NASA PARTNER FDL X HELIO

Can we better model thermospheric density changes by integrating ***High Cadence EUV images directly*** *rather than relying on daily proxy indices?*

FDLXHELIO.ORG

TRILLIUM USA

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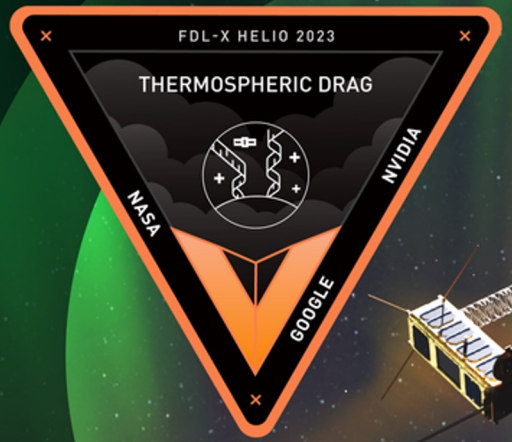

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FDL-X HELIO 2023 **THERMOSPHERIC DRAG**
EUV IRRADIANCE & THERMOSPHERIC DENSITY

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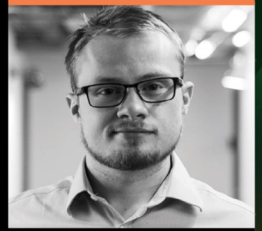

