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High-latitude Joule heating hot spot in the afternoon sector

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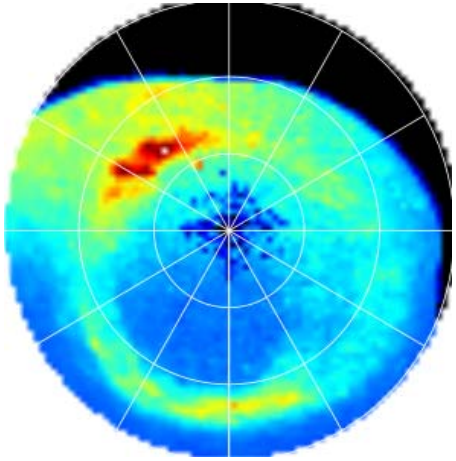
Afternoon hot spots in the high-latitude ionosphere

- Close to 15 MLT and 75° MLAT
- Seen in several frameworks:

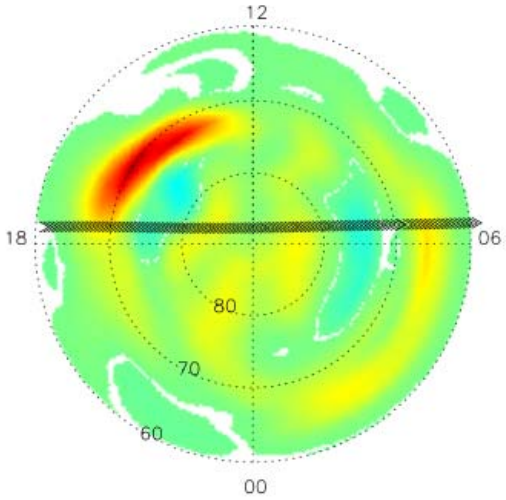
Auroral precipitation



[Liou et al., 1997]

Soft electron precipitaion

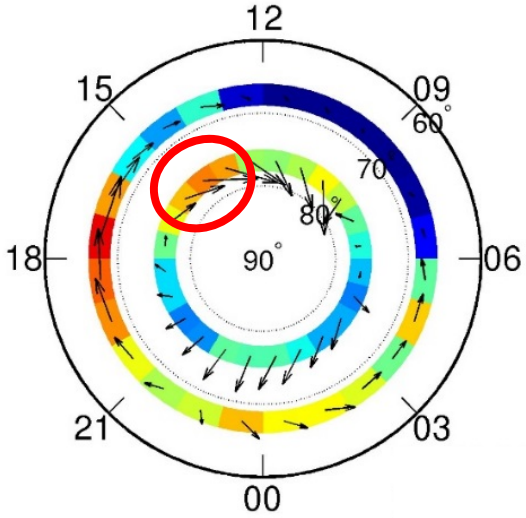
Poynting flux



[Waters et al., 2004]

Located between an enhanced FAC pair

Joule heating



[Cai et al., 2014]

