Overview of patch observations in various instruments and challenges

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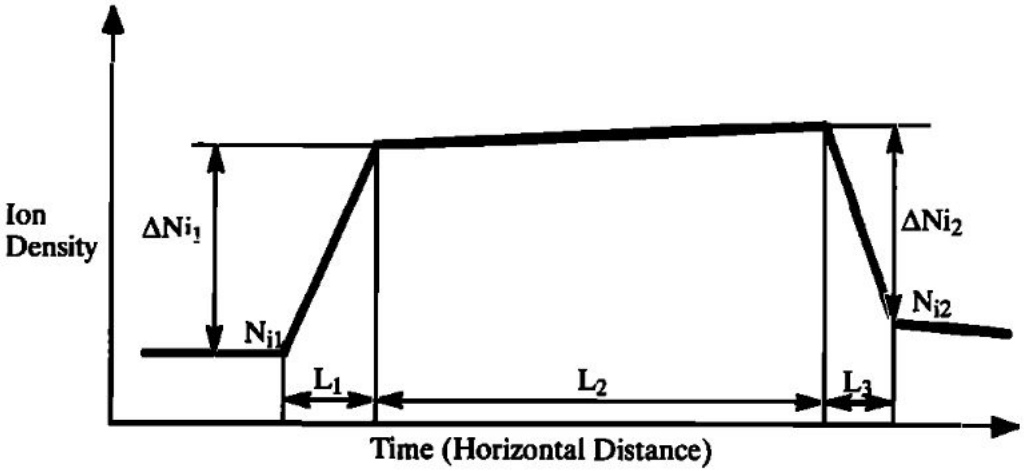
- What is the definition of the **polar cap**?
- What is the **density (TEC) threshold** to define a patch?
- How are the **background** density (TEC) level and **edges** determined?
- How are density enhancements in the **oval, polar cap arcs and TID** excluded?
- How do the patches defined by **various observations** (in-situ, ASI, ISR, TEC, and SuperDARN) compare to each other?

In-situ observations



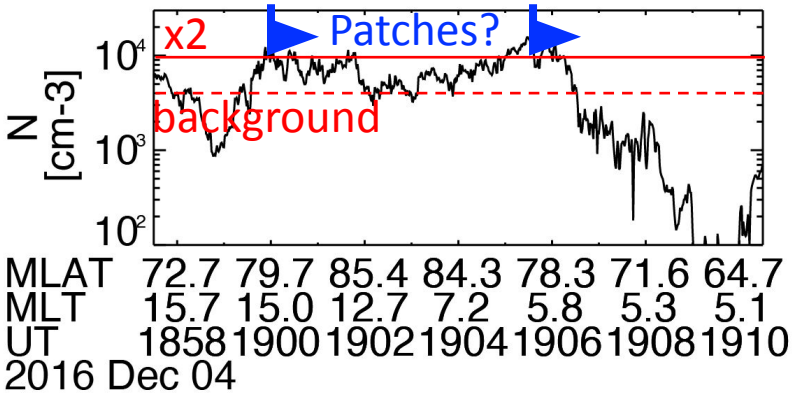
DE2
>70° MLAT
$\Delta N_i/N_i > 1$ (>twice background)
L_1: 40% increase in 140 km
L_2: 100-1250 km
N_i: Median over 1250 km
[Coley and Heelis, 1995]

DMSP
Poleward of precipitation
$\Delta N_i/N_i > 1$
L_1: No restriction
L_2: >200 km
N_i: Average excluding patches
[Zhang et al., 2021]