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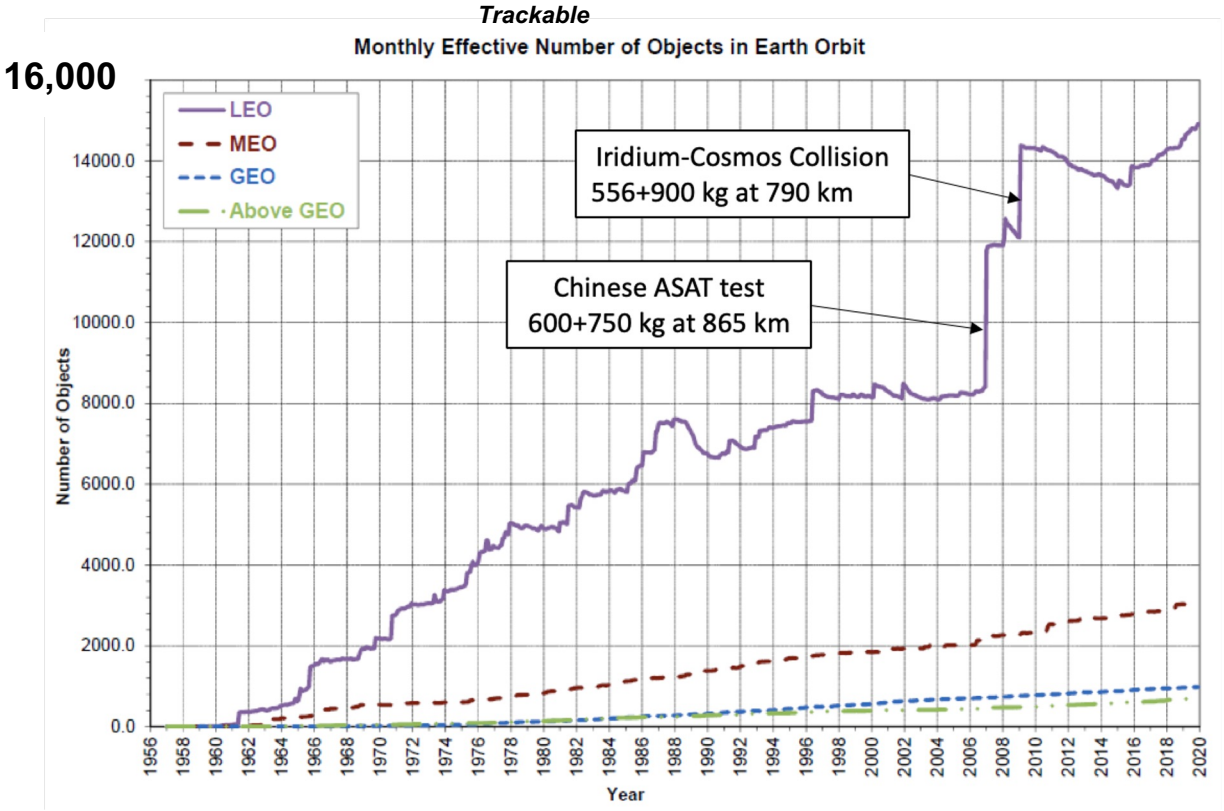
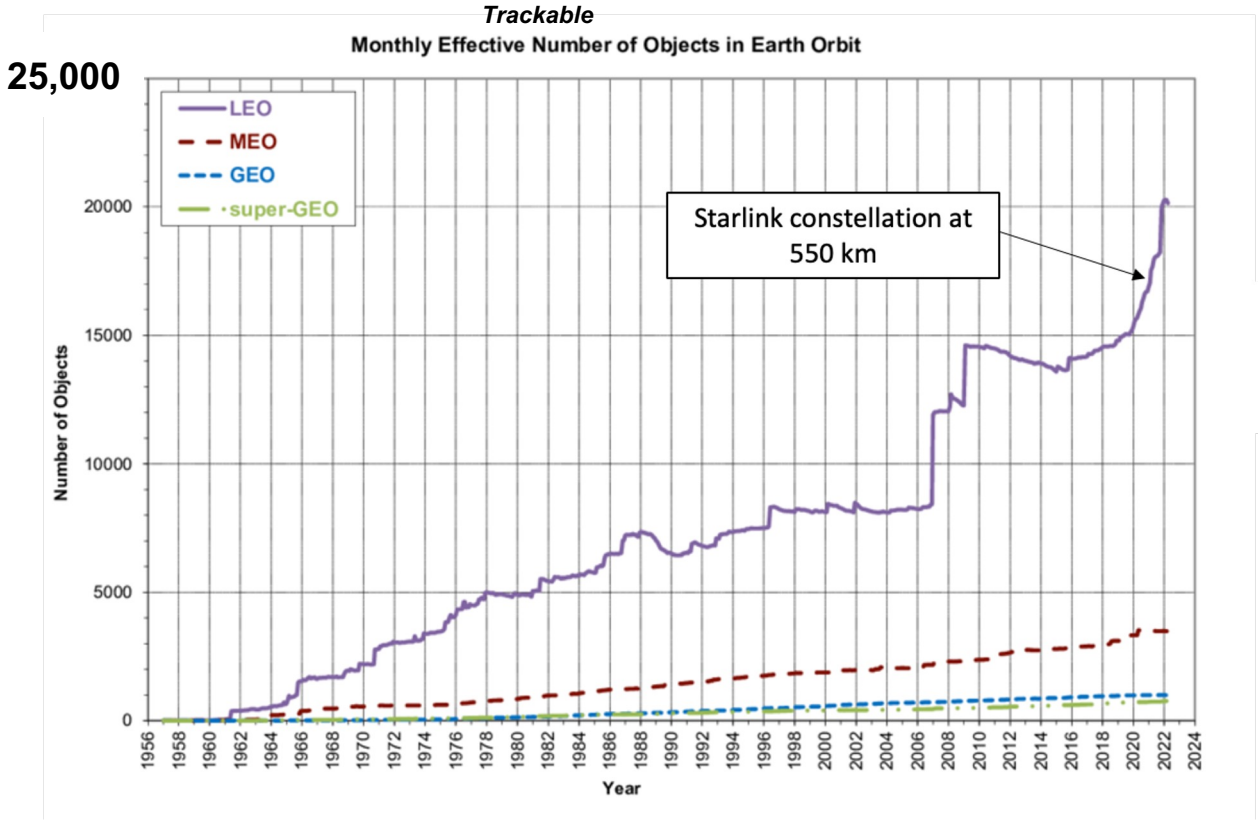
The Low Earth Orbital Domain Population is Rapidly Growing



