

# SMRAI project's current status and future SuperDARN and SuperMAG Data Assimilation

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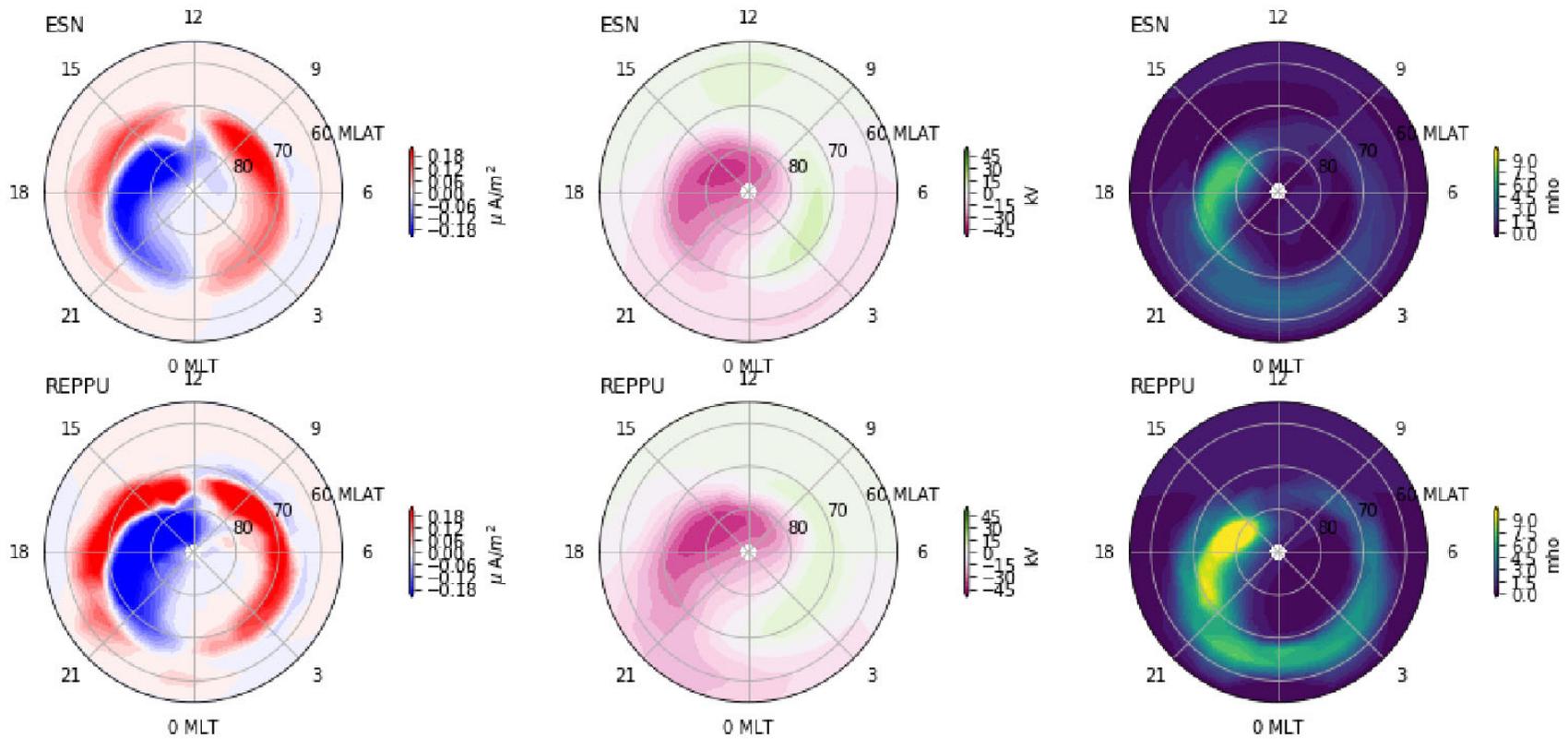
2026/3/10 SuperDARN研究会@九州（リモート講演）

Kataoka, Nakano, Fujita (2023, EPS)

# Example of ESN emulator ver1.0 results

Million times faster run than the physics-based simulation

Emulation



Simulation

# Specifications of ver1.0 and ver2.0

Kataoka, Nakano, Fujita  
(2023, EPS)

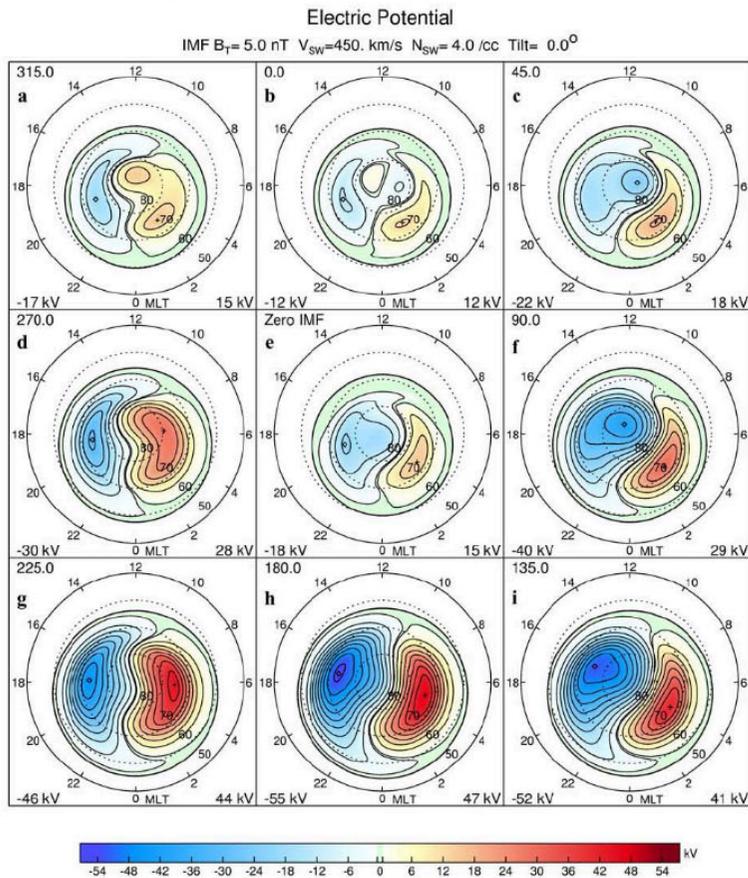
Kataoka, Nakamizo, Nakano, Fujita  
(2024, Space Weather)

<b>Parameters</b>	<b>Ver1.0</b>	<b>Ver2.0</b>
Time resolution	10 min	5 min
Latitude resolution	~2 deg	~1 deg
Longitude resolution	11.25 deg	4.5 deg
Input solar wind parameters	By, Bz, Np, Vsw	Tilt, By, Bz, Np, Vsw
Training dataset	~10 days worth	~100 days worth
	(ISM&NIPR supercomputers)	(NICT's supercomputer)

