On the Generation Mechanism of Polar Cap Patches

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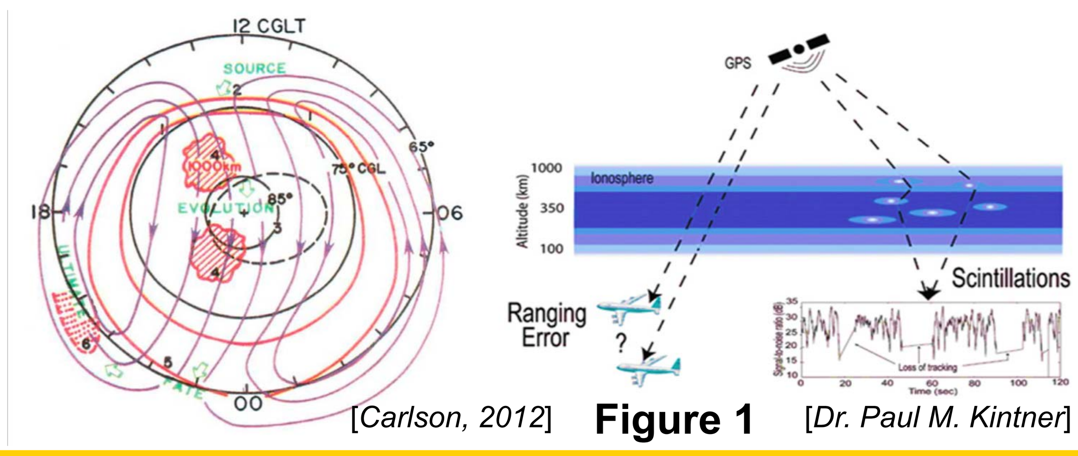
INTRODUCTION

Polar cap patches

- 100 - 1000 km islands of **high-density** plasma in the polar cap ionosphere.
- Double the density of their surrounding background, at least.
- Main cause for disruptions of satellite navigation and communication signals in polar cap regions.



[Carlson, 2012] **Figure 1** [Dr. Paul M. Kintner]

PURPOSE & METHOD

- Study the generation mechanism of polar cap patches in a database based on observations from Incoherent Scatter Radar at Resolute Bay, Canada (RISR-C).
  1. Previously developed an automatic algorithm to identify the patches observed by RISR-C and constructed a database of 443 patches.
  2. Trace patches back to the dayside cusp region using SuperDARN convection measurements.
  3. Construct the typical IMF changes at the time of patch generation using superposed epoch analysis.

