# Investigating the Role of Ionosphere-Thermosphere-Mesosphere Coupling on Auroral Systems Using GEMINI

MITC-4

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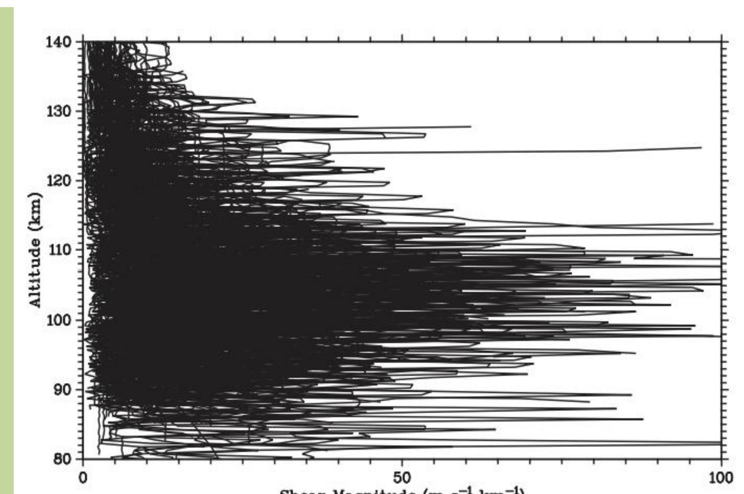
## Introduction

### Overview:

- Background
  - Neutral winds generating low altitude ion shears
  - The GEMINI model
  - Instrumentation
- Case Study: March 22nd 2023 (with x10 winds)
  - Comparison of different wind measurements
  - GEMINI Drivers
  - Field-Aligned Current effects
- Conclusions
  - Low altitude FAC structuring
  - Advancing ion-neutral coupling
  - GNEISS Sounding Rocket



*Larsen 2002*

### Background/Theory

- Local auroral current coupling (Wolf, 1975; Cowley, 2000; Khazanov et al., 2018; Lynch et al., 2022).
- Common assumption: negligible neutral thermospheric winds effects.
- From a study of Saturn's neutral wind dynamo (Gandhi 2026), we looked at the ways neutral winds changed currents
- Ionospheric Ohm's Law is (Vasyliūnas 2012)

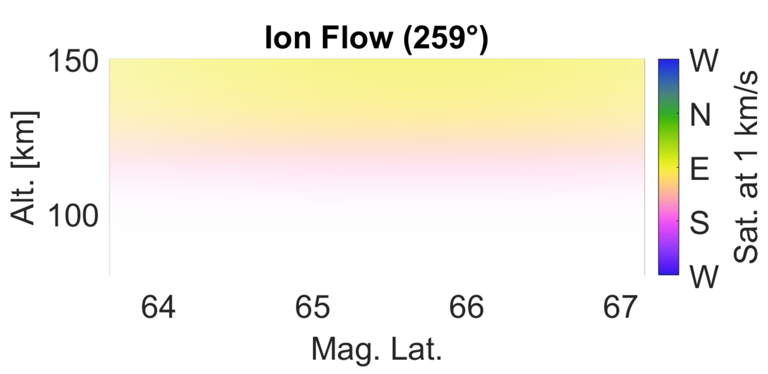
$$\mathbf{J} = \sigma \cdot \mathbf{E}'$$

- From Current Continuity:

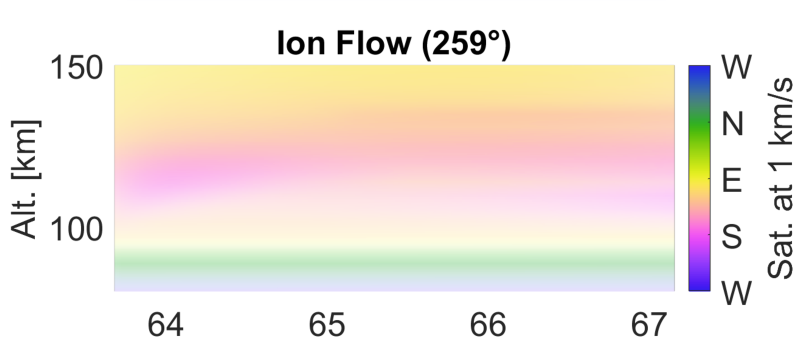
$$\frac{\partial}{\partial z} J_{\parallel}(x,y) = \nabla \cdot \sigma_P (\mathbf{E} + \mathbf{U}(z) \times \mathbf{B}) + \nabla \cdot (\sigma_H \mathbf{b} \times (\mathbf{E} + \mathbf{U}(z) \times \mathbf{B}))(\mathbf{b} \times \mathbf{E})$$