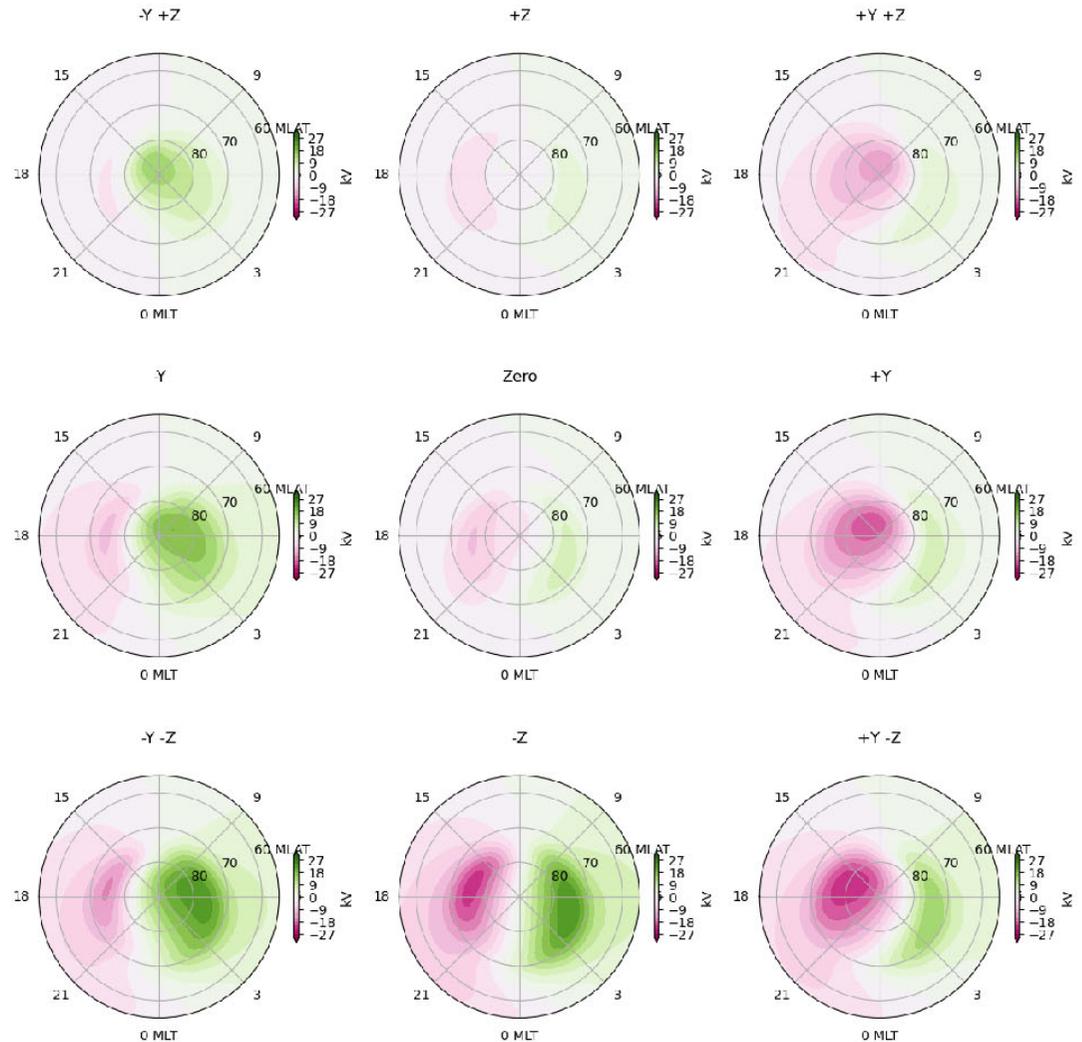


# POT clock-angle dependence

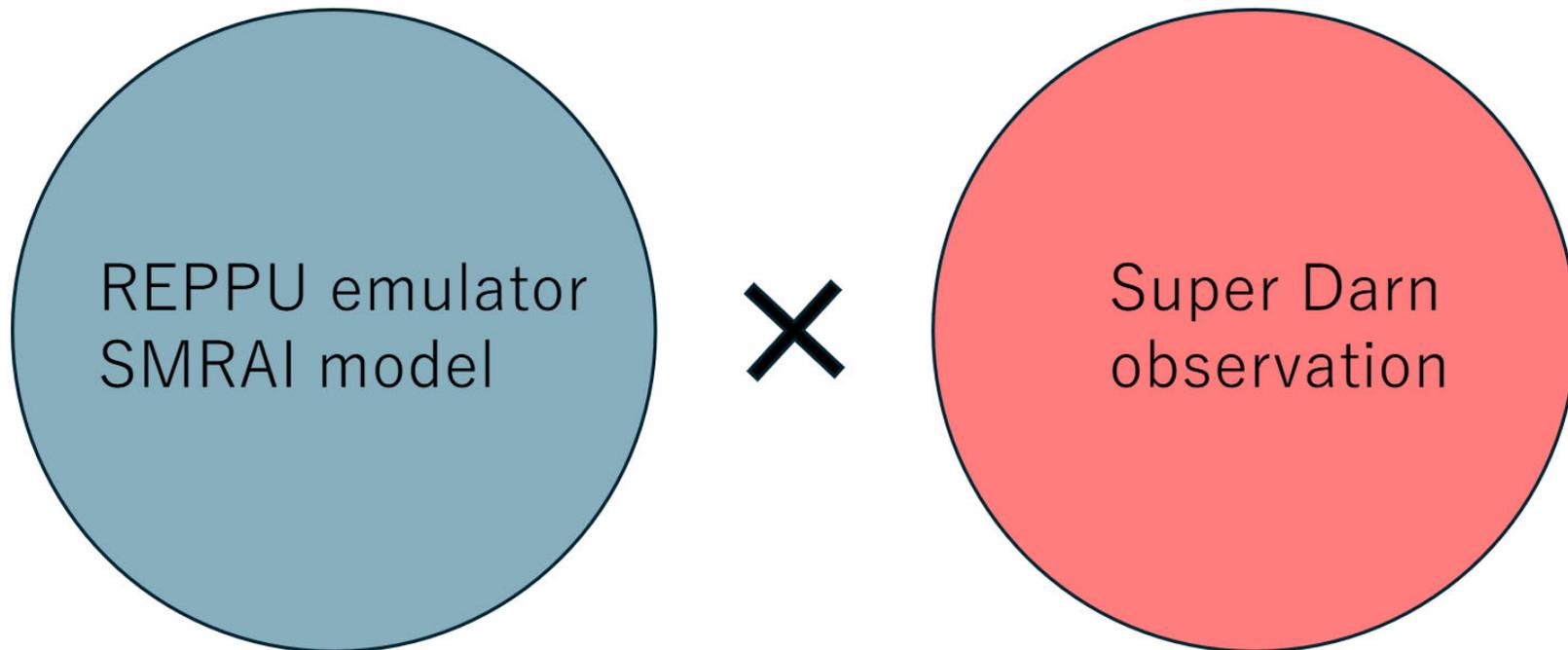
Steady state (Tilt = 0.0, B = 5.0 nT, N = 5/cc, V = 400 km/s)



Weimer (1995)



# Data assimilation, Ensemble Transform KF

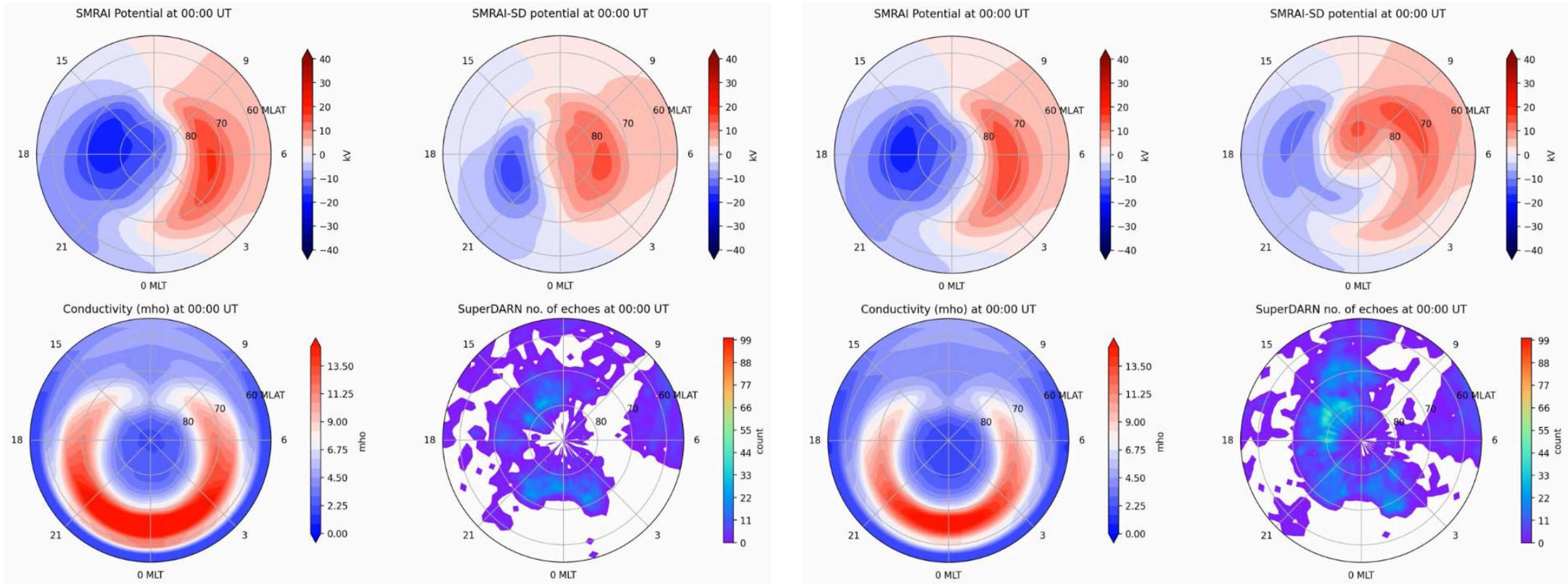


1,000,000 faster REPPU

[Nakano+2025, doi:10.1029/2025SW004488](https://doi.org/10.1029/2025SW004488)

