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Swarm Langmuir Probe measurements : analysis and characterization of the data quality

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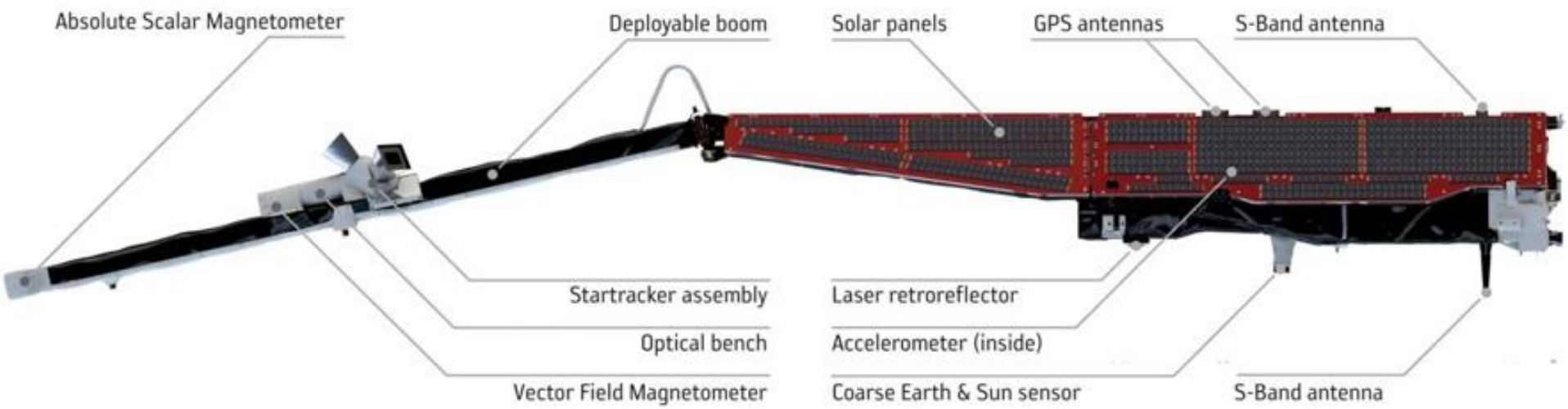
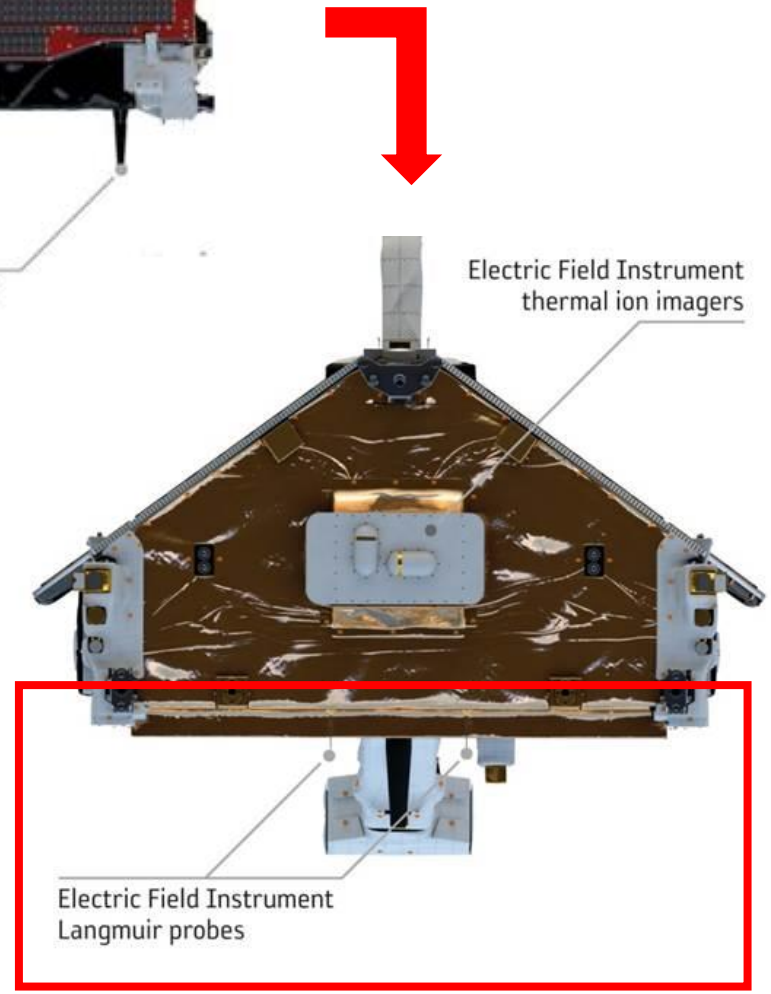
esa swarm SWARM DISC serco

