A SAPS intensification associated with weak injections: SuperDARN-Arase campaign in Fall 2022

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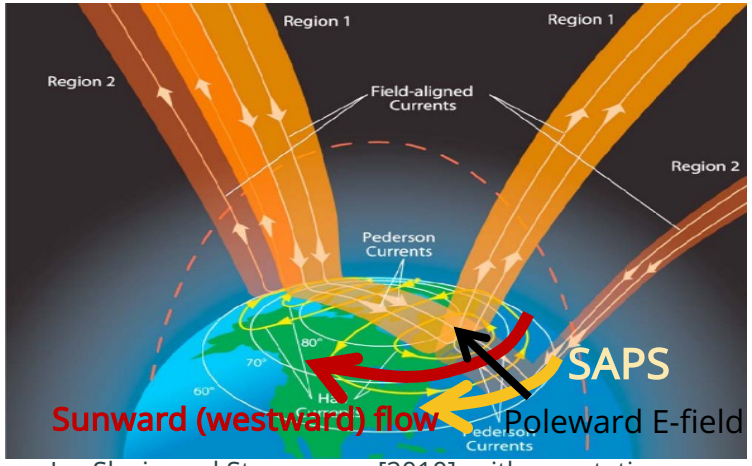
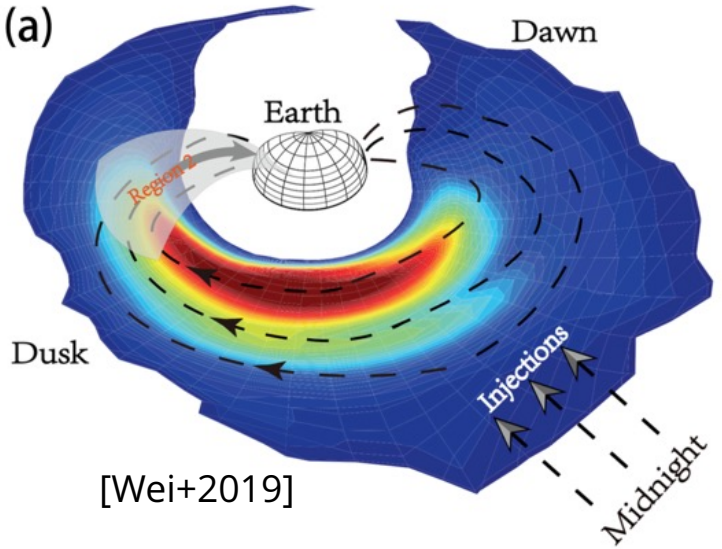
Subauroral polarization streams (SAPS)

SAPS:

- A fast westward flow formed during geomagnetically disturbed times over midnight to dusk in the subauroral ionosphere [e.g., Foster and Burke, 2002]
- Can be a subauroral structure of the sunward return flow [e.g., Parkinson+2003] or a somewhat distinct flow [e.g., Foster and Vo, 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]

Intro.:
A simple electrodynamics model assuming the current closure ($J_{||}=\nabla_{\perp}\Sigma_P E_{\perp}$) in the ionosphere

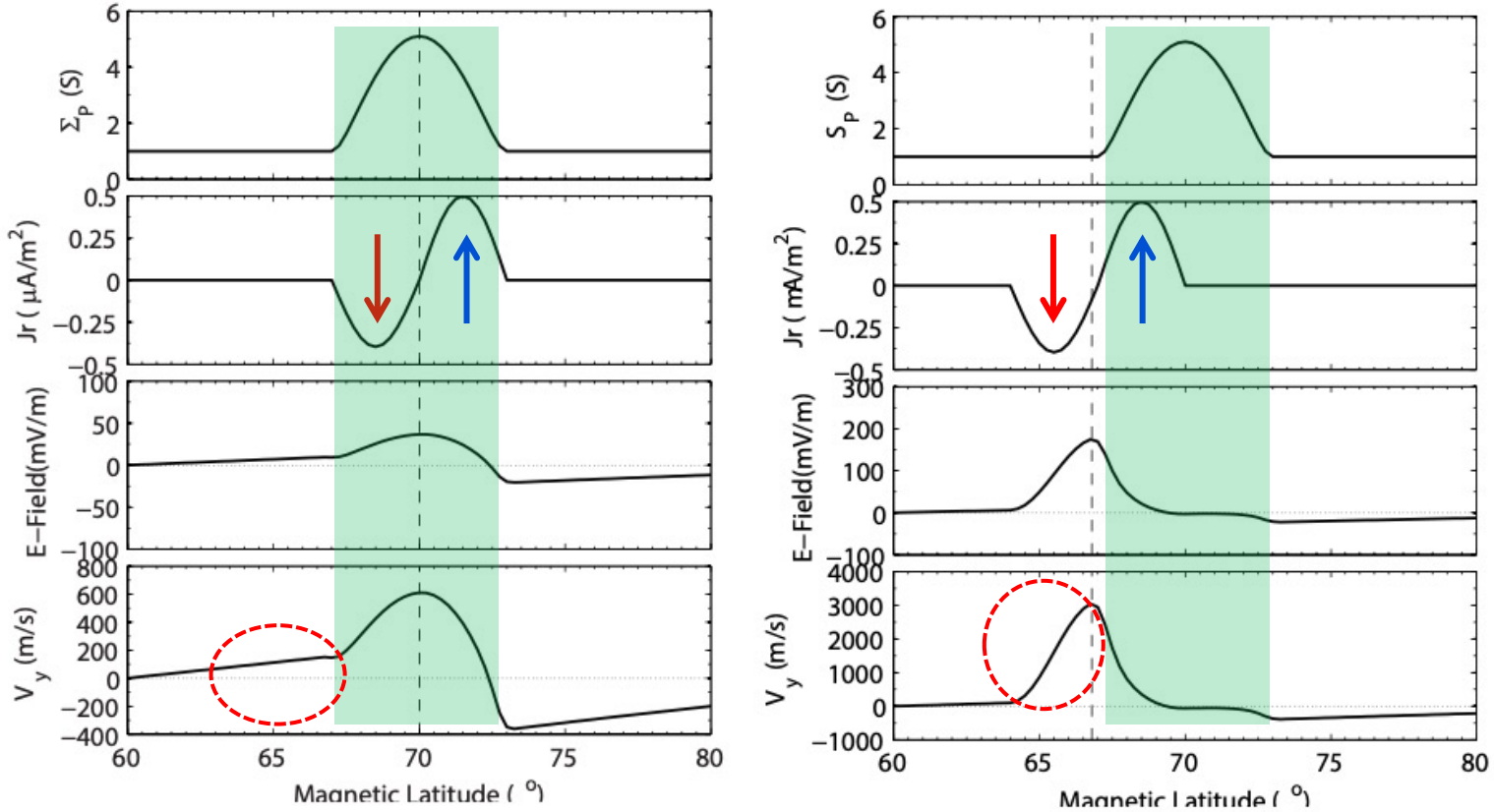
[Wang+2014]