- Strong thermospheric wind shears led to more shearing in the ion flows in collisional altitudes
- Larsen 2002 showed that wind shearing in this altitude region can be very large

**No Neutral Wind**




**Structured Neutral Wind**

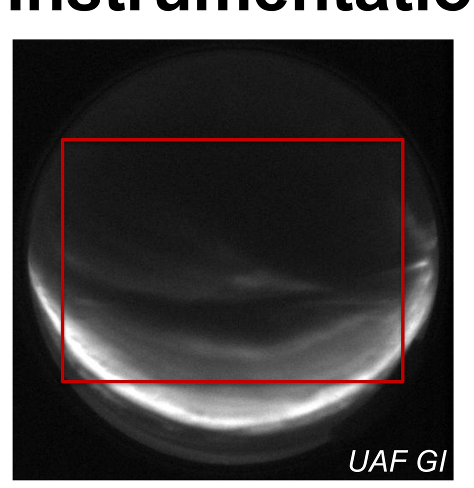



### The GEMINI Model

- GEMINI is a multi-fluid model that simulates the ionosphere at auroral arc scales (Zettergren & Semeter, 2012; Zettergren & Snively, 2019). For details see github.com/gemini3d.
- GEMINI solves for static current continuity to account for changes in model parameters affecting conductivities as it steps forward in time.
- Drivers:
  1. top-boundary precipitation maps of energy flux and characteristic energy covering impact ionization (Fang et al., 2008).
  2. the model is forced at the top-boundary with either a map of FAC or plasma flow; **here flow driven.**
- Here GEMINI is driven by data.

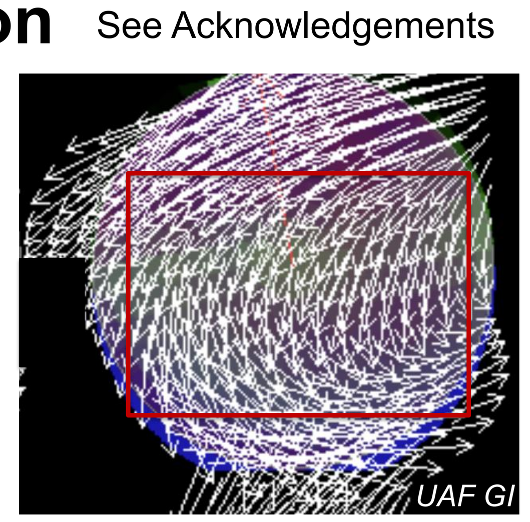
### Instrumentation

See Acknowledgements



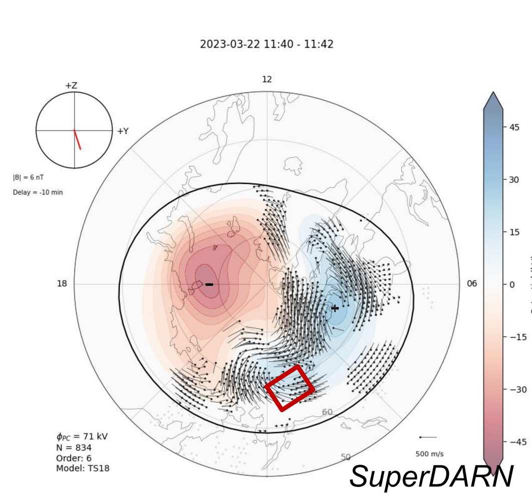

**Poker DASC**

- Inversion gives precipitation spectra
- Averaged to avoid geometric distortion




**Scanning Doppler Imager**

- Evolutionary Model gives 4D wind profile (Branning 2022)




