Assimilative Mapping of Geospace Observations

Building Community for Collaborative CEDAR Data Science

Tomoko Matsuo

NSF EarthCube

Smead Aerospace
UNIVERSITY OF COLORADO BOULDER

Connection of Data

Community

Culture Change

Project Team Members

CU Boulder
- Tomoko Matsuo (PI)
- Liam Kilcommons (Lead Developer)
- Willem Morkovitch (Developer)

Virginia Tech
- Mike Ruohoniemi (Institutional PI)
- Shibaji Chakraborty (Postdoc)

JHU/APL
- Brian Anderson (Institutional PI)
- Sarah Vines (Co-I)
- Larry Paxton (Co-I)

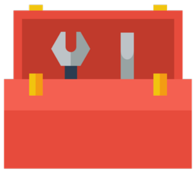
NASA-GSFC
- Liz Macdonald (Collaborator)
- Katie Garcia-Sage (Collaborator)

SRI
- Asti Bhatt (Collaborator)

NOAA-NCEI
- Rob Redmon (Collaborator)

GFZ Potsdam
- Claudia Stolle (Collaborator)

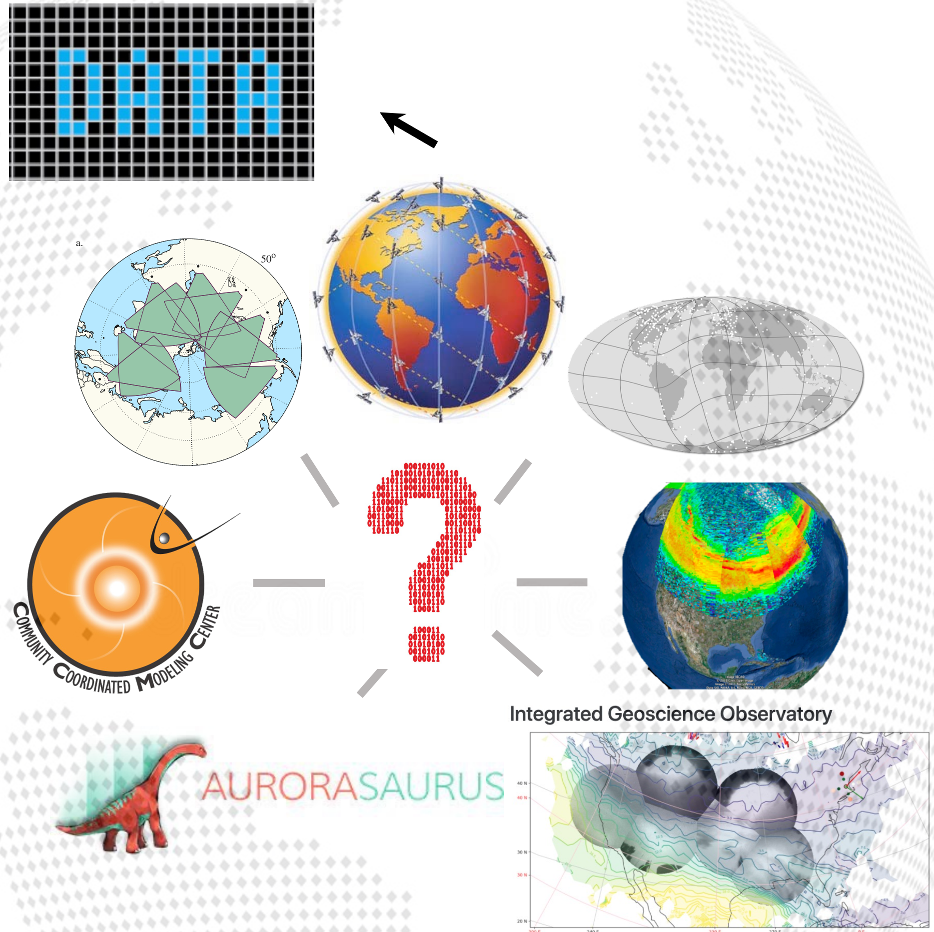
Data Science Challenges



Toolbox
inverse methods
machine learning methods

Discovery Ready Form

Meaning
Understanding
Scientific Discovery



EarthCube

What We Did

Why It's Important

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Collaborative data science tool for high-latitude geospace observations

