Estimating the Energy Budget of the Polar Wind Outflow

Kun Li

Institute of Geology and Geophysics, Chinese Academy of Sciences

with supports from:
Y. Wei, S. Haaland, E. Kronberg, Z. J. Rong, L. Maes, R. Maggiolo, M. Andre,
H. Nilsson, E. Grigorenko

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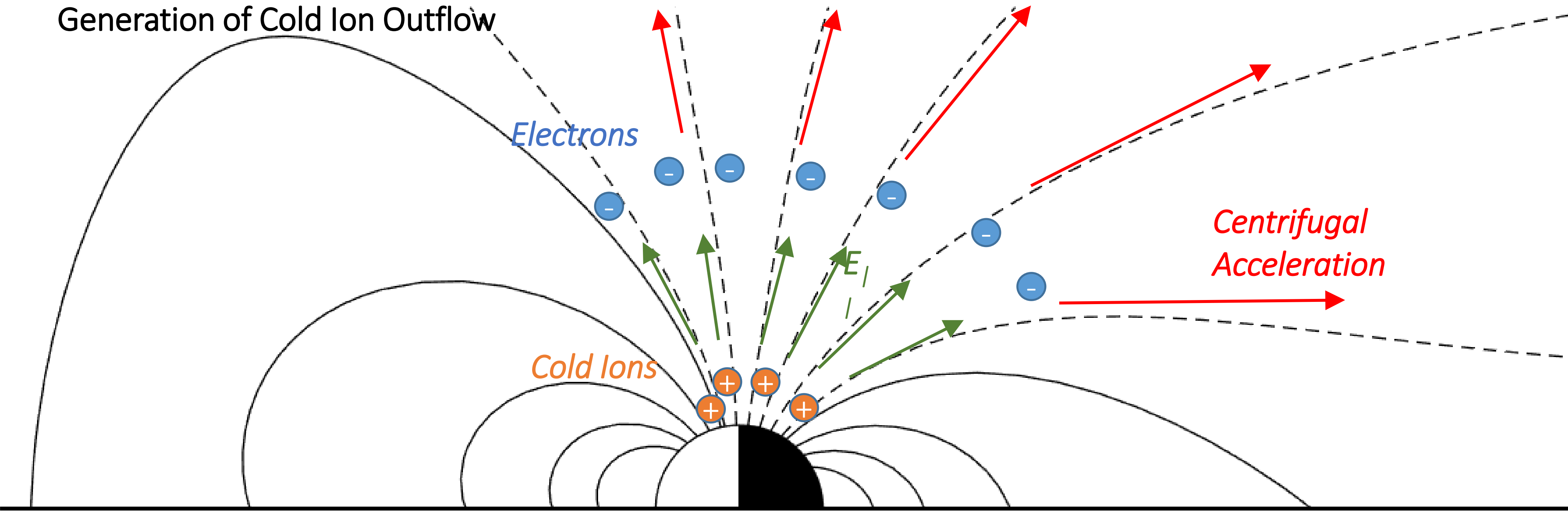
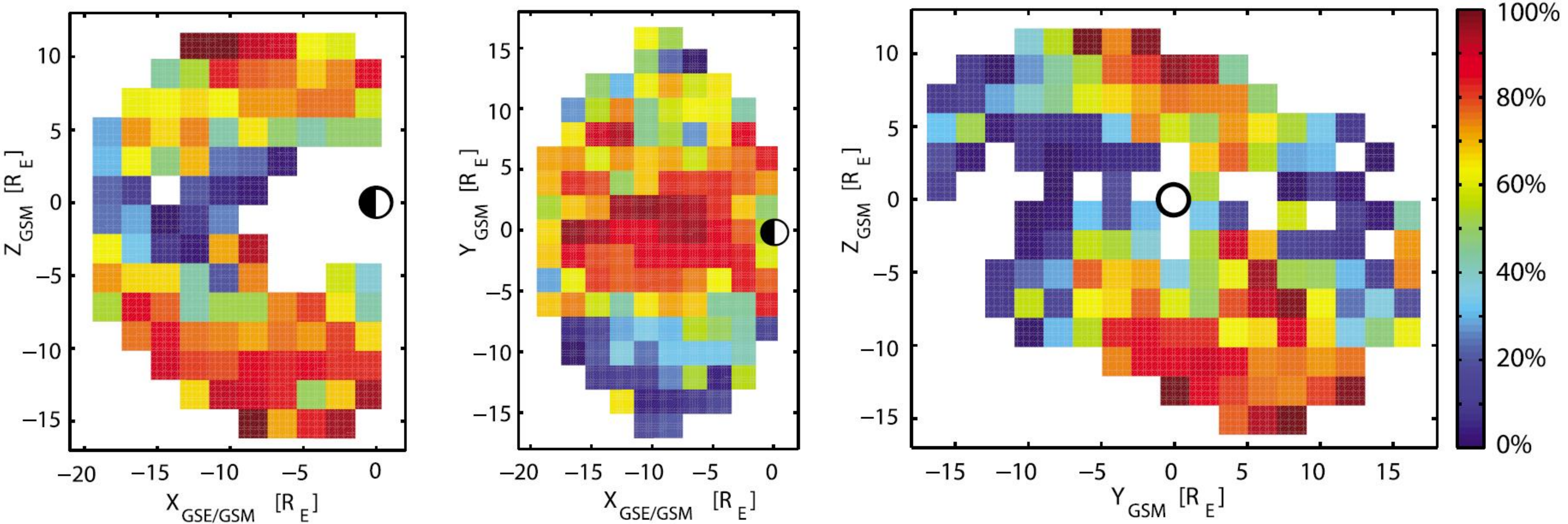
Introduction

