AOMSUC-15 FYSUC-2025

FIFTEENTH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE

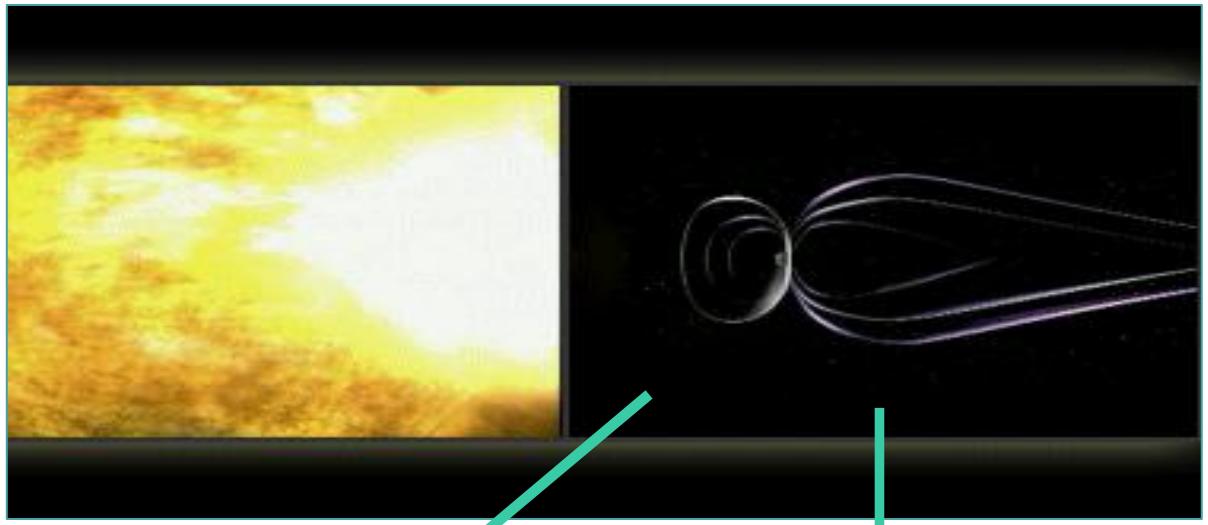
THE JOINT 2025 FENGYUN SATELLITE USER CONFERENCE

New Research on the Progress of the FengYu Space Weather Model

Chen Zhou

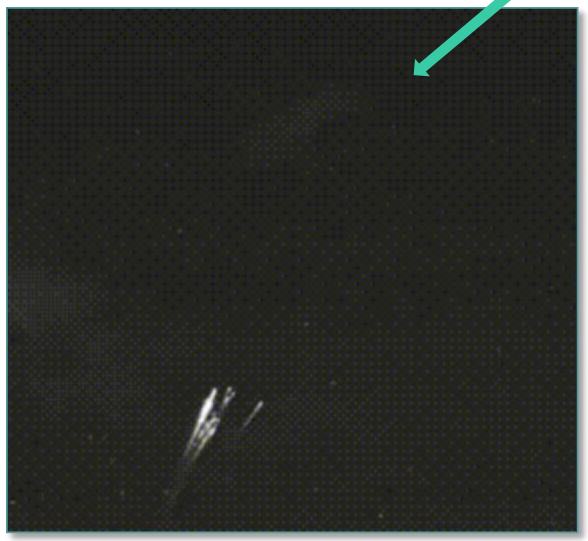
What is Space Weather?

Solar Storm
CME



Geomagnetic
Storm

Satellite
Failed to
Reach Orbit



Massive
Power grid
Failure

空间天气灾害对人类的影响
Impacts of Space Weather Hazards on Humans

2024年5月，超大地磁暴事件
May 2024: Extreme Geomagnetic Storm Event

2008年美国科学院特别报告指出：**“我们未来面临的最大自然灾害，可能就是超级太阳风暴导致的极端空间天气事件。”**

“The greatest natural disaster we may face in the future could be an extreme space weather event triggered by a super solar storm.”

Space weather disaster

空间天气灾害

- 载荷失灵 Payload Failure
- 通讯中断 Communication Outage
- 导航错误 Navigation Errors
- 辐射损伤 Radiation Damage
- 电网故障 Power Grid Failure

Weather and Climate Impacts

天气气候影响

- 臭氧变化 Ozone Variation
- 极地涡旋 Polar Vortex
- 季风雨带 Monsoon Zone
- 闪电活动 Thunderstorm Activity
- 年代际振荡 Interdecadal Oscillations

空间天气预报能力提升遇到瓶颈

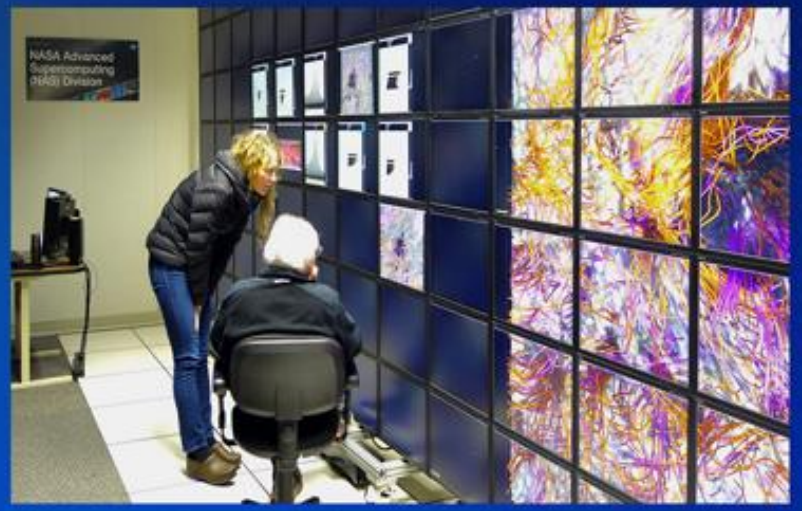
The improvement of space weather forecasting capabilities has hit a bottleneck

传统模型耗时、耗算力、难以满足业务需求，开展空间天气人工智能预报是必然的发展方向。

To overcome traditional numerical models' limitations in terms of timeliness and efficiency.

