

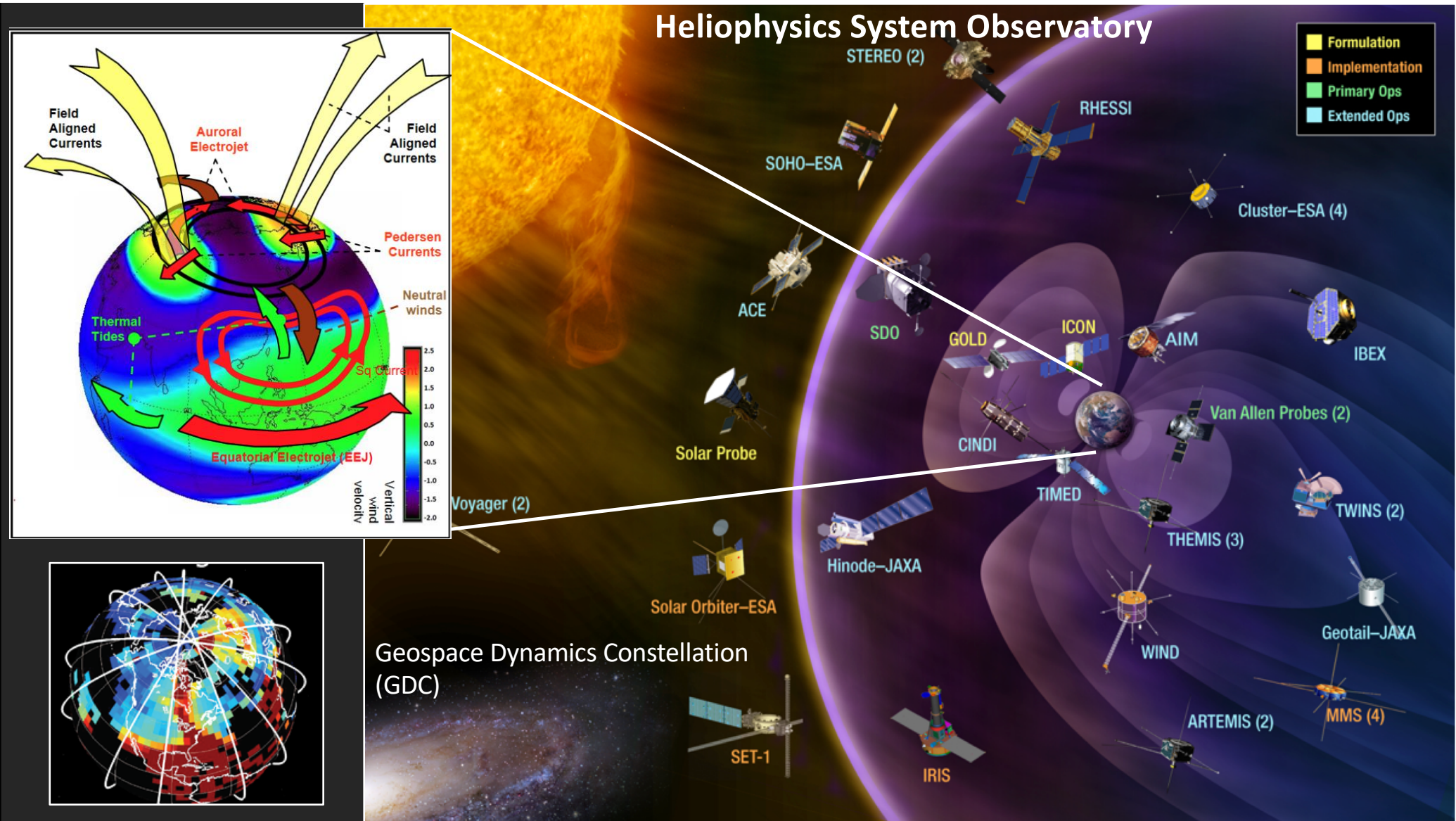
The LEO–Ground-based Collaborative

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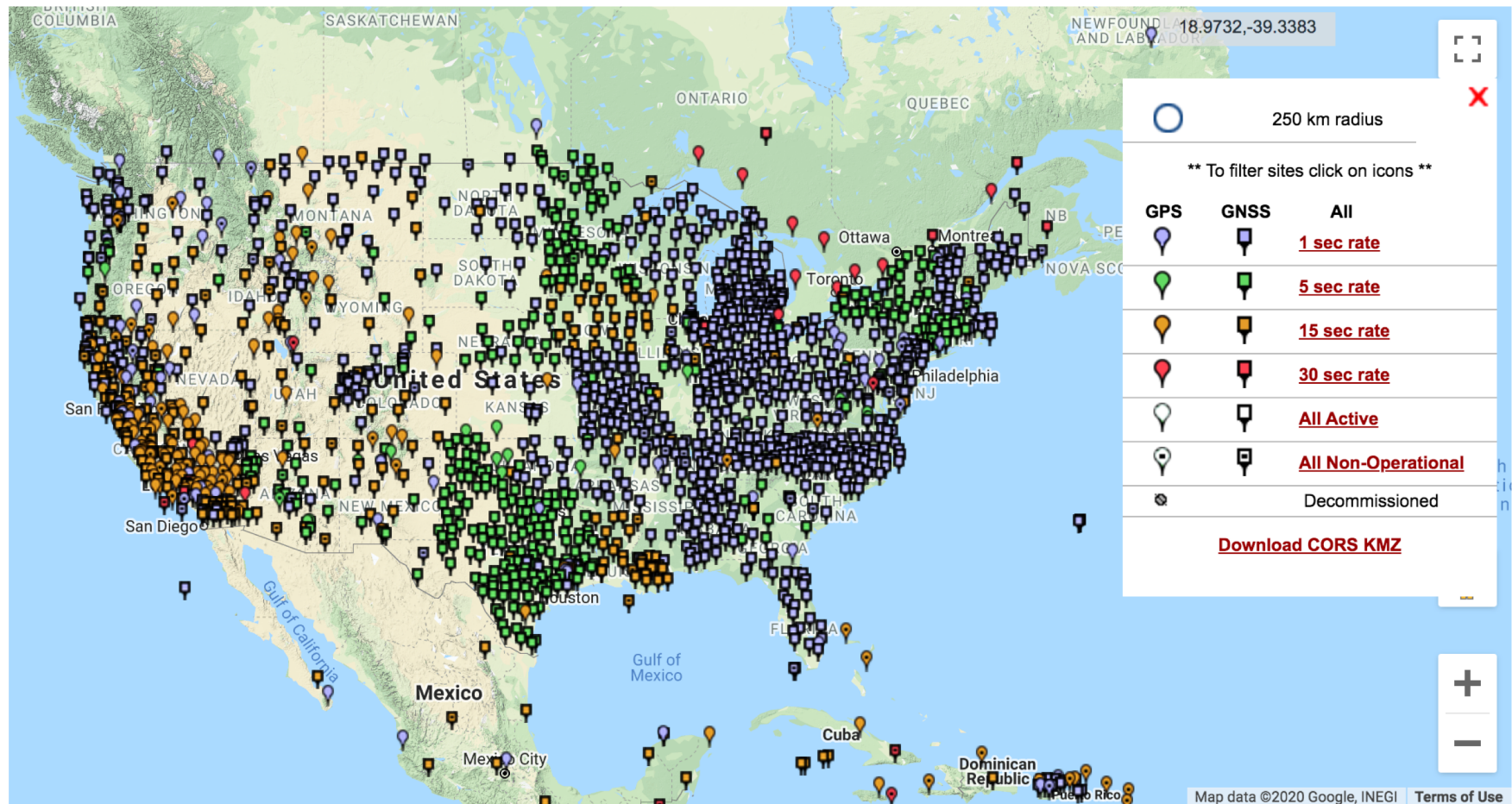
Boston University Center for Space Physics

Thesis:

Collaborative observations by sensors on the ground and in low-Earth orbit provide a projection of the broader heliophysics system. Collaborations among physicists, computer scientists, and engineers allow us to optimally exploit this projection for space weather operations.



