

# A survey of polar cap densities based on EFW probe measurements.

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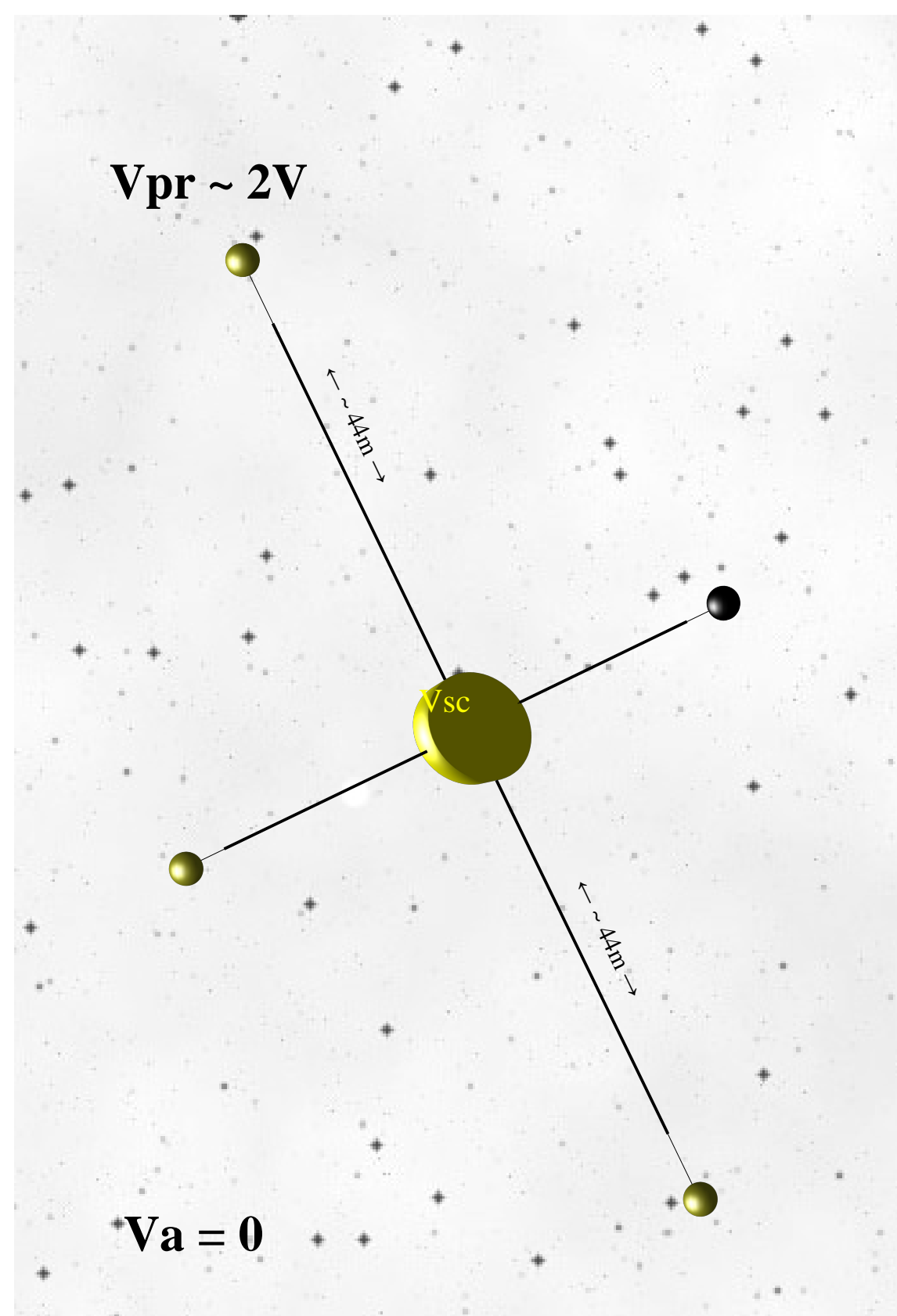
The polar cap and magnetospheric lobe regions are interfaces between plasma sources in the solar wind and ionosphere. Due to the low plasma density and high potential obtained by spacecraft in these regions, in-situ measurements based on traditional particle instruments are notoriously difficult. We have obtained new and more accurate plasma densities in these regions based on spacecraft potential measurements from the EFW-instrument. Plasma density values are found from such observations by converting from the potential measurements using a functional relationship between these two parameters. From a database containing 10 years of data, the density distribution can be obtained for the lobe- and polar cap regions and to some extent their footprint in the polar ionosphere. Based on this material, statistical investigations of variations in the density and polar cap size are carried out with respect to solar wind driving as well as internal magnetospheric processes. Similarities and variations in solar cycle dependency are discussed.

