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A6.01 Geospace System Science: Thermosphere, Ionosphere, Magnetosphere and Their Coupling

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# Characterizing very high electron temperature events as observed by Swarm constellation at high latitudes

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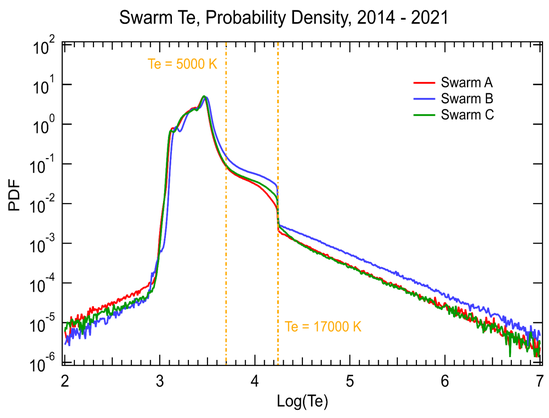
## Rationale

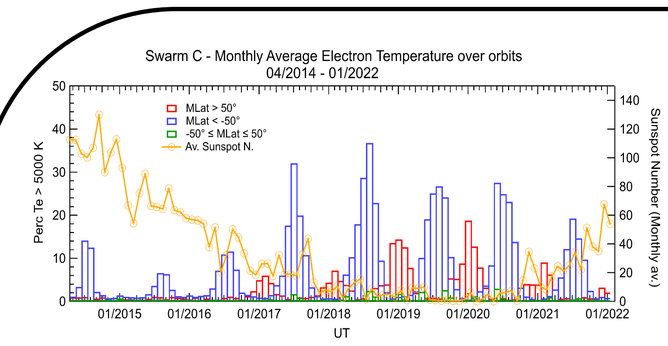
The electron temperature (**Te**) observations taken by the Swarm constellation often show spikes and/or time series characterized by fluctuations and very high values, well above the expected ionospheric background. Different "families" of such occurrences can be recognized: one family of spikes most likely constitutes artifacts due to a combination of instrumental and local environmental effects and it affects specific portions of orbits in particular conditions; another family of high temperature values is instead typical of high latitudes and nocturnal local times, often associated with very low values of the electron density.

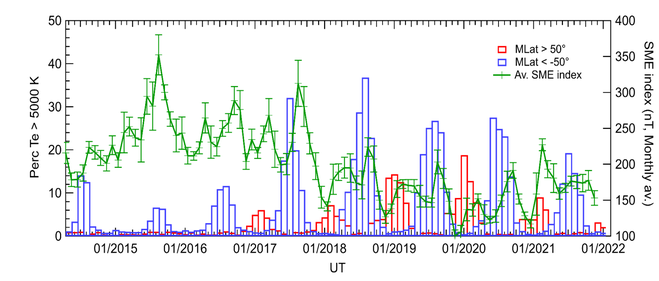


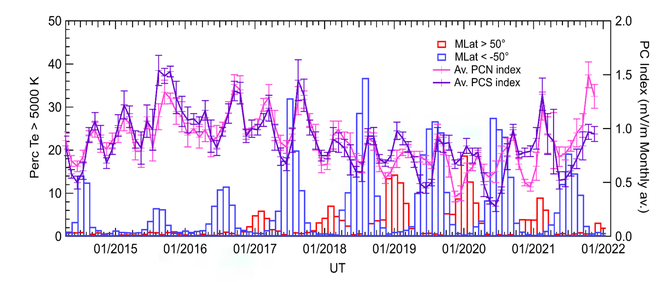

The Probability Density Functions obtained from all the 1 Hz «valid» measuremnts (Quality Flag = 10 or 20) of Te from 2014 to 2021 clearly show a long tail of high and very high values for all spacecraft. The distributions change starting from about 5000 K, getting close to a power law (Log-Log plot).

After a sharp step at about 17000 K (instrumental?) the functional form seems to be kept, but the occurrence rate drops down dramatically.

