2021-04-22 Space Weather Workshop

Harnessing Big Data to Improve Understanding and Predictions of Geomagnetically Induced Currents

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University of Alaska Fairbanks and University of New Hampshire

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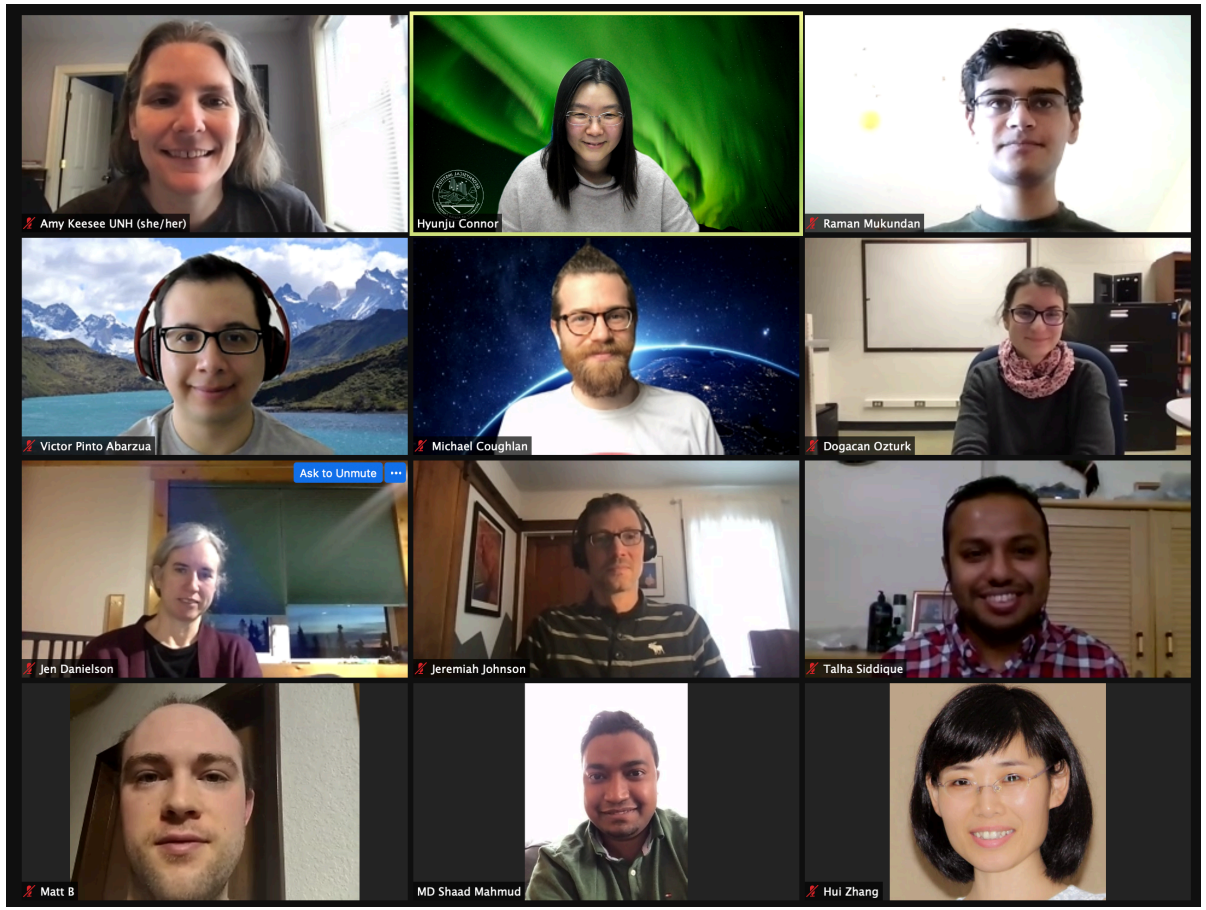
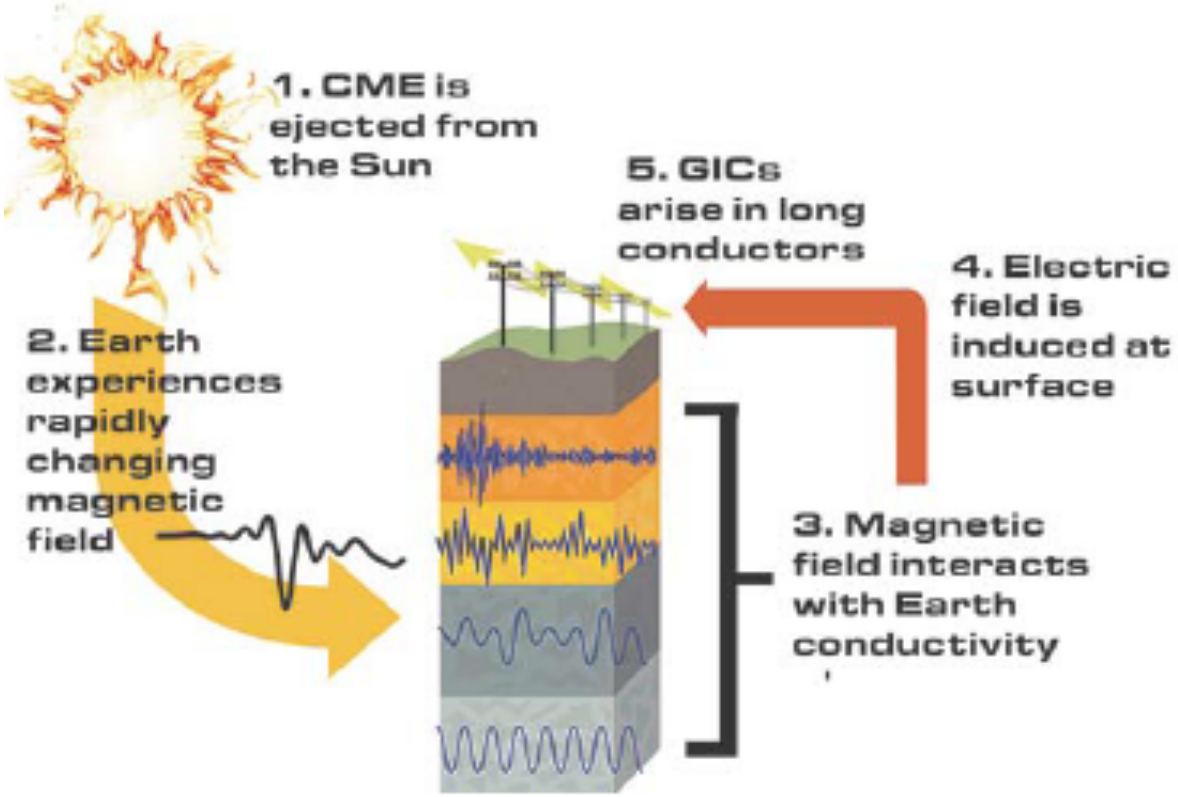
Machine Learning Algorithms for Geomagnetically Induced Currents in Alaska and New Hampshire