美国NASA的Pleiades超级计算平台

NASA's Pleiades Supercomputer

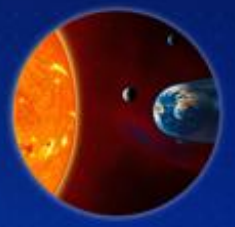


传统MHD模型模拟太阳风与磁层交互过程中，需动用约1300个计算节点，总计52000个计算核心，依然难以满足空间天气所需的及时性和准确性

Traditional MHD Modeling Falls Short in Solar Wind-Magnetosphere Simulations

中国气象局第四个国家级人工智能模型

CMA's Fourth National-Level AI Forecast Model

0-3小时预报 0-3 Hour Forecasting	0-15天预报 0-15 Day Forecasting	0-60天预报 0-60 Day Forecasting	空间天气预报 Space Weather Forecasting
			
风 雷 FengLei	风 清 FengQing	风 顺 FengShun	风 宇 FengYu

2024年6月18日，发布0-60天无缝隙人工智能气象预报系列模型
June 18, 2024, Launch of 0-60 Day Seamless AI Weather Forecasting Model Series

全链式空间天气预报
A Full-Chain Space Weather Forecasting System

完善我国气象人工智能预报业务体系，填补了空间天气的人工智能模型预报
Enhances China's AI-based weather forecasting system and fills the gap in AI-driven space weather prediction.

国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center (National Center for Space Weather)

风宇模型的开发生态圈：产学研应用联合体

FengYu Model Ecosystem: Industry-Academia-Research Consortium

全国产化AI-空间天气算子
Fully domestic AI-based space weather operator

空间天气基础模型
Space weather basic model

中国气象局第一代空间天气数值预报业务系统（CMA-SWx1.0）
CMA's First Operational Space Weather Numerical Forecasting System

国产硬件加速
Accelerated by domestic hardware

底层算法适配
Underlying algorithm adaptation

128块910B智算卡
2.2PB全闪存
128 Ascend 910B AI cards
2.2 PB all-flash storage

华为昇腾架构
Huawei Ascend architecture

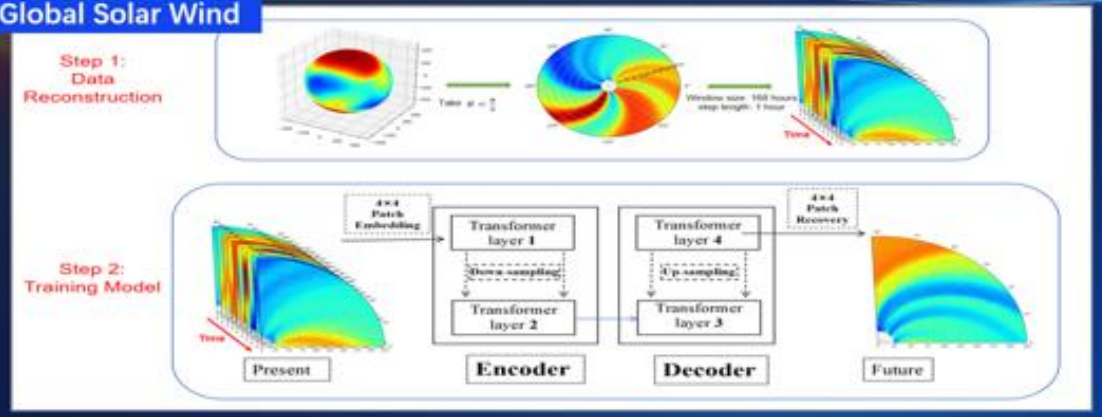
华为2012实验室
Huawei 2012 Labs

促进了我国AI模型产学研用一体发展
Accelerating the Integration of AI Model Development, Research, and Application in China

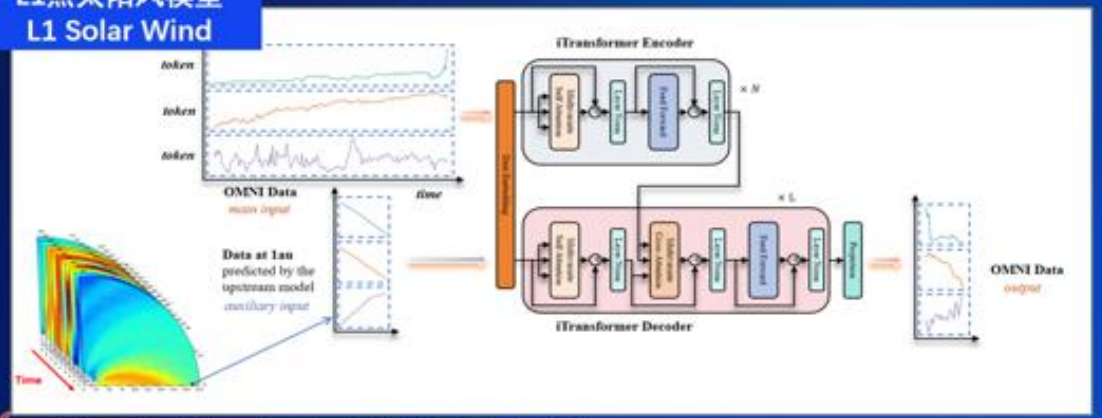
国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center （National Center for Space Weather）

太阳风模型
Solar Wind Model

全域太阳风模型 Global Solar Wind



L1点太阳风模型 L1 Solar Wind



1.数值模式数据驱动，L1点观测检验
Data-Driven Numerical Modeling with L1 Observation Validation.

2.实现黄道面内太阳风扰动的滚动预报
Rolling Forecast of Ecliptic Solar Wind Disturbances.