Sampling the system response

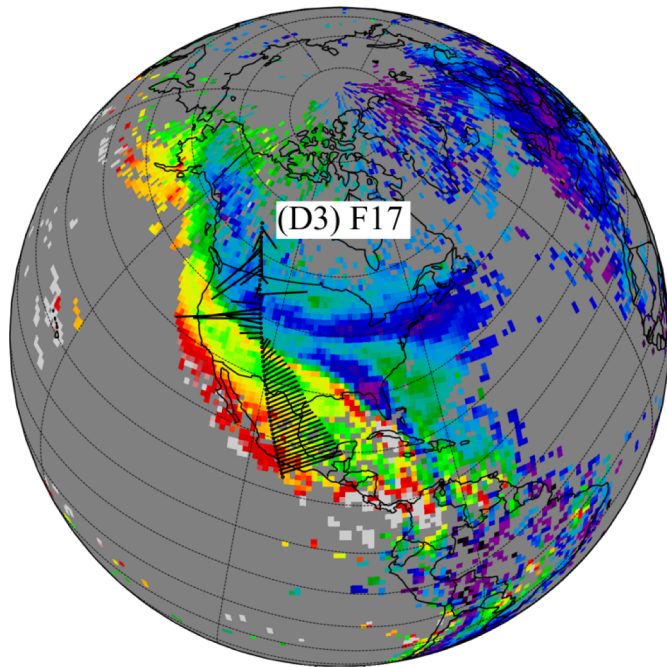


GPS scintillation over the continental U.S.

- Tasks: 1) Construct an image of the ionosphere using ~40,000 observations (5000 receivers x 8 satellites).
2) Compare with direct measurements of ionospheric flows by DMSP.

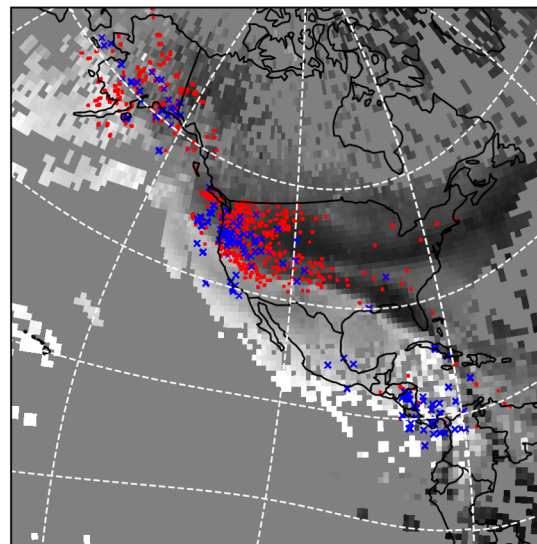
Result: A single diagnostic provides a map of the operational impact and the physical conditions that caused it.

