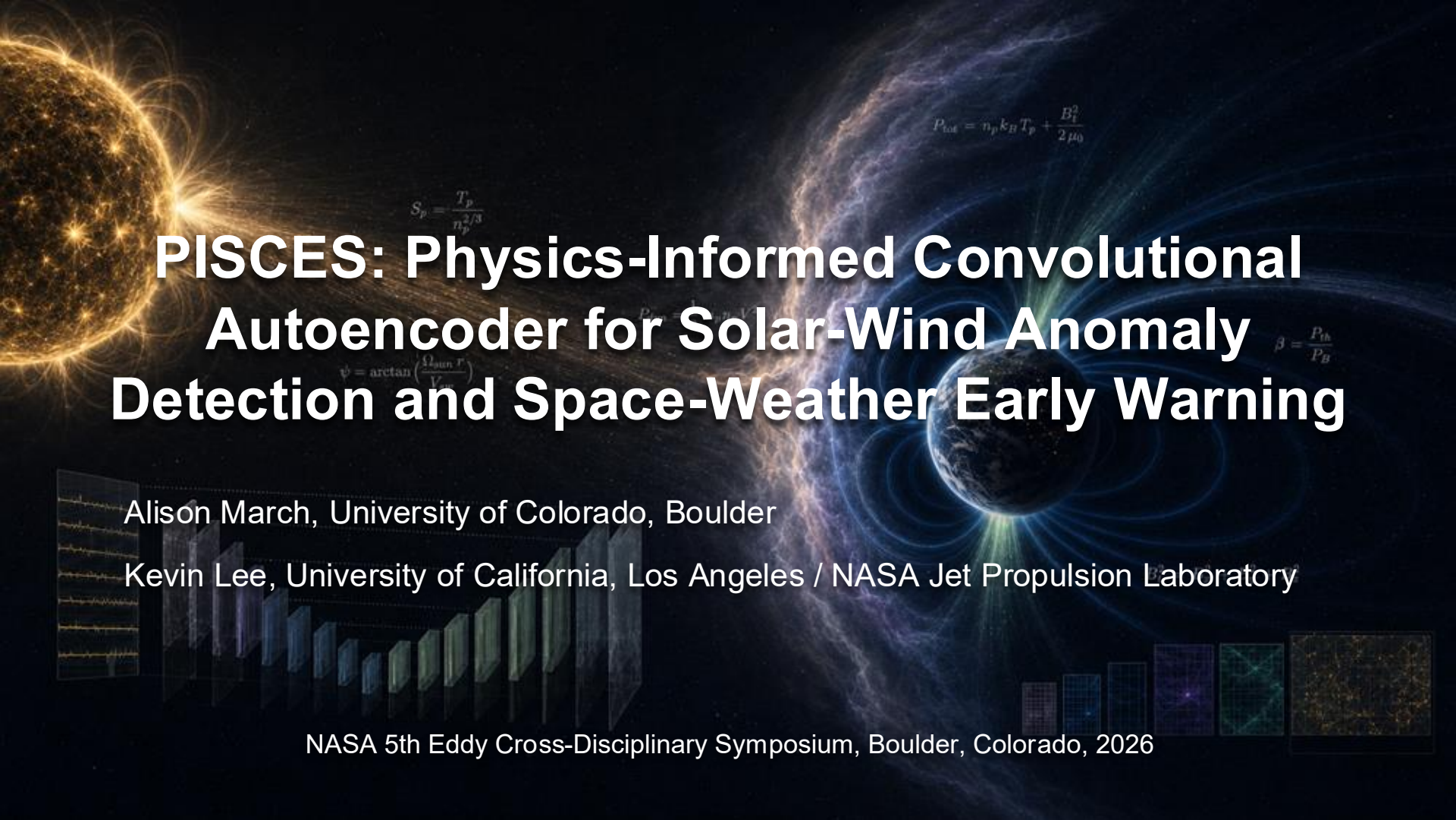

PISCES: Physics-Informed Convolutional Autoencoder for Solar-Wind Anomaly Detection and Space-Weather Early Warning

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NASA 5th Eddy Cross-Disciplinary Symposium, Boulder, Colorado, 2026

Background and Data

Data and Input Specification

Category	Details
Training Data	NASA OMNI high-resolution solar wind, 2005–2024 (1-min cadence at L1)
Real-time Input	NOAA SWPC RTSW JSON feeds
Evaluation Catalogs	DONKI HSS & IPS; Richardson–Cane near-Earth ICME catalog
Train Split	2005–2015
Validation Split	2016–2017
Test Split	2018–2024
Training Labels	None (unsupervised)
Evaluation Labels	DONKI IPS/HSS and Richardson–Cane ICME