Pedersen conductance

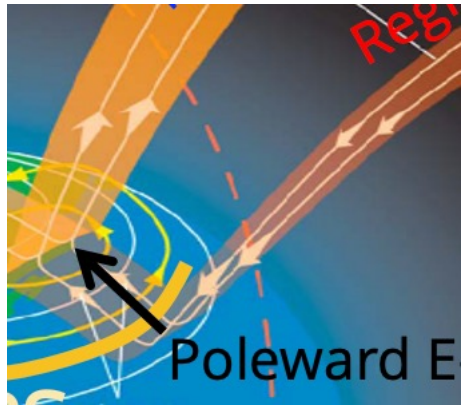
Field-aligned current

Poleward E-field

Westward flow velocity



Magnetic latitude

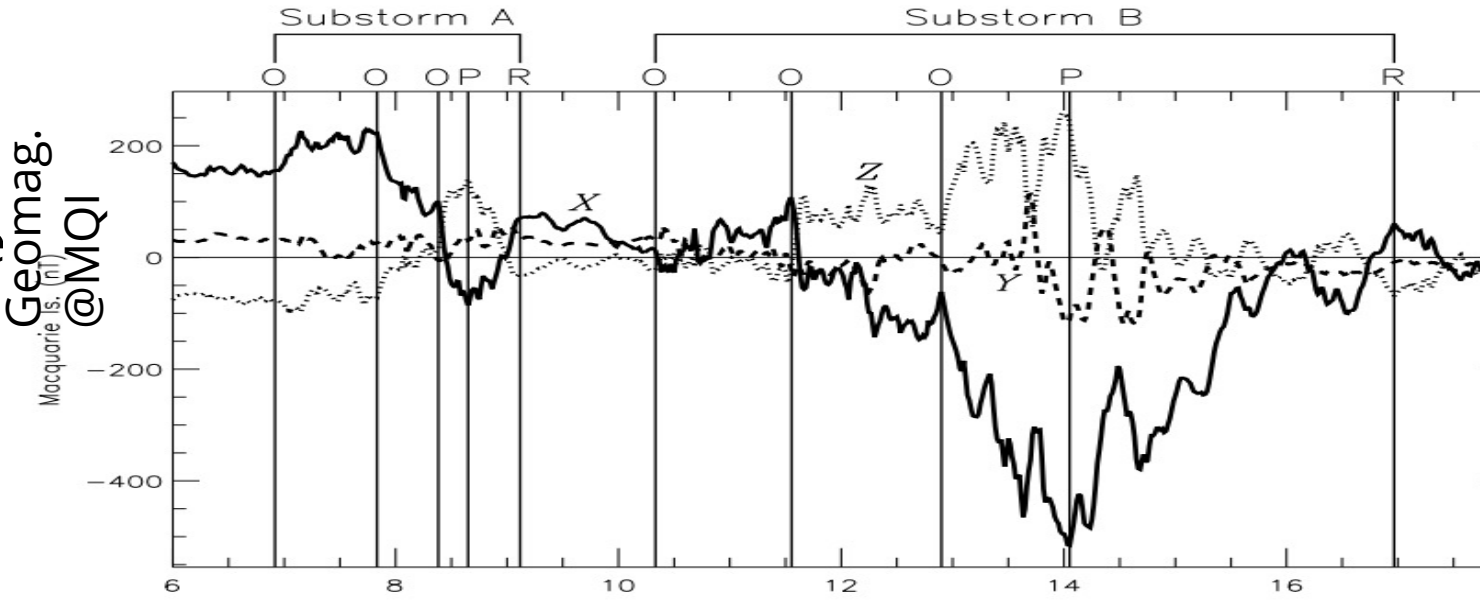


Detail timing of SAPS intensification

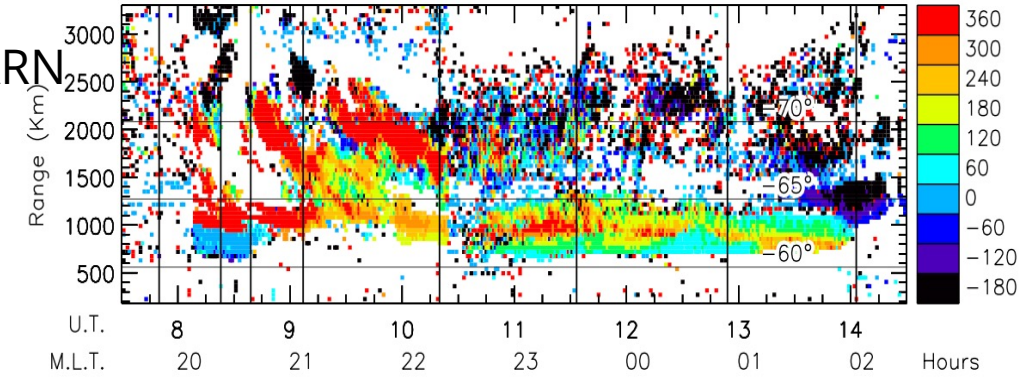
SAPS flows intensify during a substorm, but in what phase / what timing?

- Expansion phase or recovery phase
  - lagging the substorm onset by 6–30 min
    [Anderson et al., 1993, 2001; Karlsson et al., 1998; Makarevich et al., 2011; Mishin, 2016; Puhl-Quinn et al., 2007; Wang & Lühr, 2011]
- Quick response to onset
  [Nishimura+2008, Zou+2009a, Zou+2009b, Parkinson+2005 (with WTS)]
- **Growth phase or pseudobreakup**
  [Zou+2009a, Parkinson+2005]

Geomag. @MQI



SuperDARN TIG



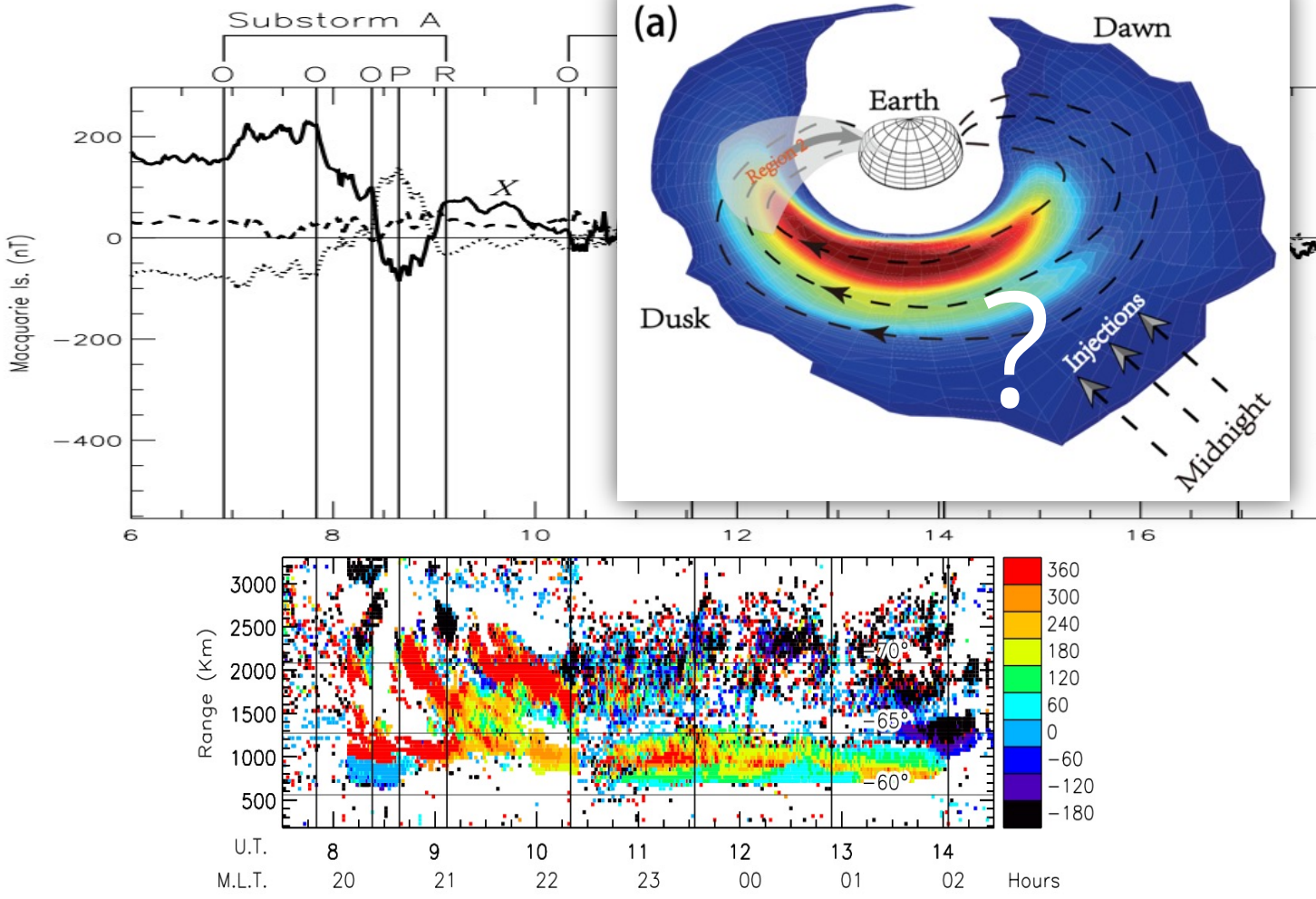
[Parkinson+2005]

Open question:
SAPS intensification during substorm growth phase and/or pseudobreakup

- SAPS can intensify in association with pseudobreakup, and even during substorm growth phase.