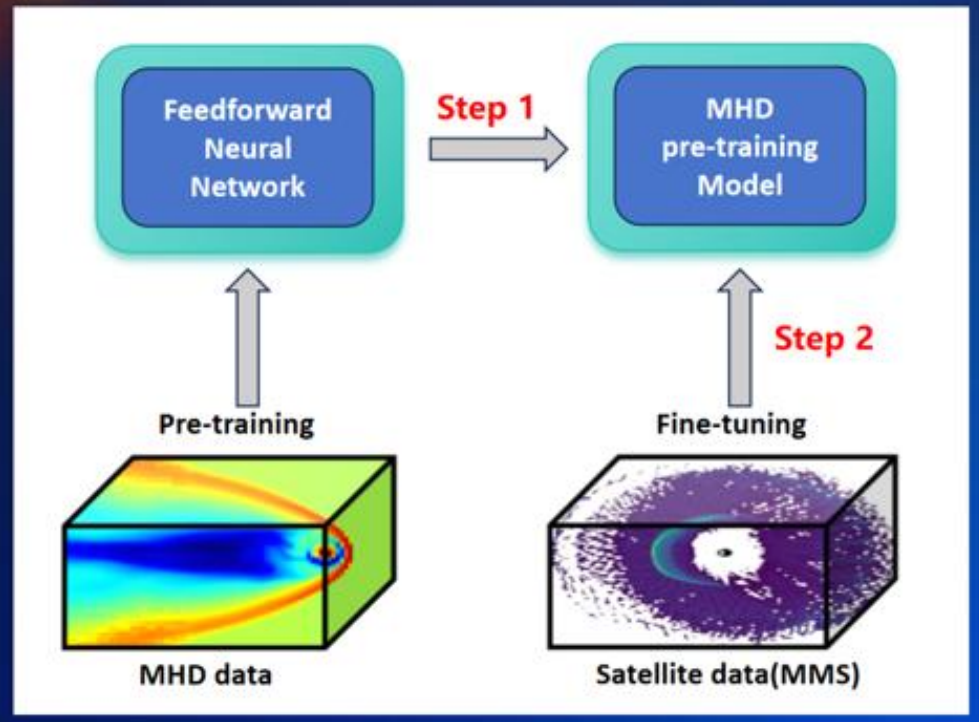
3.同步预测太阳风速度三分量、磁场三分量、质子密度与温度共8个关键参数
Simultaneous 8 Parameters of Solar Wind Forecasting.

4.模型框架采用Swin Transformer主干与自研iTransformer模块
Swin-Transformer Backbone and Custom iTransformer Modules.

5.推理速度相比传统MHD模拟提升约1000倍
1,000× Speedup Over Traditional MHD Simulations.

国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center （National Center for Space Weather）

磁层模型
Magnetospheric Model



1.观测数据+数值模式数据驱动，观测数据检验
Driven by observational data and numerical model data; validated by observational data.

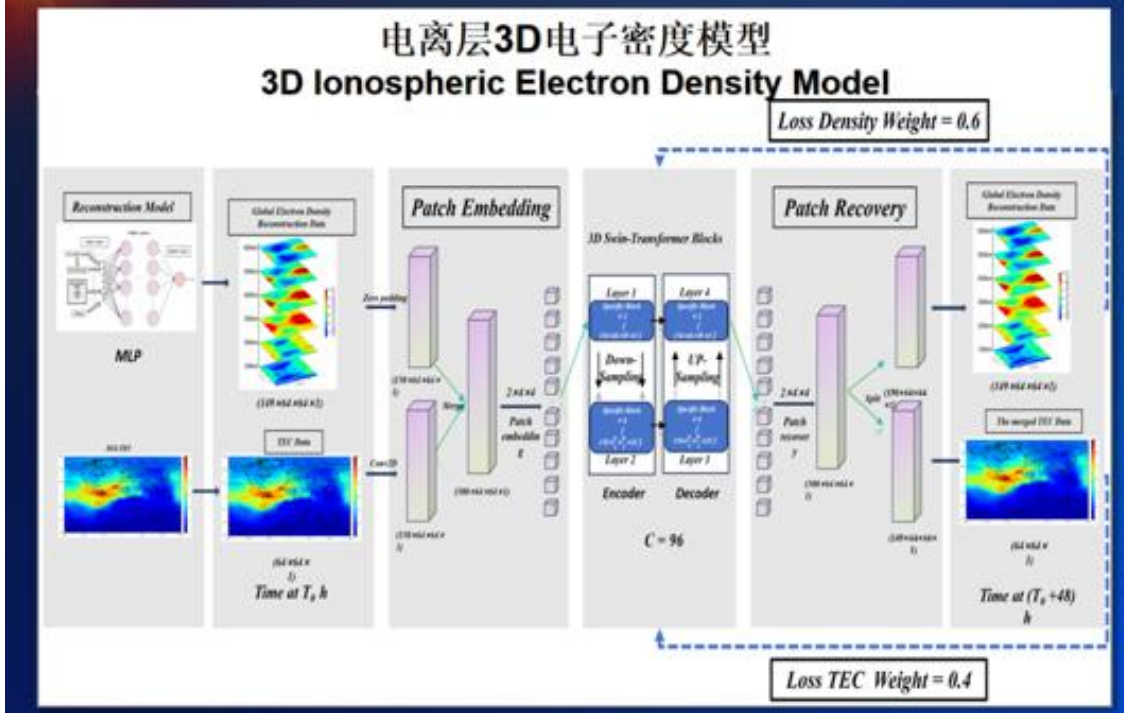
2.实现全球尺度磁层扰动的快速动态预报
Global-Scale Magnetospheric Disturbance Nowcasting.

3.同步预测磁场、等离子体速度、电流密度与等离子体压强等关键参数
Simultaneous Forecasting of Key Magnetospheric Parameters.

4.采用基于MLP架构的双阶段训练策略，先在数值模拟数据上预训练，再在MMS卫星观测数据上精细调优
MLP-Based Two-Stage Training Strategy: Numerical Simulation Pretraining Followed by MMS Satellite Data Fine-Tuning.

5.相比传统MHD模拟，磁层主要参数的相关性提升约40%，RMSE误差整体下降超过90%
Enhanced Performance: 40% Correlation Gain & >90% RMSE Reduction vs MHD.

电离层模型
Ionospheric Model



1.观测数据驱动，观测数据检验
Observation-Driven Modeling with Observation-Based Validation.