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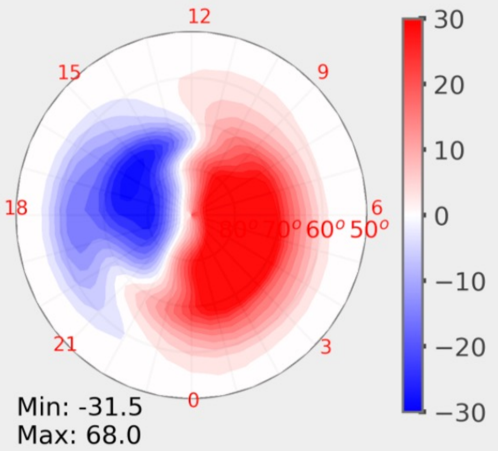
https://amgeo.colorado.edu

AMGeO Maps



Electrostatic Potential

Large-scale electrostatic potential patterns in the Earth's high-latitude ionosphere, shown in mV/m from 90 to 50 magnetic latitudes with the 12 noon local solar time at the top.

The equipotential countour lines track the convective motion of ionospheric plasma in the direction perpendicular to the Earth's main magnetic fields and the electric fields.

Φ Electrostatic Potential | Σ_H Hall Conductance | Σ_P Pedersen Conductance | J Field-Aligned Current

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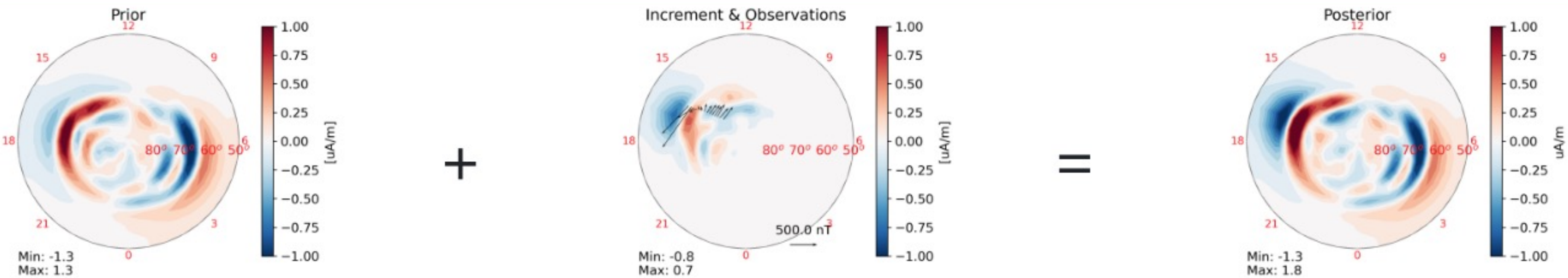
Making AMGeO Maps

SuperDARN Assimilation	SuperMAG Assimilation	SuperDARN & SuperMAG	Iridium Assimilation



Prior Model

Data Impact

AMGeO Map

AMGeO v2beta – algorithm

States $\mathbf{x}$

$$\vec{E}, \Phi, \underline{\underline{\Sigma}}, \vec{J}_{\perp}, \vec{J}_{//}, \Delta\vec{B}$$

Forward model $\mathbf{H}$

$$\vec{E} = -\nabla\Phi$$

$$\vec{J}_{\perp} = \underline{\underline{\Sigma}} \cdot \vec{E}$$

$$\vec{J}_{\|} = \nabla \cdot \vec{J}_{\perp}$$

$$\nabla \times \Delta\vec{B} = \mu_o \vec{J}$$

Observations $\mathbf{y}$

plasma drifts from SuperDARN
ground-level magnetic fields (SuperMAG)
Iridium magnetic fields (AMPERE)

Background $\mathbf{x}_b$

Cousins and Shepard [2010]
OVATION Prime [Newell et al., 2009]

