SAPS wave structures and their magnetospheric counterpart: Fall 2023 SuperDARN-Arase conjunction campaign

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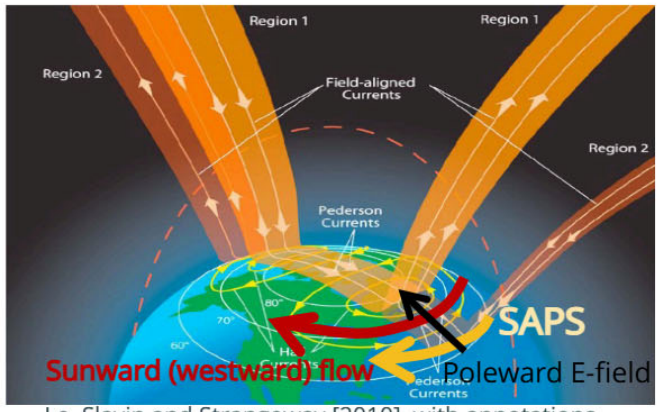
Intro.:
Subauroral Polarization Streams (SAPS)

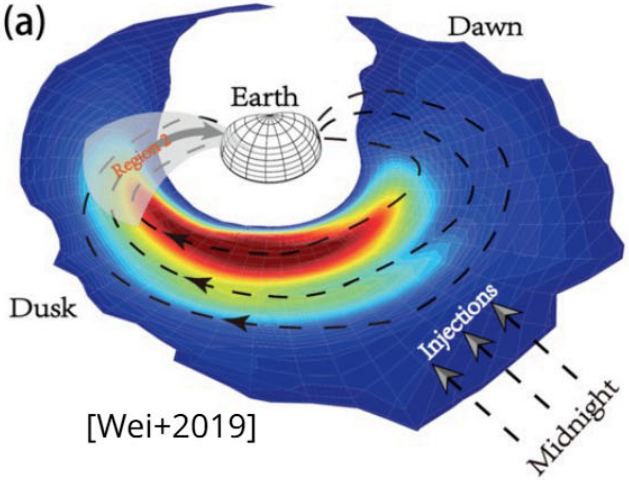
SAPS:

- A fast westward flow formed during geomagnetically disturbed times over midnight to dusk in the subauroral ionosphere [e.g., Foster and Burke, 2002]

- SAPS can appear at mid-latitudes during very disturbed times such as magnetic storms [e.g., Oksavik+2006, Kataoka+2008].



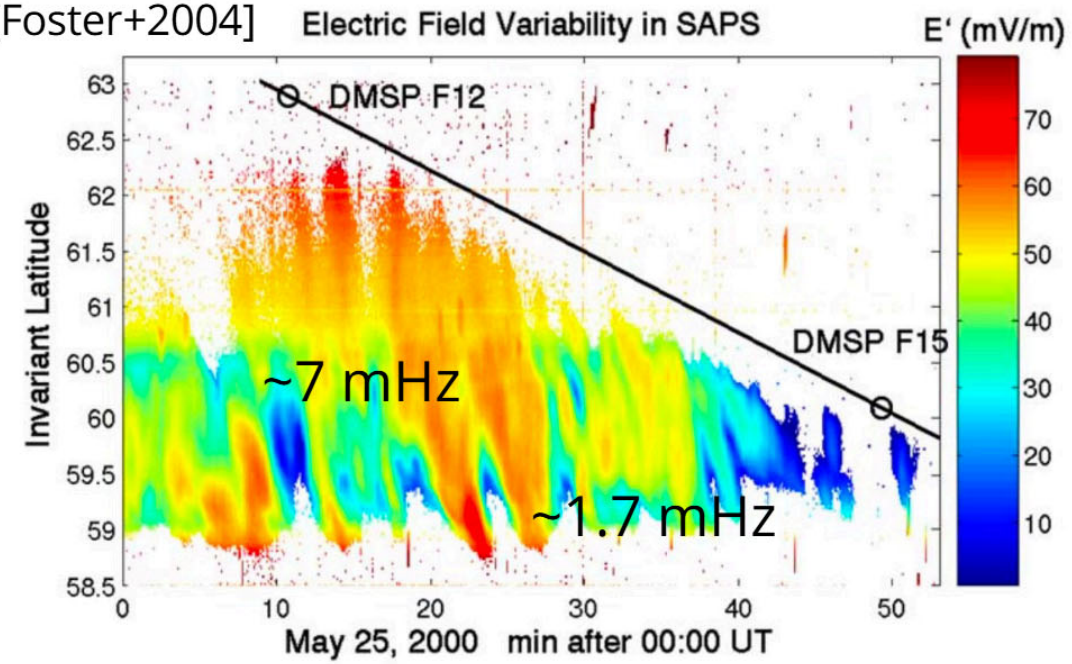
Le, Slavin and Strangeway [2010], with annotations

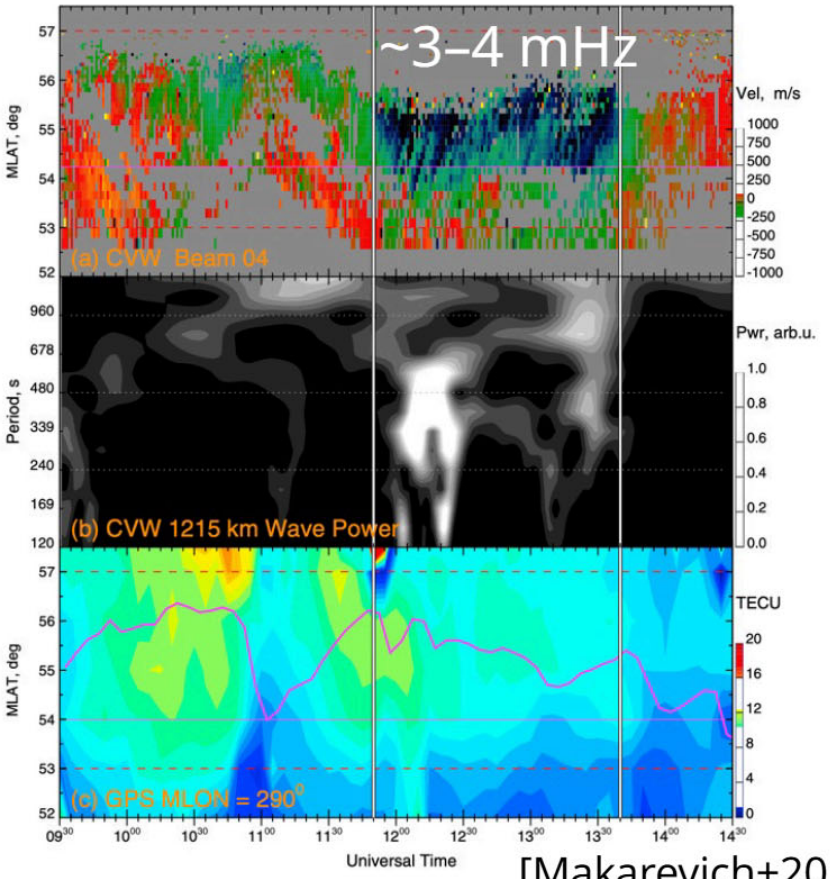


[Wei+2019]

SAPS is highly variable: SAPS wave structure (SAPSWS)

[Foster+2004]

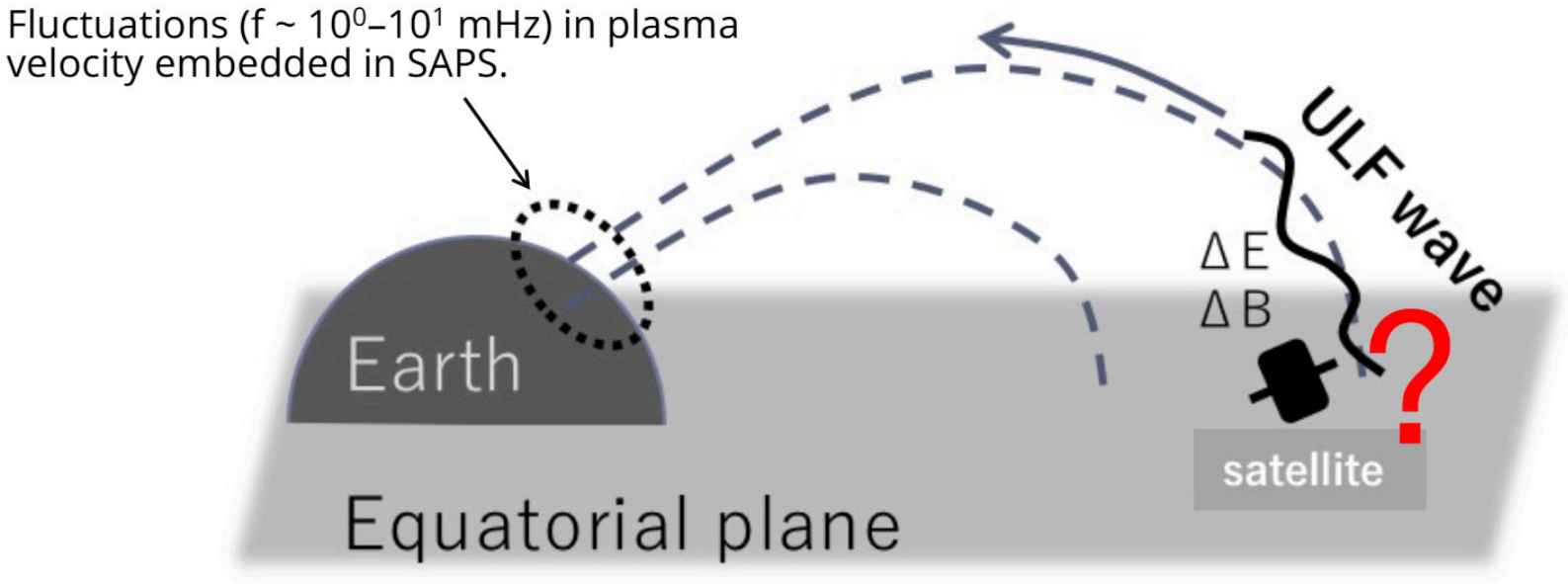




[Makarevich+2014]

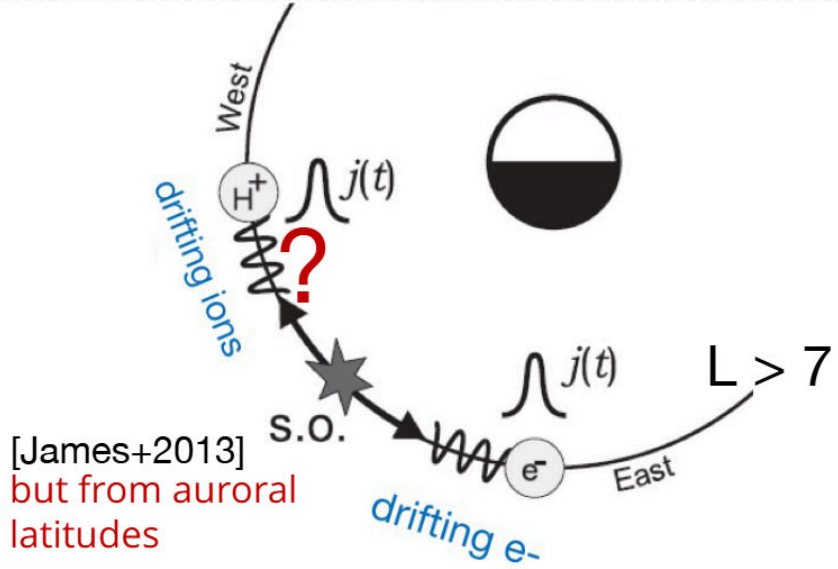
- SAPSWS [Mishin+2003; 2004; 2005], originally identified with satellite observations, can be seen as E-field modulations in radar observations.

Intro.:
SAPS wave structure (SAPSWS): dynamically varying SAPS

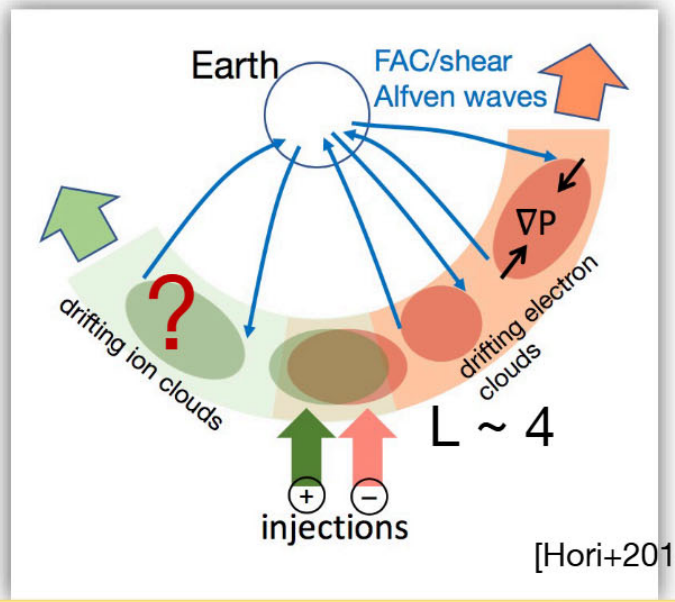


Although equatorial satellite observations were made at conjugate points of SAPS in the inner magnetosphere [e.g., Mishin+2005], the generation mechanism of SAPSWS has still remained to be examined.

Intro.:
What causes SAPSWS seen by SDs?



[James+2013]
but from auroral latitudes



[Hori+2018]

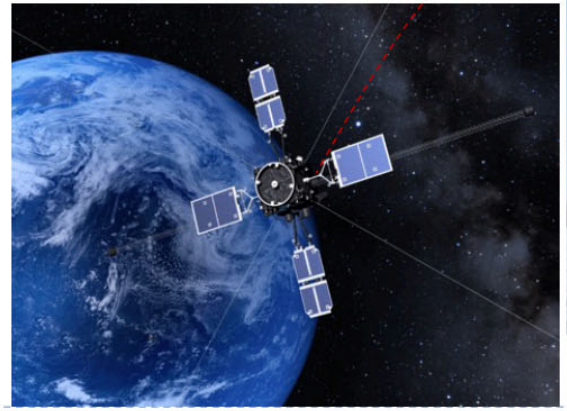
Possible drive mechanisms that have been proposed are:

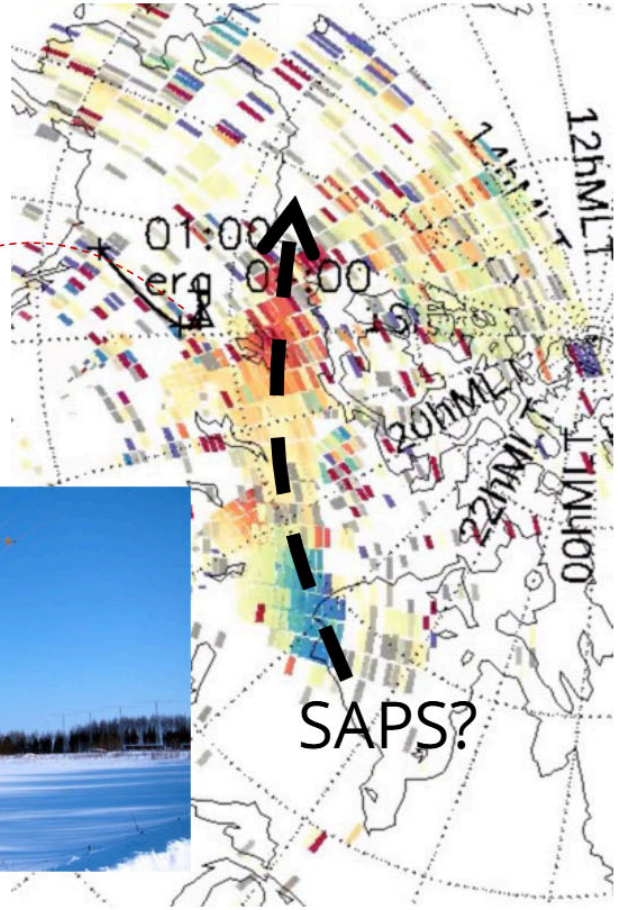
- Driven coherent wave: via drift resonance [e.g., James+2013]
  - Bump-on-tail distribution? (∂f / ∂W > 0)
  - radially inward gradient of phase space density (∂f / ∂L <0)
- Not coherent wave:
  - Pressure bumps by multi-injections [e.g., Hori+2018]
  - Ne fluctuations or other waves? [e.g., Mishin+2003, Makarevich+2014]

∂f/∂W>0?
∂f/∂L<0?
dP/dt?