Existing for both Bz- and Bz+ conditions

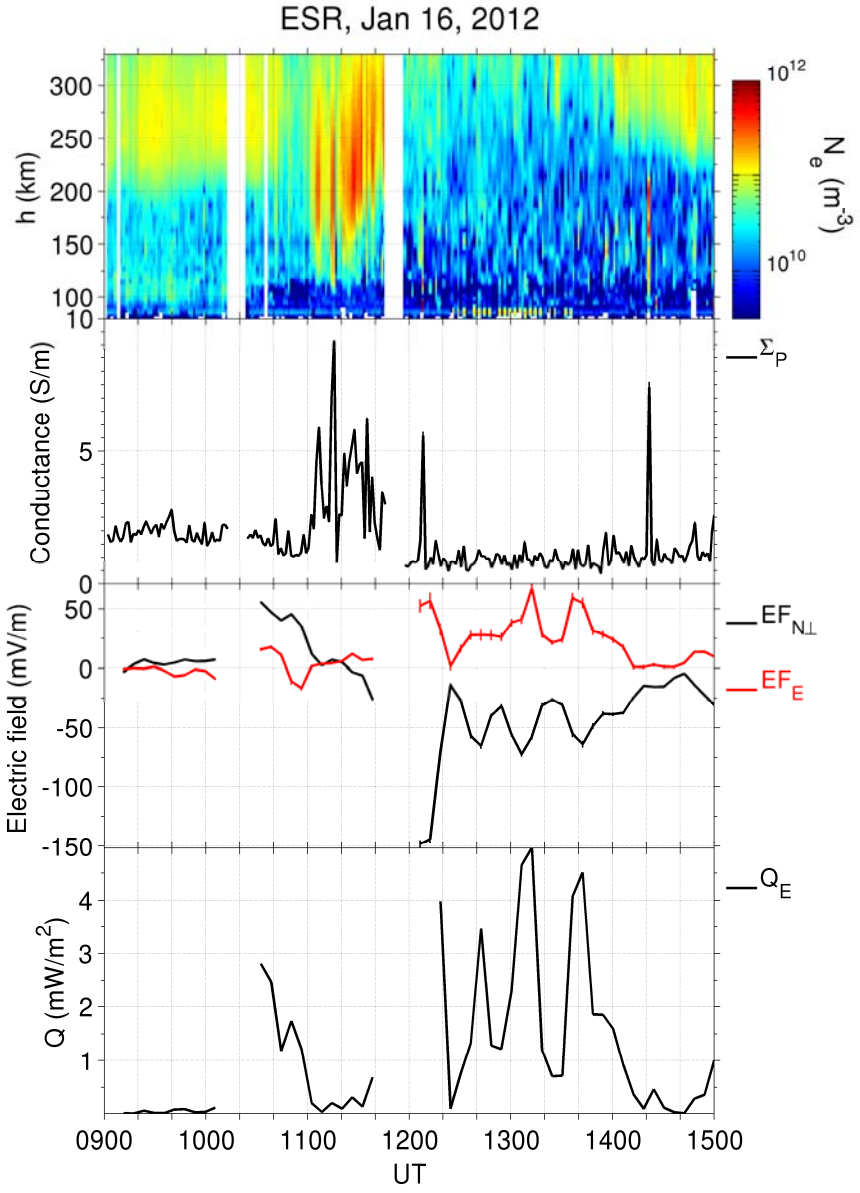
Motivation

- Cai et al. [2014]: **34 days** of EISCAT CP2 measurements
  - During September 2005 and November 2003.
  - Joule heating hot spots appear in all four IMF quadrants in the GSM y-z plane.
  - Indicating a region of persistent magnetospheric electromagnetic energy input.
- After Cai et al. [2014]: **233 days** of CP2 measurements were collected from 2000 to 2014.
- What is the appearance of the hot spot depending on
  - Seasons (Equinox, Winter, and Summer)
  - IMF direction (B_z and B_y)
  - Solar wind speed ($\boldsymbol{v}_{sw}$)
- What's the relationship between the hot spot and the FAC structures?

EISCAT CP2 measurements

- EISCAT Svalbard Radar (ESR)
  - 75.4 ◦ MLat
  - Close to polar cap boundary
- CP2 program
  - 3- or 4-position scan
- A powerful tool for measuring
  - Electron density (N_e)
  - Ion and electron tempretures (T_i and T_e)
  - Line-of-sight ion velocity (v_i)
- Estimate of conductivities and electric field
- Joule heating rate