Background Covariance $\mathbf{C}_b$

Cousins et al. [2013]
Shi et al. [2019]

$$\mathbf{C}_b \approx \mathbf{Q}\Gamma\mathbf{Q}^T$$

PCA estimated from large volumes of data

With assumptions of Gaussian errors

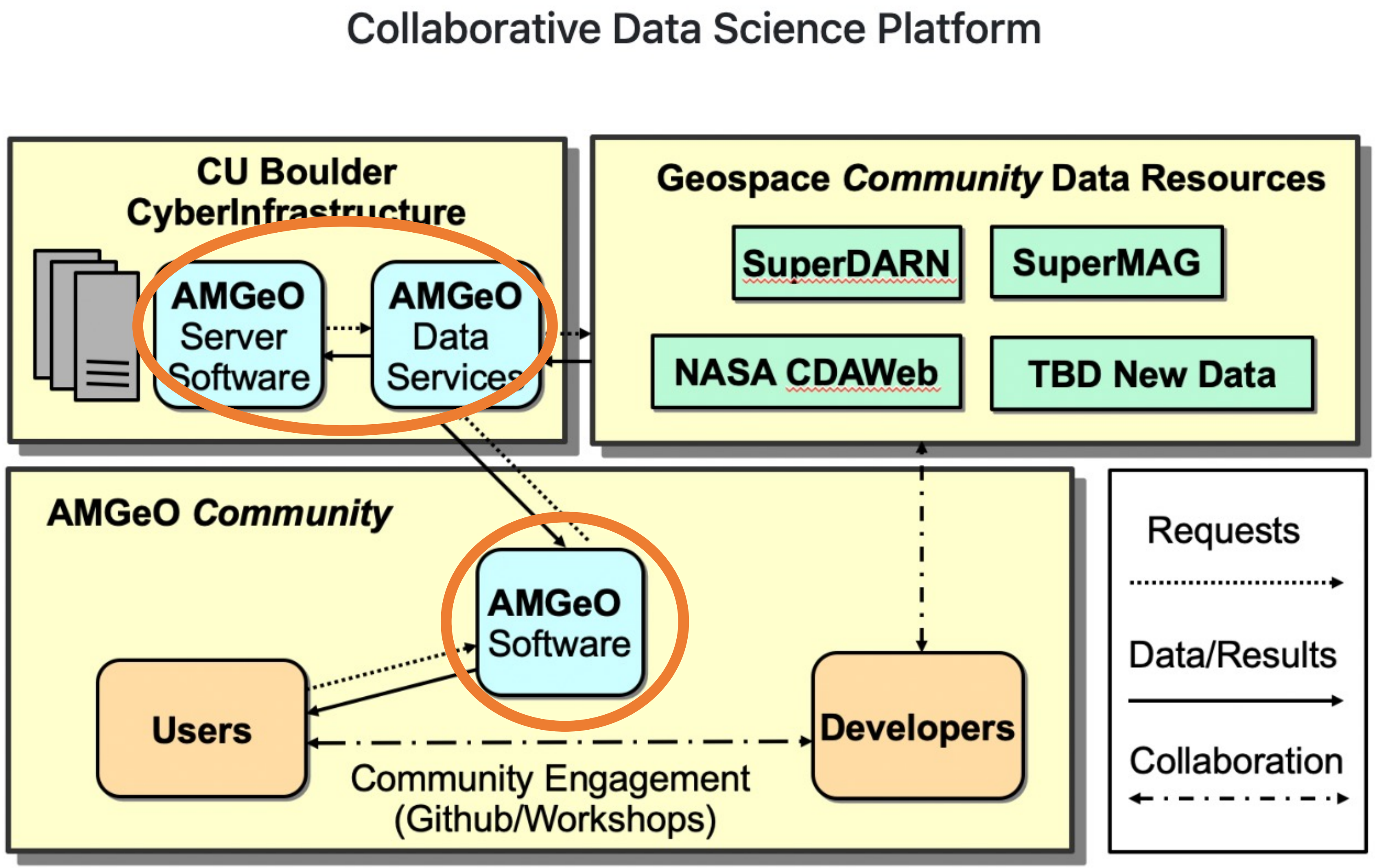
$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{K}(\mathbf{y} - \mathbf{H}(\mathbf{x}_b))$$

$$\mathbf{C}_a = (\mathbf{I} - \mathbf{K}\mathbf{H})\mathbf{C}_b$$

Analysis Uncertainty

[Richmond and Kamide, JGR,1988; Matsuo, ISSI Book, 2020]

