Statistical Characteristics of the Ionospheric Polar Cap Patches

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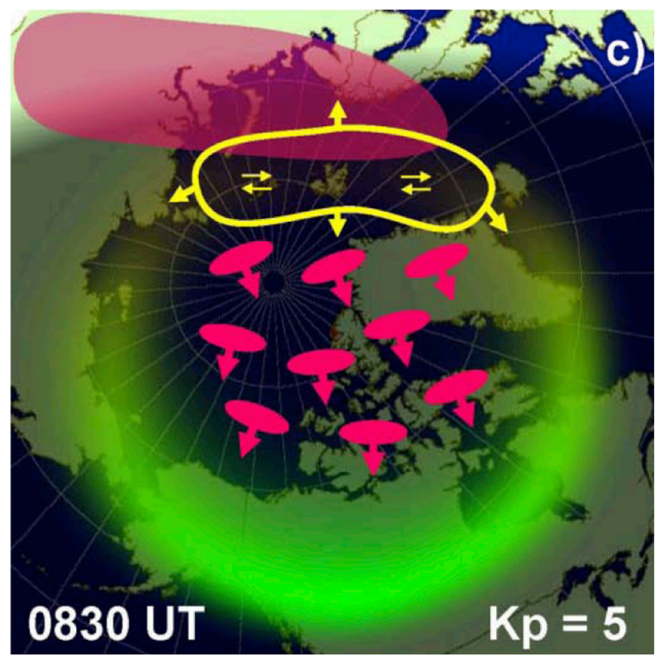
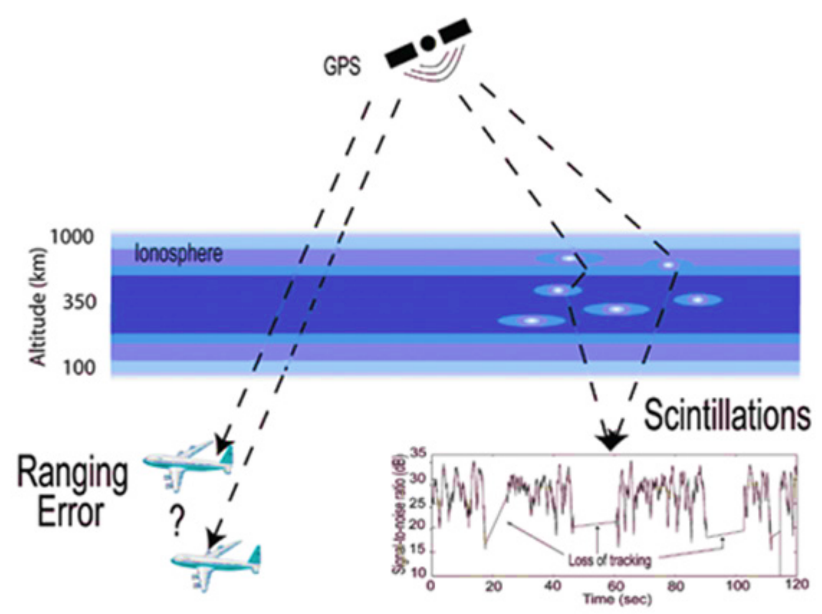
INTRODUCTION

Polar cap patches

- 100-1000 km islands of **high-density** plasma in the ionosphere above the polar region.
- **Double** the density of their surrounding background, at least.



[Moen, 2013]



[Dr. Paul M. Kinter]

- Main cause for disturbances on navigation and communication signals in polar regions:
  - Cause scintillation and outages of satellites communication.
  - Degrade performance of Global Navigation Satellite System (GNSS).

