Predicting GNSS Disruptions using Machine Learning

ML in Heliophysics 2019

Laura A. Hayes

Kibrom Ebuy Abraha, Daniel Kumar, Karthik Venkataramani

Asti Bhatt, Red Boumghar, Sylvester Kaczmarek, Ryan McGranaghan, Sean McGregor

Check out Lika's talk on Wednesday!

NASA Frontier Development Lab

- 8 week applied research accelerator
- Public-Private Partnership
- Hosted at SETI Institute and NASA Ames

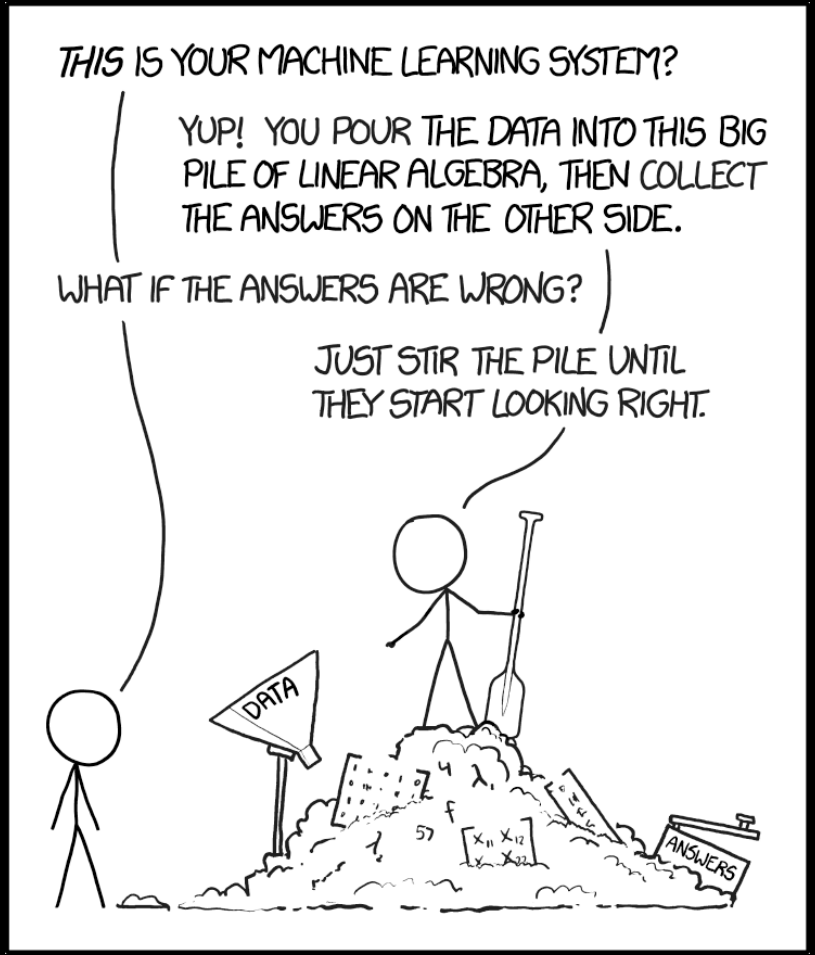
NASA Ames Research Center - Silicon Valley - 2018

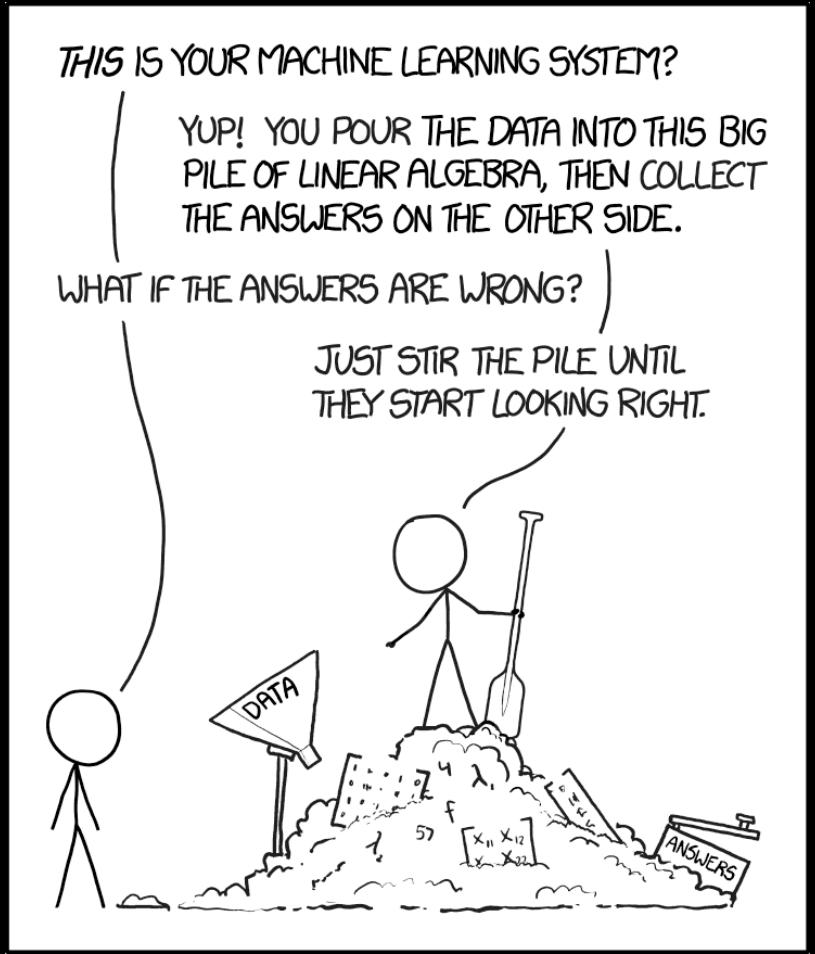
FDL 2018

FDL

SETI INSTITUTE · intel AI · SPACE RESOURCES.LU · XPRIZE · Google Cloud · NVIDIA · LOCKHEED MARTIN · kx · IBM · KBRwyle We Deliver