AMGeO v2beta – software & web application



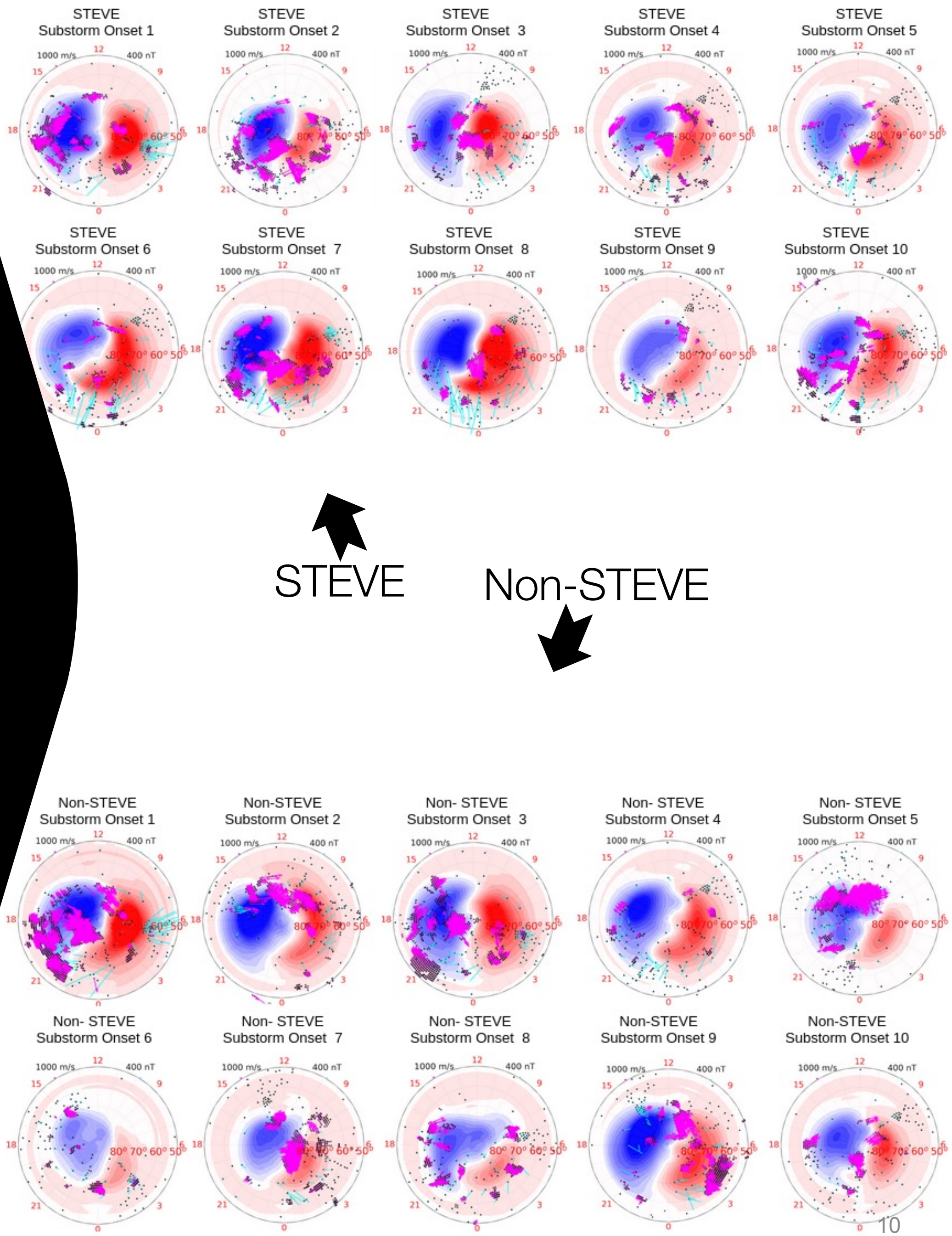
[AMGeO Collaboration, 10.5281/zenodo.3564913, 2019]

Going Beyond Event Studies with AMGeO

From ***64*** ***events***

Characterizing global electrodynamics during STEVE vs Non-STEVE substorms

[Svaldi, Matsuo, Kilcommons, Gallardo-Lacourt, Under Preparation, 2021]