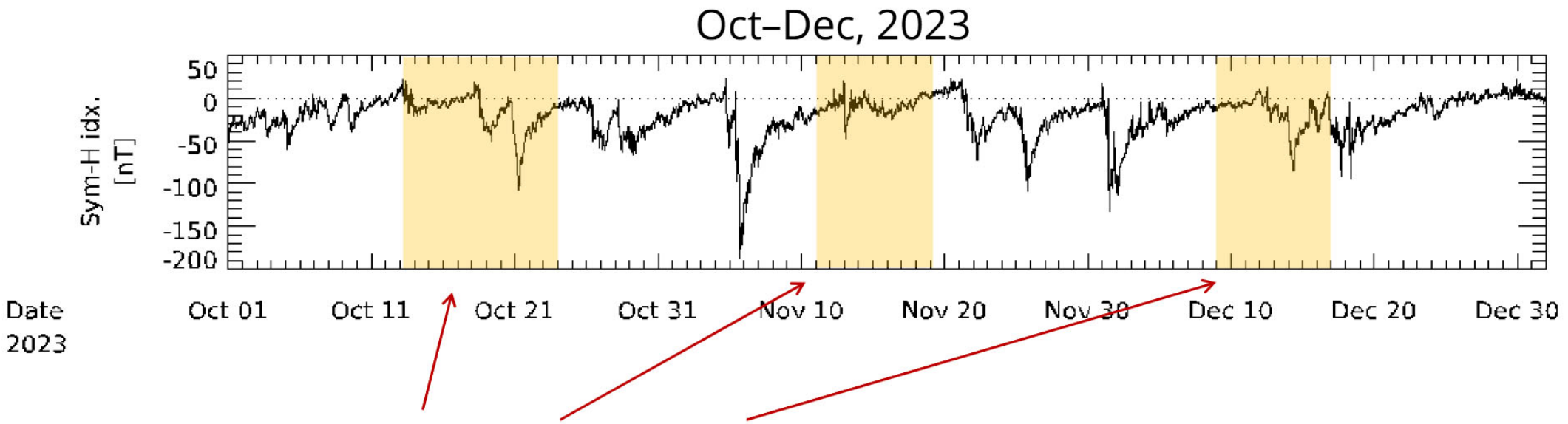
Our approach:
Arase–SuperDARN campaign observations

Some researchers and SD PIs in Japan conducted campaign observations with SD and Arase in Fall 2022 and 2023. Well coordinated campaigns have achieved a dozen (even more?) of good conjunction observations.





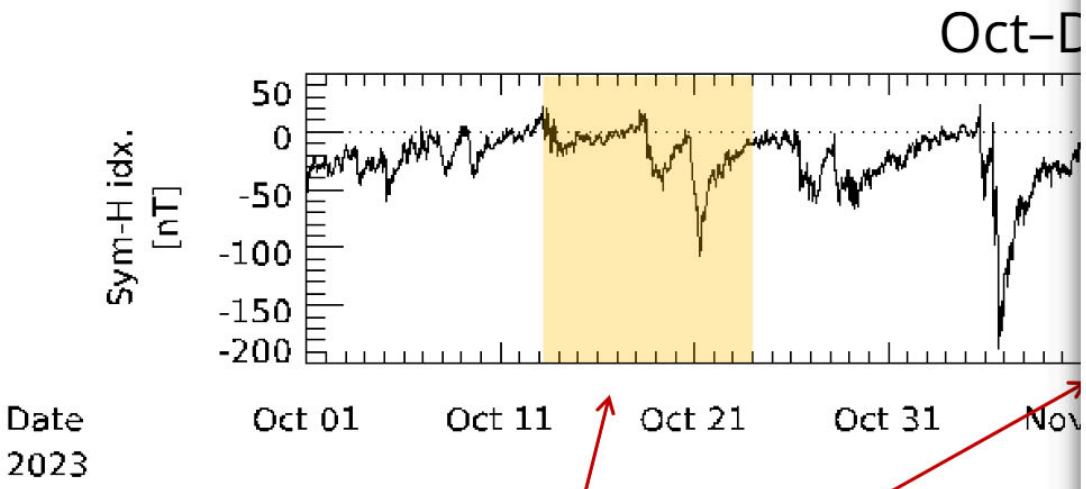
2023 Fall SuperDARN-Arase campaign observations

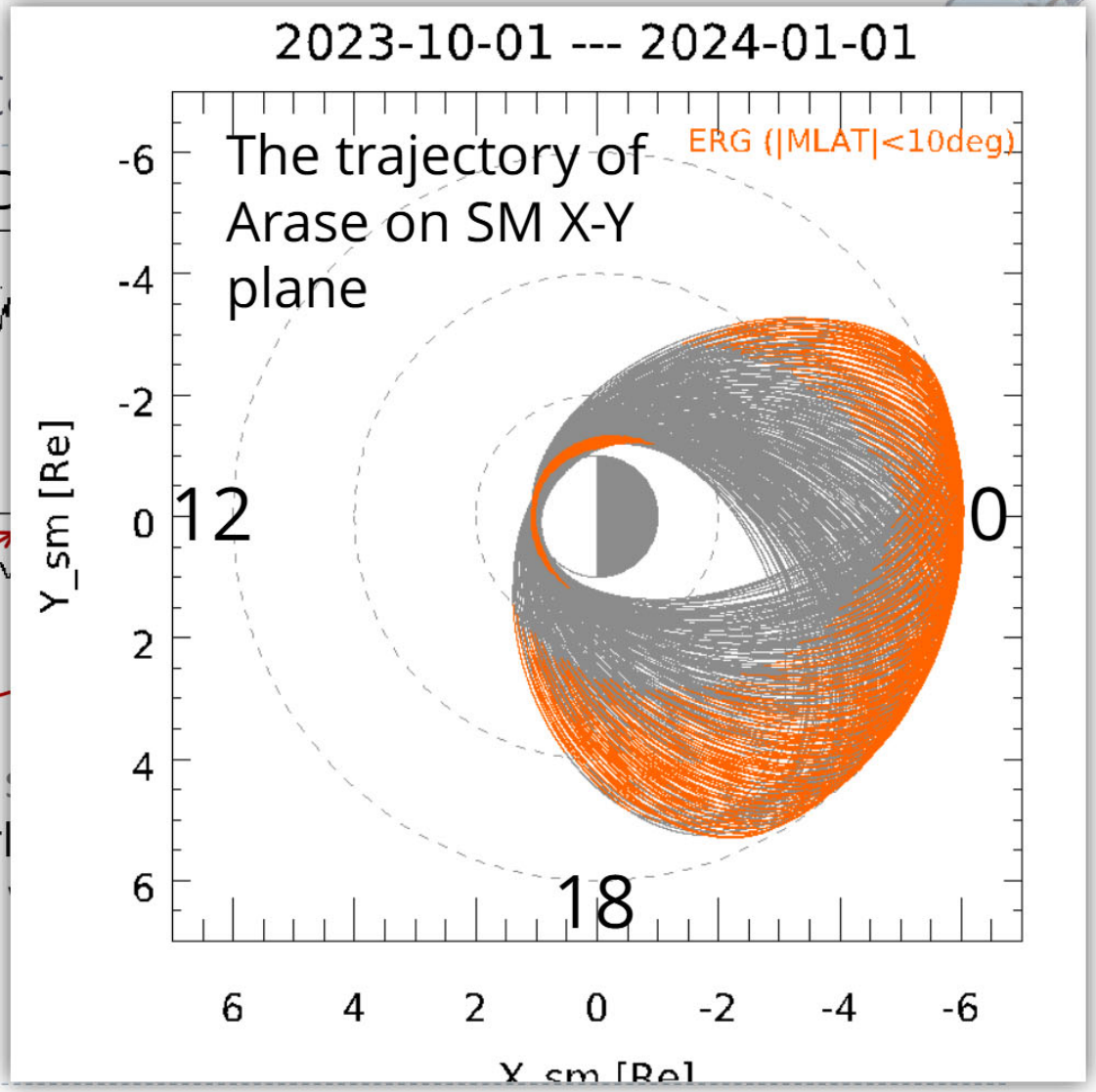


Campaign observations: several days / month

- SuperDARN: operated with interleaved normal scan
- Arase: MEP-i and LEP-i operated with the normal mode (3-D flux distri.)

2023 Fall SuperDARN-Arase c

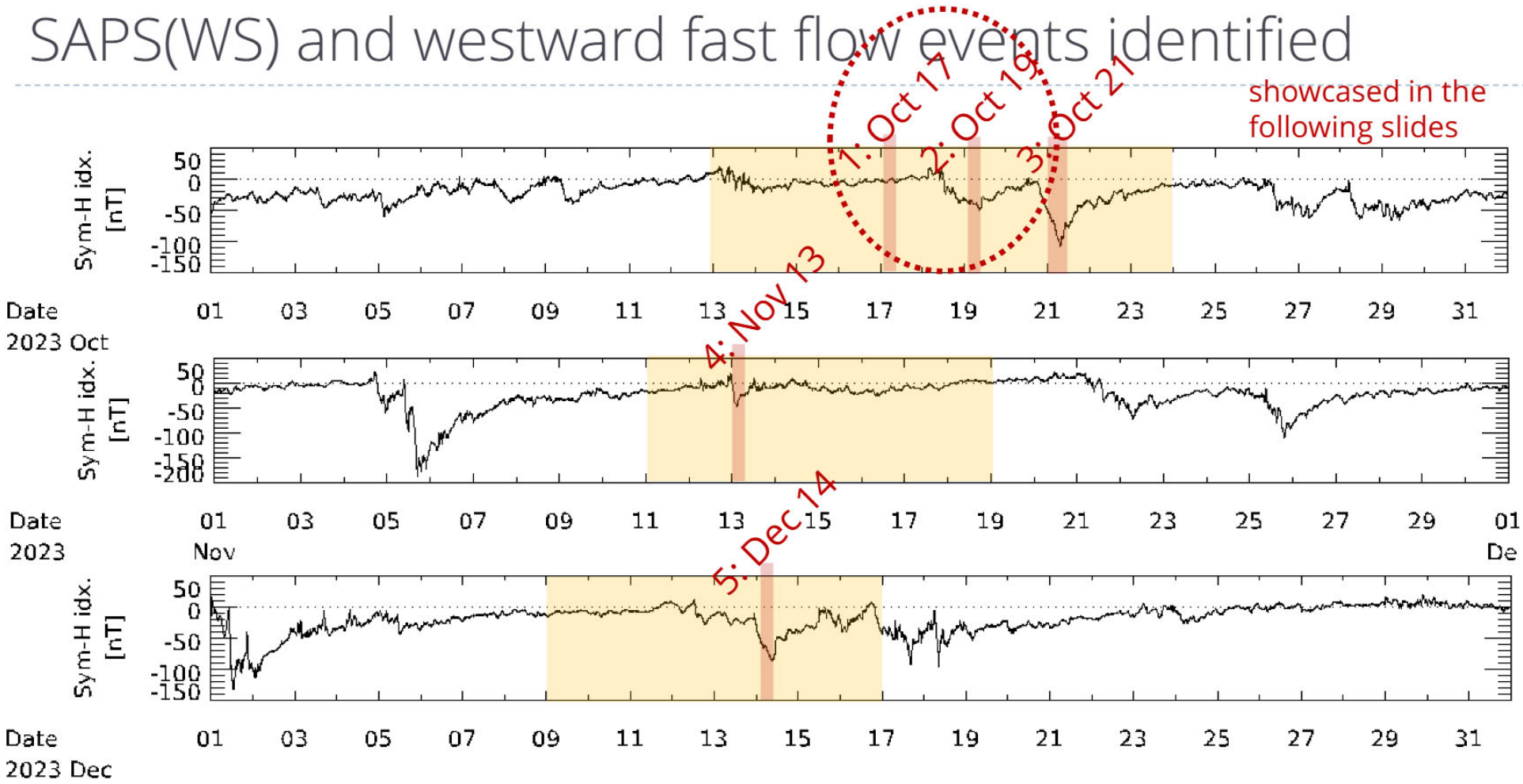




Campaign observations:

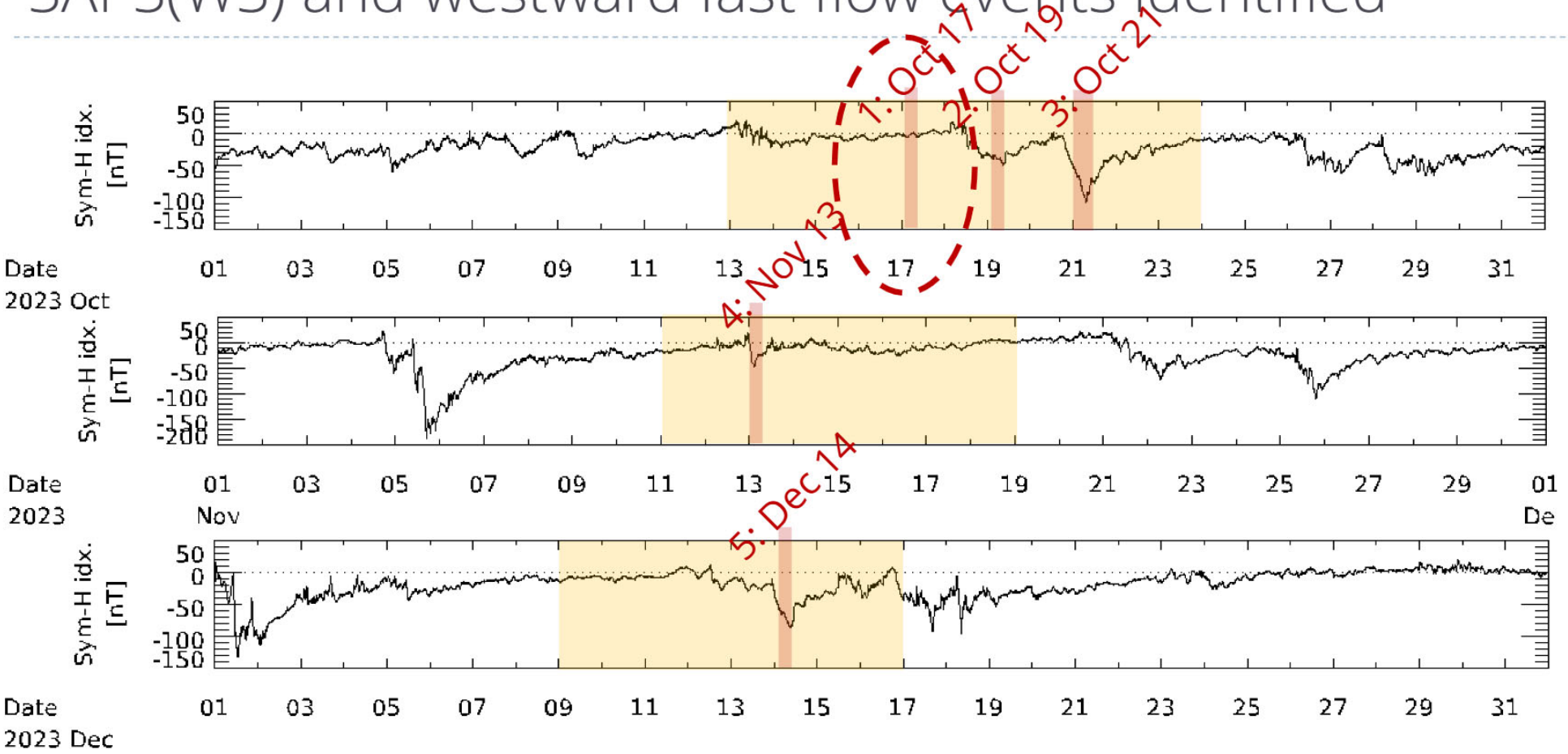
- SuperDARN: operated with interl
- Arase: MEP-i and LEP-i operated