Focusing on Langmuir Probe measurements

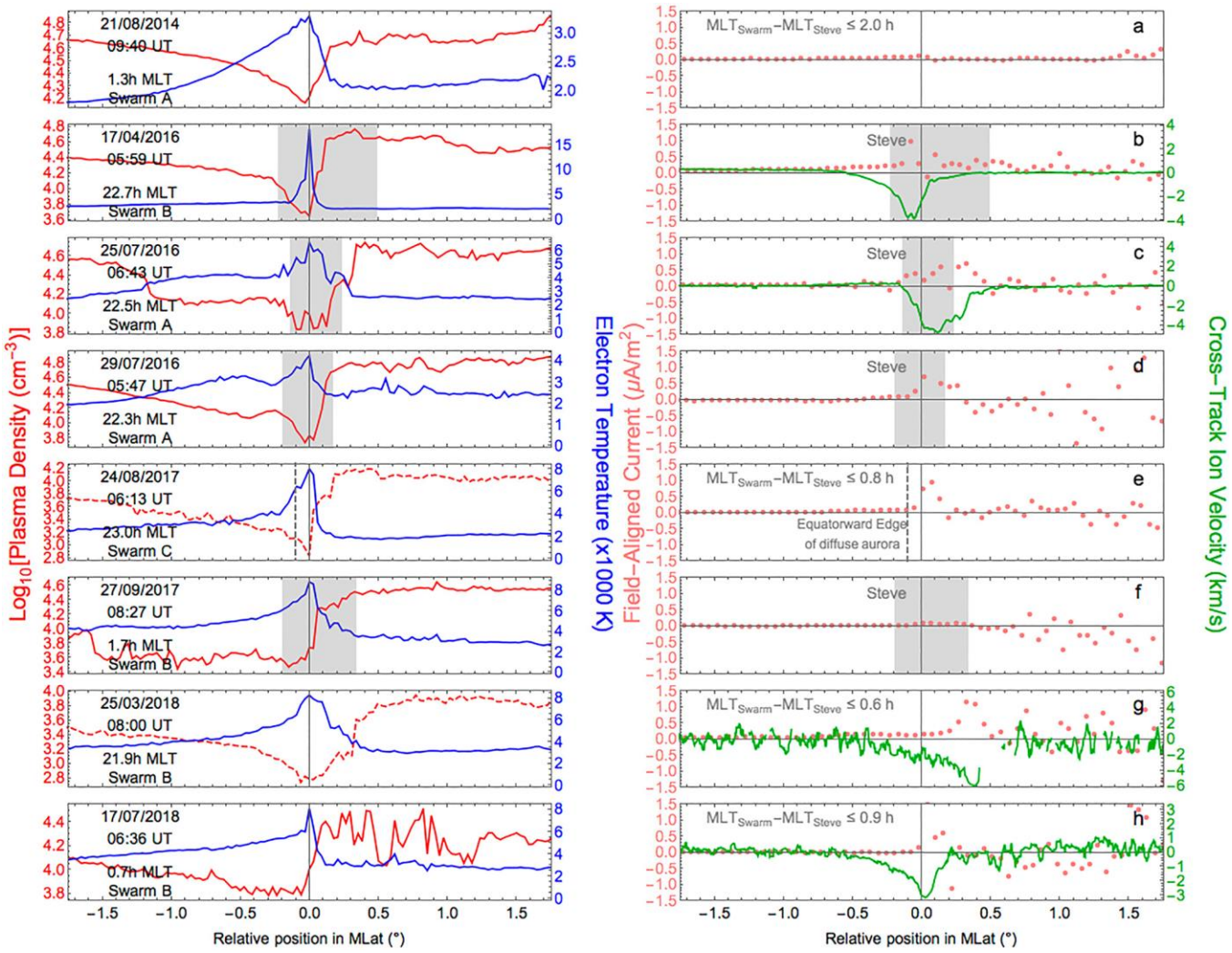




- LPs estimate the density (Ne), electron temperature (Te), and spacecraft potential (Vs).
- Probe 1 : bottom left side, set in high gain, made of TiN
- Probe 2 : bottom right side, set in low gain, covered with Au.
- L1B Data products :
  EFIx_LP_1B : 2Hz at LP timestamp
  EFIxLPI_1B : 1Hz at exact UTC

High quality of Swarm LP data products

Example1: Swarm measurements of STEVE events

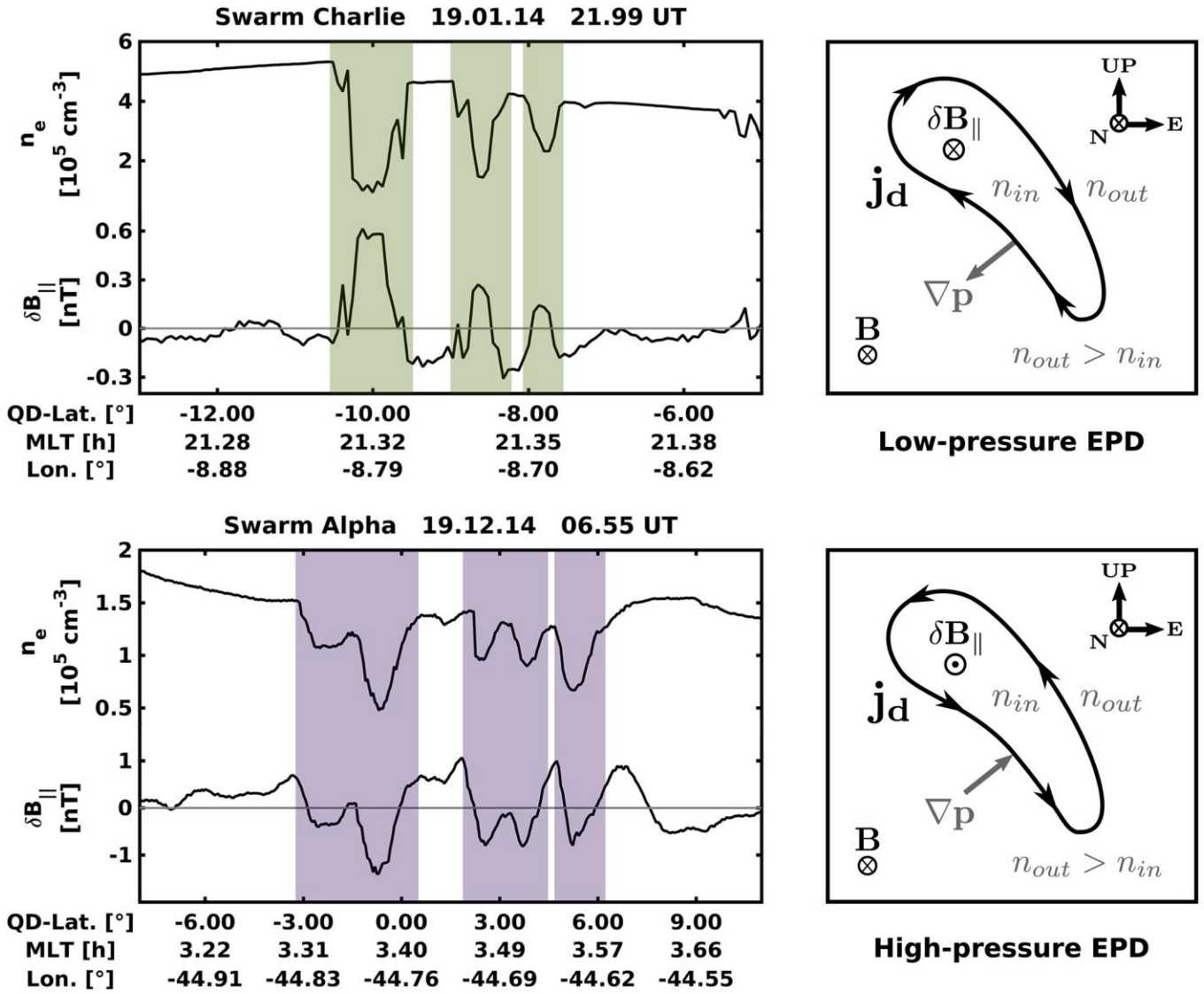


[Archer et al., 2019]

- Steve = Strong Thermal Emission Velocity Enhancement.
- Location of Steve along the satellite track is shaded in grey. The equatorward edge of the diffuse aurora is marked with a dashed grey line for the event of 24 August 2017 (panel e).
- Plasma density is shown in red with solid lines estimated from Langmuir probed ion current and dashed lines estimated from electron current.
- In left panels the red solid line = Ni, dashed red lines = Ne.