MAGICIAN is a joint UAF – UNH team funded by the 2018 NSF EPSCoR RII Track 2 Program that develops machine-learning (ML) algorithms for predicting hazardous Geomagnetically Induced Currents.

Geomagnetically Induced Currents (GICs)



Gannon [EEonline, 2016]

- Worldwide/Nationwide GIC data are not available
- We focus on large geomagnetic field disturbances, a trigger of GICs.

MAGICIAN team addresses three key science questions using artificial intelligence with ever-growing space science dataset:

- What transient solar wind features lead to large changes in the geomagnetic fields?

  Global & Local Geomagnetic Field Models

- What magnetospheric and ionospheric (MI) parameters account for regional differences in geomagnetic field changes?

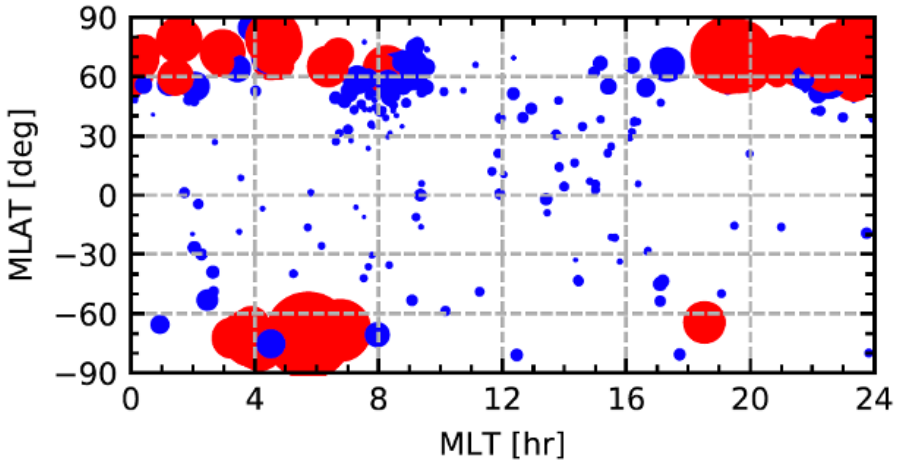
  Ionospheric Plasma Convection Model
  Aurora Image Classification Model

- How can an array of simple, commercial magnetometers contribute to regional GIC Modeling?