Input Channels (7 Features)

Domain	Channels
Magnetic Field	B_x, B_y, B_z, B_t [nT]
Plasma	n_p [cm^{-3}], V [$\mathrm{km\,s}^{-1}$], T_p [K]

Preprocessing Pipeline

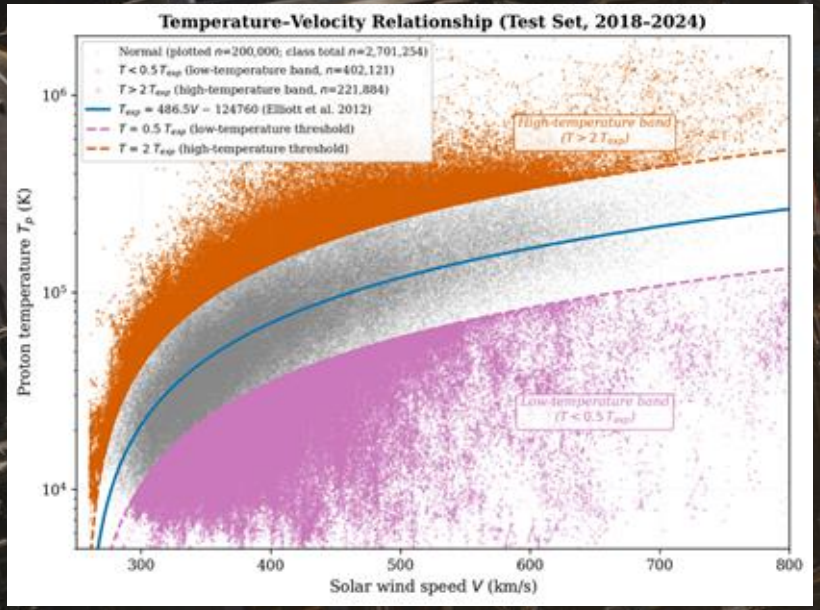
Step	Method
Missing Data	Forward-fill $\leq$ 2 min; interpolate $\leq$ 15 min; NaN: longer gaps
Transform	$\log(n_p,\ V,\ T_p)$ and z-score standardization
Windowing	7×60-min windows; 15-min step for training; 1-min step for inference

Physical Scoring Criteria

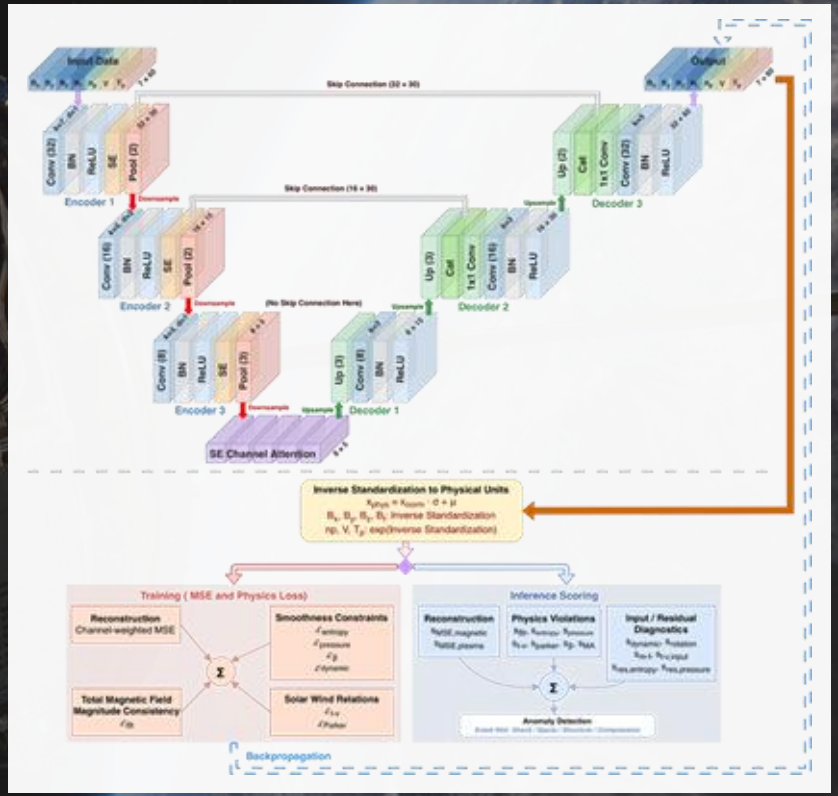
Class	Signatures
Quiet Solar Wind	Smooth entropy, thermal pressure, magnetic pressure, plasma β
Shock/Compression	Abrupt jumps in total pressure, dynamic pressure, and mass flux
ICME	$\beta < 0.5$; magnetic field rotation; Parker-spiral and T–V deviation