PURPOSE & METHOD

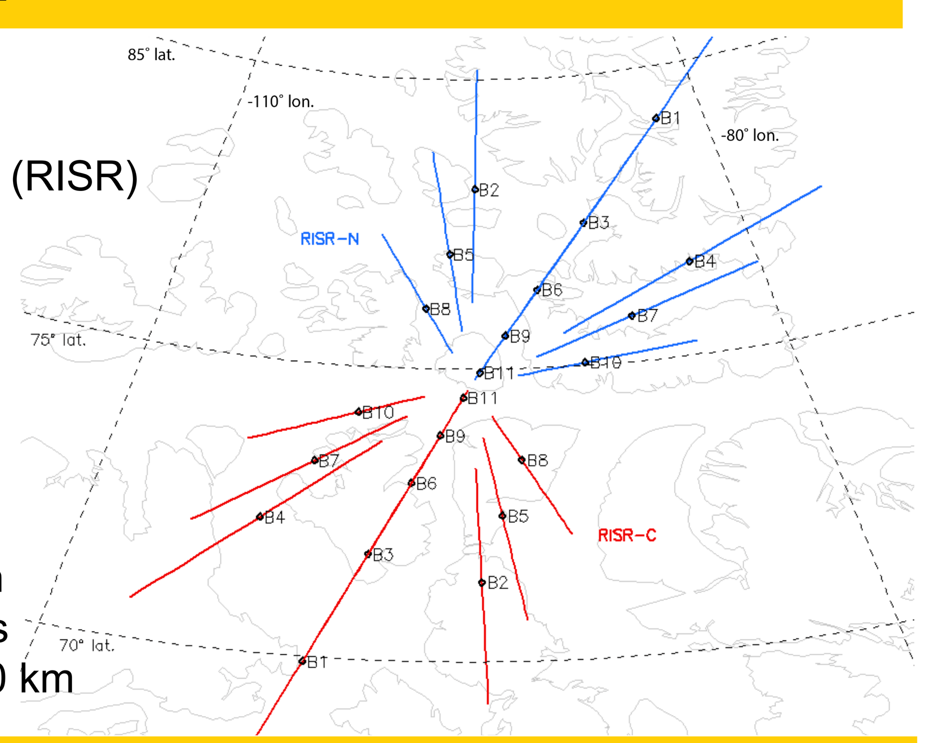
Question: How/when do they form and propagate across the polar cap?

- Develop the ability to predict this kind of ionospheric irregularities.
- Understand the formation mechanism, transpolar evolution and detailed structure of the polar cap patches.
- Use observations from the ground-based Incoherent Scatter Radar and other instruments such as all-sky imagers (ASI) and satellites.

INSTRUMENTATION

Incoherent Scatter Radar

- Located at Resolute Bay, Canada (RISR)
- Multiple-beam measurement of
  1) Electron density (N_e)
  2) Electron temperature (T_e)
  3) Ion temperature (T_i)
  4) Line-of-sight velocity (V_{los})
- Temporal resolution: 1 min / 5 min
- Spatial resolution: up to 51 beams
- Spatial coverage: ~ 800 km × 400 km