The Low Earth Orbital Domain Population is Rapidly Growing



Density Estimation is the Largest Source of Uncertainty for Satellite Drag

Satellite Drag Coefficient

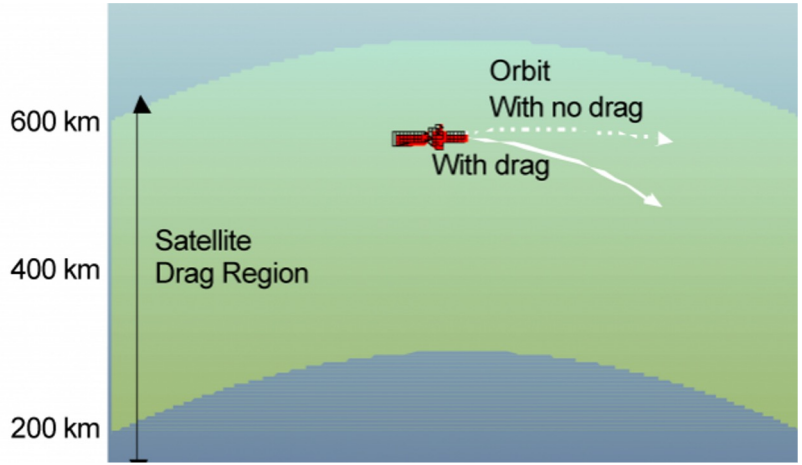
Satellite Surface Area

Atmospheric Density

$$\mathbf{a}_D = -\frac{1}{2}\rho\frac{C_D\,A}{m}V_{rel}^2\,\hat{\mathbf{V}}_{rel}$$

Satellite Mass

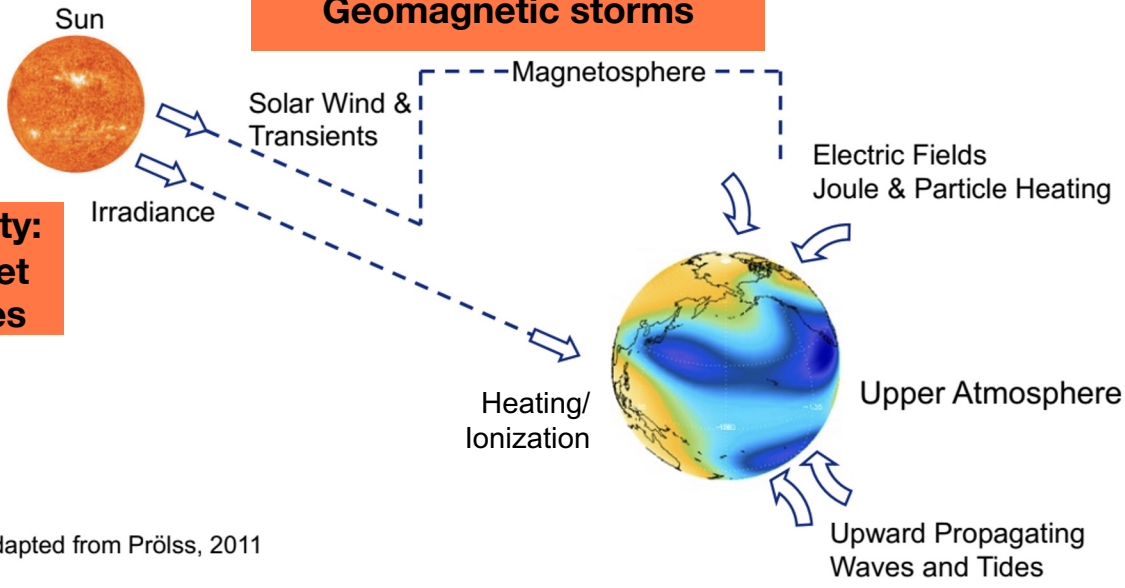
Satellite Velocity relative to Atmosphere



Density Prediction is Hard: A Complex Interconnected System

Major density changes: Geomagnetic storms

Background density: Extreme Ultraviolet Irradiance & Flares



Adapted from Prölss, 2011

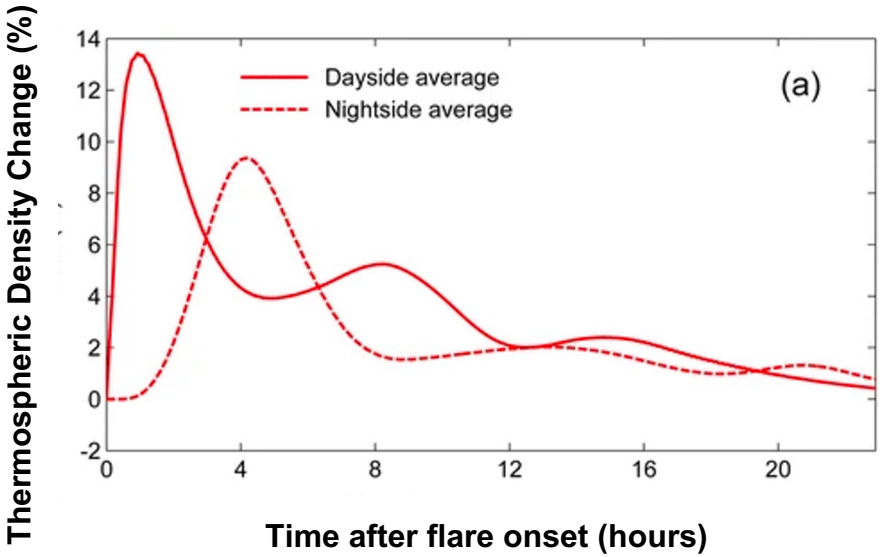
Current models do not account for EUV irradiance *directly*

1. **Complex ground-based proxies** - F10.7 has complicated formation mechanism.

