CEDAR Grand Challenge: Polar Cap Patches

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Redefining Polar Cap Patches: Understanding High-Latitude Irregularities, and their implications for the coupled MIT system

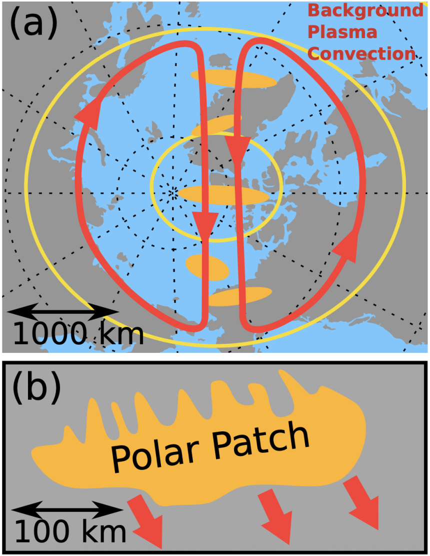
What is a Patch?

What are Polar Cap Patches?

A plasma density enhancement in the polar cap that is twice the background density.

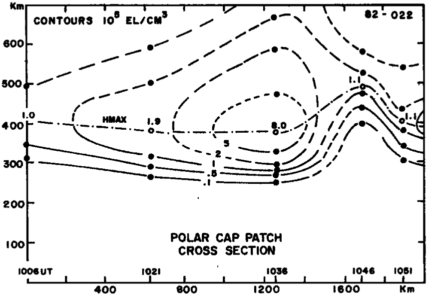
Additional "Accepted" Properties:

- Large scale phenomena (50 – 500 km)
- Moves with the background plasma convection, typically antisunwards across the center of the polar cap
- Plasma instability mechanisms may be active on the trailing edge, leading to irregularity formation



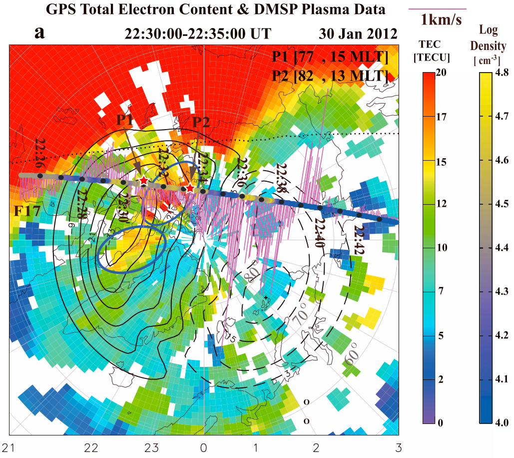
History

- Hill (1963) - First observations of polar cap patches
- Buchau et al. (1983, 1985); Weber et al. (1984); Weber et al. (1986) - Original definition of polar cap patches and description of properties
- Lockwood and Carlson (1992) - Formation of patches in the polar cap from dayside plasma
- Rodger and Graham (1996) - Peak patch occurance in winter and noon sector



(Weber et al., 1984)

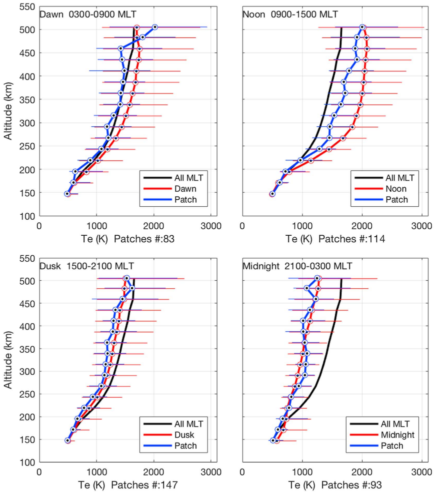
“Classic” Patches



(Zhang et al., 2017)

- Regions of dense dayside plasma that are dragged into the polar cap through the cusp
- Separated through fast flow channels driven by bursty reconnection at the magnetopause
- Move with the background plasma convection (anti-sunwards through the center of the polar cap for negative IMF Bz)

"Hot" Patches



(Ren et al., 2018)

Density enhancements of a similar morphology and size to "classical" polar cap patches, but hotter than the background plasma (instead of cooler). These are thought to be caused by soft precipitation.