**SuperDARN**

- Defines top side potential BC (Davidson 2026)

**Meteor Radar**

- Measures low altitude neutral winds from meteor trails (Thorsen 2026, Kumar 2026)

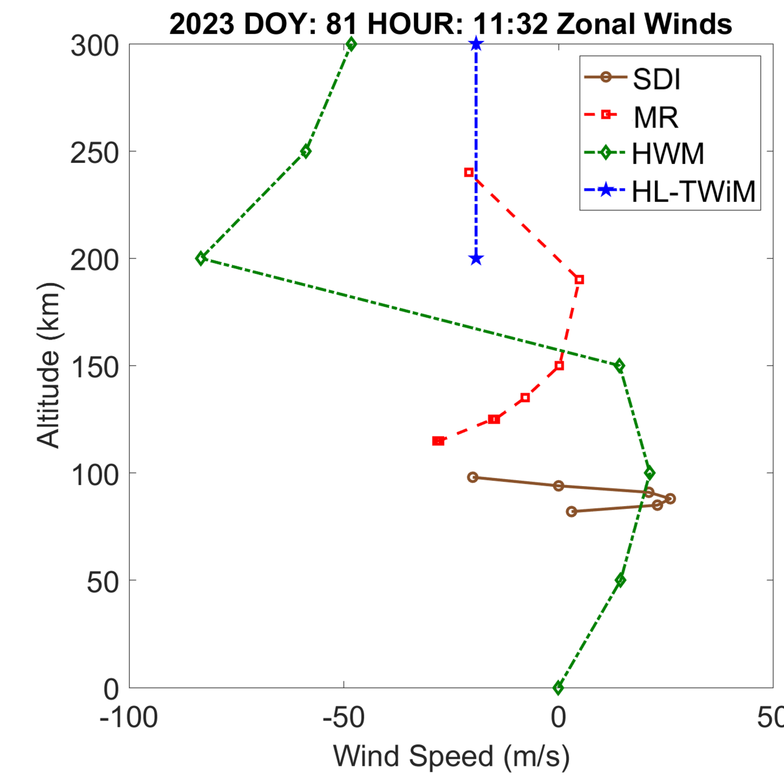
**HWM14**

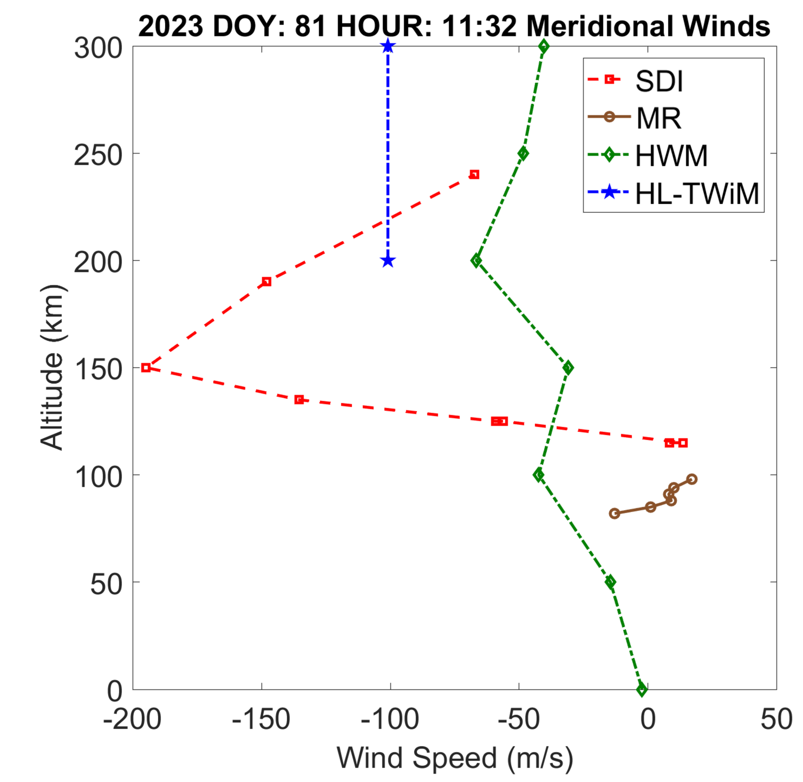
- Empirical model that defines neutral wind profile (Drob 2015)