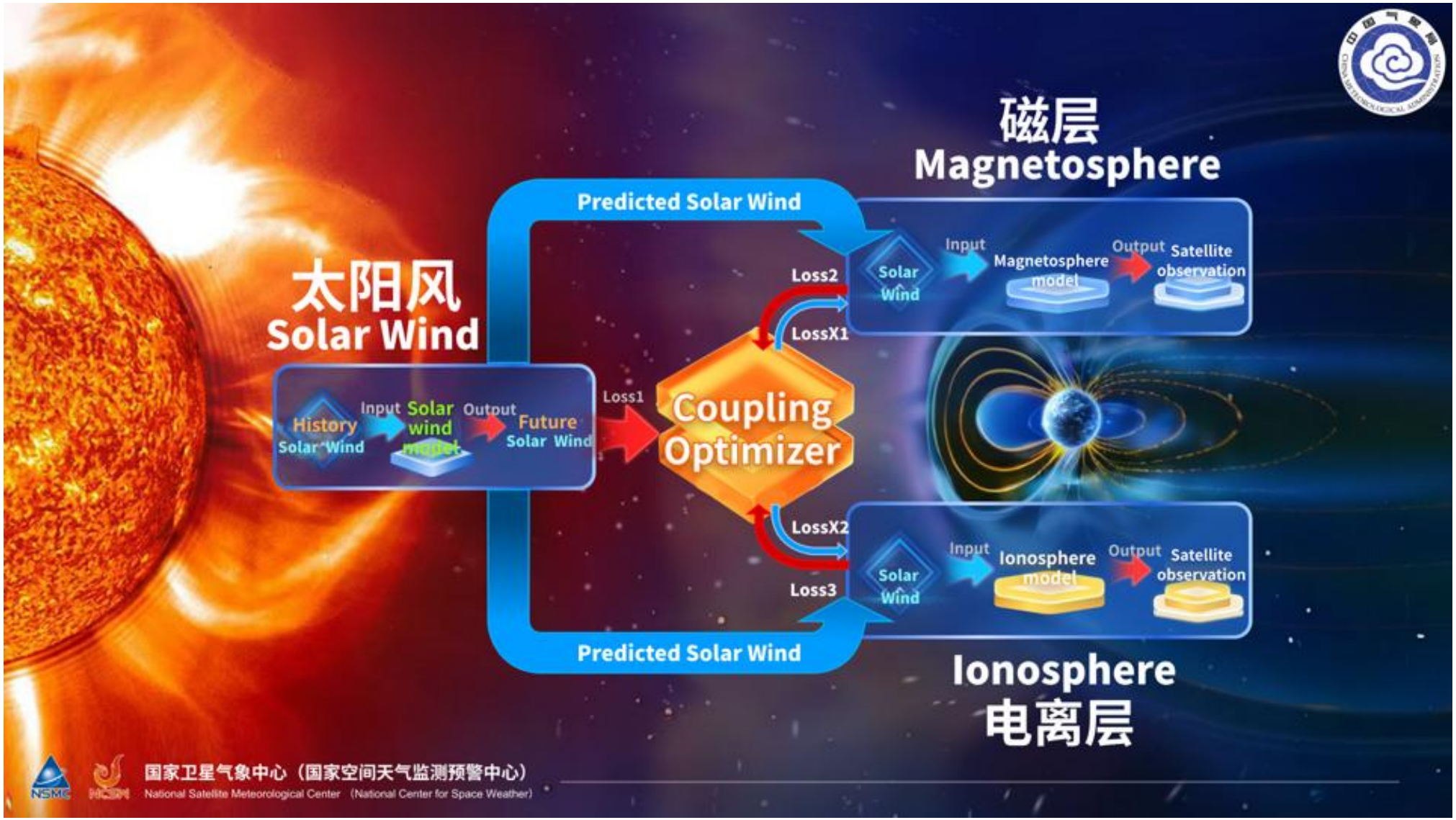
2.实现全球尺度三维电离层电子密度分布的逐小时滚动预报
Global-Scale 3D Ionospheric Electron Density Nowcasting with Hourly Updates.

3.同步预测电离层电子密度的时空演变过程，支持任意空间分辨率输出
Predict ionospheric electron density evolution with flexible spatial resolution.

4.采用基于MLP的轻量级深度学习结构，结合数值模拟数据预训练与COSMIC卫星观测数据精细微调
Lightweight MLP model, pretrained on simulations, fine-tuned with COSMIC data.

5.相比IRI2020模型，电离层电子密度预测的相关性提升约15%，RMSE误差整体下降约39%
Compared to the IRI2020 model, correlation improves by ~15% and RMSE decreases by ~39%.

国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center （National Center for Space Weather）

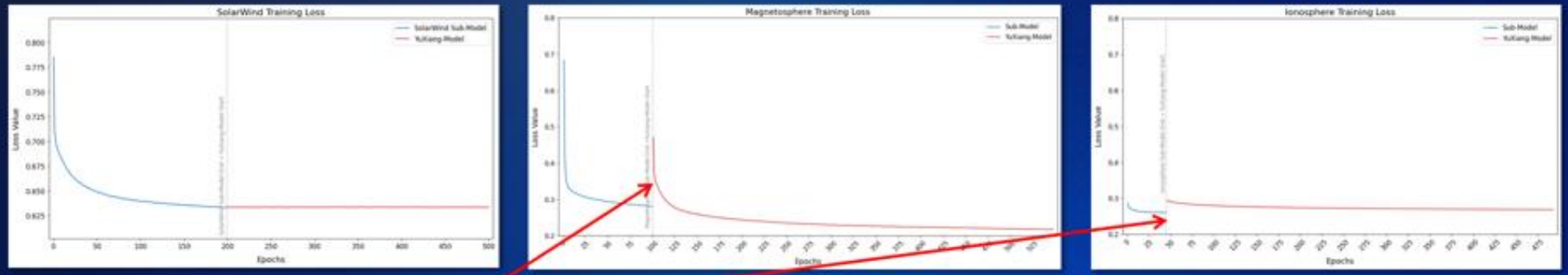

磁层
Magnetosphere
Predicted Solar Wind
太阳风
Solar Wind
History Solar Wind
Input
Solar wind model
Output
Future Solar Wind
Loss1
Coupling Optimizer
Loss2
LossX1
LossX2
Loss3
Solar Wind
Input
Magnetosphere model
Output
Satellite observation
Solar Wind
Input
Ionosphere model
Output
Satellite observation
Predicted Solar Wind
Ionosphere
电离层
国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center （National Center for Space Weather）

独立训练和耦合训练
Independent Training vs. Coupled Training

蓝线（Blue Line）：三个子模型独立训练过程 Sub-model Independent Training Process

红线（Red Line）：模型全局训练的过程 Global Model Training Process

太阳风 磁层 电离层-热层



没有进行耦合训练时，多模型结合，空间天气位于后端的子模型性能显著下降。
Uncoupled multi-model systems exhibit significant backend space weather sub-model degradation

联合训练过程中，实现了多个独立模型之间的耦合优化，性能显著提升。
Joint training achieved coupled optimization across independent models, yielding significant performance gains.