RESULT ①: Patch identification and database

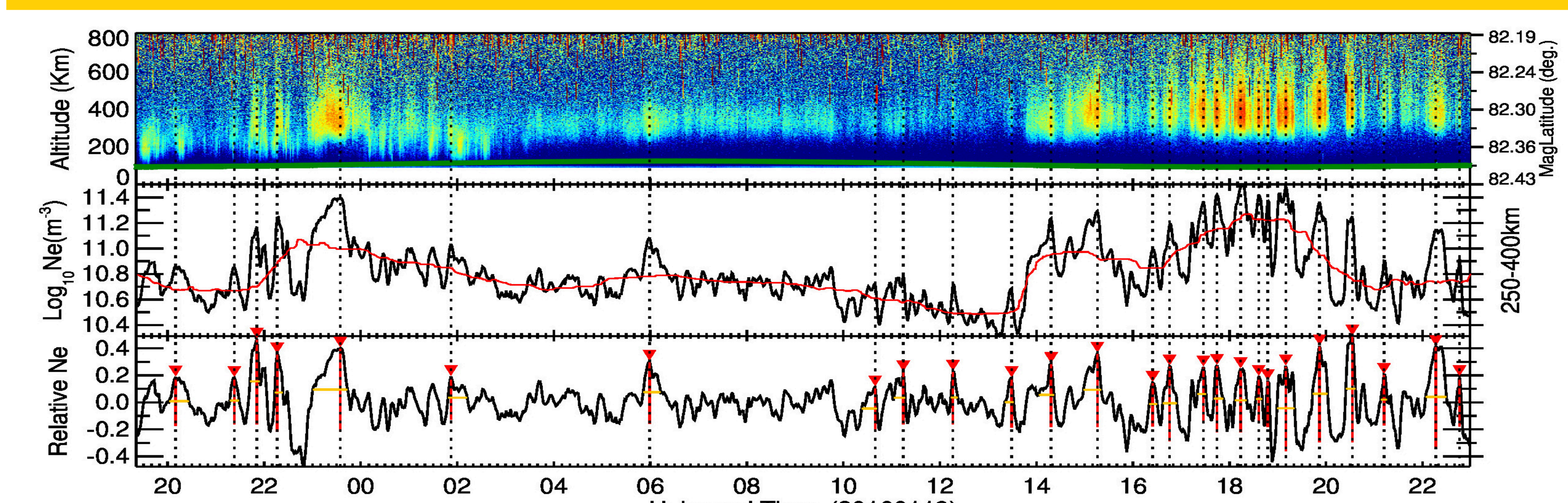


Figure 2

- **First panel: Electron density (Ne)** measurements from a vertical beam. Ne values in log-scaled color vs. universal time and altitude.
- **Second panel:** Average Ne from 250 km to 400 km altitude (black curve). Apply a 2-hour-window median filter to get the background variation in Ne (red curve).
- **Third panel:** Subtract background variation from the average Ne. An algorithm is applied to only identify those peaks with minimum prominences of $\log_{10}(2)$ and maximum widths of 2 hours.

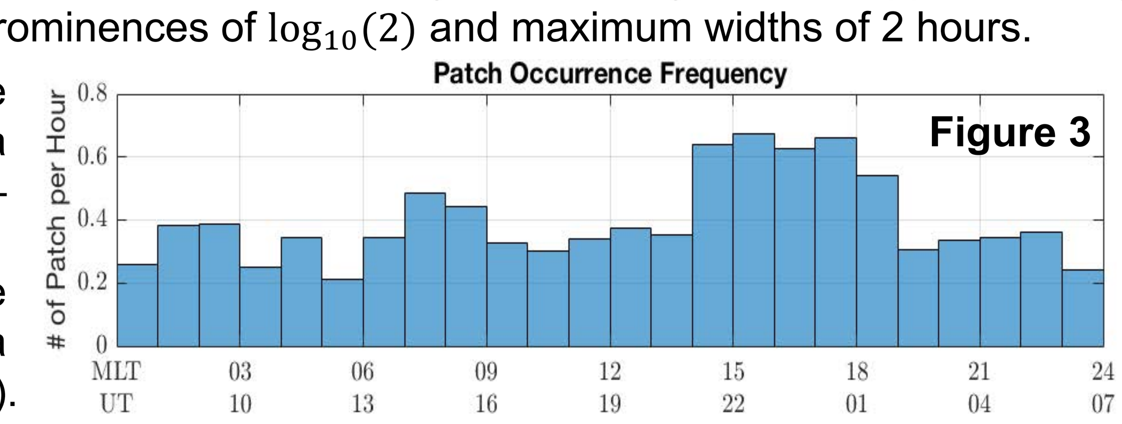


Figure 3

- A dataset of 443 patches are constructed using RISR-C data taken in Jan.–March and Sept. – Dec., 2016.
- **Figure 3** shows distribution of the patch occurrence frequency as a function of magnetic local time (MLT).
- The patches are observed more often in the afternoon sector between 1400-1900 MLT.

RESULT ③: IMF conditions for patch generation

- All the patches in the database are traced back to the dayside cusp, where they are generated and the time of the generation is recorded.
- Quality of the tracing result is affected by the amount of real velocity measurements near the tracking points.
- **Figure 4** shows tracing trajectories of 4 different patches observed by RISR-C at different MLTs. The start and end UTs of each trajectory are labeled.
- Color indicates number of SuperDARN real velocity measurement data points within 200 km radius of each tracking point (Oksavik et al.,2010).