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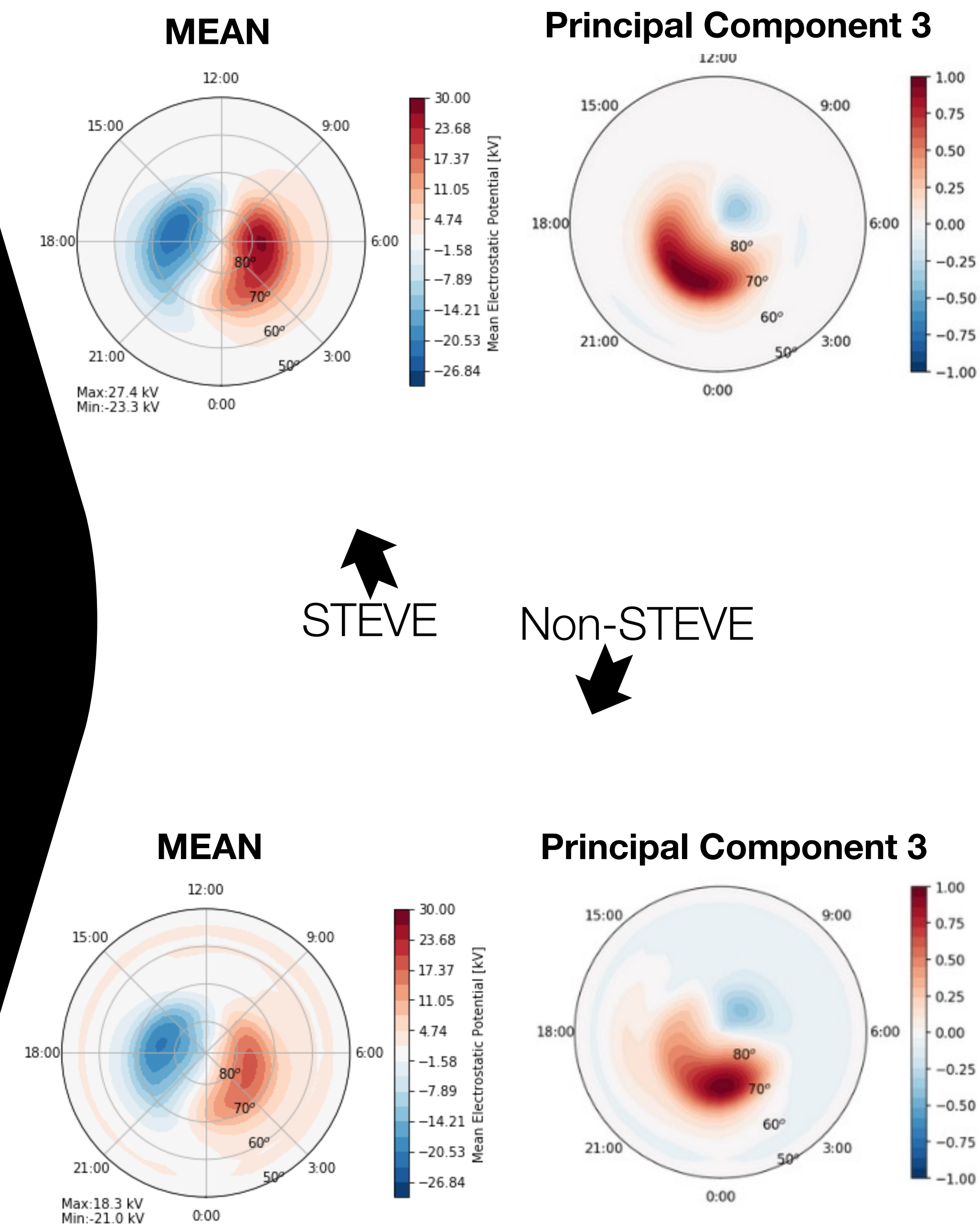