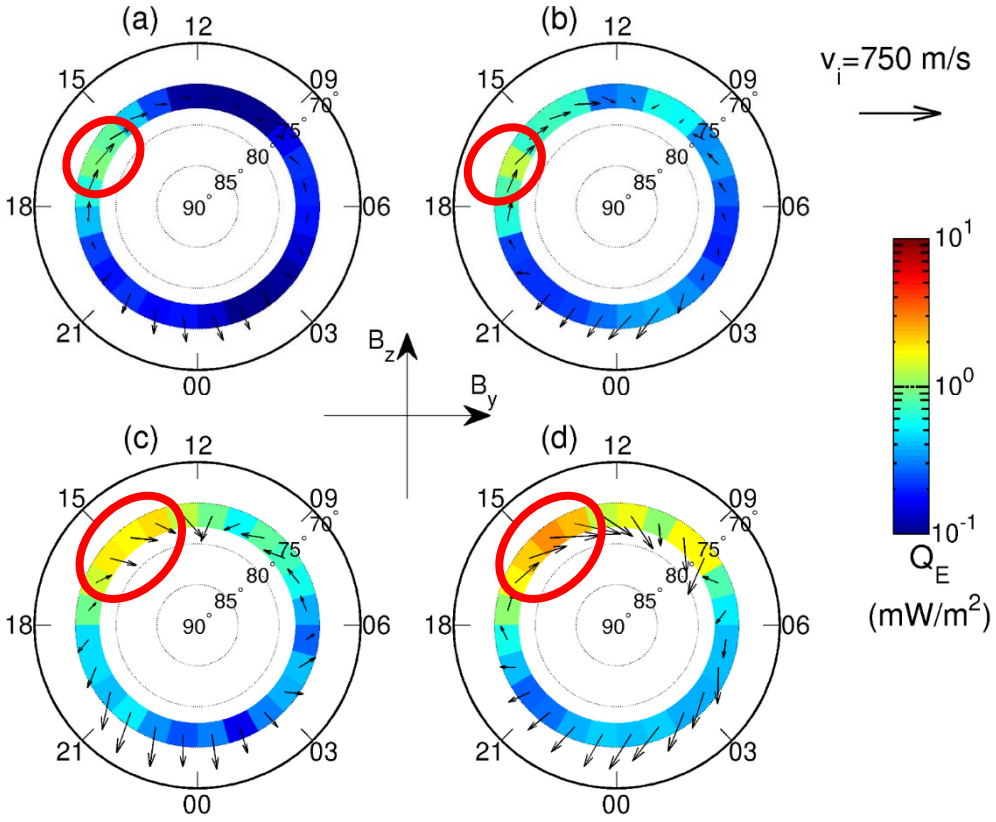
$$q_E = \sigma_P E^2$$



Seasonal dependence

- Afternoon hot spot in Joule heating Q_E at ESR
  - 233-day CP2 data from 2000 to 2014
- Grouped into three seasons:
  - Equinox, summer, and winter
  - Best statistics in equinox