Machine Learning



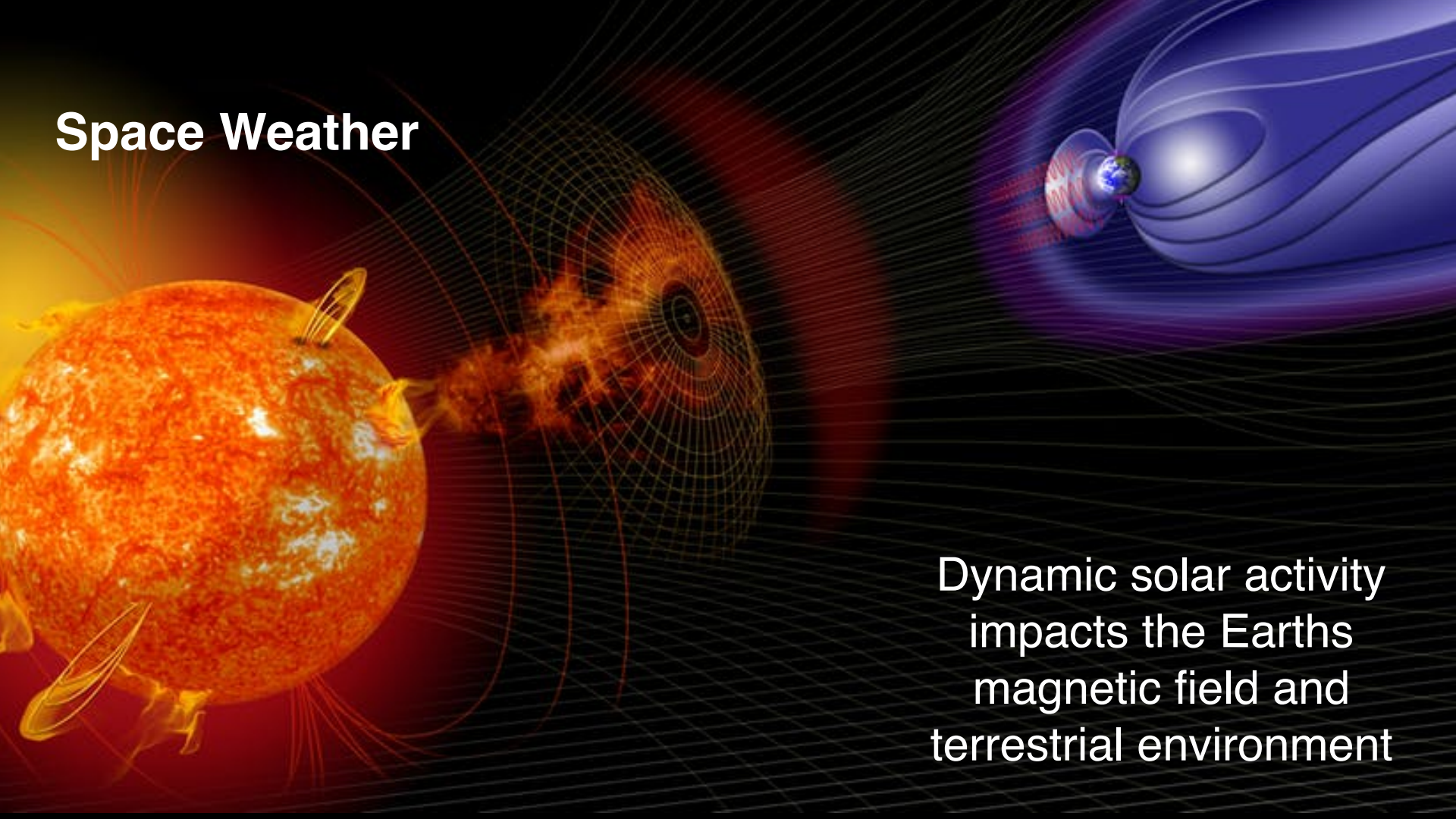


Machine Learning

- Scientifically informed data-driven approach

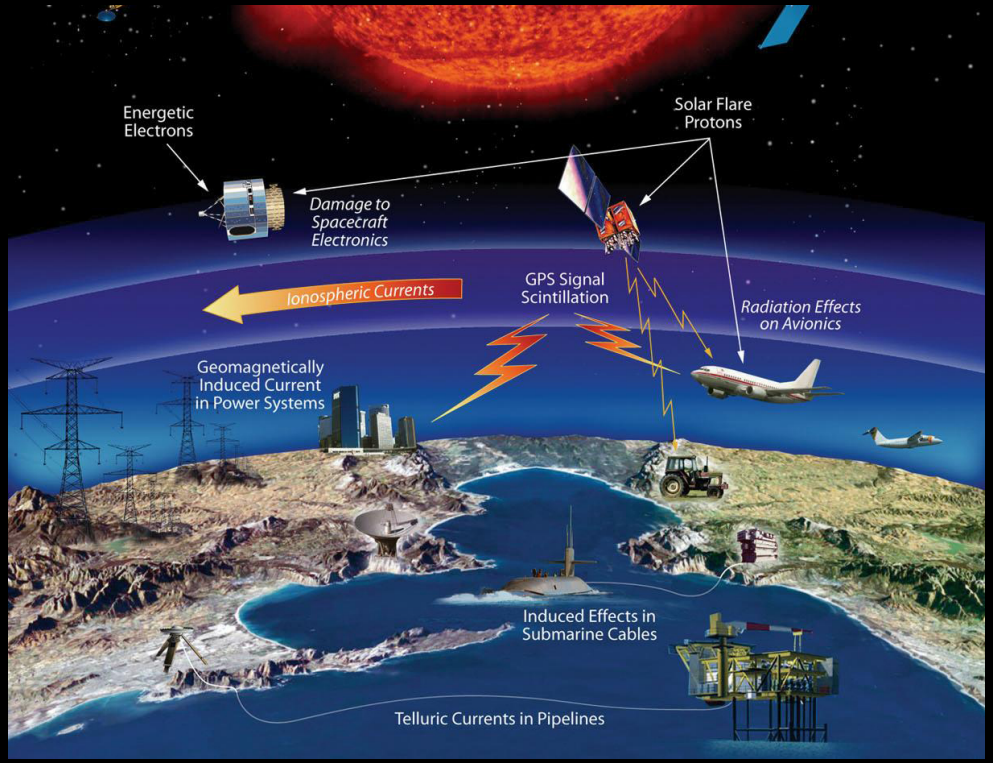
Maximise AI/machine learning techniques to space science challenges

Space Weather

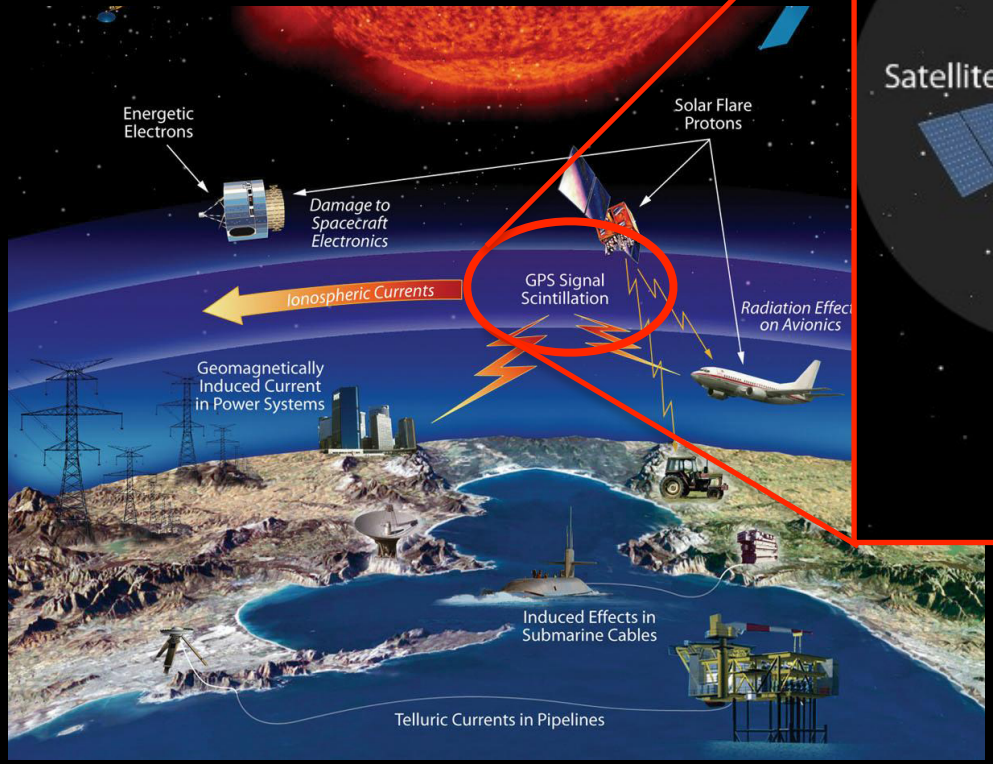


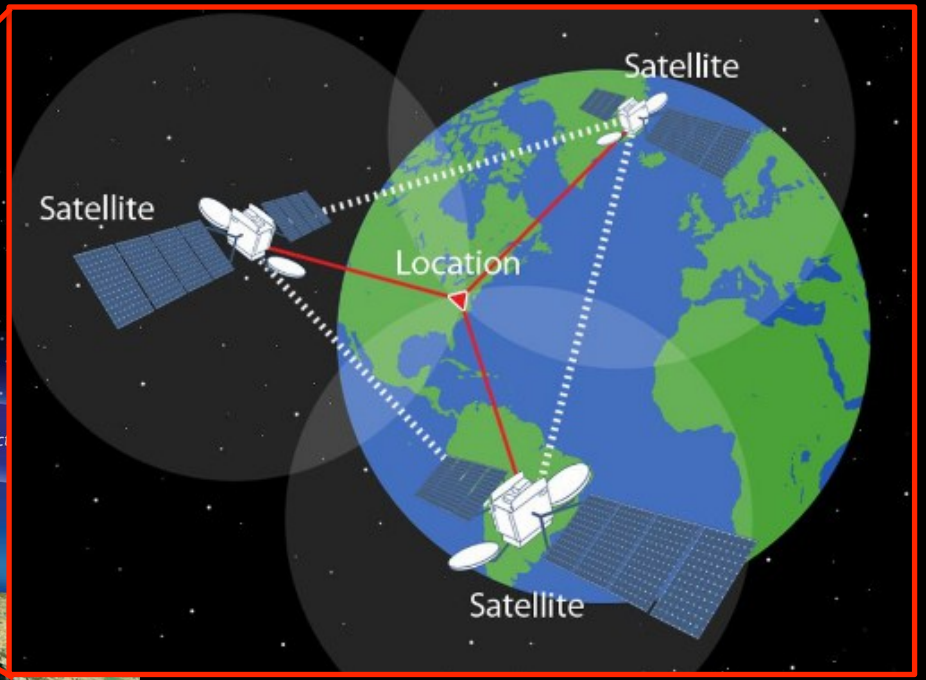
Dynamic solar activity impacts the Earths magnetic field and terrestrial environment