High quality of Swarm LP data products

Example2: Swarm measurements of EPD



Low-pressure EPD

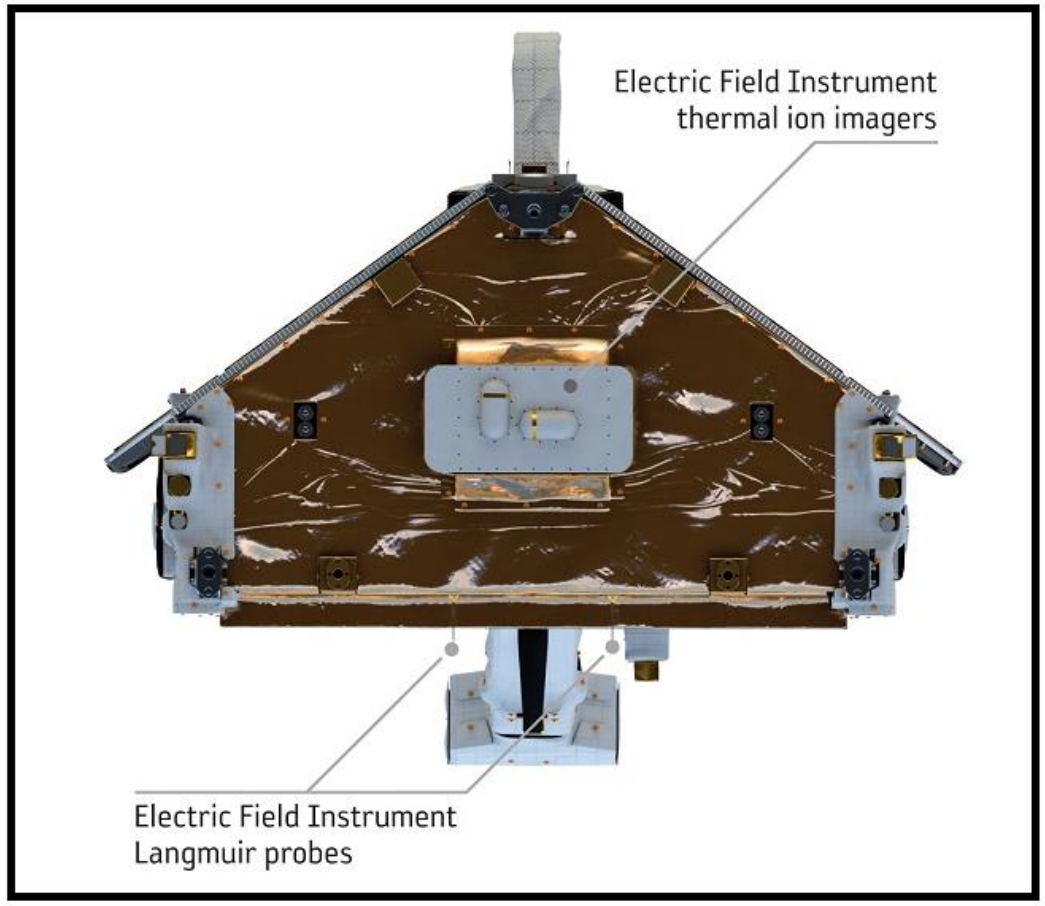
High-pressure EPD

[Rodríguez-Zuluaga, et al., 2019]

- EPD = equatorial plasma depletion.
- EPDs are well known for their steep plasma density gradients and adverse effect on radio wave propagation.
- Generally, the magnetic pressure in EDS is balanced with density variations as for low-pressure EPD. Thus changes in the plasma temperature are not expected to play a significant role. On the contrary, variations of the plasma temperature are significant for high-pressure EPDs.
- High-pressure EPDs are apparently characterized by temperatures as high as twice the ambient plasma temperature.
- The highest occurrence rate of high-pressure EPDs is near the SAA.

High quality of Swarm LP data products

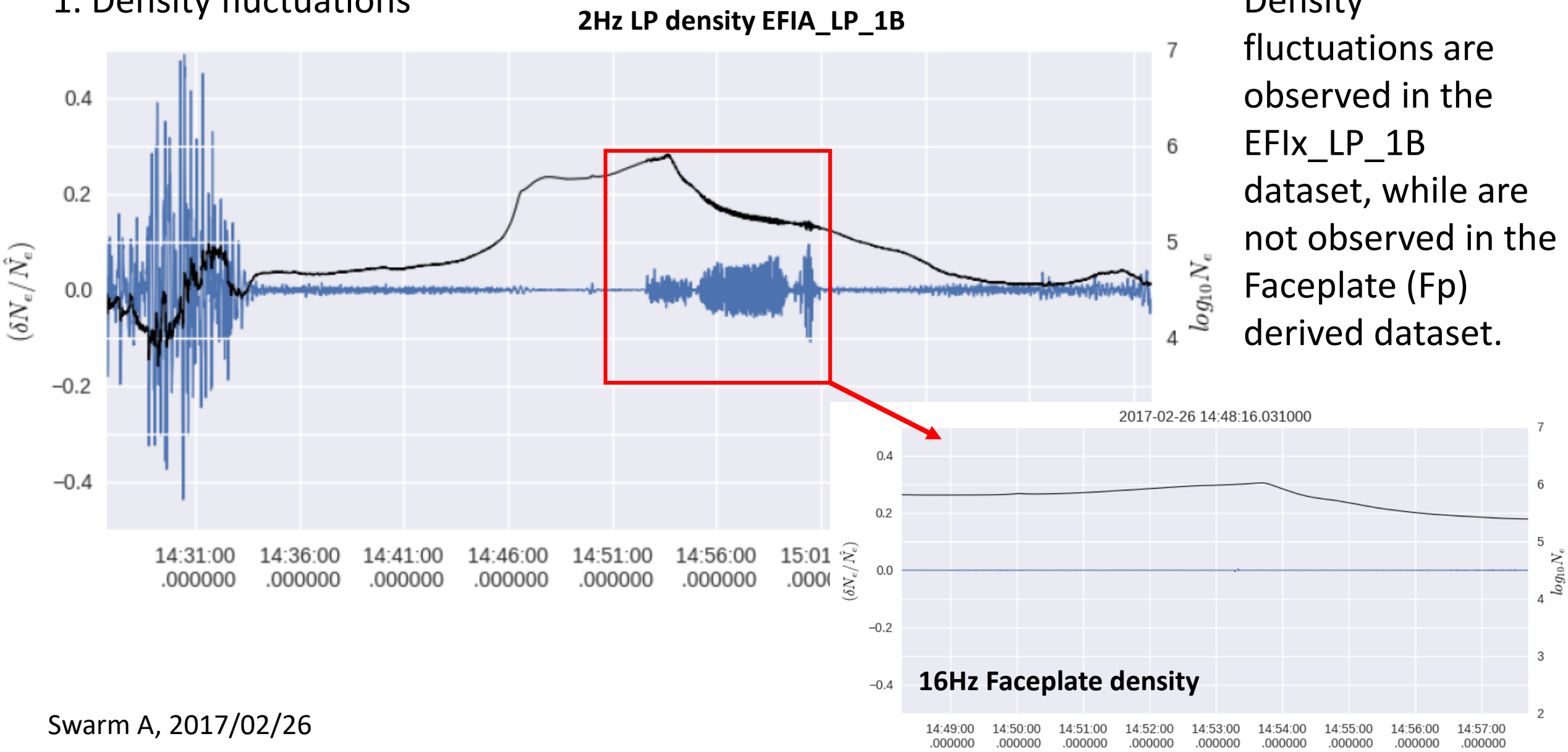
Langmuir Probe (LP)



- The two examples show the high quality of Swarm LP data products, supporting scientific investigations both for instrument observations and numerical simulations.
- However, some anomalies affect LP data. Some of those are discussed in the following slides.