Unknown or not well studied:

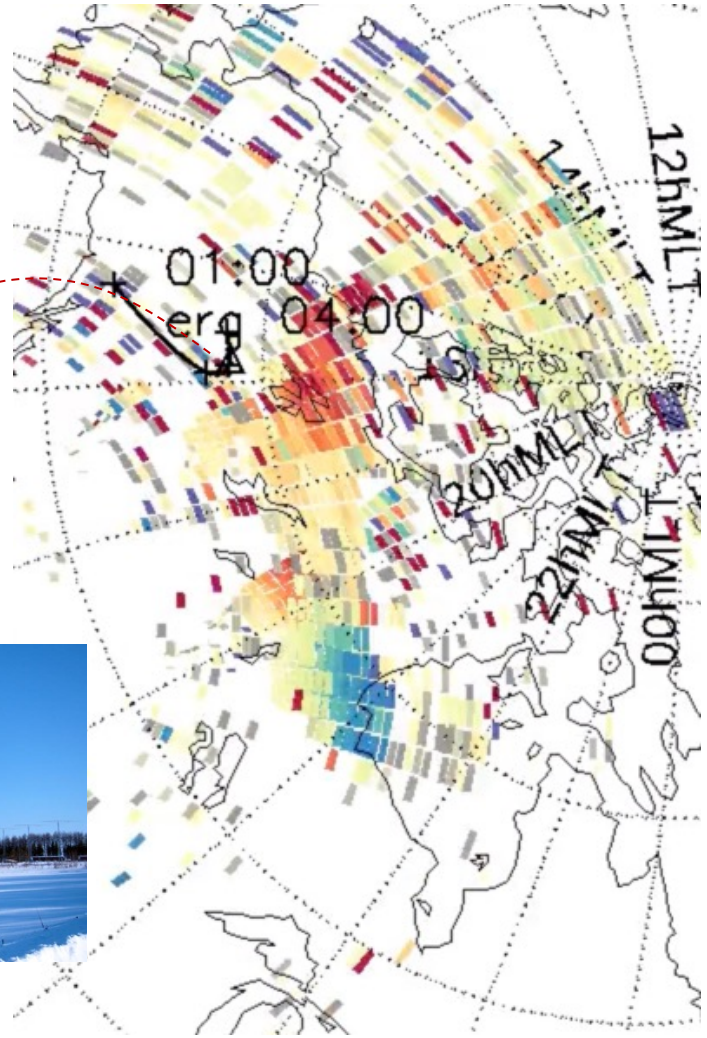
- when / how / in what spatial range SAPS intensifies?
- what's the driver for R2FAC?

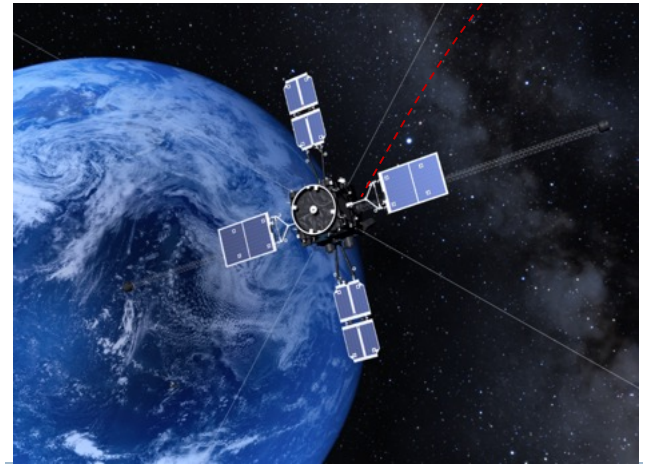


[Parkinson+2005]

Our approach: Arase–SuperDARN conjunction on Oct. 28, 2022

A few tens of conjunction observations were conducted using the Arase satellite and Super Dual Auroral Radar Network (SuperDARN) during the fall-winter season campaign of 2022. Among the interesting observations yielded by the campaign, both Arase and SuperDARN successfully captured a dynamically-evolving fast westward flow including SAPS during 2–4 UT on Oct. 28, 2022. We take this precious opportunity to examine how the ionospheric westward flow expands latitudinally and extends westward in association with energetic protons that have been injected at a later local time.





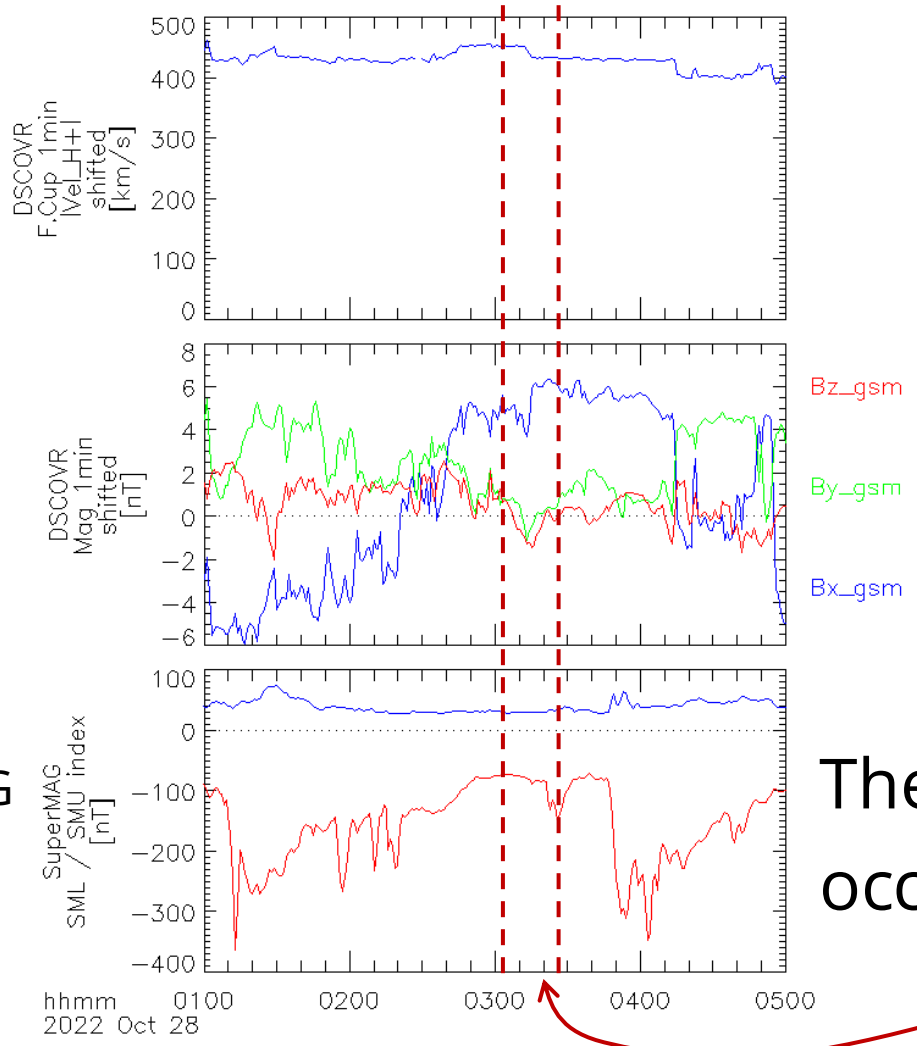
Solar wind / IMF condition and satellite positions during the event on Oct. 28, 2022

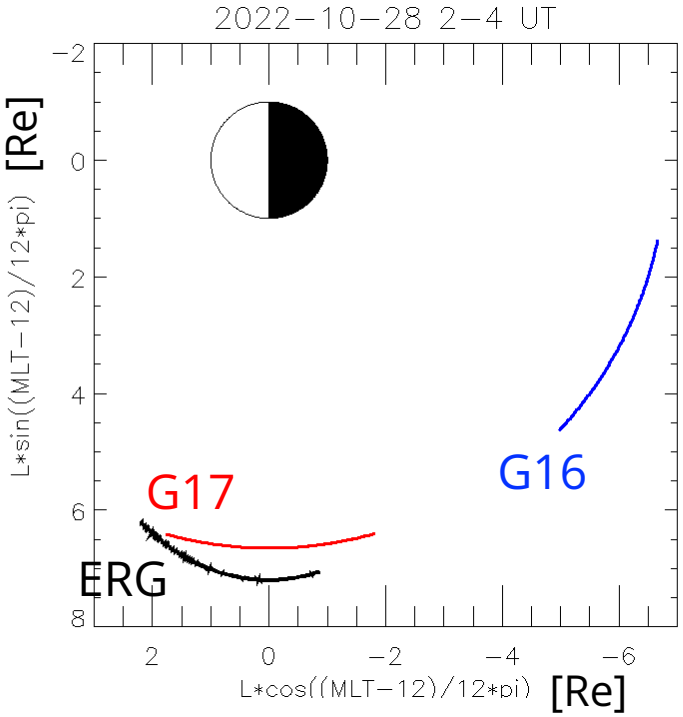
SAPS intensification
near ERG at ~03:04 and ~03:26 UT