SAPS(WS) and westward fast flow events identified



The most critical factor: how much SD echoes obtained and how close Arase located

SAPS(WS) and westward fast flow events identified



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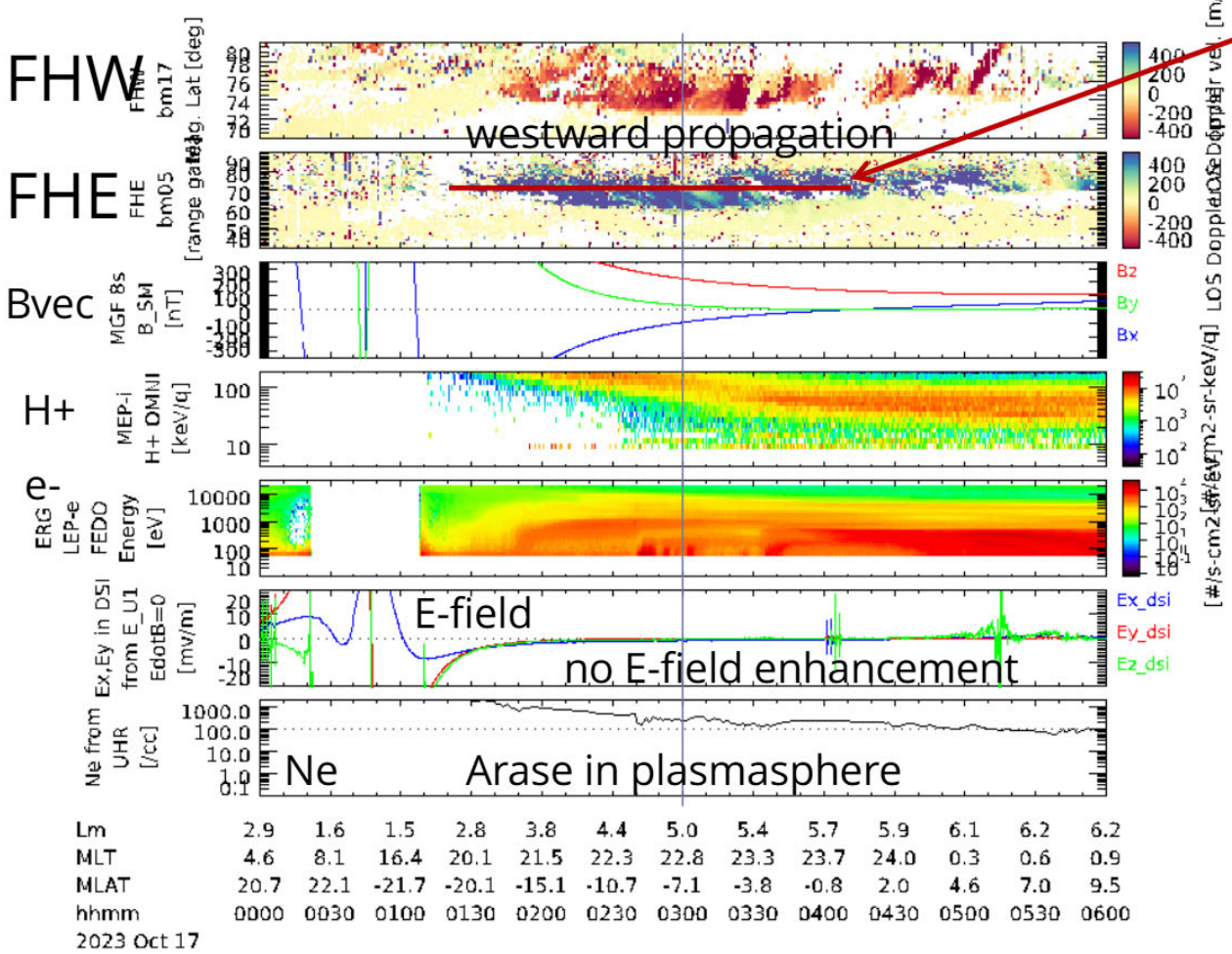
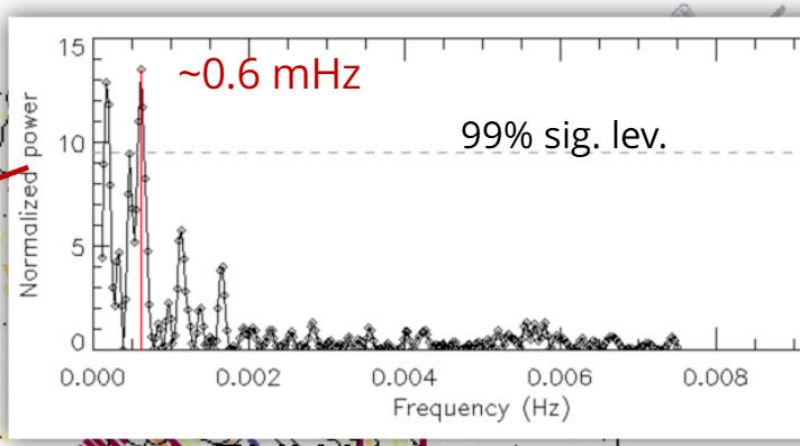
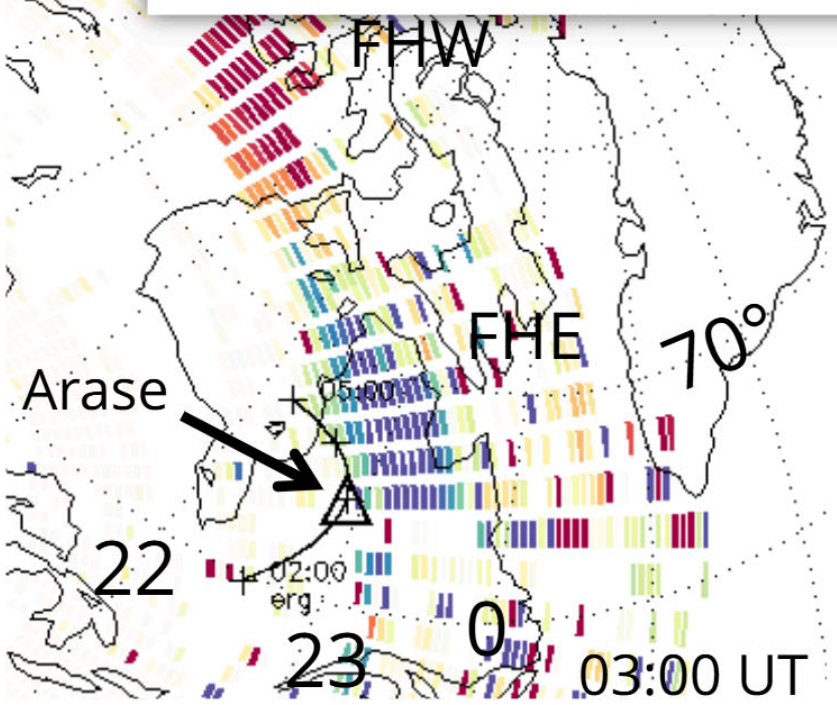
Event 1: Oct. 17, 2023







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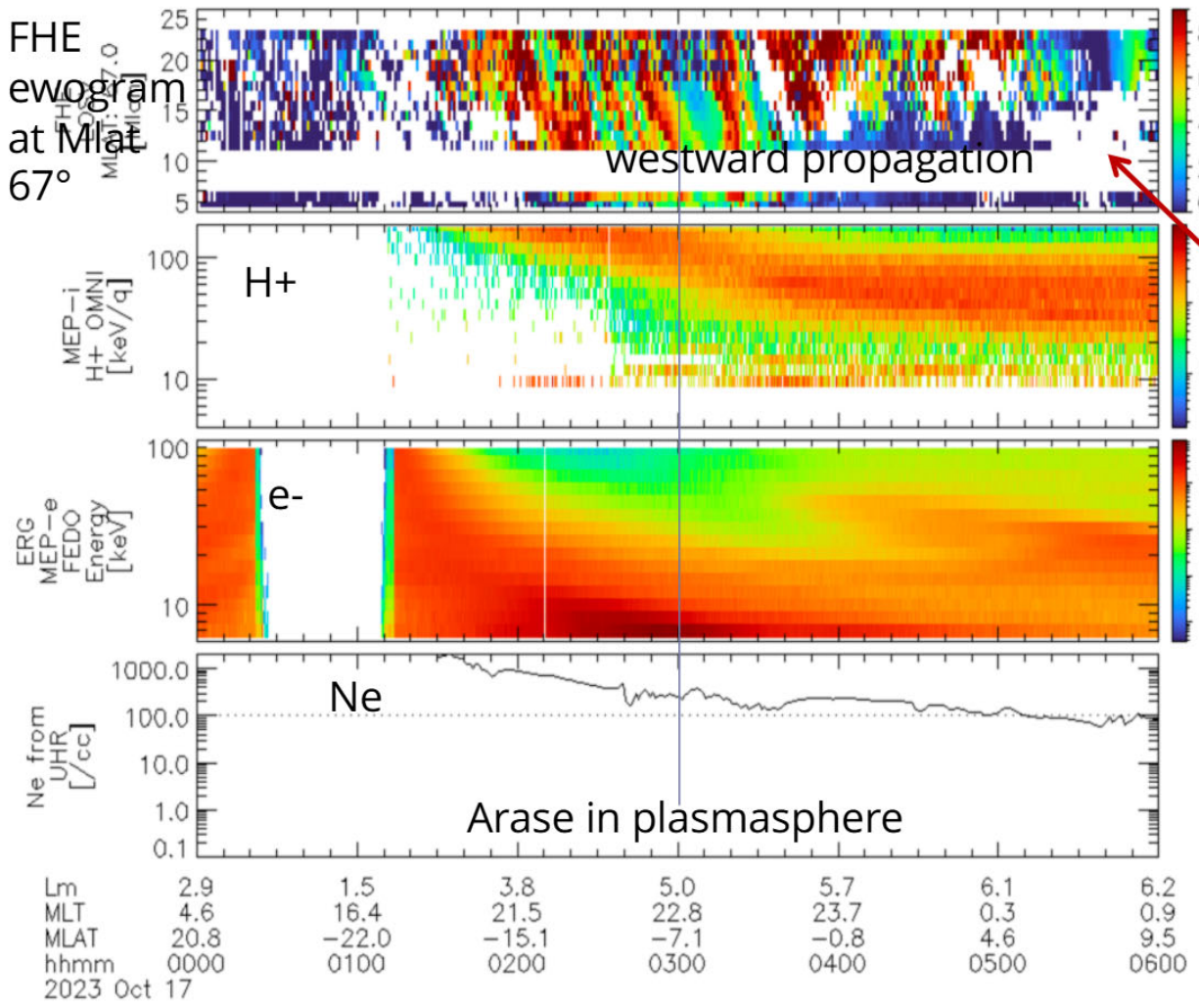