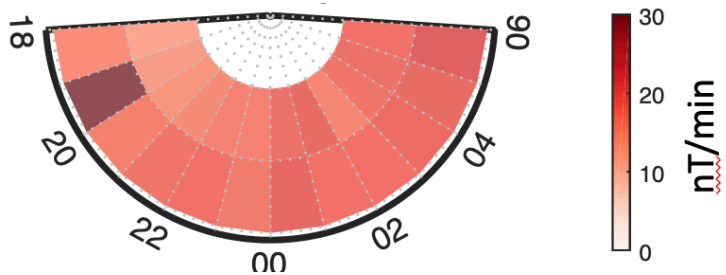
  SWUG Education Outreach Program

Global Geomagnetic Field Disturbance (dB/dt) Model

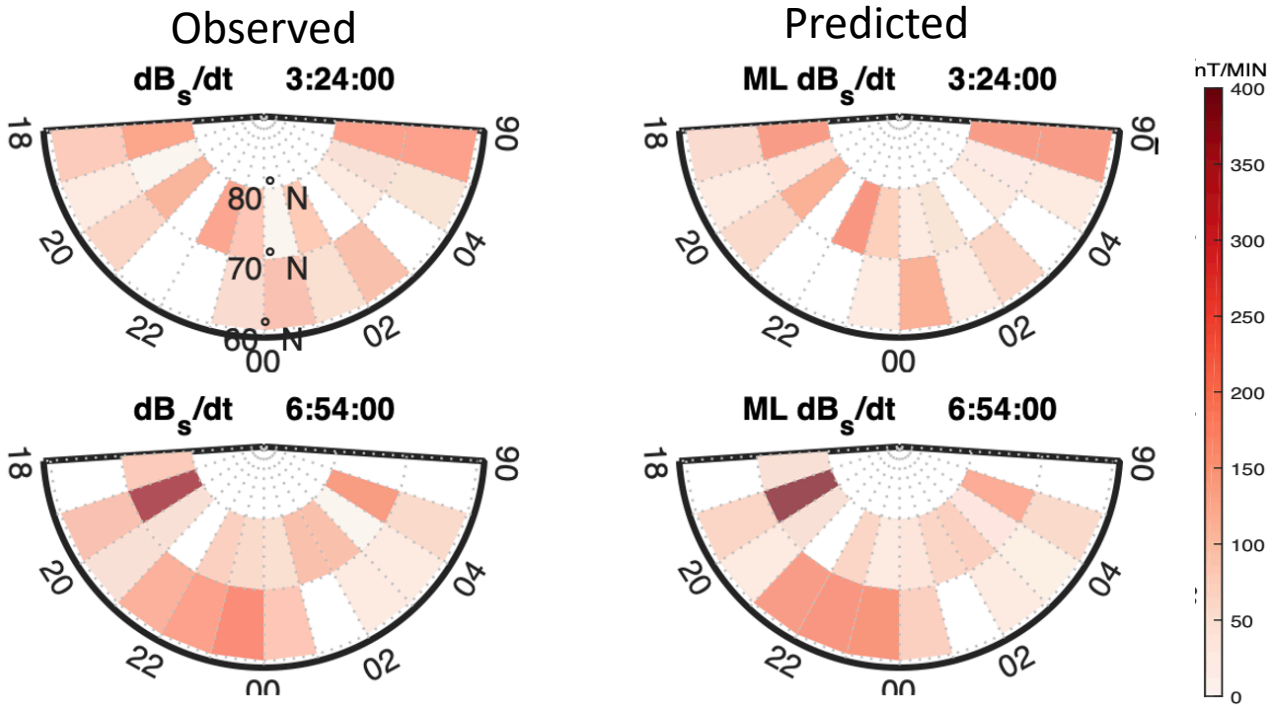
SuperMAG stations



RMSE Analysis of the 09-Mar-2012 storm



Model-Data Comparison of dBs/dt over northern nightside hemisphere during the 09-Mar-2012 storm



GOAL : Predict global dB/dt patterns driven by solar wind and IMF conditions, and provide advance GIC warning.