Generation of Cold Ion Outflow

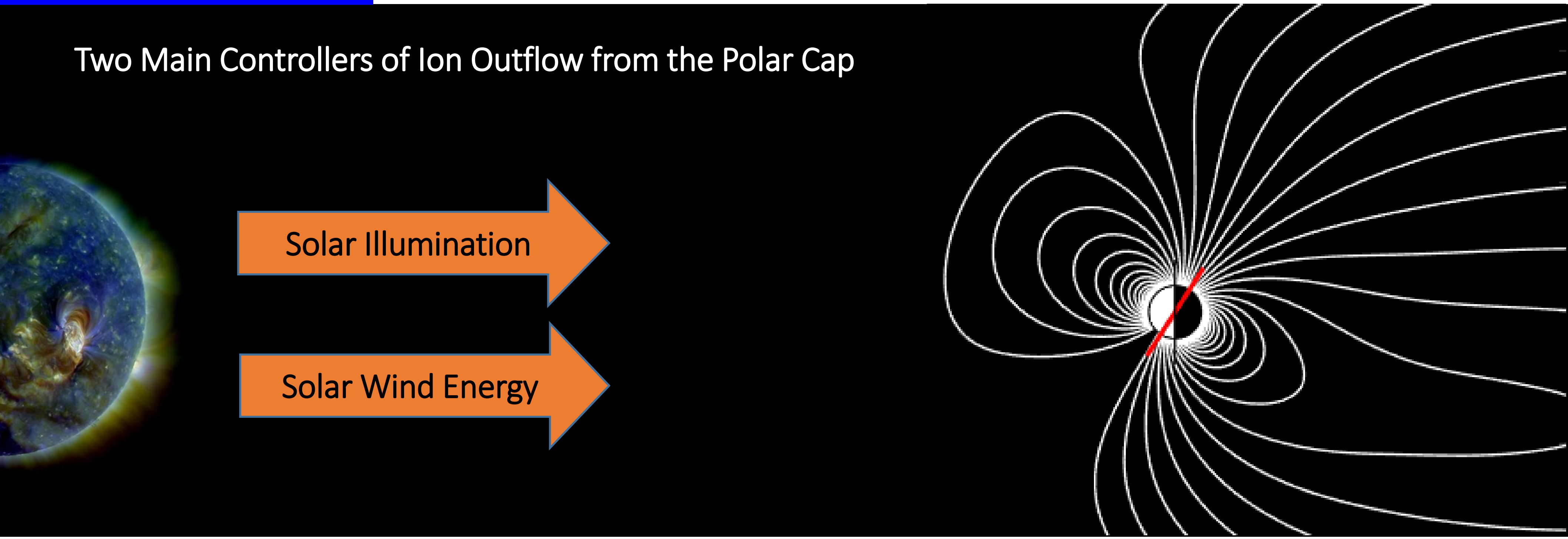


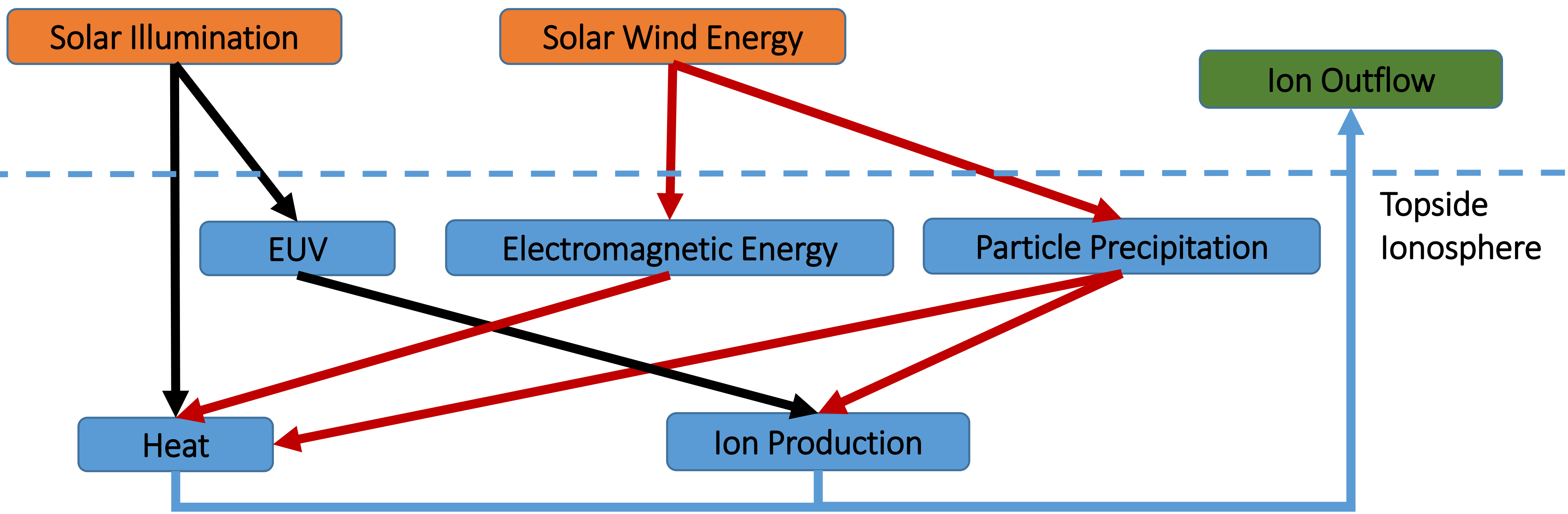
Cold Ion Dominates the Ion Population in the Magnetosphere

[*Engwall et al.*, 2009, AG]