Data and Training Summary

Methods and Model



Example Constraint: T–V Relationship

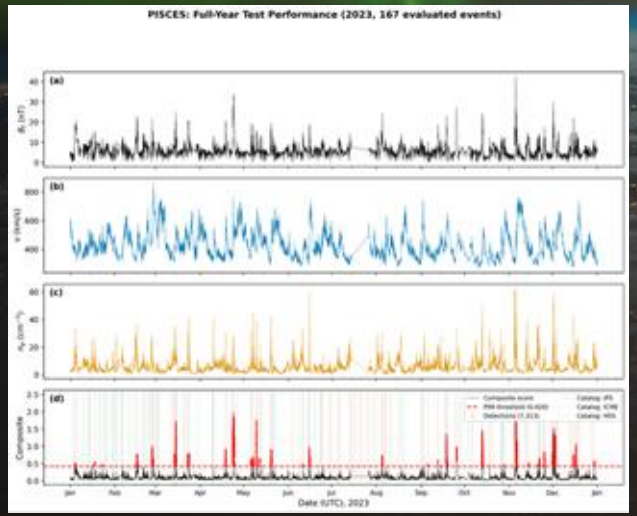


PISCES Architecture and Anomaly Detection Pipeline

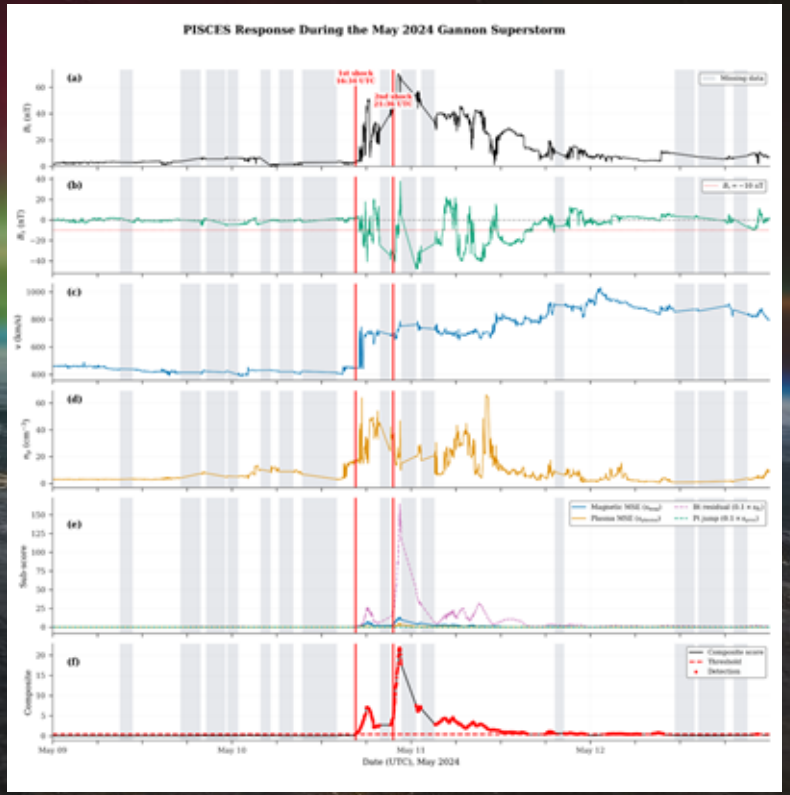
Results and Case Study

Method	PR-AUC	POD	FAR	Precision	HSS
PISCES	**0.349**	0.059	**0.305**	**0.695**	0.092
OC-SVM	0.256	**0.082**	0.328	0.672	**0.124**
PCA	0.228	0.039	0.437	0.563	0.058
Conv-VAE	0.222	0.035	0.440	0.560	0.053
LSTM-AE	0.214	0.038	0.445	0.555	0.056
Max-Jump	0.190	0.054	0.614	0.386	0.068

Benchmark of Models and Methodologies



Test Set Performance (2023)



PISCES Response During the May 2024 Gannon Superstorm

Contacts

GitHub Repository*: http://github.com/magnaprog/PISCES

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Repo, Model, Q&A

**Code Available after mid-May 2026.*