Tongue of Ionization (TOI)

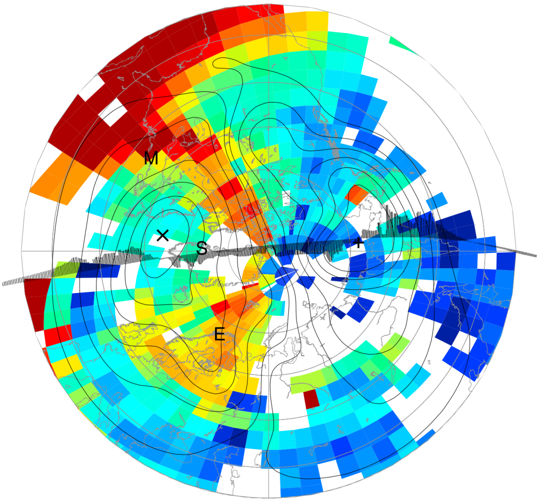
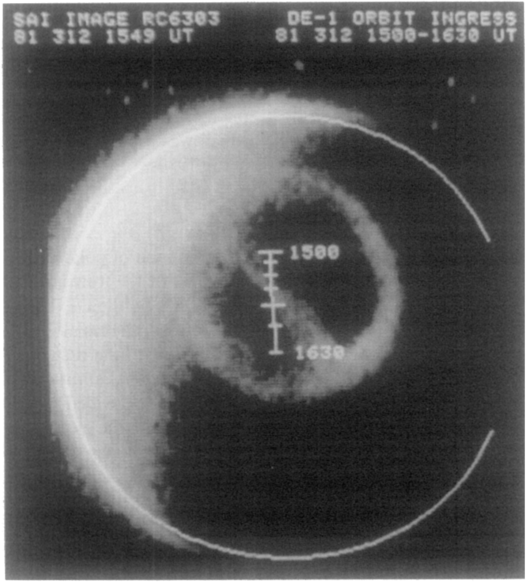


Figure 6. Polar projection of the TEC plume shown in Figure 2 is presented in the format of Figure 3. The SED/TOI plume is seen to extend continuously from its low-latitude source in the prenoon sector, through the dayside cusp and across the polar cap to the midnight sector over the EISCAT facility (E).

(Foster et al., 2005)

- A TOI is a stream of dense dayside plasma being pulled into the polar cap by the background convection.
- Are patches and TOIs different, or subcategories of the same general process, or different stages in the life cycle of a common process?

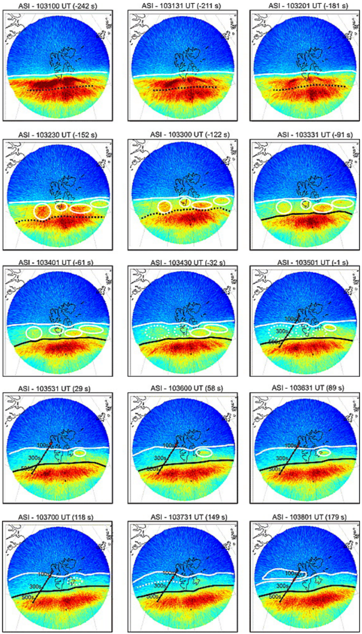
Sun-Aligned Arcs (SAA)



(Zhu et al., 1997)

- Auroral structures in the polar cap
- Also known as "polar cap aurora" or "theta aurora"
- Typically extend along the sun-earth line
- Generally associated with northwards IMF Bz

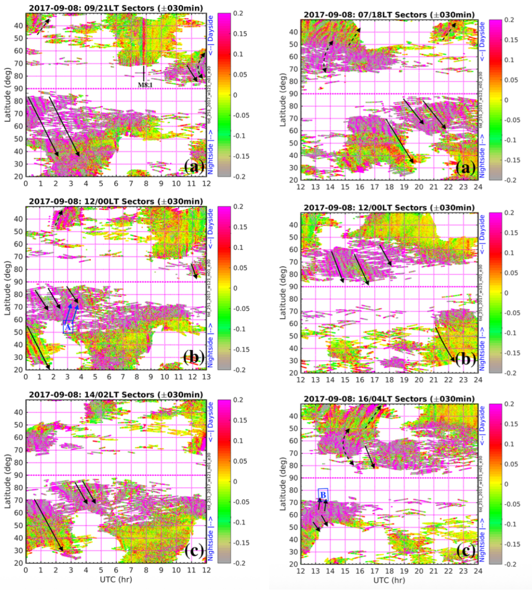
Polewards-Moving Auroral Forms (PMAF)