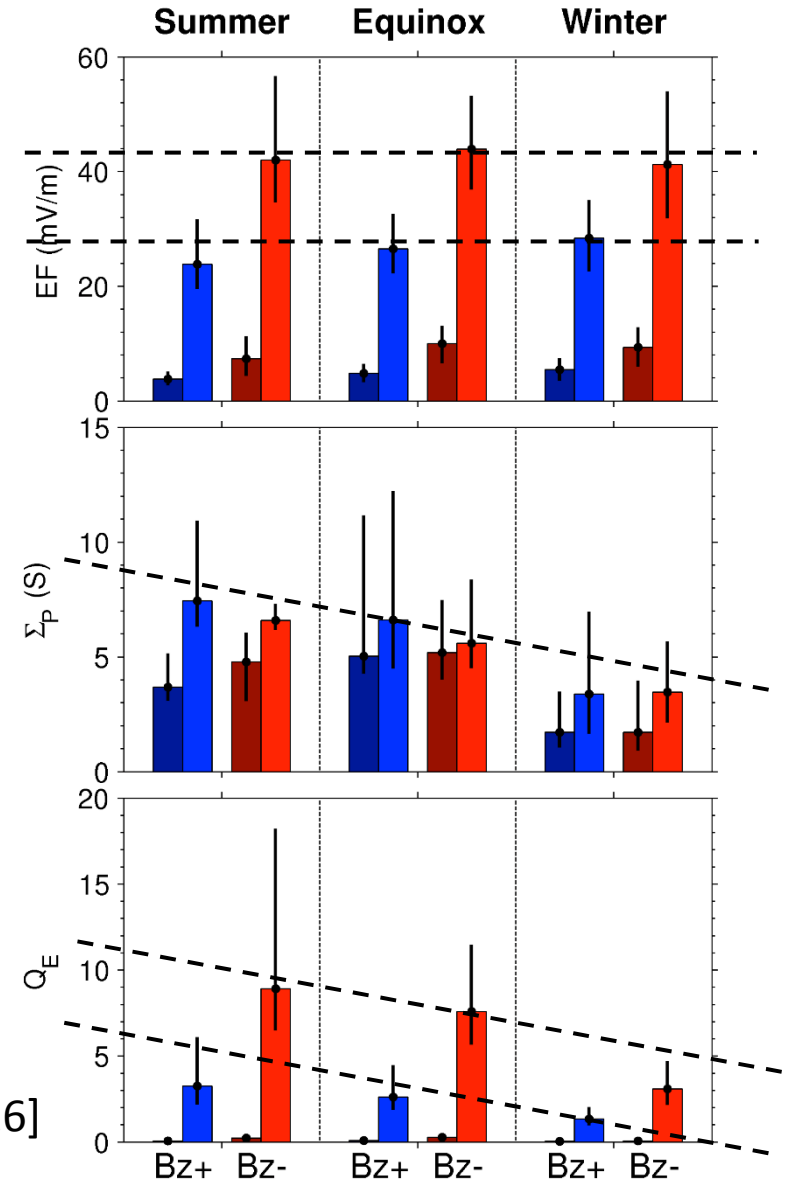
Joule heating at equinox



[Cai et al., 2016]

Seasonal dependence

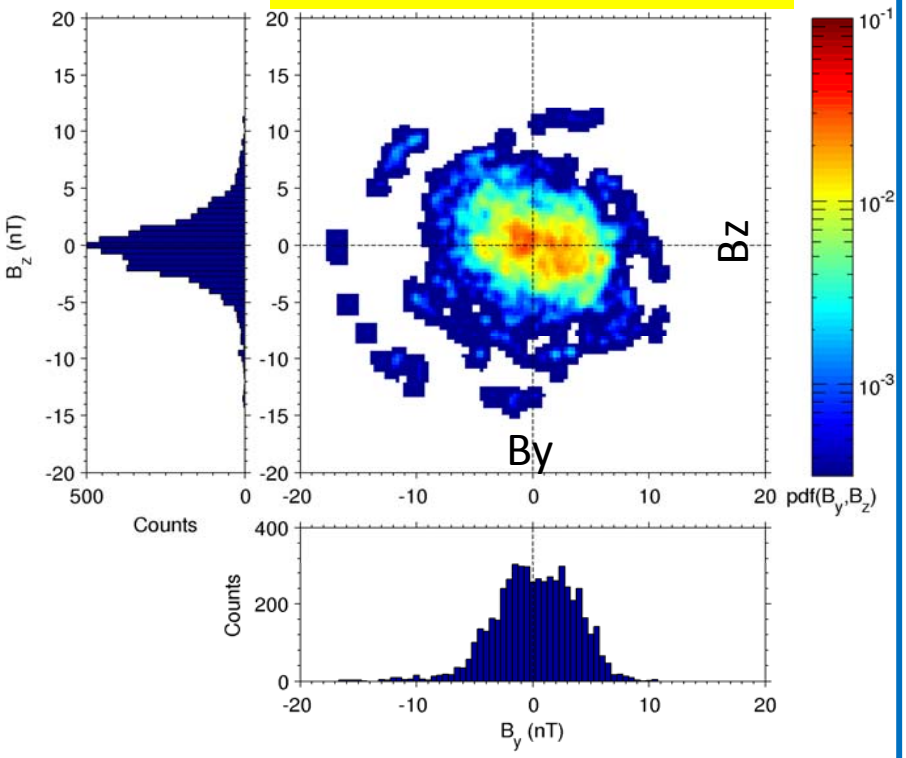
- Similar magnitude of electric field
- Pedersen conductance: summer>equinox>winter
- Joule heating Q_E : summer>equinox>winter



[Cai et al., 2016]