Solar wind speed

IMF

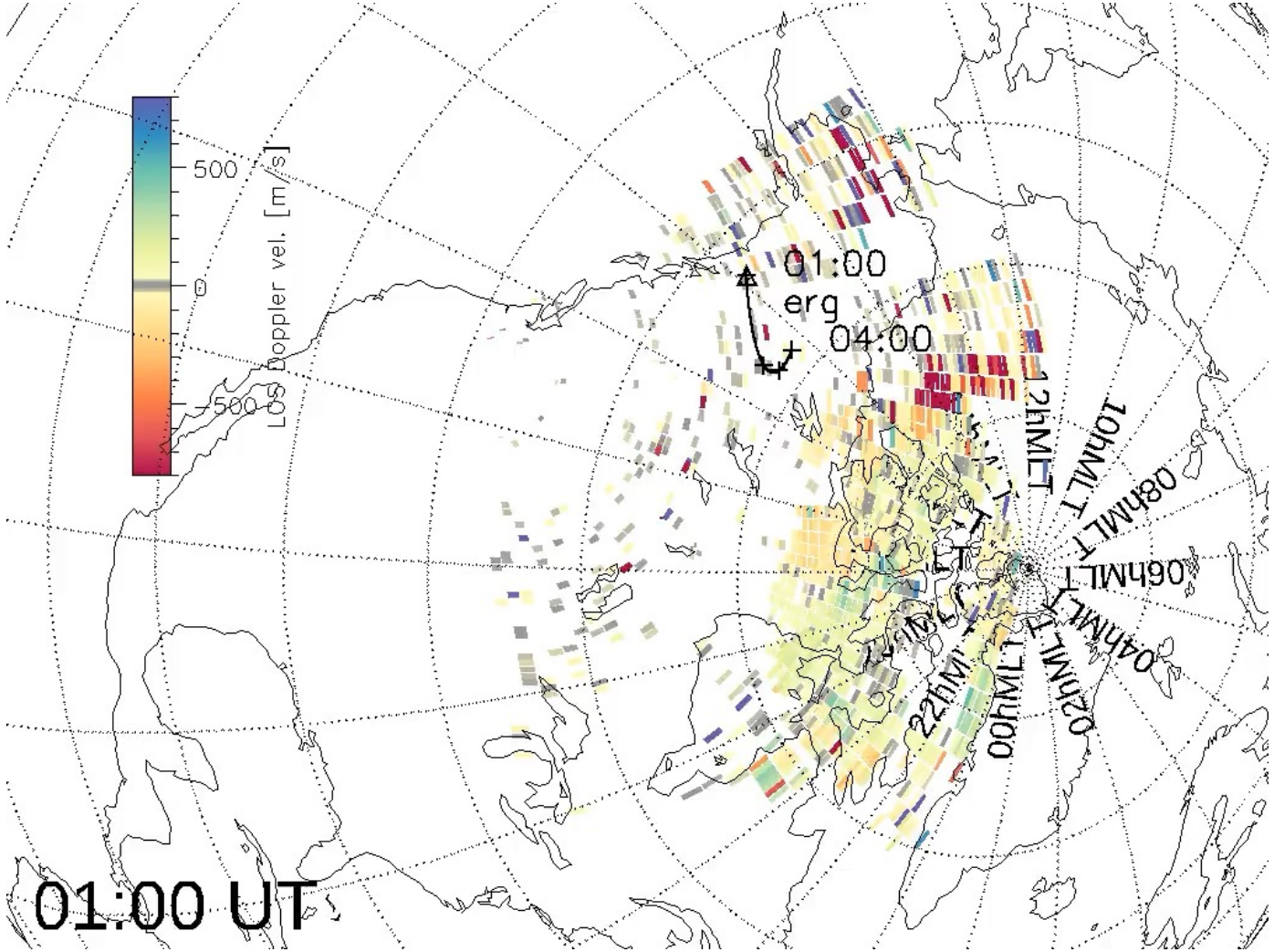
SuperMAG SML/SMU



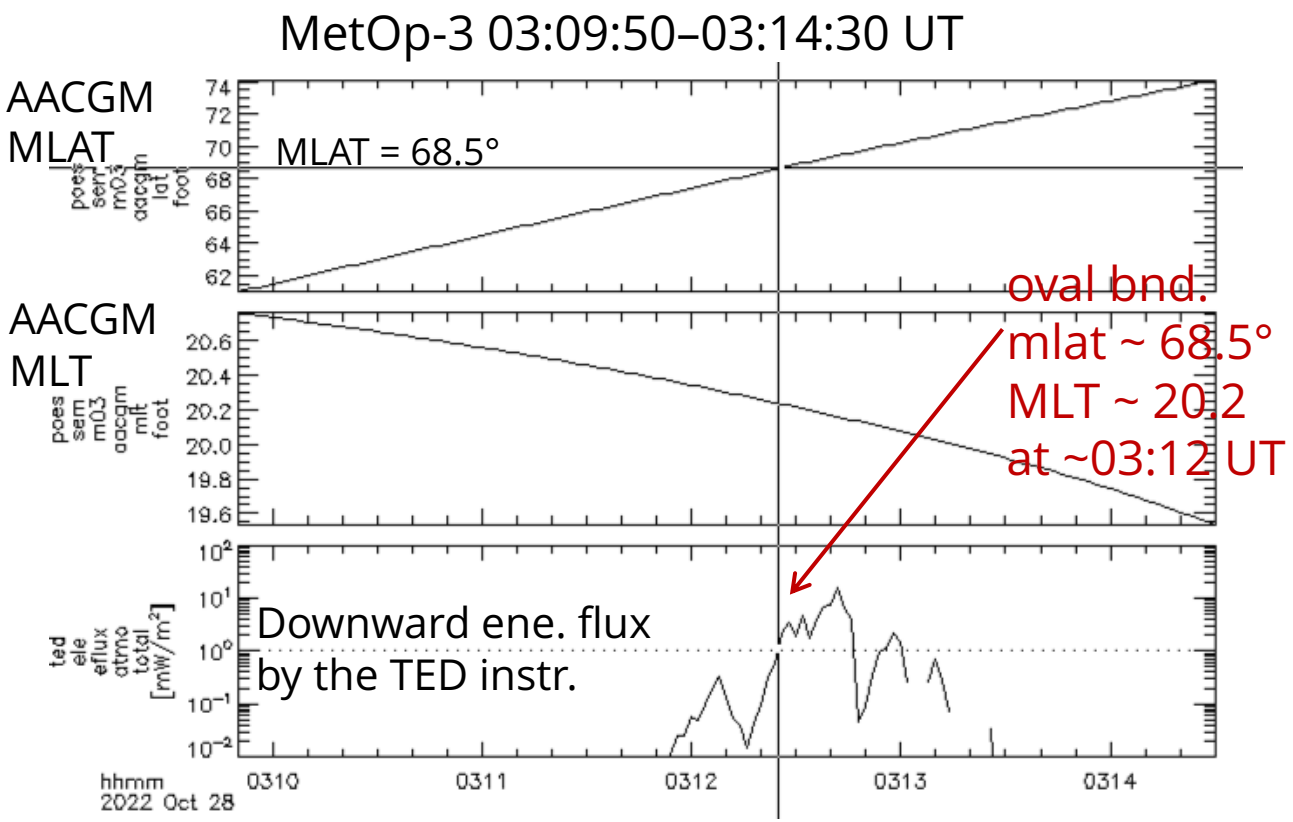


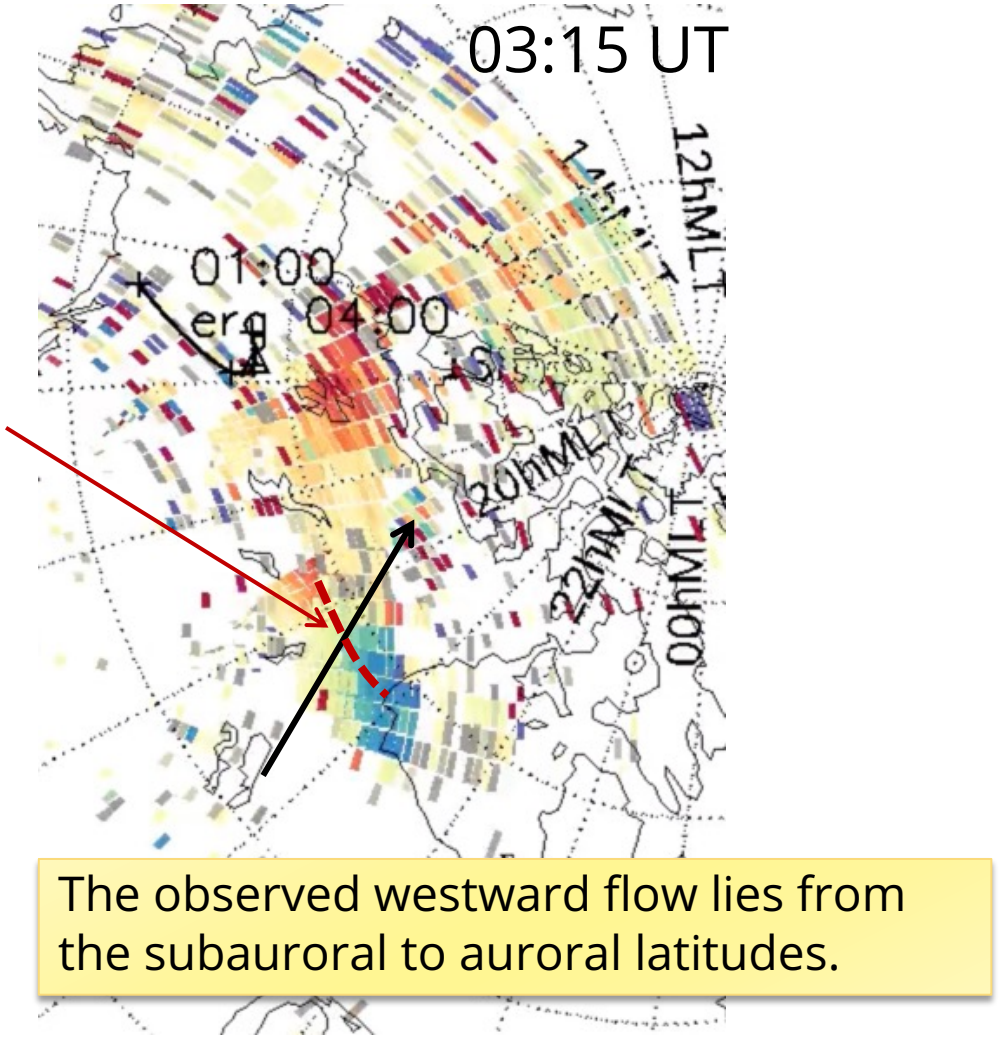
The SAPS intensification of interest occurred in between two substorms.