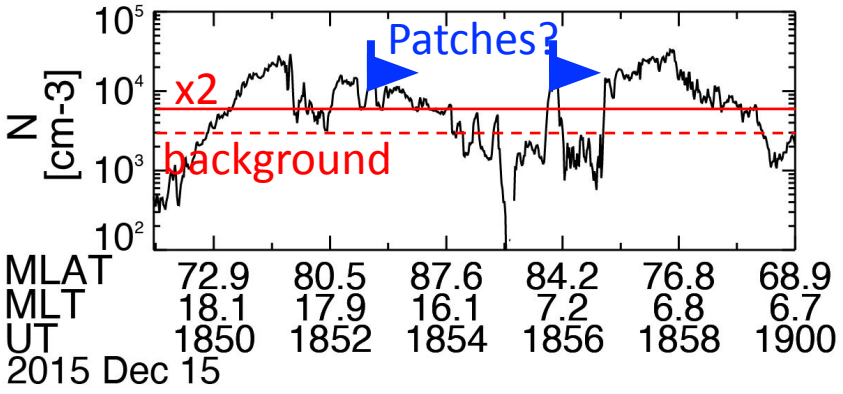
Swarm
>77° MLAT
$\Delta N_i/N_i > 1$
L_1: 30% of the patch density
L_2: 25-2000 km
N_i: 35th percentile
[Spicher et al., 2017]

- The $\Delta N_i/N_i > 1$ definition is generally accepted.
- There is no consensus about the background density, gradient, and patch size criteria.
- Various definitions are used to define the polar cap.

Are they polar cap patches?

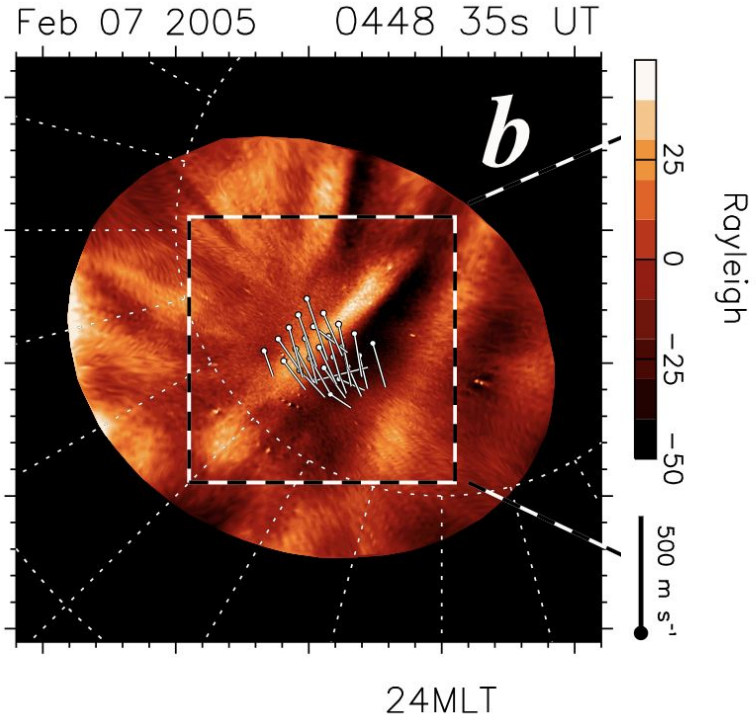


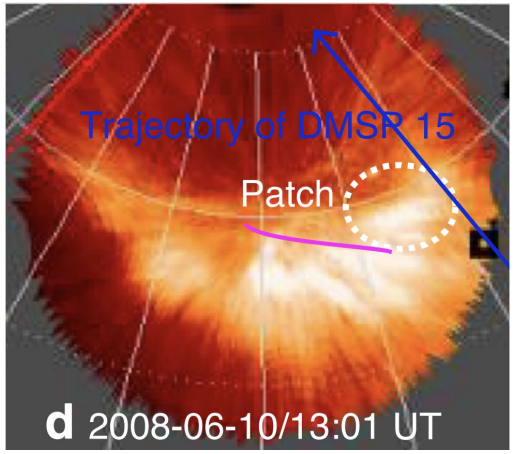
[Nishimura et al., 2021]