## Introduction

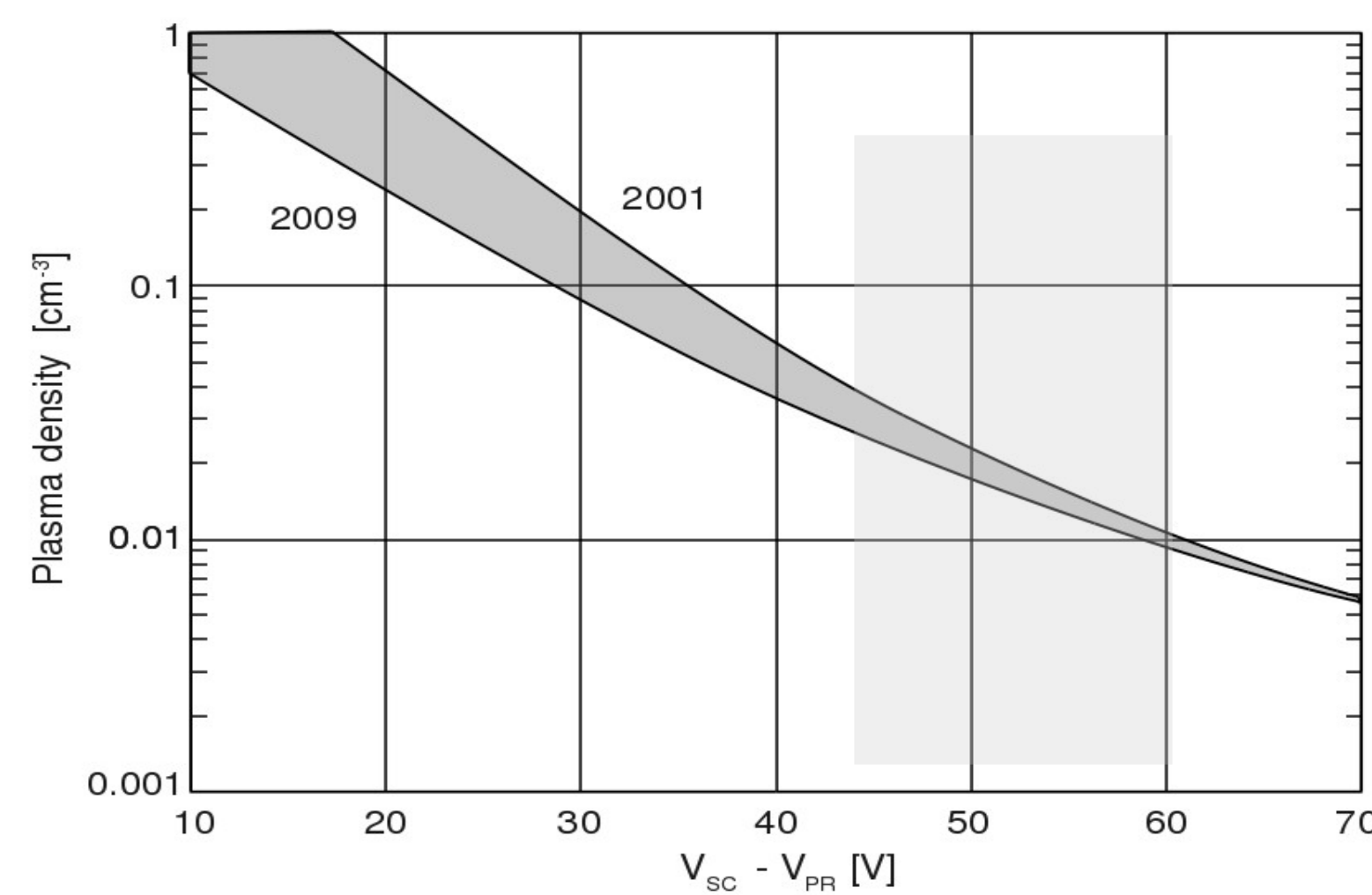
The low particle density above the polar cap regions makes direct measurements with plasma instruments difficult. In addition to the low count rates, measurements are often severely affected by spacecraft charging. A spacecraft immersed in a thin plasma emit photo electrons and will eventually be charged to large positive potentials. A significant part of the low energy ion population will therefore be shielded from the detectors, and e.g., moment calculations will not be very reliable. An additional challenge is that the low density which requires either long integration times or large geometric factors of the sensor to obtain sufficient number of counts for reliable moment calculations. Most of our recent knowledge about the density of polar cap and lobe region have therefore been based on measurements from double probe instruments. In this poster, we present a survey of polar cap density obtained with this technique during 10 years of EFW operation.