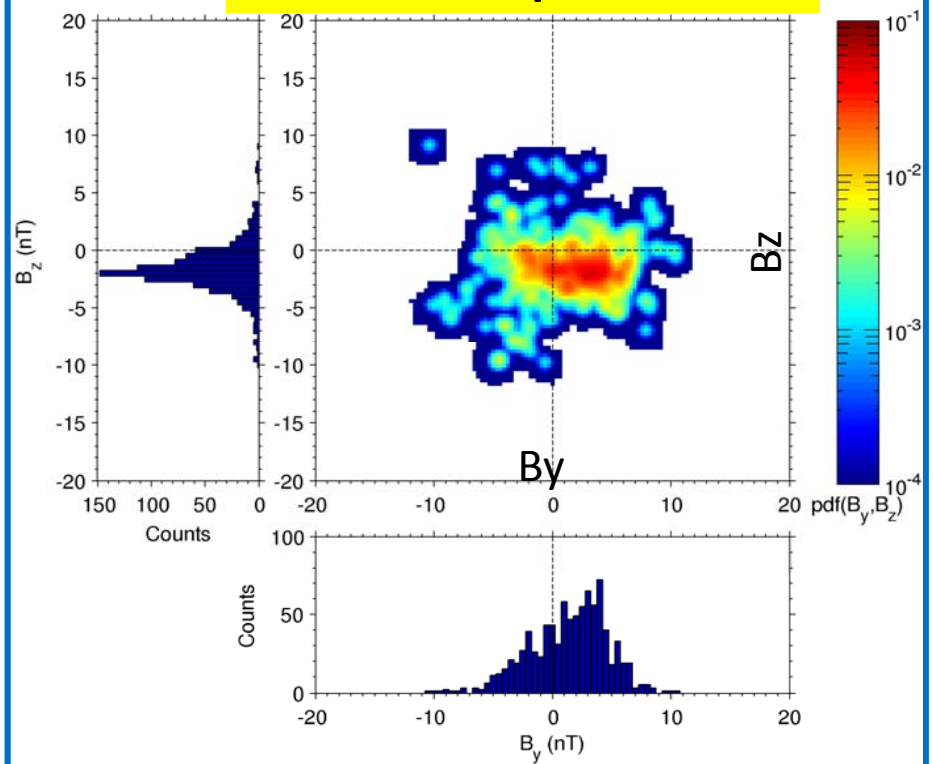
IMF Bz and By distribution for slow-speed solar wind events ($v_{sw} < 450$ km/s)

All data



- Nearly symetric distribution for B_z.
- Somewhat more samples for B_y+.

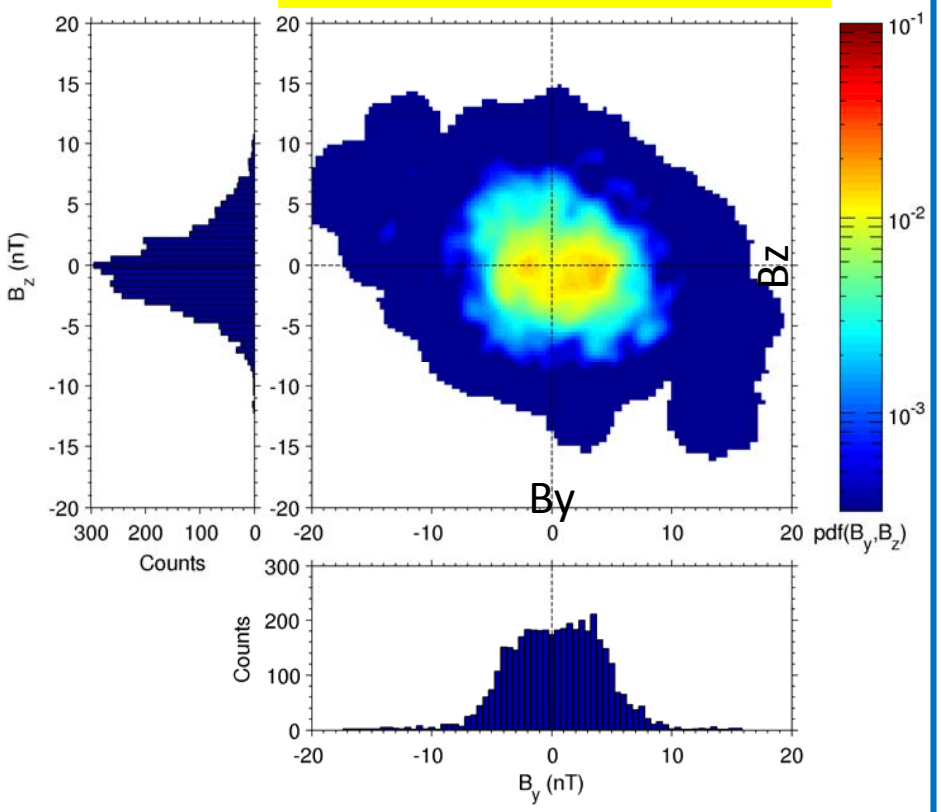
Hot spots



- Southward IMF (B_z-) dominates.
- B_y+ favored.