SD observations with Arase's footprint during 1–4 UT on Oct. 28, 2022



Electron precipitation seen by the MetOp-3 satellite





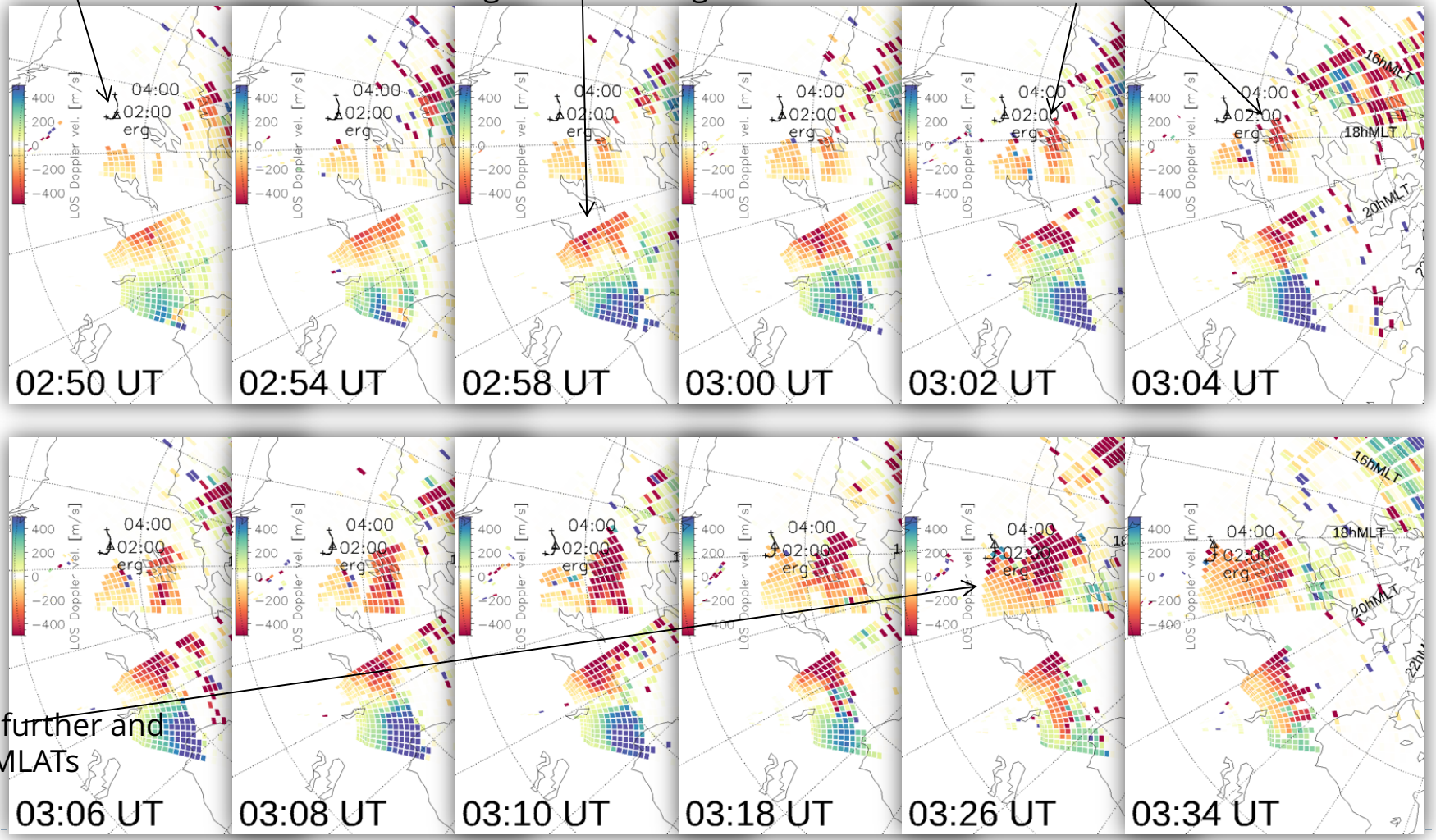
The observed westward flow lies from the subauroral to auroral latitudes.

Evolution of fast westward flow including SAPS

Arase's footprint (△)

Westward / SAPS flow started enhancing in the evening sector

The flow intensified also near Arase



The flow intensified further and expanded to lower MLATs

Solar wind / IMF condition and satellite positions during the event on Oct. 28, 2022

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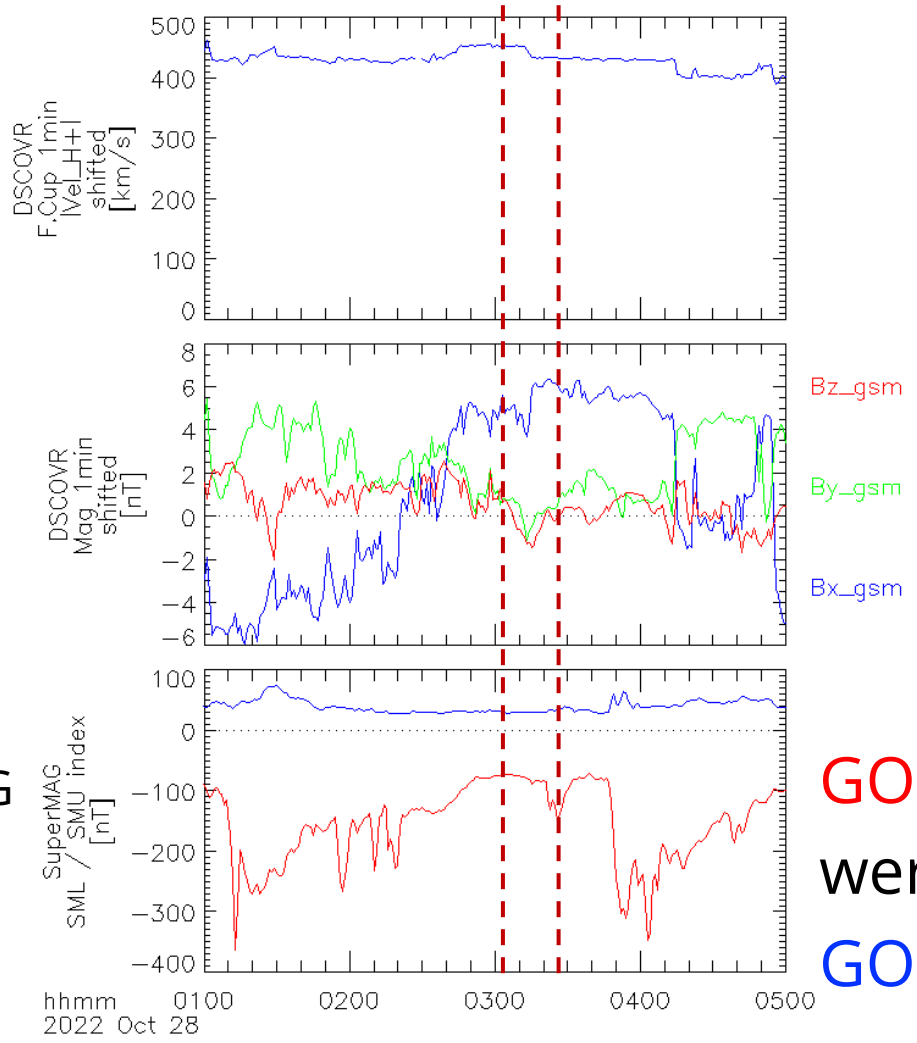
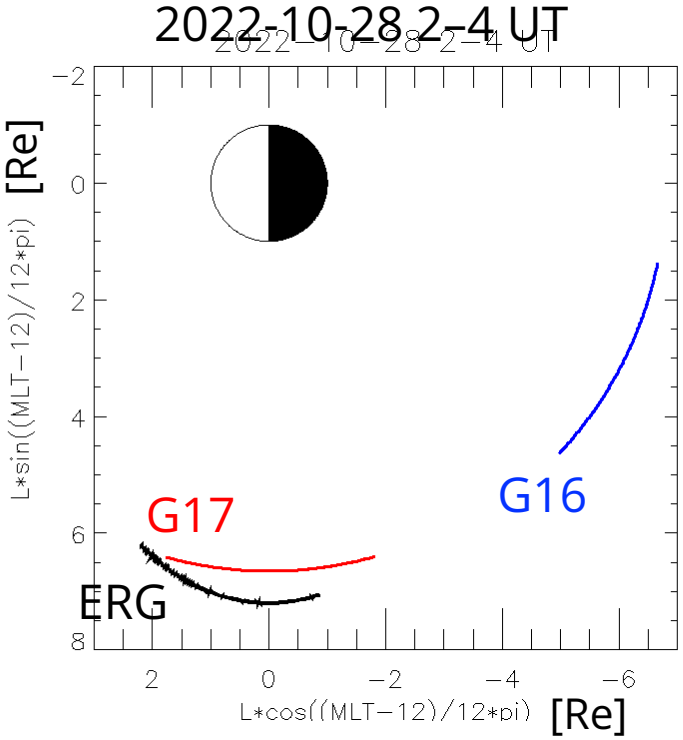
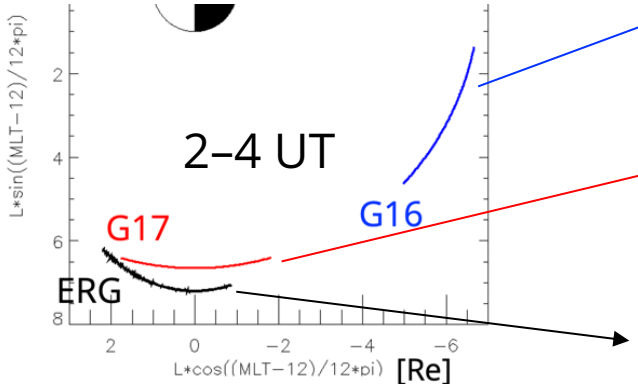