Improving the Swarm LP data quality

1. Density fluctuations

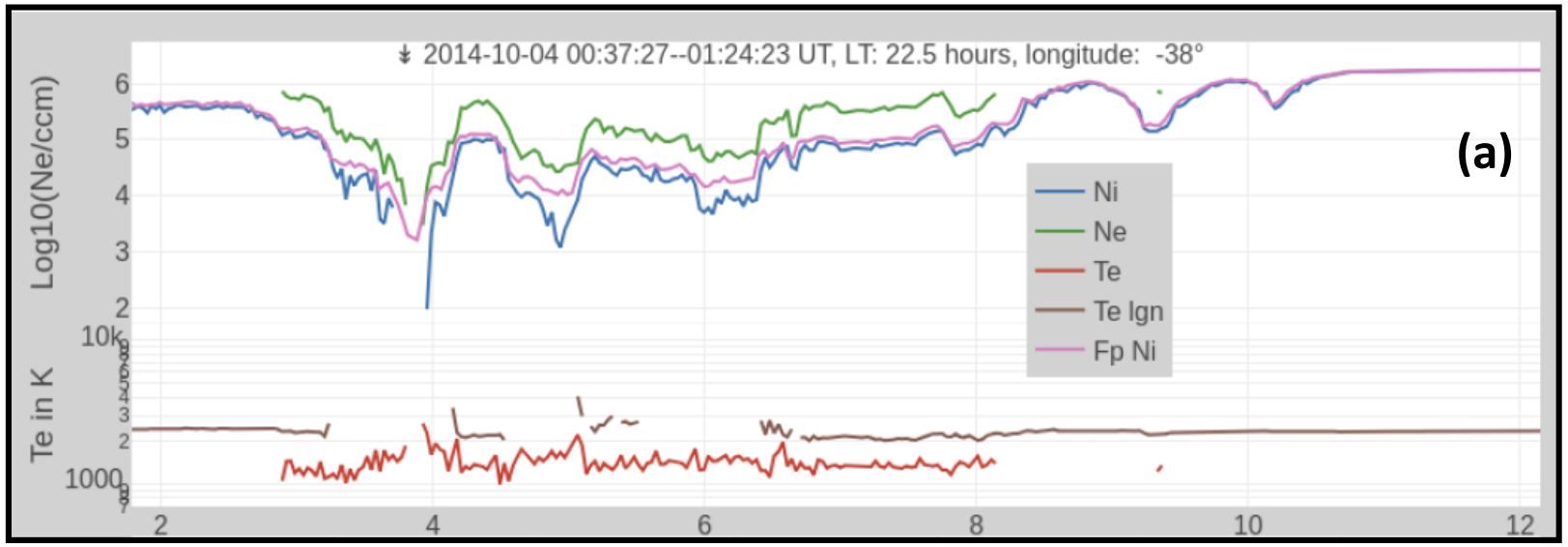


Density fluctuations are observed in the EFIx_LP_1B dataset, while are not observed in the Faceplate (Fp) derived dataset.

Swarm A, 2017/02/26

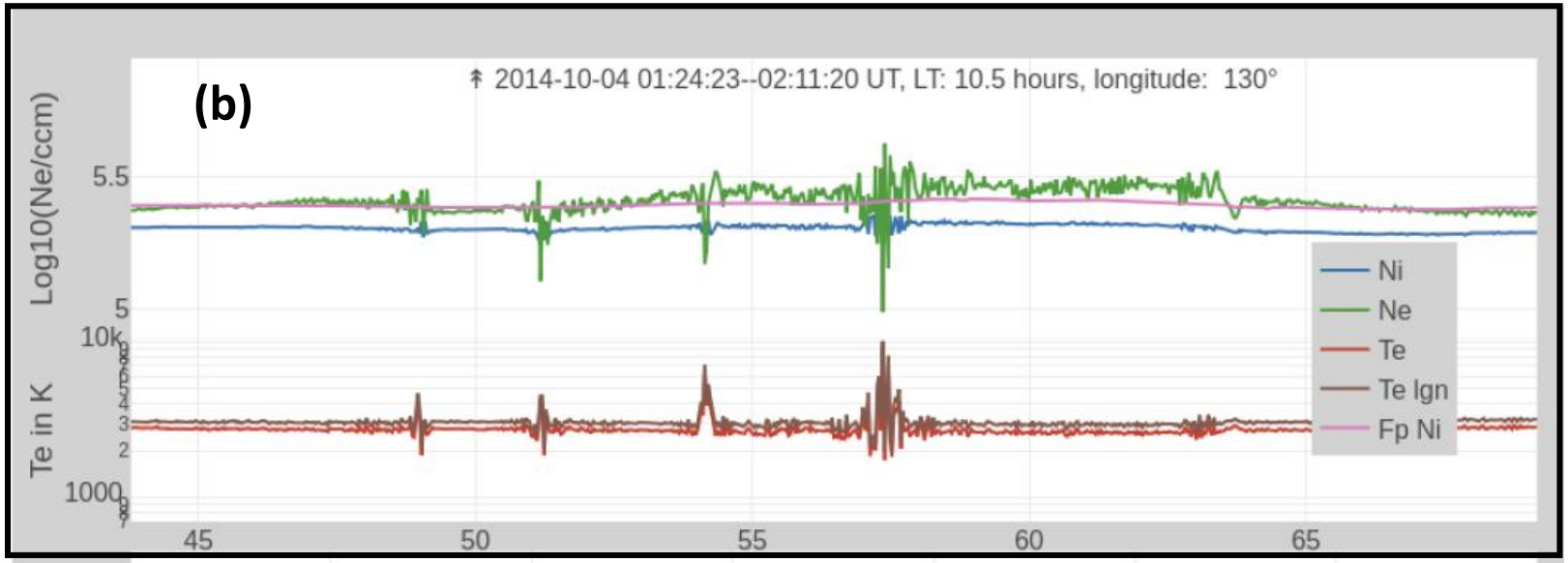
Improving the Swarm LP data quality

1. Density fluctuations



Both LP and Fp (magenta line) derived variables measure real ionospheric variations, as shown in Fig (a).

The Fp derived density (magenta line) is almost constant, while the LP derived variables measure some disturbances, as shown in Fig (b).