Space Weather Impacts



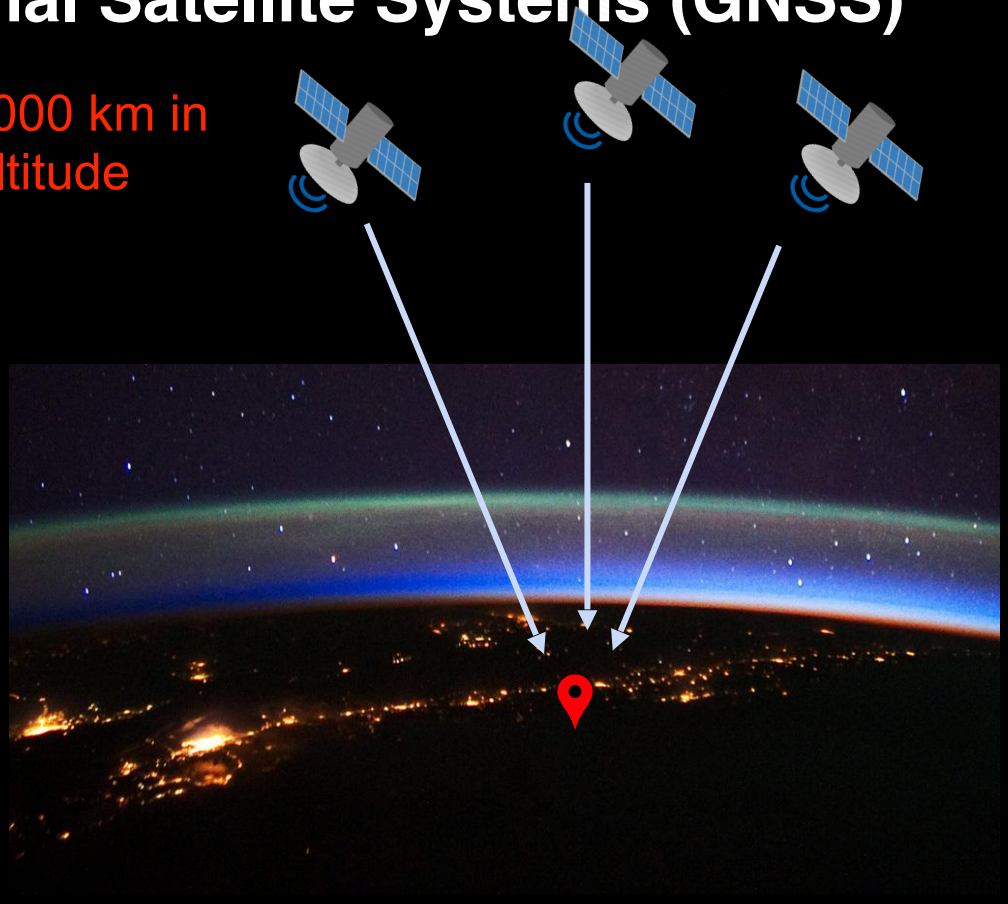
Space Weather Impacts





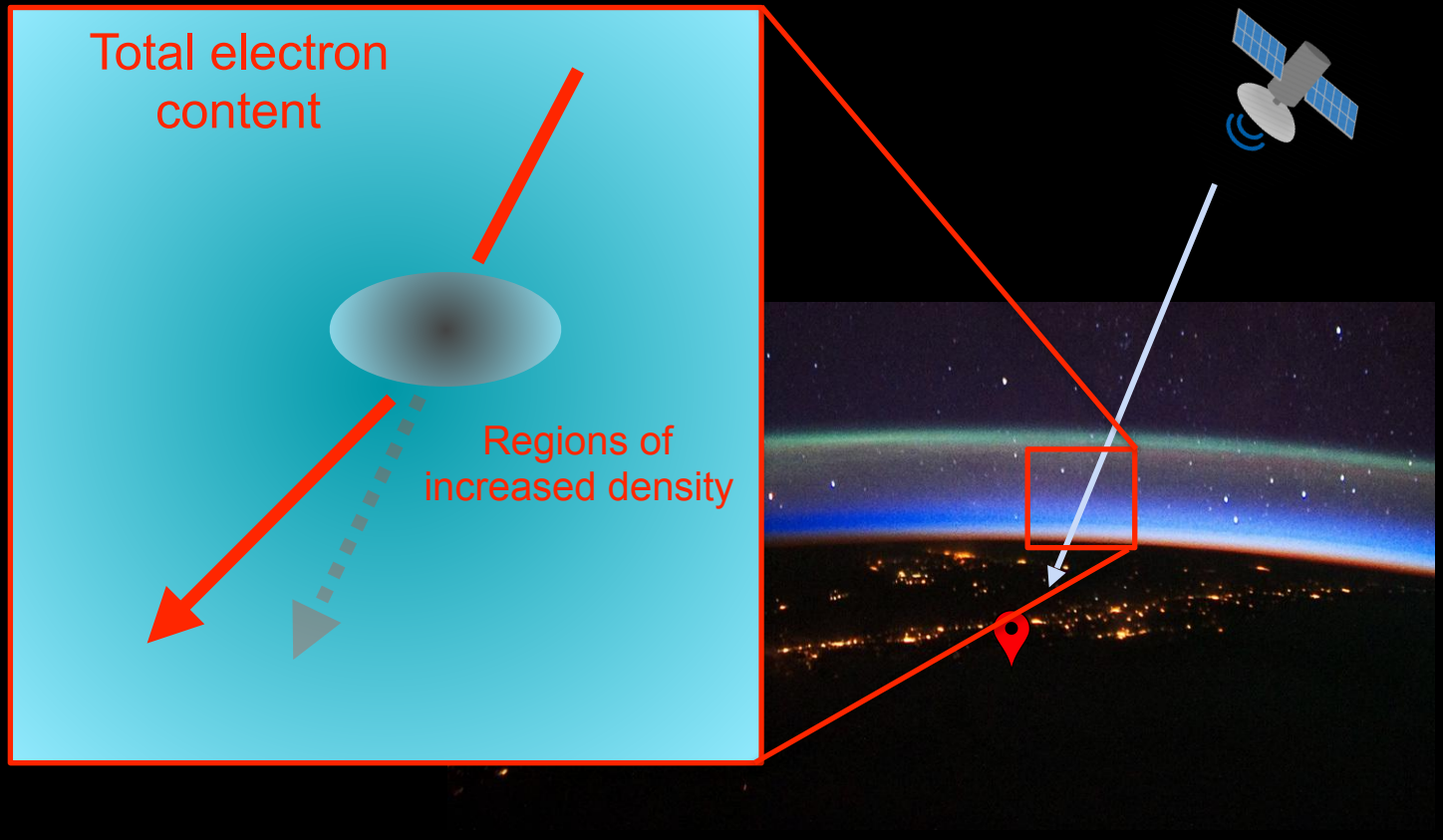
Global Navigational Satellite Systems (GNSS)