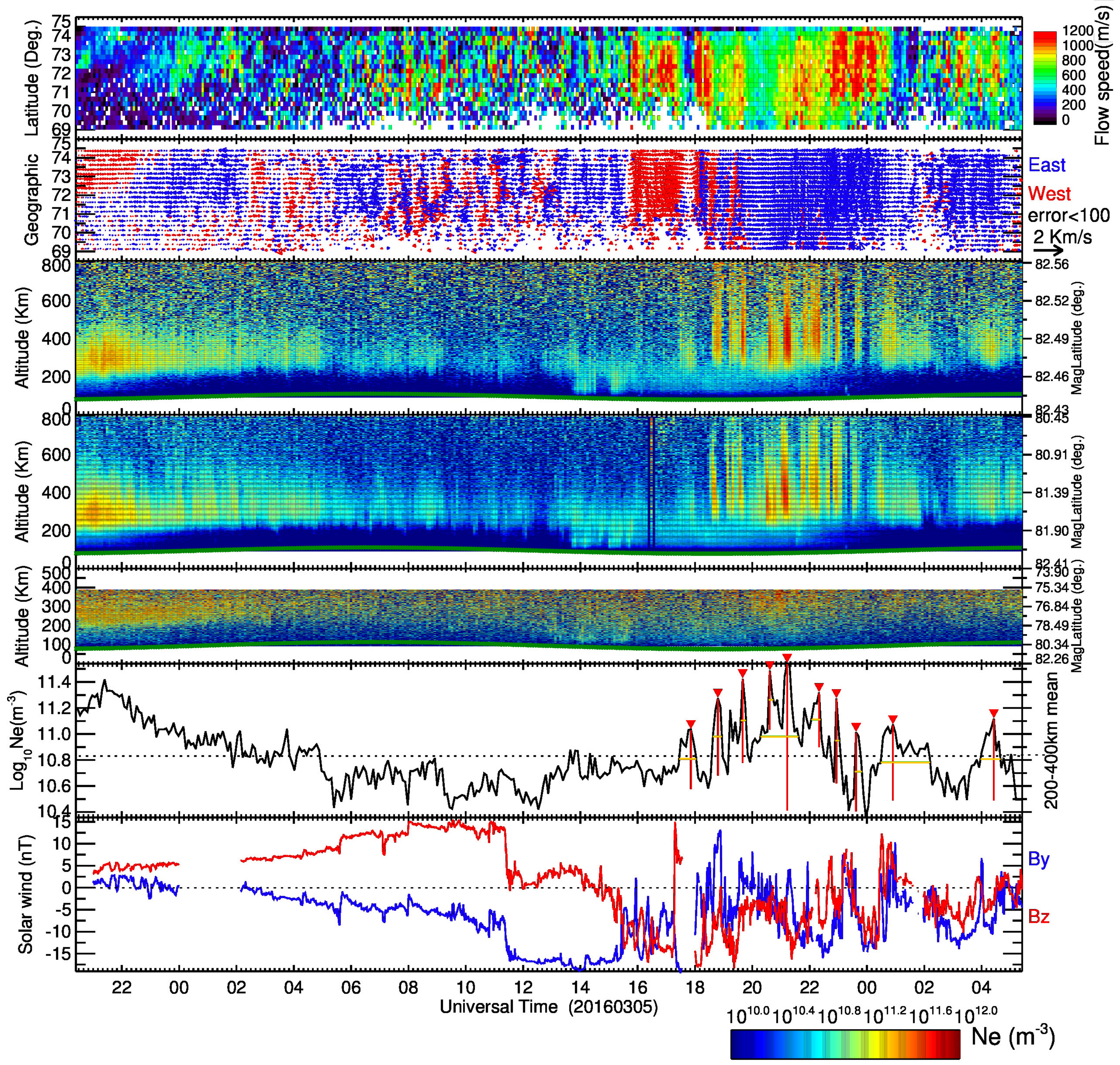


RESULTS

RISR-C 5-min Data Sample

- **First two panels**: The **speed** and **vectors** of horizontal flow velocity of ionospheric plasma, obtained by combining V_{los} data from all the beams.
- **Middle three panels: Electron density (*Ne*)** measurements from three beam, such as B11, B6 and B1. *Ne* values in log-scaled color vs. time and altitude.
- **Sixth panel**: Using the vertical beam, B11 (the third panel), average *Ne* from 200 km to 400 km altitude. **Find those peaks with at least two times values of their surroundings.** The dashed line shows average *Ne* over the entire time period.
- **Bottom panel:** Measurement of the **interplanetary magnetic field (IMF)** in the **solar wind** from NASA OMNI database.