2. Proxies are given **daily** - cannot account for rapid solar variability e.g. **active region emergence & solar flares**

3. Perform poorly in periods of high solar activity → **when it matters most**

Simulation of Flare Effect on Thermosphere @ 400km



Le, H., Ren, Z., Liu, L. *et al.* Global thermospheric disturbances induced by a solar flare: a modeling study. *Earth Planet Sp* 67, 3 (2015).

NASA provides data that continuously captures solar activity at high cadence

Solar Dynamics Observatory (**SDO**)

- NASA mission observing the Sun since 2010
- EUV images at 12 second cadence
- Magnetograms at 45 second cadence.

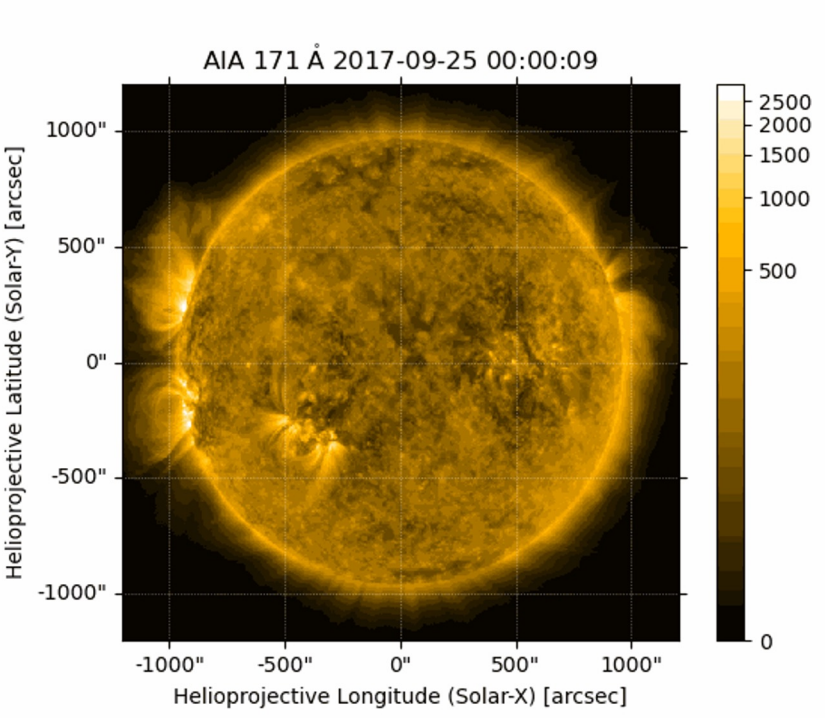
SDOML dataset (FDL 2019)

- **Medium Cadence: 12 minutes**
- Inter-Calibrated, ML-ready Data

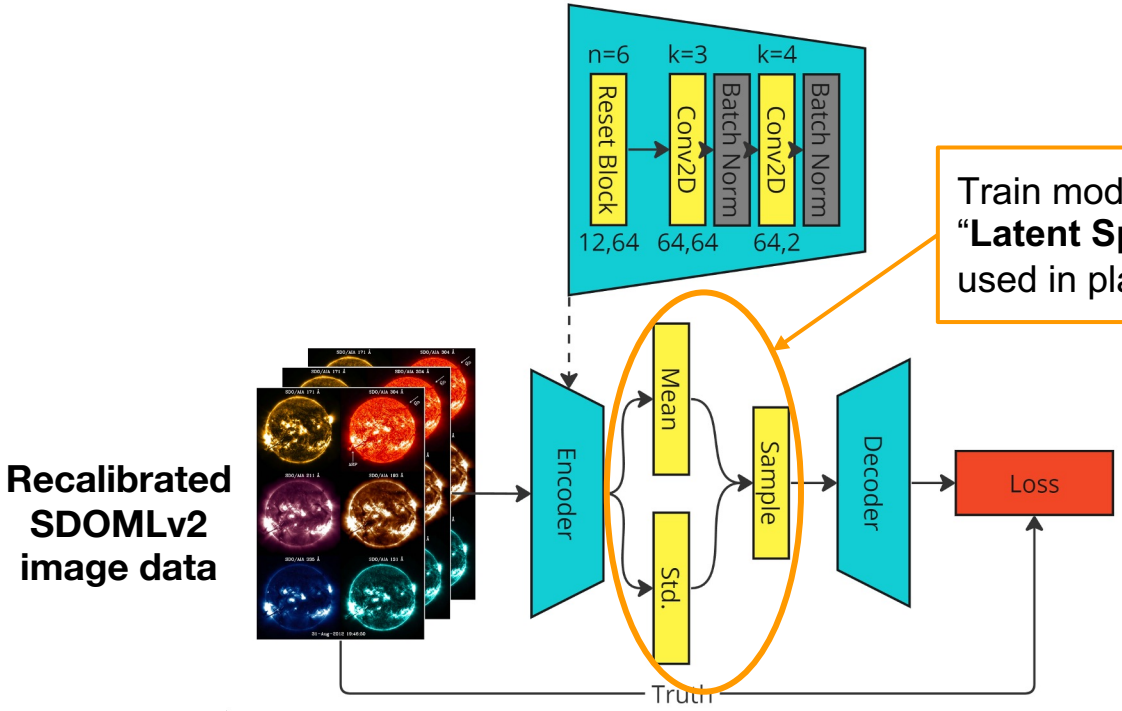
Karman ML model (FDL 2021)