## Methodology

The density is derived from a functional dependence between the spacecraft-probe potential and electron density density. Details about calibration can be found in *Pedersen et al, 2008* and poster EGU2011-6817, (ST 3.2 - Friday) :



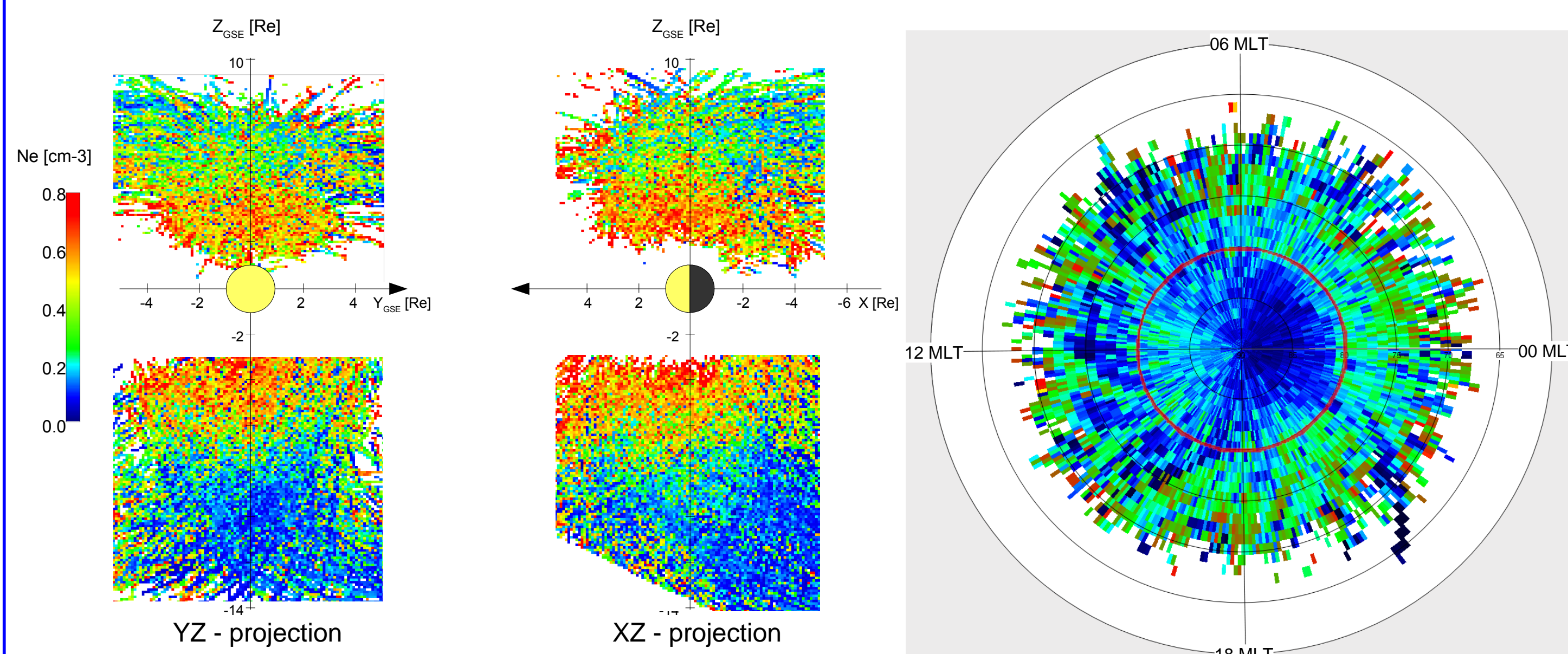
- $V_{sc}$  controlled by balance between photo electrons escaping (IPHS) and electrons collected (IES) from the ambient plasma.
- $I_{ES} = Ne C_F V_e^{1/2} A_{SC} [1 + (V_{sc} - V_{pr}) / V_e]$
- $Ne \sim A e^{-\frac{V_{sc}}{B}}$
- $A, B$  changes over time due to changes in solar irradiance (EUV)