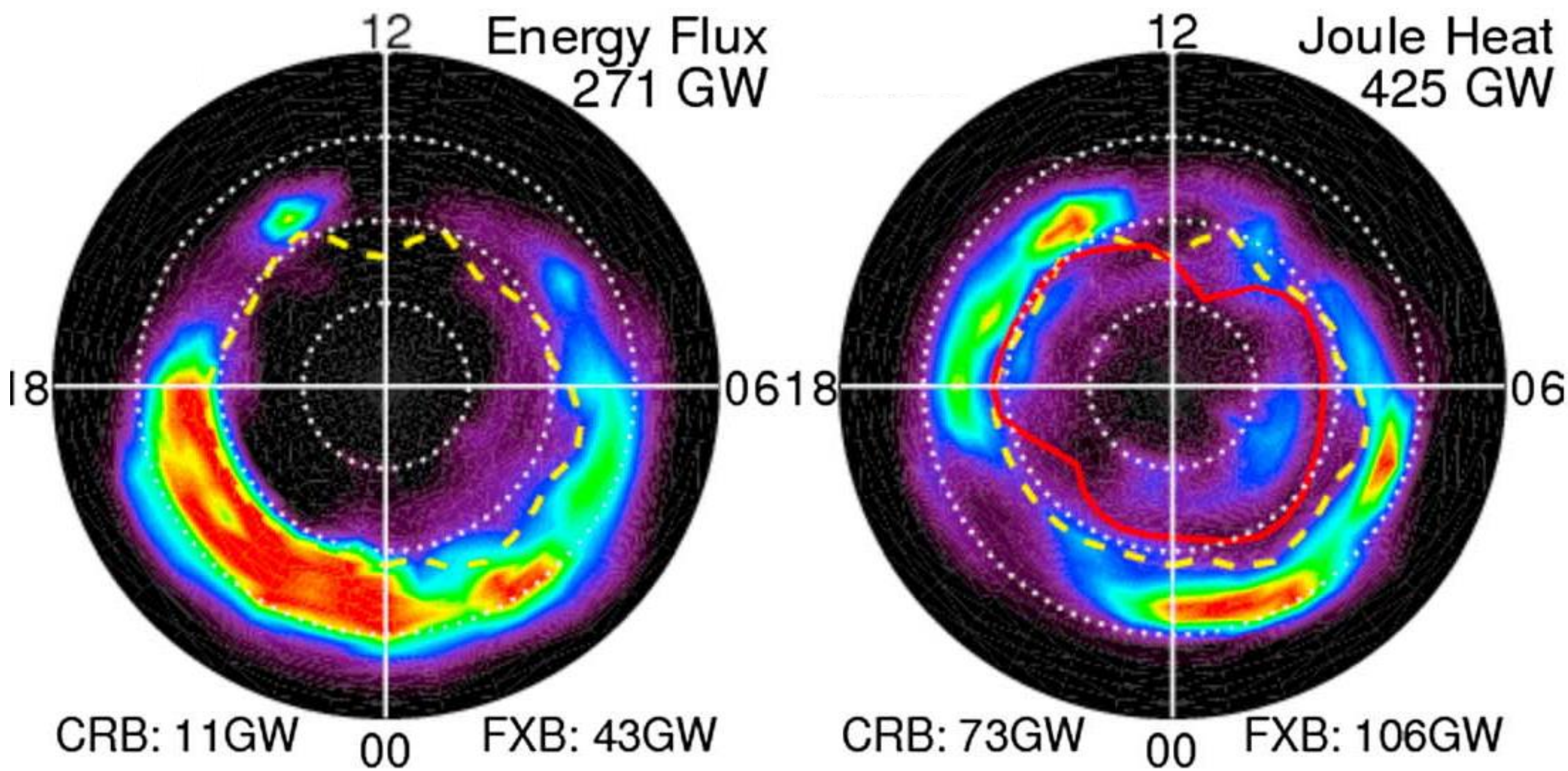


Introduction





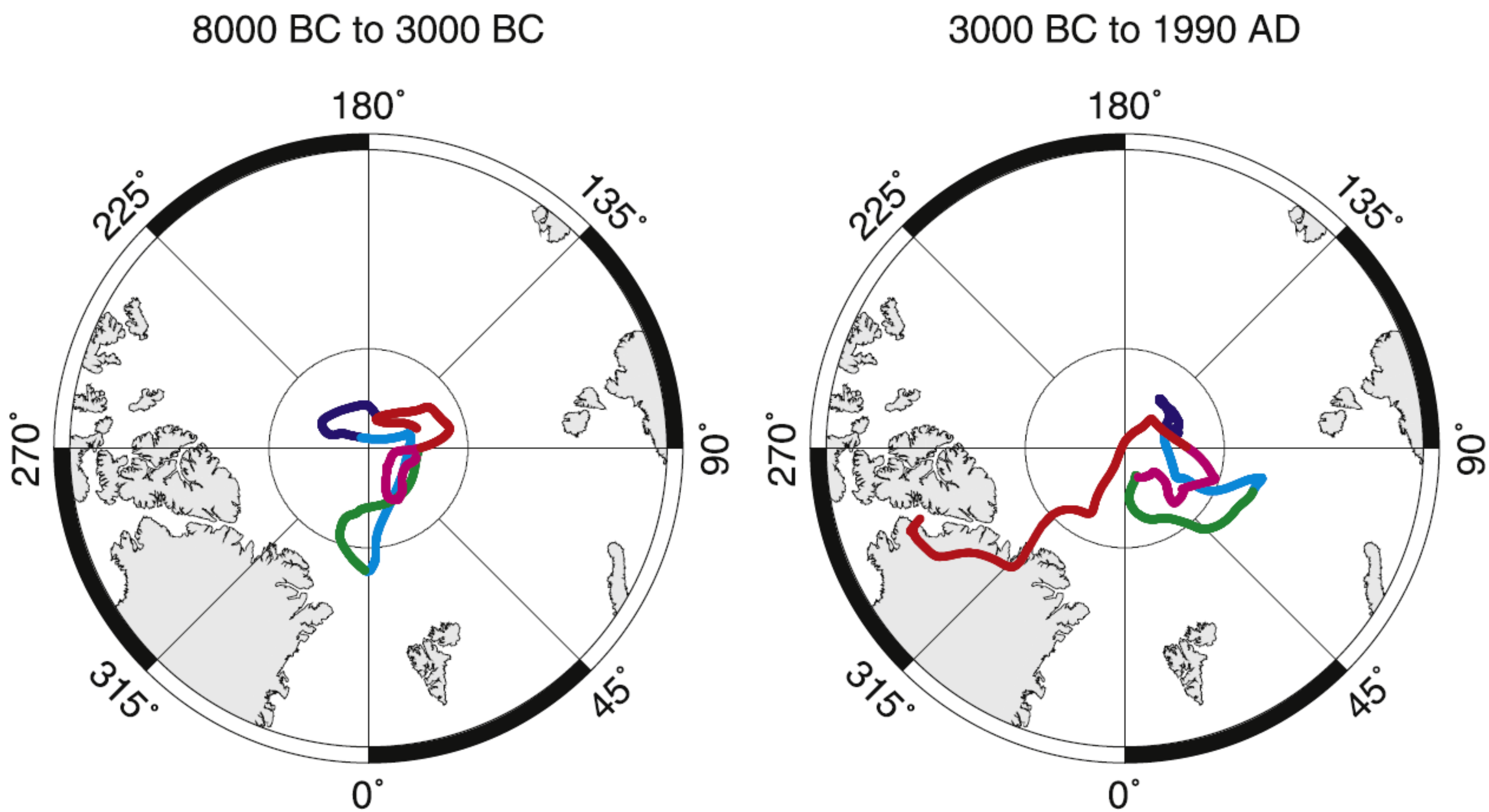
Question 1: How Is Cold Ion Outflow Affected by the Changing Solar Wind Energy Input?



About 22-25% of the energy dissipation in the polar ionosphere take place in the polar cap

[*Lu et al.*, 2016, JGR]

Question 2: How Is Cold Ion Outflow Affected by the Changing Geomagnetic Dipole in the History?

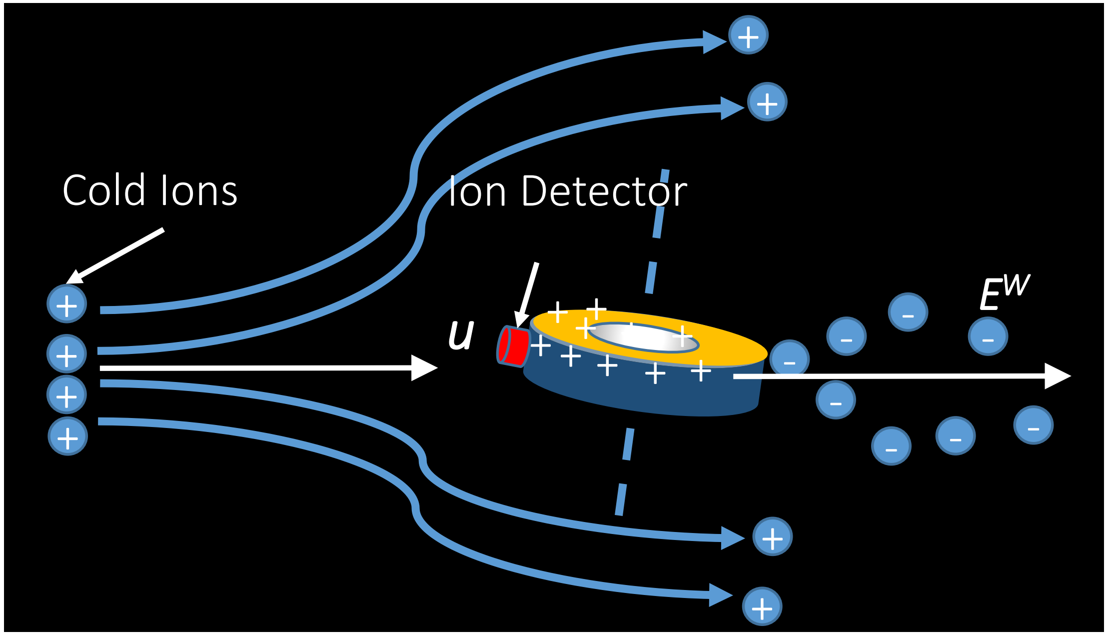


The geomagnetic dipole has been changing.

[*Korte et al.*, 2011, EPSL]