风宇对国产AI生态的贡献

FengYu's Contributions to the Domestic AI Ecosystem

1. 优化典型算子在MindSpore中的兼容性与稳定性

   Optimization of Core Operators for MindSpore Compatibility

2. 验证GPU至NPU迁移的完整流程

   End-to-End Validation of GPU-to-NPU Migration

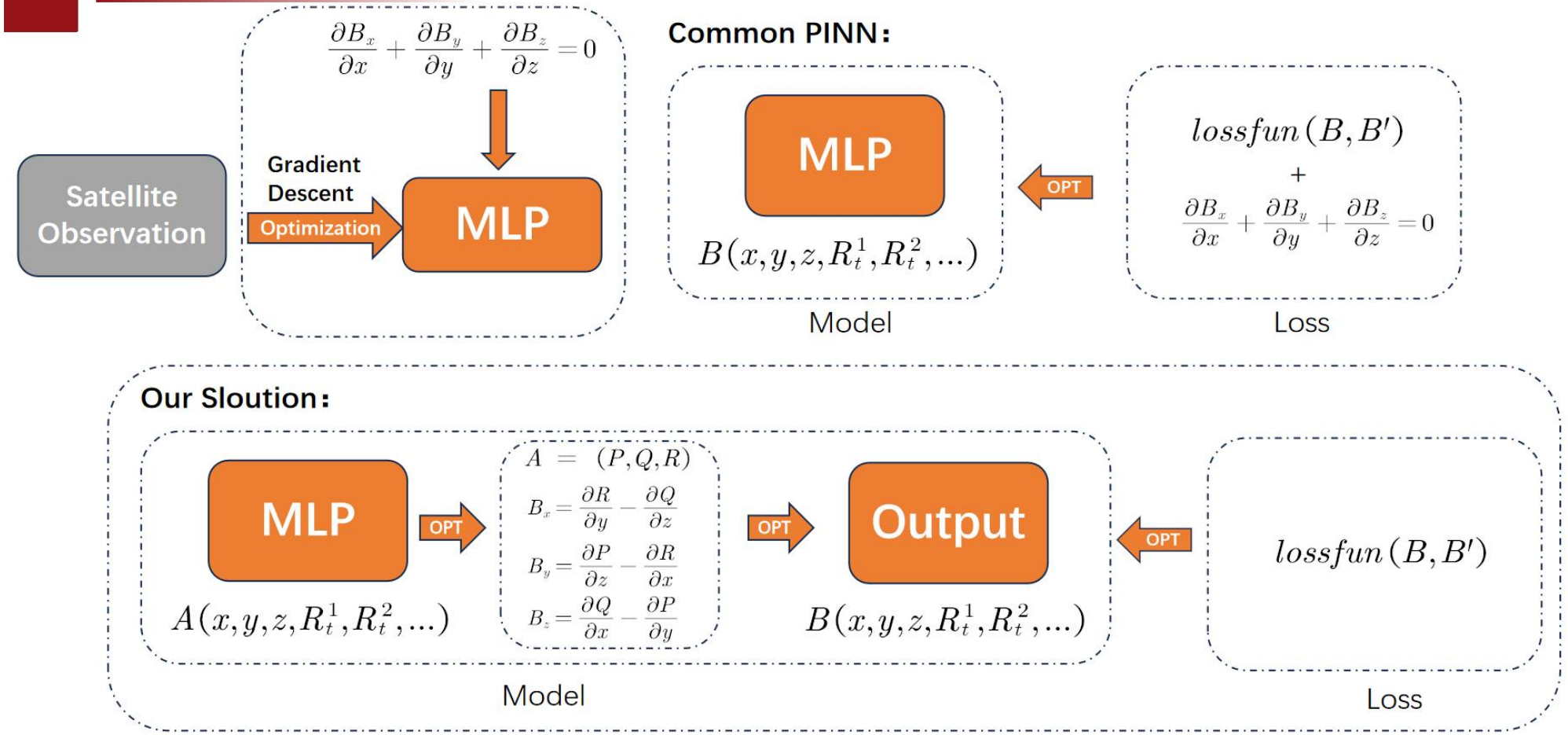
3. 积累MindSpore平台下的工程实践经验

   MindSpore Engineering Best Practices Development

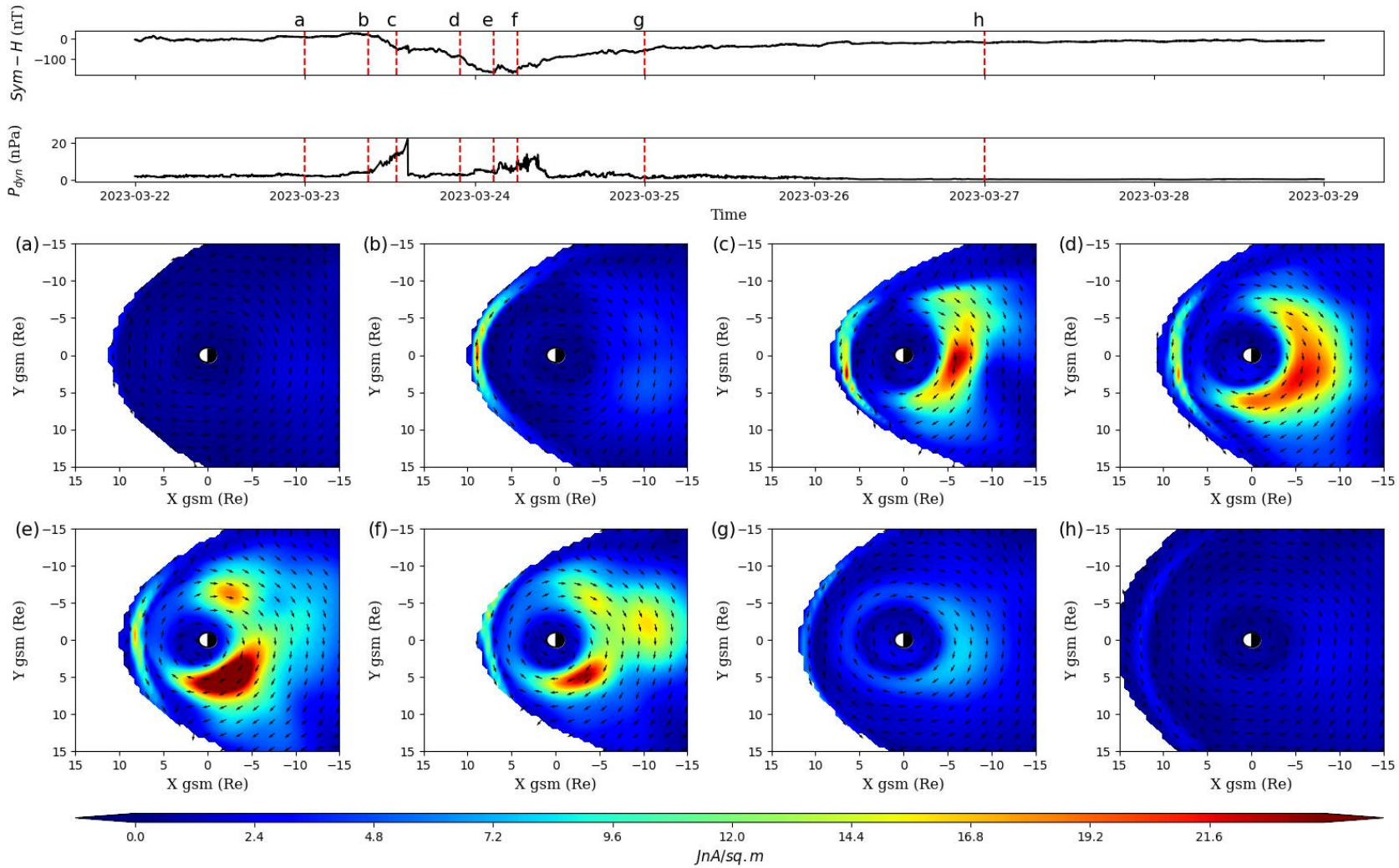

创新点一
创新点一：国际首次实现太阳风-磁层-电离层全链路智能建模
Innovation 1: The world's first end-to-end AI modeling of solar wind-magnetosphere-ionosphere coupling