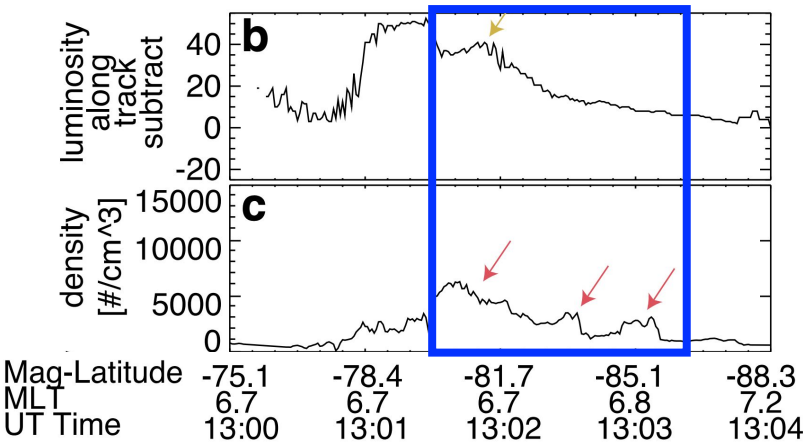


[Reidy et al., 2020]

All-sky imagers







[Wang et al., 2016]

Airglow patch definition

$\Delta I_{630.0} > 30$ Rayleigh at 630.0 nm

$\Delta I_{557.7} < 20$ Rayleigh at 557.7 nm

Background: 1-hour average

[Hosokawa et al., 2009]

- Considers precipitation and time history.
- Not biased to dense patches.

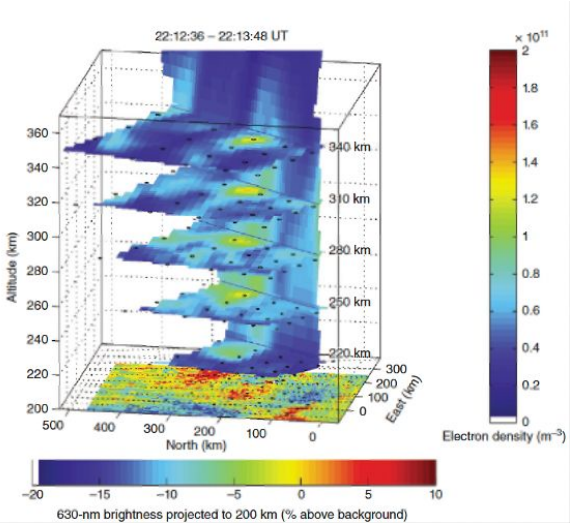
- Airglow luminosity and in-situ density do not necessarily agree.
- Airglow comes from recombination, not sensitive to high-altitude density.