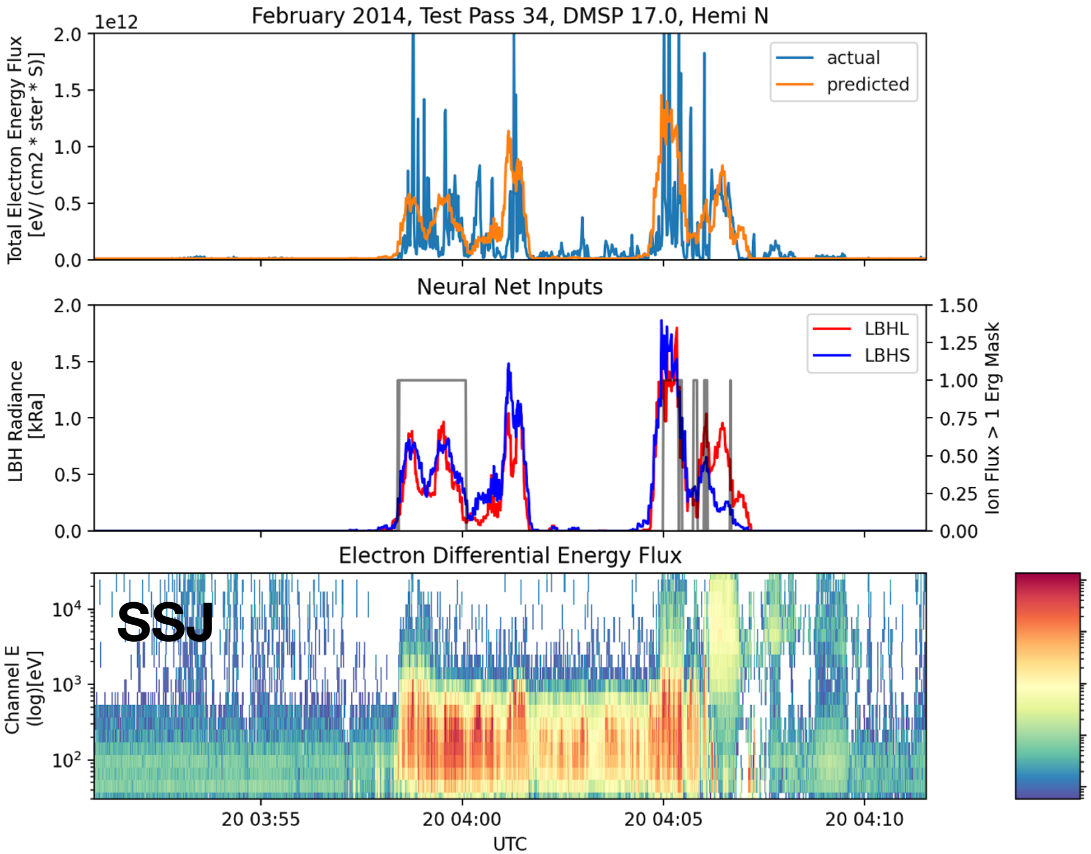
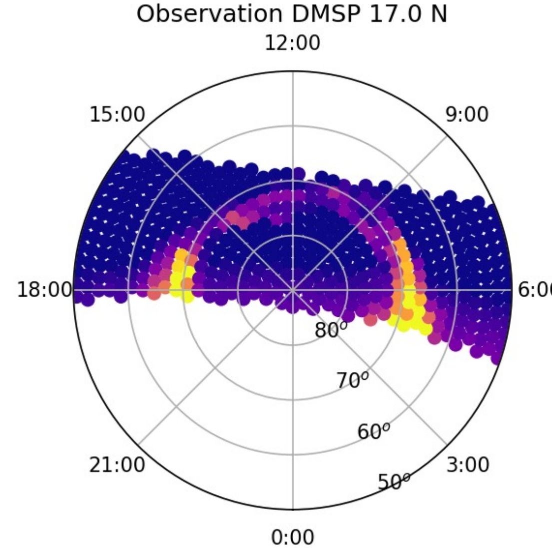