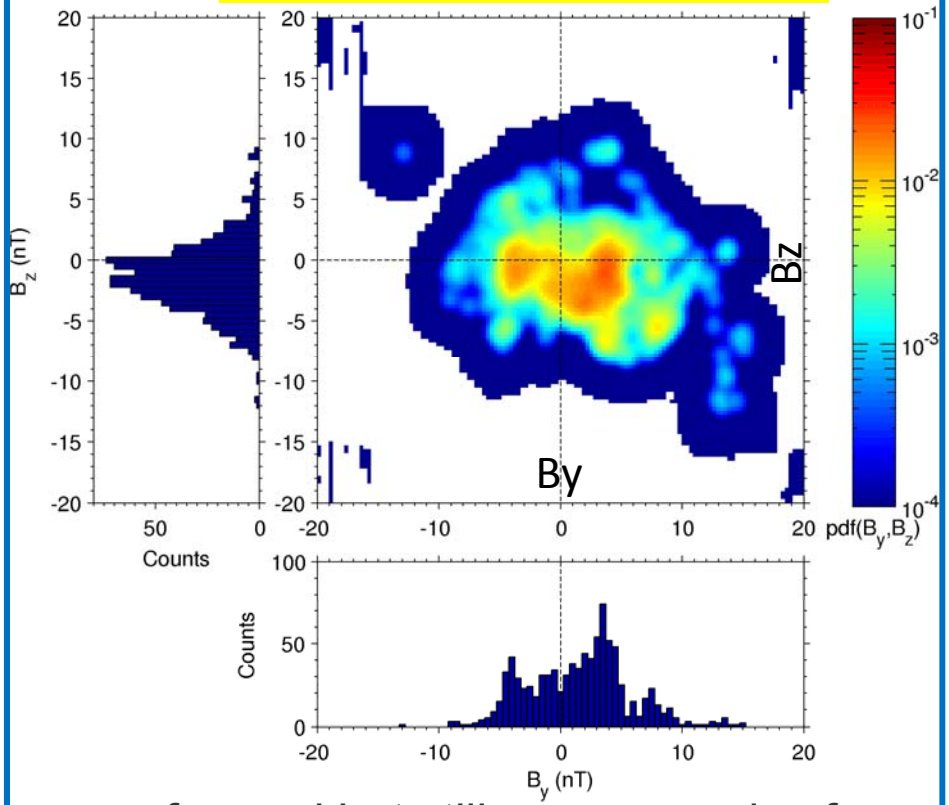
IMF Bz and By distribution for high-speed solar wind events ($v_{sw} > 450$ km/s)

All data



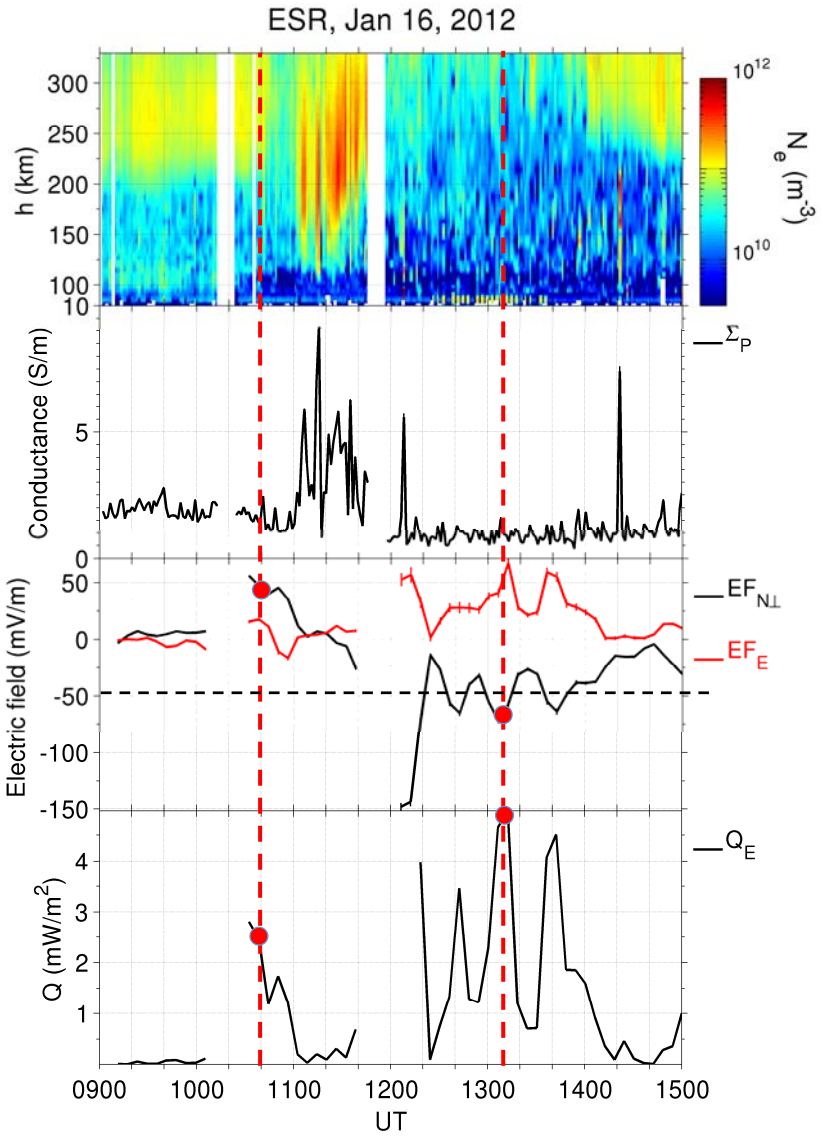
- Approximately symetric distribution for both B_z and B_y.