GPS-TEC 09/08 01:15



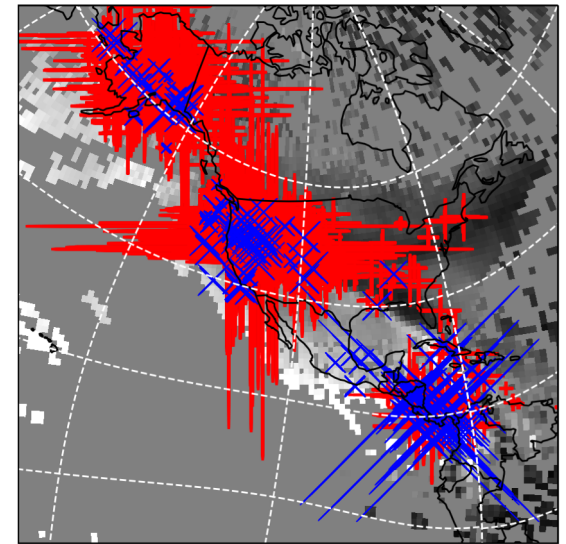
Location of scintillation

2017-09-08 01:45:00



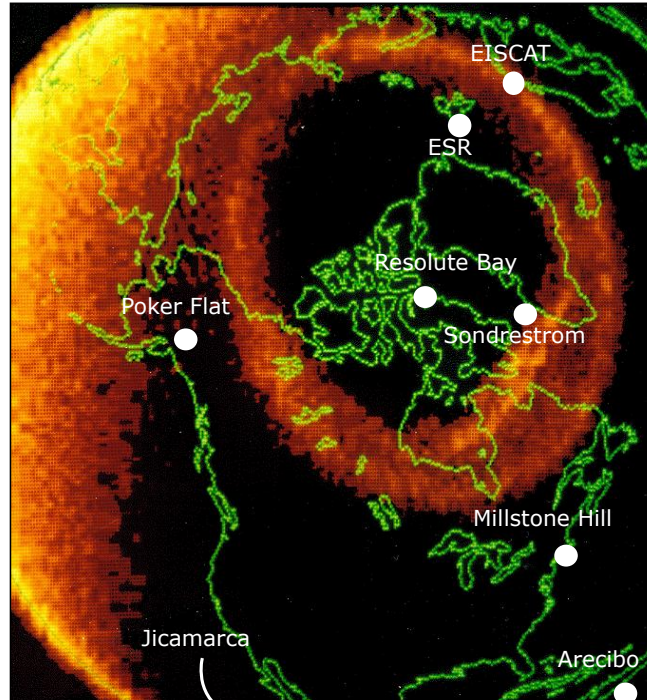
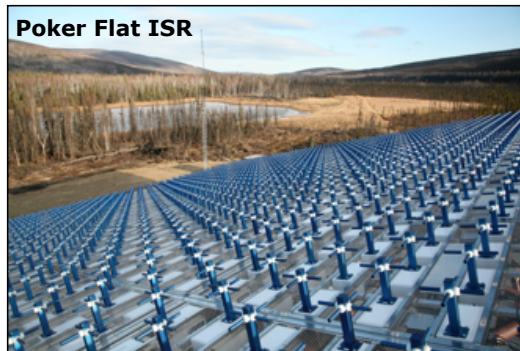
Strength of scintillation

2017-09-08 01:45:00



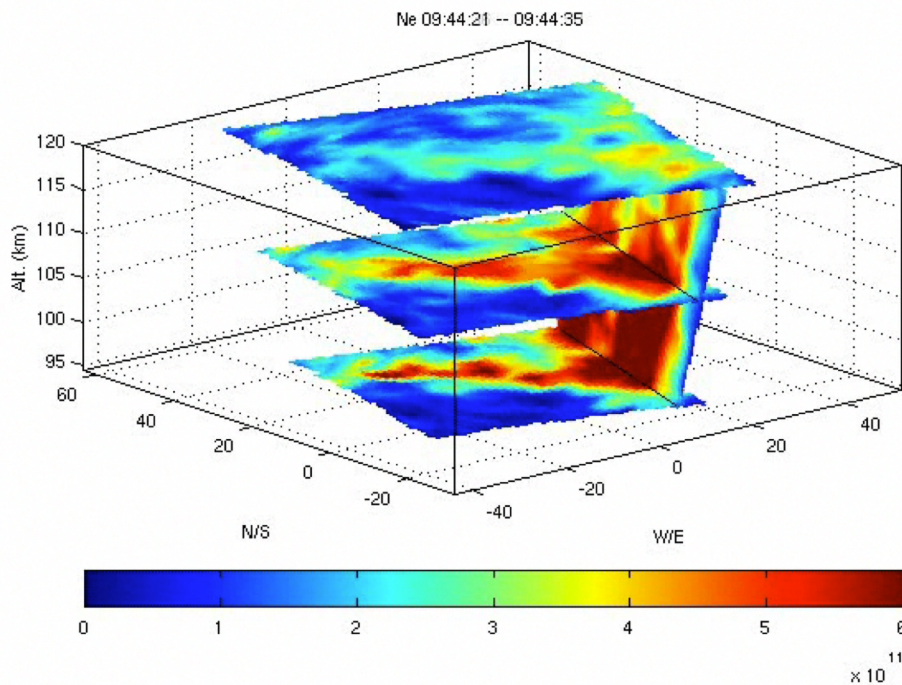
Red = phase scintillation Blue = amplitude scintillation

