[2025 Workshop: Machine Learning in Geospace and Atmosphere]

Long title

Machine Learning for Geospace and Atmospheric Environment Modeling

CEDAR-GEM

Conveners

Hyunju Connor (NASA GSFC), Bashi Ferdousi (AFRL), Xiangning Chu (LASP, CU Boulder), Matthew Argall (UNH), and Sai Gowtam Valluri (NASA GSFC/CUA).

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Description

Machine learning (ML) is rapidly transforming the study of geospace and atmospheric dynamics by enabling data-driven modeling and predictive capabilities that complement traditional physics-based approaches. This joint CEDAR-GEM workshop session brings together researchers from both communities to explore the latest advancements in ML applications for space and atmospheric sciences.

The session will highlight innovative ML methodologies used to model solar-terrestrial interactions, including the solar wind's impact on the magnetosphere, ionosphere, and thermosphere, as well as atmospheric processes influenced by space weather. Discussions will focus on integrating ML-based models across different regions of the geospace system, developing interpretable ML techniques, and advancing system-of-systems research to improve space weather forecasting.

We welcome contributions on topics such as ML-enhanced data assimilation, model coupling strategies, event classification, and new datasets optimized for ML applications. The session aims to foster interdisciplinary collaboration, share best practices, and identify challenges in applying ML to geospace and atmospheric modeling.

We plan to have two joint sessions: one for general contributions on ML applications in the CEDAR-GEM community and another special session focusing on model validation during the following geomagnetic storms.

January 4, 2023 (minimum Sym-H :-74nT at 09:04UT)

May 6, 2023 (minimum Sym-H : -108 nT at 05:11 UT)

May 11, 2024 (minimum Sym-H : -518nT at 02:14 UT)

Agenda

MLGEM/CEDAR Schedule link

ML-GEM wiki page

Session 1: General Contributions Session - 06/25/2025 (Wed, 10:00 AM - 12:00 PM) - Room 309-310

Zoom Link: https://cua.zoom.us/j/84478187920

- Daniel Da Silva: Data-Mining Similar Scenarios for Uncertainty Quantification of Solar Wind Predictions at L1
- Gonzalo Cucho-Padin: Machine learning-based modeling of the Northern Earth's cusp
- Connor O'Brien: Magnetosheath Control of the Cross Polar Cap Potential: Correcting for Measurement Uncertainty Using Machine Learning
- Mikhail Sitnov: The 26 February 2008 substorms: Data-mining picture
- Savvas Raptis: Characterizing Earth's Plasma Sheet through Multi-Spacecraft Observations and Machine Learning
- Brendan Powers: Machine Learning Applications for Injection and Bursty Bulk Flow Identification
- Chuanfei Dong: Integration of Kinetic Effects in Multi-Moment Multi-Fluid Models through Machine Learning
- Qusai Al Shidi: Reduced Order Probabilistic Emulator of RAM-SCB: Orthogonal Autoencoders
- Jonathan Mellina: Investigating Tidal Effects in Earth's Plasmasphere Using a Machine Learning Model
- Simon Mackovjak: Automation of all-sky images classification
- Gregory Riggs: Statistical ULF Wave Latitude Distribution: A Key to Understanding Off-Equatorial Radiation Belt Electron Radial Diffusion

Session 2: General Contributions (Cont.) + Storm Challenge Session - 06/25/2025 (Wed, 1:30 PM - 3:30 PM)- Room 309-310

Zoom Link: https://cua.zoom.us/j/88222028213

- Andong Hu: Long-Term and Short-Term Dst Forecasting of the Gannon Event Using Advanced ML Approach
- Lucas Jia: Imbalanced Regression Artificial Neural Network Model for Auroral Electrojet Indices (IRANNA): Can We Predict Strong Events?

- Piyush Mehta: Storm-Time Prediction of Thermospheric Density with Reduced Order Probabilistic Emulator
- Sai Gowtam Valluri: ML-based auroral particle precipitation and electrodynamics models
- Jubyaid Uddin: ML-AIM model for Calculating High Latitude Ionospheric Electrodynamics
- Ben Martinez: High Latitude Ionospheric Prediction and Forcing Deconvolution: A Tree-Based Machine Learning Approach using PFISR and SD-WACCM-X
- Grant Stephens: Data mining reconstruction of extreme geomagnetic storms
- Donglai Ma: Machine Learning interpretation of radiation belt dynamics
- Xiangning Chu: Imbalance regression is critical for space weather
- Evan McPherson: Imbalanced Regressive Model of Electron Fluxes in the Earth's Outer Radiation Belt

Justification

Machine learning (ML) has emerged as a powerful tool in the study of geospace and atmospheric environments, offering data-driven insights that complement traditional physics-based modeling approaches. With the increasing availability of high-resolution observational datasets from ground- and space-based instruments, ML techniques are enabling researchers to uncover complex patterns, improve predictive capabilities, and enhance our understanding of solar-terrestrial interactions. Despite these advancements, the application of ML within the CEDAR and GEM communities remains largely fragmented, with limited efforts to integrate existing ML models across different regions of the geospace and atmospheric system. This workshop session aims to address this gap by fostering collaboration between researchers from both communities, facilitating discussions on ML-based modeling approaches, and promoting the development of holistic, system-wide ML frameworks.

As ML continues to revolutionize space physics and atmospheric modeling, there is a critical need for coordinated efforts to evaluate its strengths, limitations, and best practices. This session will provide a dedicated platform for researchers to exchange ideas, showcase innovative ML methodologies, and explore strategies for integrating ML with first-principles simulations. By bringing together experts from CEDAR and GEM, this session will help bridge disciplinary divides and accelerate the adoption of ML techniques in space and atmospheric sciences. Moreover, it will contribute to the development of more robust space weather prediction models, enhance event classification and data mining efforts, and facilitate the creation of ML-ready datasets that will benefit the broader research community. Through these efforts, this session will play a pivotal role in shaping the future of ML-driven geospace and atmospheric environment modeling.

Related to CEDAR Science Thrusts:
Encourage and undertake a systems perspective of geospace
Explore exchange processes at boundaries and transitions in geospace
Explore processes related to geospace evolution
Manage, mine, and manipulate geoscience/geospace data and models
Workshop format
Short Presentations
Round Table Discussion
Keywords
Machine Learning, Heliosphere, Geomagnetic storms, System-of-systems modeling
Focus Group and Group Leader

MLGEM Resource Group Leader: Hyunju Connor (NASA GSFC), Bashi Ferdousi (AFRL), Xiangning Chu (LASP, CU Boulder), Matthew Argall (UNH), and Sai Gowtam Valluri (NASA GSFC/CUA).

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