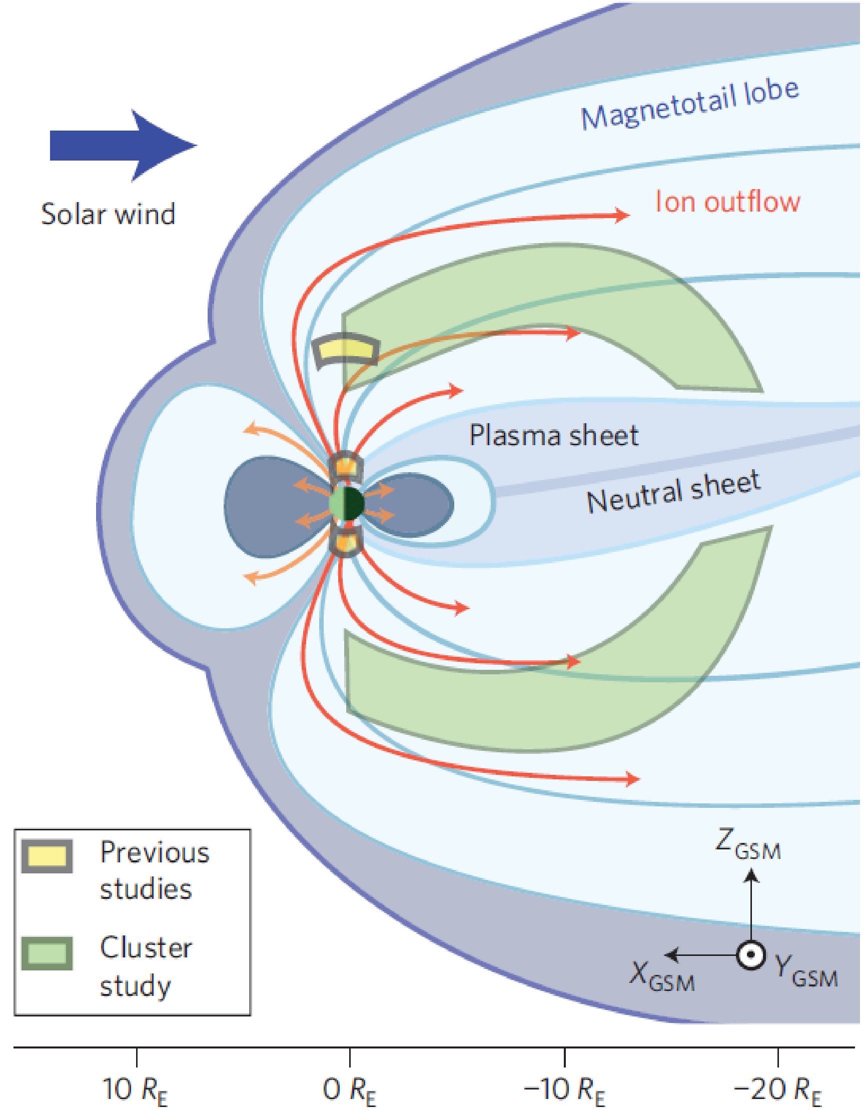
Data and Method

1. Measure the cold ions (E_K<70eV, E_T~few eV)



Input Data		Output Data
EFW, EDI, FGM	➡	Bulk Parallel Velocity
EDI	➡	Bulk Perpendicular Velocity
EFW	➡	Density

[*Engwall et al.*, 2009a, AG]

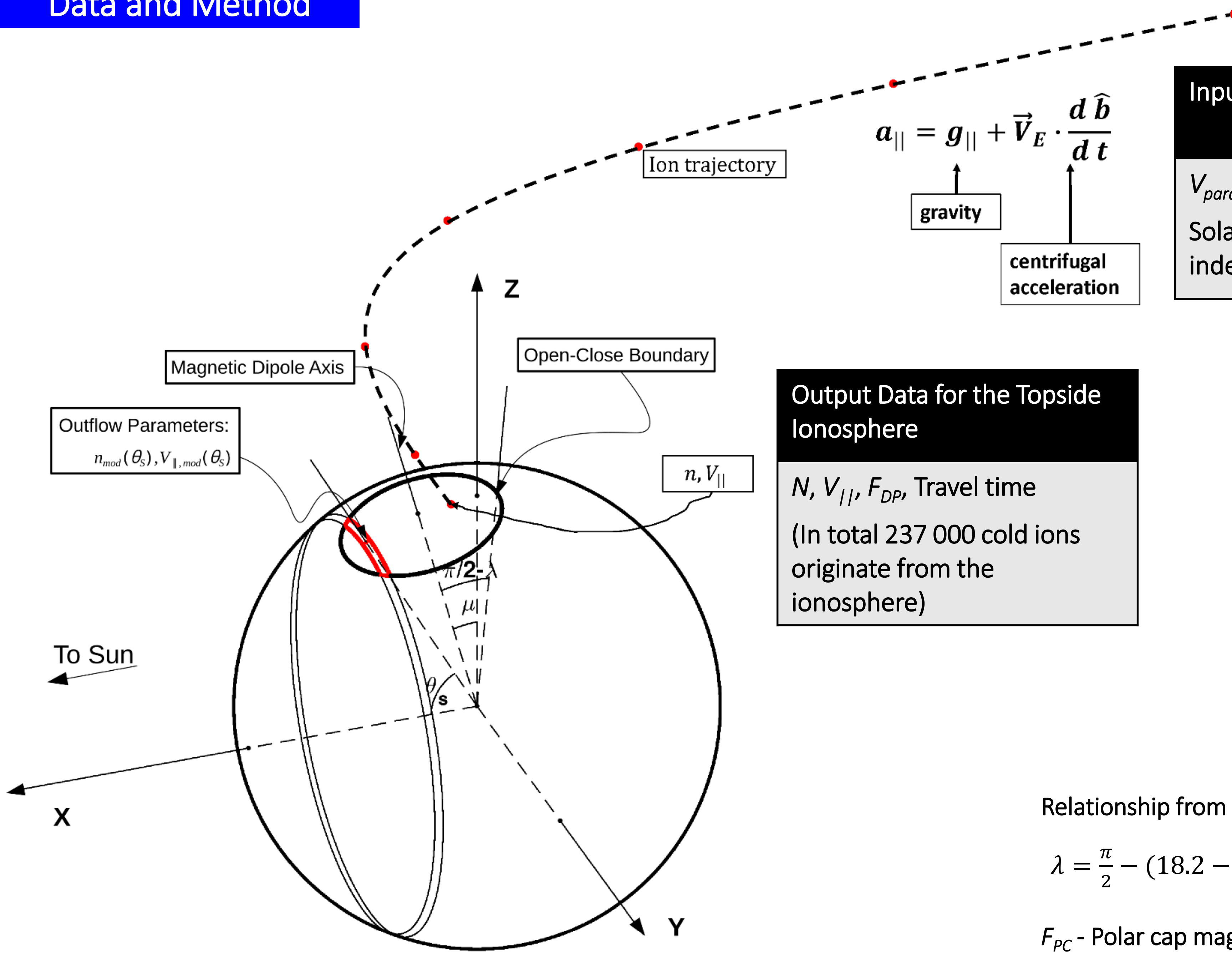


[*Engwall et al.*, 2009b, Nat. Geophys.]

- Extended data set from two Cluster spacecraft from the years 2001-2010.
- In total 320 000 measurements of tailward moving cold ions.

[*Andr é et al.*, 2015, JGR]

Data and Method



Input Data

V_{para}, V_E and N_{lobe}

Solar wind parameters, Dst index (T01 model required)

Output Data for the Topside Ionosphere

N, $V_{||}$, F_{DP}, Travel time

(In total 237 000 cold ions originate from the ionosphere)

[*Li et al.*, 2018, in prep.]