Hot spots



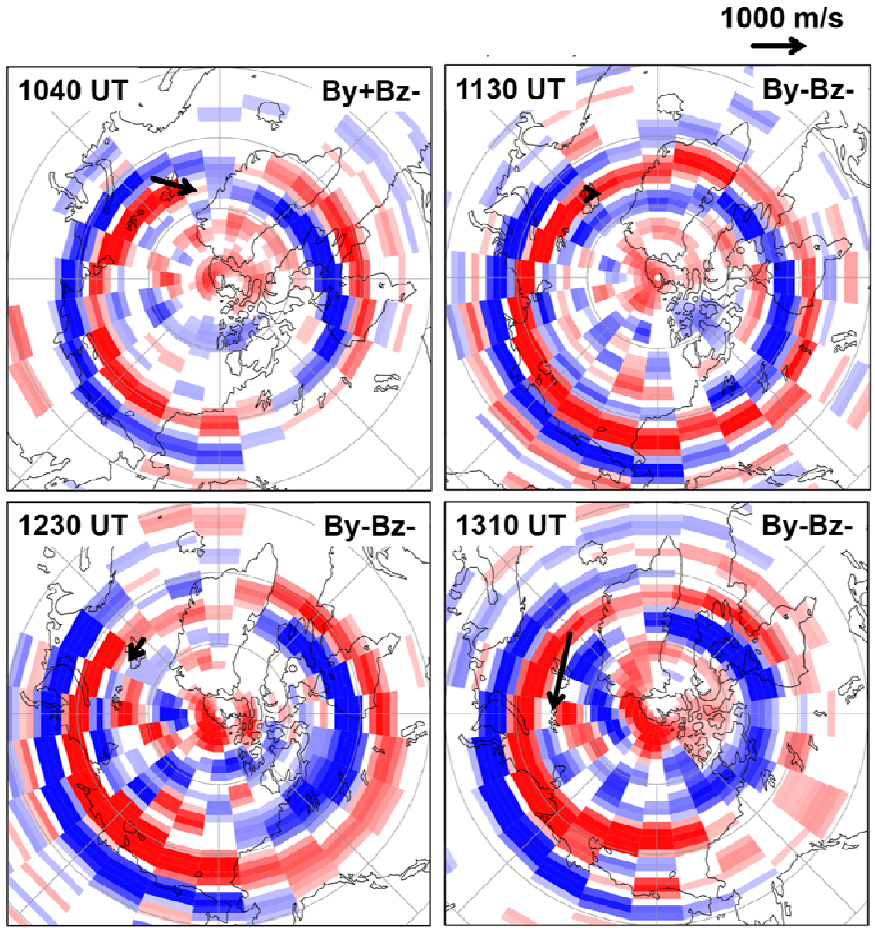
- B_z- favored but still some samples for B_z+.
- Large values of B_y± dominate.