~ 20000 km in altitude

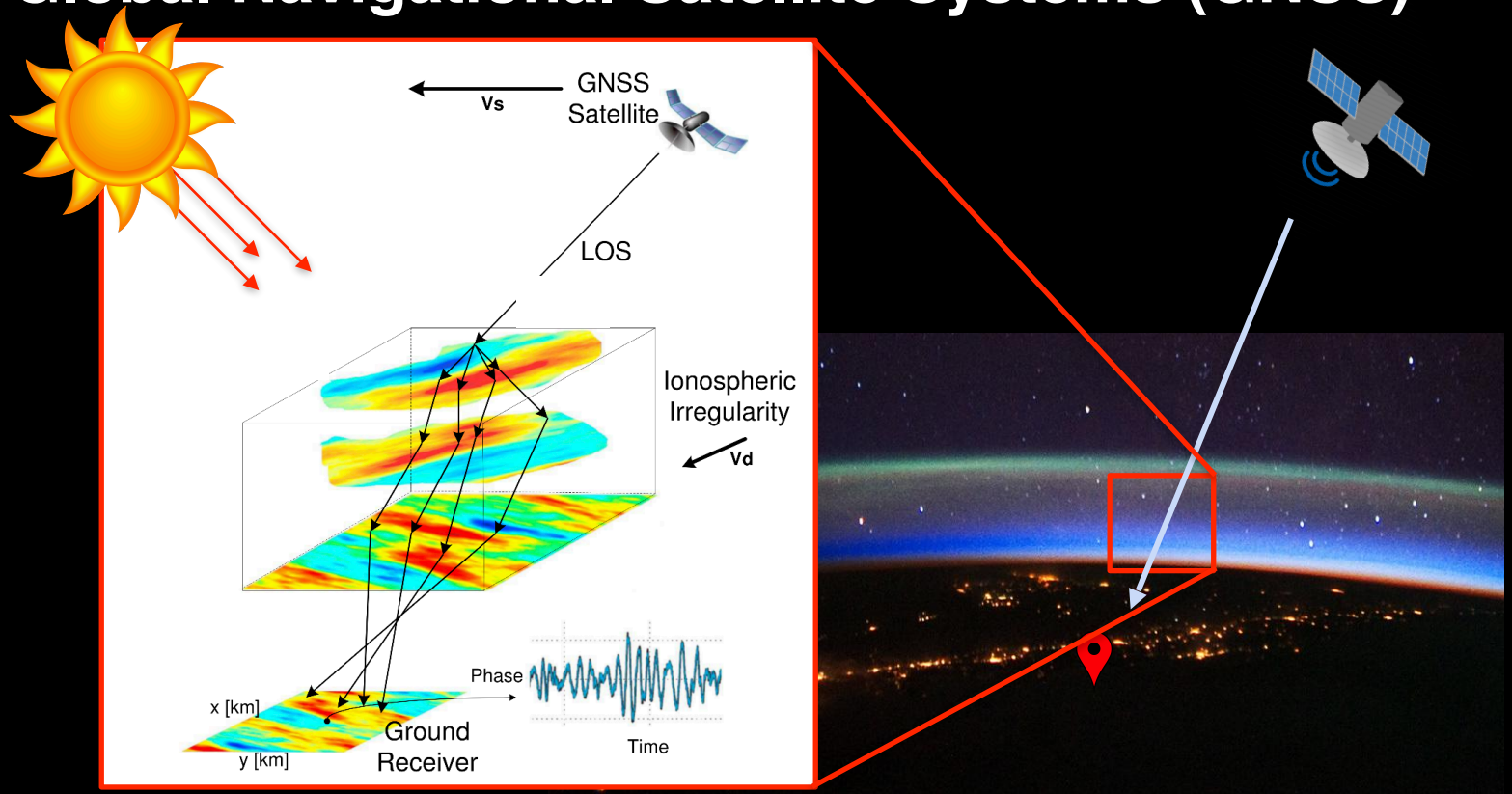


Ionosphere 100-1000 km

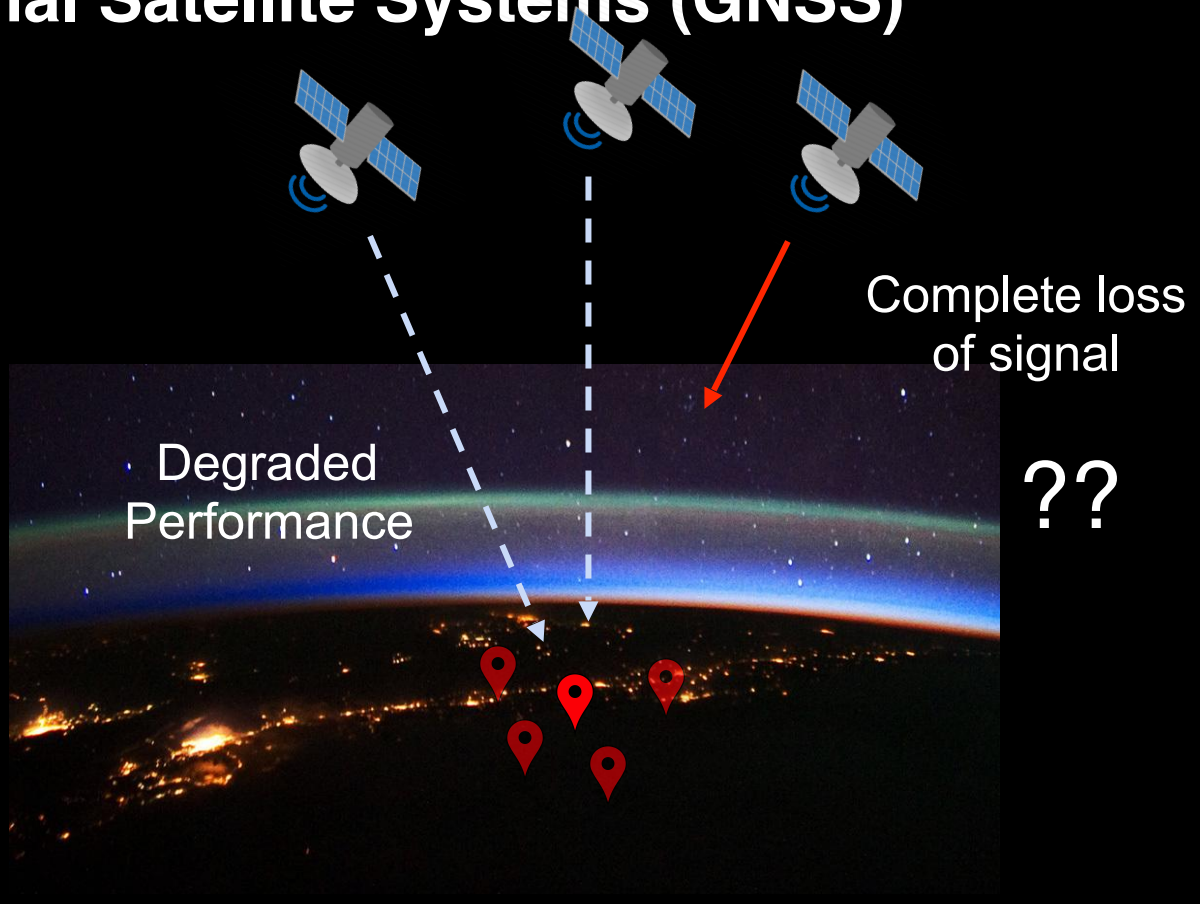
Global Navigational Satellite Systems (GNSS)



Global Navigational Satellite Systems (GNSS)

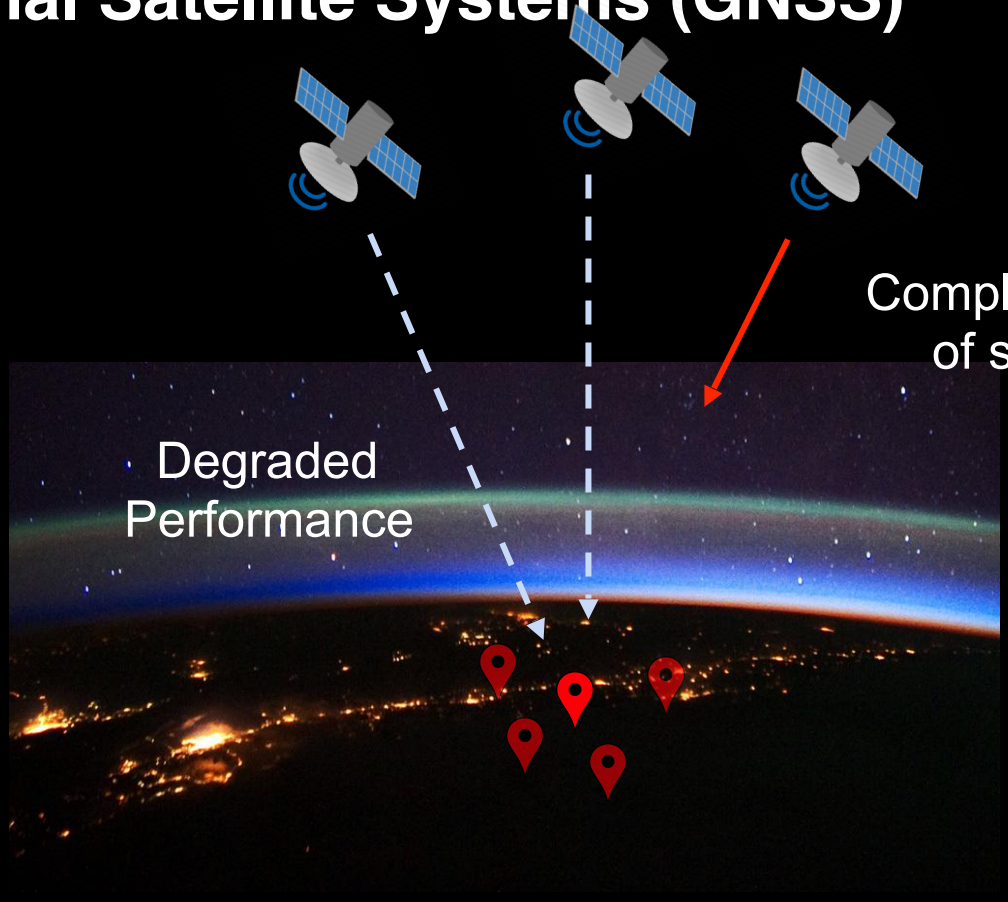


Global Navigational Satellite Systems (GNSS)



Global Navigational Satellite Systems (GNSS)

Need robust forecasting methods



Complete loss of signal

??

Can we use data-driven machine learning techniques to forecast GNSS disruptions?