Relationship from least-square fitting

$$\lambda = \frac{\pi}{2} - (18.2 - 0.038\, D_{st} + 0.042\phi_D)$$

F_{PC} - Polar cap magnetic flux

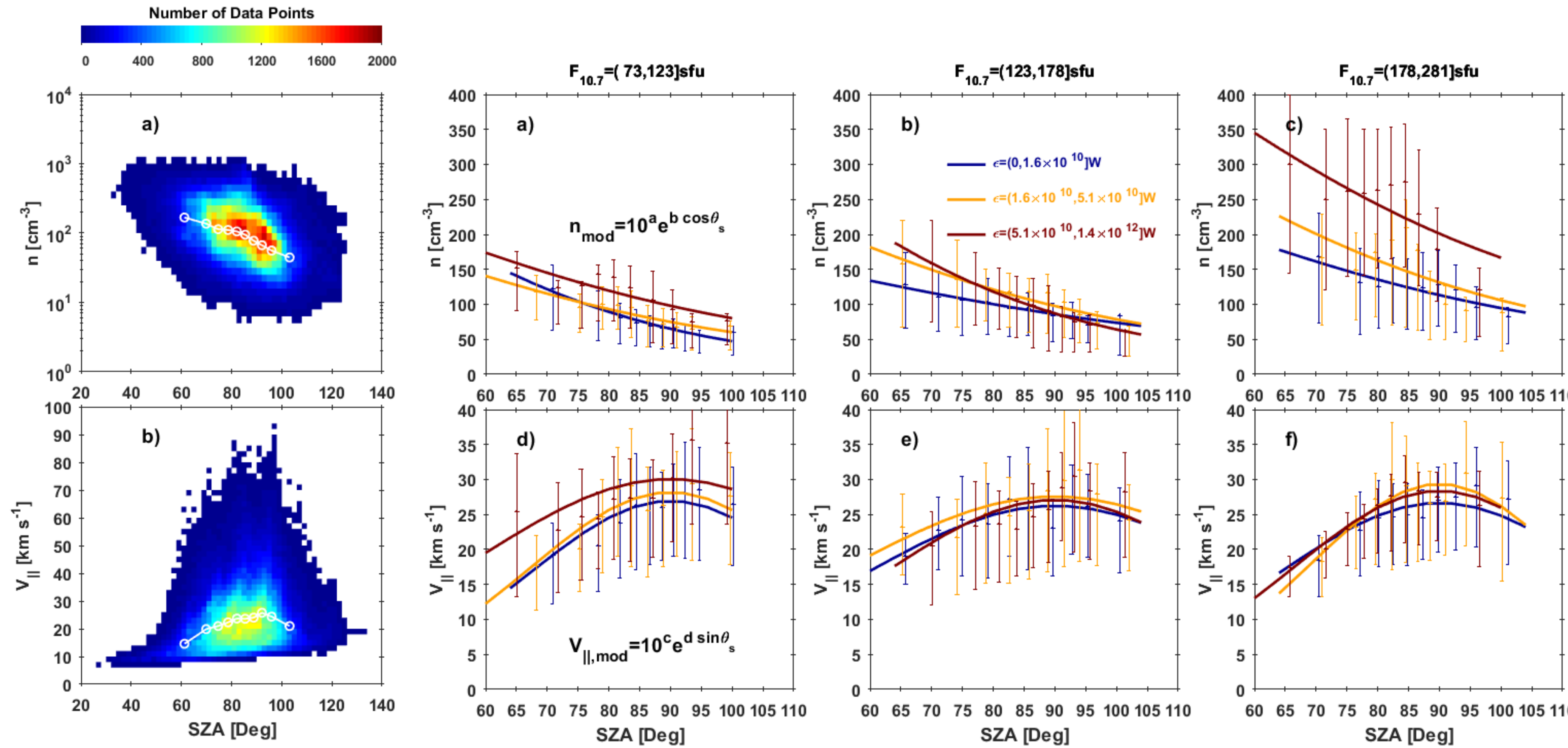
ϕ_D - Dayside reconnection rate

λ - Magnetic latitude of polar cap boundary

$$F_E = \sum_{\theta_S} F_{DE,mod}(\theta_S)\Delta S(\theta_S, \lambda, \mu) = \frac{1}{2} m_p \sum_{\theta_S} n_{mod}(\theta_S) V^3_{||,mod}(\theta_S)\Delta S(\theta_S, \lambda, \mu)$$

Data and Method

Deriving $n_{mod}(\theta_S)$ and $V_{||,mod}(\theta_S)$ using n and $V_{||}$ from particle tracing:



$$n_{mod}(\theta_S) = 10^a e^{b\ \cos\theta_S} \text{ and } V_{||,mod}(\theta_S) = 10^c e^{d\ \sin\theta_S}$$

***b* and *d* are determined from least square fitting**

***a* and *b* are determined from:**

$$a = log_{10}\left(\frac{n}{e^{b\cos\theta_S}}\right) \text{ and } c = log_{10}\left(\frac{V_{||}}{e^{d\sin\theta_S}}\right)$$

Results

1. Total Kinetic Energy Power of Polar Wind as a Function of the ε Parameter

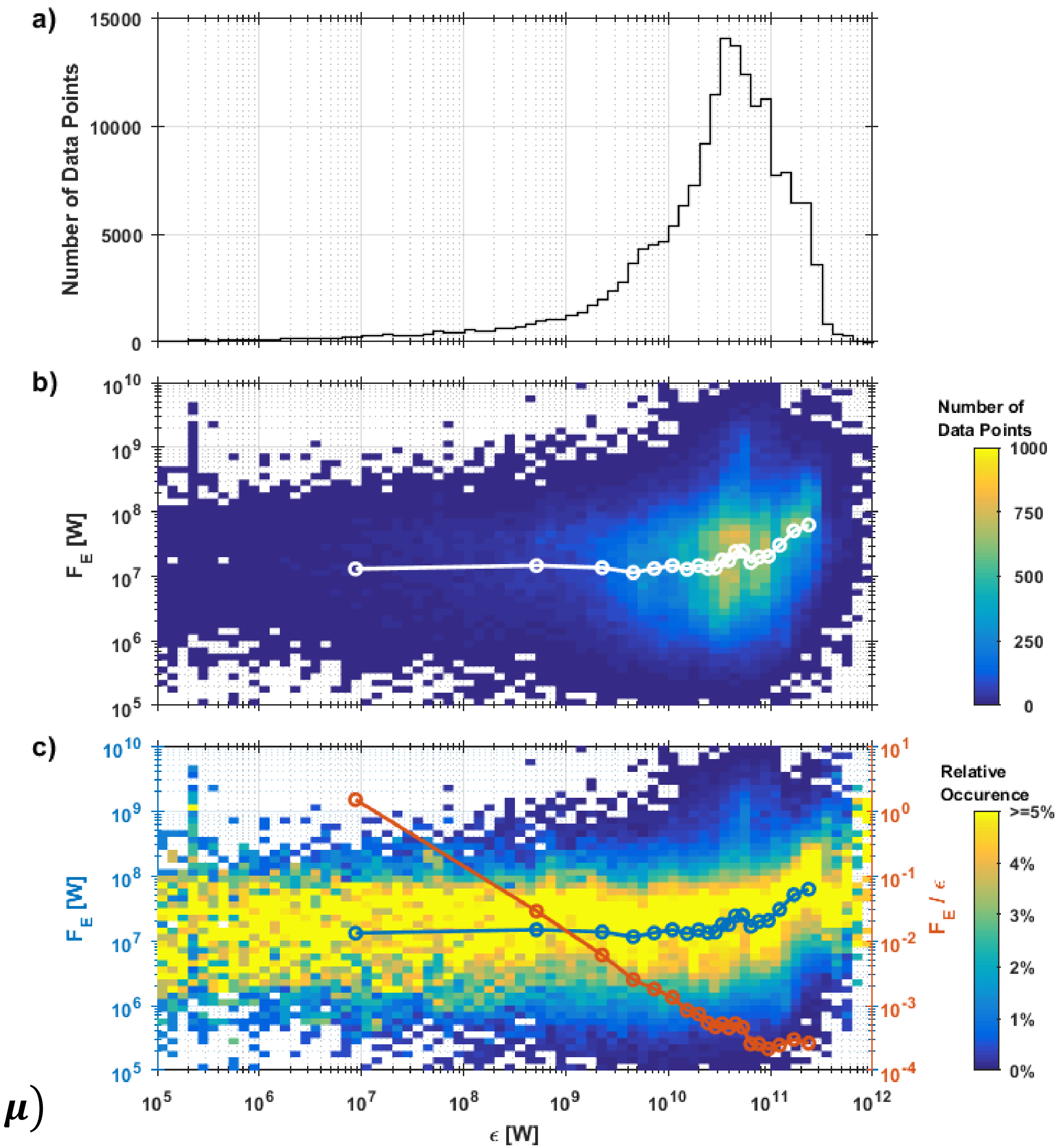
$$\epsilon = \frac{4\pi}{\mu_0} V_{SW} B^2 sin^4 \frac{\theta}{2} R_{cf}^2$$

$$R_{cf}^2 = (B_0 / 4\pi\rho V_{SW}^2)^{\frac{1}{3}} R_E^2$$

[*Perreault, P., and S.-I. Akasofu*, 1978]
[*Mac-Mahon and Gonzalez*, 1997]