- Pre-existing ML model using proxy indices from ground truth satellite data measurements

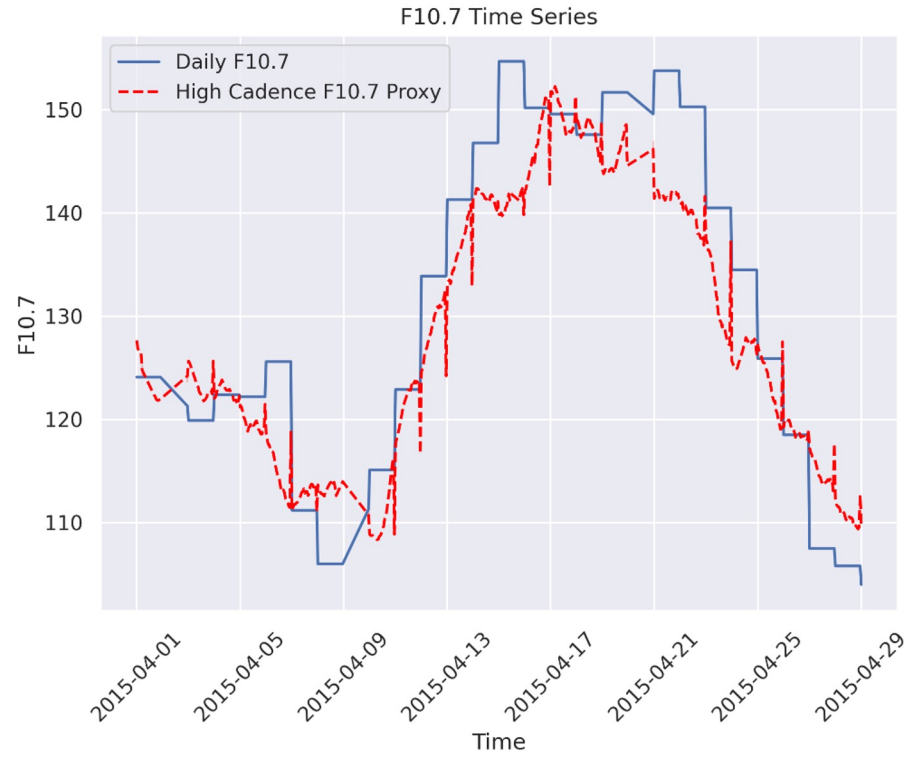
KARMAN



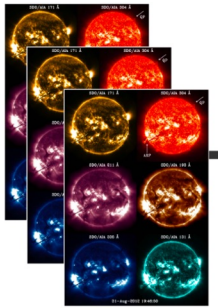
SDOML Dimensional Reduction: Variational Autoencoder