- Auroral structures that may move into the polar cap and act as patches
- A reservoir of dense plasma is heated and transported to the F-region through upwelling, and is then convected into the polar cap

(Lorentzen et al., 2010)

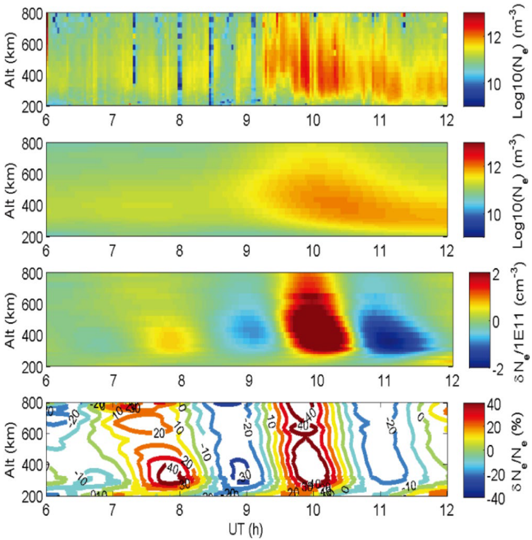
Traveling Ionospheric Disturbances (TID)



- TIDs are large-scale wave-like structures that have been observed propagating along the same direction as 2-cell convection in the polar cap.
- It is not entirely clear how antisunwards moving TIDs are generated.

(Zhang et al., 2019)

Atmospheric Gravity Waves (AGW)



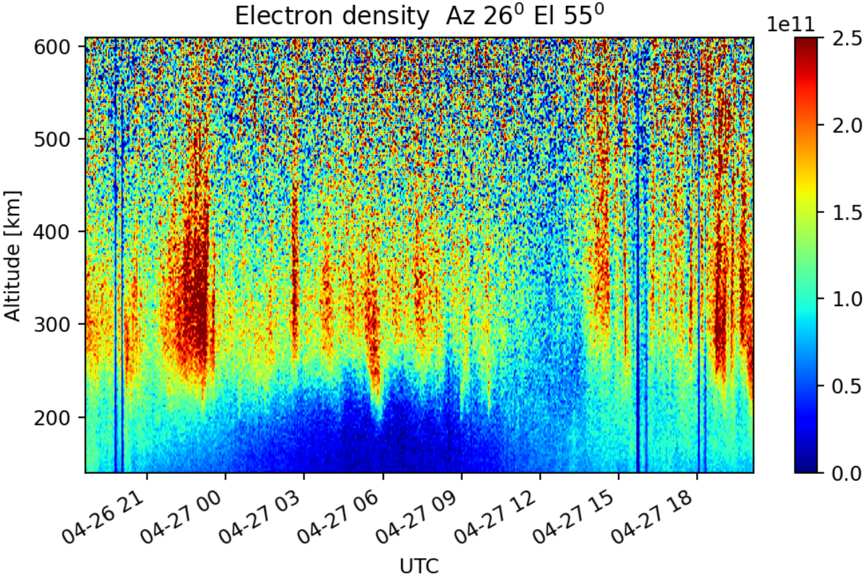
(Cai et al., 2011)

- AGWs generated from the secondary or tertiary dissipation of mountain waves, or generated by the polar vortex, can travel across the polar cap.
- Due to filtering based on the direction of the polar vortex, these waves travel preferentially sunwards across the polar cap.

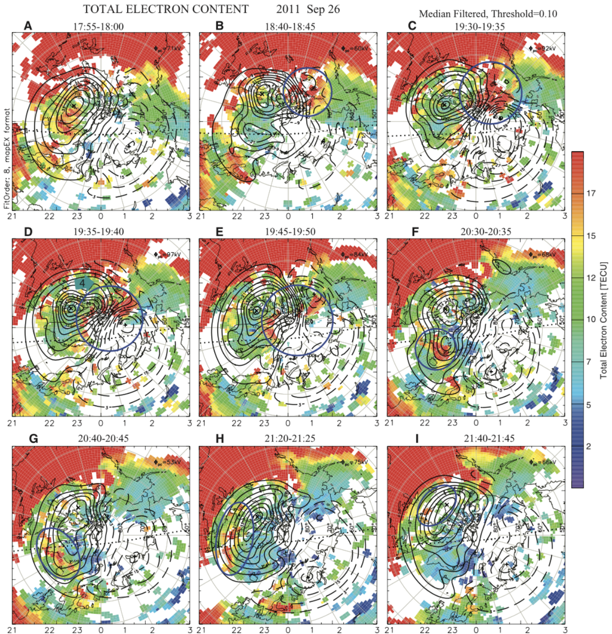
Potential Basis for an Updated Definition