**HL-TWiM**

- Empirical model that defines F region neutral winds (Dhadly 2019)

## Case Study: March 22nd 2023 11:32 UT

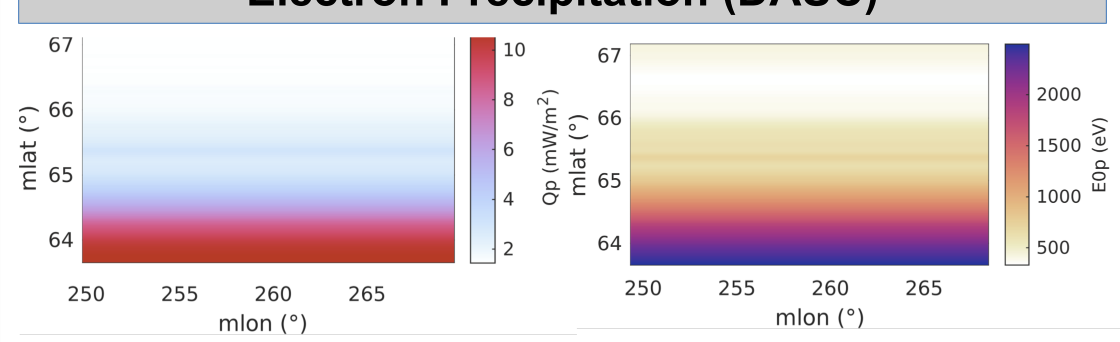


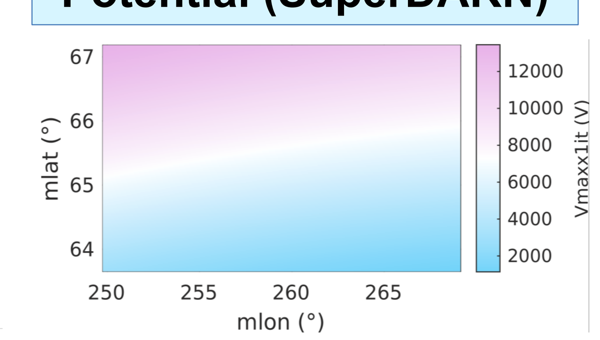

- Comparisons of empirical models (HWM14, HL-TWiM) and observations (SDR, Meteor Radar) over Poker Flat, AK
- To exaggerate neutral wind effects, we multiplied a combined SDI/Meteor Radar profile by 10