**Between 5000 and 17000 K about 2% (3.5%) of the overall temperature records occur for Swarm A and C (B).**



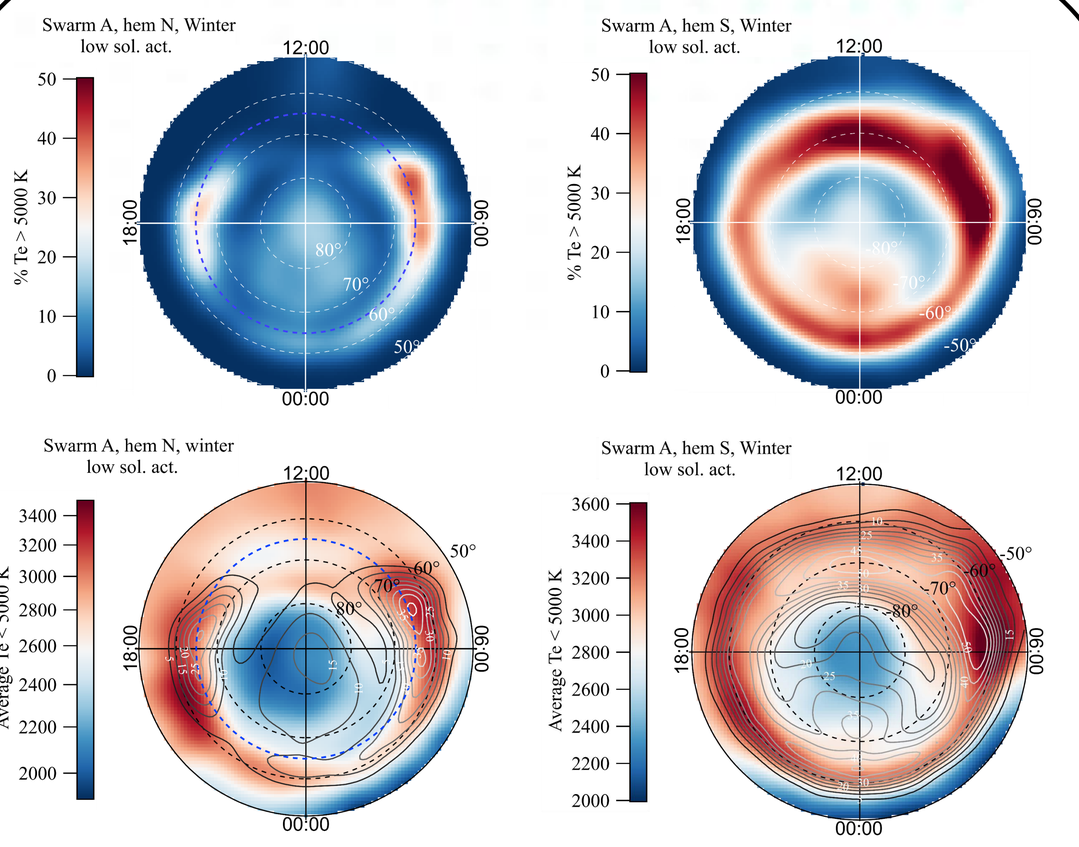




**Percentage of Te > 5000 K occurrences monthly averaged over portions of orbit**. Example of Swarm C (general behaviour similar also for Swarm A and B).

- **Mid/low latitude portion** (between +/- 50° MLAT), green histogram in the upper panel: high Te values percentage negligible with respect to high latitudes.
- High Latitudes portions (above +50° or below -50° MLAT): marked seasonal variation! Relative maxima of high Te occurrences at **local winter**, in both hemispheres. **Southern hemisphere** (blue histogram) registers higher percentages than **Northern hemisphere** (red histogram).
- Upper panel: Monthly averaged **sunspot number** superimposed (orange). High Te occurrences maximizes during **low solar activity** time.
- Middle panel: Monthly averaged **SuperMAG AE Index*** superimposed (SME, green). Relative maxima of high Te occurrence in Northern hemisphere seem correlated with **relative minima of geomagnetic activity**, particularly during low solar activity time.

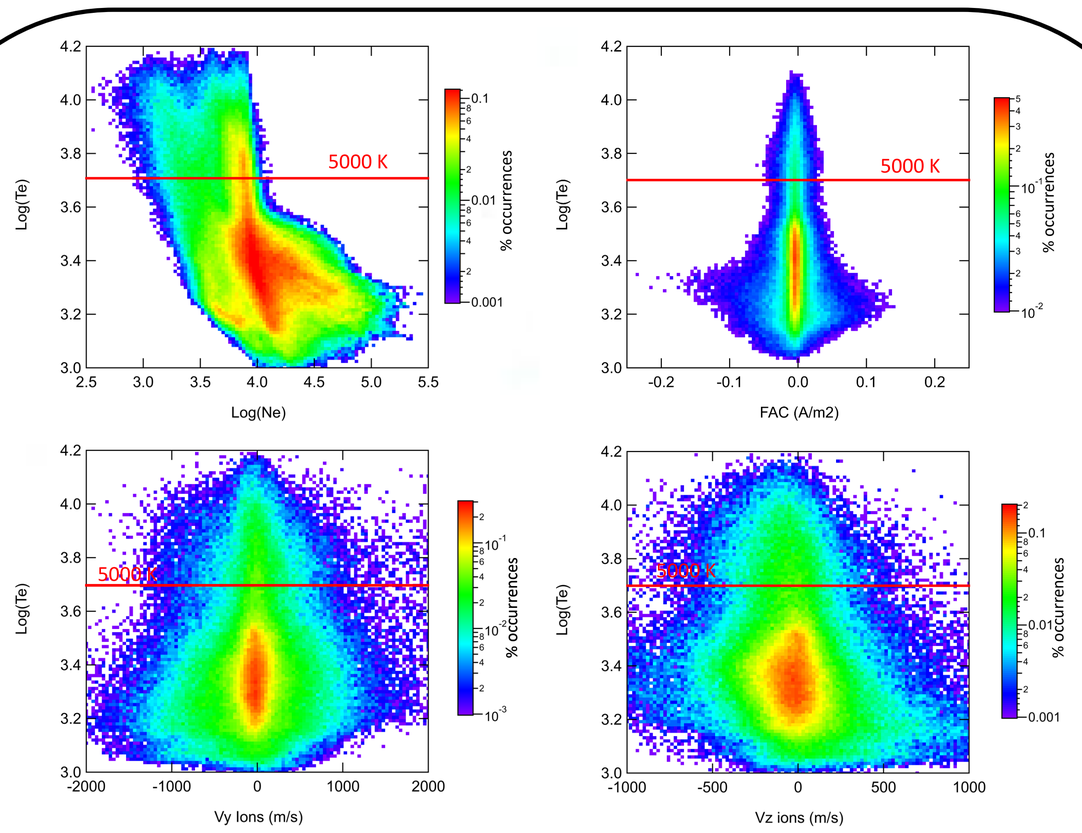
- Lower panel: Monthly averaged **PC index**** North (PCN magenta) and South (PCS purple) superimposed. During high solar activity time (up to mid 2018) the two indices go together and their variation is rather similar to SME. During low solar activity time, a decoupling seems to occur between PCN and PCS, each reaching **relative minima during local winters**, so correlating with relative maxima of high Te occurrence.