1. **Temperature** - "Hot" enhancements are more likely to be generated from precipitation ("hot" patches, SAA, or PMAF) rather than dayside plasma transported into the polar cap.
2. **Motion** - Patches are expected to move with the background convection while AGWs and TIDs are *likely* to have a propagation direction relative to the background convection.
3. **Polar cap boundary** - Many studies use a hard latitude cutoff to define the polar cap, making it difficult to distinguish auroral and polar structures.
4. **Focus on the impact of patches** - For example, an operational definition of patches may be useful in the future that identifies only patches that may cause HF propagation deviations or transionospheric scintillation.

Is it a patch or a wave?



Patch Movement Across the Polar Cap



Is this just a question of semantics?

- An operational definition of a polar cap patch that can be applied uniformly would be very helpful
- In this Grand Challenge, we aim to go beyond just defining a "patch" to reexamining the entire concept of large-scale polar cap structures more holistically
- Several of the phenomena that could contribute to density enhancements are very different and should not be analyzed together
- We also aim to bring attention to phenomena that are discussed less frequently in the polar cap (such as waves) and better understand what research needs to be done

Themes for Grand Challenge

Year 1:

- Data and Modeling Resources Available
- Patch Generation and Dynamics from the Magnetospheric Perspective
- Interaction Between Patches and the Broader Geospace System

Year 2:

- Patch/Polar TID Generation and Dynamics front the Thermospheric Perspective
- Small-Scale Irregularities and Plasma Instability Physics Associated with Patches

Year 3:

- Space Weather Impacts of Patches
- Redefining “Patches” and Recommendations for the Community

Strategy for Grand Challenge

- To encourage more participation, particularly among students, we will hold an additional virtual meeting every year in the early spring. This will provide additional opportunities for participants to present results, give update on prior work, and discuss ongoing collaborations.
- We will curate datasets relevant to Polar Cap Patches and present them to the community as prospective starting points for researchers new to this area.
- There will be a strong focus on community discussion in the sessions.
- We strongly encourage any students/early career scientists to get involved!

Tuesday Afternoon Session 13:30–15:30

Time	Name	Title
13:30	Shasha Zou	Tutorial
13:50	Taylor Cameron	Polar Cap Patch Impacts on HF Radio Propagation
14:00	Waqar Younas	Ionospheric Irregularities and Their Impact on Position Accuracy in the Antarctic Region
14:10	Sophie Maguire	Observations of structures in the high-latitude ionosphere and their effects for GNSS
14:20	Braeden Peterson	Correlation Analysis of Ionospheric Drivers on Scintillations
14:30	Aidan Thayer	A Statistical Background Study of Polar Latitudes Using Longterm AMISR Data
14:40	Olu Jonah	Long-term variability of polar cap patches using Advanced Modular Incoherent Scatter Radars (AMISRs)
14:50	Amelia Lee	Meso-scale Polar Cap Flows and their Impact on Polar Cap Patch Evolution
15:00	Roger Varney	No Pinching: Topological Constraints on Polar Cap Patch Formation Mechanisms

Wednesday Morning Session 10:00–12:00

Time	Name	Title
10:00	Shunrong Zhang	GNSS TEC measurements of polar cap patches and TIDs during recent storms
10:10	Gareth Perry	A case study of HF scintillation during a polar-cap patch event
10:20	Larry Lyons	Importance of flow channels in greatly structuring the polar cap, including on large temporal and spatial scales
10:30	Ying Zou	Polar cap patches traced by PMRAFs: Hemispheric symmetry and asymmetry
10:40	Asti Bhatt	Datasets for investigating polar cap patches
10:50		Open Discussion

Thank You!
Please Attend Our Sessions!

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