Recent EarthCube Efforts
Auroral Conductance

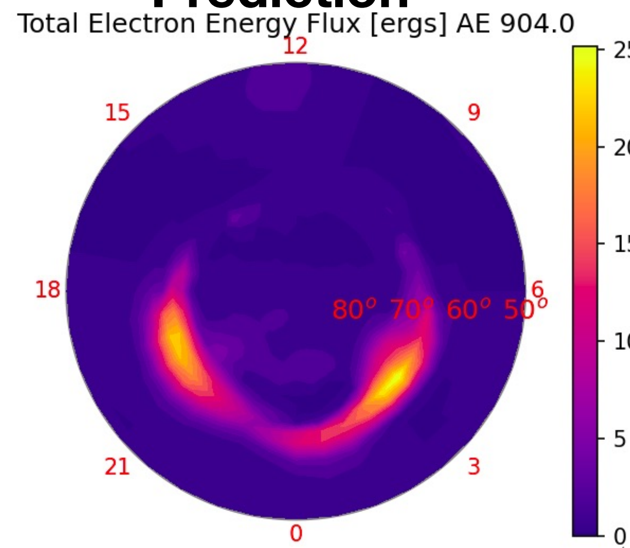
Neural Network + PCA + Assimilative Mapping



SSUSI

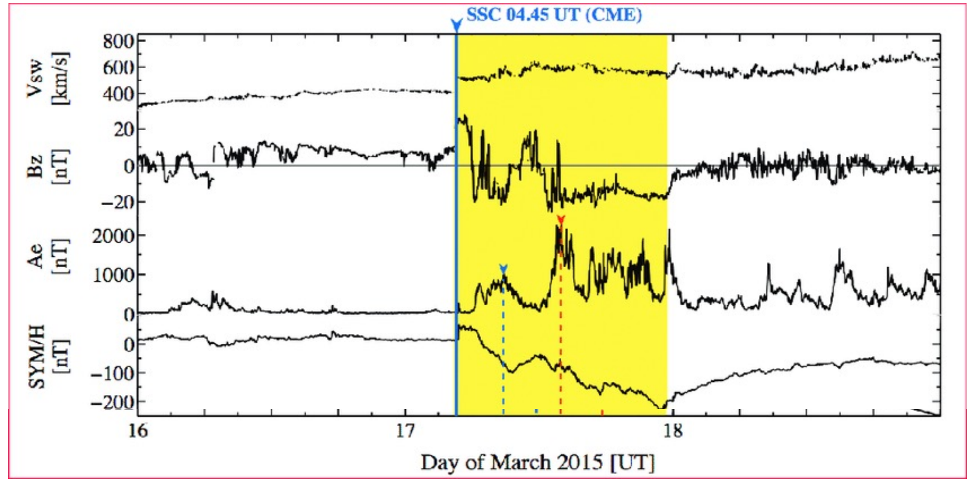


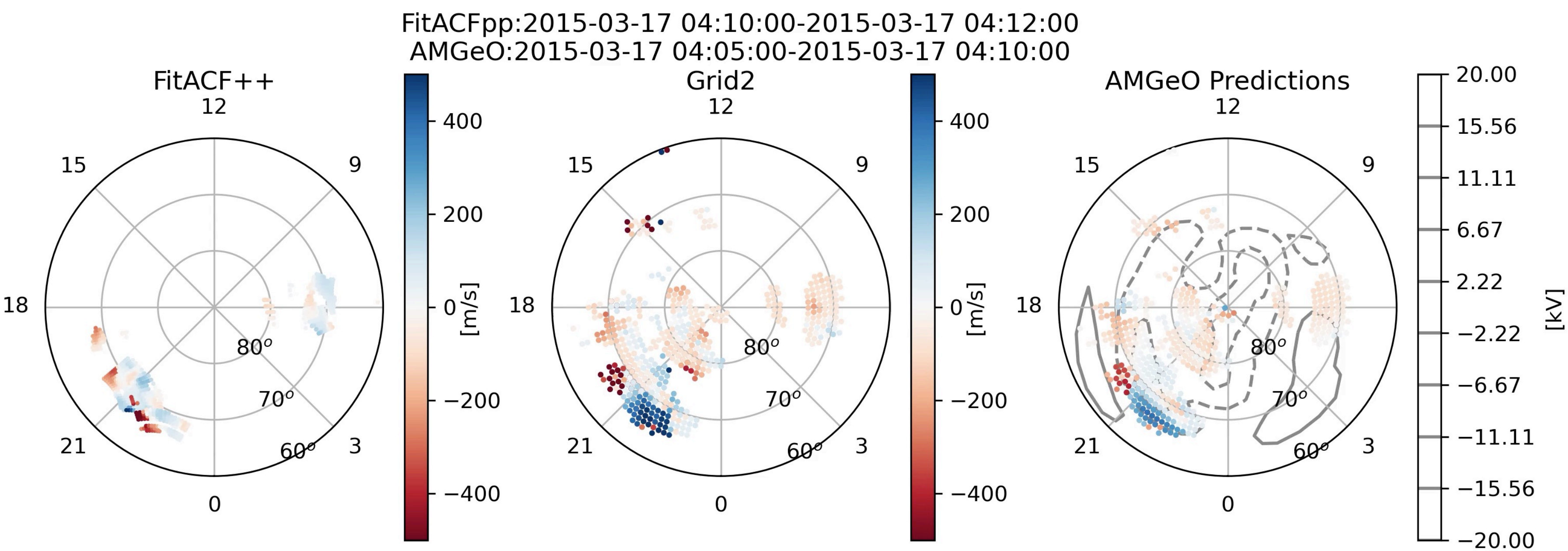
Prediction



[Li, Matsuo and Kilcommons, Under Review, 2021]

Recent EarthCube Efforts SuperDARN + AMGeO





FitACF++ from Ruohoniemi and Chakraborty

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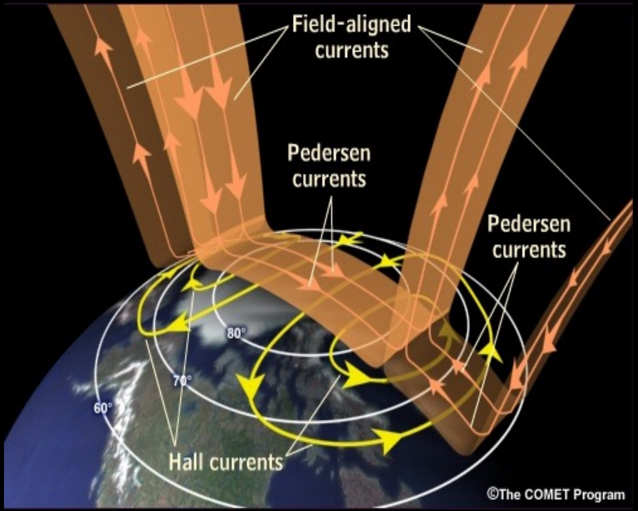
AMGeO v1 and v2beta is Available to Support Transparent, Reproducible, & Open Research