## Dataset characteristics

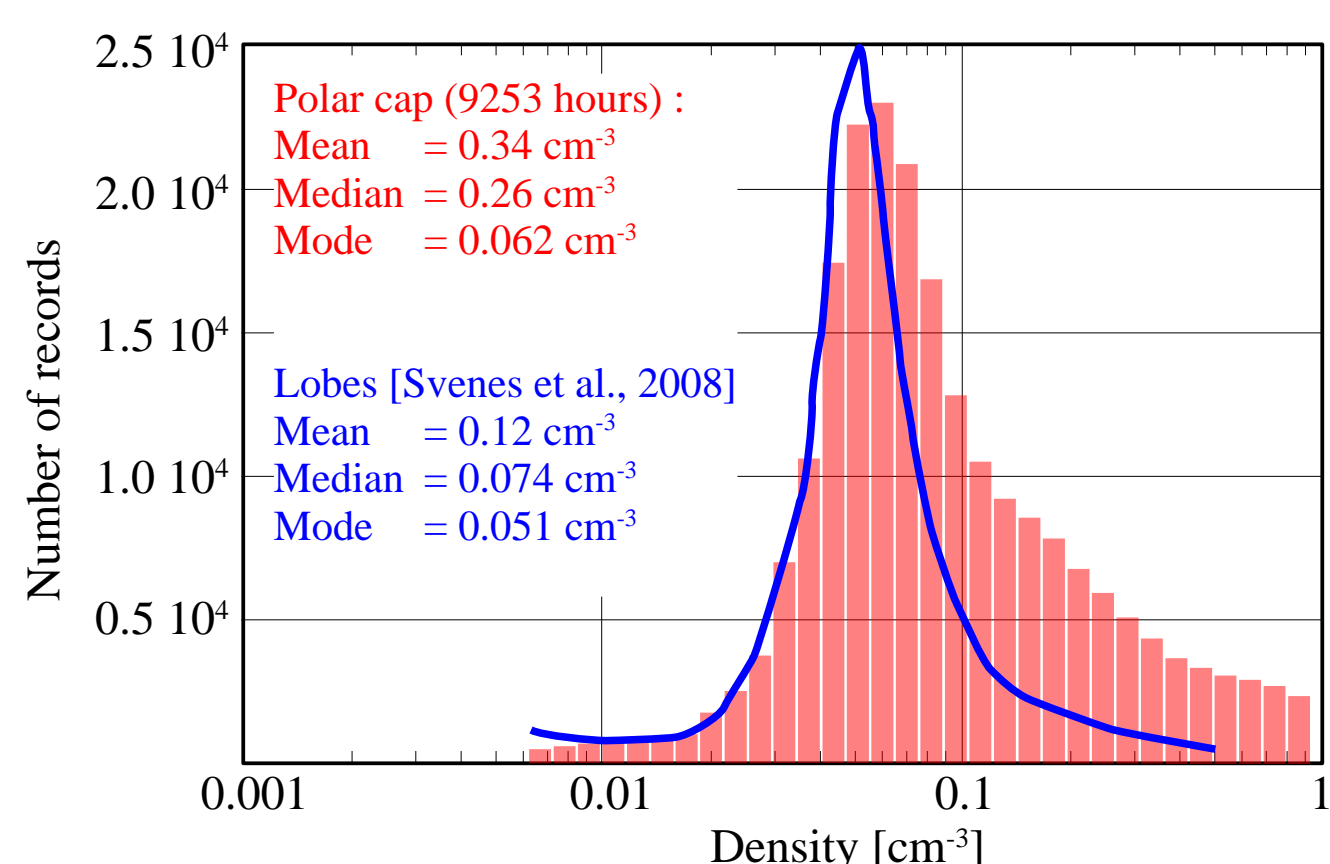
The total data set used for this survey consists of ~555'000 (~9'300 hours) 1 minute averages of derived density as well as auxiliary data such as the corresponding spacecraft position, activity indices, solar wind and IMF observations. From this data set we then extract subsets and look for correlations and dependencies.

### Spatial coverage :



Since we focus on polar cap, we first limit the data collection to two roughly 10 x 10 x 10 Re boxes above the northern and southern hemisphere. To study correlations and dependencies (see histograms to the right), we also include only data taken along field lines above 80 deg AACGM latitude. This selection is conservative, but prevents inclusion of data from e.g., the auroral zone or regions with closed field lines.

### Distribution



The figure to the left shows the distribution of densities for the data set, and a corresponding data set from the magnetotail lobes.

The distribution has a high density tail, which may be the result of inclusion/contamination from other source regions, thus the difference between the statistical moments.