创新点二
创新点二：首创空间天气上下游智能耦合技术
Innovation 2: Original AI-based coupling of space weather upstream/downstream systems
AI
创新点三
创新点三：基于自主可控AI框架的算子领域优化技术
Innovation 3: Domain operator optimization via autonomous AI framework
国家卫星气象中心（国家空间天气监测预警中心）
National Satellite Meteorological Center （National Center for Space Weather）

Progress in the Magnetosphere Module of the FengYu Model

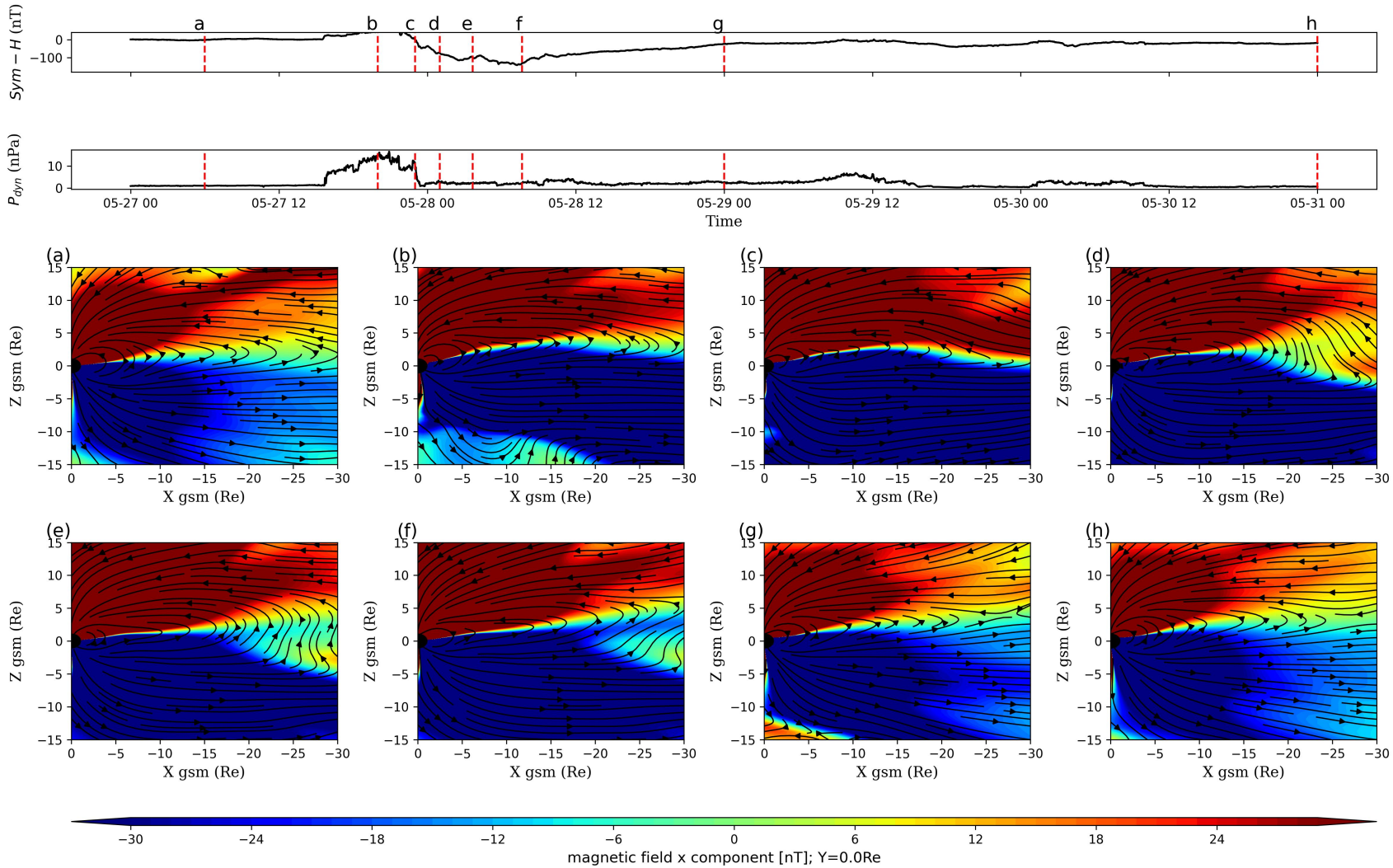
Strongly Physics-Constrained Neural Network