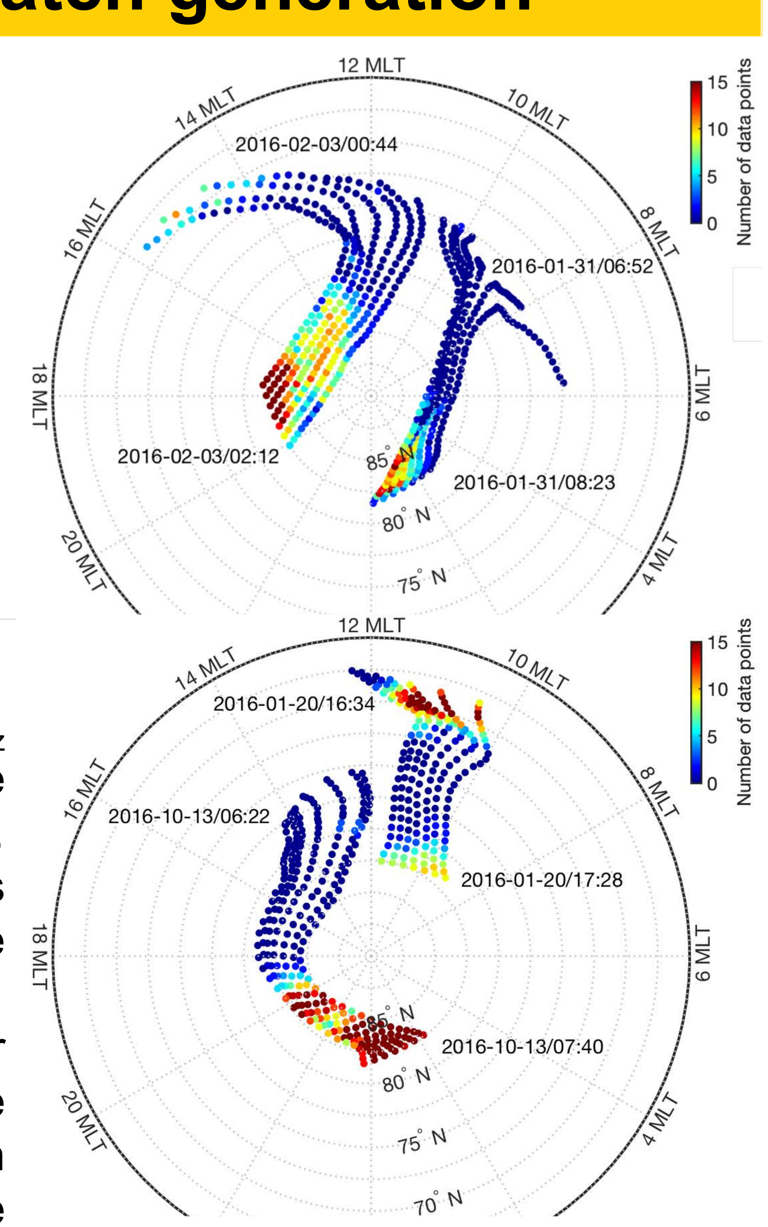