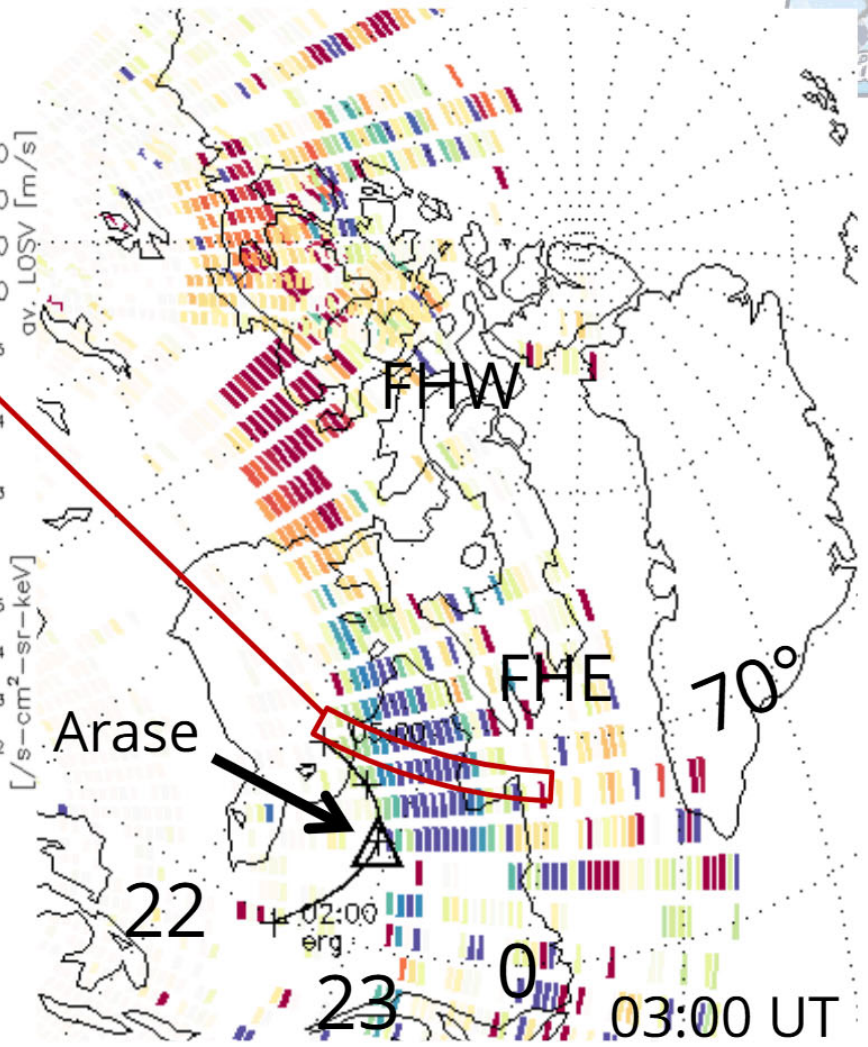

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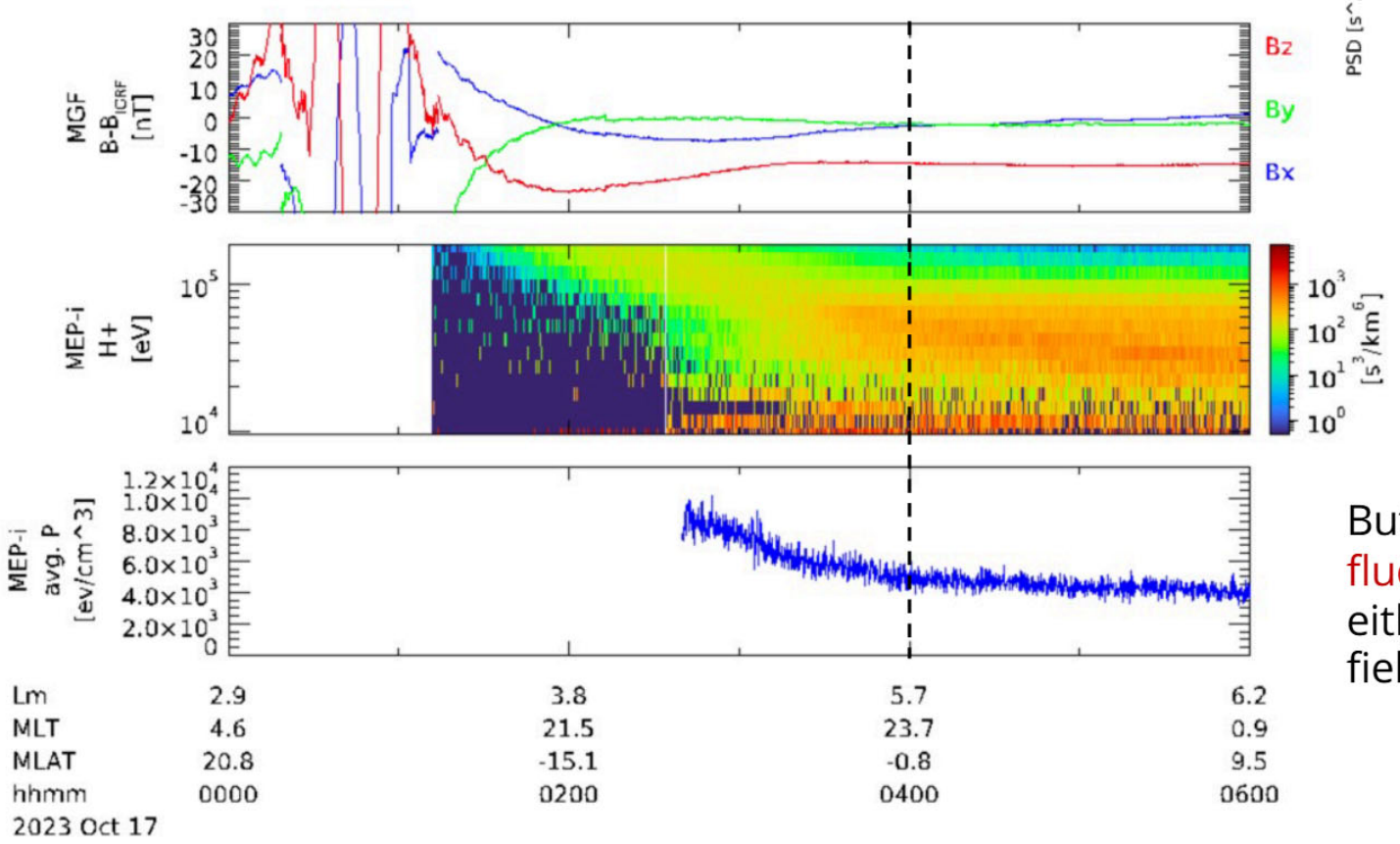
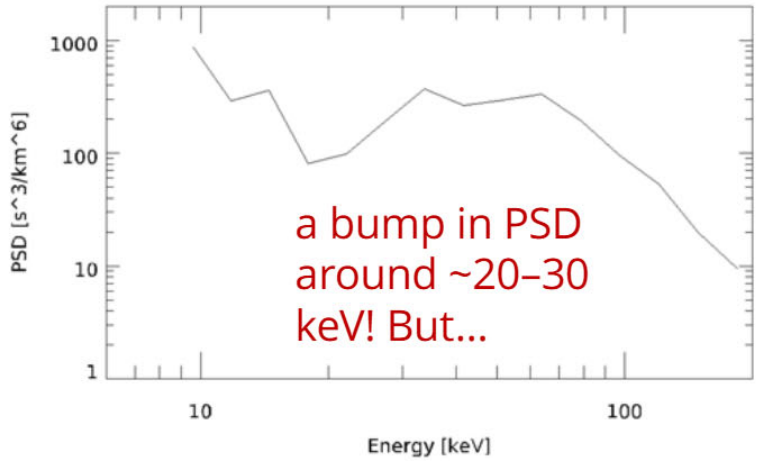


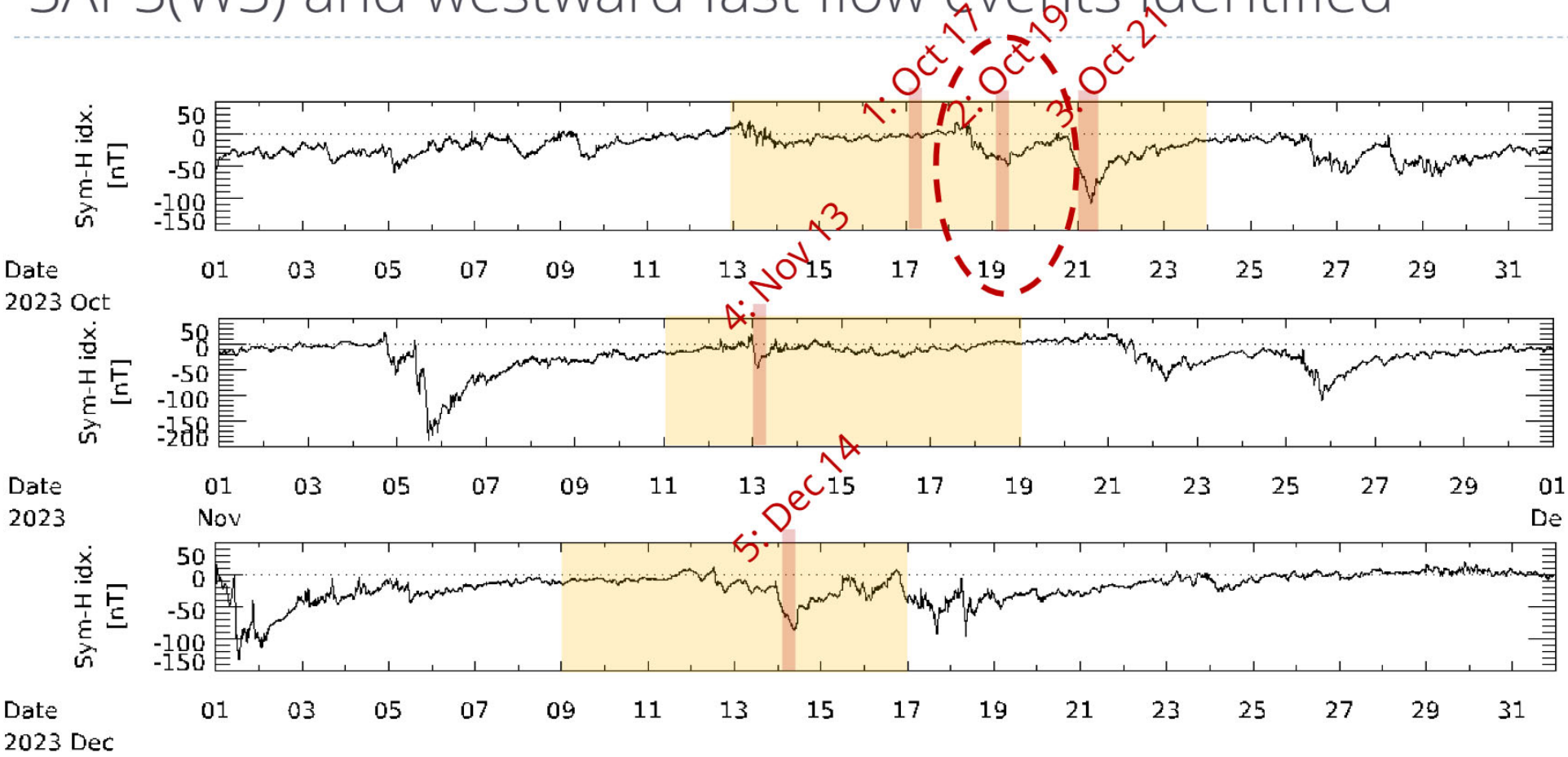


a bump in PSD around ~20–30 keV! But…

∂f/∂W>0?
∂f/∂L<0?
dP/dt?

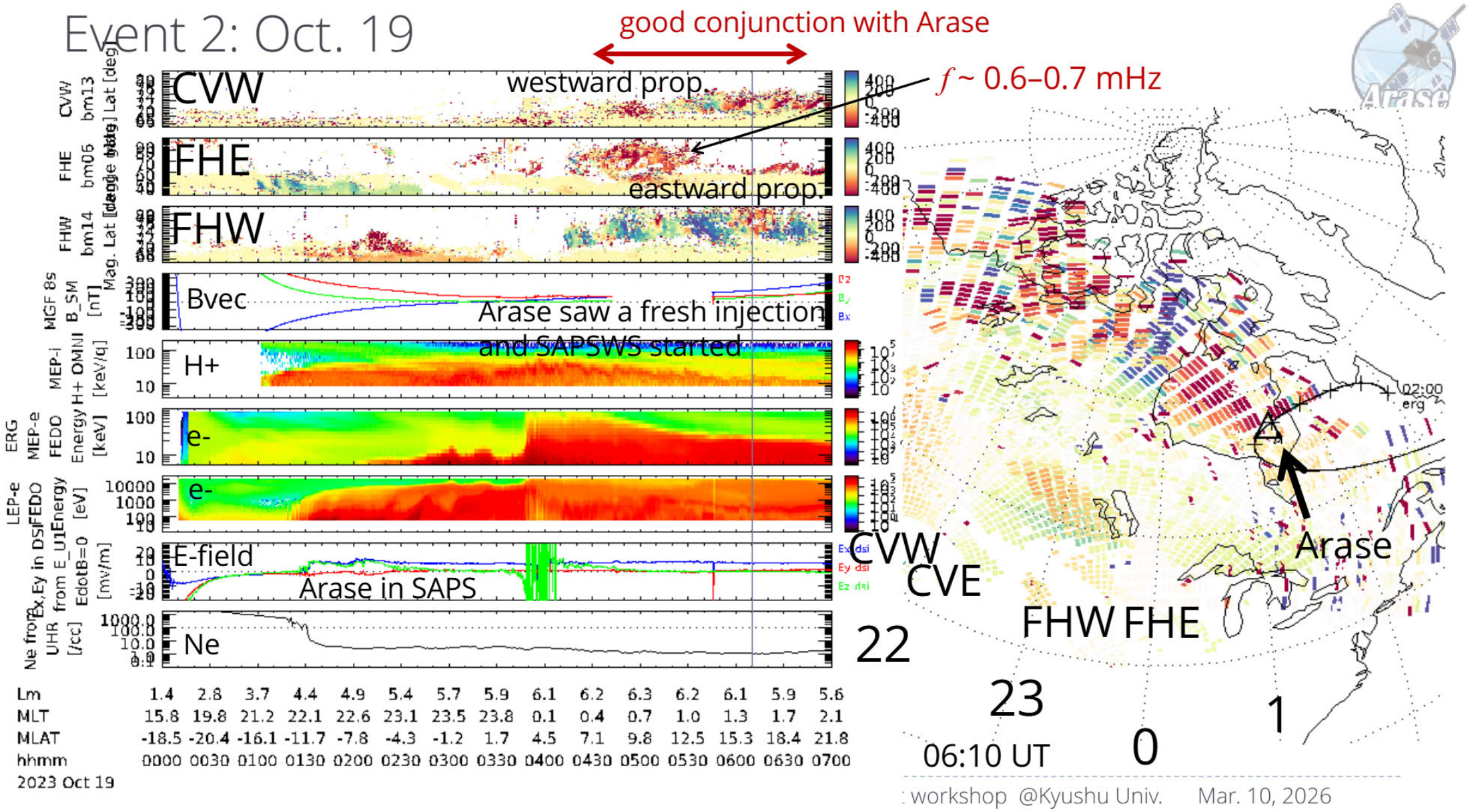
But no (significant) fluctuations were seen in either ion pressure or E/B-field…

SAPS(WS) and westward fast flow events identified



The most critical factor: how much SD echoes obtained and how close Arase located

Event 2: Oct. 19



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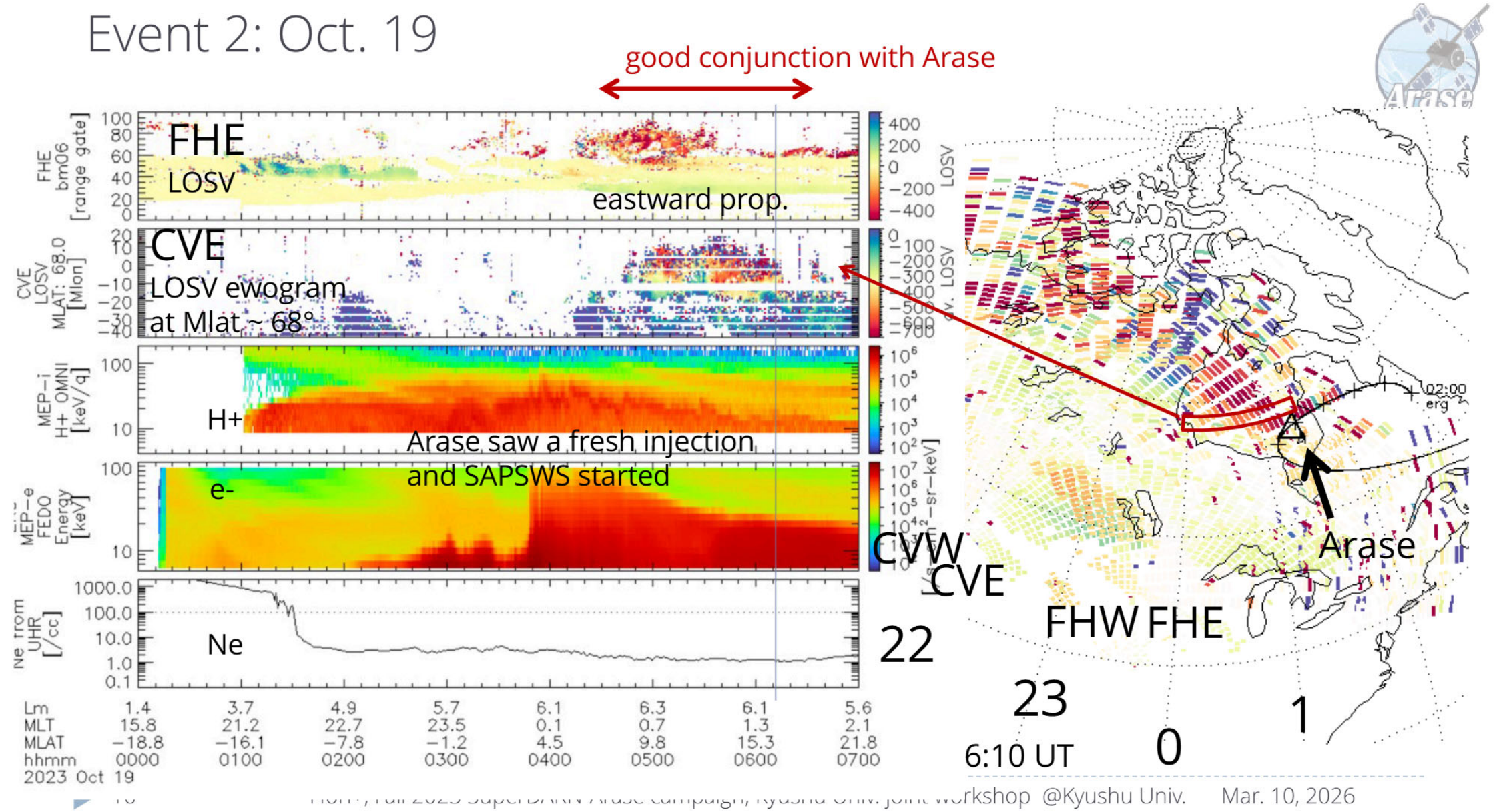