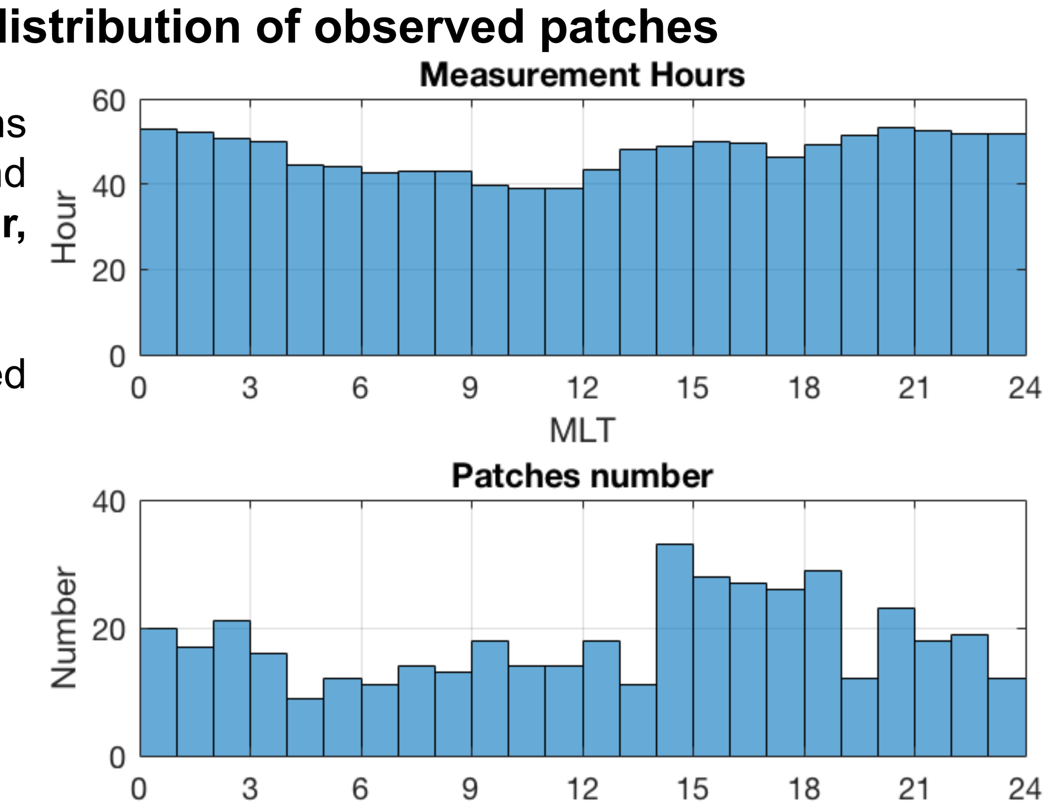
RESULTS



- During the nearly 28-hour observation, firstly we see a continuous band of enhanced electron density and slower flow speed in the earlier 22-04 UT (15-21 MLT) period.
- During 06-12 UT (23-05 MLT) the density is low on the night side.
- Starting at around 11:30 UT (4:30 MLT) there is a geomagnetic storm coming, followed by particle precipitation beginning at around 14 UT (7 MLT) and then a series of separate patches with significantly increased density ~$10^{11.5}$ m^{-3} at 18-00 UT (11-17 MLT, noon and afternoon sector). The convection flow speed also increases and shows some patch-like features.
- In the sixth panel, the red triangles mark those peaks that are identified as patches. The red and yellow solid lines within those peaks represent their prominences and half-prominence widths, respectively.
- Peaks with prominences larger than $\log_{10}(2) \approx 0.3$ are identified as patches.
- Peaks with widths larger than 2 hours are excluded and regarded as background or tongue of ionization.