DATA : SuperMAG & OMNI data in 2012 & 2015
METHOD : Multi-variate Long Short Term Memory (LSTM) Neural Network

S. Priyadarshi (spshishir@gmail.com), H. Connor, M. Blandin, A. Keesee

Local |B| model – Alaska Magnetometer Chain

Alaska Magnetometer Chain

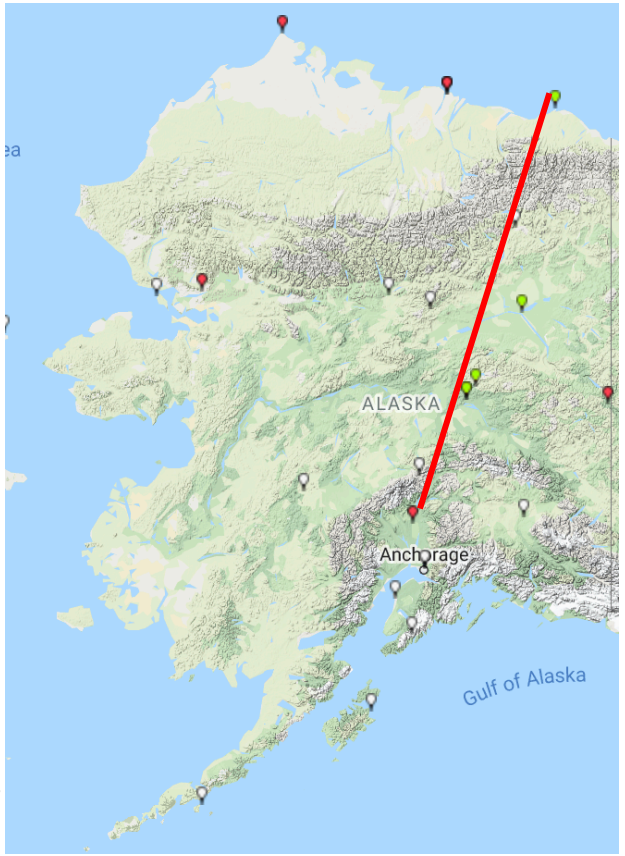
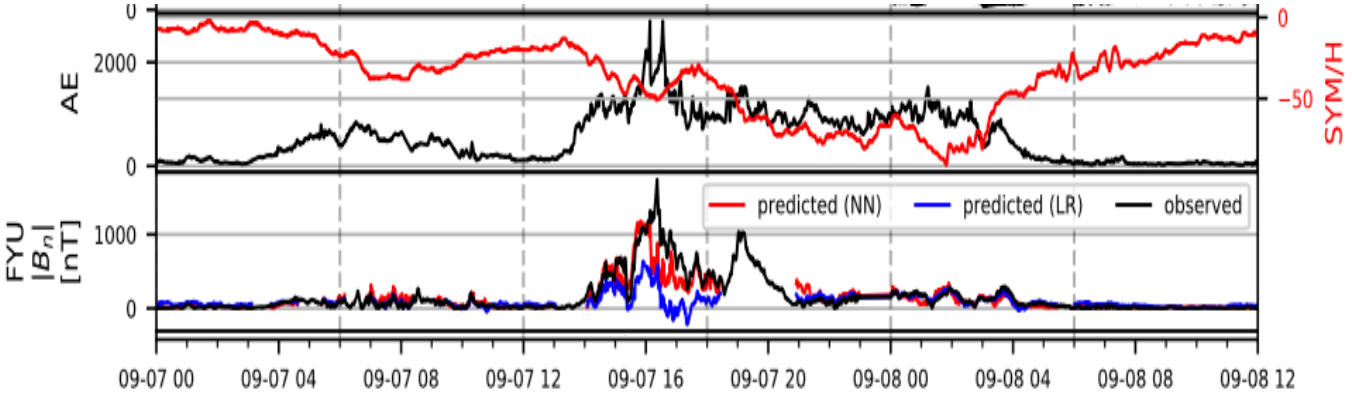
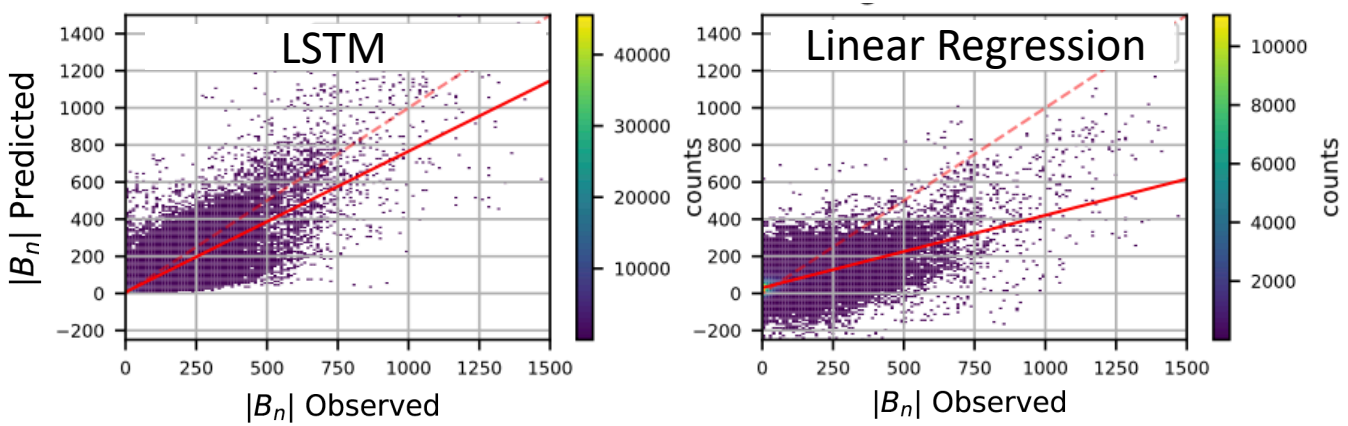