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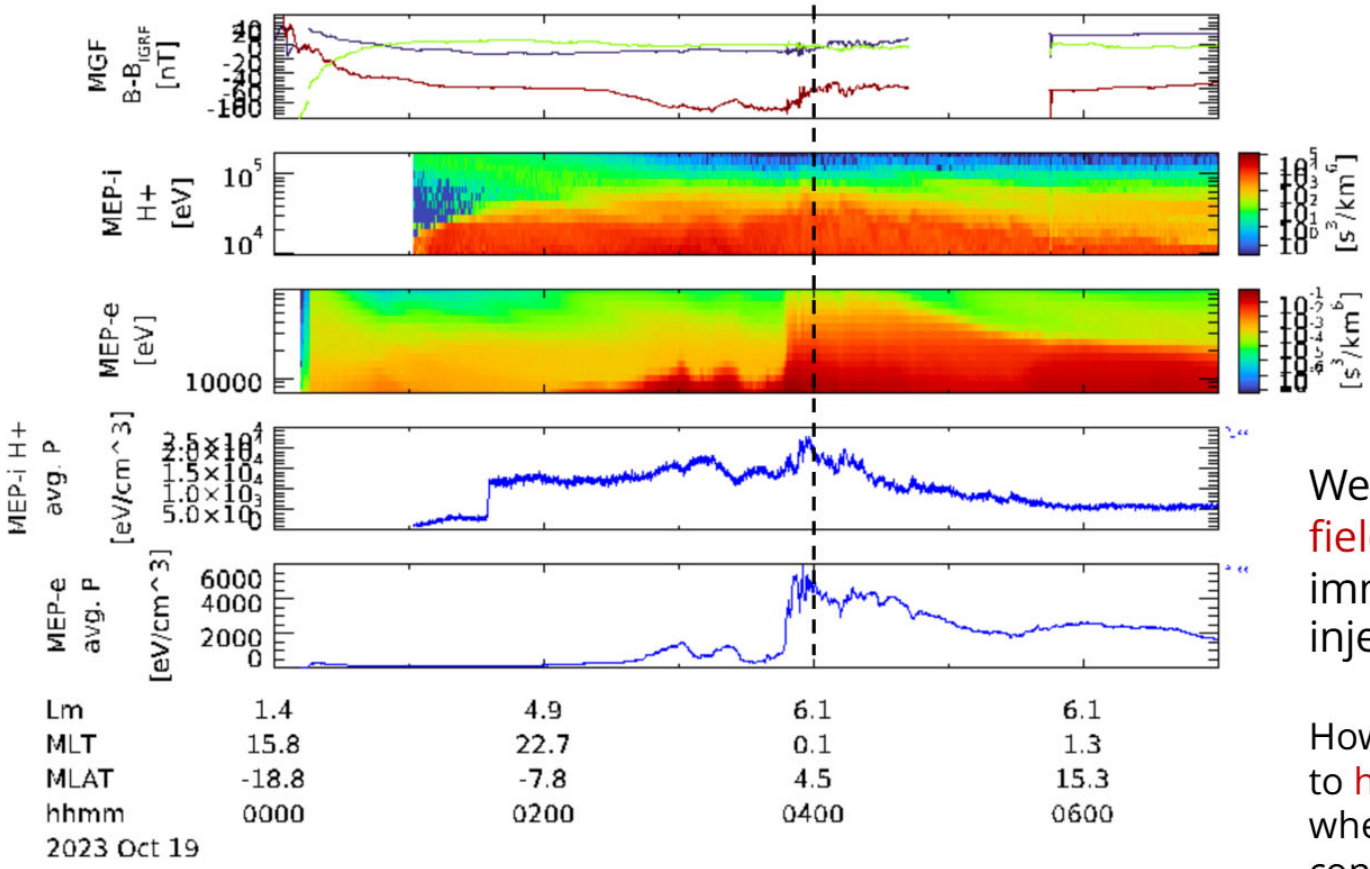
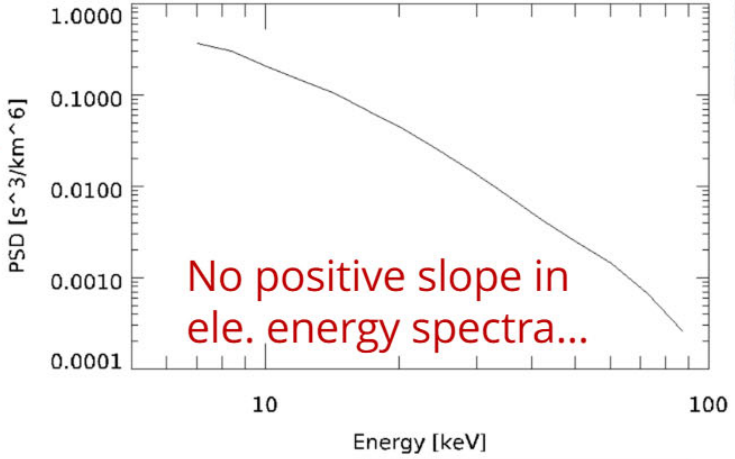




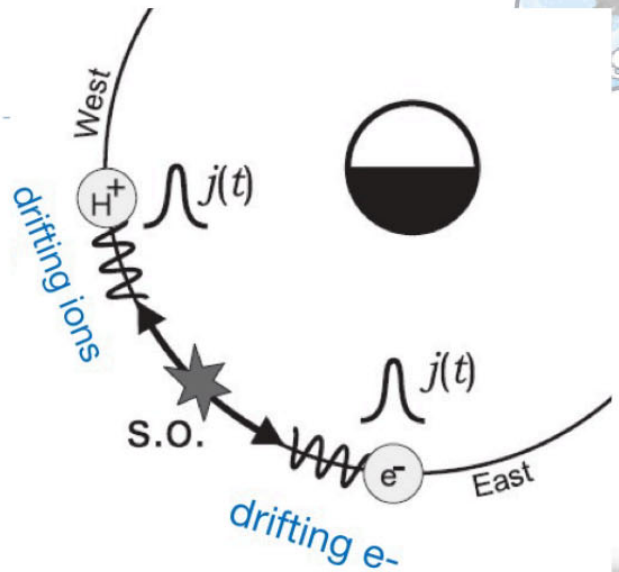
∂f/∂W>0?
∂f/∂L<0?
dP/dt?

We do see fluctuations in B-field and H+ / e- pressures immediately following an injection.

However, the fluctuations seem to have ceased before ~6 UT, when Arase arrived at a conjunction site.

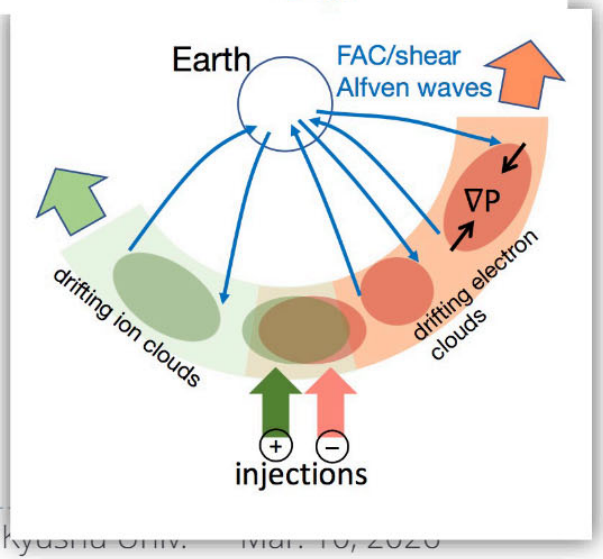
Summary and conclusions

- The SuperDARN–Arase campaign has successfully been carried out during Oct–Dec, 2023, achieving many interesting events in terms of SAPS-related studies, as well as those for ULF waves.
- We examined two events of them in terms of the driving factor of SAPSWS that was seen by SuperDARN around the satellite's ionospheric footprint.

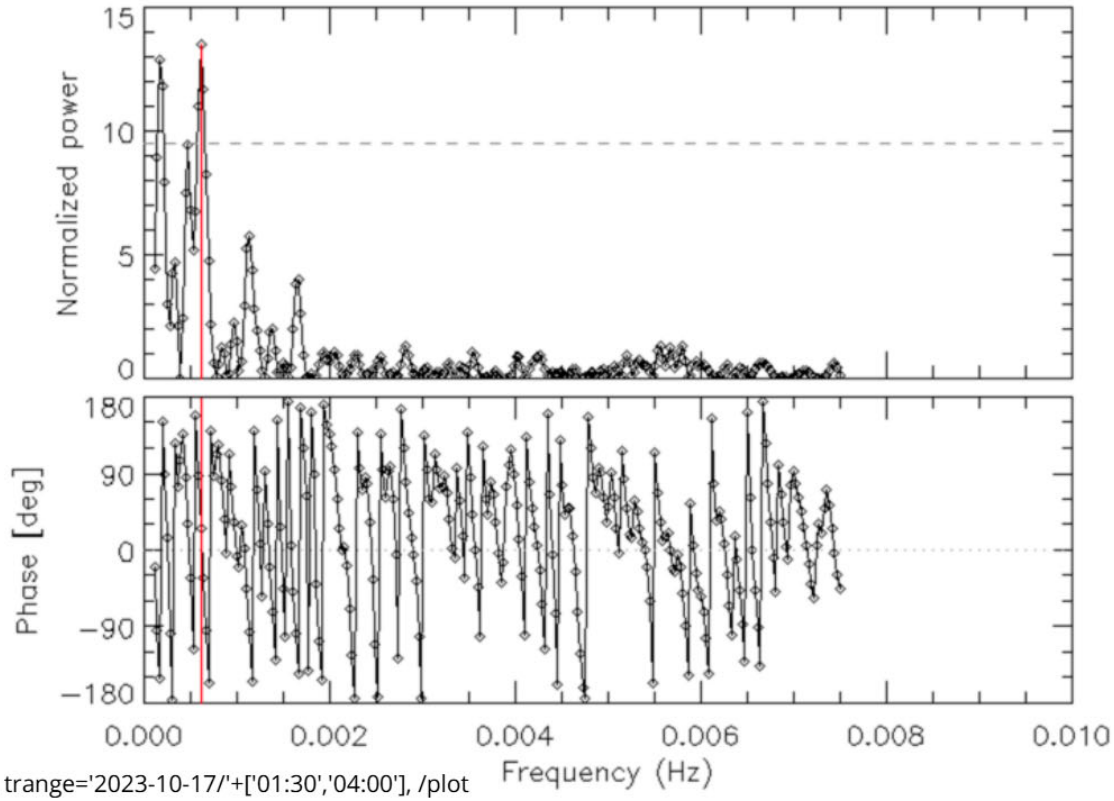


Conclusions:

- Either of SAPS with WS or SAPS without WS can form. The former tends to appear more frequently during storm times.
- SAPSWS appears in association with energetic particle injections, dipolarization, and such.
- **The 2nd conjunction event** shows that clear fluctuations were seen in B-field and H+/e- PSD, while no positive slope in e- spectra was identified, suggestive of **the drifting pressure bump scenario** possibly combined with the varying current scenario.
- **The 1st event** suggests that none of fluctuations penetrate further inward of the SAPS region.



Backup slides and the other events

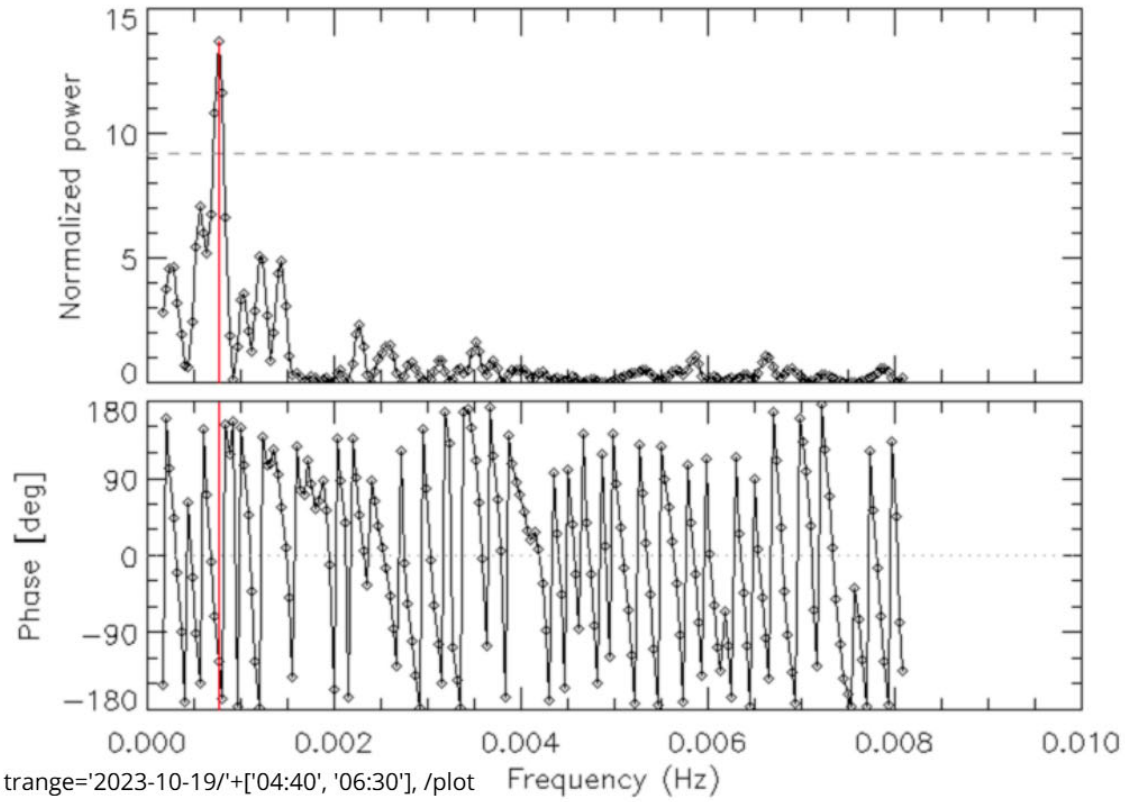


ERG> tlsp_test, 'sd_fhe_vlos_6_azim05_70', trange='2023-10-17/'+['01:30','04:00'], /plot

===== sd_fhe_vlos_6_azim05_70 =====

The max power 13.4750 (signi. lvl: 9.4980266)

is found at frequency 0.00060955685 Hz, with phase 25.5586 deg.



ERG> tlsp_test, 'sd_cve_vlos_6_azim04_61', trange='2023-10-19/'+['04:40', '06:30'], /plot
===== sd_cve_vlos_6_azim04_61 =====
The max power 13.6780 (signi. lvl: 9.2053697)
is found at frequency 0.00075946073 Hz, with phase -123.212 deg.