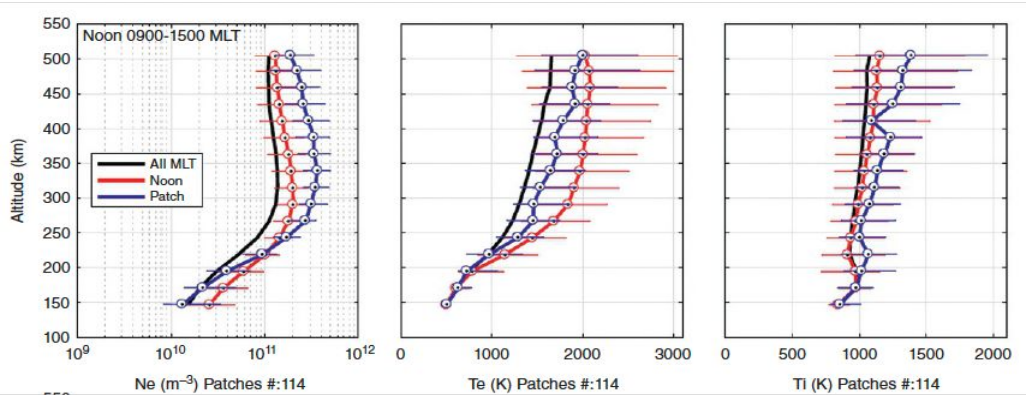
Polar cap patches observed by ISRs

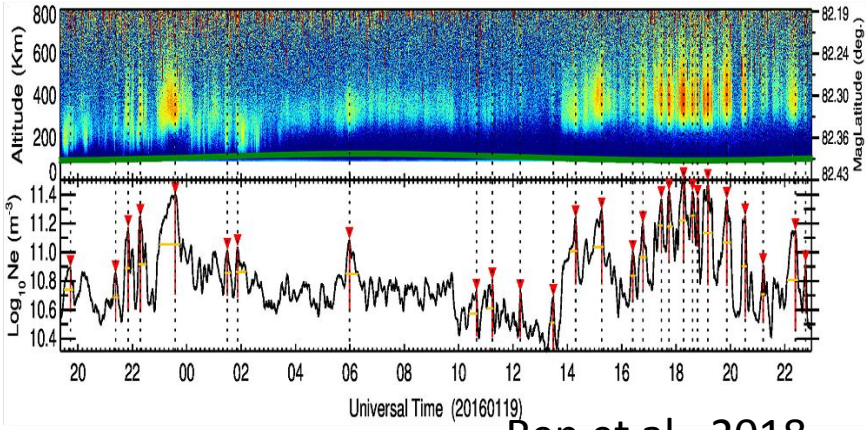
Ren et al., 2018

- A patch should appear as a density peak in the F-region (200-450 km) with a minimum prominence of $\log_{10}(2)$ in log scale, according to the classical definition by (Crowley, 1996).
- A patch should last >3 min but <2 hr in the radar observation, given a typical patch size range of ~100–1,000 km (Coley & Heelis, 1995) and a patch convection velocity range of ~150–500 m/s that Hosokawa et al. (2009) reported at Resolute Bay.