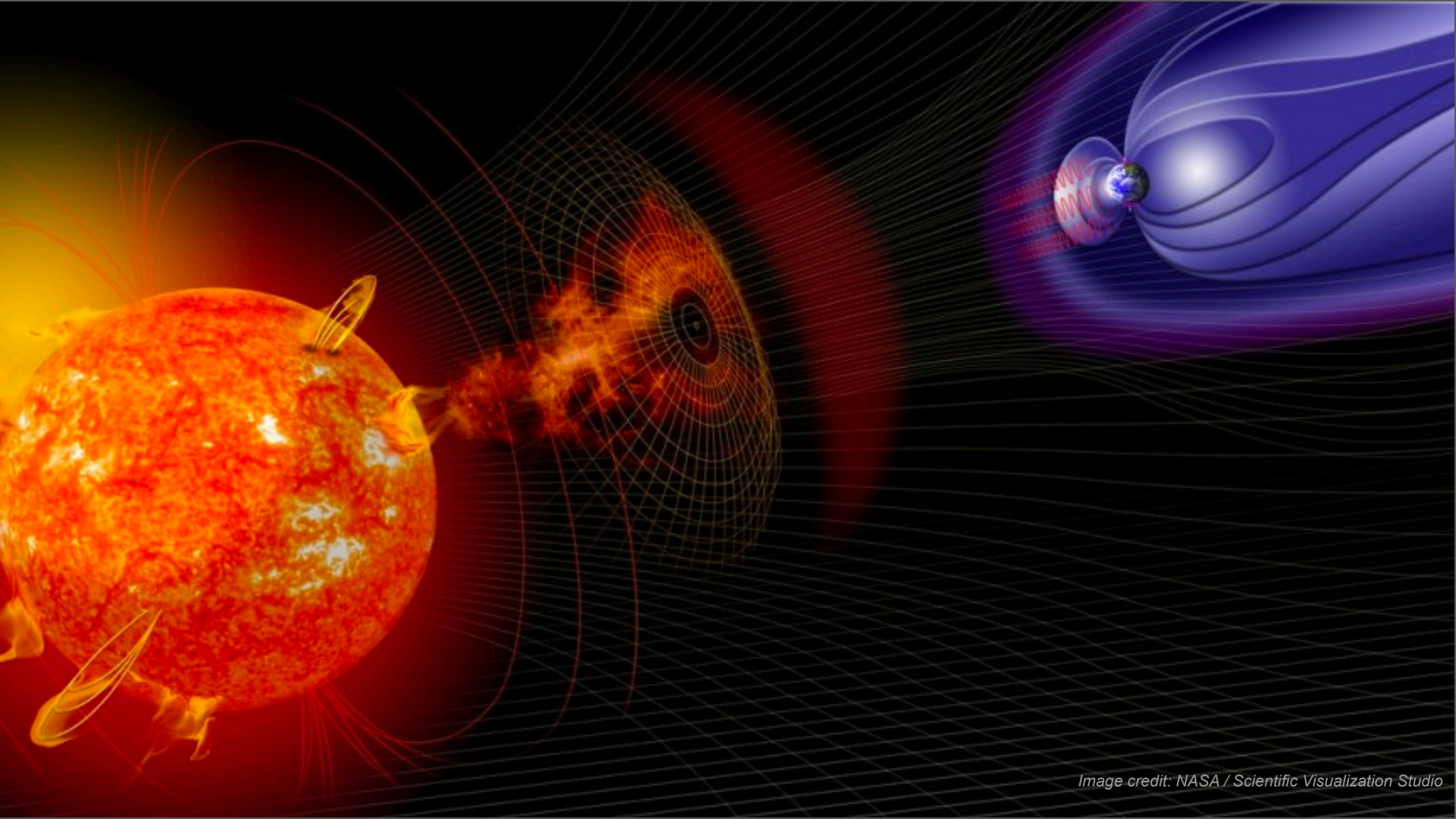


Image credit: NASA / Scientific Visualization Studio

Solar Data

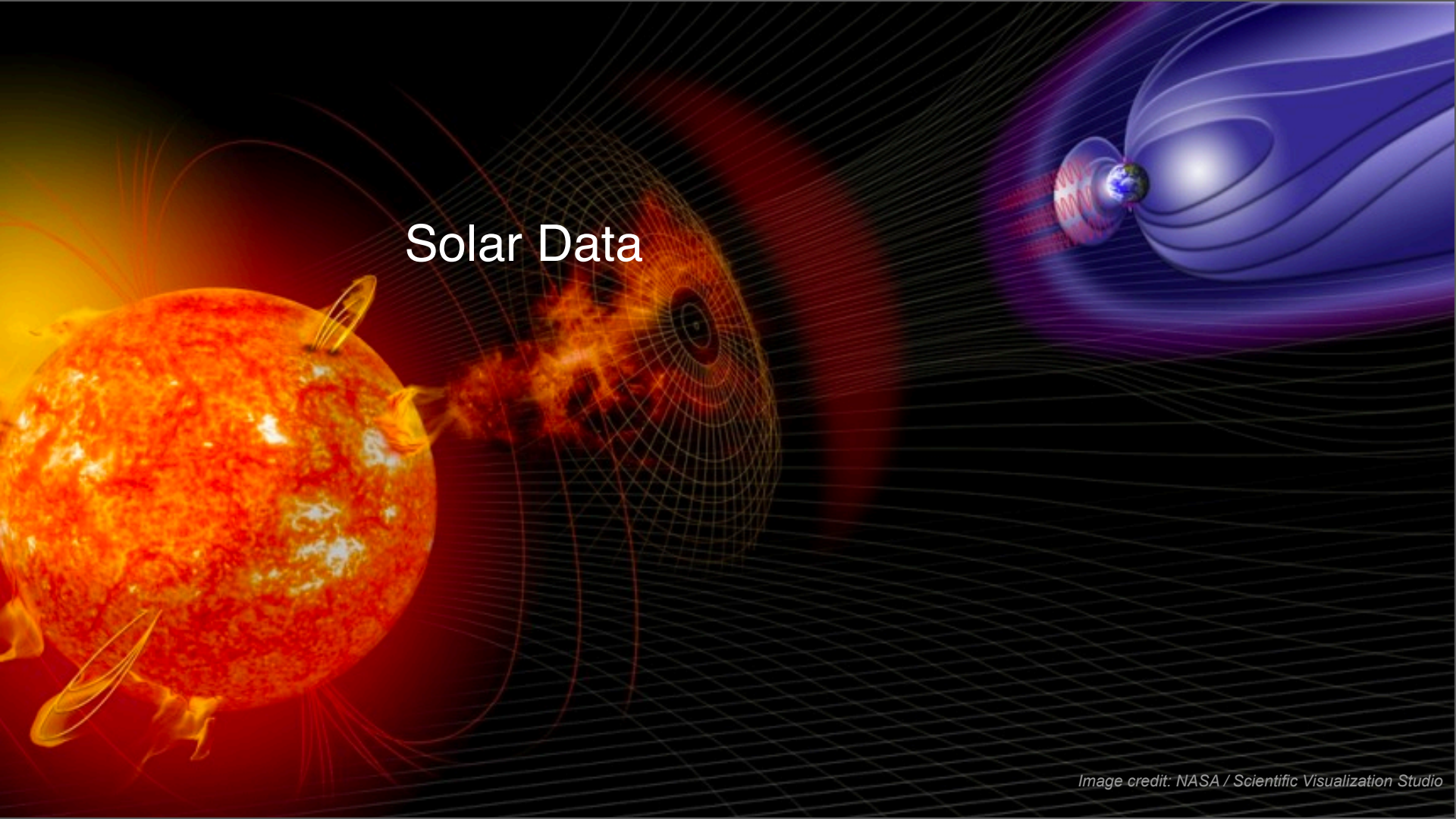