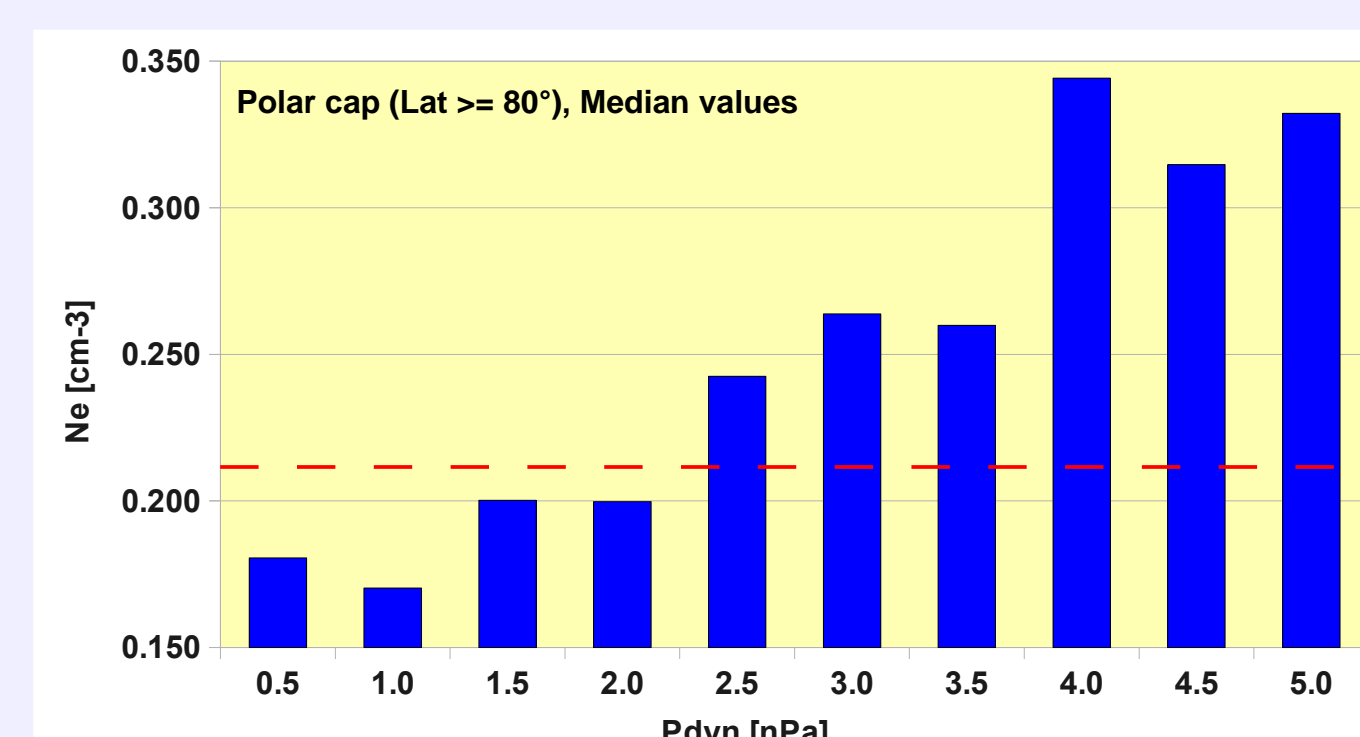
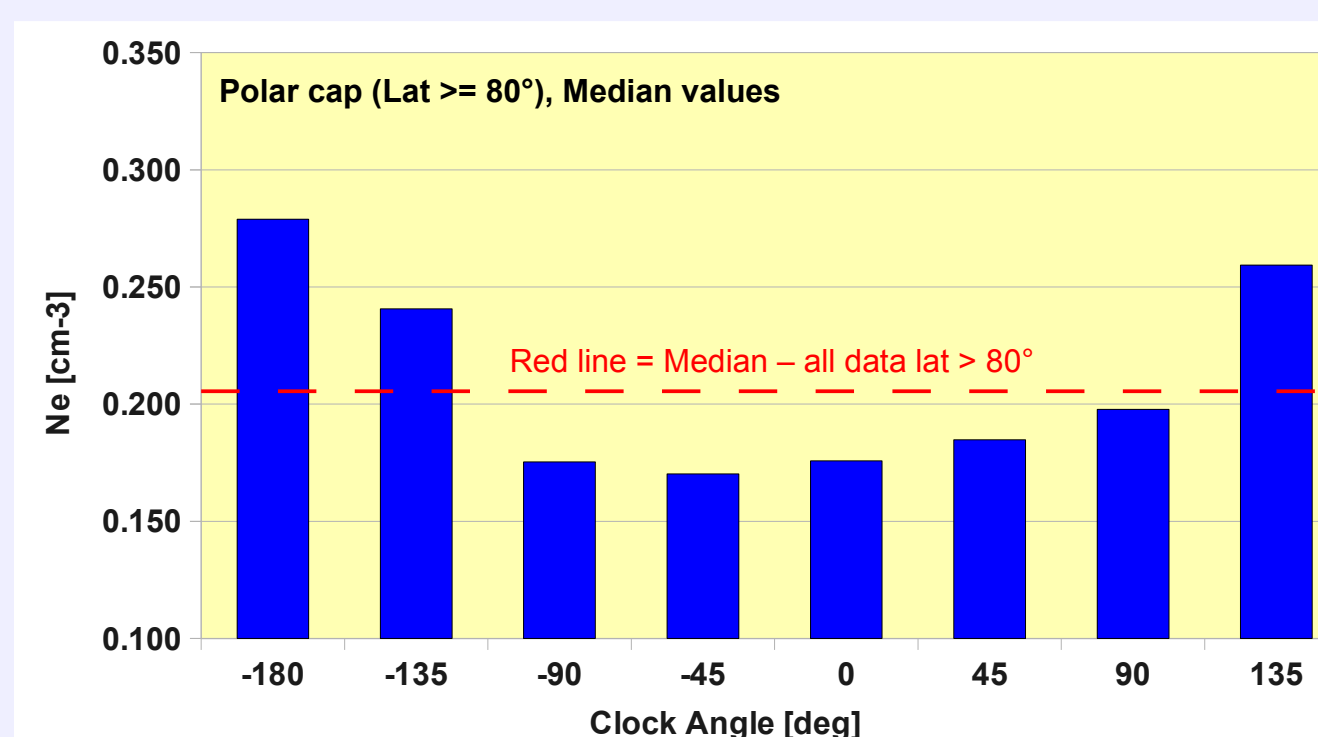
For comparison, we also show a similar data set, derived from the same instrumentation and methodology, but from the magnetospheric lobes [*Svenes et al, 2008*].