Key Result:
ML-informed replication of F10.7 at **higher cadence.**



Thermospheric Density Models



SDOML

Encode

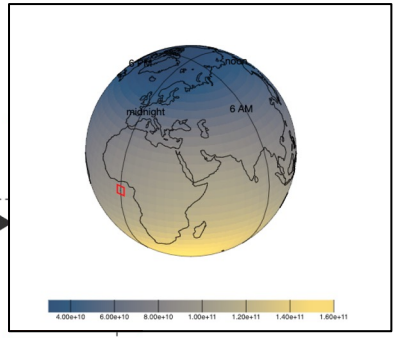
VAE

Aggregate

Latent Dataset Generation

Latents

Density Prediction



Original Karman

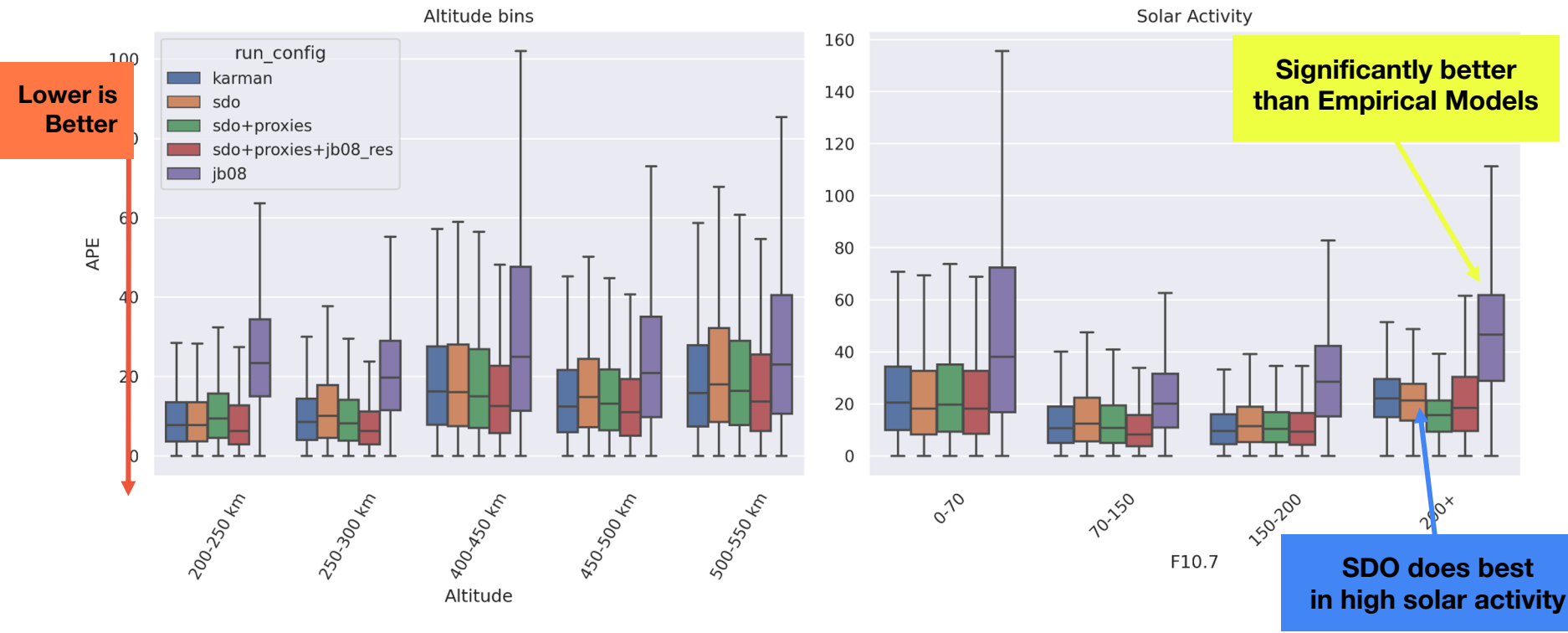
Empirical Model Features

Encode

Fusion

FFN

Key Result: SDOML can **replace proxies** with **the same (or better) performance** across altitudes/solar activity levels!



FDL-X combines integrated AI pipelines, machine learning and domain science across heliophysics challenges. Please join us for presentations from all three teams.

Multiscale Geoeffectiveness Forecasting using SHEATH and DAGGER

Vishal Upendran
Tuesday 2:25 PM

Improving thermospheric drag modeling with EUV images: an FDL-X 2023 project

Tom Berger
Wednesday 1:45 PM

AIA is All You Need: SDO MEGS A&B virtualization via Convolutional Deep Learning

Daniel Gass
Tuesday 2:15 PM

A Scientific Cloud Computing Platform for Ingestion and Processing of SDO Data

Manuel Indaco
Wednesday 2:10 PM

AI Inference products, foundation models and multi-domain approaches to NASA Heliophysics.

FDL-X
James Parr
Wednesday 2:20 PM

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