Improving the Swarm LP data quality

1. Density fluctuations

Guidelines:

- It is always useful to compare the LP derived variables with the 16Hz density estimate, if it is available

- This anomaly is under investigations with the scope to characterize the density fluctuations and to introduce a related data flag

Related useful links:

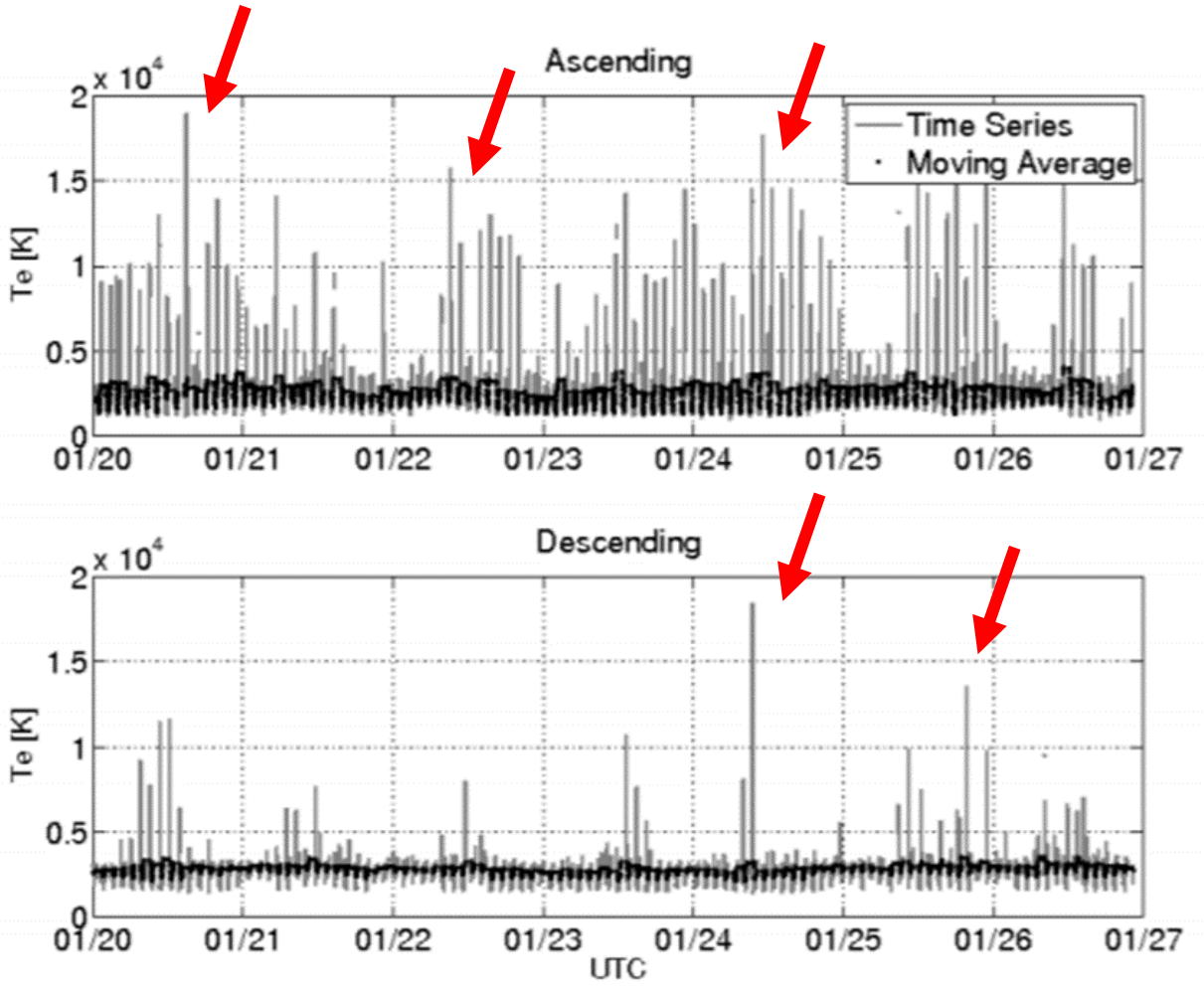
- EFIx_LP_1B dataset : https://swarm-diss.eo.esa.int/#swarm%2FLevel1b%2FLatest_baselines%2FEFIx_LP
- 16Hz Faceplate dataset : https://swarm-diss.eo.esa.int/#swarm%2FAdvanced%2FPlasma_Data%2F16_Hz_Faceplate_plasma_density
- L1B data quality information : https://earth.esa.int/web/guest/swarm/data-access/quality-of-swarm-l1b-l2cat2-products#232

Improving the Swarm LP data quality

2. Electron temperature spikes

- High values of Te (even extremes) are often observed by Swarm.
- It is not always clear whatever high but impossible values are related to physical processes or instrumental disturbances.
- This phenomena is under investigation on its different aspects and possible sources.
- In the figure the grey lines represent the daily time series, while black lines represent the 20 min moving average.

Swarm A; LT= 4 am- 4 pm



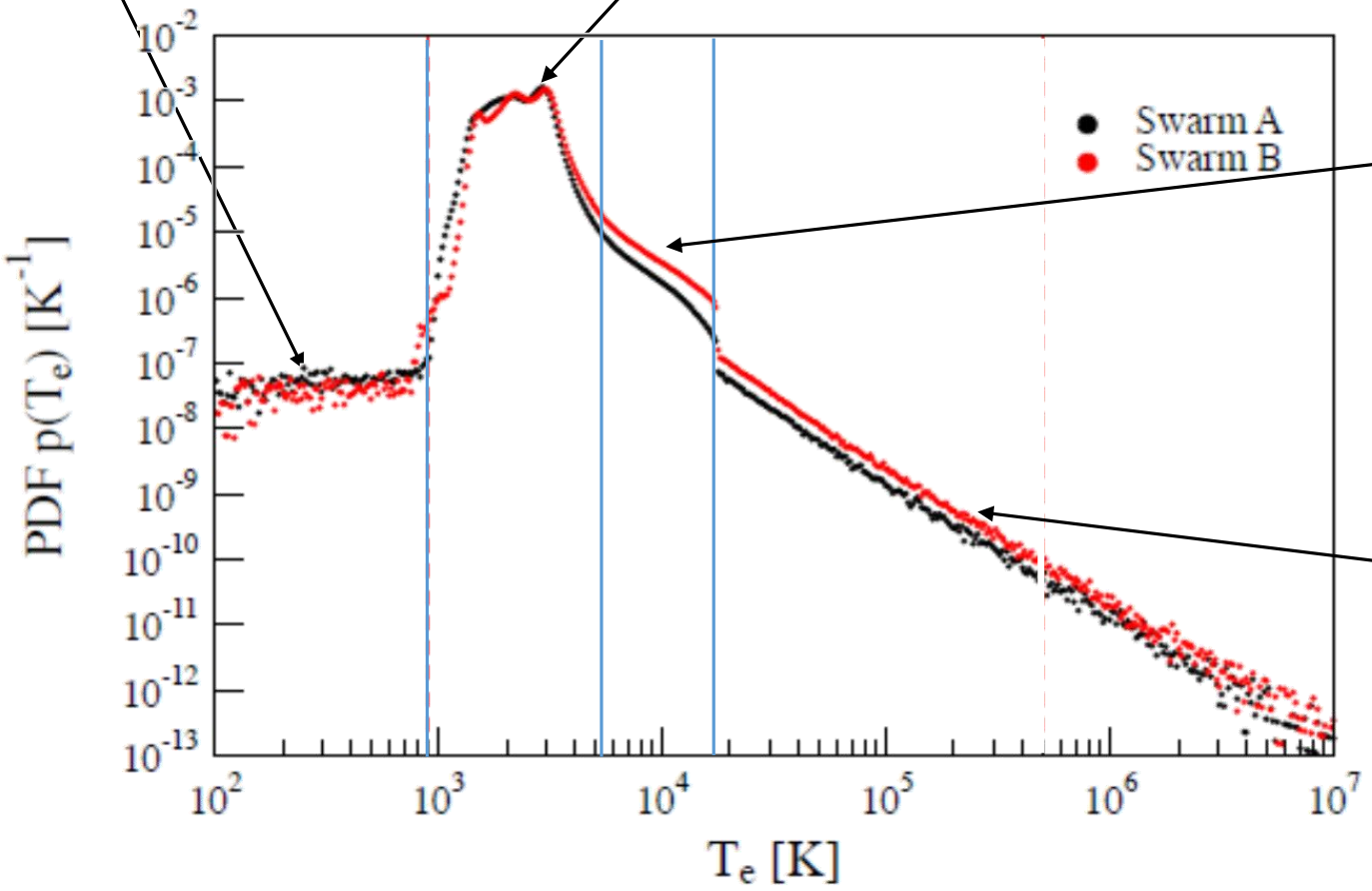
[Image from Swarm weekly data quality reports]