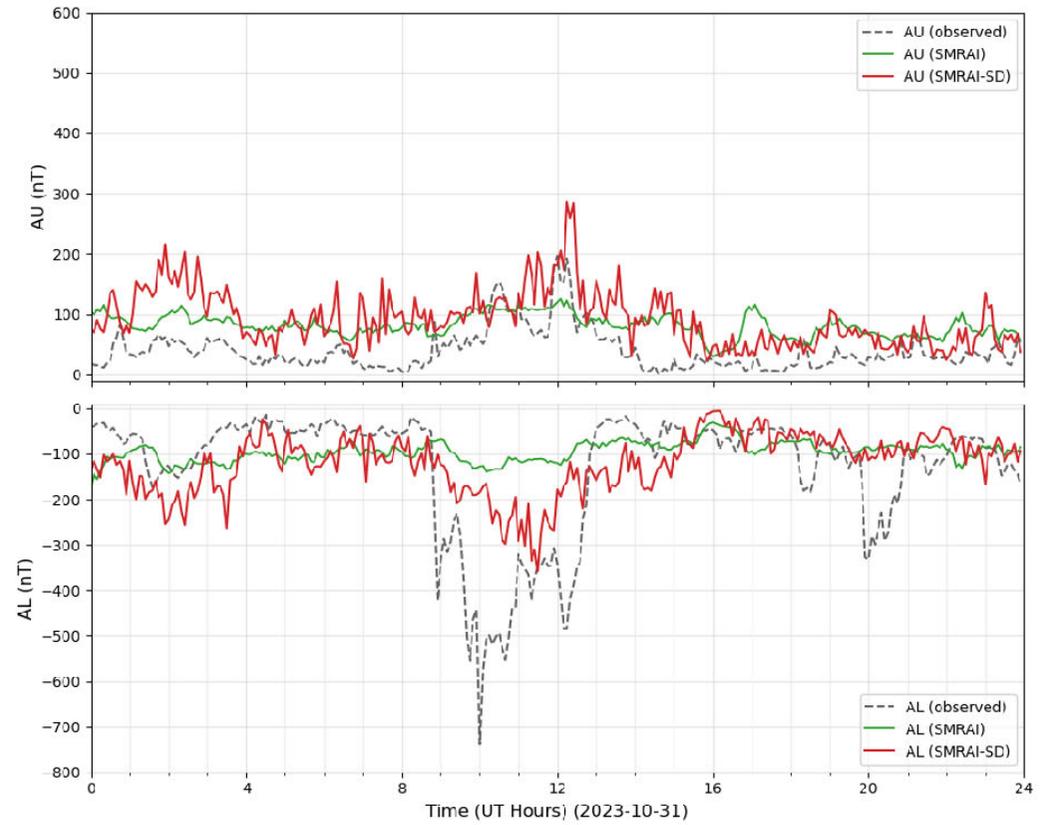
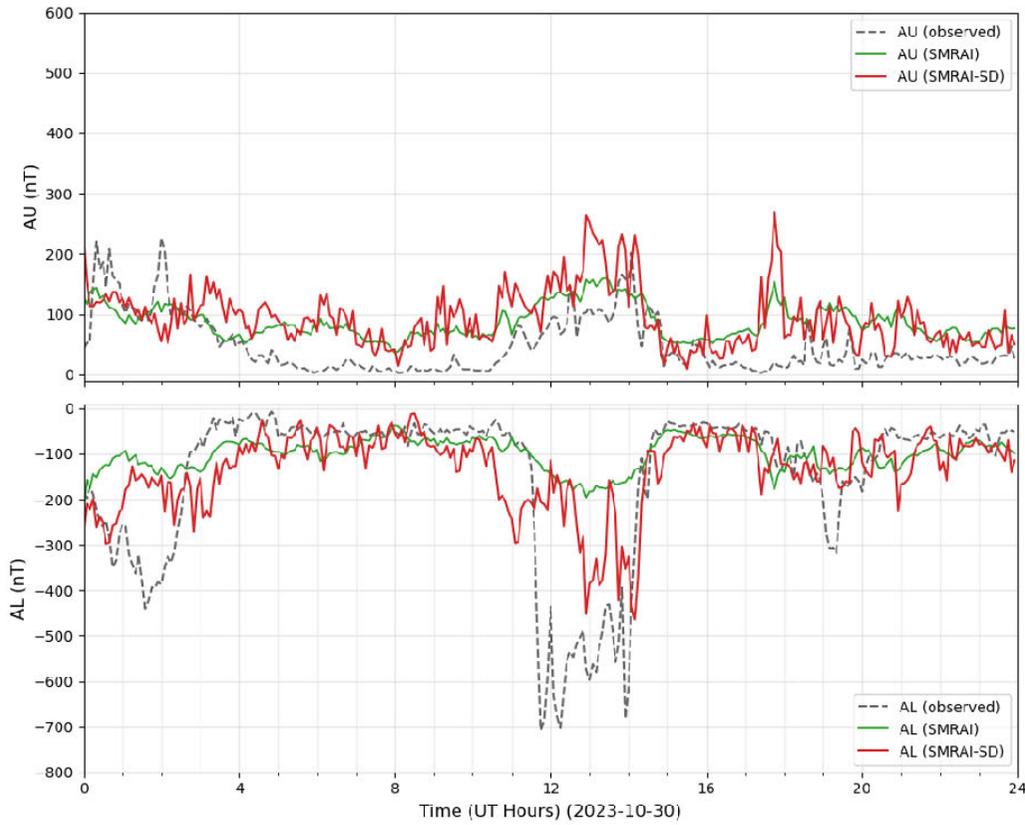
Nilam et al., 2026 submitted