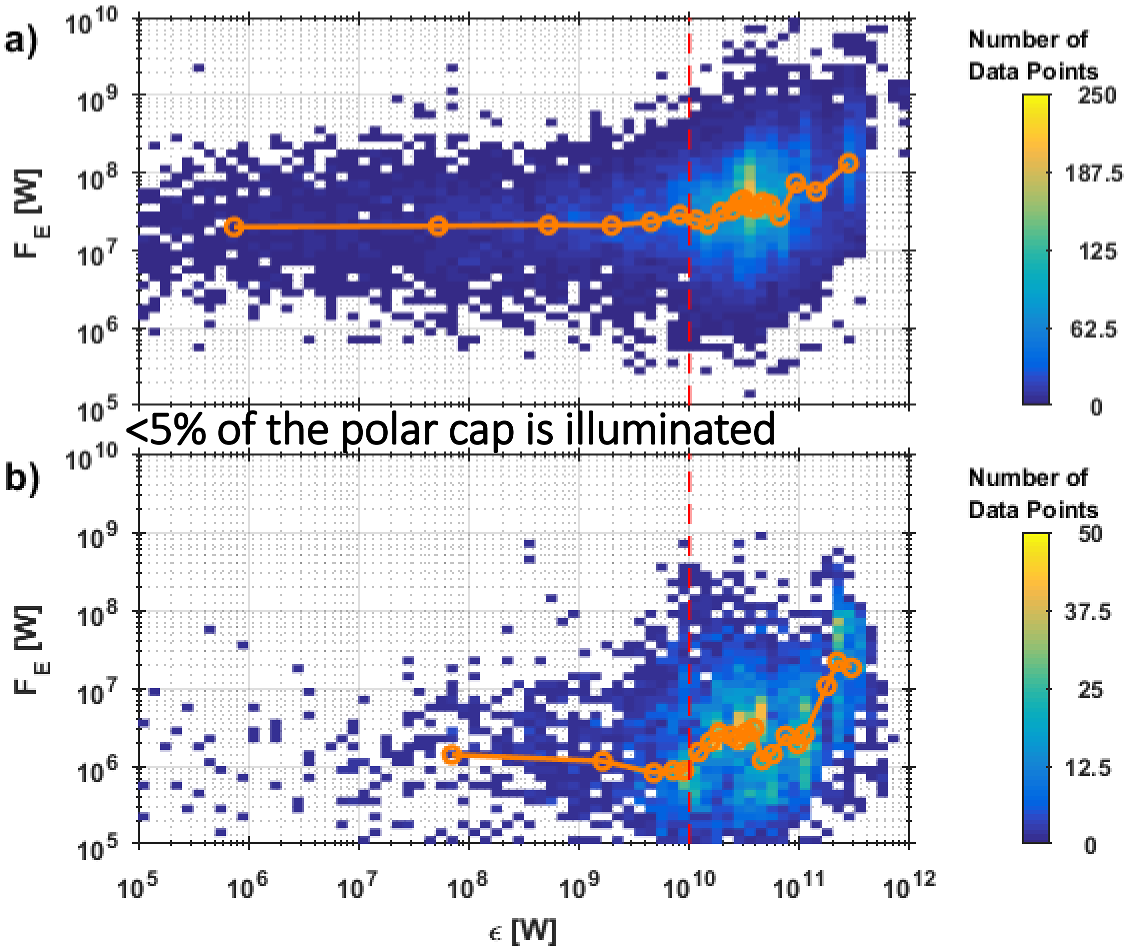
$$F_E = \sum_{\theta_S} F_{DE,mod}(\theta_S) \Delta S(\theta_S, \lambda, \mu)$$

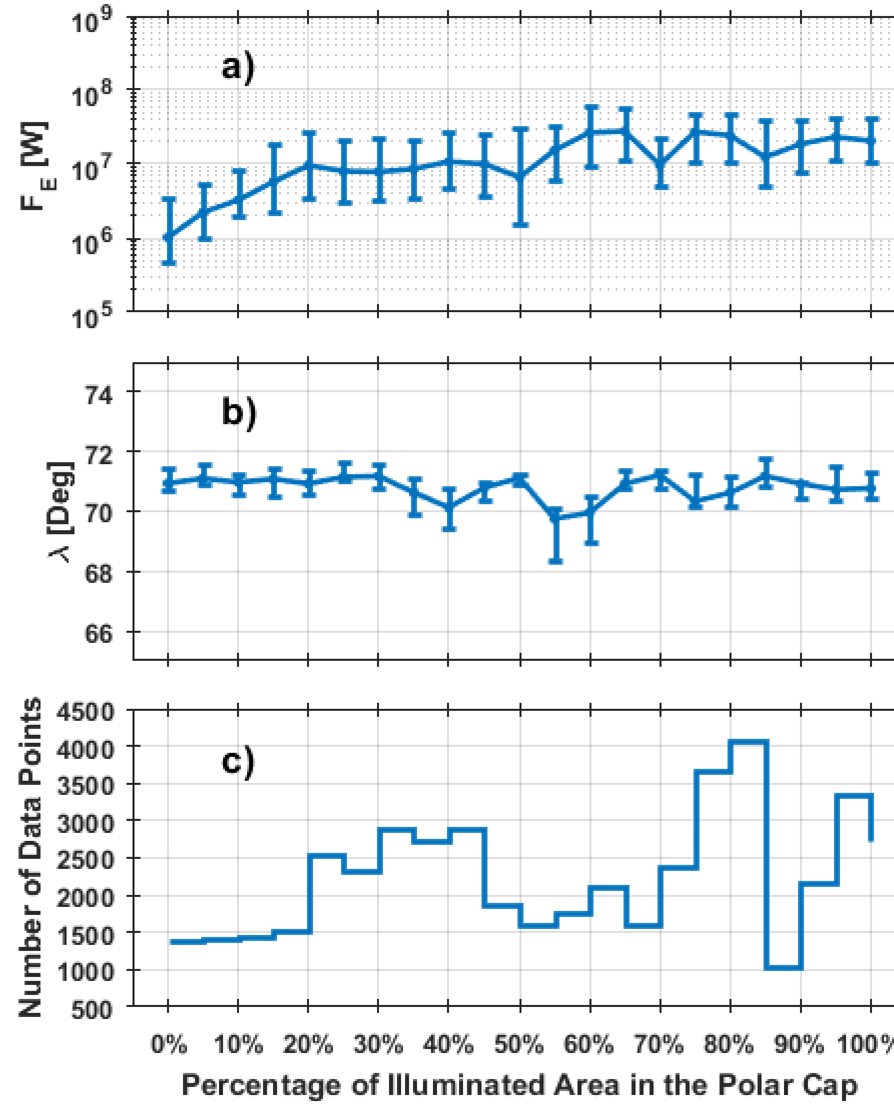
$$= \frac{1}{2} m_p \sum_{\theta_S} n_{mod}(\theta_S) V_{||,mod}^3(\theta_S) \Delta S(\theta_S, \lambda, \mu)$$