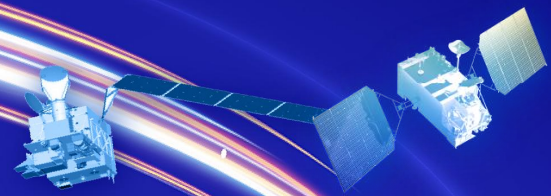


Evolution of Current Density During Geomagnetic Storm

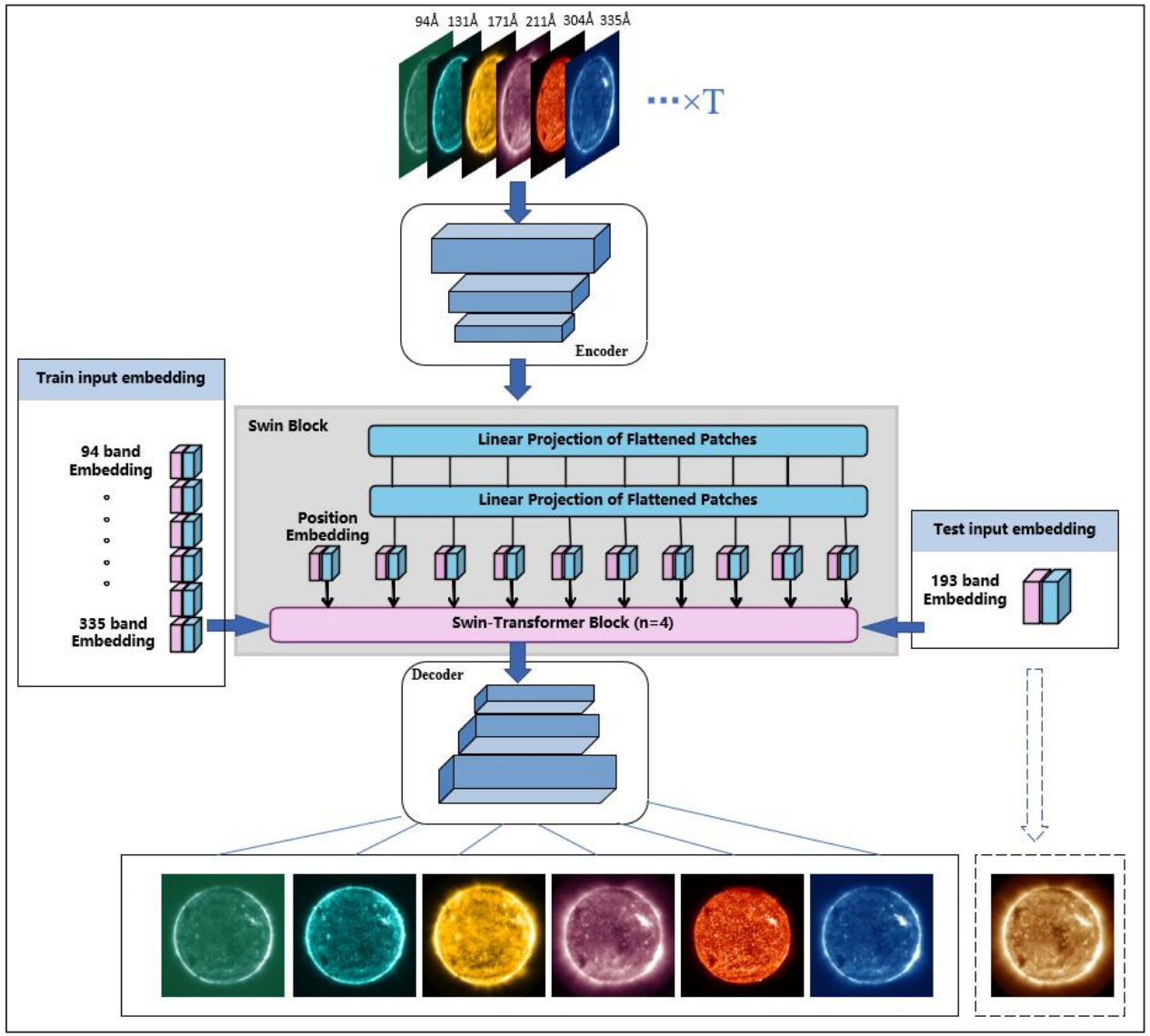


Evolution of Magnetotail Reconnection

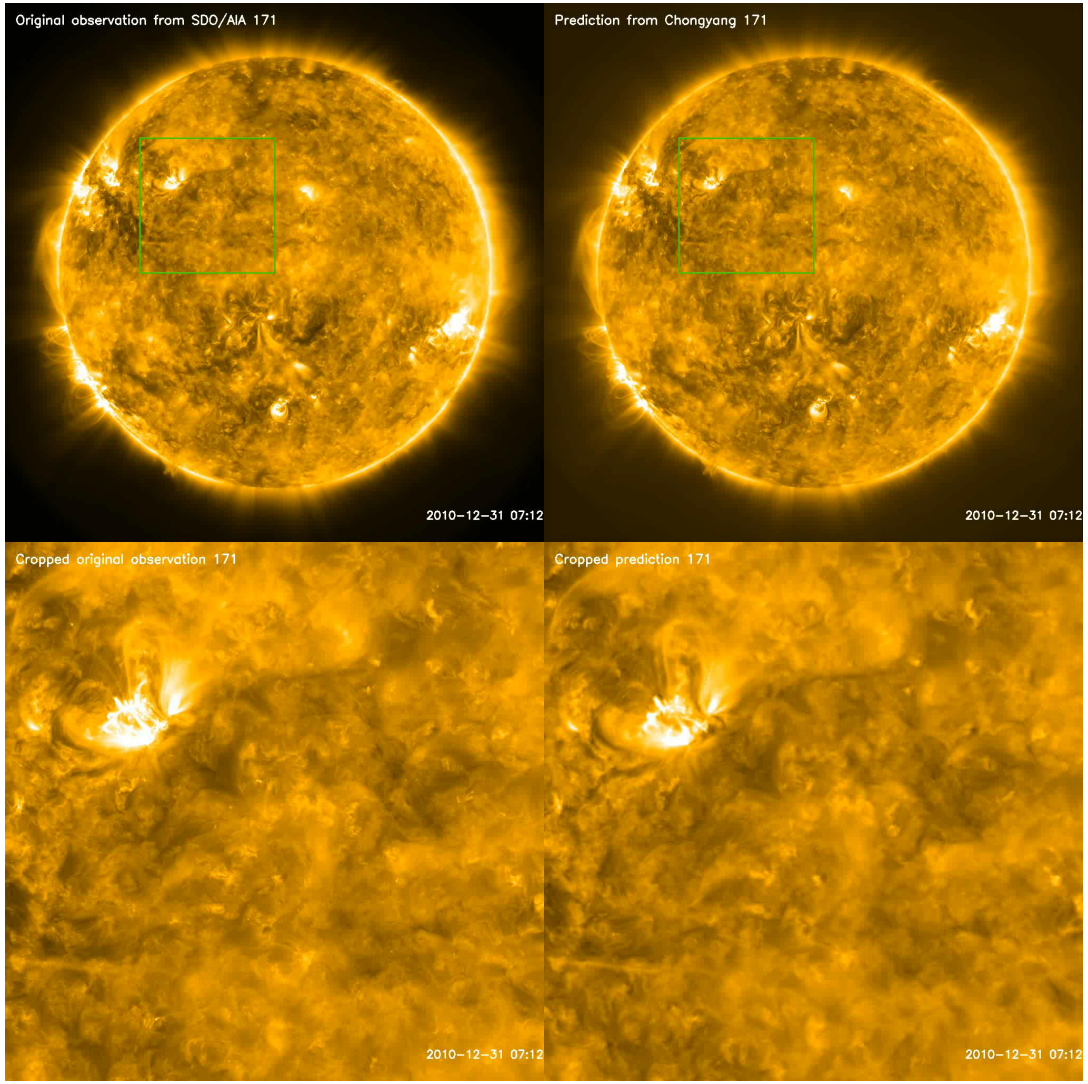




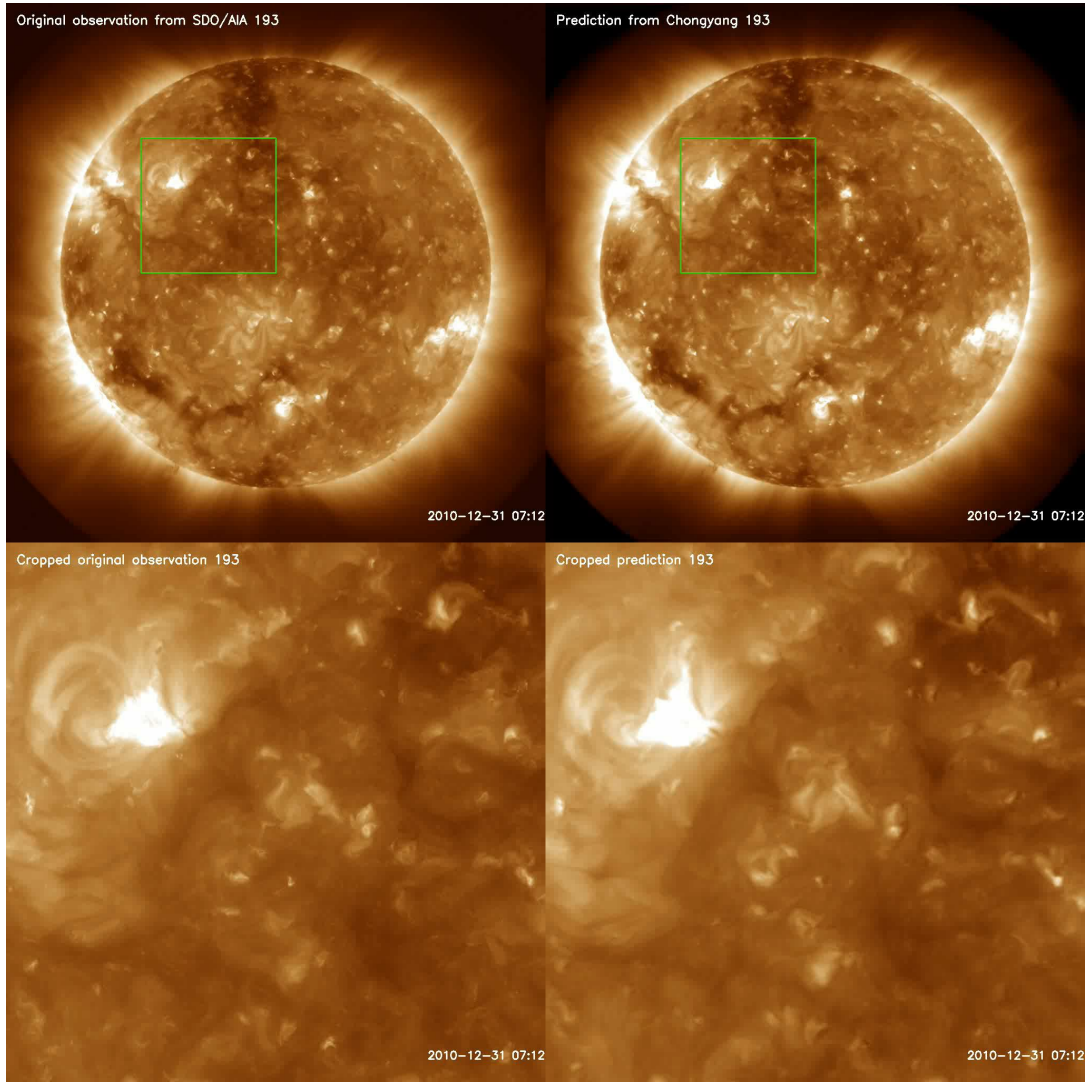
Progress in the Solar Module of the FengYu Model

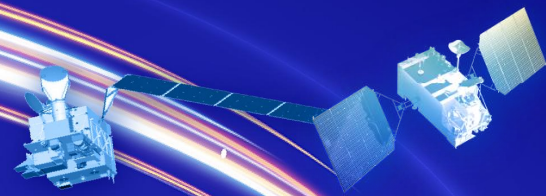

94Å 131Å 171Å 211Å 304Å 335Å
···×T
Encoder
Train input embedding
94 band Embedding
335 band Embedding
Swin Block
Linear Projection of Flattened Patches
Linear Projection of Flattened Patches
Position Embedding
Swin-Transformer Block (n=4)
Test input embedding
193 band Embedding
Decoder

In-band Prediction



Out-of-band Prediction





Thank you for your attention!