Image credit: NASA / Scientific Visualization Studio

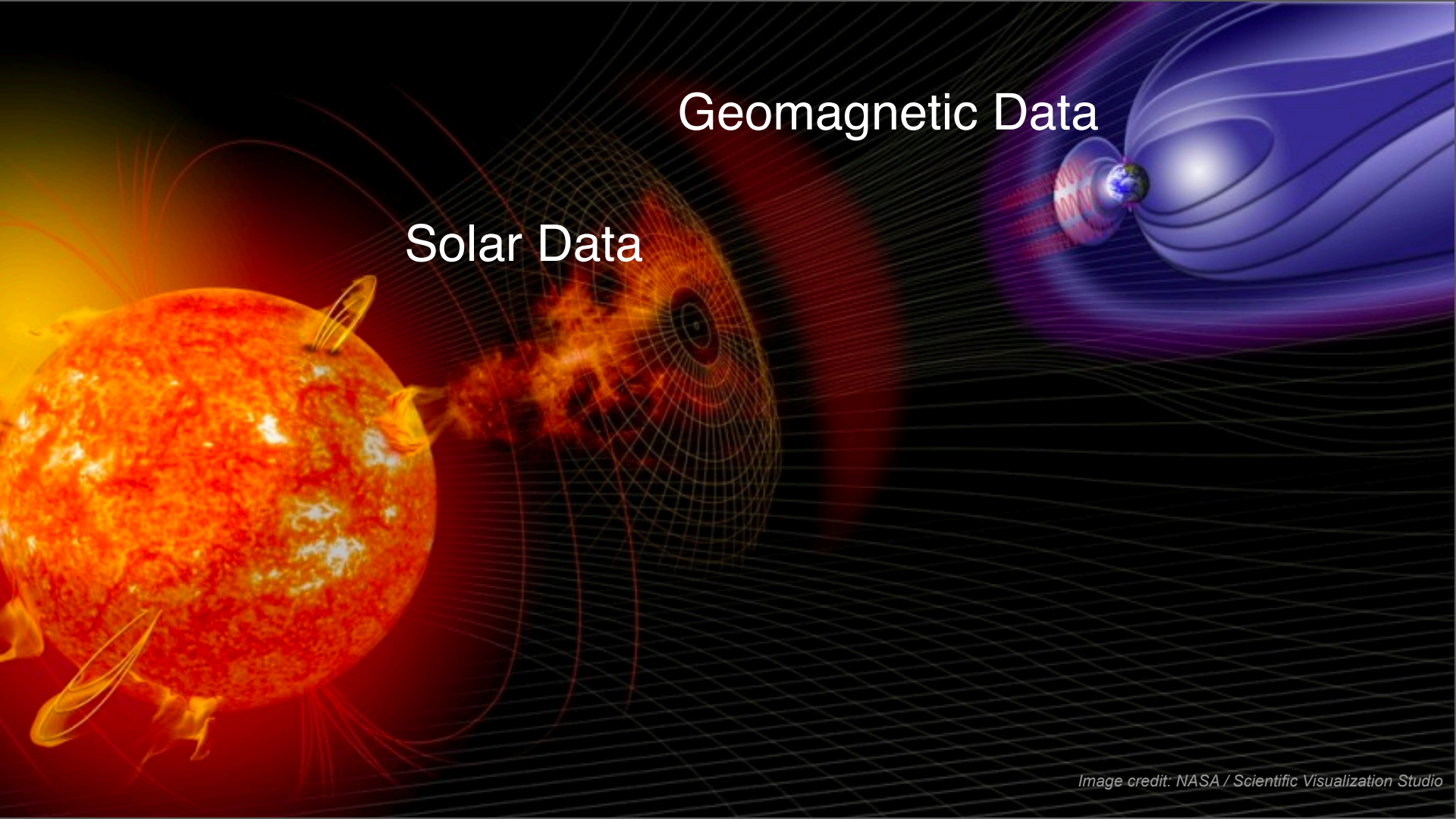
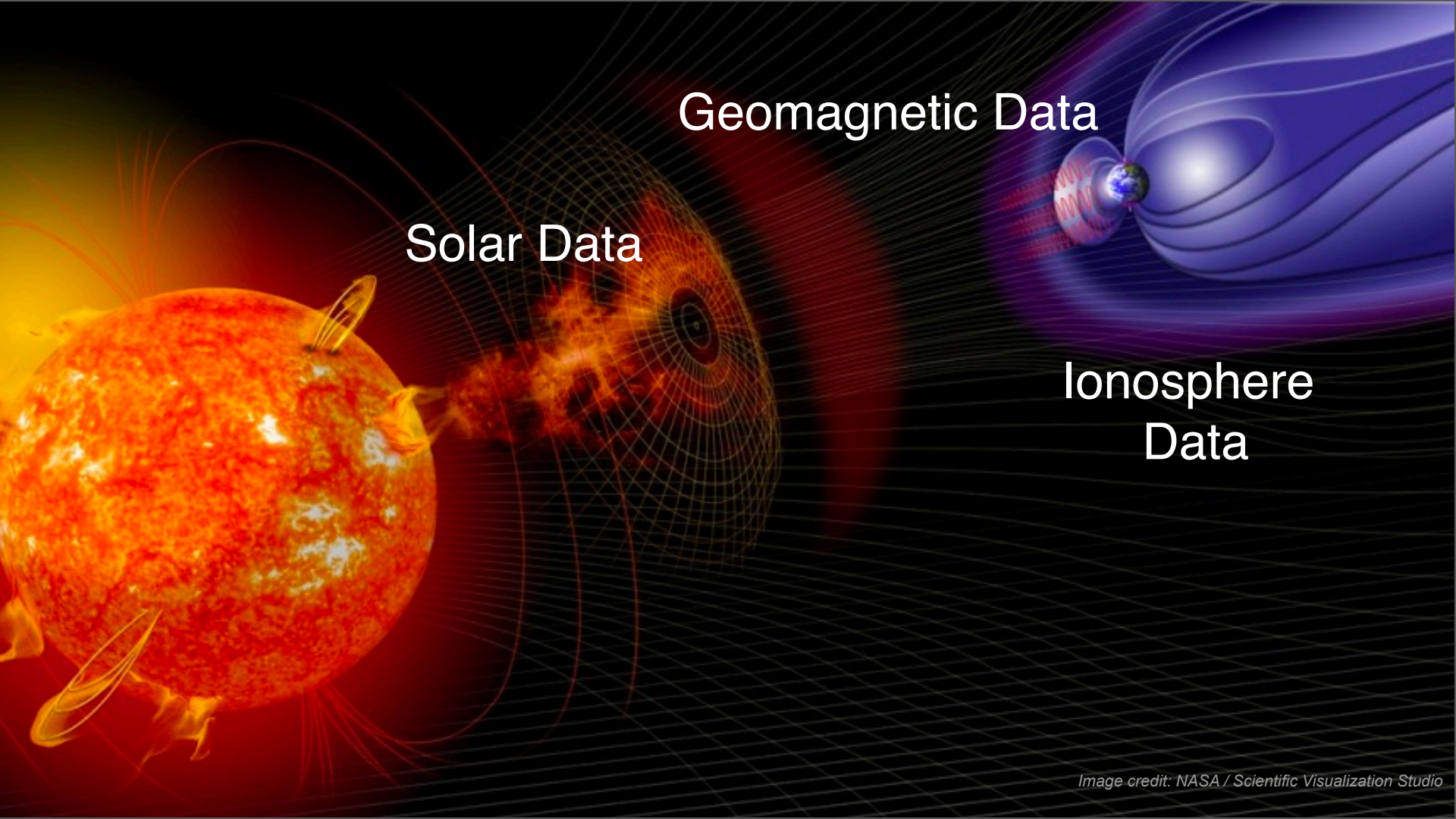
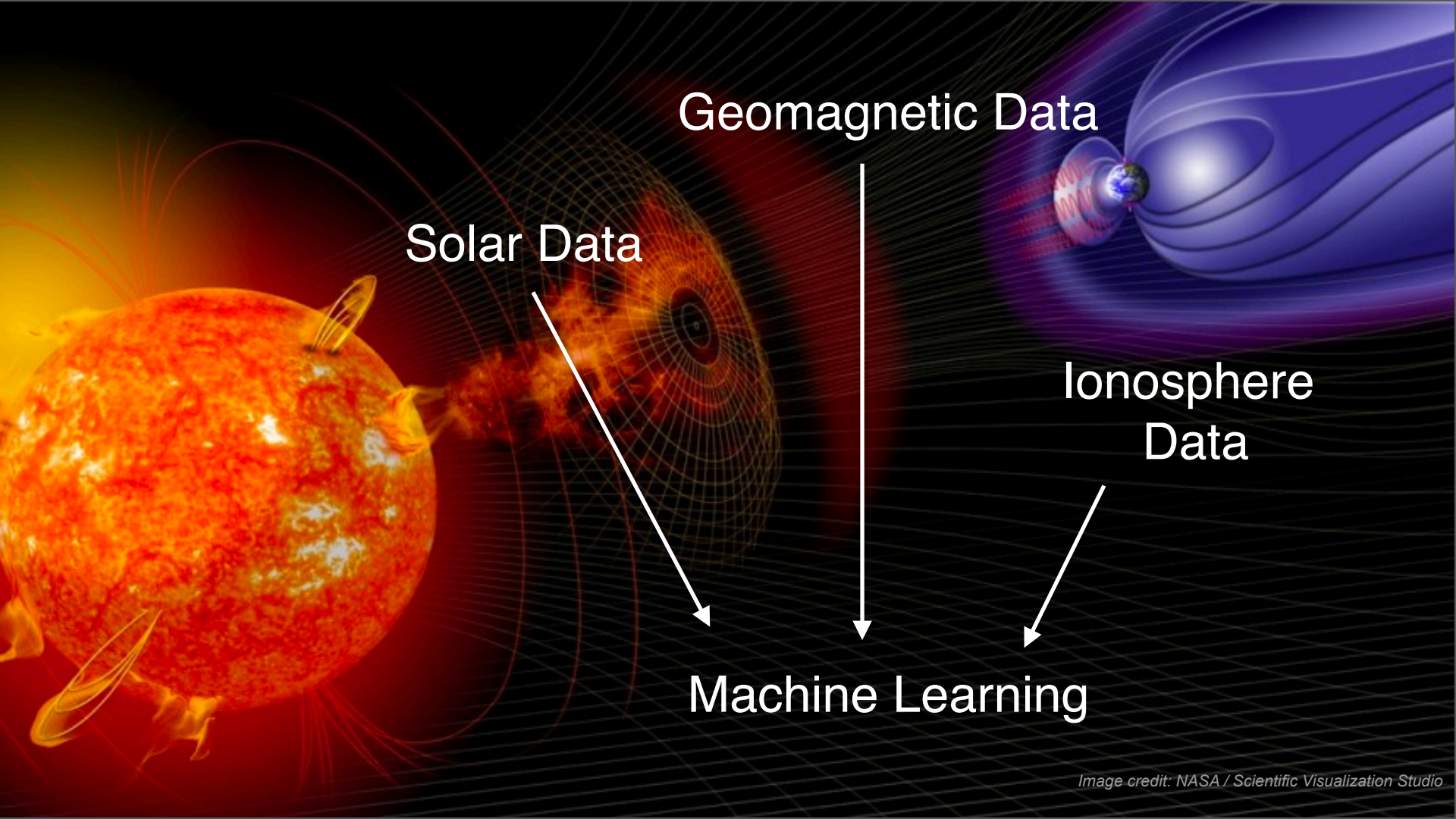