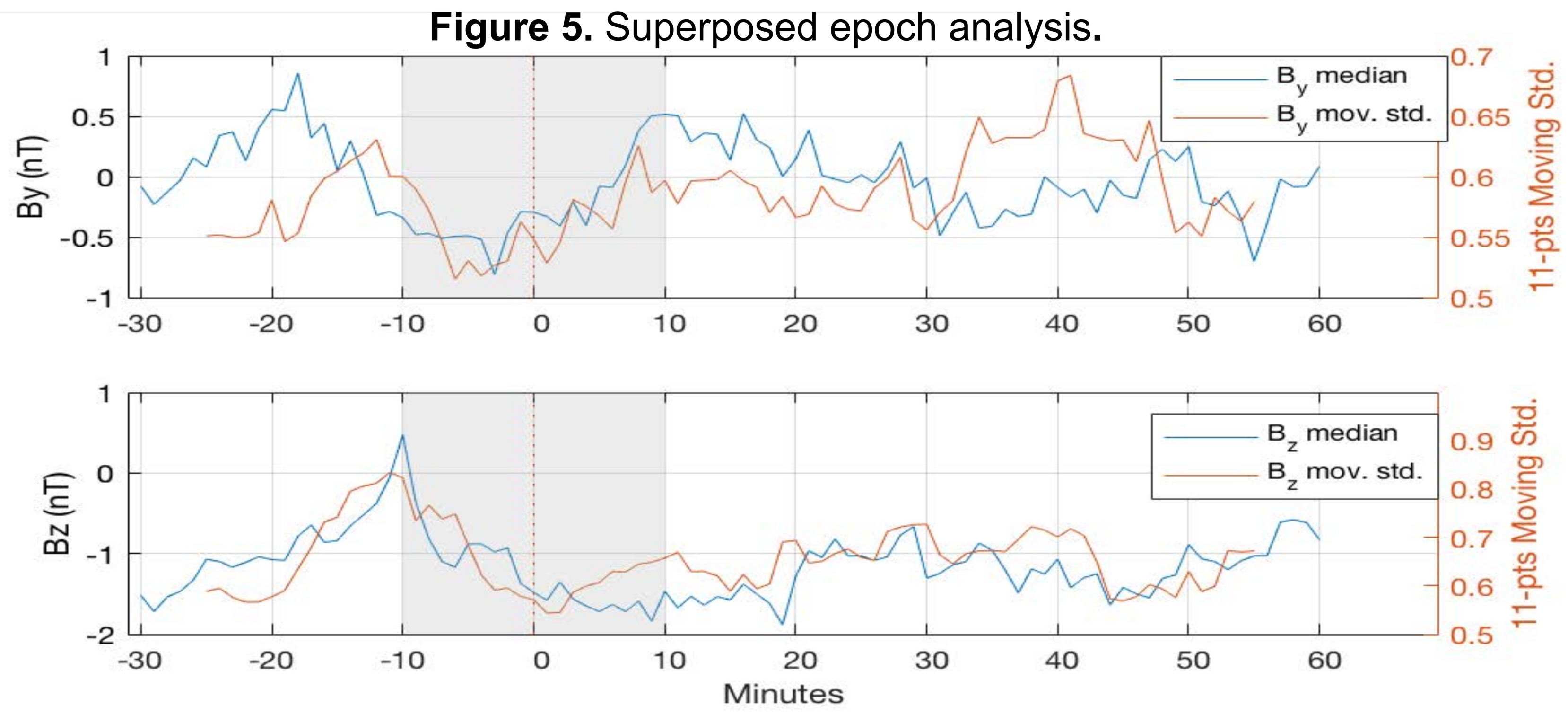