## What controls the polar cap density

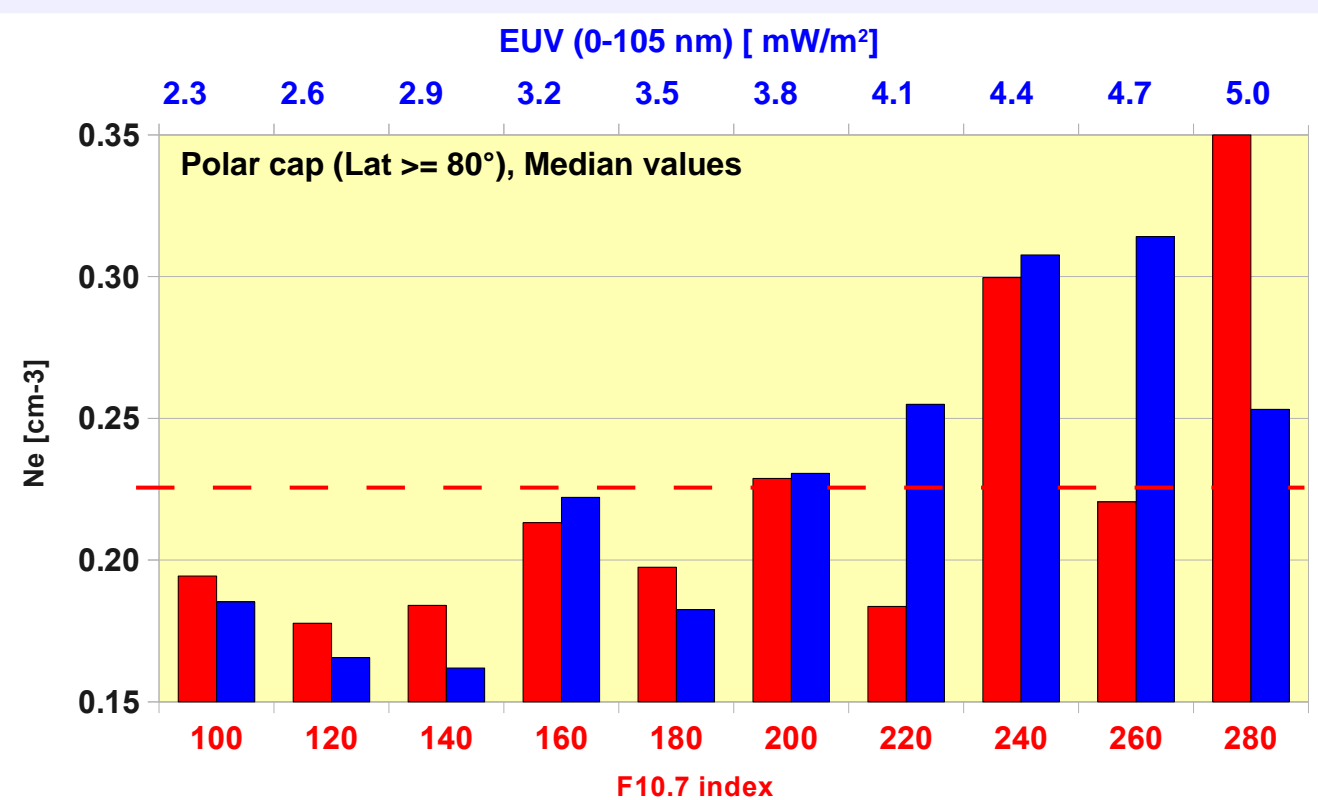
To answer this question, we bin the data according to solar wind, IMF and geomagnetic activity levels. Only data obtained along magnetic field lines with footpoints above 80 degrees AACGM latitude are used.

### Solar wind and IMF control

The highest densities are found for southward IMF condition, perhaps as a result of solar wind plasma entry. Binning according to solar wind dynamic pressure (right panel) shows a clear correlation. This may be another indication of solar wind plasma penetration, but more likely the result of increased magnetosphere compression.



