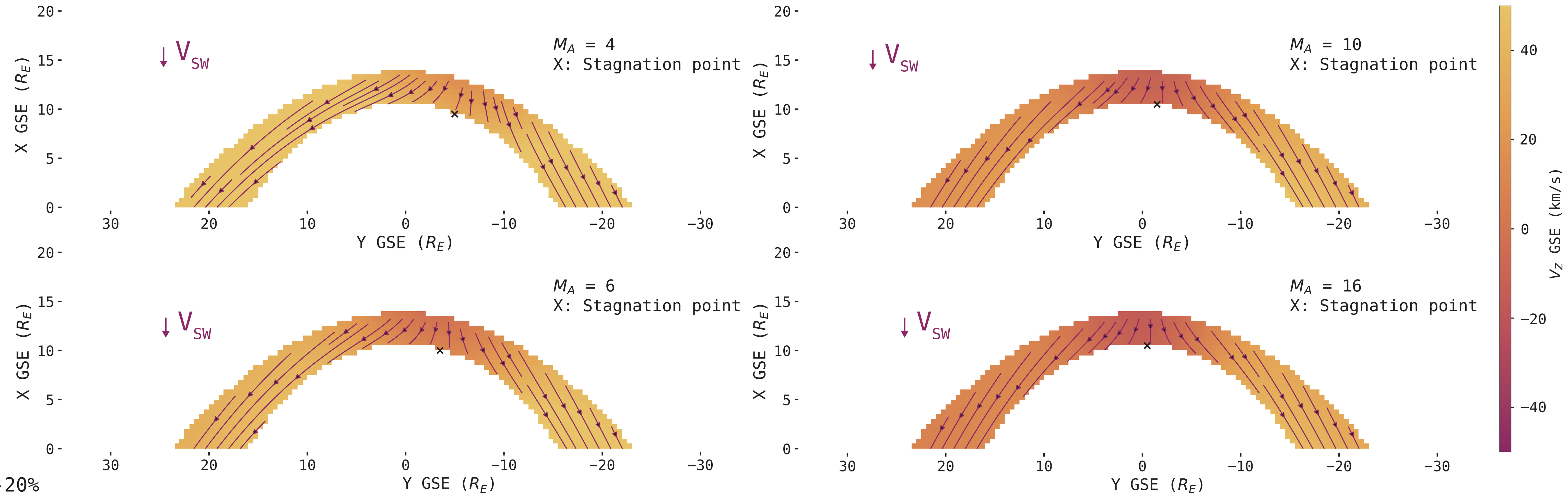


Left: Magnetic field magnitude and clock angle PRIME-SH predicts for the test dataset (top, purple) are compared to the Cooling et al. 2001 analytical magnetosheath magnetic field model outputs for the test dataset (bottom, orange). PRIME-SH is more accurate by almost a factor of two.

Bottom: PRIME-SH reliability diagram calculated on test dataset. PRIME-SH's uncertainties are reliable (i.e. match observed distributions) within 15%.

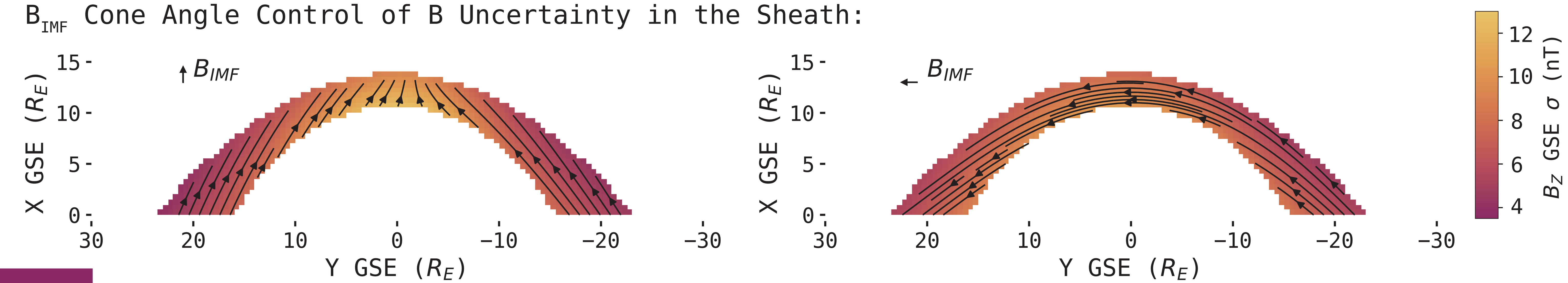


Alfven Mach Number:



PRIME-SH outputs are generated on a 0.1R_E grid between Shue et al. 1998 magnetopause and Jelinek et al. 2012 bow shock for a range of solar wind Alfven Mach numbers (4-16). Shown in purple arrows are velocity streamlines in GSE X and Y, with color representing GSE Z velocity. Cells with black Xs are the stagnation points in each magnetosheath. The stagnation point is observed to move dawnward with decreasing Alfven Mach number, consistent with MHD simulations and observations (e.g. Russell et al. 1981).

B_{IMF} Cone Angle Control of B Uncertainty in the Sheath:



PRIME-SH outputs are generated on a 0.1R_E grid between Shue et al. 1998 magnetopause and Jelinek et al. 2012 bow shock for a B_{IMF} cone angles 180° (left, radial IMF) and 90° (right). Shown in black arrows are magnetic field lines in GSE X and Y. Color is the uncertainty in B_z predicted by PRIME-SH. Uncertainty is largest behind the quasiparallel bow shock for cone angle 180° (left, radial IMF), and is evenly distributed for cone angle 90° (right). Note also that the magnetic field drapes across the magnetopause boundary in both cases and additionally "piles up" in the case of cone angle 90° (right).

Despite not being explicitly enforced during training, PRIME-SH reproduces the physics of plasma flow around the magnetopause, the modification of the frozen-in IMF as the flow is diverted, and even the Rankine-Hugoniot MHD shock jump conditions (not pictured).

Summary:

1) PRIME-SH is a new statistical magnetosheath model utilizing a Bayesian recurrent neural network architecture.

2) PRIME-SH is more accurate than analytical models, and faster to execute than MHD simulations on 2D grids.

3) PRIME-SH reproduces known physics of plasma flow around the magnetopause, IMF draping, and the R-H MHD shock jump conditions.

4) PRIME-SH can be applied to statistical studies of the magnetosheath, including ones that rely on kinetic physics (e.g. temperature anisotropy)

The algorithm demonstrated here has been applied to solar wind propogation as well. Scan the code at left for the manuscript detailing PRIME.

Follow PRIME-SH on GitHub for updates + production release.

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