# 2023/10/30, 31 substorm events



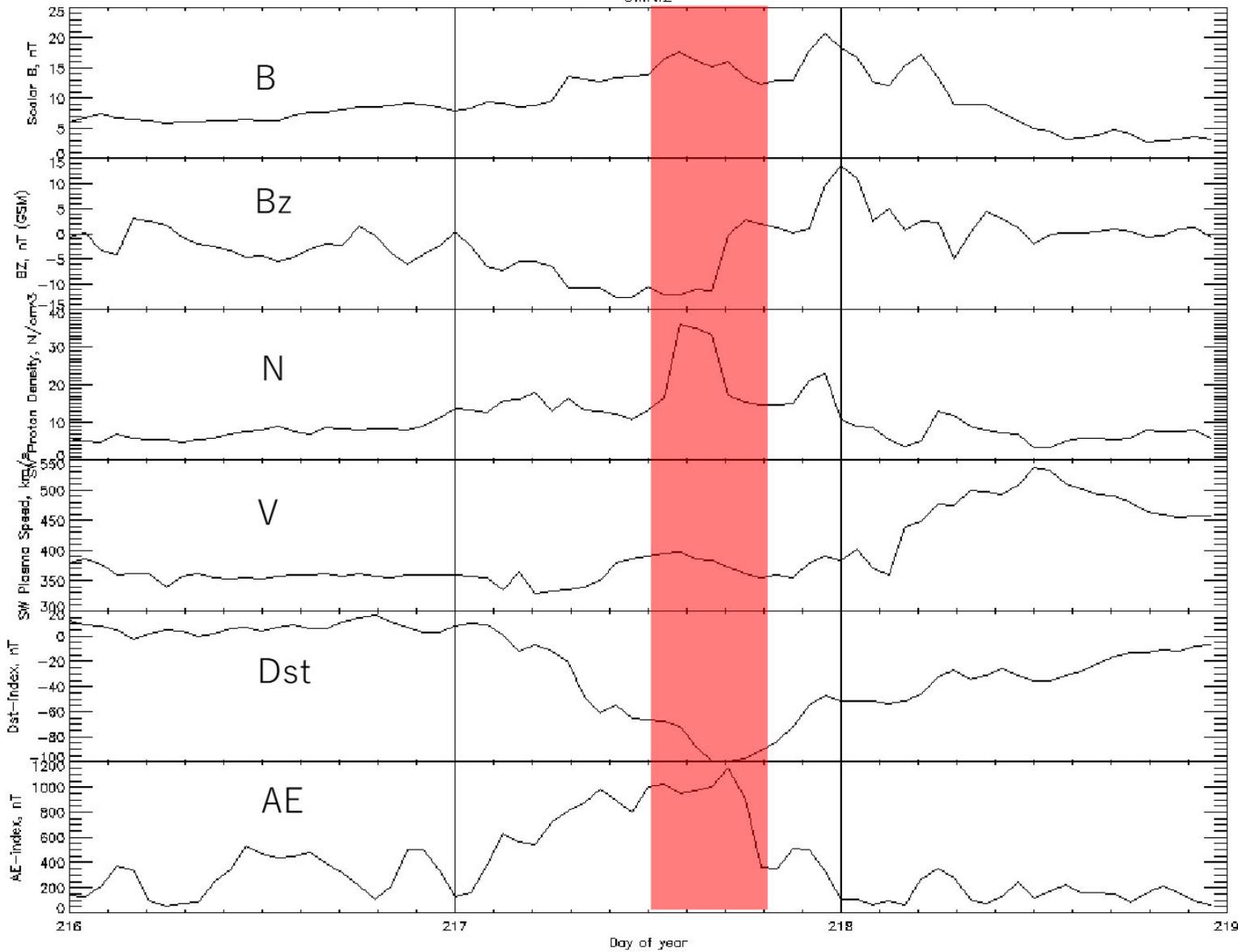
Nilam et al., 2026 submitted

# 2023/10/30, 31 substorm events

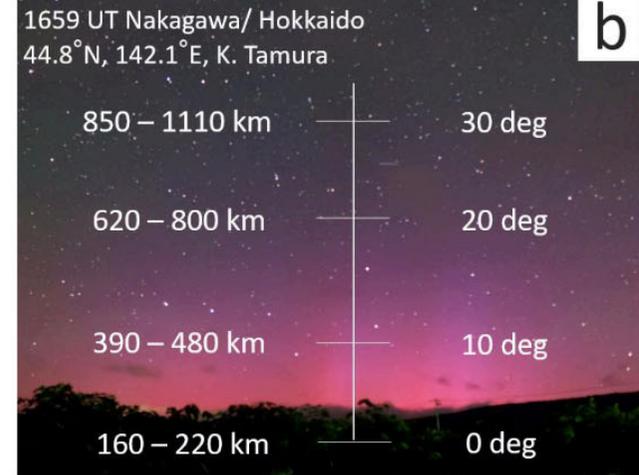


August 4, 2024

OMNI2



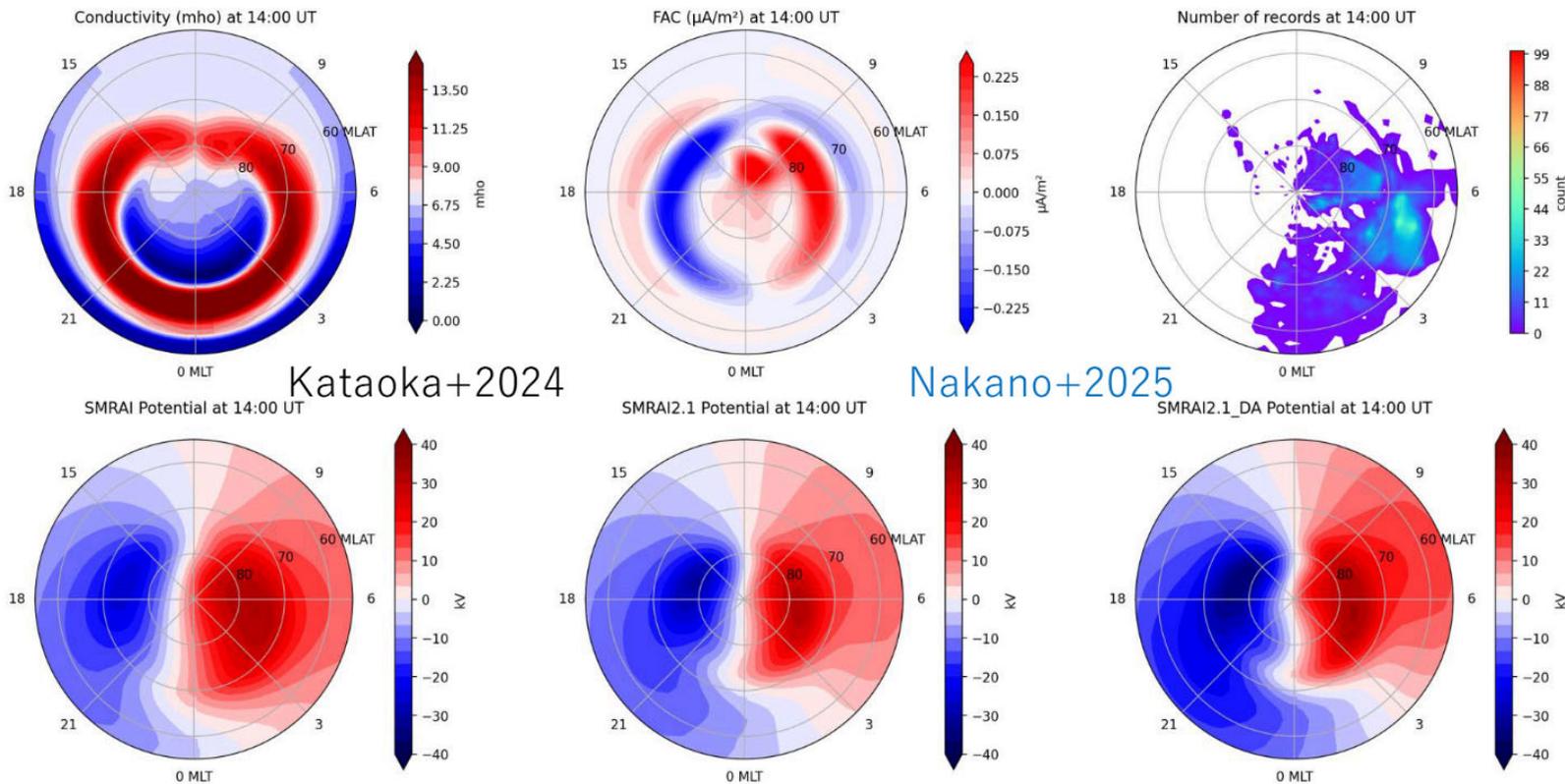
**Motivation of this study:**  
Why Japan's red aurora during only 100 nT storms?