### Solar irradiance



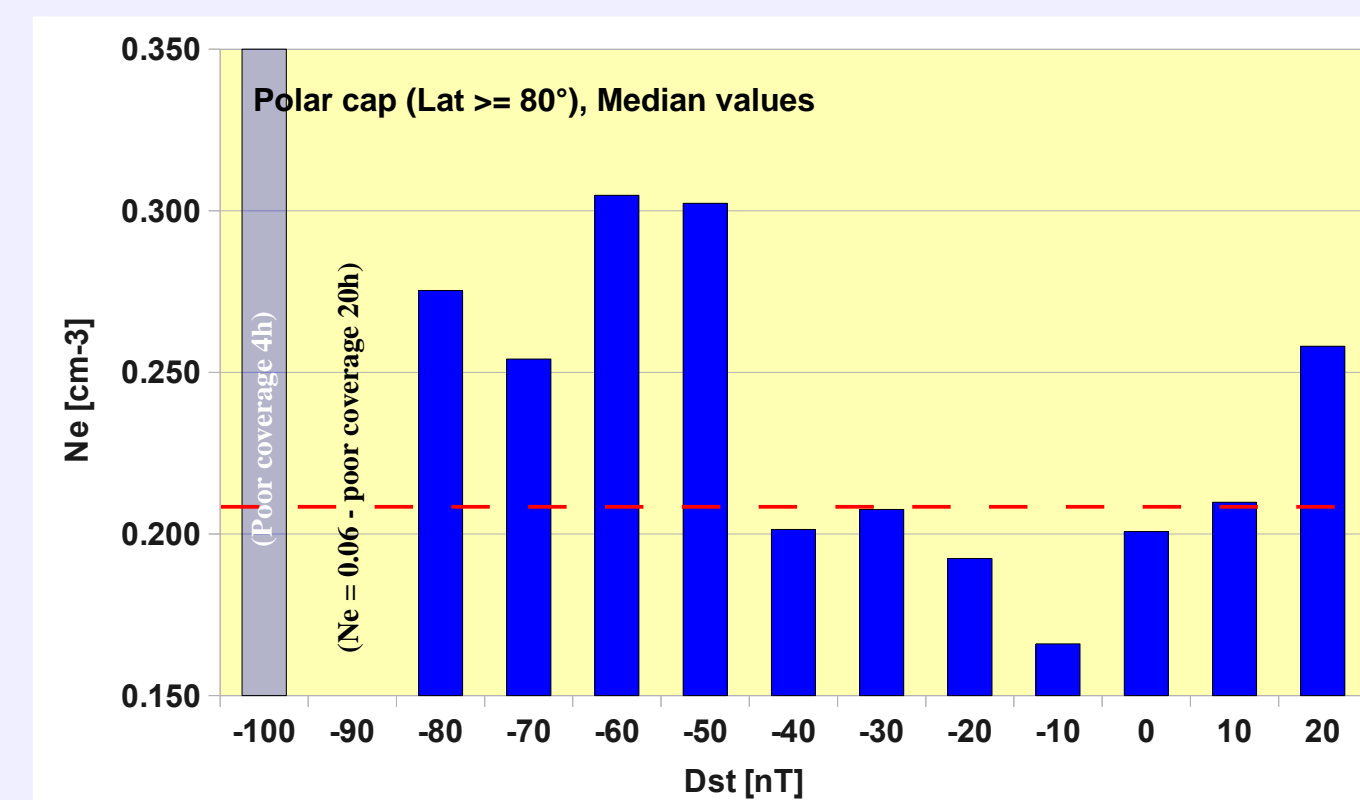
We have two proxies for solar irradiance in our data set; the F10.7 index and measured EUV from the TIMED satellite (not available for 2001).

Both show a clear positive correlation between with UV radiation and polar cap density. This result is a strong indication of ionospheric origin; Higher UV means stronger ionization of the ionosphere. Outflow will then transport the plasma from the ionosphere into the magnetosphere and Cluster altitudes.