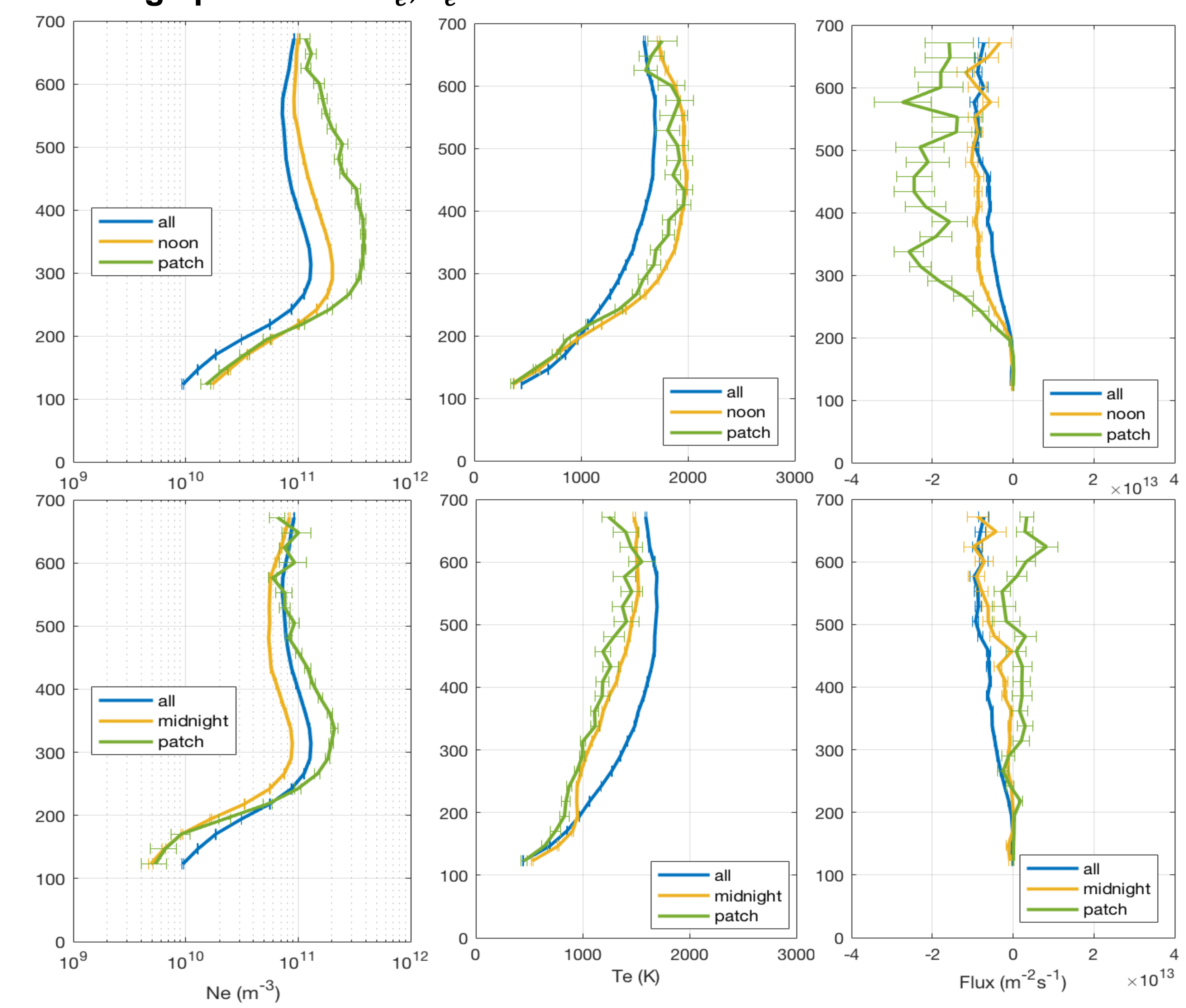
Magnetic local time (MLT) distribution of observed patches

- Based on data in 6 months from **January to March** and from **September to December, 2016.**
- 435 patches are identified using the criteria.
- A peak of occurrence stands out at the **dusk** sector at **15-19 MLT**, while the **dawn** sector at **4-8 MLT** seems to have slightly less patches observed.



RESULTS

Average profiles of N_e, T_e and vertical ion flux



- Average profiles of **electron density (left), electron temperature (middle)** and **vertical ion flux (right)** in **noon (top row)** and **midnight (bottom row)** sector.
  - Blue: average over all the MLT.
  - Yellow: average over noon sector (9-15 MLT) or midnight sector (21-03 MLT).
  - Green: average over all the patches that observed in the corresponding sector.
- The peak density within the patches (green) is higher than the sector-averaged value (yellow), while their temperatures Te (green) are lower than the sector-averaged values (yellow).
- The ion flux within the patches (green) tends to be downward at dayside and very close to zero or even upward at some altitude at nightside, while the overall ion flux (yellow) shows downward direction at both dayside and nightside.

CONCLUSIONS

- Using RISR measurements we have the ability to observe and study the characteristics of high-density ionospheric patches deep in the polar cap region.
- Statistically speaking, based on the data obtained in these 6 months:
  - More patches tend to appear and be observed on the afternoon-dusk sector **15-19 MLT**.
  - While the density within the patches is higher, the electron temperature of those patches is lower than their background.
  - While the vertical ion flux within the patches is downward on the dayside, it is close to zero or even upward within the patches observed on the nightside.

FUTURE WORK

- Correlation study between patch occurrence, seasons and IMF conditions.
- Individual case study for each series of patches.
  - Test the existing theory for patches formation: transient reconnection, pulsating particle precipitation, sudden change of convection pattern, high-speed jet flow.
  - Track the transpolar propagation of the patches and study their structuring process while travelling.

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[CEDAR, June, 2017]