Figure 4. Tracing trajectories.

Statistical IMF conditions for patch generation

- Superposed epoch analysis of the IMF B_y and B_z components 30 min before and 60 min after the recorded patch generation time is shown in **Figure 5**.
- In **Figure 5**, both the median IMF B_y and B_z curves (blue) and the median curves of their 11-minute moving standard deviations (red) are plotted.
- Assuming ~10 min time delay between the solar wind and the dayside convection response, there are sharp IMF B_z southward turning and IMF B_y sign change from positive to negative near -10min. These conditions are favored for the patch generation.

Figure 5. Superposed epoch analysis.



RESULT ②: Patch tracing

- Track the patch back to its origin near dayside cusp by calculating its trajectory based on SuperDARN convection measurement with a 2-minute time cadence.
- For each patch observed by RISR-C, several tracking points near RISR-C are launched.
- The tracing process stops when patch reaches near cusp, whose location is estimated by empirical formulas parameterized by IMF conditions (Zhang et al., 2013).
- To illustrate this method, a patch observed by GPS total electron content (TEC) and the tracing results are shown in **Figure 6**.

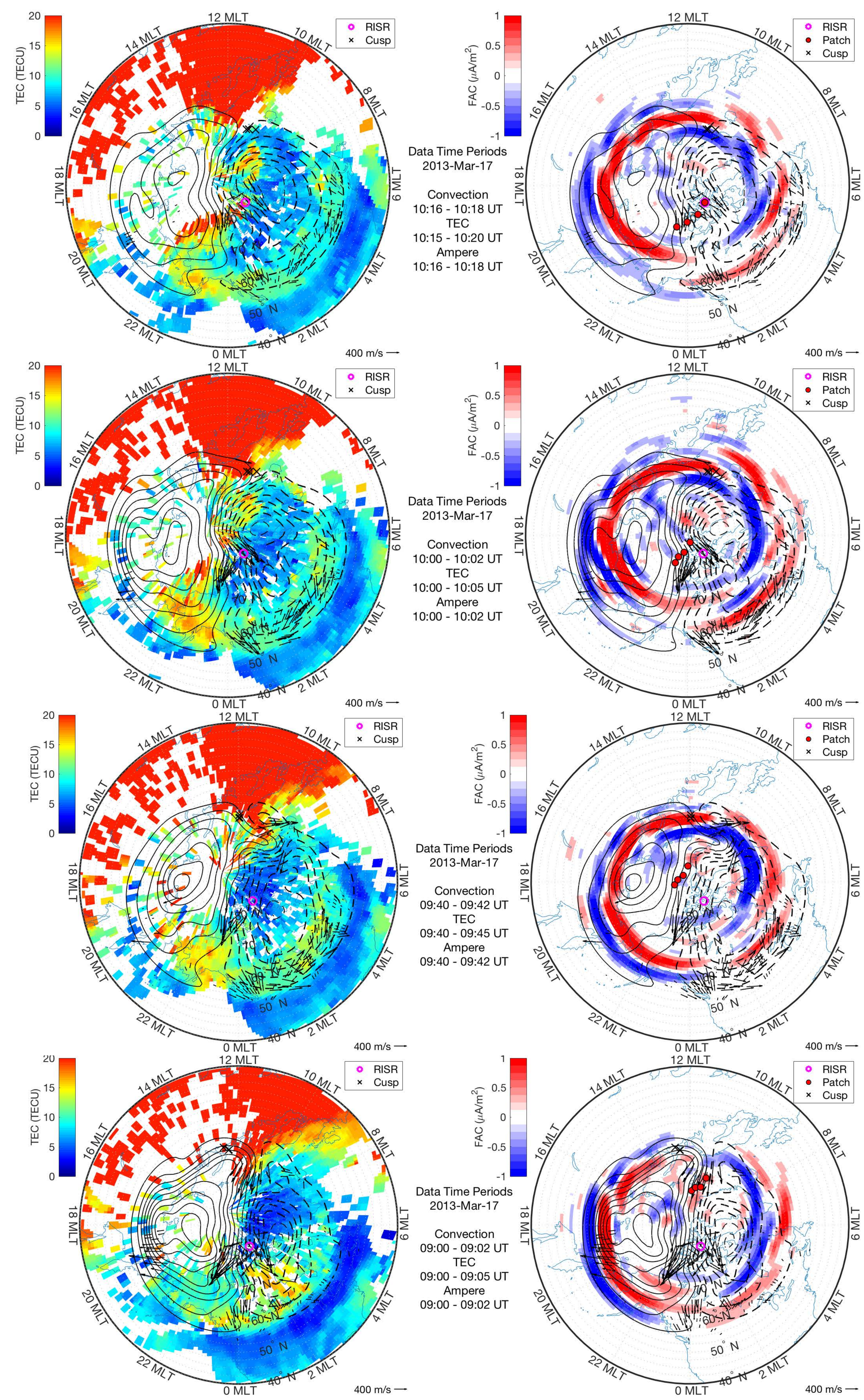


Figure 6. Tracing process of a polar cap patch observed on GPS TEC map (left column, data from Madrigal) on March 17, 2013. The tracking points are shown on the right column with AMPERE field-align current density. Data of convection contours and vectors are from SuperDARN.

CONCLUSIONS

1. By analyzing the data taken by RISR-C in 2016, a dataset of 443 polar cap patches has been constructed and their statistical characteristics are reported (Ren et al., 2018, submitted).
2. An automatic method has been developed, which can successfully trace patches to their origins at the dayside cusp, allowing a superposed epoch study of the typical IMF conditions for patch generation.
3. Statistically, the IMF B_z southward turning ~2 nT and the IMF B_y sign change from positive to negative are preferred conditions for the patch generation.

References:

- Oksavik, K., Barth, V. L., Moen, J., & Lester, M. (2010). On the entry and transit of high-density plasma across the polar cap. Journal of Geophysical Research: Space Physics, 115(A12).
- Zhang, B., Brambles, O., Lotko, W., Dunlap-Shohl, W., Smith, R., Wiltberger, M., & Lyon, J. (2013). Predicting the location of polar cusp in the Lyon-Fedder-Mobarry global magnetosphere simulation. Journal of Geophysical Research: Space Physics, 118(10), 6327-6337.
- Ren, J., Zou, S., Gillies, R., Donovan, E., Varney, R. H., Statistical Characteristics of Polar Cap Patches Observed by RISR-C, manuscript submitted for publication.