Incoherent Scatter Radar (ISR) Facilities

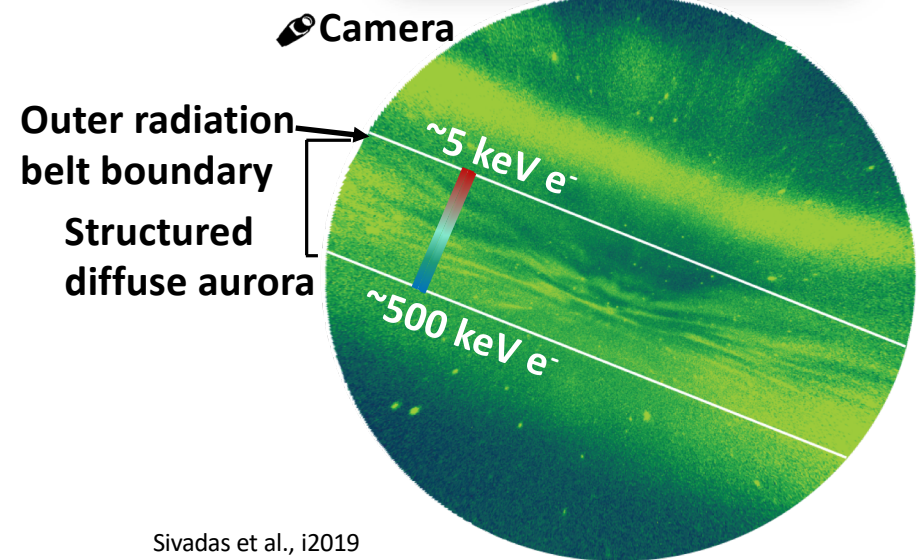
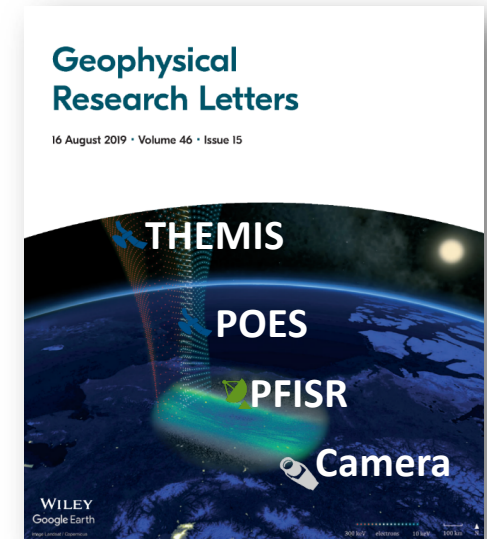


Atmosphere as particle detector

3D Image of the ionospheric response to a geomagnetic substorm, captured with the electronically steerable ISR at Poker Flat, AK



ISR provides high quality localized 'ground truth' for developing space weather monitoring techniques