### Geomagnetic activity

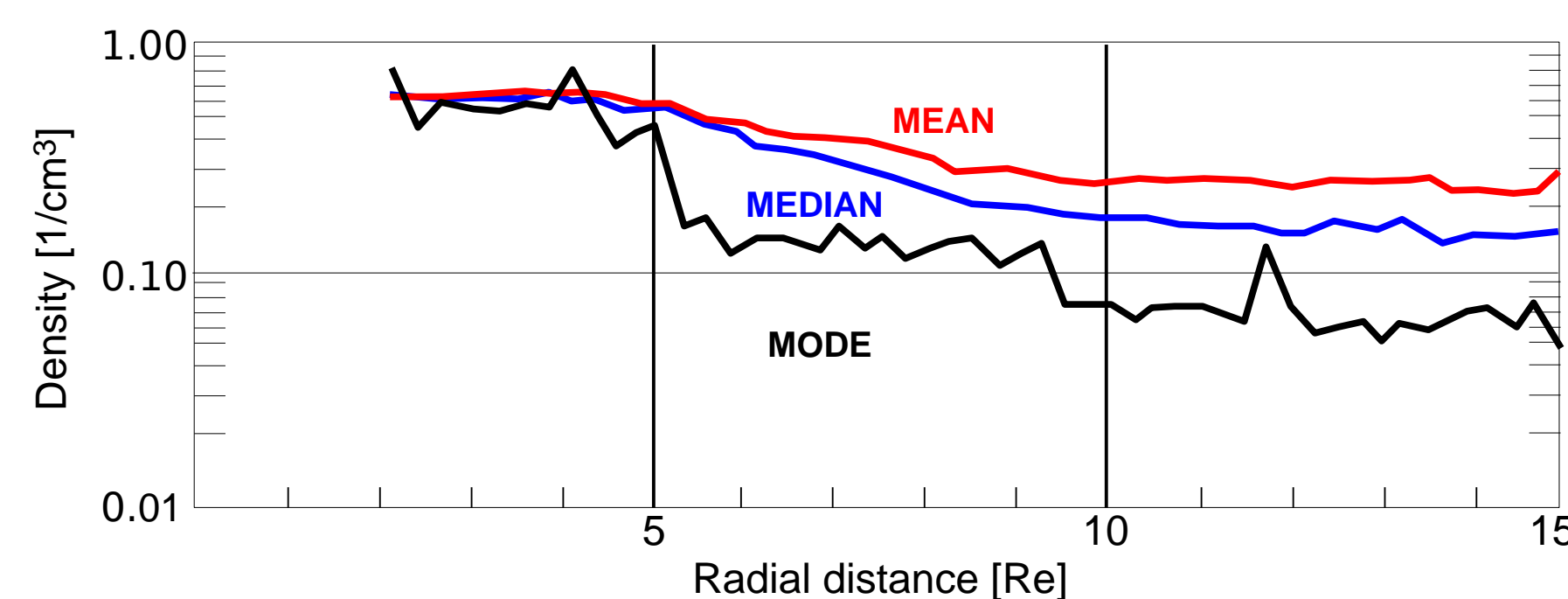
The Dst and AE indices reflect processes internal to the magnetosphere; A strong negative Dst is typically associated with enhanced dayside reconnection and enhanced convection. AE is primarily related to short time, transient events like BBFs which set up and enhance field aligned currents in the auroral zone.

For low and moderate Dst values, we see little or no correlation. For strongly negative Dst values, the higher densities may be related to penetration of solar wind plasma. Large positive Dst values occur under strong compressions (e.g., SSCs) and may explain the higher polar cap density under such conditions.



## Sources of polar cap plasma

Two conceivable plasma sources exist; 1) outflow from the upper ionosphere due to ionization as demonstrated above. 2) solar wind entry. The figure below, which shows the density as function of radial distance, shows a marked drop in the density around 5 Re; The statistical mode inside 5-6 Re is roughly order of magnitude higher than at larger distances, and may be a signature of the plasma of ionospheric origin. Unlike the correlation plots above, we here use the full, 9'300hr data set.



## Summary and conclusions

We have used 10 years of electron density measurements derived from the Cluster EFW probe potential to study polar cap density variations. The results show :

- \* For the full dataset, the statistical mean, median and mode are 0.34, 0.26 and 0.062 cm<sup>-3</sup>, respectively.
- \* The polar cap plasma density varies with solar activity; Higher UV irradiance leads to increased ionization and thus higher electron density.
- \* Increased solar wind dynamic pressure (which may be due to either increased solar wind density or velocity) leads to a higher polar cap density. This can probably be explained by a compression of the whole magnetosphere.
- \* We also find a correlation between IMF and the density; Southward IMF is associated with higher densities, but it is unclear whether this is due to solar wind penetration or secondary effects.
- \* Internal processes in the magnetosphere, such as substorms, BBFs (reflected in the AE index) does not seem to play any direct role for polar cap density. During storms (strong negative Dst), the polar cap density is on average higher than during quiet conditions. This may be caused by increased solar wind plasma entry, but secondary effects may also play a role.

## References

Lybekk, et al., *Solar cycle variations of the Cluster spacecraft potential and its use for electron density estimations*, Ann. Geophys. Submitted (see also EGU2011-6817, Friday)

Pedersen et al, *Electron density estimations derived from spacecraft potential measurements on Cluster in tenuous plasma regions*, J. Geophys Res, Volume 113, 2008.

Svenes et al, *Cluster observations of near-Earth magnetospheric lobe plasma densities a statistical study*, Ann. Geophys., Volume 26, 2008.