Image Credit: https://SuperMAG.JHUAPL.edu

Geomagnetic Storm on Sep 07 2015



Model vs Data Comparison for 2015



GOAL : Predict the dB/dt and ionospheric current patterns in Alaska for improved understanding of GICs.

DATA : SuperMAG Alaska data & OMNI data in 2000 – 2015

METHOD : Multi-variate LSTM Network & Multi-variate Linear Regression Method

M. Blandin (mjblandin@alaska.edu), H. Connor, D. Ozturk, P. Victor, A. Keesee, MD Mahmud

Ionospheric Plasma Convection Model

SuperDARN Stations on Northern Hemisphere

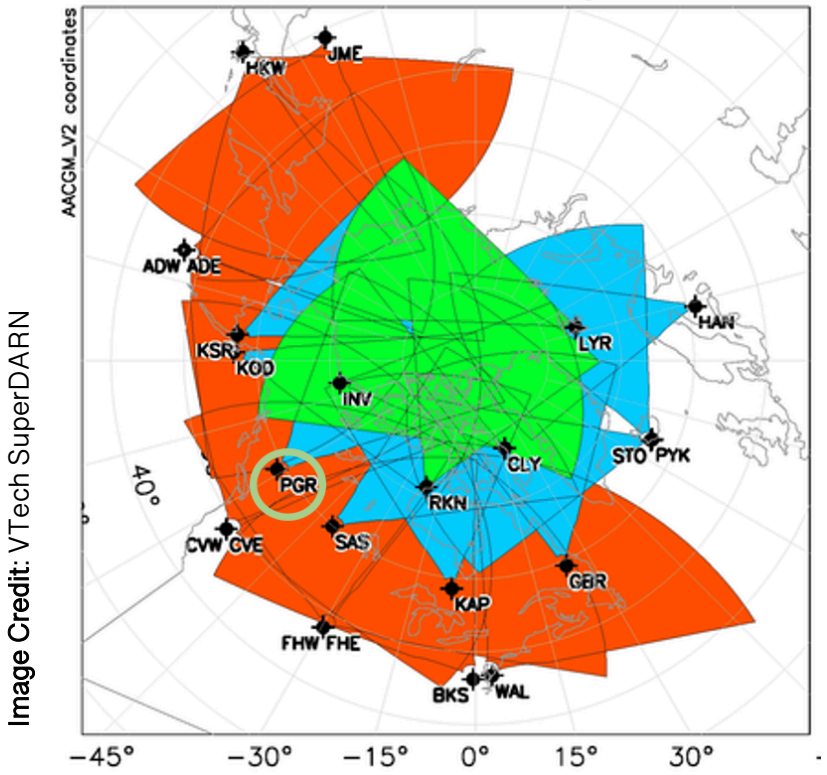
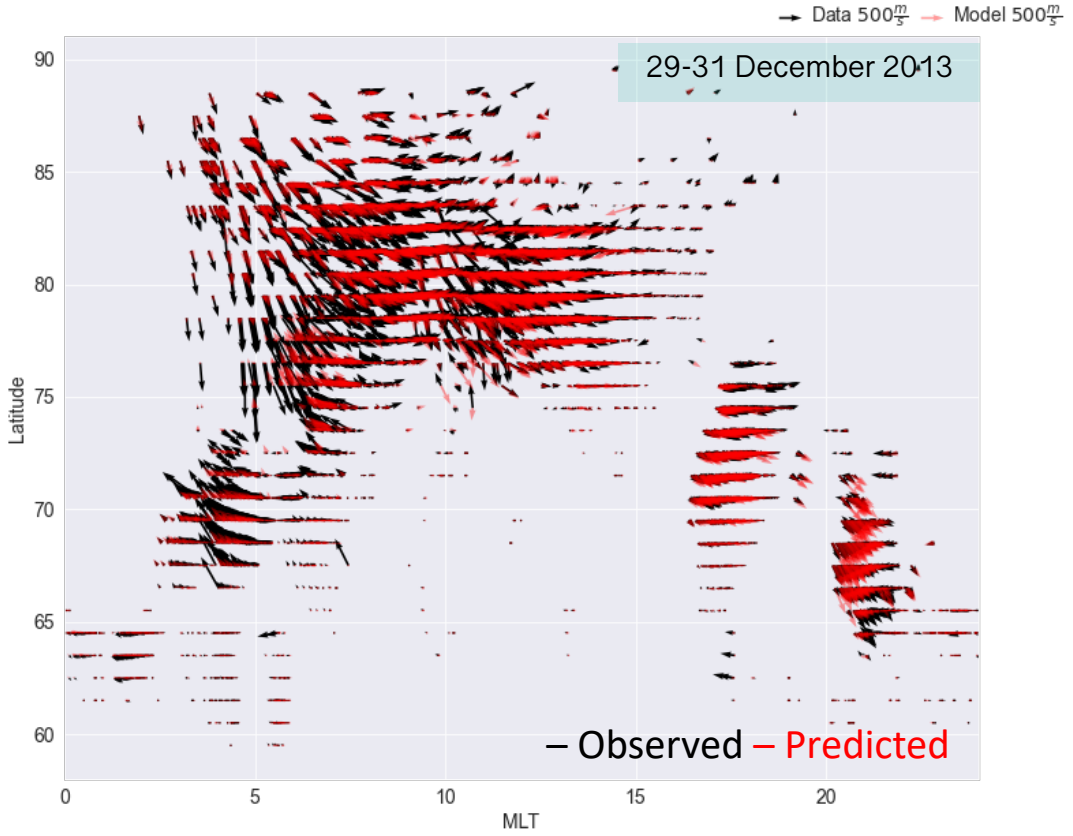


Image Credit: VTech SuperDARN

Model-Data comparison for Prince George Radar (PGR)