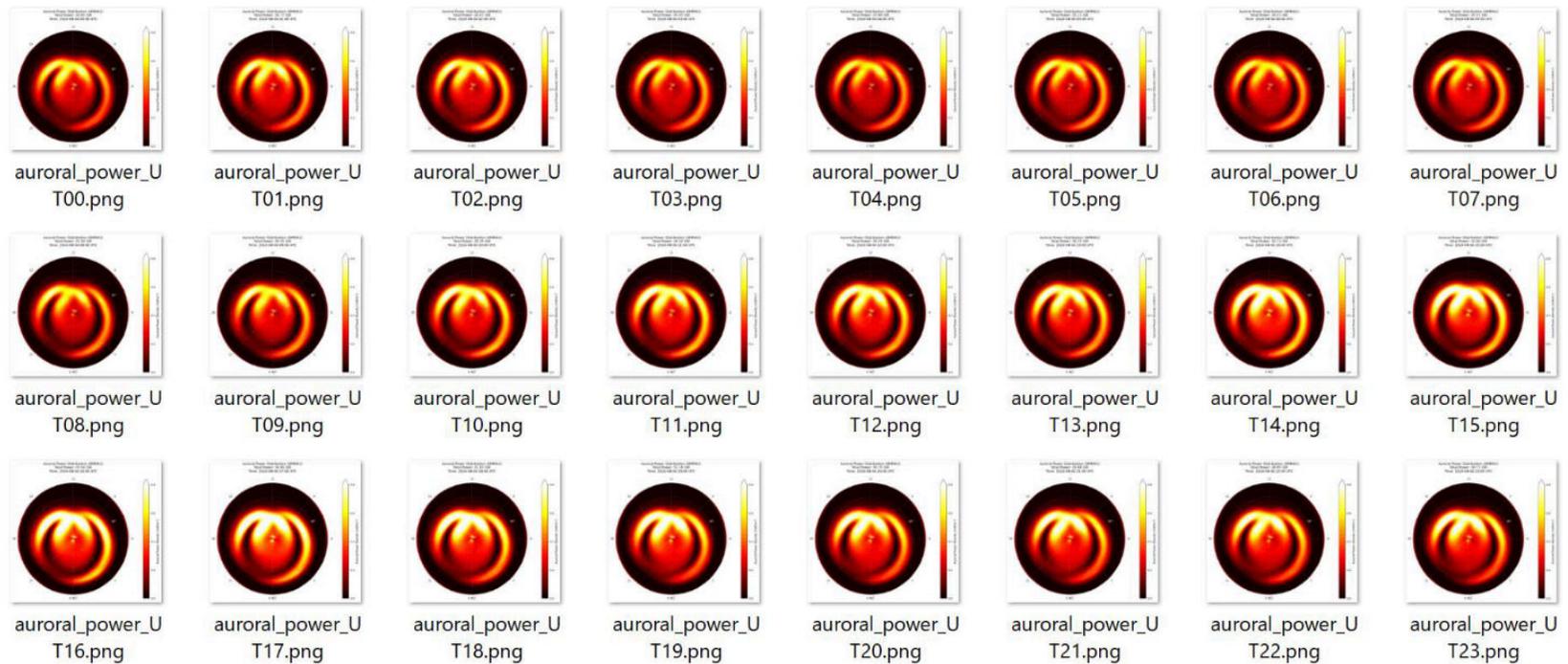
Nakayama&Kataoka  
(2025 in press)