- **Upper panels:** Northern (left) and Southern (right) ditributions of the **% Te > 5000 K** during winter and low solar activity times (December and January months from 2017 to 2021) for Swarm A.
- **Lower panels:** Distributions of **average Te** (taking only occurrences of **Te < 5000 K**) in the same conditions. Isolines of % Te > 5000 K as from upper panels distributions are superimposed.

- High Te values are distributed very differently in the two hemispheres: an overall higher % of Te values > 5000 K occurs in the Southern hemisphere, mostly confined in a wide «ring» roughly corresponding to the auroral oval with maxima in the cusp and pre-noon regions and around midnight. In the Northern hemisphere two relative maxima are observed at around 6 and 18 MLT.

- Relative maxima of Te > 5000 K generally occur where the average Te is high as well (around 3400-3500 K). The actual peaks of occurrence seem often located slightly poleward of the «high-but-not-too-much» temperature regions, around 75° MLAT.




**Characterization by event (Example for Swarm A, Northern hemisphere):** selection of the portions of orbits in the nightside (0 < MLT < 5 or 19 < MLT< 24) and winter times (months of December and January from 2014 to 2021), where at least 10 values of Te > 5000 K occurred. For the same time series of Te, also selected time series of: 1) electron density, **Ne**, 2) Field Aligned Current density (**FAC**, Swarm product), 3) ion velocity perpendicular to the direction of motion, **Vy** and 4) **Vz**, from the Swarm Thermal Ion Imager.

- Computed and displayed the **joint distributions** of Te-Ne (top left), Te-FAC (top right), Te-Vy (bottom left), Te-Vz (bottom right); red line in figures represents the limit of 5000 K of the electron temperature.
- The Te > 5000 K occurrences are associated, at least in part, with **low electron densities** ($10^3$ $cm^{-3}$ or even less)
- No correlation can be established between Te > 5000 K occurrences and other parameters related to the plasma dynamics in the polar cap.

**Conclusions (preliminary):** A «family» of high (and often very high) electron temperature events seem to show up at high latitudes as evidenced by all the three Swarm satellites. Such events are not sporadic but rather recurrent in winter (dark) hemispheres and preferably during both low solar and low geomagnetic activity. They are mostly concentrated in the auroral oval with very different distributions in the two hemispheres, and they are more abundant in the Southern than the Northern hemisphere, and also more abundant at higher altitudes (Swarm B). They can be mostly associated to regions of reduced electron density, but no perturbation of other dynamical parameters (e.g. FAC and bulk ion speed) seem to occur.

*We gratefully acknowledge the SuperMAG collaborators (https://supermag.jhuapl.edu/info/?page=acknowledgement); **SuperMAG:** Gjerloev, J. W. (2012), The SuperMAG data processing technique, J. Geophys. Res., 117 , A09213, doi:10.1029/2012JA017683. **Indices SML, SMU, SME:** Newell, P. T., and J. W. Gjerloev (2011), Evaluation of SuperMAG auroral electrojet indices as indicators of substorms and auroral power, J. Geophys. Res., 116, A12211, doi:10.1029/2011JA016779.. **Thanks to Oleg Troshichev from AARI, Russia, and Anna Naemi Willer from DTU, Denmark - https://pcindex.org/



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