- *Capability to ingest SuperDARN, SuperMAG, AMPERE*
- *Improving uncertainty quantification through close collaboration with data providers*
- *Improving conductance analysis*
- ***CEDAR workshop session on AMGeO Tutorial and Interactive Demos at 1-3pm on June 25 (Friday)***



jupyter

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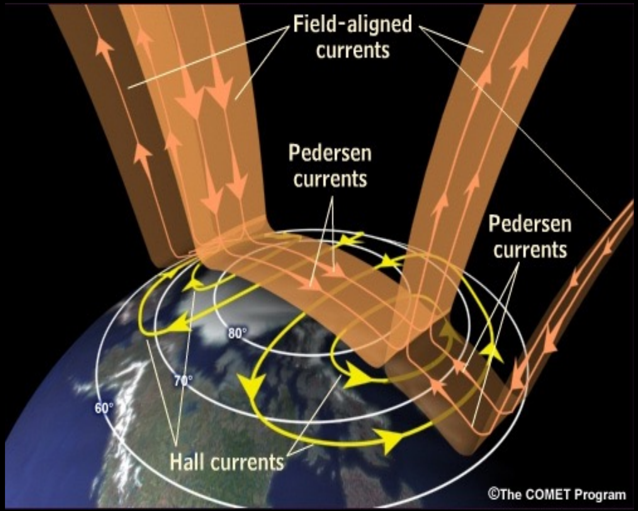
What's Next?

- *Interoperability with CCMC and InGeO cyberinfrastructures*
- ***Collaborative geospace data science campaigns to produce reanalysis data product***



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