### Drivers

**Electron Precipitation (DASC)**

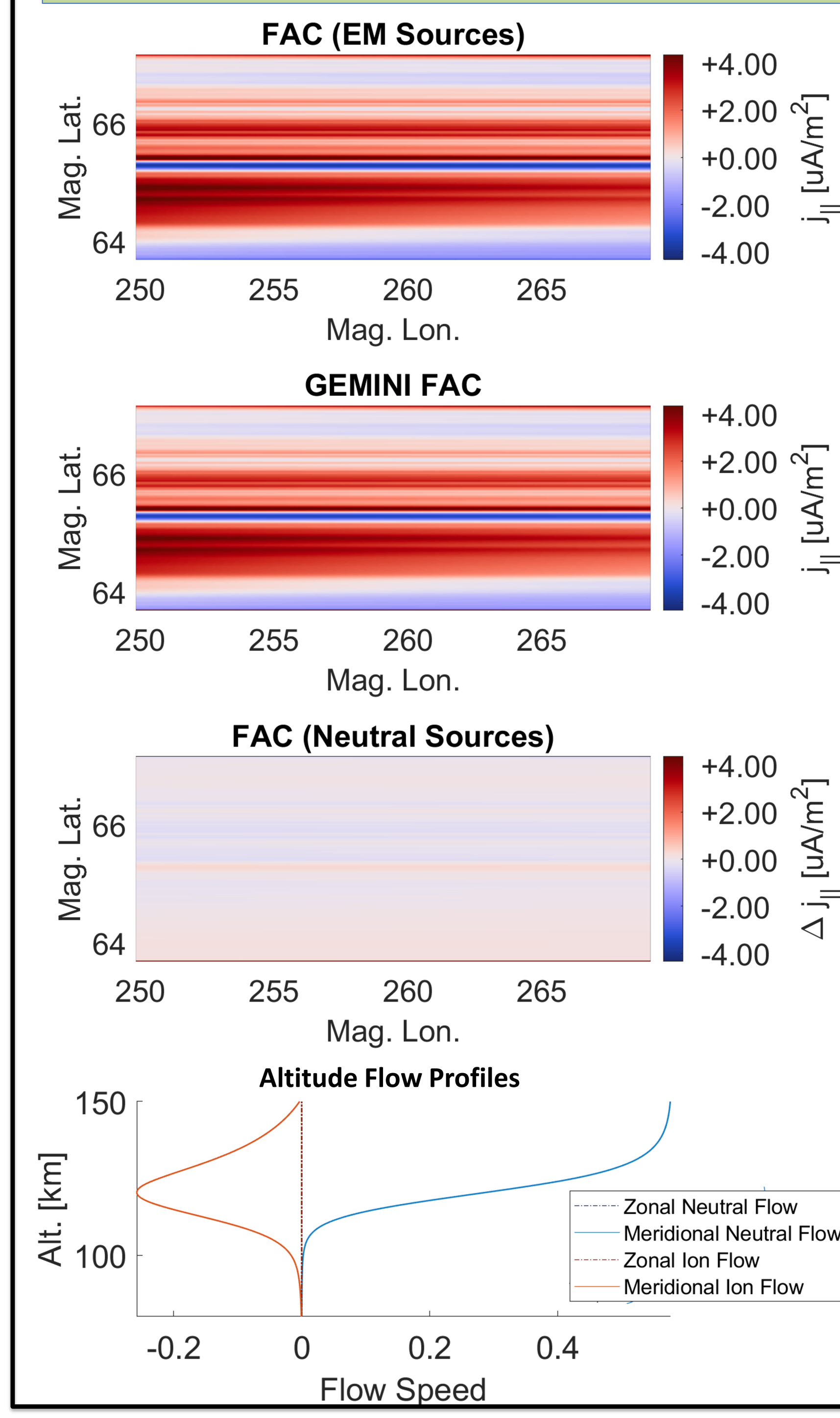



**Potential (SuperDARN)**

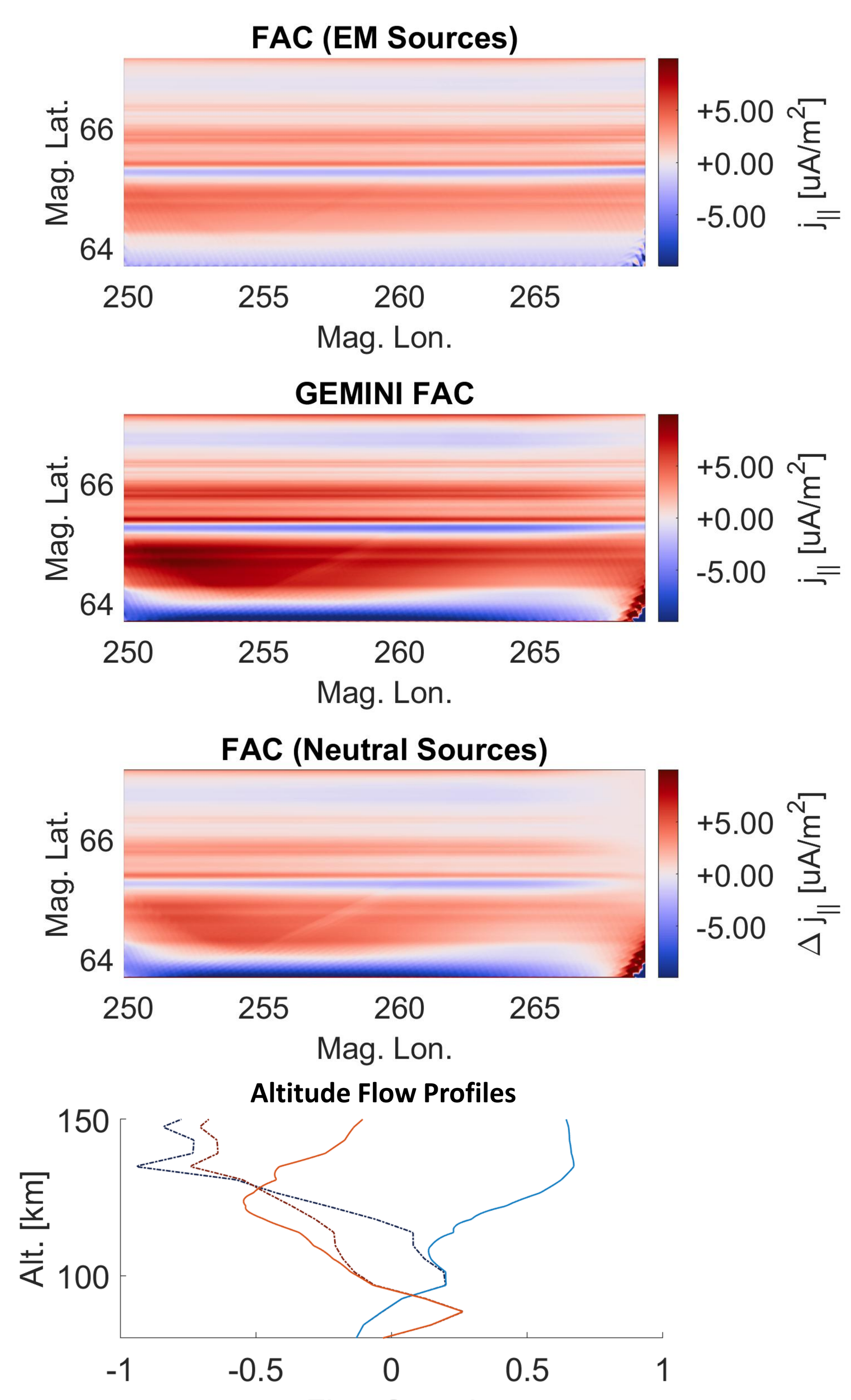



### Results: F-region FAC Comparison

**No Wind**

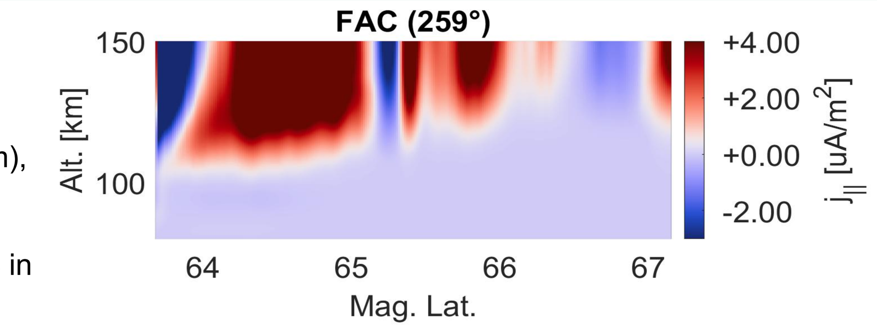



**Strong Winds (x10)**

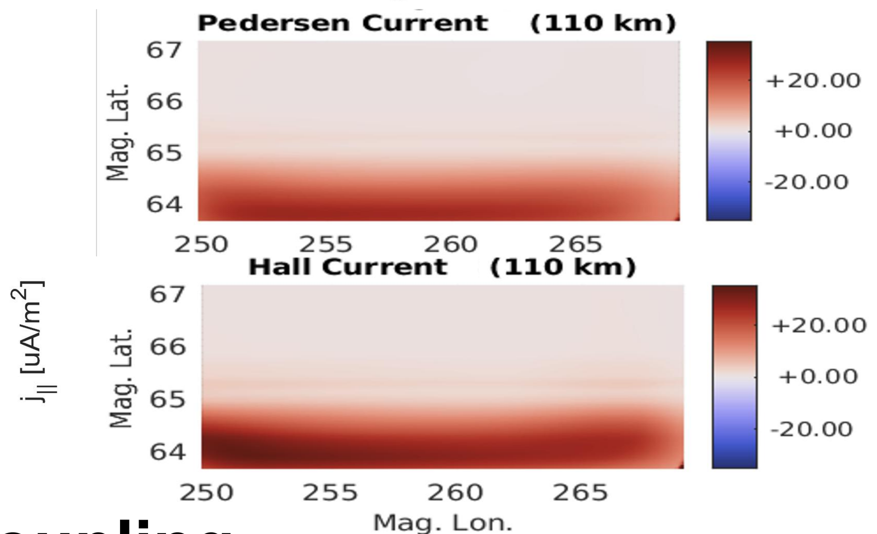