Improving the Swarm LP data quality

2. Electron temperature spikes: Properties of Te spectra (obtained over 4 years of Swarm data)

Low Te (< 1000 K) flat spectrum

Main Te distribution (1000 < Te < 6000 K): log-normal or double log-normal depending on Lat/LT…



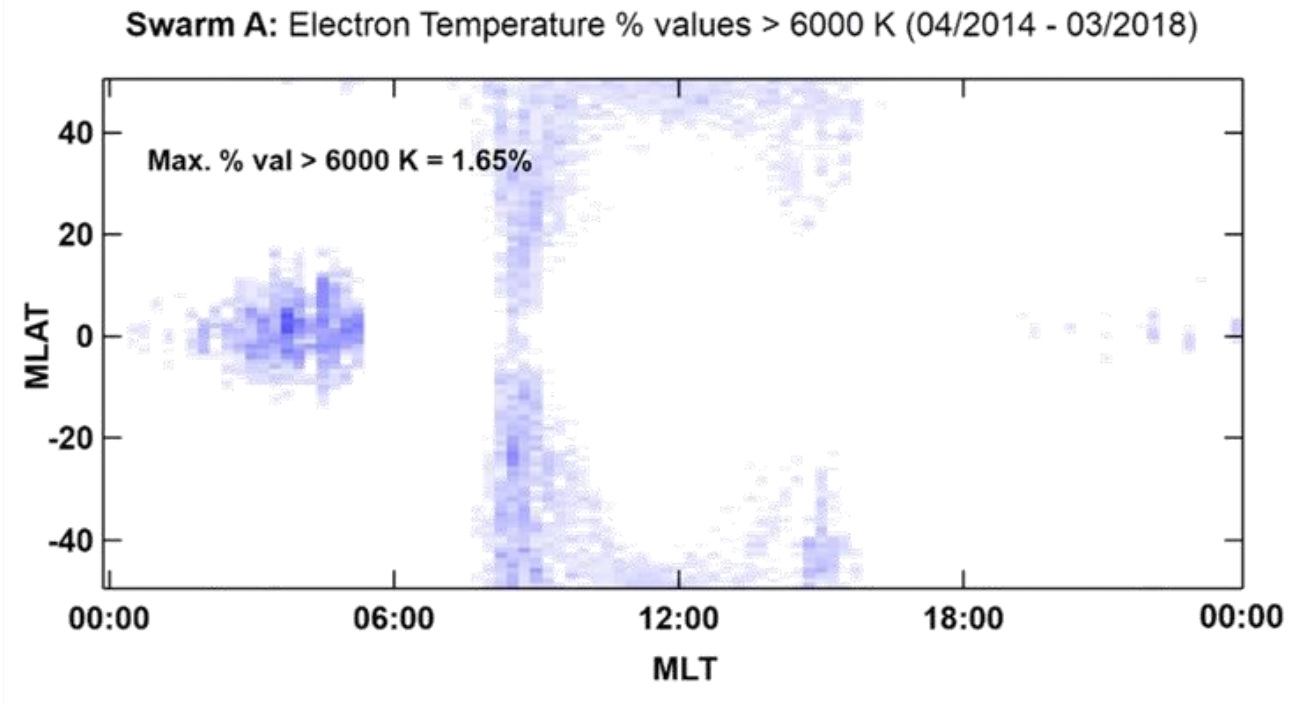
«High Te» distribution (6000 < Te ~ 20000 K): power law + some other more exotic (Weinbull, Fréchet…)

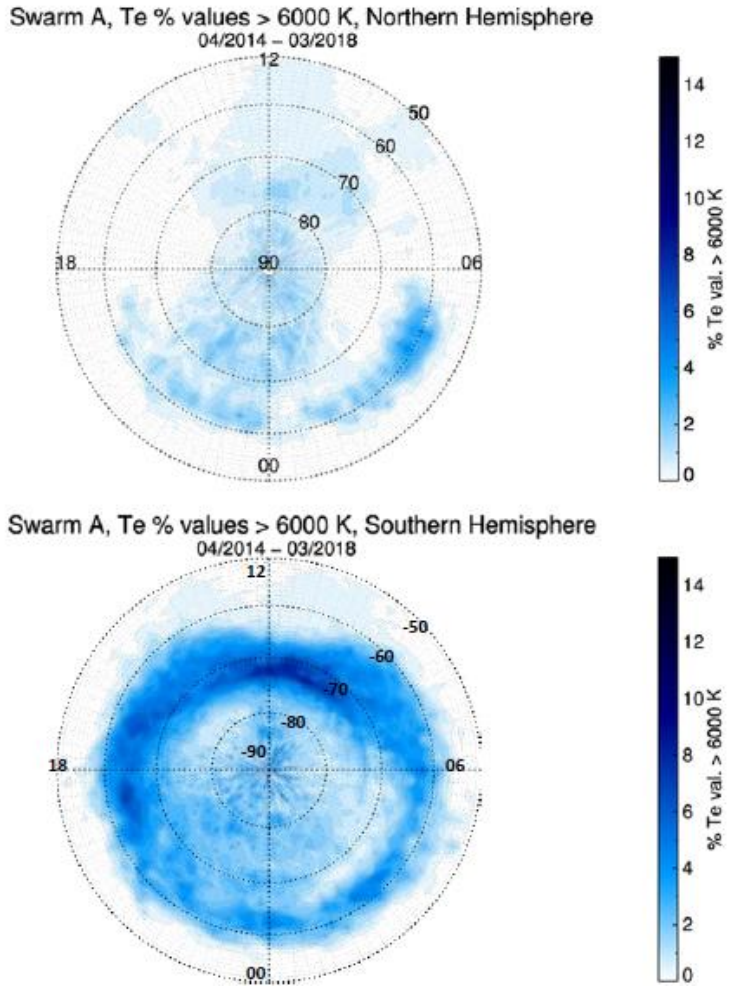
«Extreme Te» distribution (Te > 20000 K): power law.