GOES-17 (L ~ 6.6) and ERG (L ~ 7.1) were located around dusk, while GOES-16 was situated at premidnight.

Arase and GOES observations in the conjugate magnetosphere

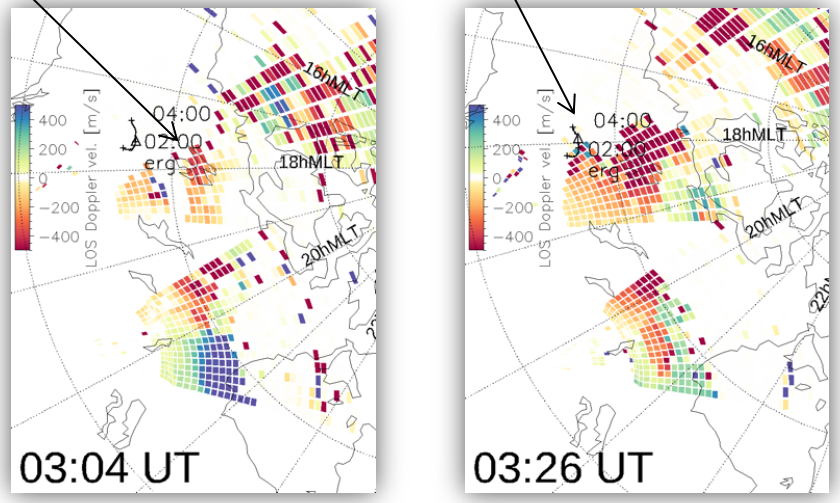


(A)

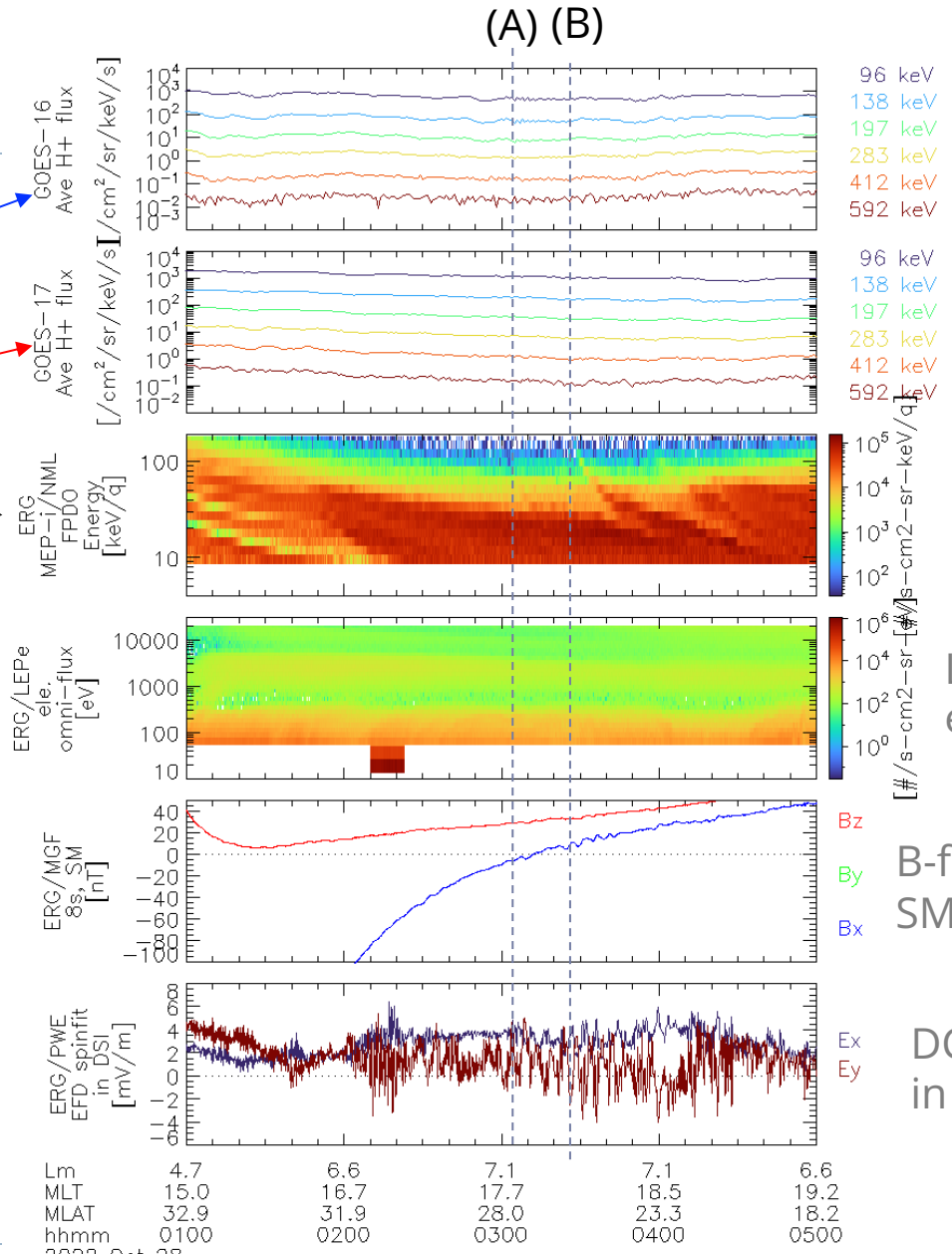
The flow intensified also near Arase

(B)

The flow intensified further and expanded to lower MLATs



(A) (B)