Image credit: NASA / Scientific Visualization Studio


Geomagnetic Data
Solar Data
Ionosphere Data
Image credit: NASA / Scientific Visualization Studio

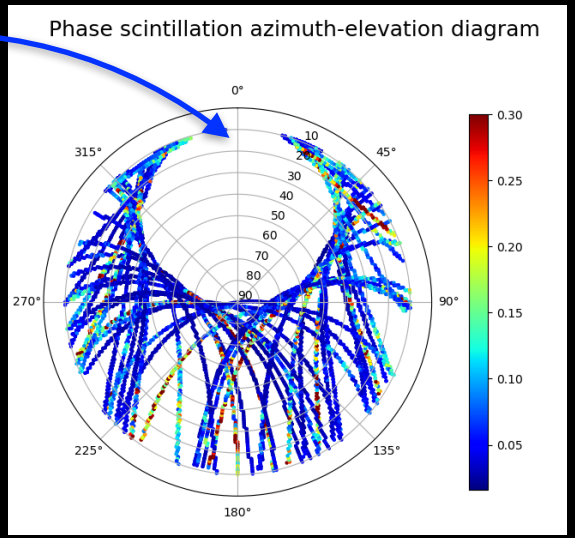

Geomagnetic Data
Solar Data
Ionosphere Data
Machine Learning
Image credit: NASA / Scientific Visualization Studio

High Latitude GNSS Stations

Canadian High Arctic Ionospheric Network (CHAIN) GPS receivers

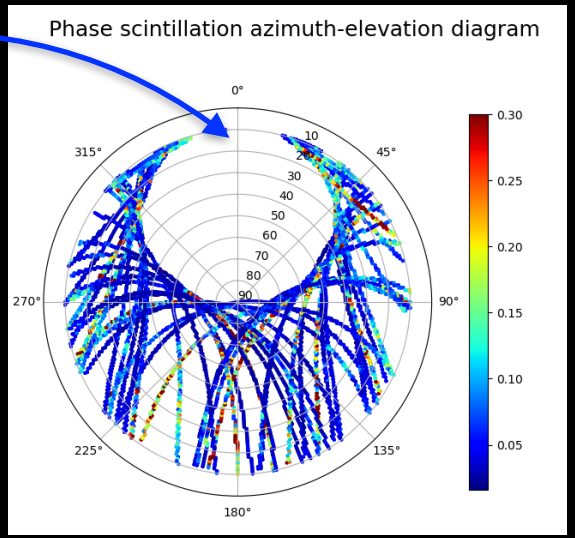
High Latitude GNSS Stations

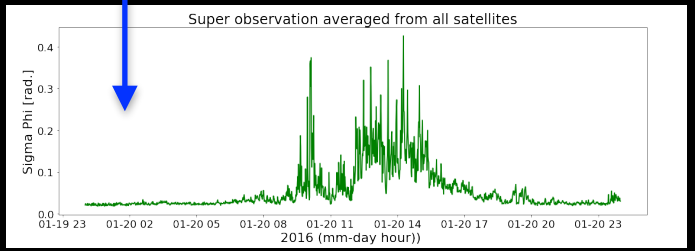
Canadian High Arctic Ionospheric Network (CHAIN) GPS receivers



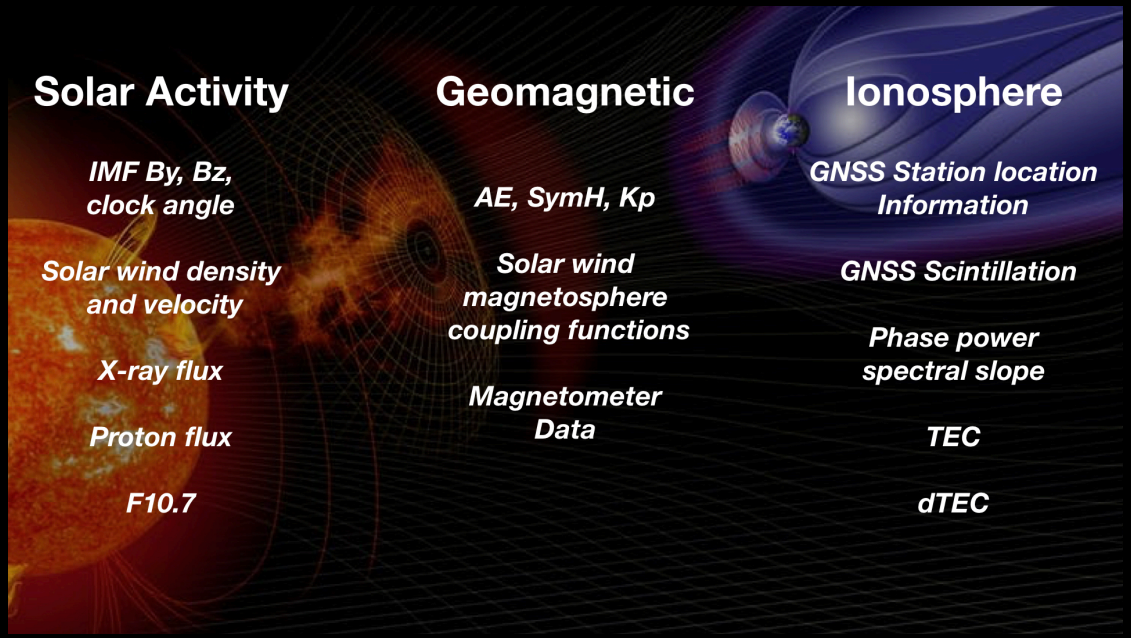
High Latitude GNSS Stations

Canadian High Arctic Ionospheric Network (CHAIN) GPS receivers





Approach



t

t + dt

41 inputs
> 100 feature engineering

Predicted GNSS scintillation

Build a predictive model for GNSS scintillation

Tools, Compute and Software Environment

Used

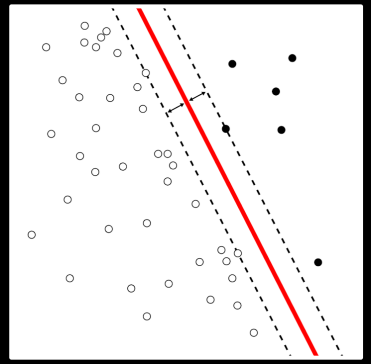
- Python open-source tools for data acquisition, wrangling and machine learning
- IBM POWER8 and POWER9 processors
  - Enabled the rapid exploration and testing of ML techniques

Created

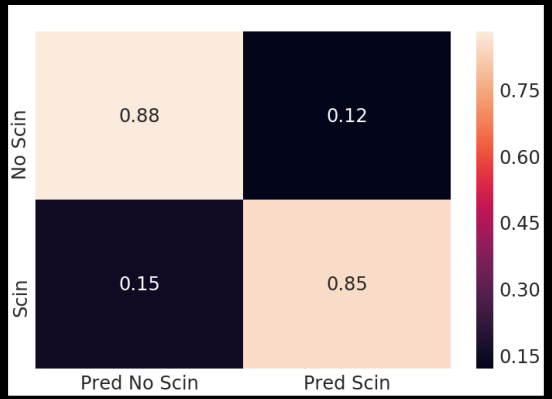
- Python-based tools and cohesive data pipeline generated
- Machine learning framework on data pipeline

Forecasting GPS disruptions

Classification baseline



Support Vector Machines



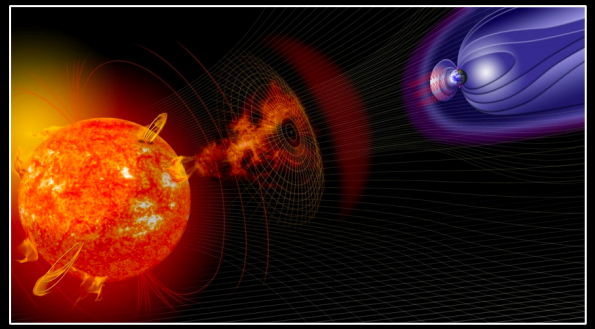
Forecasting GPS disruptions

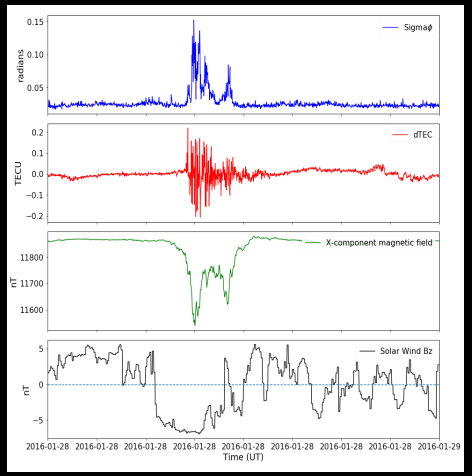
Classification baseline → Localized models