Improving the Swarm LP data quality

2. Electron temperature spikes

Analysis performed over four years of Swarm A data.





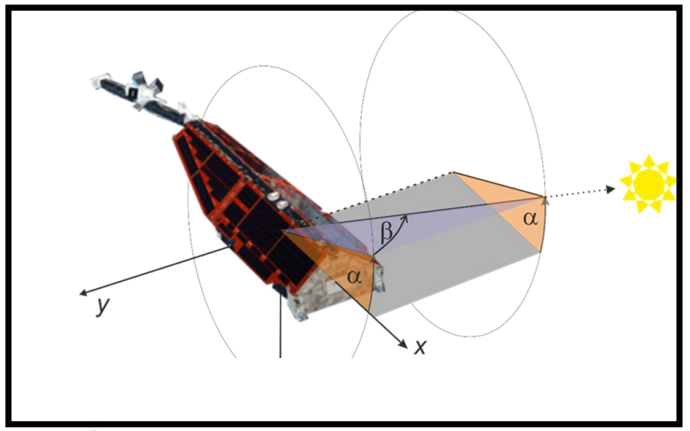
- The percentage of Te > 6000 K, respect to the total observations, do not exceed the 5% in mid-low latitudes, while it is much larger at higher latitudes reaching the 15%.

- Te spikes are more frequent in the SH. Indeed, SH and NH behave differently: NH has the Te spikes distribution peak in correspondence of nightside auroral oval, while SH has the peak at dayside polar cusps.