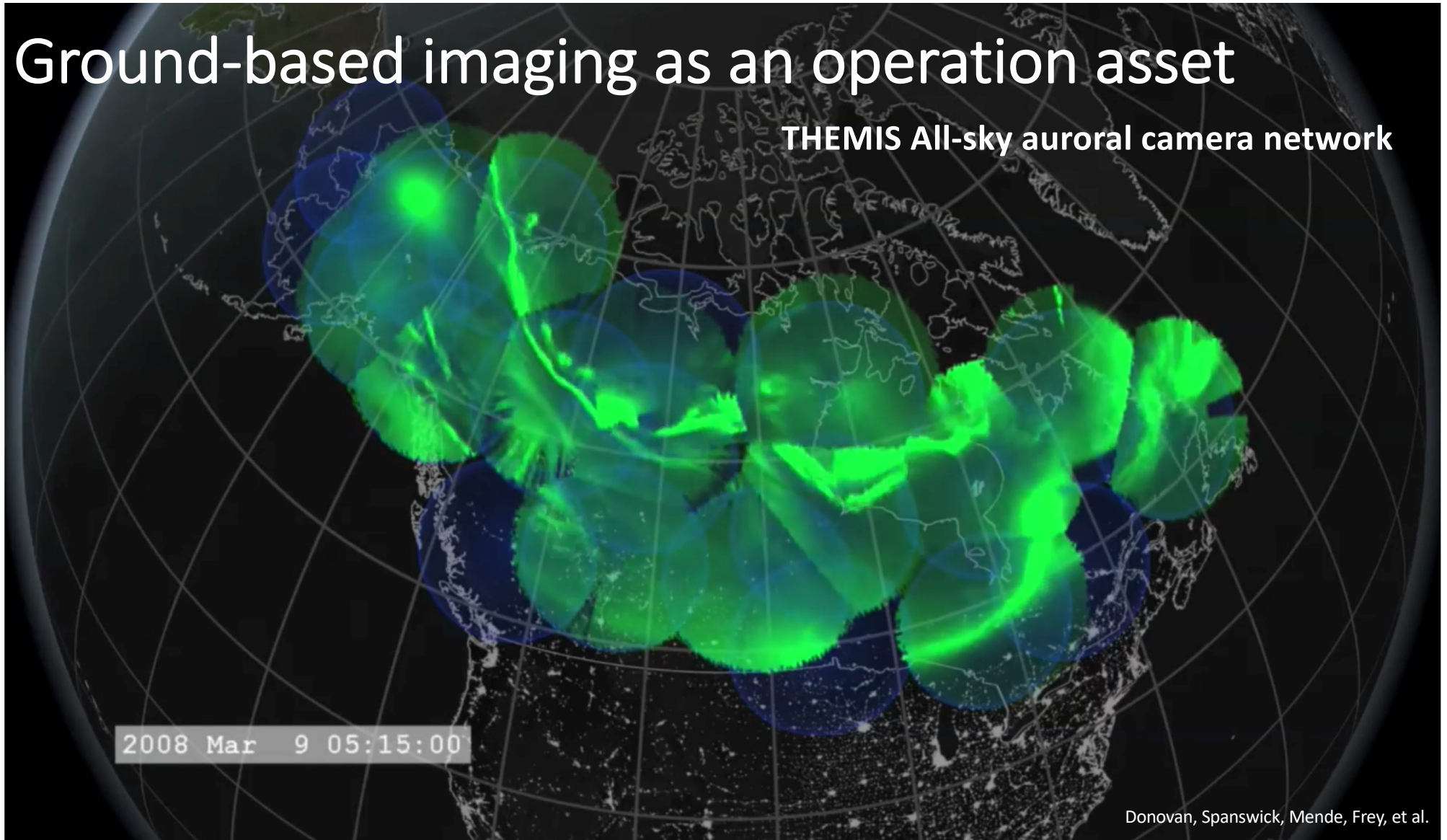
Sivadas et al., i2019

Ground-based imaging as an operation asset

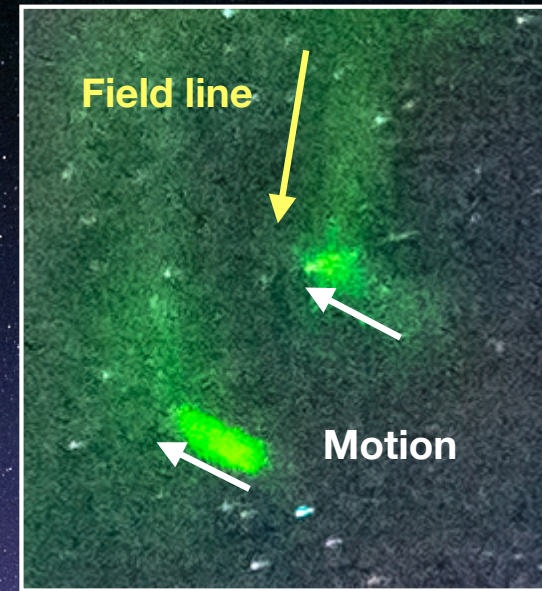
THEMIS All-sky auroral camera network

2008 Mar 9 05:15:00

Donovan, Spanswick, Mende, Frey, et al.



Role of citizen scientists (e.g., geomagnetic “storm chasers”)