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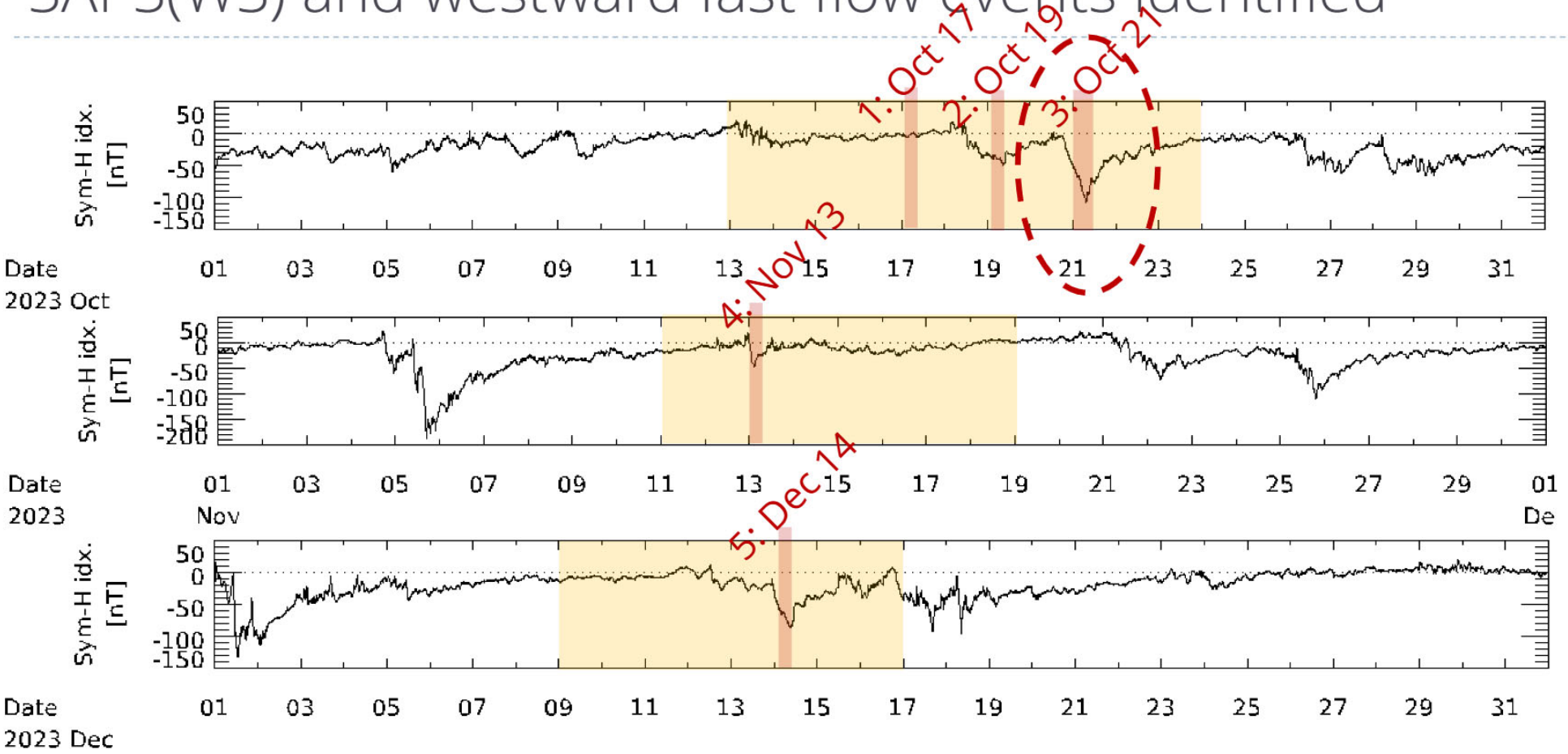
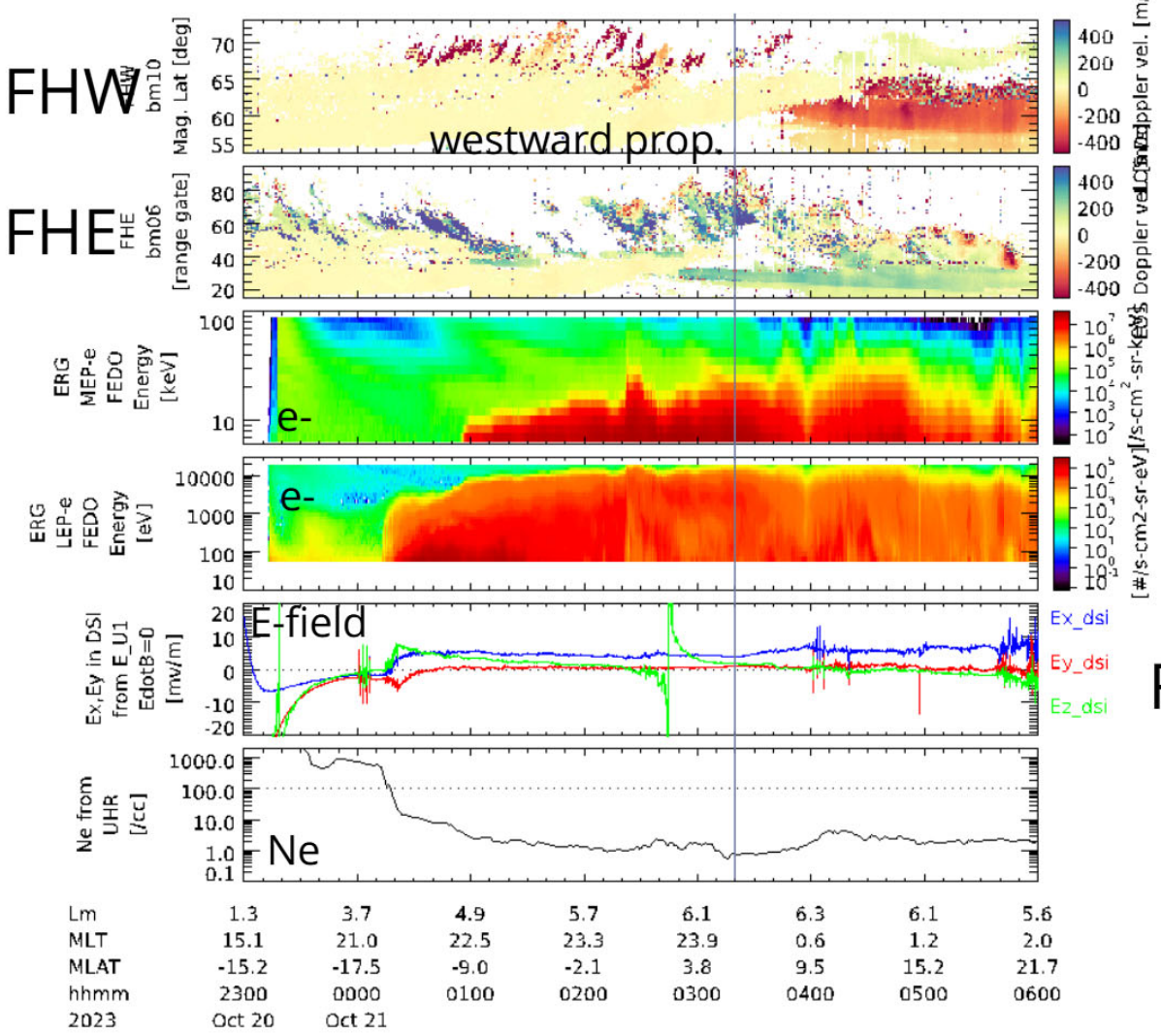
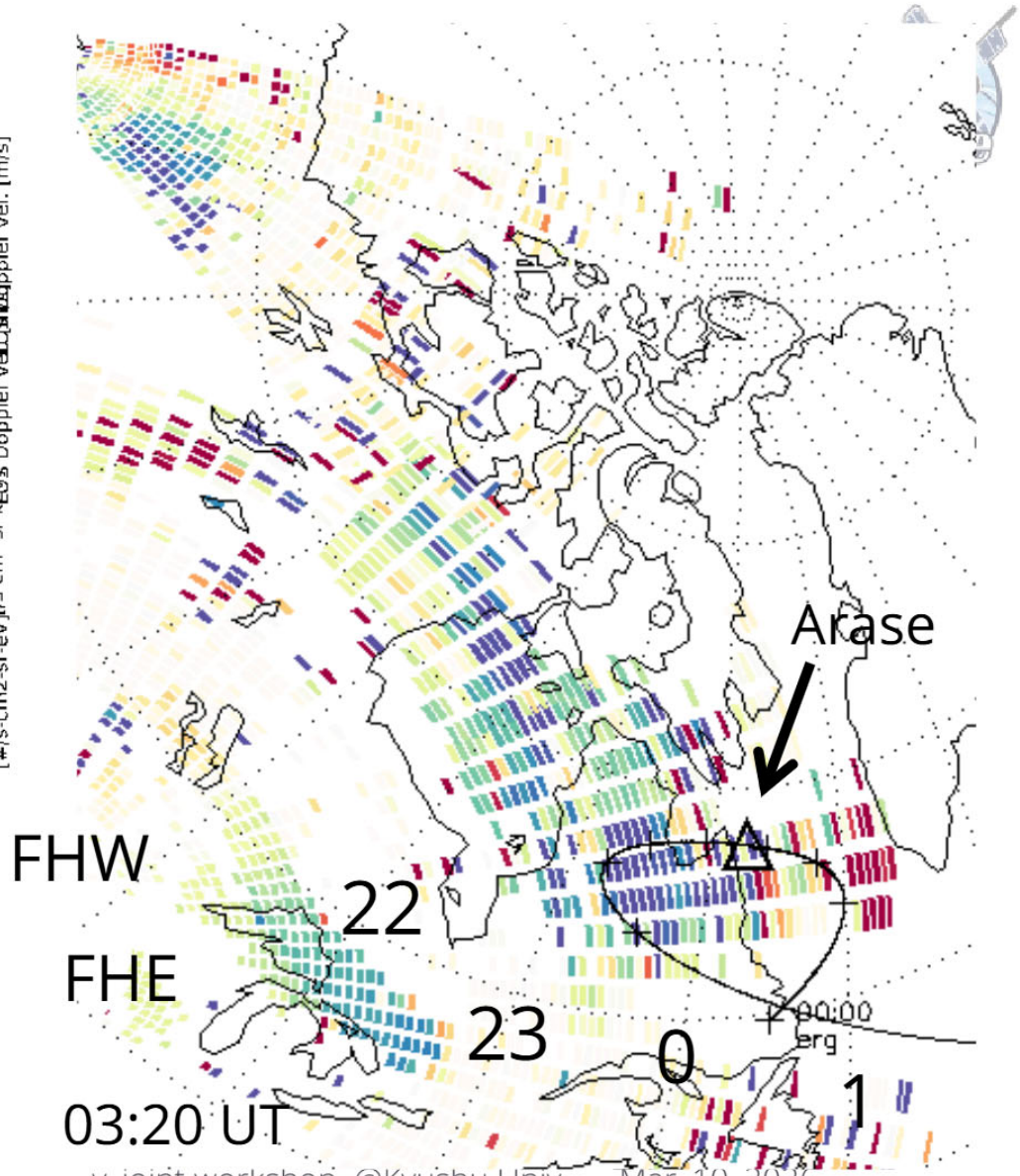


The most critical factor: how much SD echoes obtained and how close Arase located

Event 3: Oct. 21





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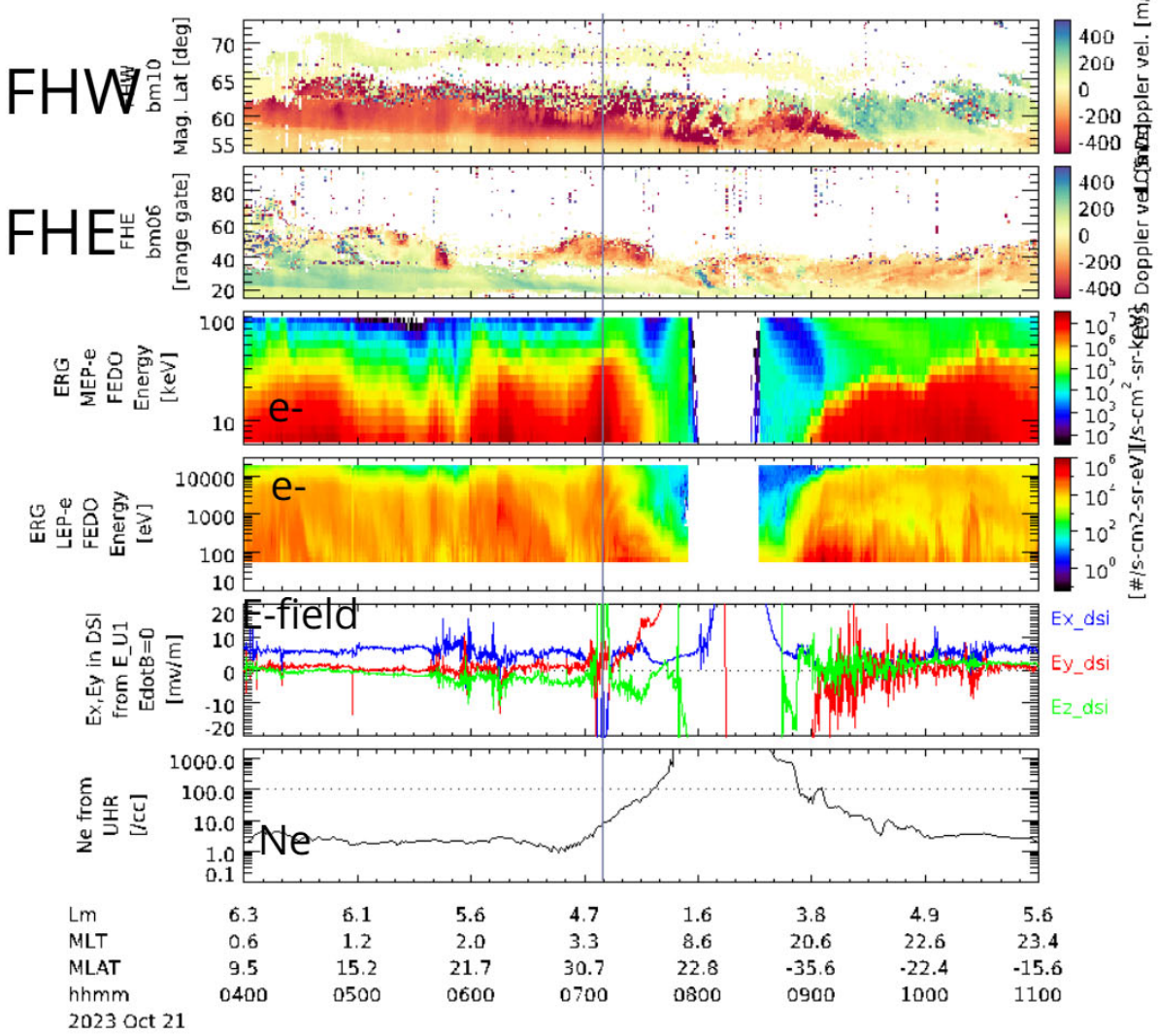
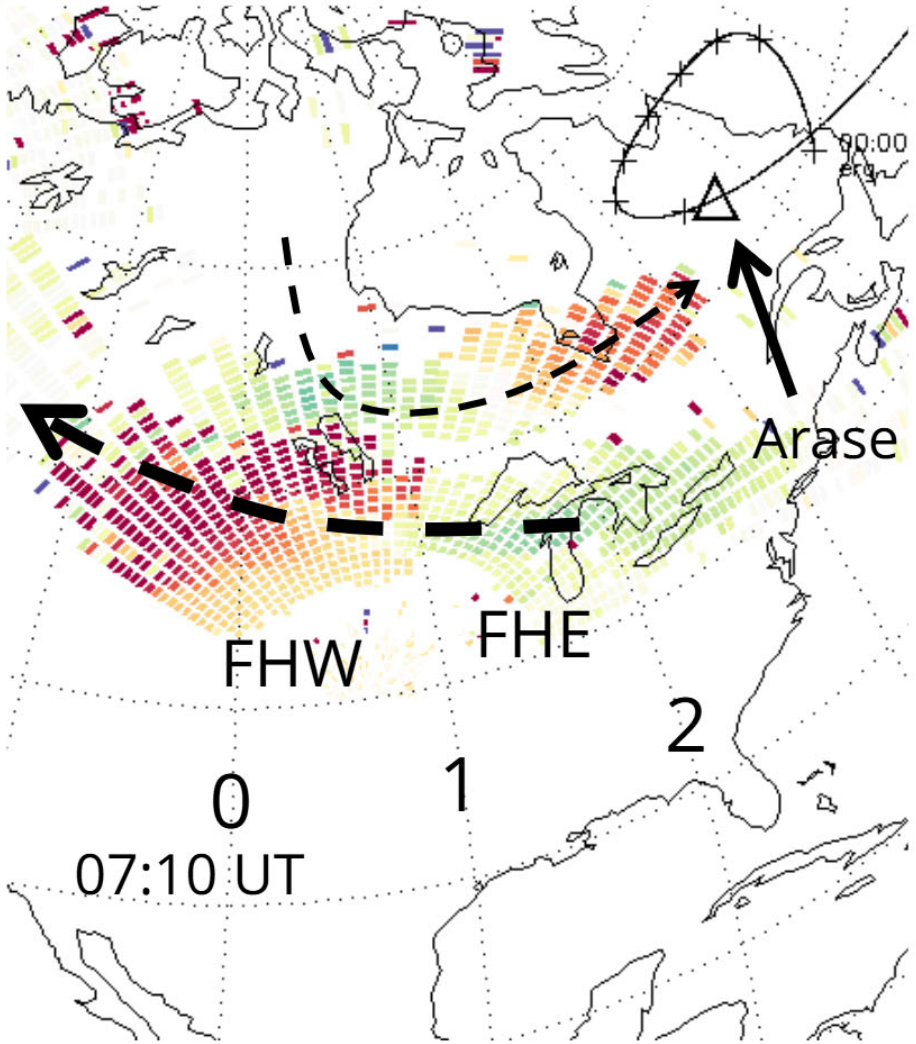


Arase missed
this beautiful flow complex...