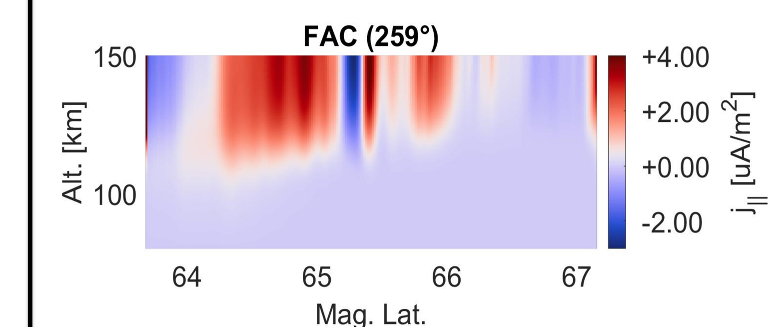

## Conclusions

### Height Integration

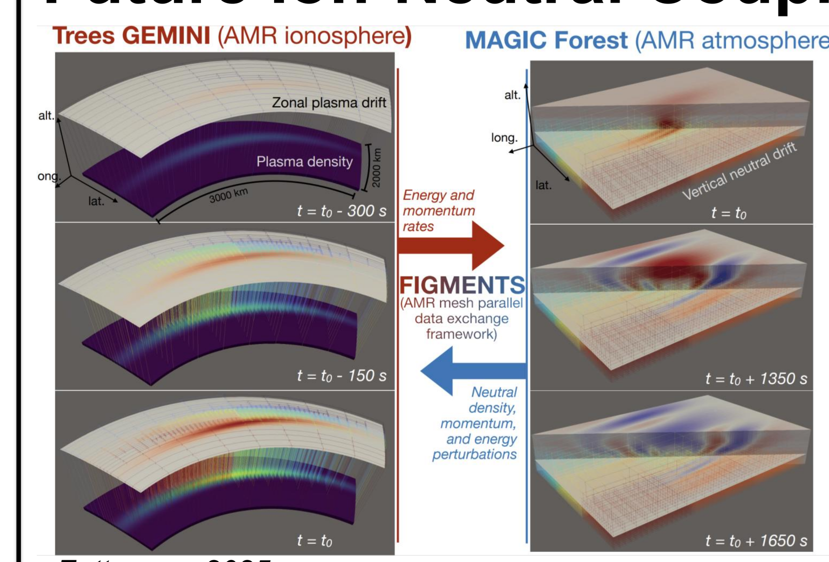



- Comparing a vertical slice of FAC from the no wind run (top) and the strong winds run (bottom), there is a visible introduction of new current structure from the neutral wind
- Some of this forms as localized regions of FAC in the collisional E region
- This suggests height-integrating neutral winds oversimplifies the low altitude effects to current closure
- This FAC structure is being sourced from divergences in the Pedersen and Hall Currents



