PRIME

Non-Deterministic Solar Wind Propagation and Uncertainty

SPACE PHYSICS + TECHNOLOGY LAB

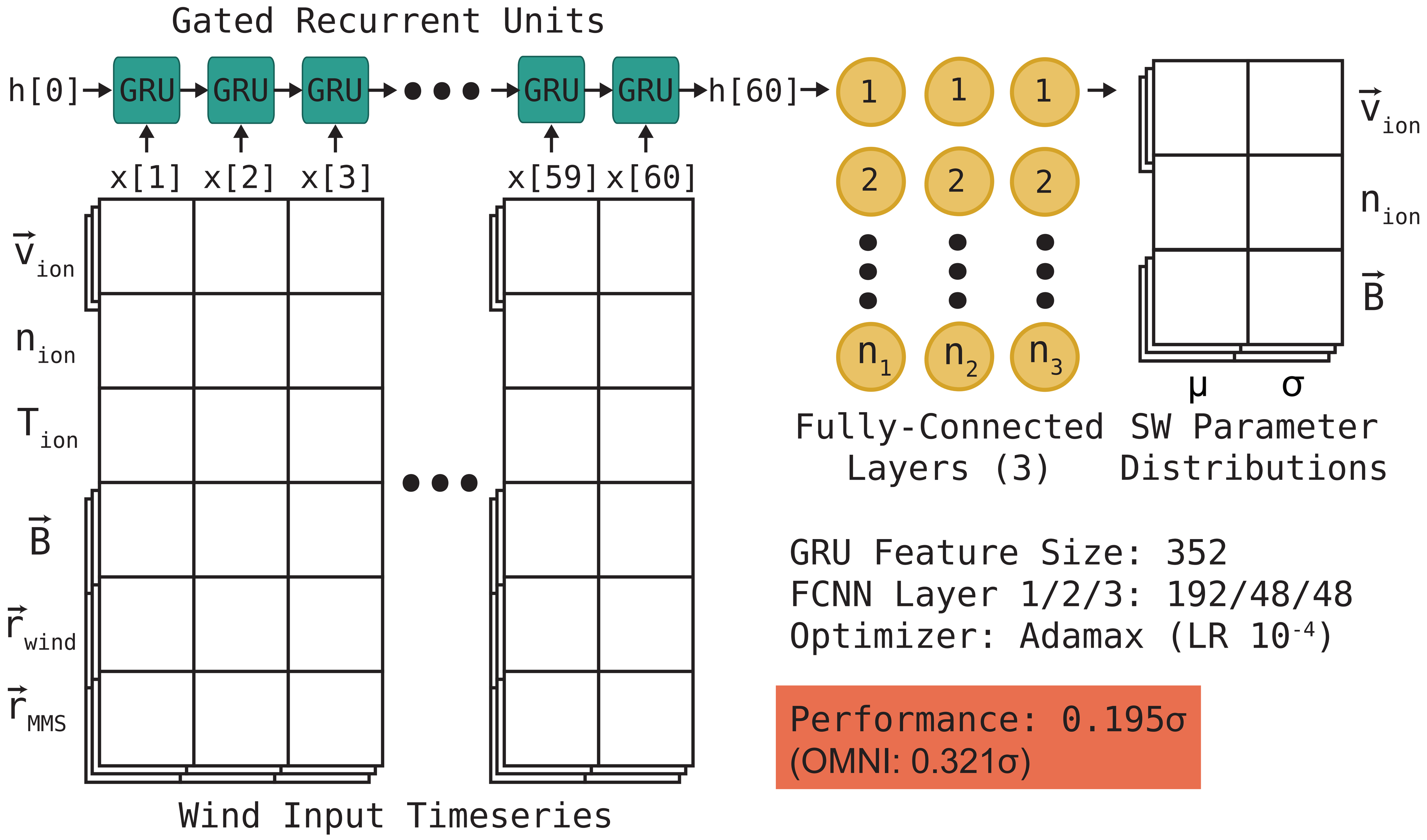
BOSTON UNIVERSITY

C. O'Brien[1], B. M. Walsh[1], Y. Zou[2], S. Tasnim[3], H. Zhang[3], D. Sibeck[4]

[1] Center for Space Physics, Boston University, Boston, MA, USA
[2] Johns Hopkins Applied Physics Lab, Laurel, MD, USA
[3] Department of Space Science, University of Alabama in Huntsville, Huntsville, AL, USA
[4] NASA Goddard Space Flight Center, Laurel, MD, USA

PRIME (Probabilistic Regressor for Input to the Magnetosphere Estimation) is a novel solar wind propagation algorithm that uses solar wind time history from L1 to predict near-Earth solar wind with uncertainties. PRIME's predictions statistically better match spacecraft measurements just upstream of the bow shock than existing techniques, up to a factor of three for some parameters.