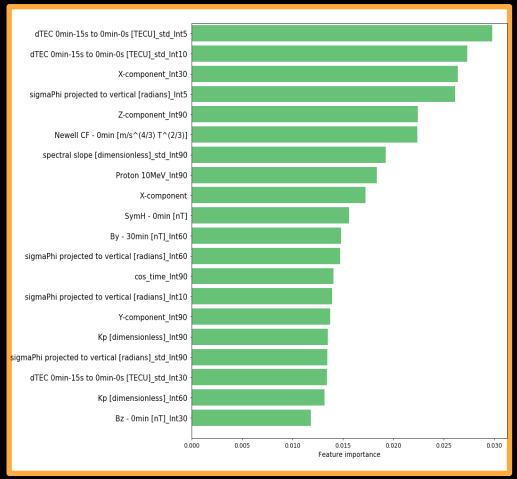
Localised models improved performance of model unto 40%

Forecasting GPS disruptions

Classification baseline → **Localized models** → **Model input**

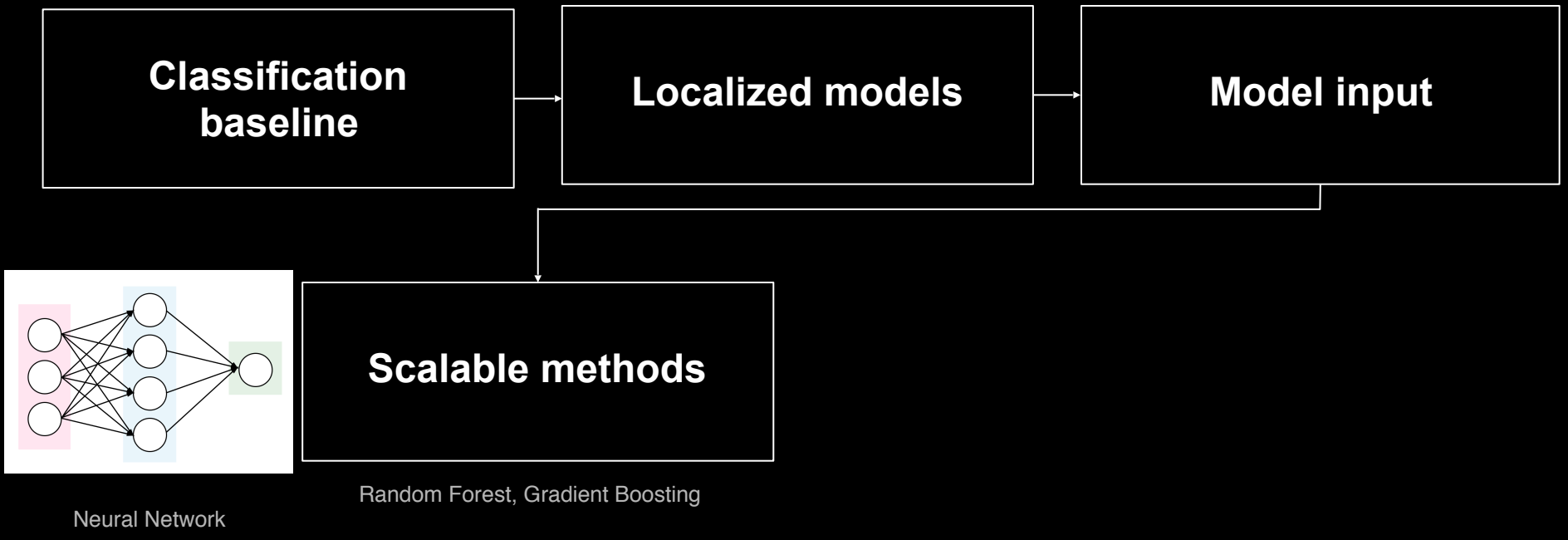




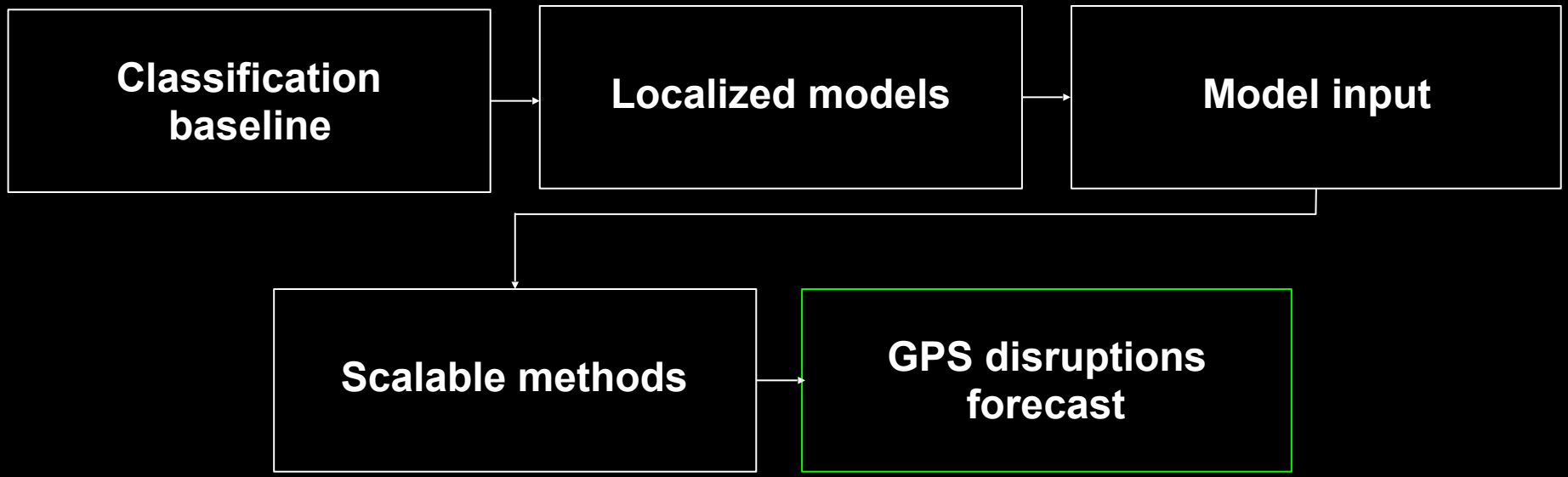


Feature engineering of inputs
Time history and variance

Forecasting GPS disruptions

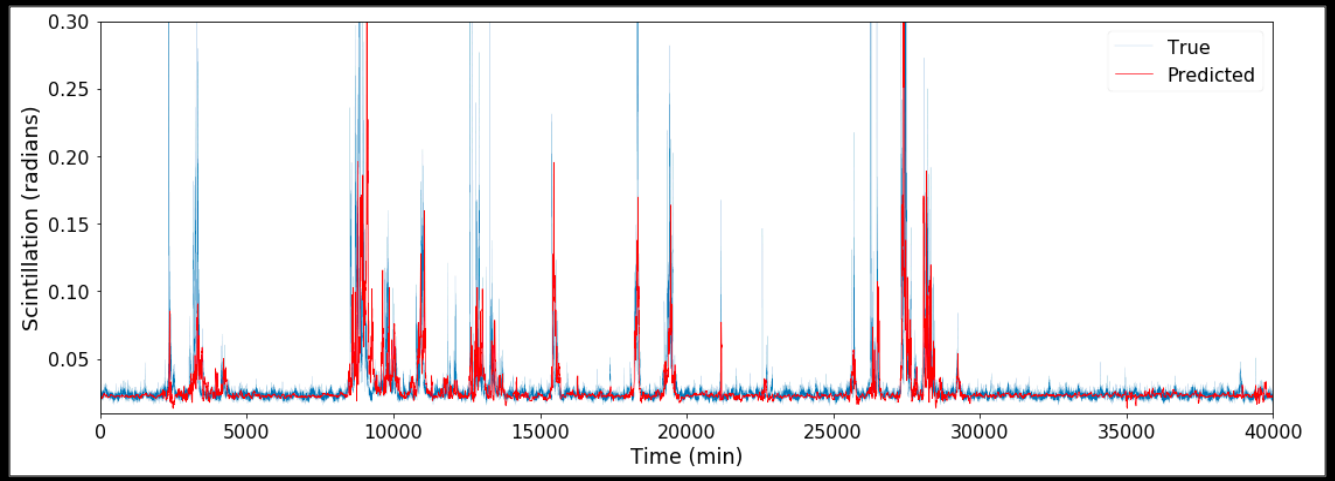


Forecasting GPS disruptions



GNSS forecasts

- GPS disruptions forecasted 1 hr in advance
- Train/validate on 2015, 2016 test on 2017
- Recall of 96%
- **Improve forecasting metrics by 70%**



Model : Neural Network with feature engineered inputs

https://gitlab.com/frontierdevelopmentlab/space-weather/SkyLab-X

Outcomes

- Developed a ML framework for predicting GPS disruptions.
- Proof of concept for machine learning applications for forecasting
- ML/Data shows localized nature of scintillation.
- +70% on baseline forecasting metrics.

https://gitlab.com/frontierdevelopmentlab/space-weather/SkyLab-X

Looking to the Future

- Pipeline set up for further exploration
- FDL 2019 included new parameters - spatially located auroral mapping
- See Ryan McGranaghan talk and poster (B session)!