**Hypothesis:** Significant Joule heat in subauroral latitudes?

SMRAI2.0 sig, SMRAI2.0 fac, SD echo#,  
SMRAI2.0 pot, SMRAI2.1 pot, DA pot

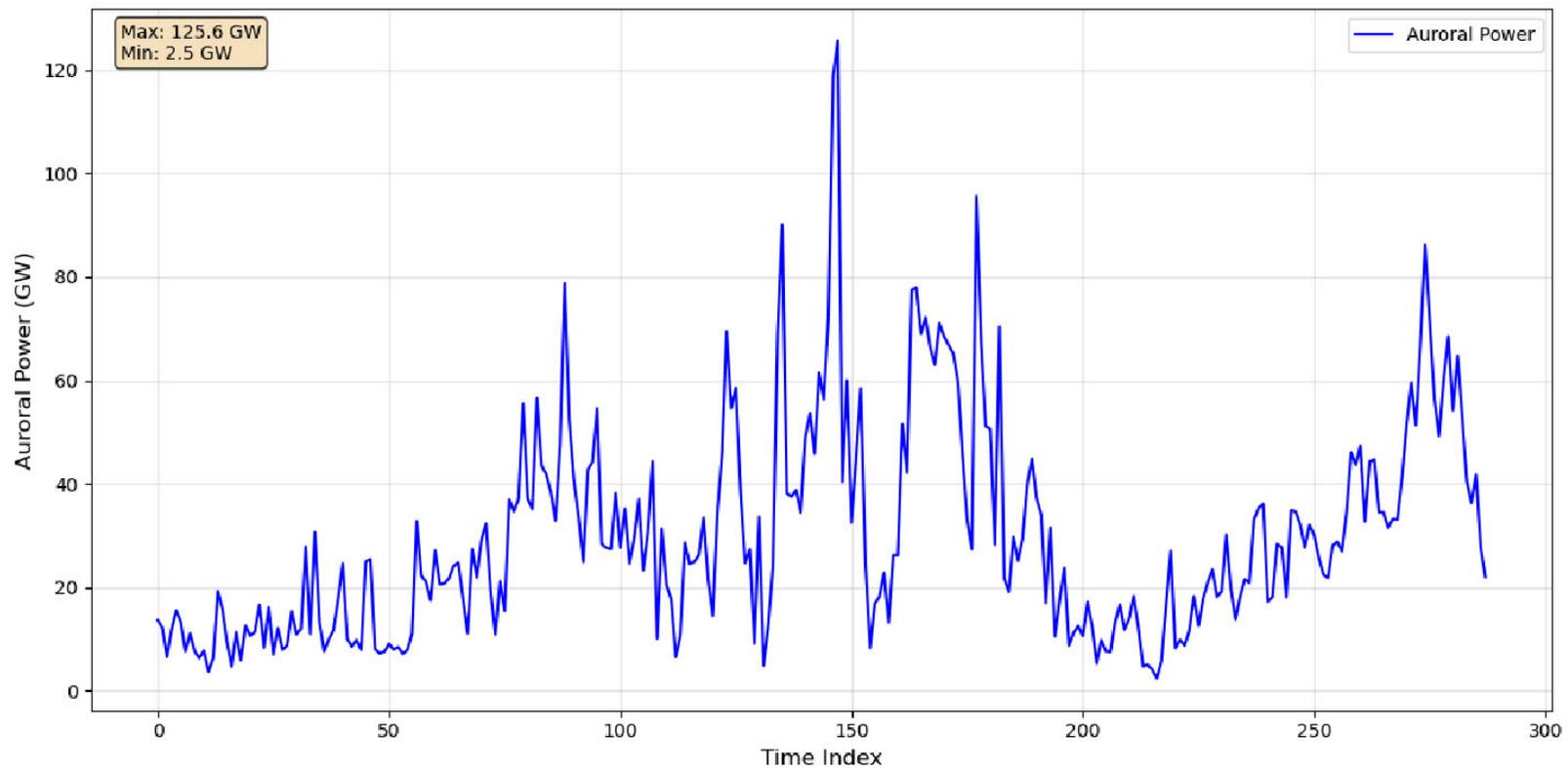


# Joule heat map w/o DA (org. SMRAI2.0)



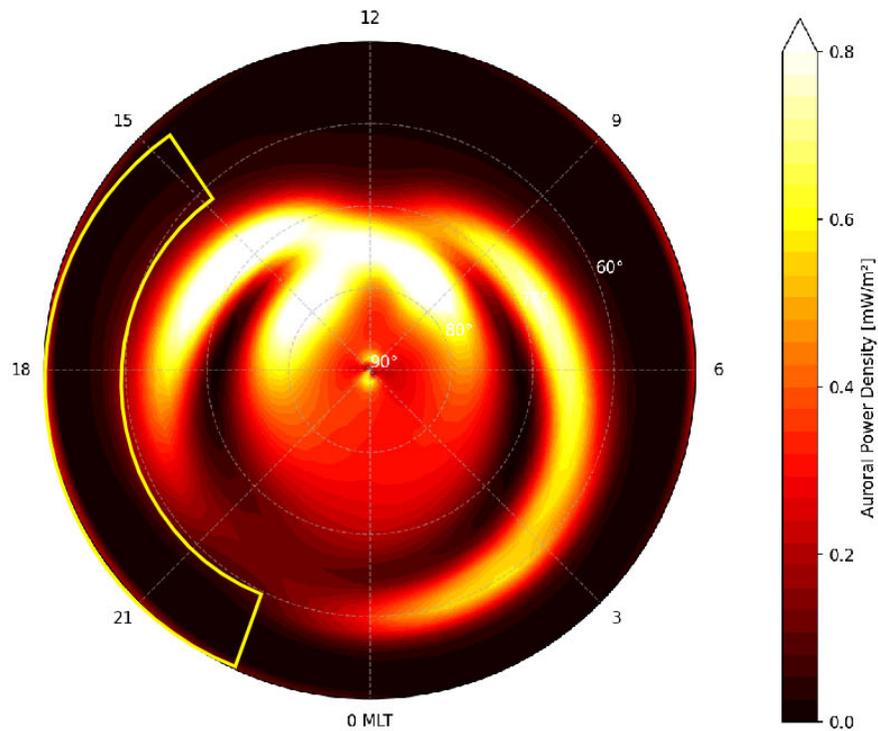


# Total Joule heat in NH after applying DA

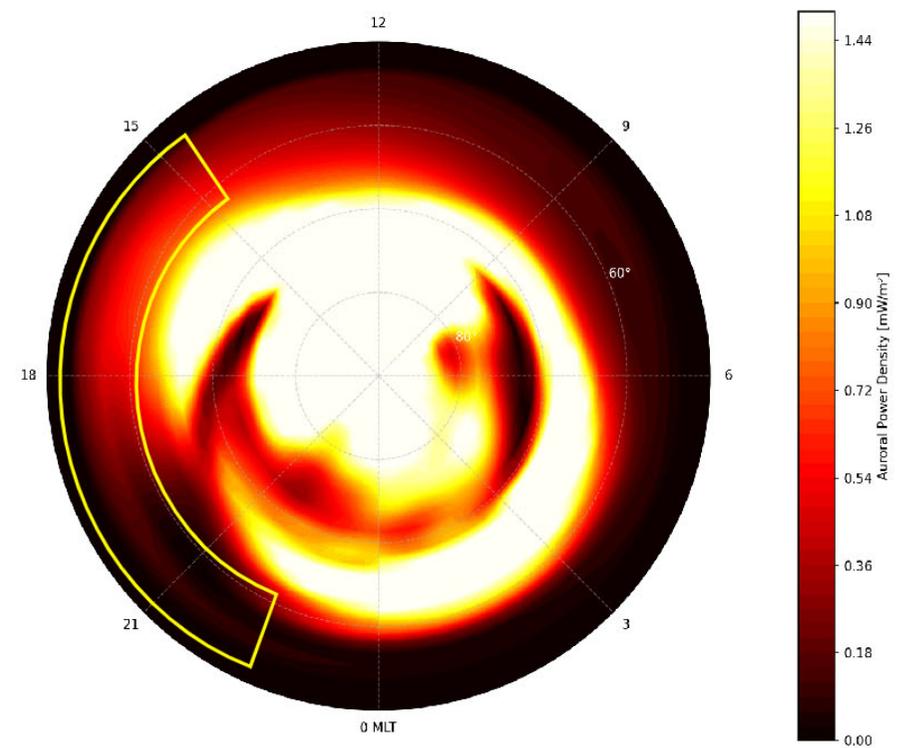


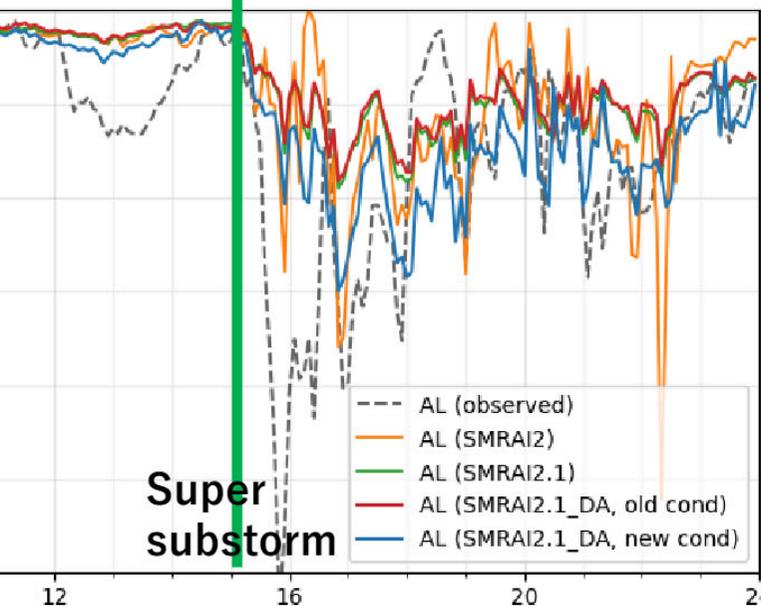
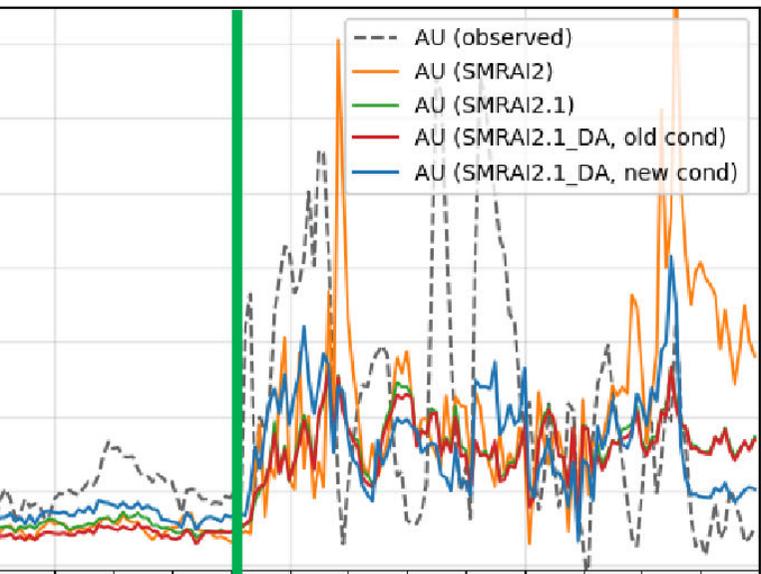
# Subauroral Joule heat peak appears in DA

Auroral Power Distribution (SMRAI2)  
Total Power: 32.72 GW  
Time: 2024-08-04 14:00 UTC