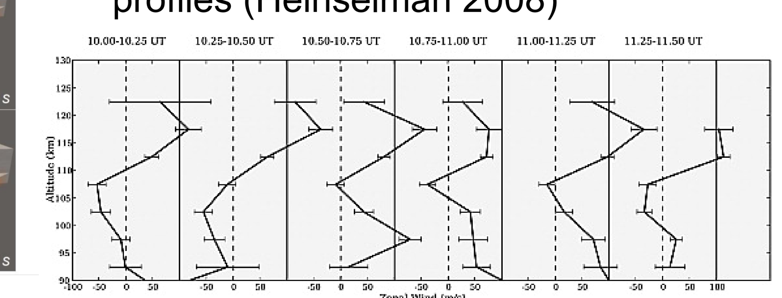




### Future Ion-Neutral Coupling



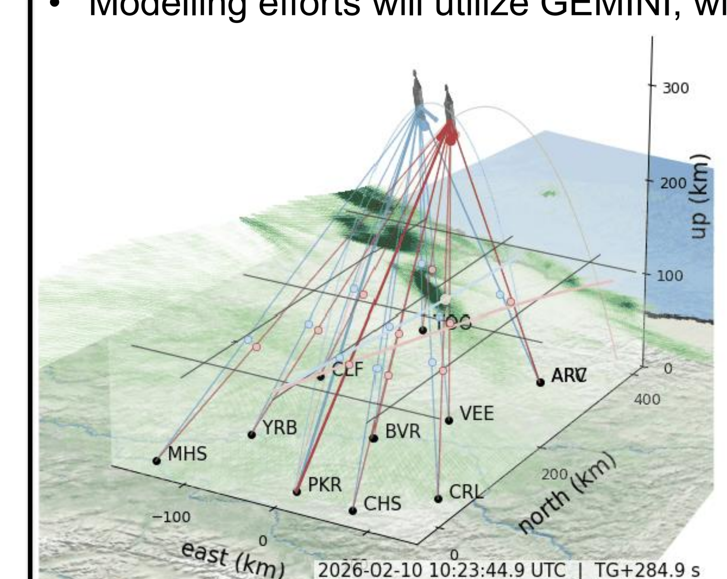
*Zettergren 2025*

- FIGMENTS coupling of GEMINI to MAGIC (Trees GEMINI; Zettergren and Snively, 2015) (MAGIC Forest; Snively 2012)
- PFISR derived E-region neutral wind profiles (Heinselman 2008)

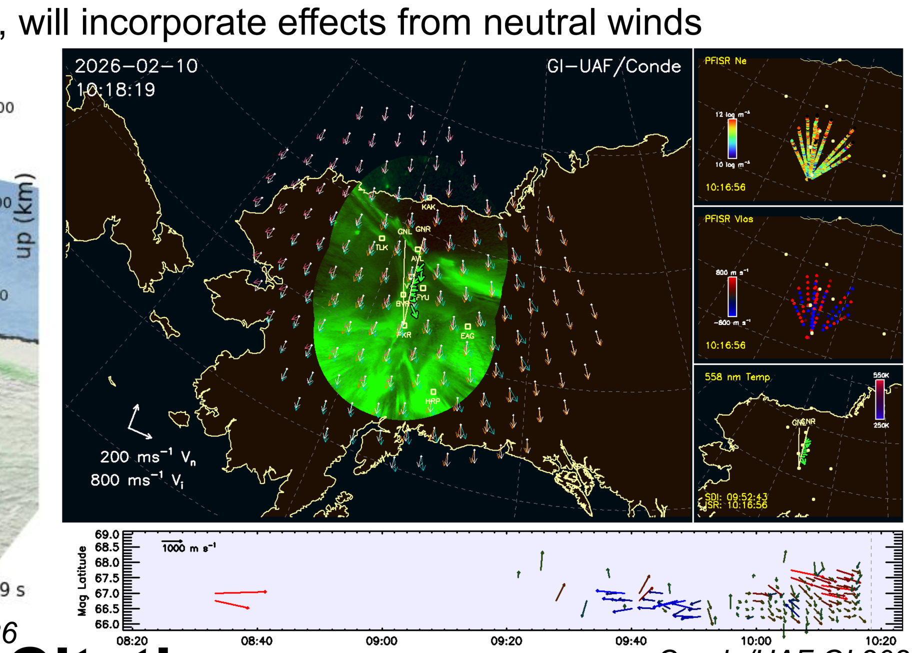

*Heinselman 2008*

### GNEISS Sounding Rocket Campaign

- GNEISS Launched from Poker Flat on February 10th, 2026
- Science Goal: multi-point measurement of auroral event (2 rockets + ejected SWARM)
- Modelling efforts will utilize GEMINI, will incorporate effects from neutral winds



*Pflaum/GNEISS 2026*



*Conde/UAF GI 2026*

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