The mysterious emissions of STEVE



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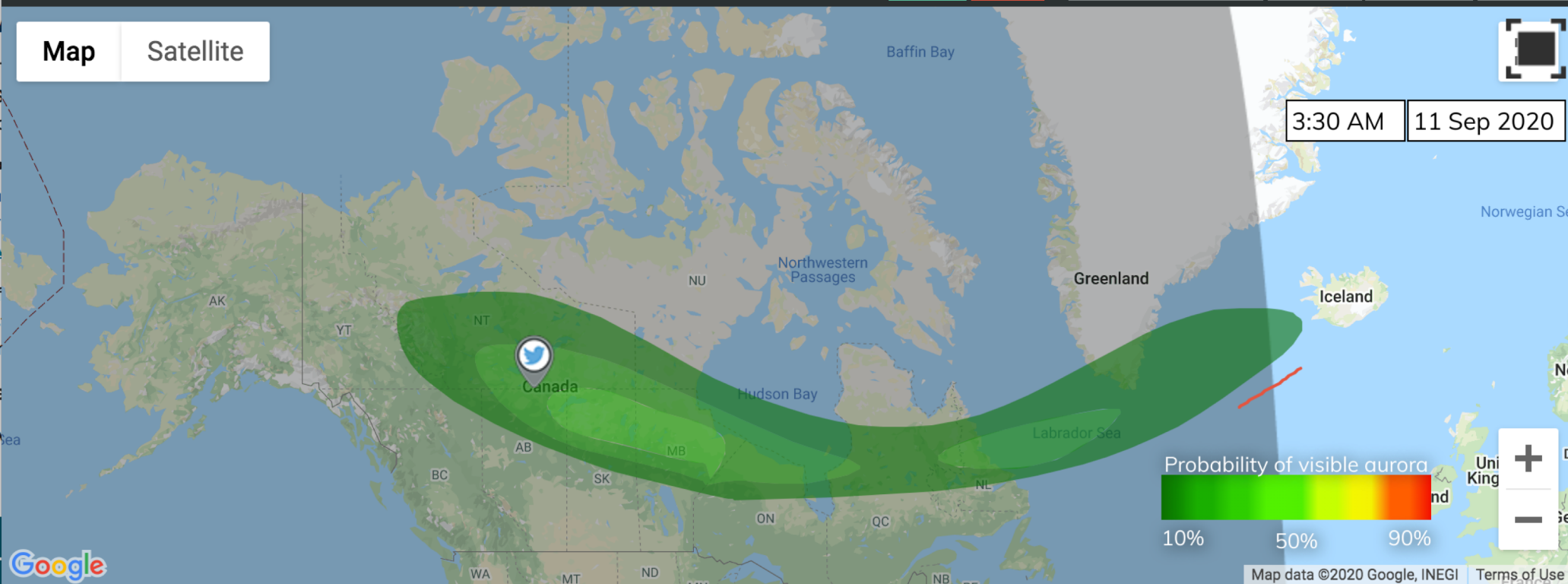
[Map](#)

[Satellite](#)



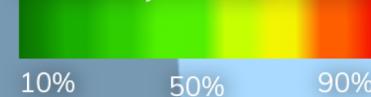
3:30 AM

11 Sep 2020



Google

Probability of visible aurora



Map data ©2020 Google, INEGI [Terms of Use](#)

Layers:

[Auroras](#)

[Weather](#)

[Legend](#)

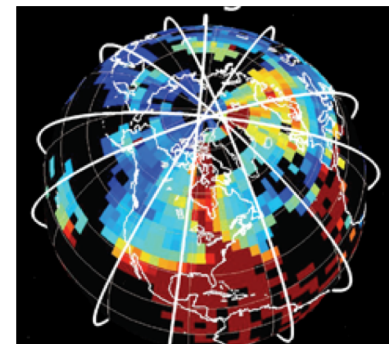
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Elizabeth MacDonald

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Distributed sensing: Challenges and Opportunities



Features of the LEO-Ground-based collaborative

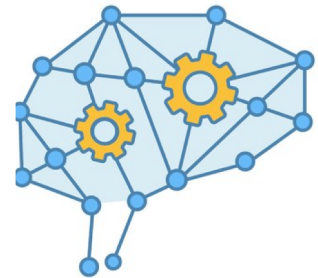
- Sampling is generally non-uniform, incomplete, heterogeneous
- Data are very high-dimensional (e.g., imaging, TEC maps)

But...

- Space weather impacts can be mapped to a cause.
- Opportunities for shared infrastructure (Earthscope, buoy networks)
- Opportunities for data capture (Earthquakes, Space Weather) multi-purpose
- Opportunities for fruitful new collaboratives with math, stats, CS, and EE.
- GDC will offer an unprecedented opportunity to acquire uniform spatial and temporal sampling the system over the entire globe from LEO.