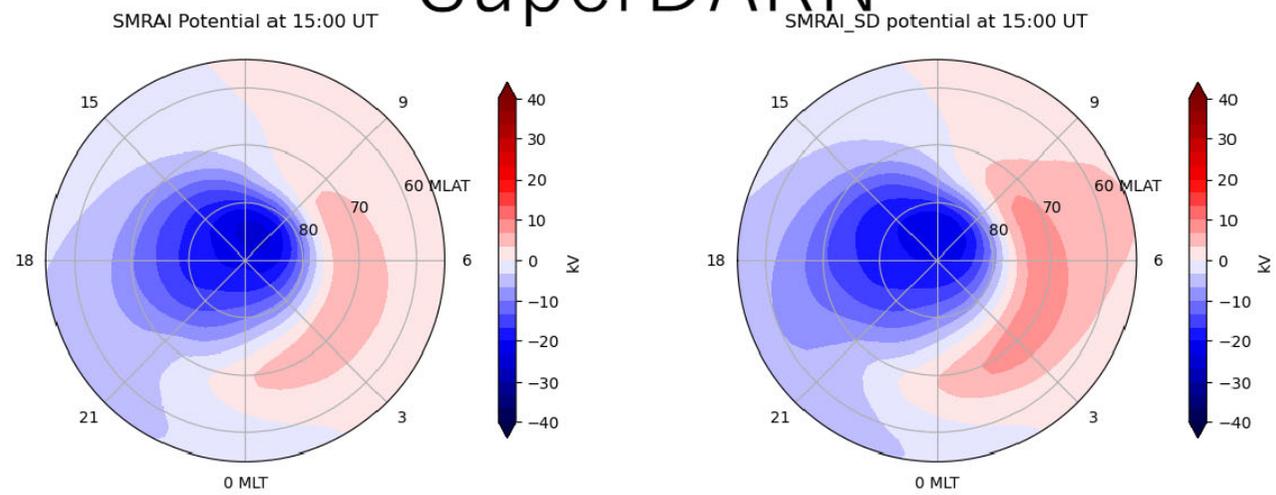


Auroral Power Distribution  
Total Power: 63.010 GW  
Time: 2024-08-04 14:00 UTC

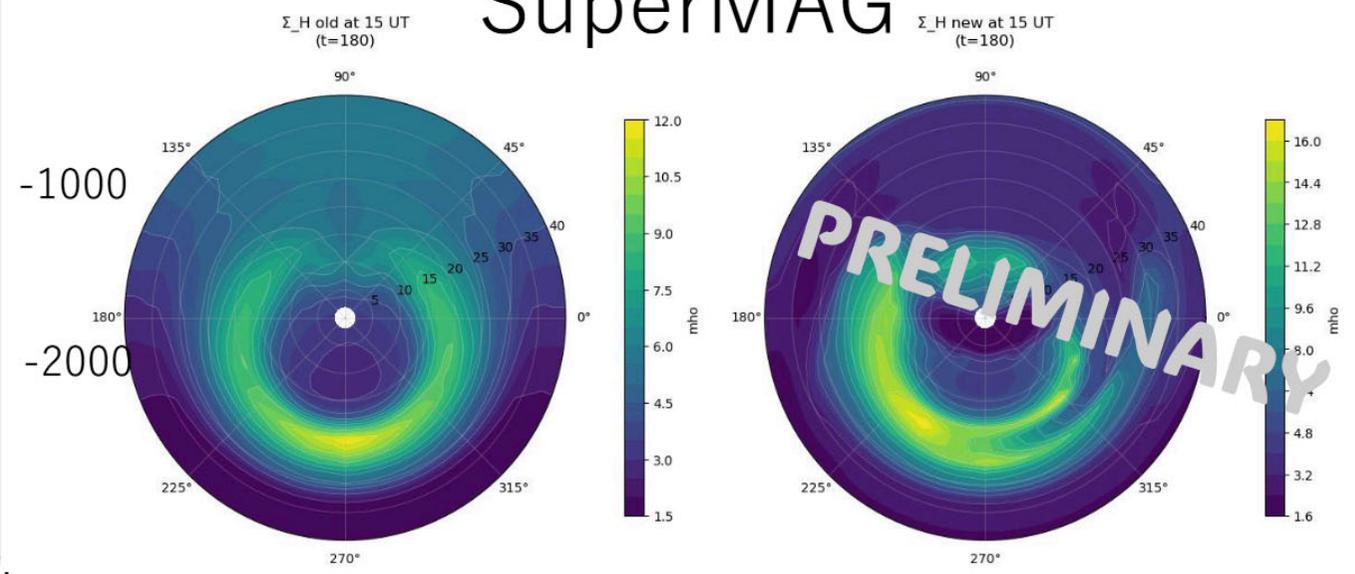




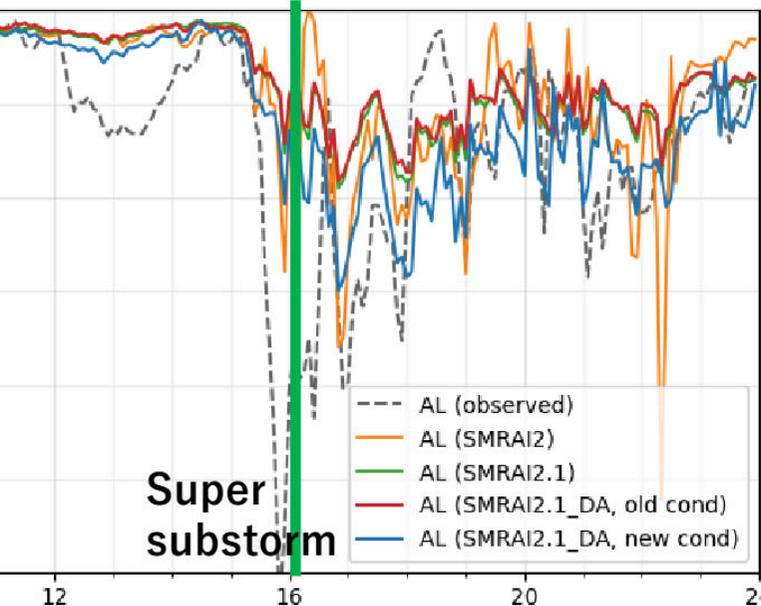
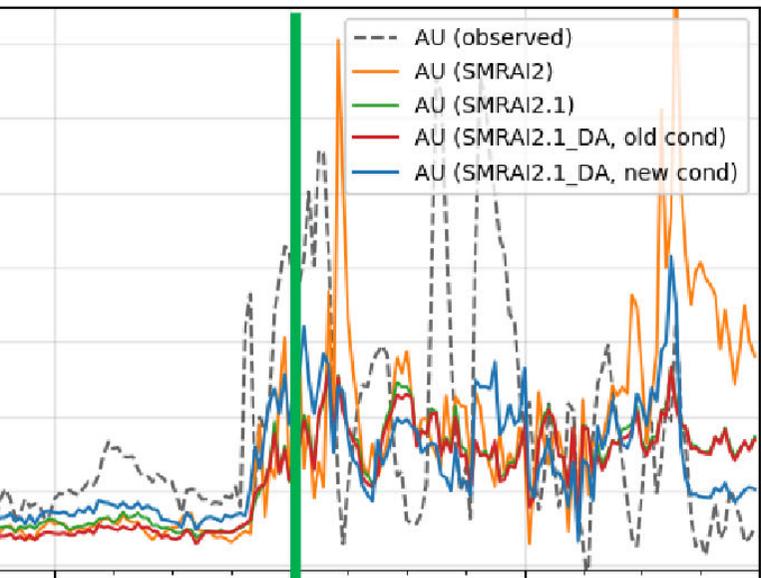
# SuperDARN



# SuperMAG



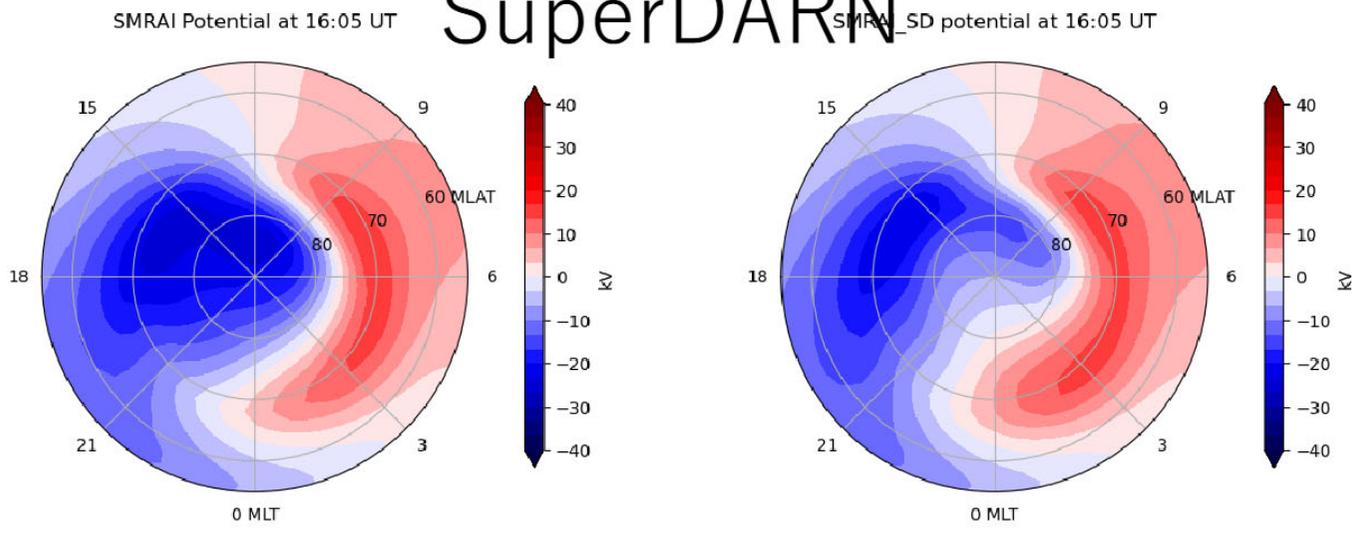
hours (2024-10-10)