Algorithm Architecture:



GRU Feature Size: 352
FCNN Layer 1/2/3: 192/48/48
Optimizer: Adamax (LR 10^{-4})

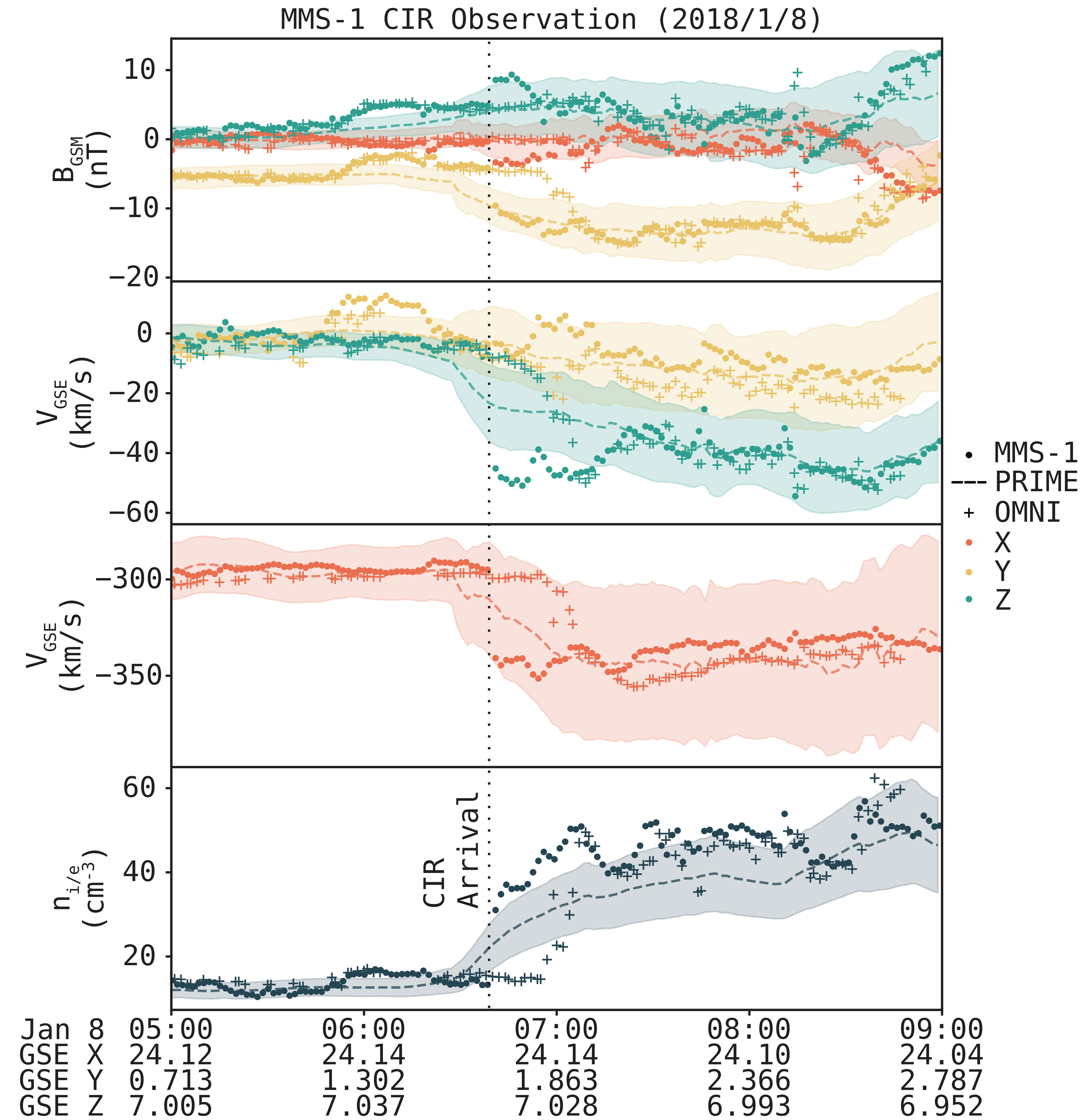
Performance: 0.195σ
(OMNI: 0.321σ)

PRIME's architecture has two main components:

1. Gated Recurrent Units (GRUs) that step through timeseries from L1 monitor
2. Dual output that produces a mean + variance for probabilistic predictions