Dahlgren et al. 2012

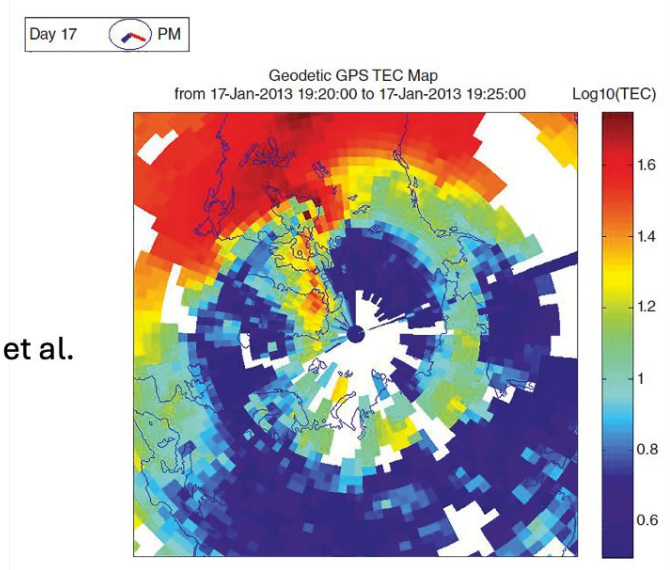




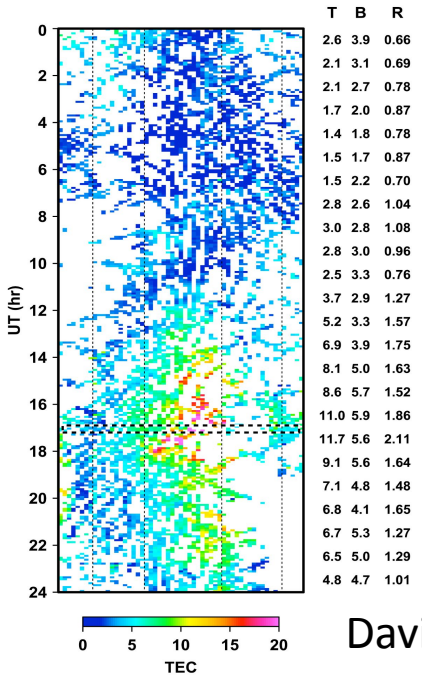


Ren et al., 2018

Patch identified in Total Electron Content (TEC) Data

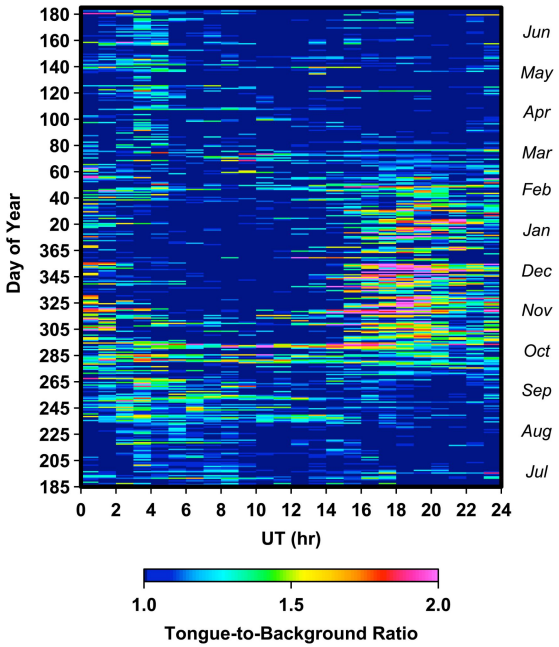


Foster et al. 2021



David et al. 2016

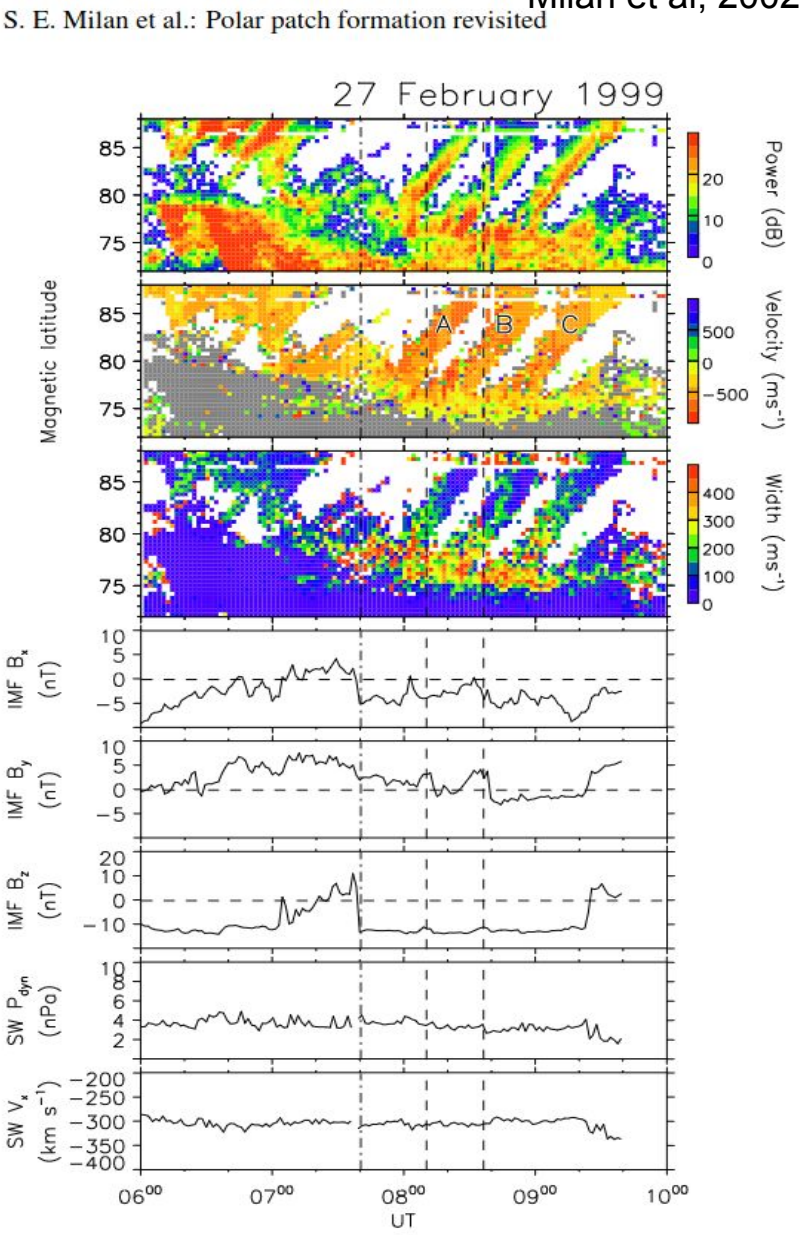
- The center segment is considered to represent the tongue (or patch), and the left and right segments represent the background.
- The ratio of the TEC average in the center segment to the average of the two background segments is “tongue-to-background ratio” or TBR
- TBR > ~1.3 pixels highlight typical patch seasonal and UT preference.