Rethinking 'basic research'

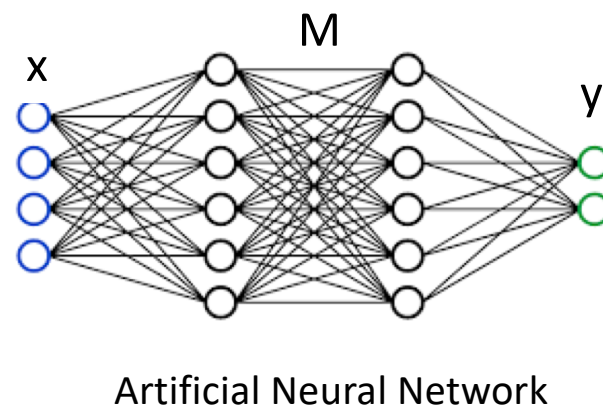
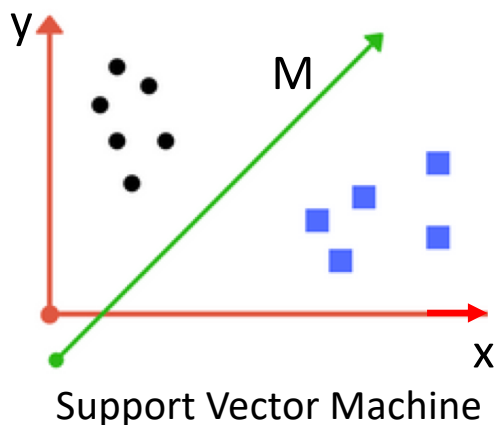
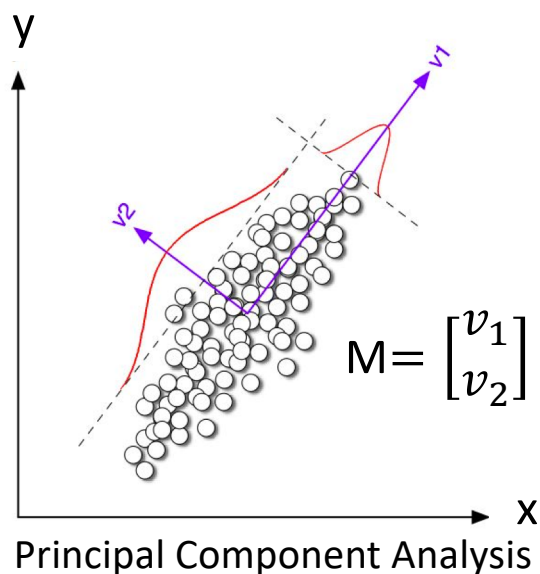
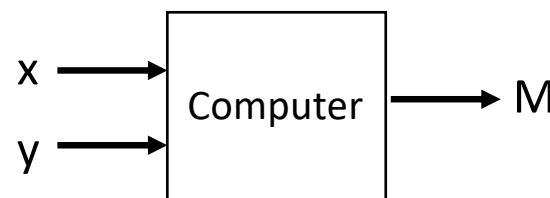
- When we refer of 'basic research', we generally mean physics.
- But in the burgeoning field data science, the analytical strategies *are* the basic research.
- Applications of Artificial Intelligence (AI) and Machine Learning (ML), to space weather prediction can exploit a vast knowledge base developed over the past 50 years in mathematics, statistics, signal processing, and information theory.
- Our data sets are ideal for this challenge.



The 'Machine Learning' toolbox

- Main tasks: Classification and Prediction
- Interpretive versus non-interpretive methods
- Relationship with information theory
- How to create training data from distributed measurements?

The Data-driven paradigm



Actions taken in response to the 1989 Hydro-Quebec blackout offers an ideal use case

1. **Software:** Raised the trip level of the grid protection system.
2. **Engineering:** Installed series compensation on power lines to enhance grid stability. This measure has been very effective in mitigating the impact of magnetic storms.
3. **Warning system:** Implemented a real-time alert system that measures disturbances on the power grid during magnetic storms.
4. **Procedural:** Modified of operating procedures: In the event of a disturbance, reduces power flow on lines, direct-current interconnections, and suspend all major switching operations.