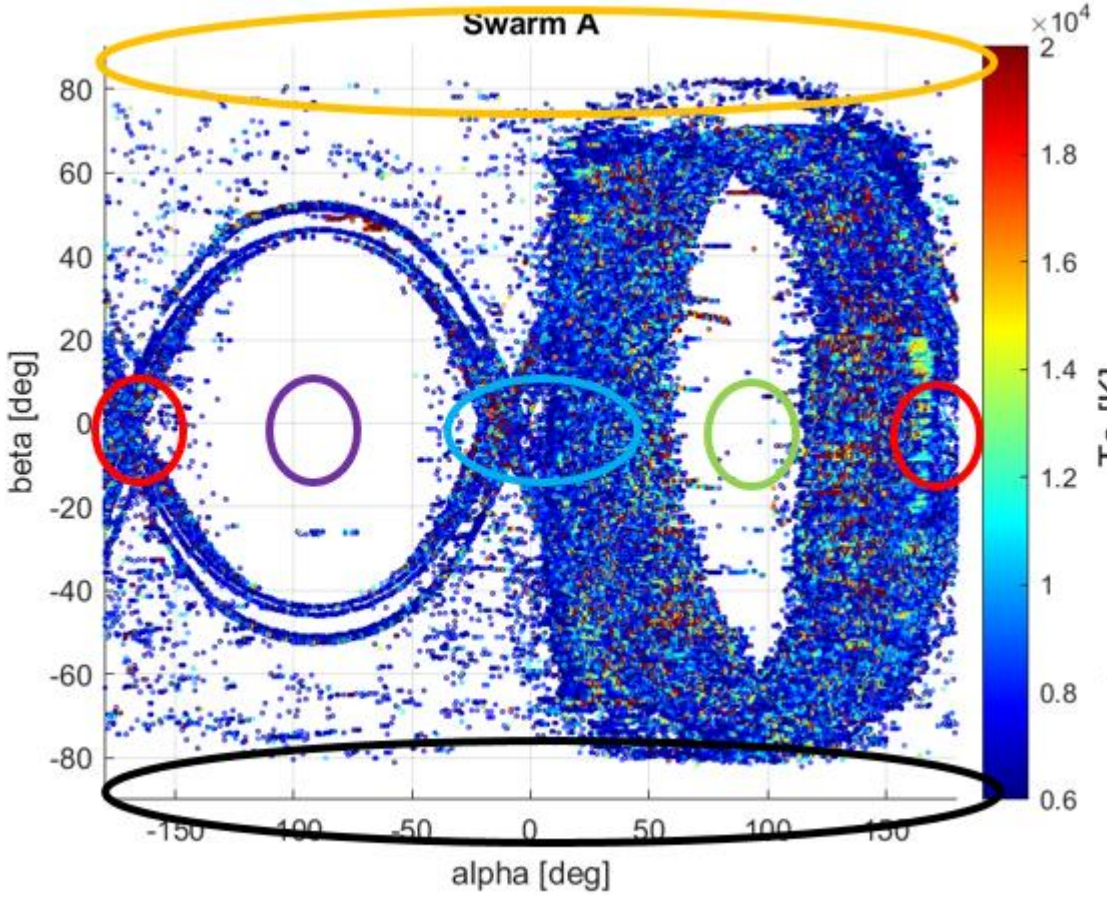
Improving the Swarm LP data quality

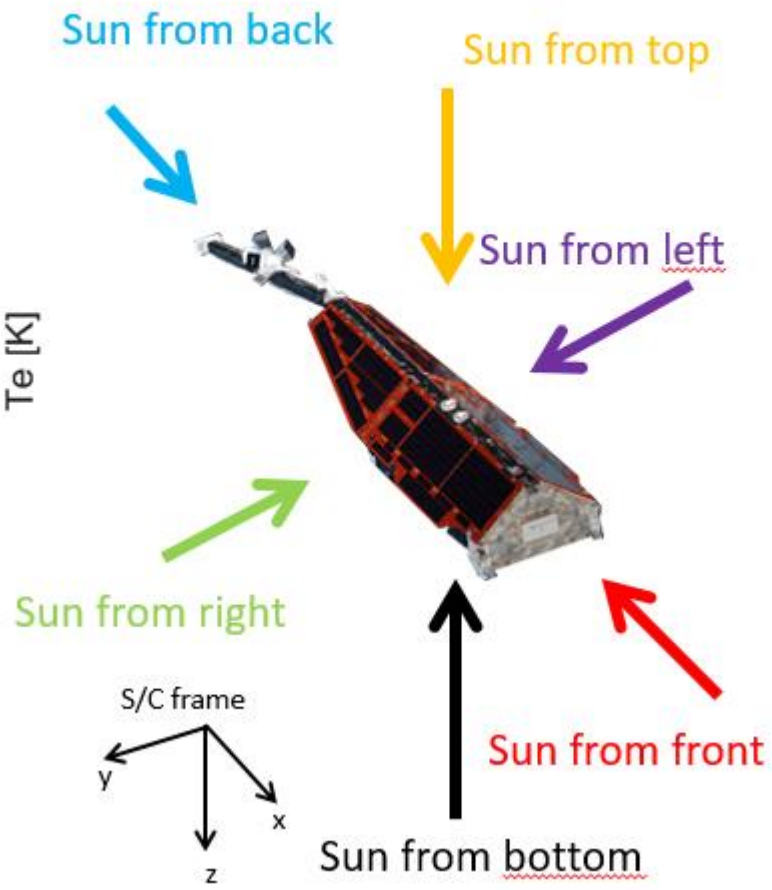
2. Electron temperature spikes

Swarm A measurements of Te > 6000 K
from Jan 2017 to June 2019



Clear dependence of the occurrence of Te spikes with respect to the Sun orientation.





Improving the Swarm LP data quality

2. Electron temperature spikes

Guidelines:

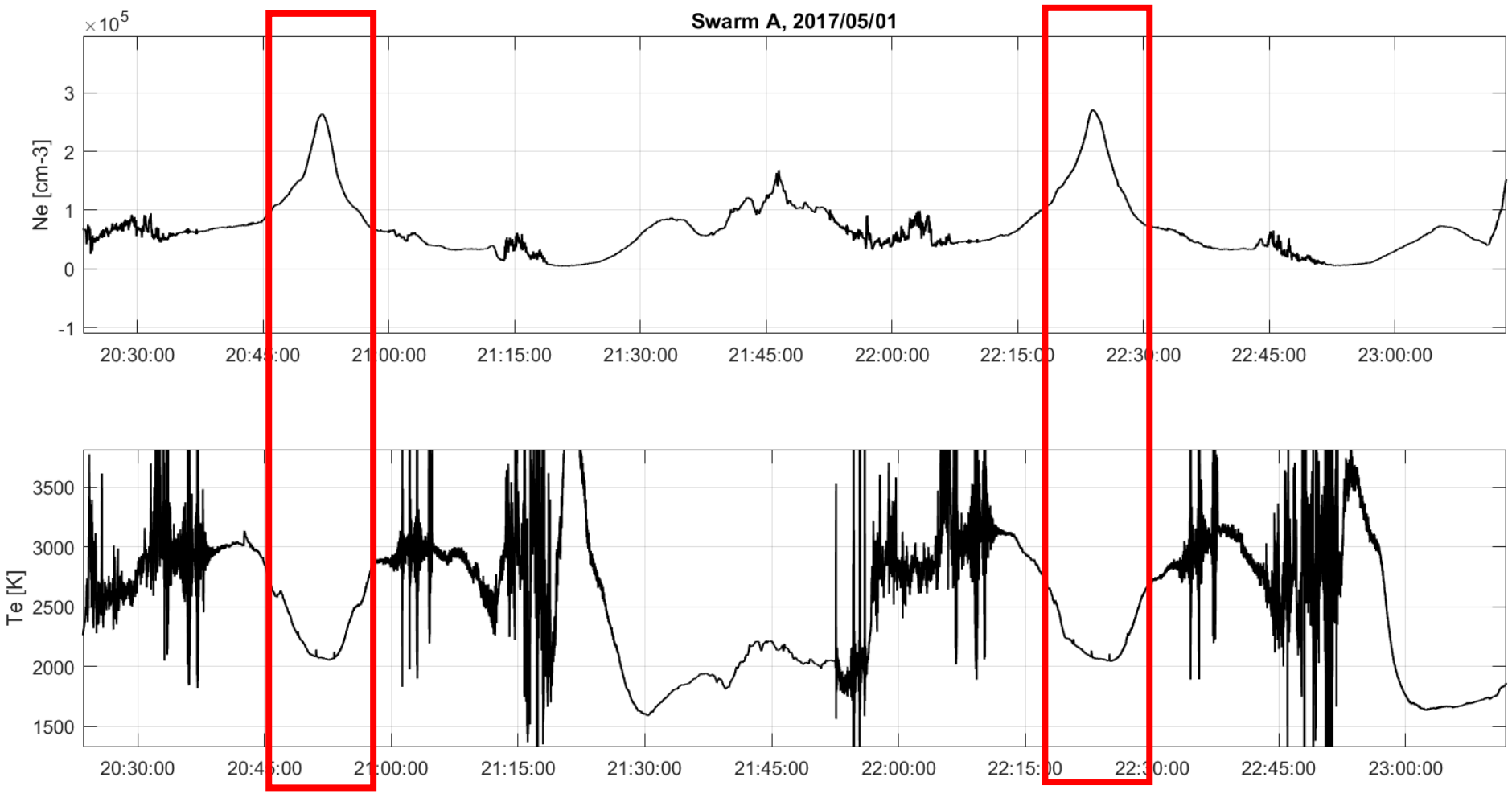
- Yet, it is not clear the nature of such extreme Te values
- This anomaly is under investigations to study the statistical characteristics of the Te spikes and to understand their source

Related useful links:

- Swarm weekly reports : https://earth.esa.int/web/sppa/mission-performance/esa-missions/swarm/weekly-quality-reports

Improving the Swarm LP data quality

3. Hick-ups in Te and Vs data



- Small jumps in correspondence of sweep mode visible for Te and Vs, particularly when Ne is larger.
- Sweep mode is flagged with Flag_LP= 9 (see Product definition doc).

Improving the Swarm LP data quality

2. Electron temperature spikes

Guidelines:

- The hick-ups appear when the instrument is switched from sweep mode to harmonic mode (see plasma processor algorithm for more details)
- The Flags_LP = 9 denotes that the sweep has occurred at this time
- The hick-ups effect last for few seconds after the sweep
- Discarding the data on the dayside when the flag is set to 2-3 thereafter will avoid most of the hick-up effect

Related useful links:

- Swarm Product definitions: https://earth.esa.int/documents/10174/1514862/Swarm_L1b_Product_Definition
- Plasma processor algorithm : https://earth.esa.int/documents/10174/1514862/swarm-level-1B-plasma-processor-algorithm.pdf

Conclusions

- Swarm LP data delivers high quality measurements, supporting both numerical and observational scientific investigations.

- Some anomalies affect the LP measurement. These are monitored and analysed by the scientific community and Swarm Data Quality team.

- Swarm data quality is continuously improved to maximise the scientific return of the mission.

Useful links:

- Swarm web page : https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/mission-fact-sheet
- Swarm Data Access : https://earth.esa.int/web/guest/swarm/data-access
- Help and feedback : swarm_feedback@esa.int