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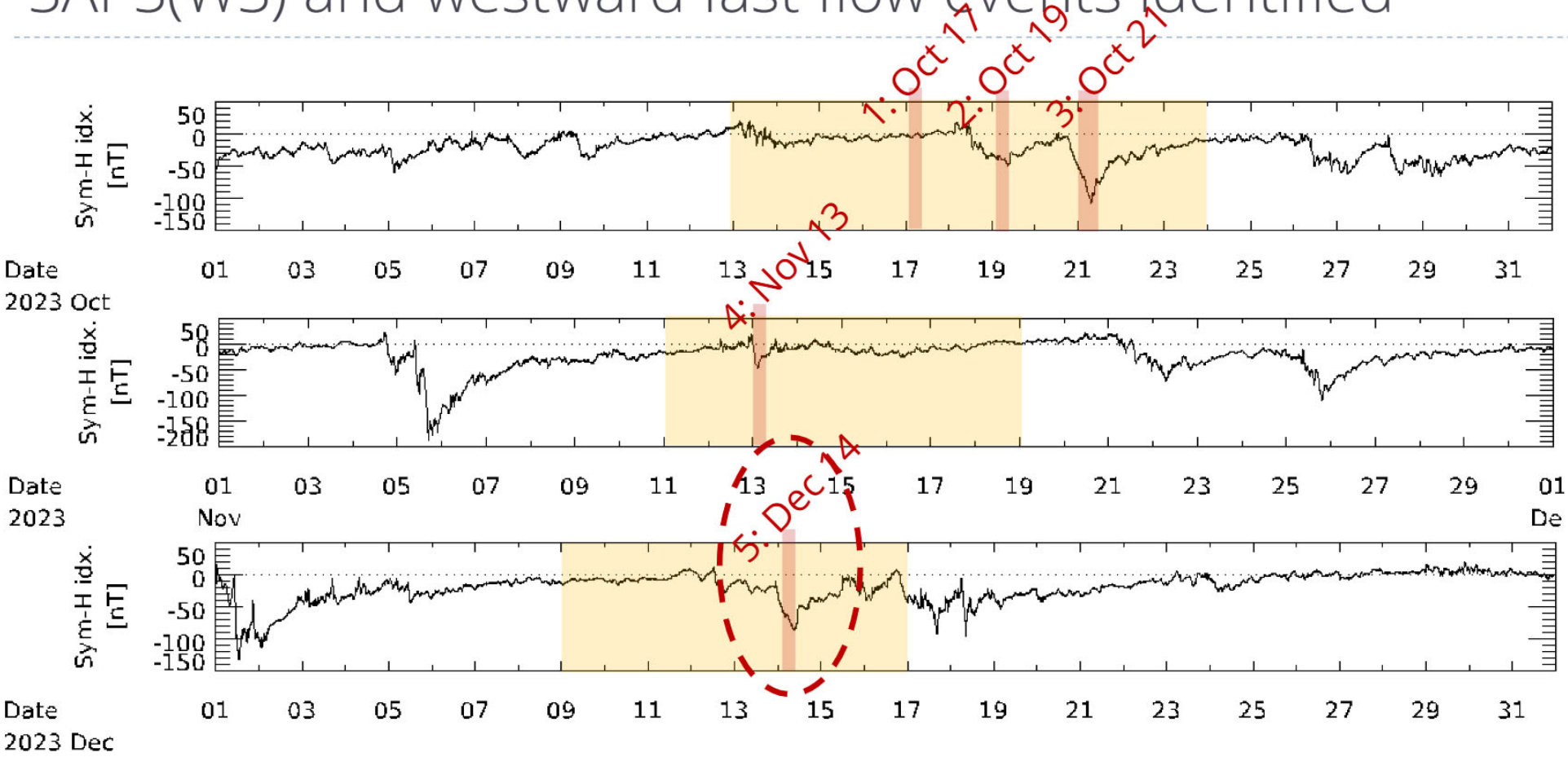

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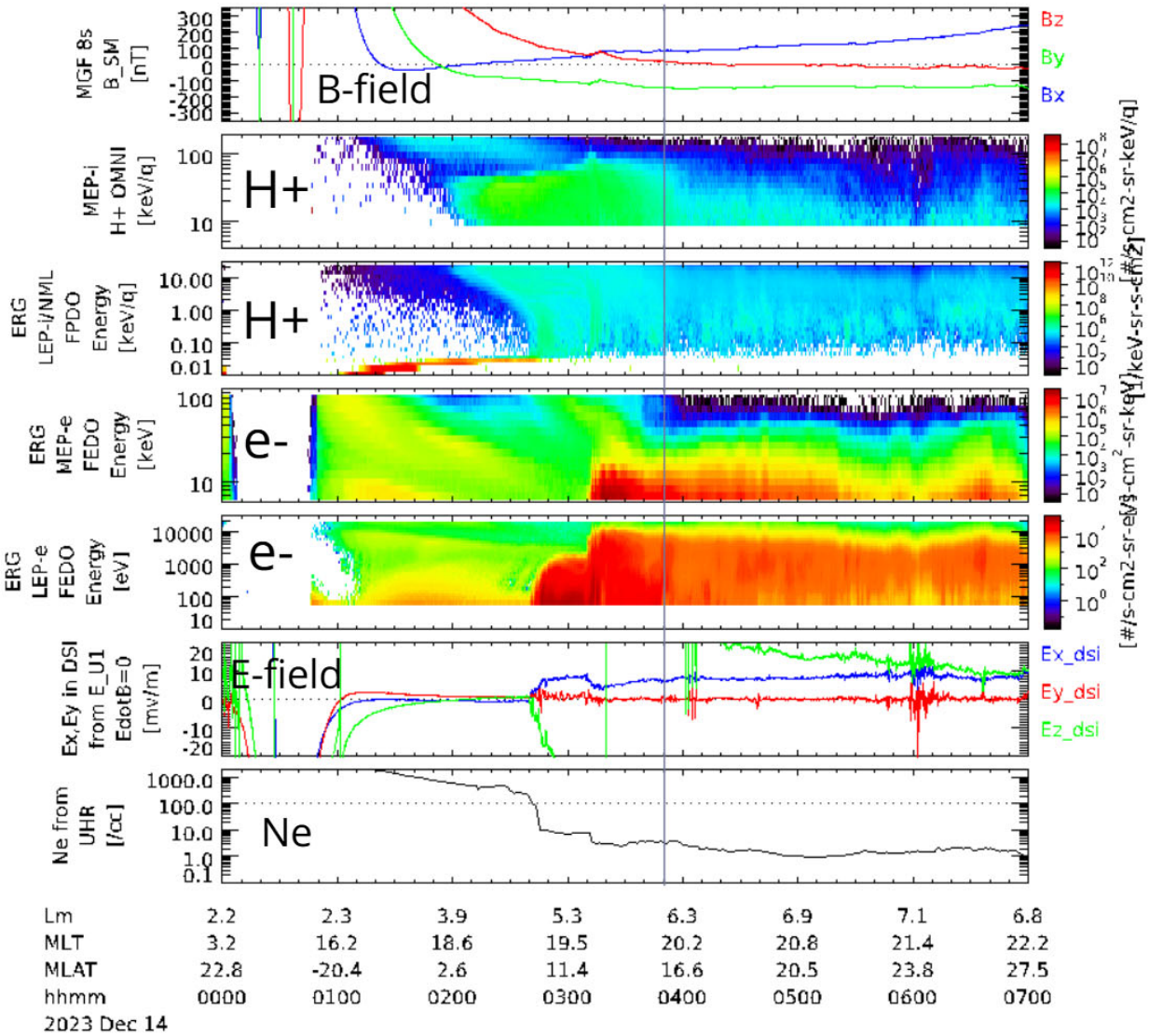
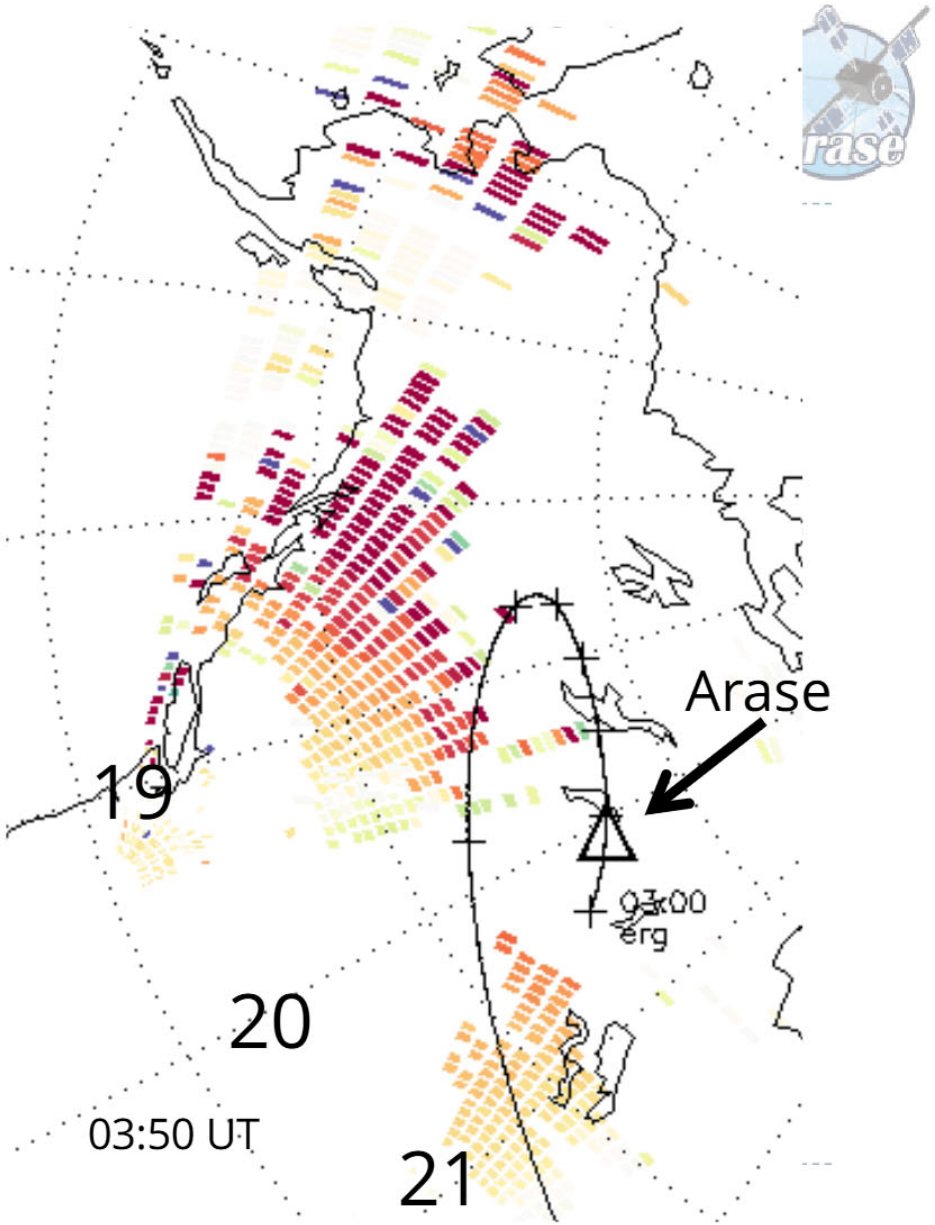
Event 5: Dec. 14





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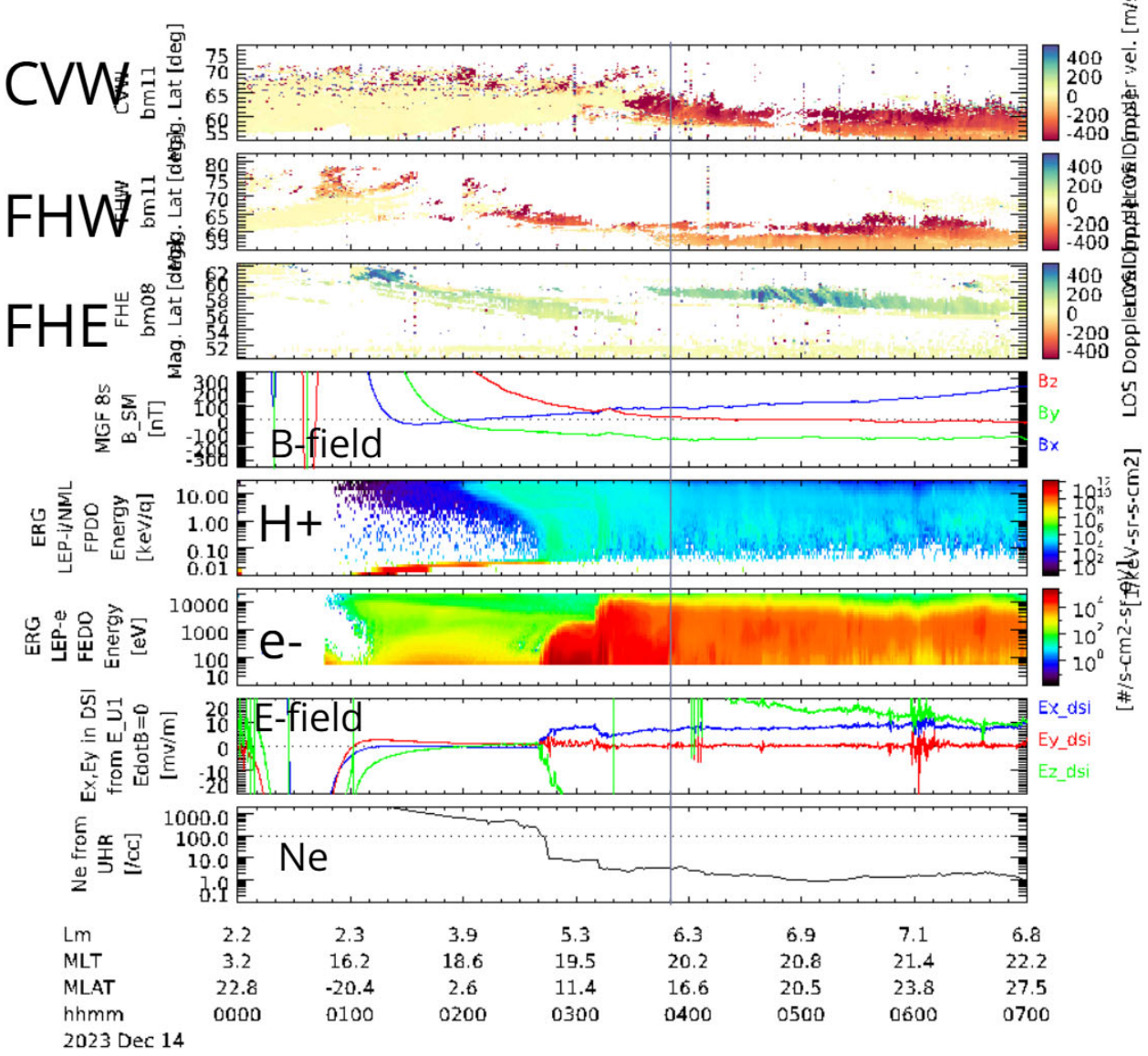