SuperDARN

Milan et al, 2002

- Automatic detections:
- - using machine learning tools to distinguish patch characteristics (more on this topic in the presentation on polar cap patches detection algorithms): if the patches have unique properties, SuperDARN could work as a standalone method for patches identification
- It would enable statistical studies and improve our understanding of physical processes involved



Summary

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- What is the **density (TEC) threshold** to define a patch?
- How are the **background** density (TEC) level and **edges** determined?
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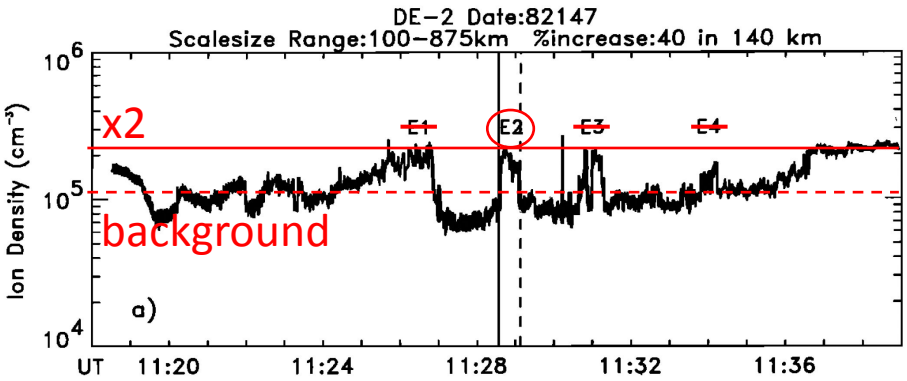
- How do the patches defined by **various observations** (in-situ, ASI, ISR, TEC, and SuperDARN) compare to each other?

- **Few consensus exists about patch definitions.** The definitions vary largely between the studies and techniques.
- It creates difficulties with comparing results and understanding patch properties. **How can we create a patch definition that we can agree on?**

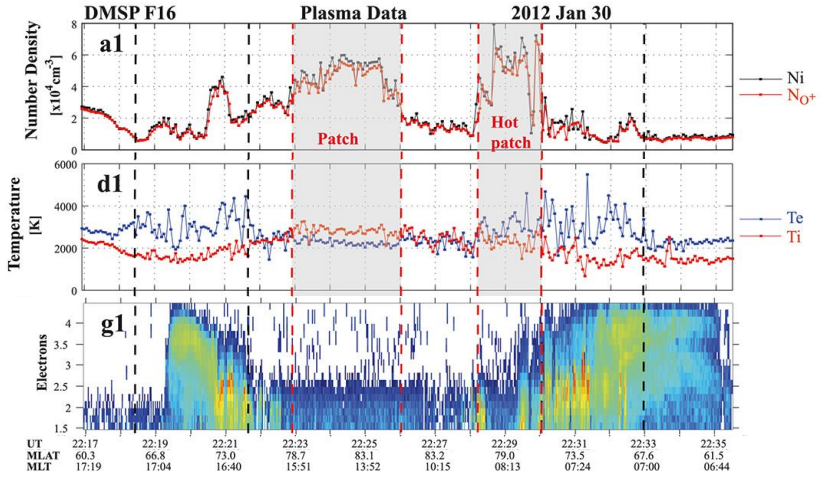
backup

Are they polar cap patches?