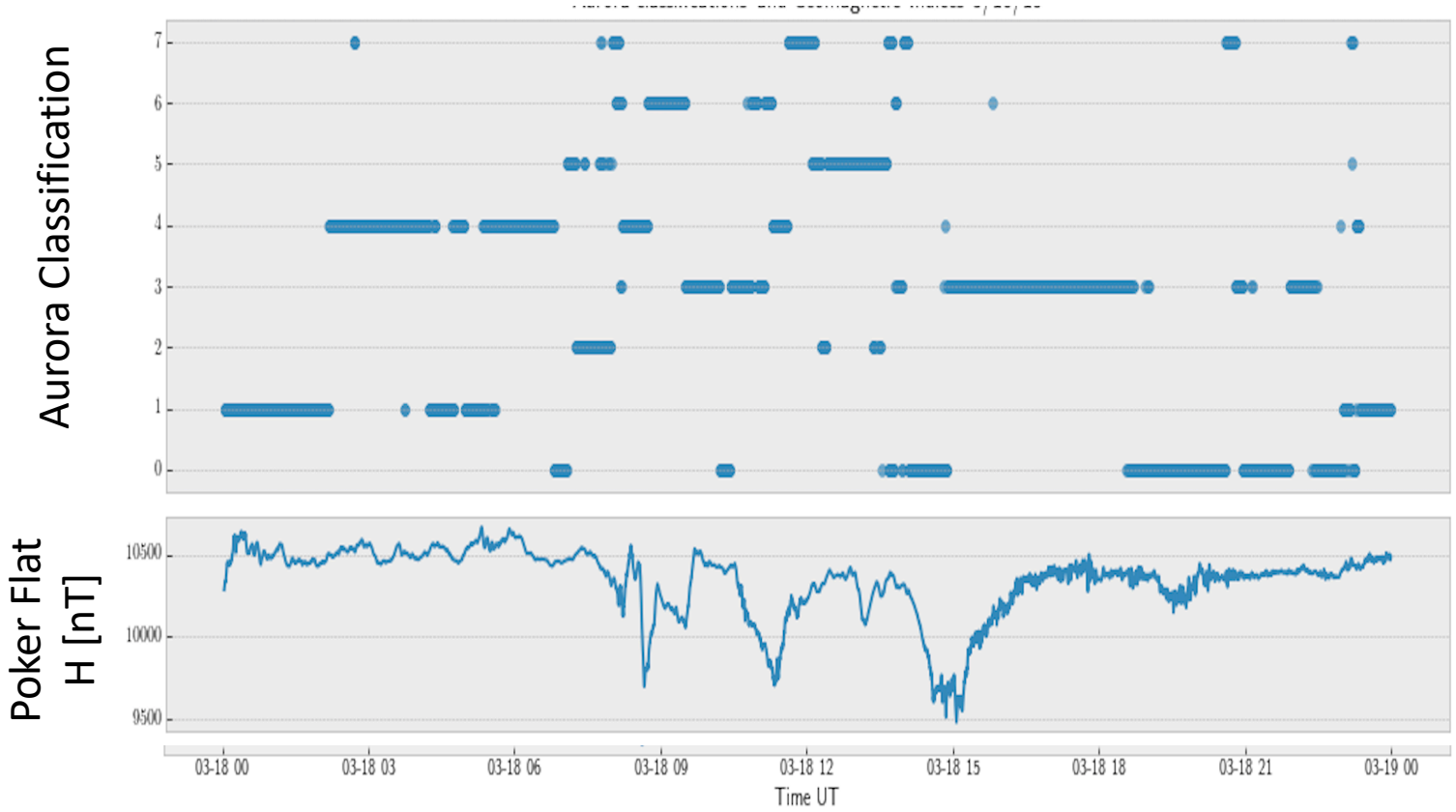


GOAL : Predict multi-scale ionospheric convection patterns and improve a GIC warning model for high-latitudes.
DATA : SuperDARN PGR data & OMNI data in 2010 - 2013
METHOD : Multi-layer perceptron model

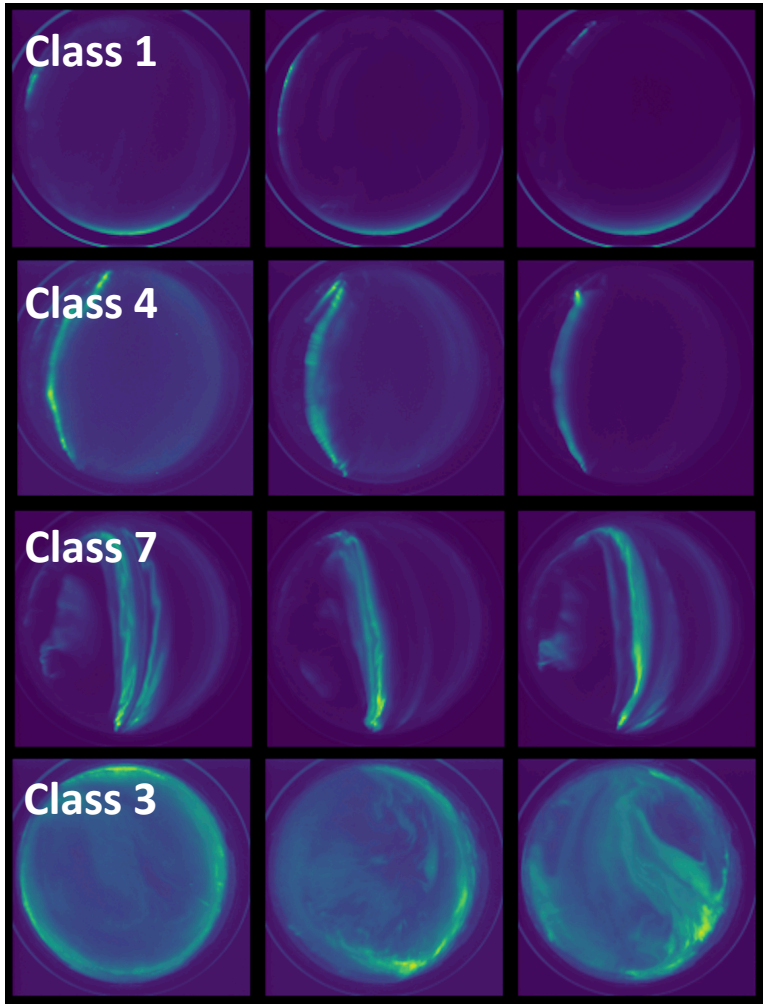
D. Ozturk (dsozturk@alaska.edu), H. Connor, B. Kunduri, E. Thomas, A. Keesee

Aurora Classification Model

Variation of Aurora Class Types during the 18-03-2015 geomagnetic storm



Aurora Classes from Unsupervised Learning



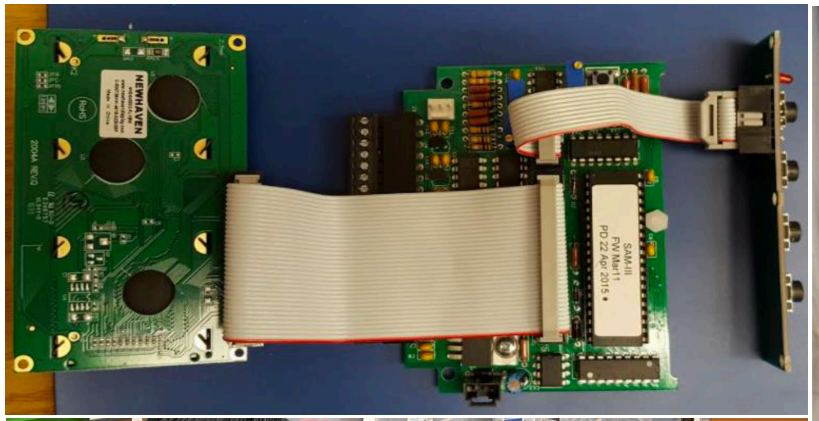
GOAL : Classify aurora types automatically for data mining and support targeted space weather studies