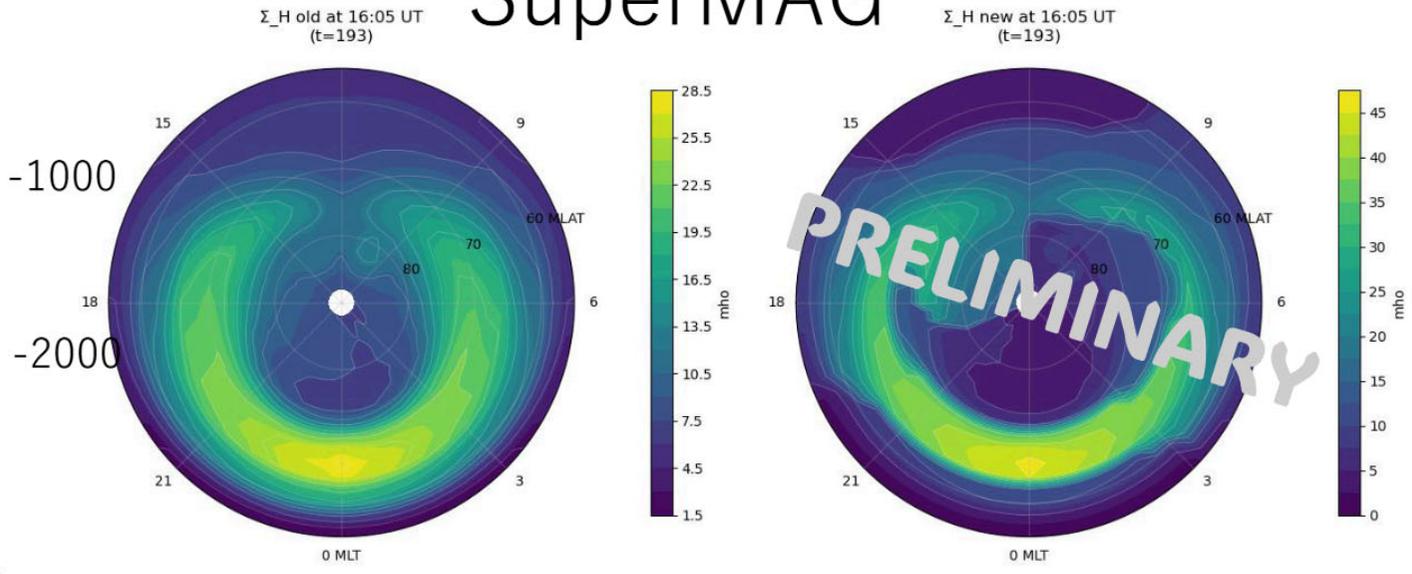
**Super substorm**

(hours) (2024-10-10)

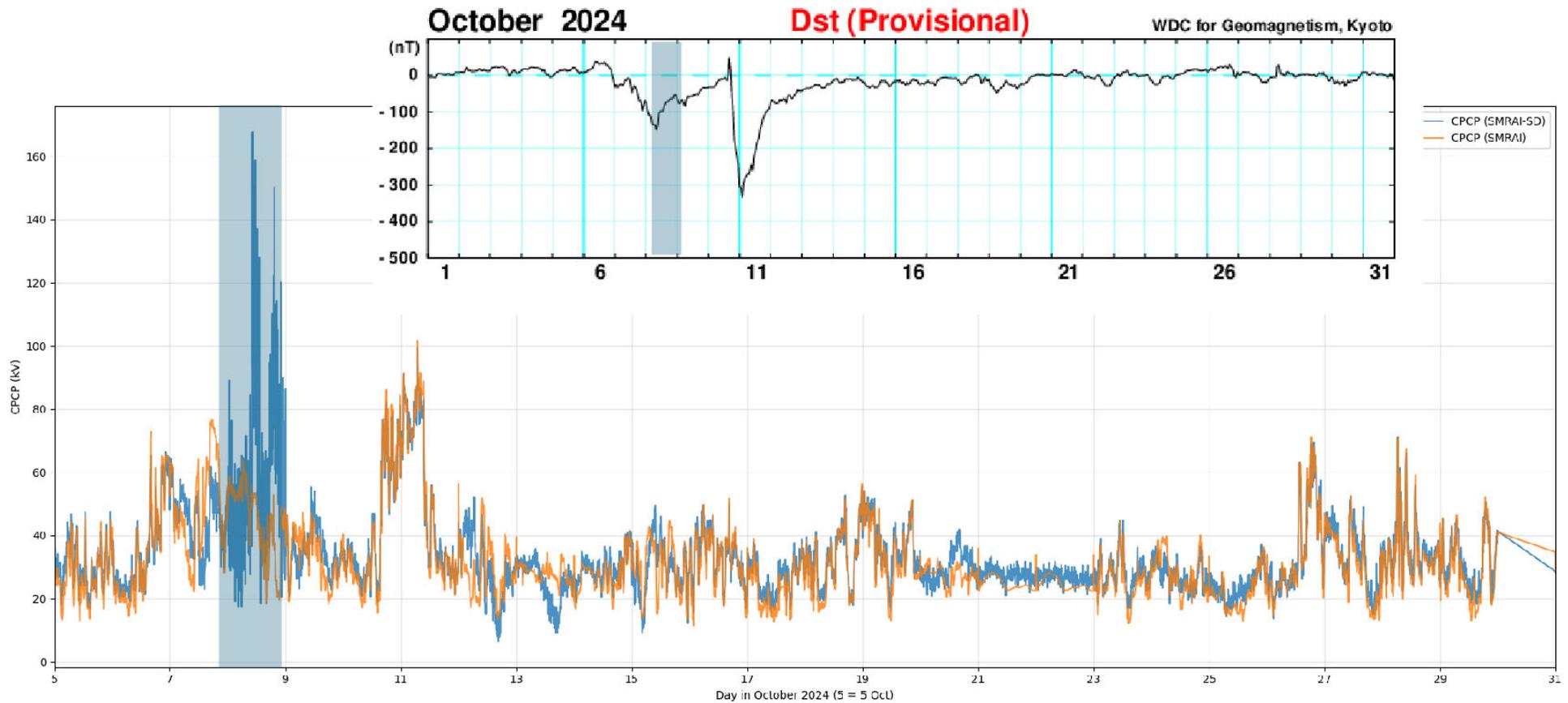
# SuperDARN



# SuperMAG



# 2024 October one-month run of SD-DA



科研費基盤A「オーロラ電流系エミュレータとデータ同化による電離圏ジュール加熱の時空間変動の解明」のご支援に感謝します。

# Summary

- We estimated the Joule heat maps using a newly-developed data assimilation technique SD-DA-SMRAI model (Nakano et al., 2025)
  - Combined with SMRAI2.0 conductivity (Kataoka et al., 2024)
  - Isolated substorm study (Nilam et al., 2026, submitted)
- We showed supporting evidence that the subauroral Joule heat in the dusk-to-midnight sector contributed to the appearance of the very-tall red aurora even during the 100 nT storms (Nakayama and Kataoka, 2026).
  - Multi-event Joule heat analysis is ongoing
- SuperMAG DA for super substorm events (Nilam et al., AOGS 2026 in August, see you soon)
  - Long-term run for many months is ongoing