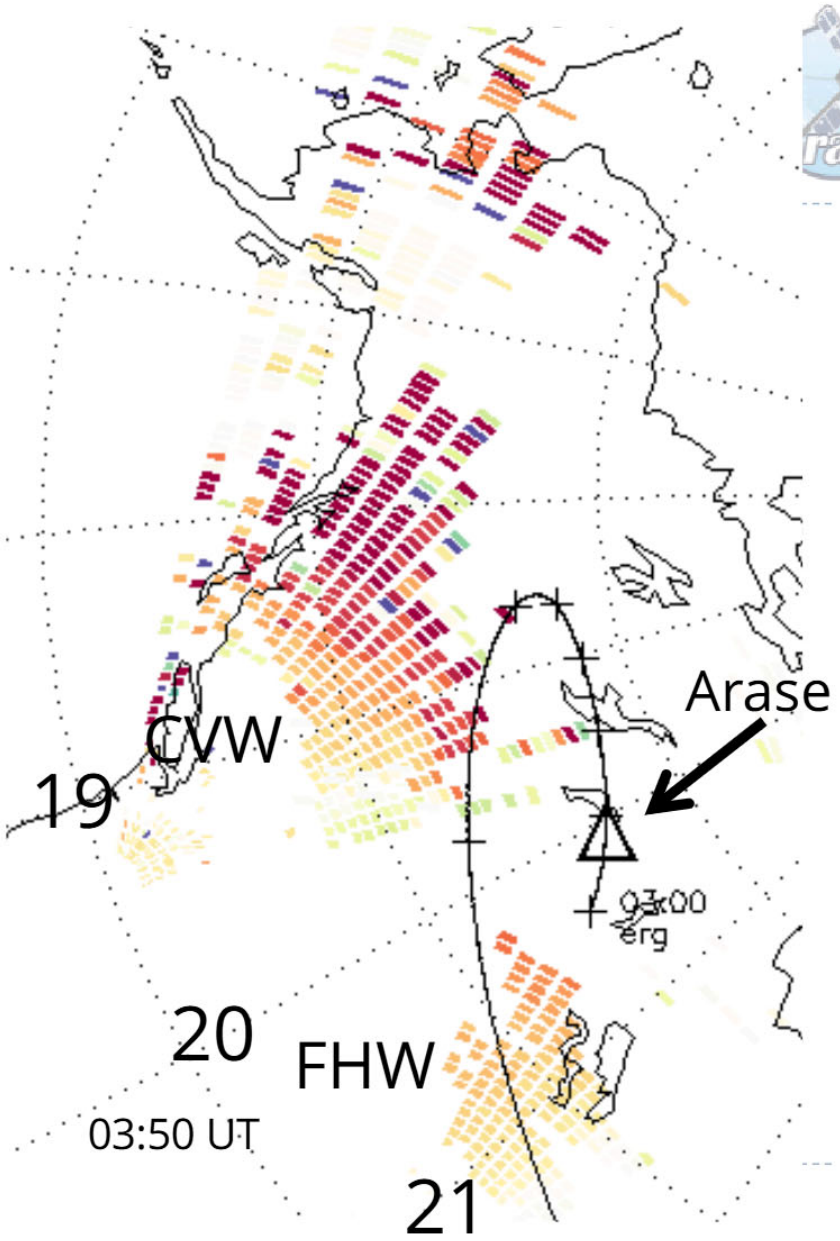

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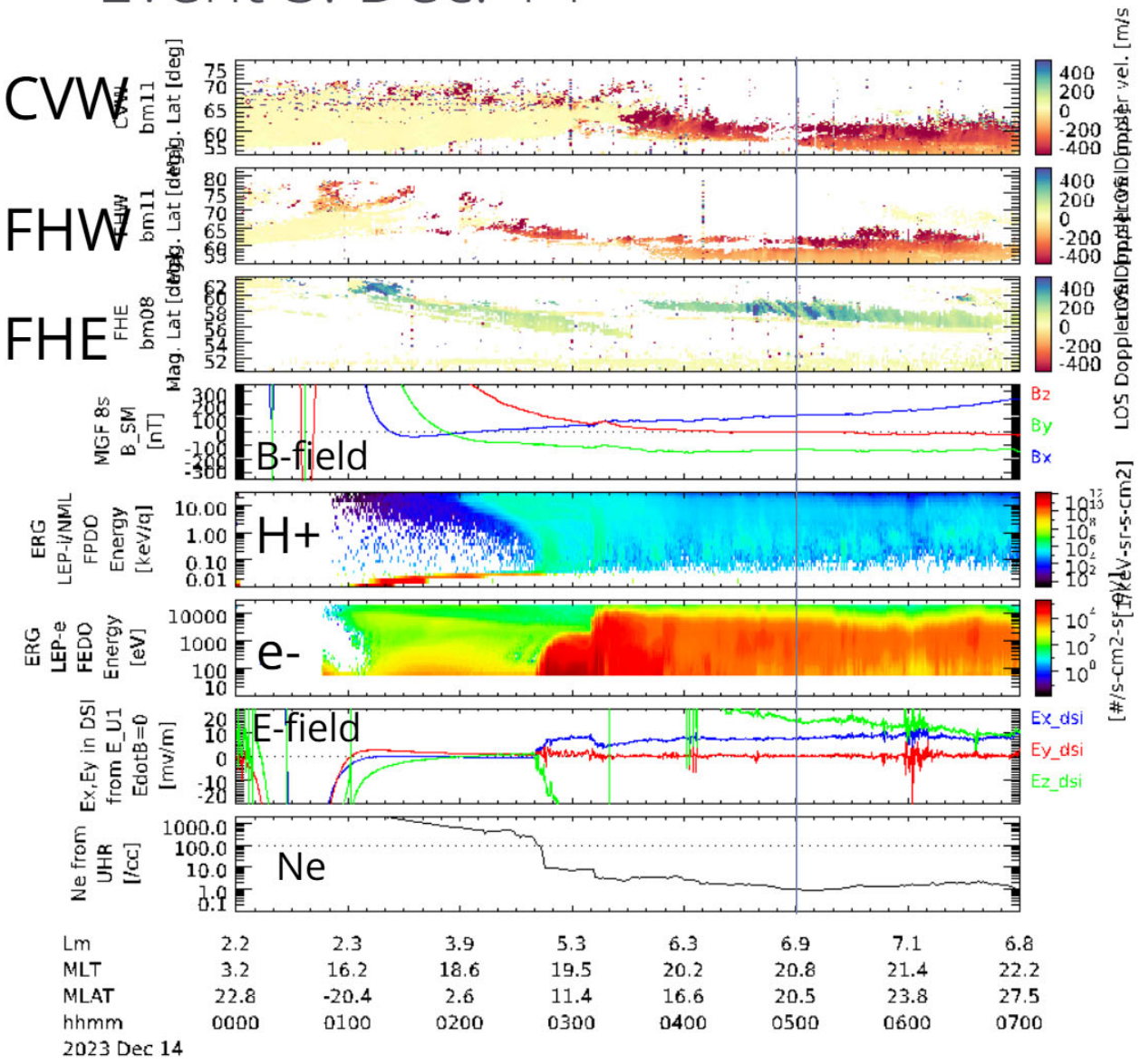
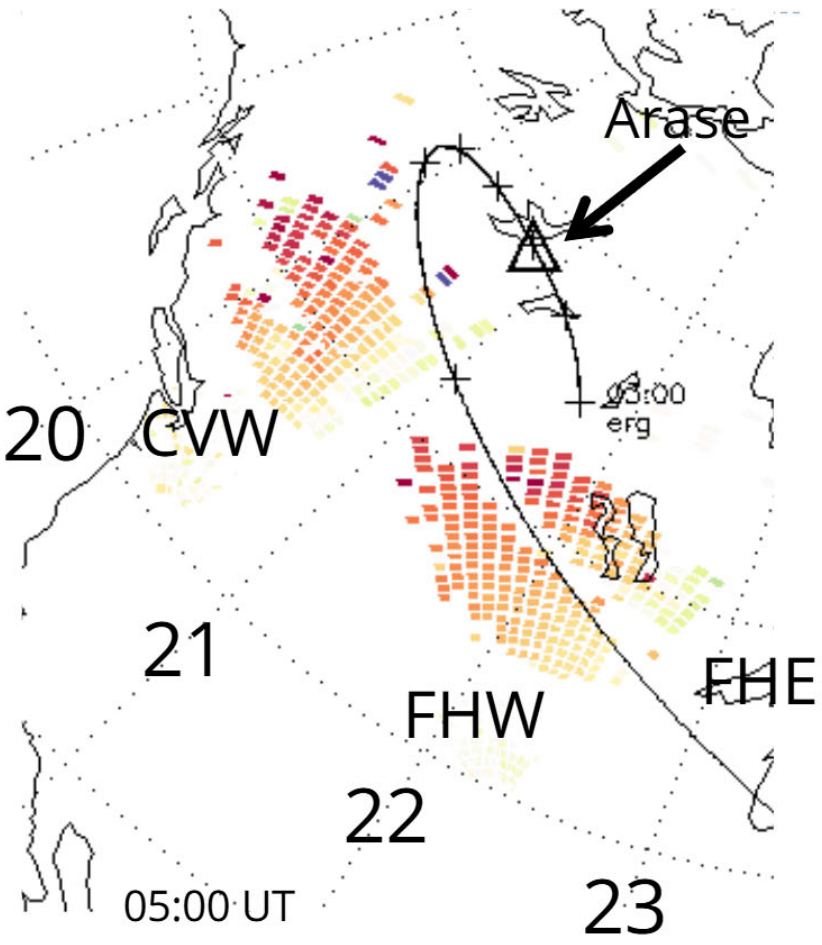
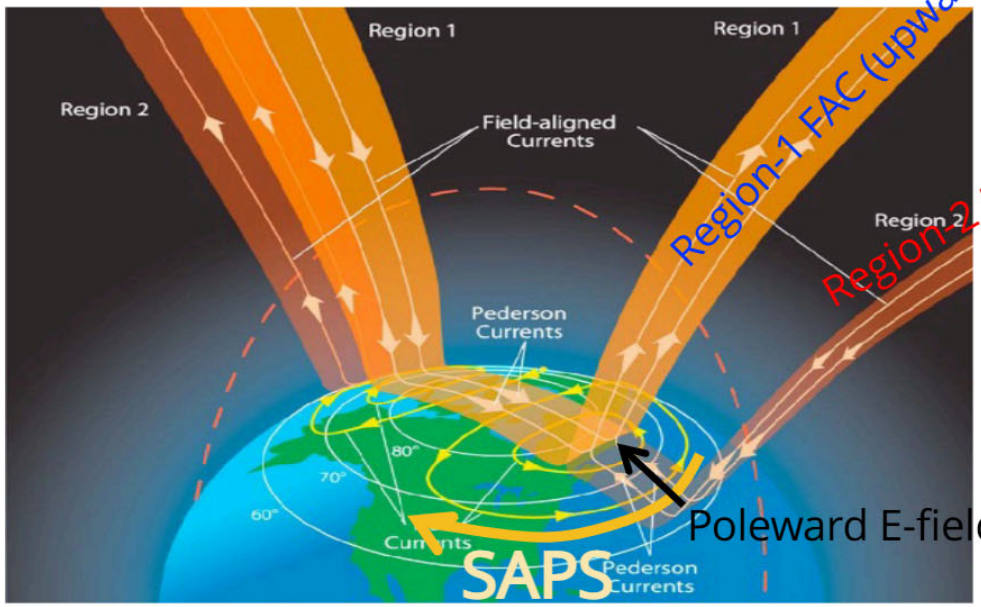




Intro.:
Subauroral Polarization Streams (SAPS)



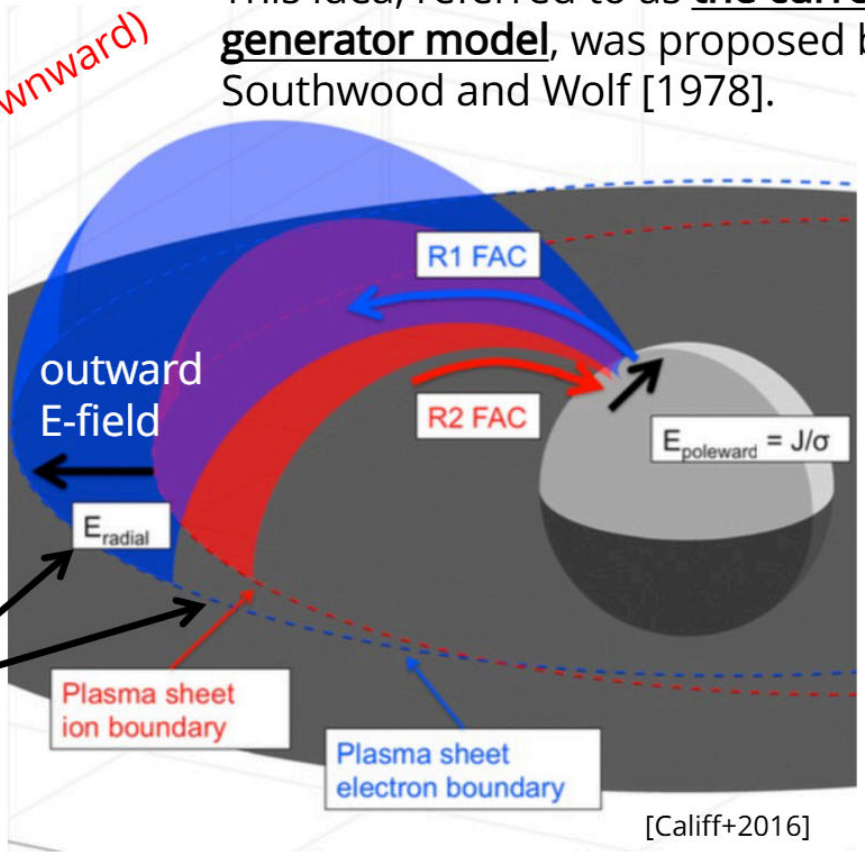
Le, Slavin and Strangeway [2010], with annotations

Region-1 FAC (upward)

Region-2 FAC (downward)

Poleward E-field

This idea, referred to as **the current generator model**, was proposed by Southwood and Wolf [1978].



[Califf+2016]

- The inward-displaced hot ions drive the downward R2 FAC and the **poleward** (radially-outward in m'sphere) **E-field**.