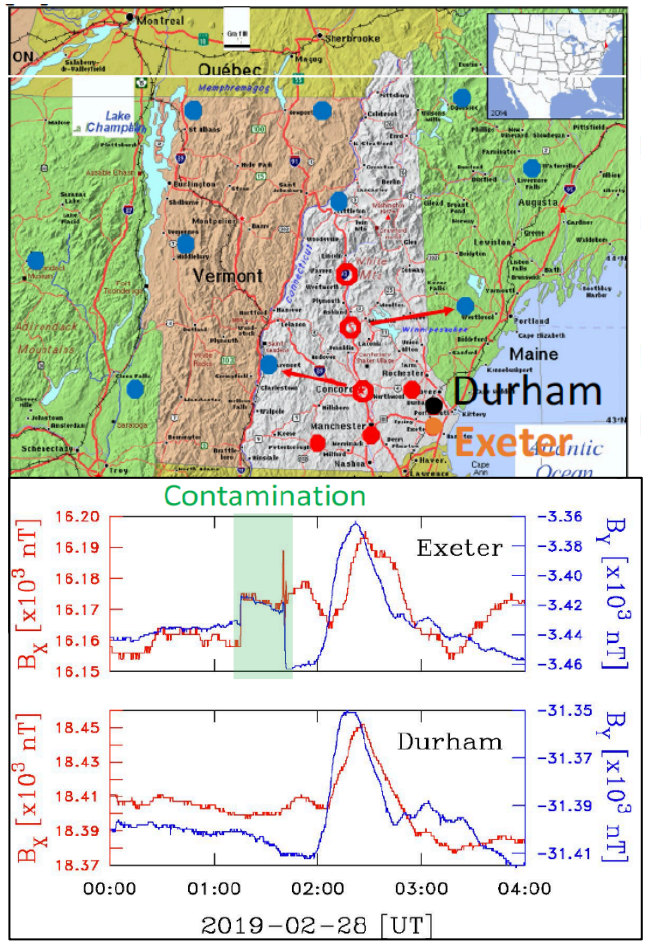
DATA : Poker Flat All Sky Aurora Image data on 18 Mar 2015

METHOD : Simple Framework for Contrasting Learning of Visual Representations (SimCLR)

J. Johnson (Jeremiah.Johnson@unh.edu) , S. Hari, D. Hampton, H. Connor

Space Weather UnderGround Educational Outreach Program





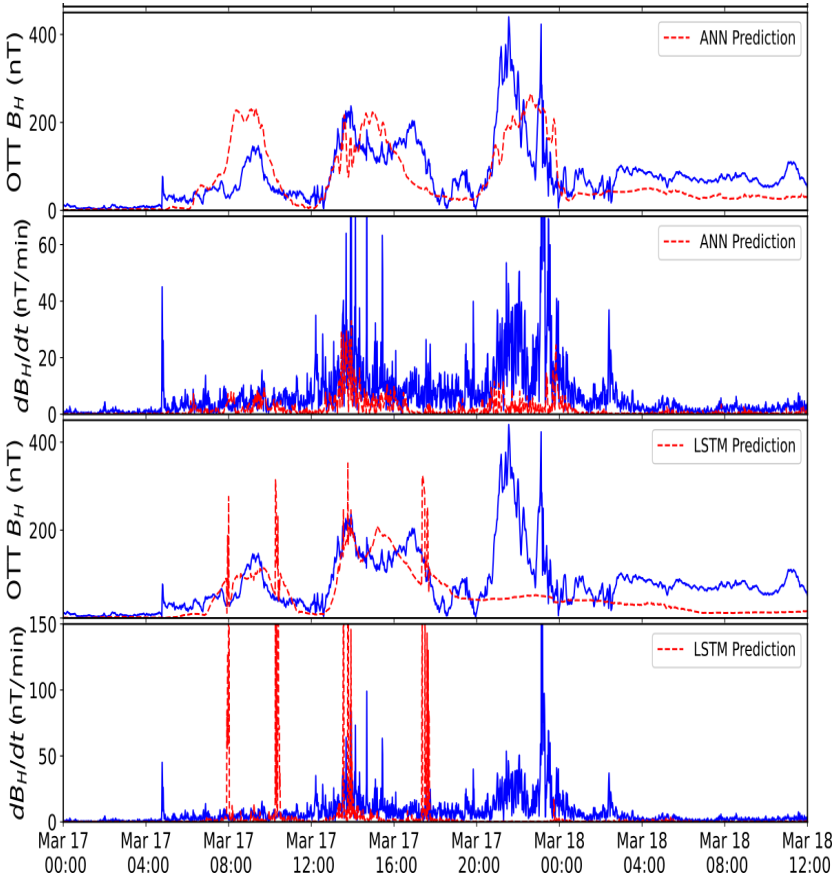
GOAL: Educate future STEM workforce, Build a cost-effective, research-capable magnetometer array across AK and NH, and Investigate the optimal spatial resolution of geomagnetic field data for GIC studies.