[Coley and Heelis, 1995]

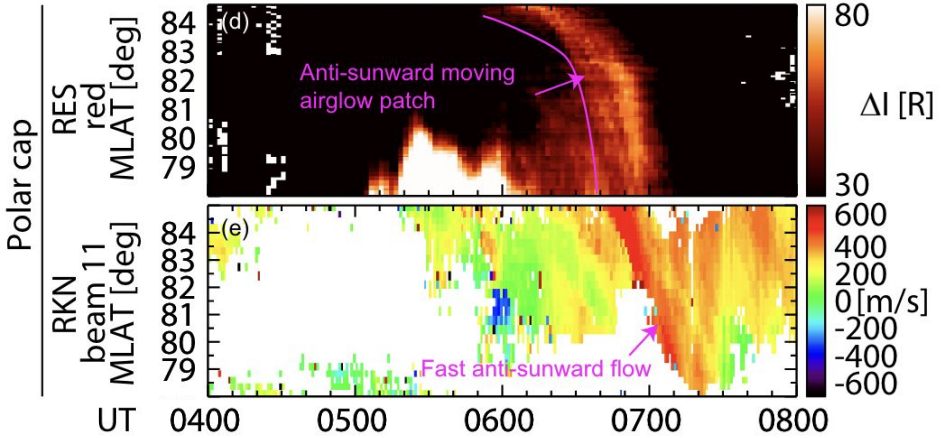
- The factor of 2 threshold misses many density enhancements.



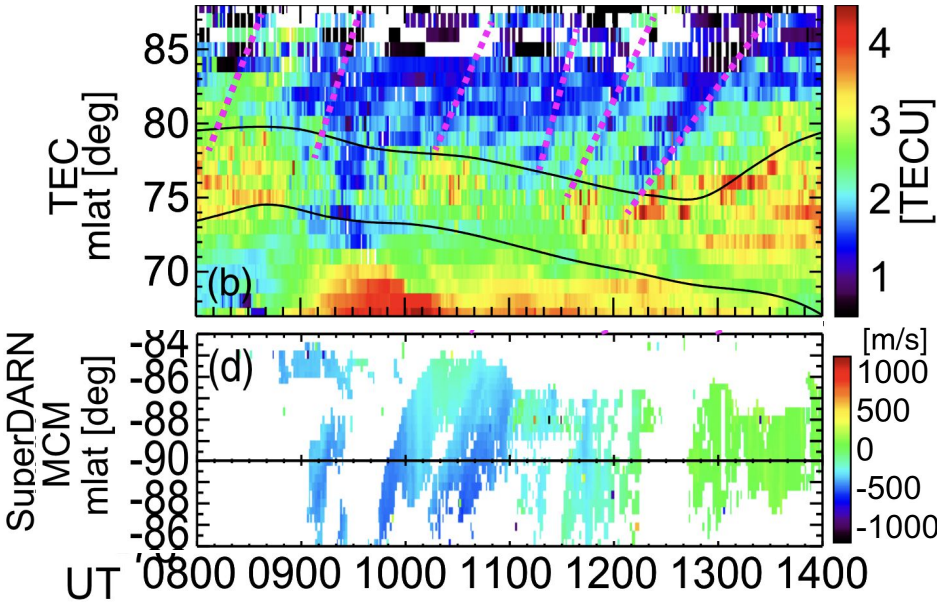
[Zhang et al., 2017]

SuperDARN

Airglow and SuperDARN



TEC and SuperDARN



[Nishimura et al., 2014, 2020]

- The SuperDARN echoes are enhanced in the airglow and TEC patches.
- The density irregularities in the patches enhance the backscatter of radar echoes.

- The echoes are also present outside the patches.
- SuperDARN detects more structures than TEC.
  - **How should we define the patches?**
    What do the differences tell us about patch properties?

$$O^+ + O_2 \longrightarrow O_2^+ + O$$

$$O_2^+ + e^- \longrightarrow O(^1D) + O$$

$$O(^1D) \longrightarrow O(^3P) + h\nu_{630.0\,nm}.$$