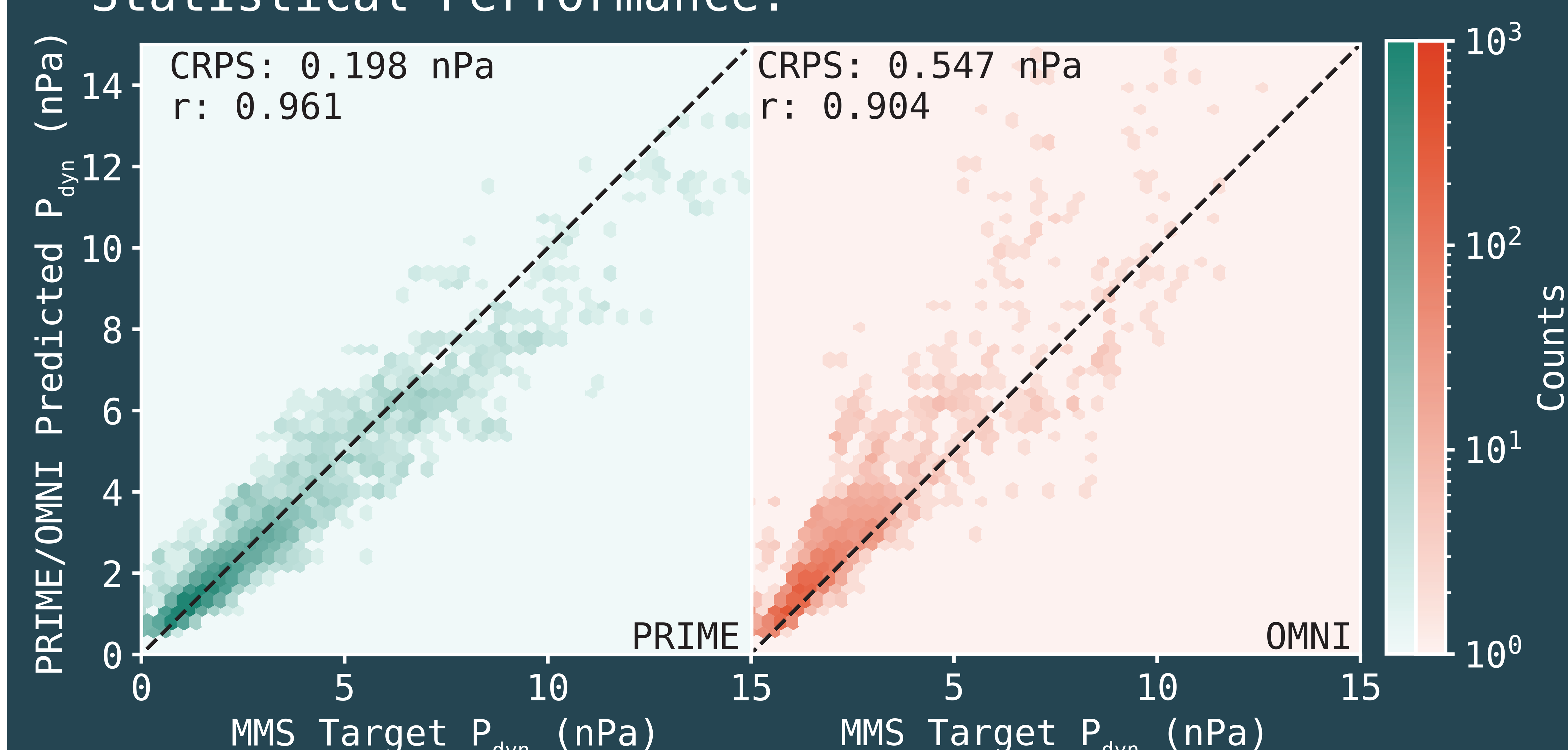
PRIME takes 1.3hrs input from the Wind spacecraft and predicts solar wind targets from MMS-1 at a 100s cadence (V_{SW}, B_{IMF}, n_i).

Overfitting mitigated via 20% dropout rate during training and layer normalization. Dataset split 60%-20%-20% train-validation-test.



Case study comparing propagated solar wind with ground truth from MMS-1 measuring Corotating Interaction Region (CIR) shock event (Jan 8 2018). PRIME accurately predicts the arrival time of the CIR at MMS-1 whereas OMNI is almost 30 minutes late. Downstream of the shock PRIME's uncertainty increases for all parameters, capturing the turbulent variation of the shocked plasma.

Statistical Performance:



PRIME's performance is evaluated against OMNI data planar propagated to MMS-1. Prediction-target joint distributions shown left. CRPS (analagous to MAE) and Pearson's r correlation coefficient shown at top left.

- PRIME outperforms OMNI by a factor of ~3 for P_{dyn}
- OMNI consistently overestimates P_{dyn} (due to overestimation of density + velocity)
- PRIME has lower CRPS over all parameters V_{SW}, B_{IMF}, and n_i (Not shown for clarity).

Follow PRIME on GitHub for updates + production release.

Author Email:
obrienco @ bu.edu