H+ injection by G16

G17

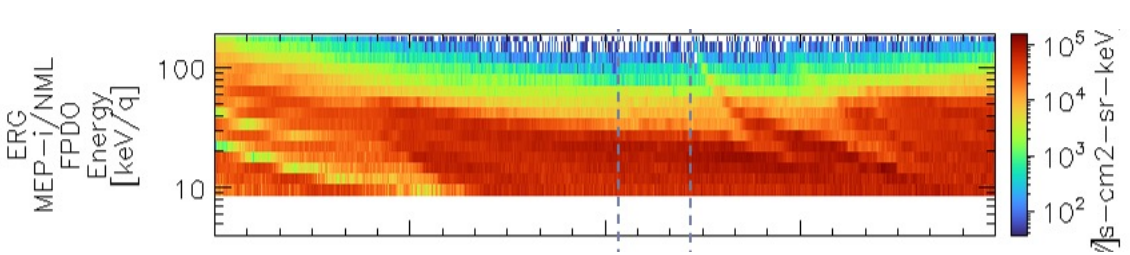
ERG H+

Low ene. e-

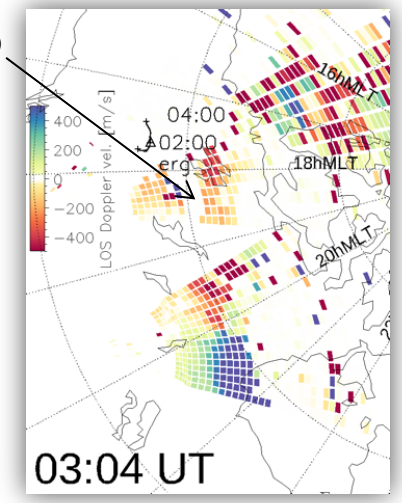
B-field in SM

DC E-field in DSI

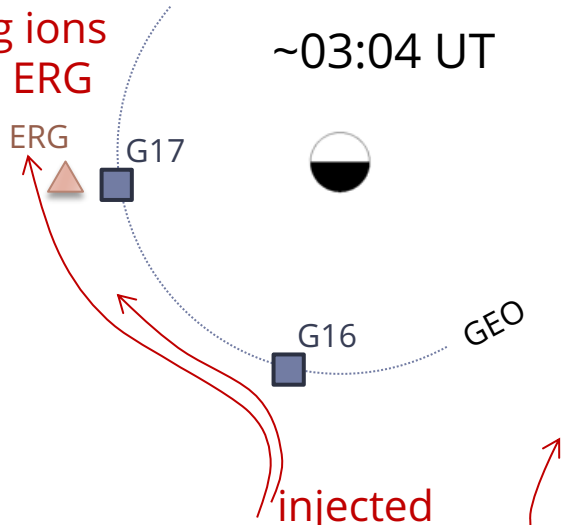
Interpretation & Discussion

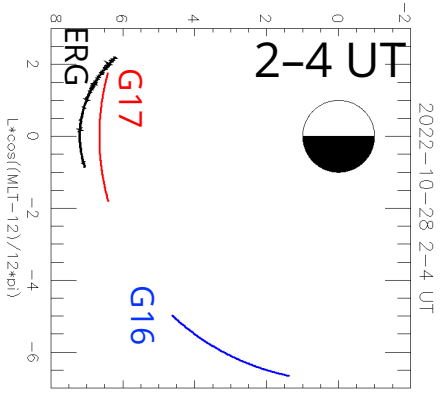


The flow intensified also near Arase



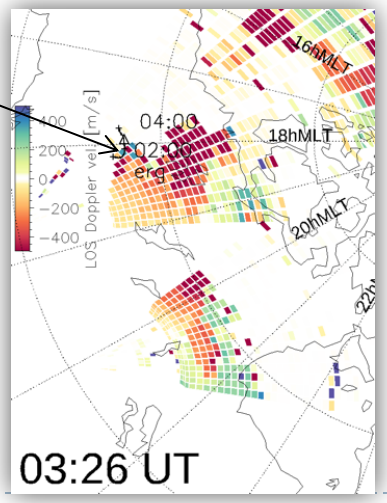
The drifting ions just grazed ERG

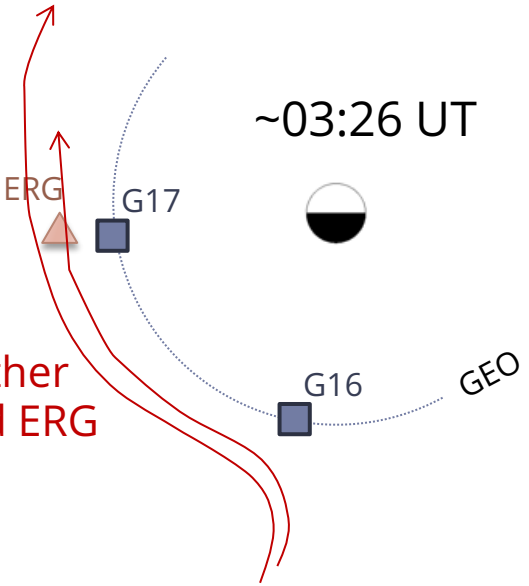




injected ions

The flow intensified further and expanded to lower MLATs

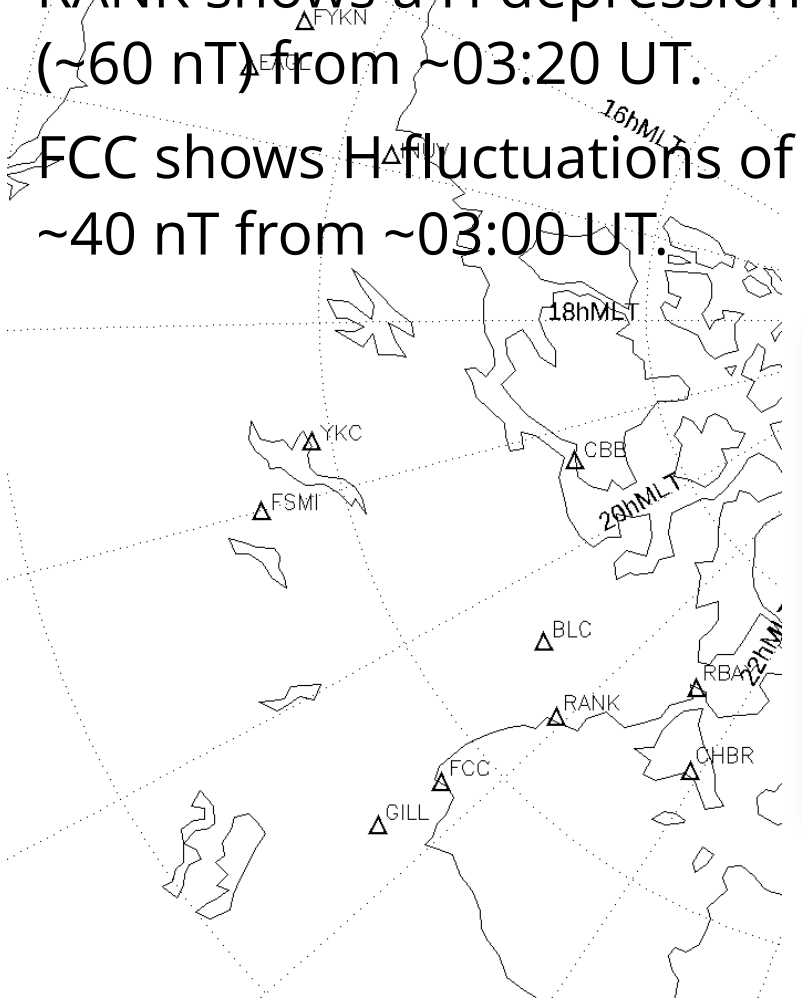


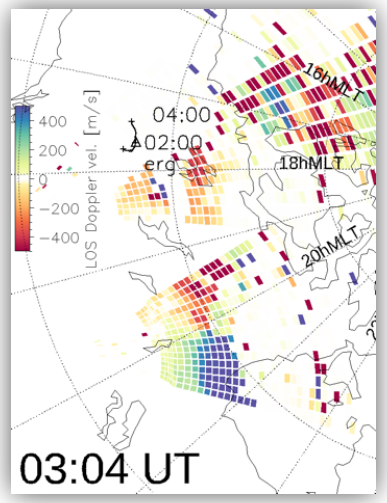


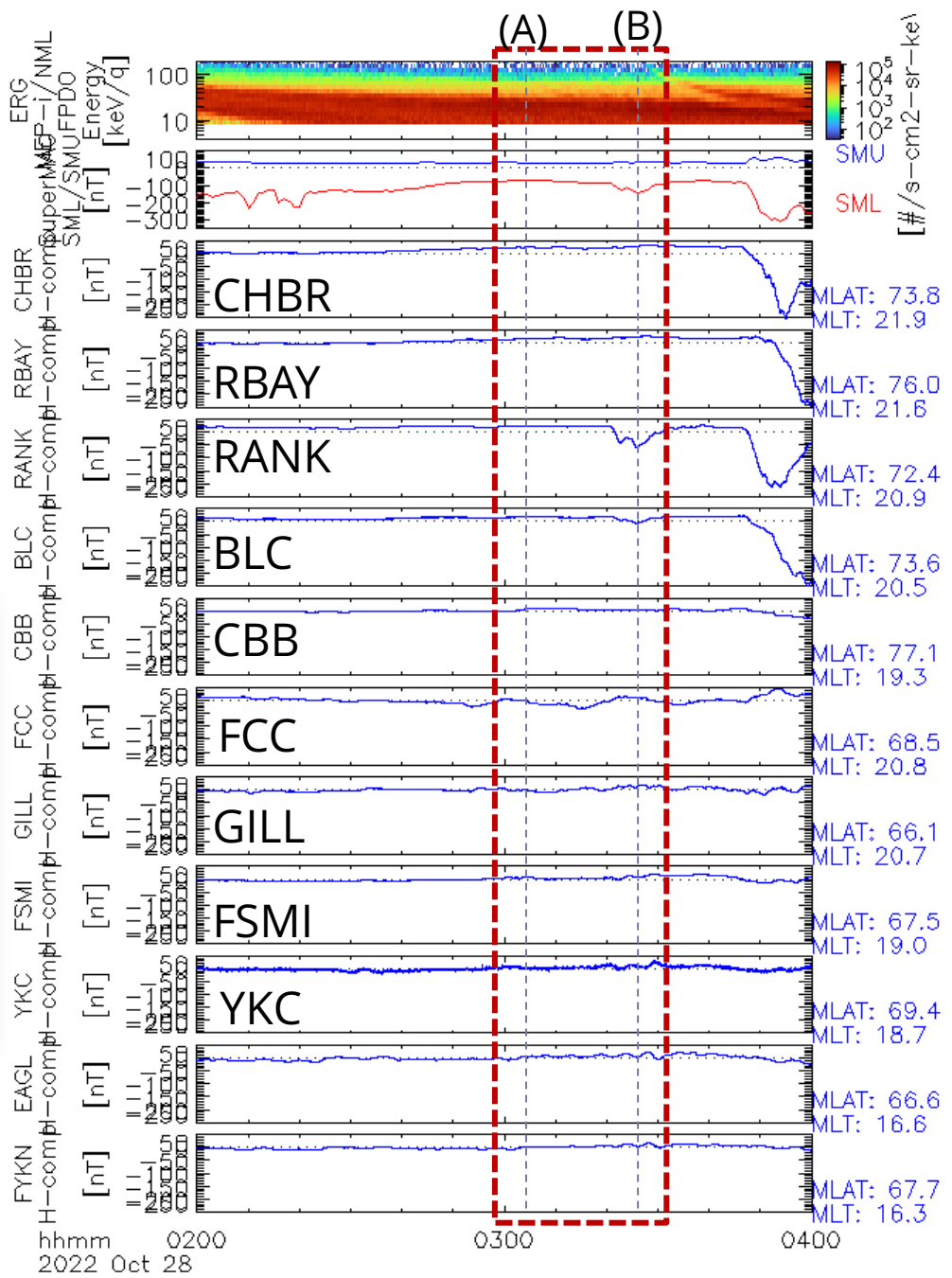
Drifted further and passed ERG by

Details of the geomag.

- RANK shows a H depression (~60 nT) from ~03:20 UT.
- FCC shows H fluctuations of ~40 nT from ~03:00 UT.







Can we find any signature of pseudo-breakup or something?

FSMI

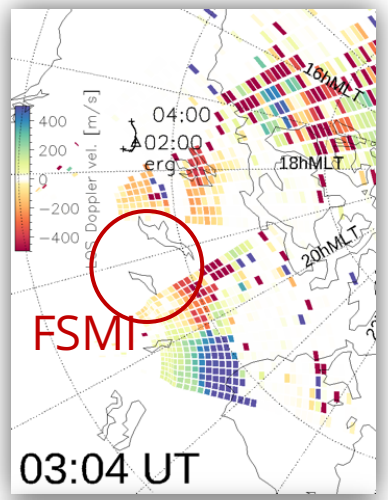
MLAT=70

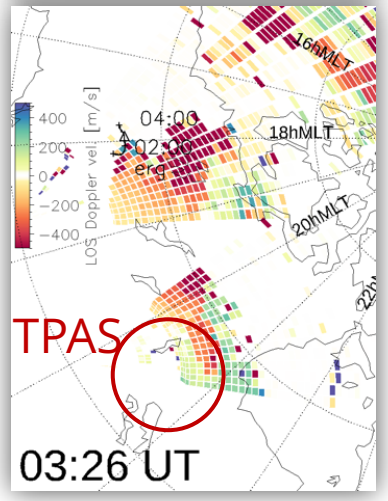
MLAT=68