UAF : H. Connor (hkconnor@alaska.edu), D. Hampton, D. Ozturk, M. Blandin
UNH : C. Smith (Charles.Smith@unh.edu), H. Kucharek, A. Keesee

Various Efforts with ML-based dB/dt models

Application of various ML methods

ANN vs LSTM on the 17-03-2015 storm

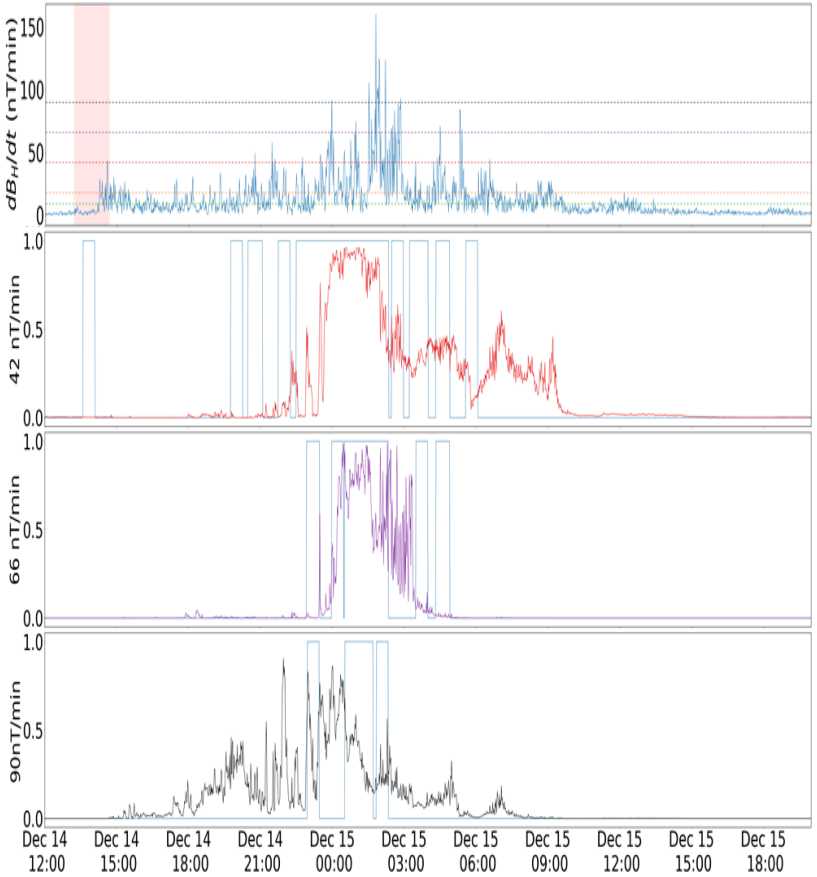


Keesee et al, Frontiers, 2020

amy.keesee@unh.edu

GIC Warning Model

Prediction of crossing dB/dt thresholds



Coughlan et al, AMS Meeting 2021

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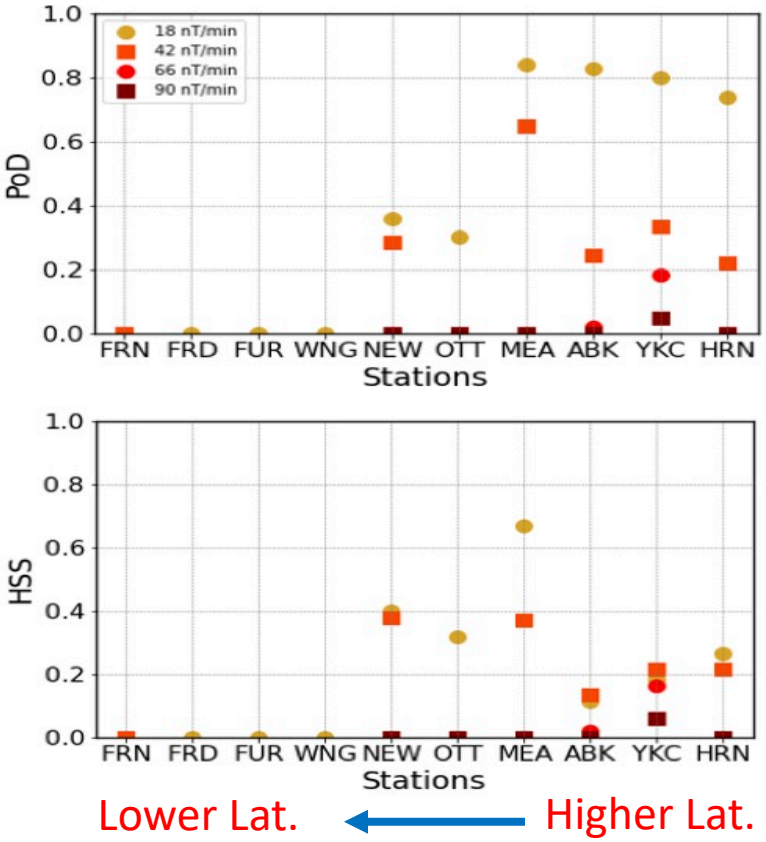
Comprehensive Model Validation

PoD and HSS scores of various stations



Pinto et al, AMS Meeting 2021

victor.pinto@gmail.com

Summary

MAGICIAN

Machine Learning Algorithms for Geomagnetically Induced Currents in Alaska and New Hampshire

- MAGICIAN is a joint UAF-UNH team that develops machine-learning algorithms for predicting hazardous GIC events under the support of NSF EPSCoR RII Track 2 program.
- Various ML models are under development, and the preliminary results are promising.
  - Global/local geomagnetic field models, SuperMAG & OMNI data
  - Ionospheric convection model, SuperDARN & OMNI data
  - Aurora image classification model, Poker Flat ASI data
- Once matured, our ML models will be provided to public and NOAA SWPC.
- Under the SWUG educational outreach program, we are building a cost-effective, research-capable magnetometer array for space weather research.
- We welcome other institutions to join the SWUG team! Visit our SWUG website for more information. →

*** This work is supported by NSF EPSCoR Grant #1920965. ***

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Thank you!