Joule heating hot spot and FACs



- 10:40 UT E_N: sunward plasma convection
- 13:10 UT E_S: anti-sunward plasma convection
- High EF, low Pedersen conductivity in Joule heating hot spot.
- Between the events, particle precipitation and higher Pedersen conductivity values.

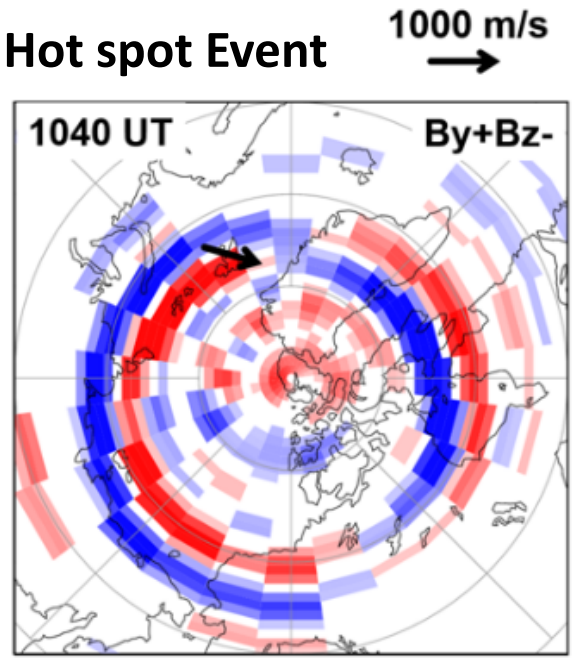
Joule heating hot spot and FACs

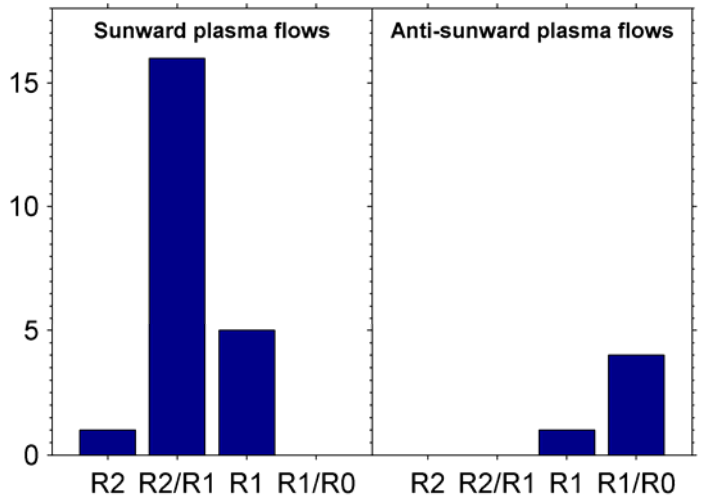


- Field-aligned currents from AMPERE project
- IMF By rotation from positive to negative affects the large-scale FAC pattern (according to Anderson et al., 2008).
- 10:40 UT EN sunward plasma convection at R2/R1 FAC reversal
- 13:10 UT ES anti-sunward plasma convection at R1/R0 reversal
- Between the events, ESR is under upward R1 FAC and experiences particle precipitation.

Association with large-scale field-aligned currents

- Field-aligned current (FAC) map during 2010-2013 from AMPERE project.
- Joule heating afternoon hot spot occurs mostly under sunward convecting plasma.
- In most cases, hot spot is located close to the R2/R1 FAC reversal.
- If EISCAT is under anti-sunward convecting plasma, the hot spot occurs at the R1/R0 FAC reversal region.





[Cai et al., 2016]

Conclusions

- Pedersen conductances affect the seasonal variation of the afternoon hot spot values, though the hot spot values are primarily associated with high velocities of the convection flows.
- During slow solar wind speed conditions, hot spot events are favored by the southward IMF and positive By conditions.
- During high solar wind speed conditions, hot spot events can appear for not only southward but also northward IMF conditions with a large IMF By component.
- By analyzing the global FAC maps from the AMPERE project, we found that the afternoon Joule heating hot spots are located close to the reversals of the large-scale FACs

Thank you. Any questions, please?