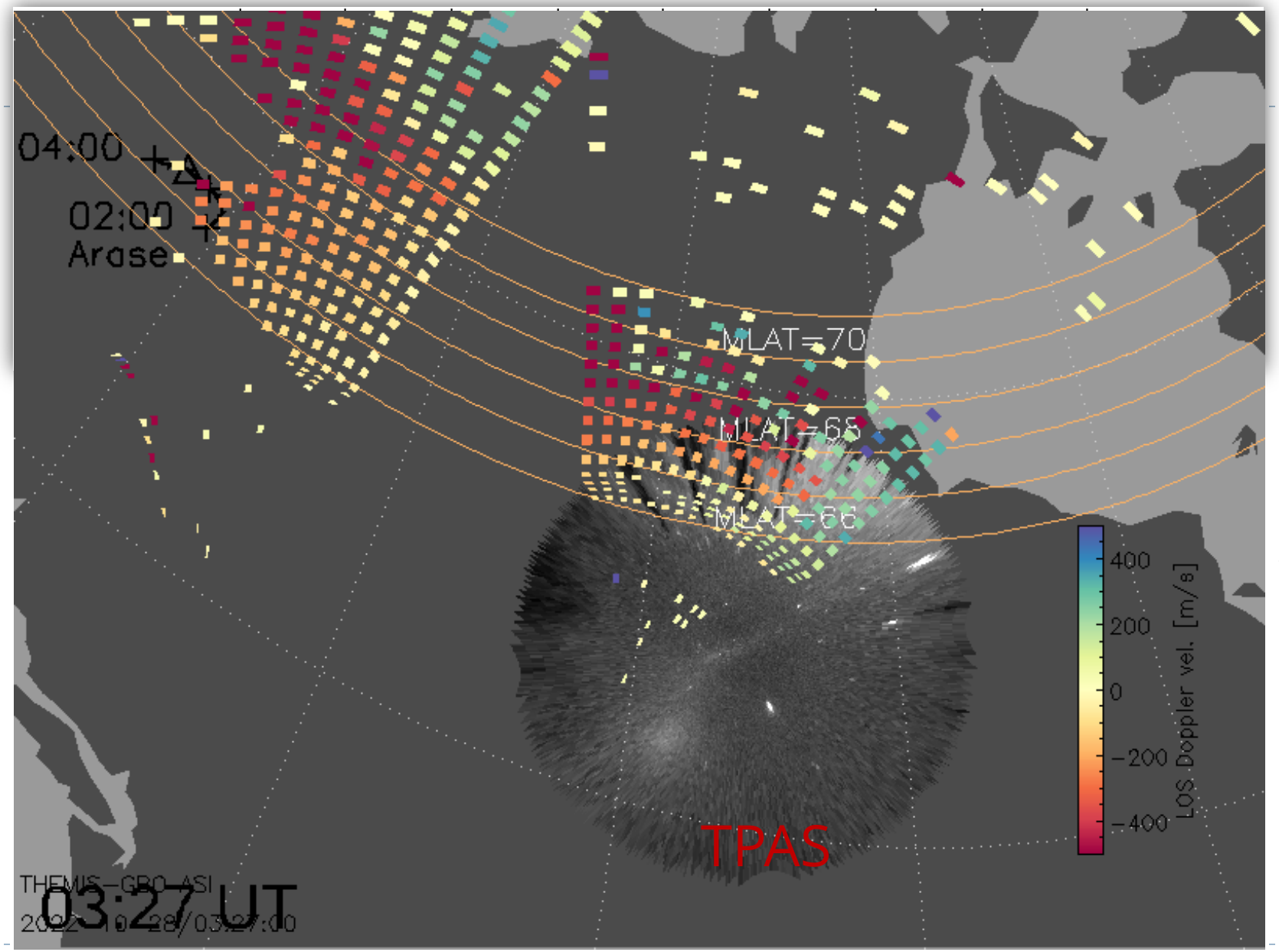
MLAT=66

only TPAS had a clear sky

THEMIS-GBO ASI
2022-10-28/02:40:00







Auroral brightening with a ray structure(?) was seen in the northern sky from ~02:55 UT!

Summary & Conclusions

Conjunction observations made by SuperDARN radars, Arase, and GOES satellites show:

- A westward fast flow including SAPS intensified and extended westward in the dusk-side ionosphere in association with an auroral pseudo-breakup.
- GOES saw no injection, while ERG detected multiple drifting clouds of energetic protons.

Indications and implications:

- These observations indicate that even a weak injection can cause a westward flow including SAPS.
- The ionospheric westward flow evolves azimuthally in association with that of energetic ions.
  - Suggesting that the poleward electric field, driving the westward flow, is applied by the westward-expanding ring current ions probably through the field-aligned current connecting the RC and the ionosphere.