Results

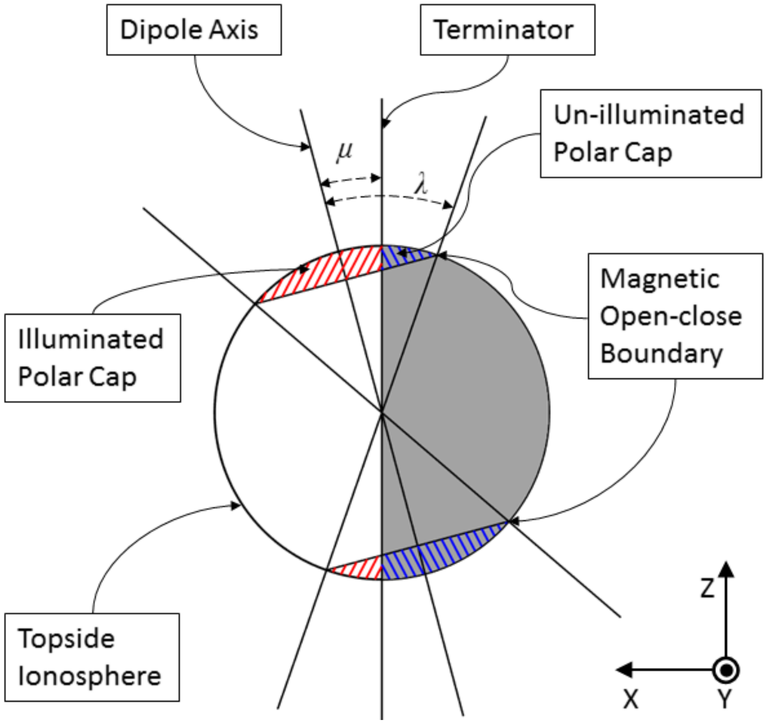
>95% of the polar cap is illuminated





Discussions

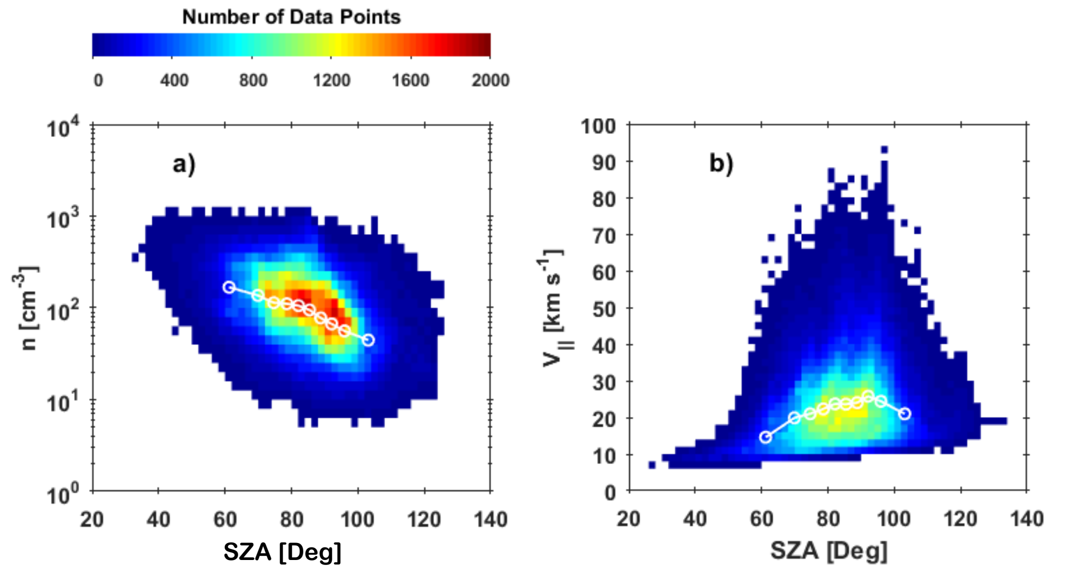
1. Assessing the Influence of the Velocity Filter Effect

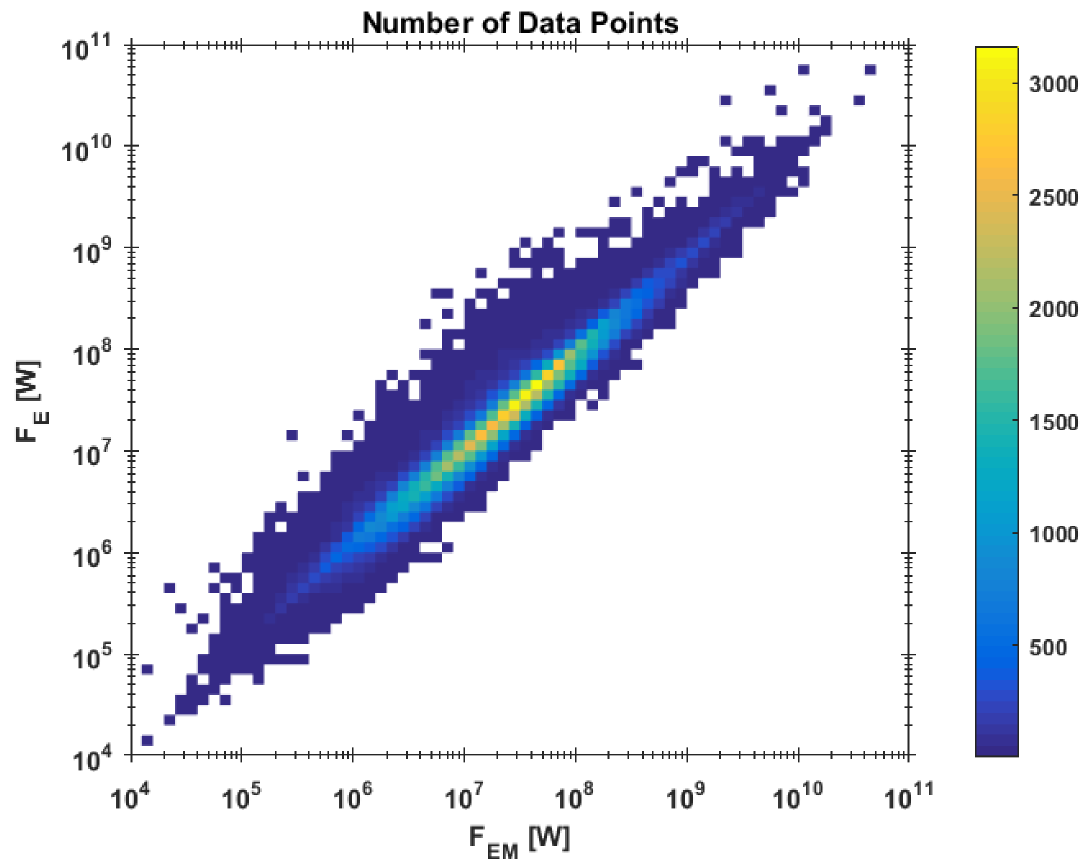


F_E is modified to exclude the velocity filter effect For a given time:

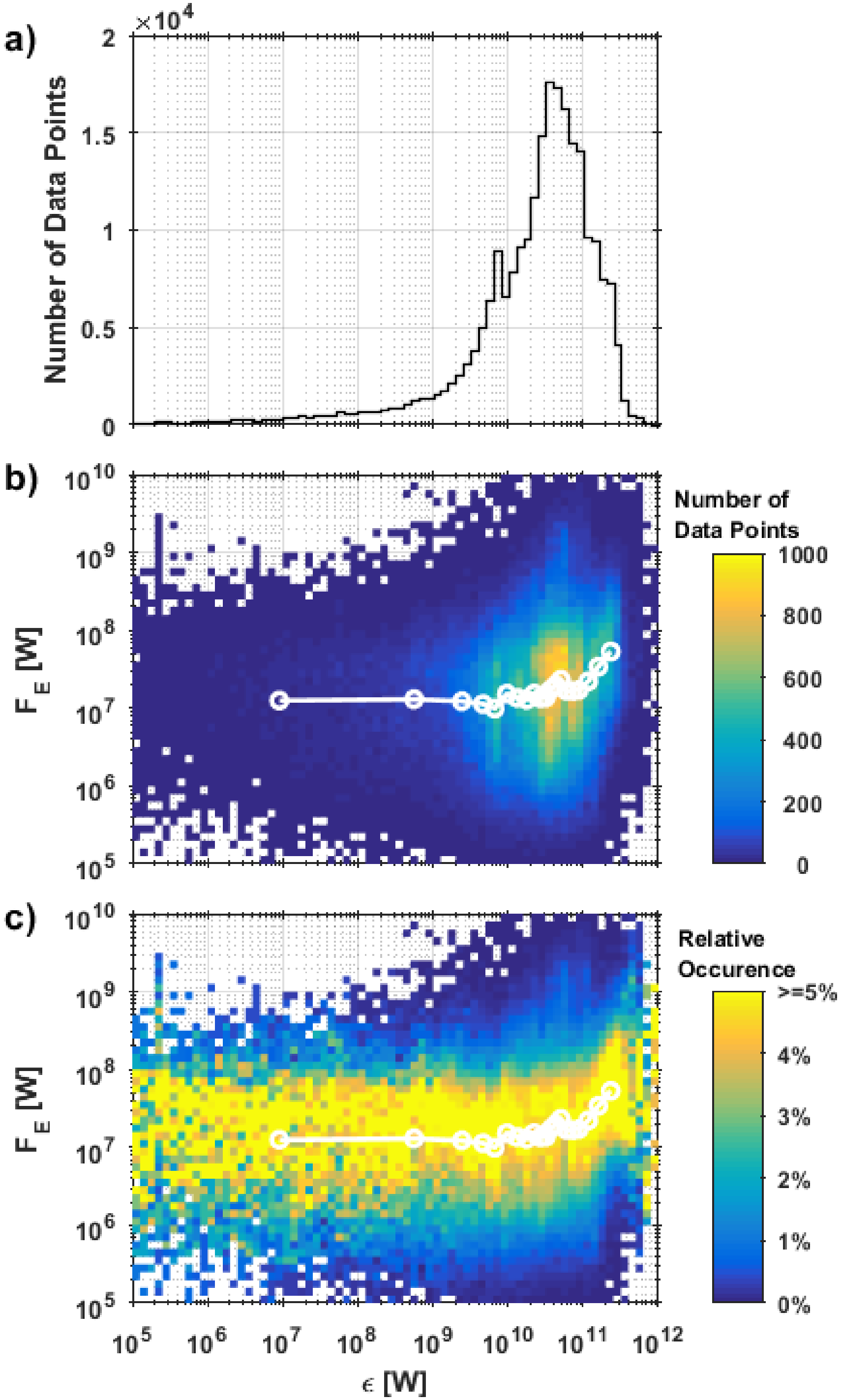
1. $n_l : n_d$=2:1
2. $V_{||}$ is assumed to be the same at all locations in the polar cap

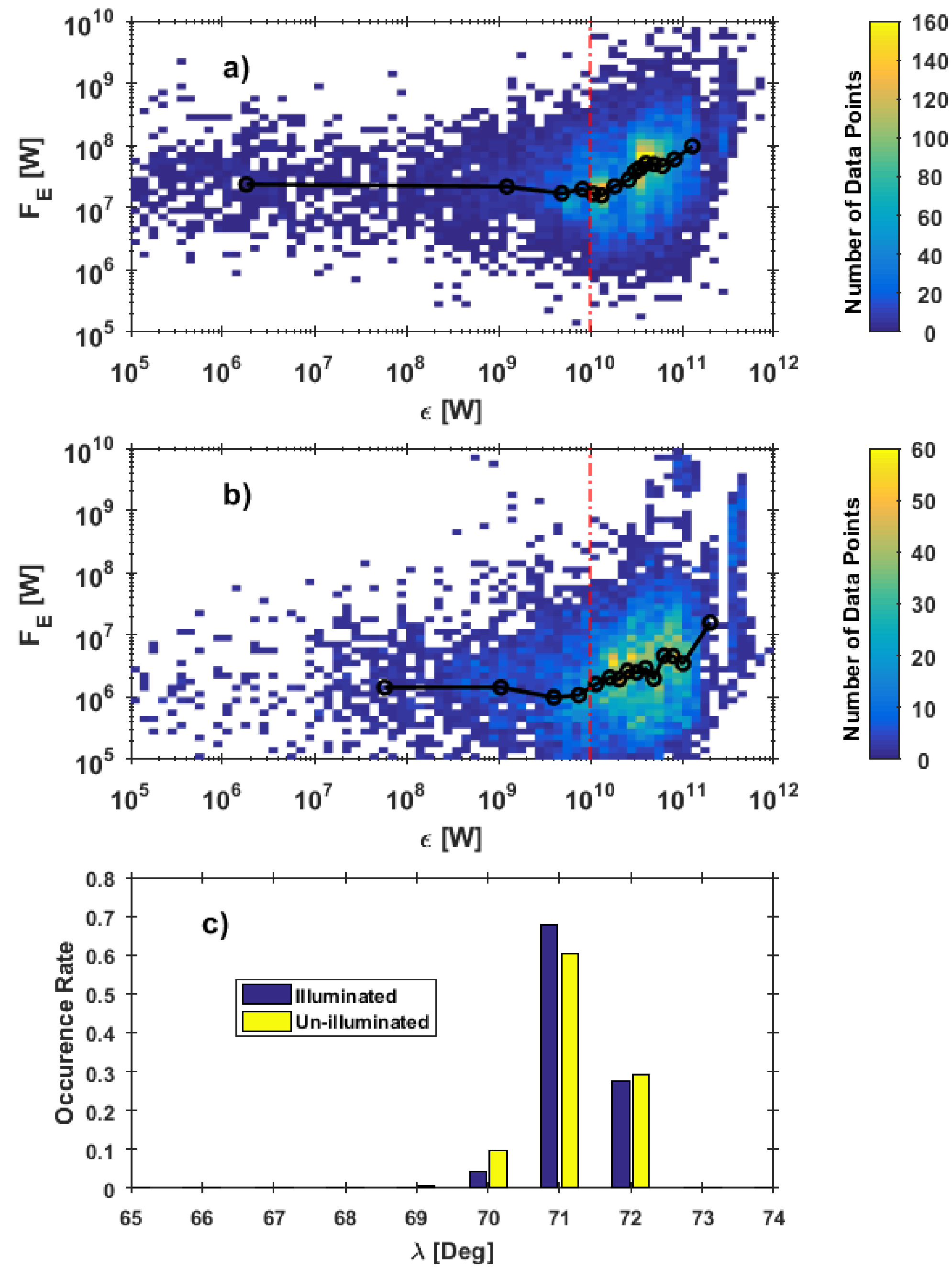
$$F_{EM} = \frac{1}{2} m_p V_{||}^2 (n_l A_l + n_d A_d)$$





Discussions





2. Energy Transfer Efficiency

From Solar Illumination to the Polar Wind (e_I)

Total Energy from solar illumination (E_T)

$$E_T = TSI \times A = 2.32 \times 10^{17} W$$

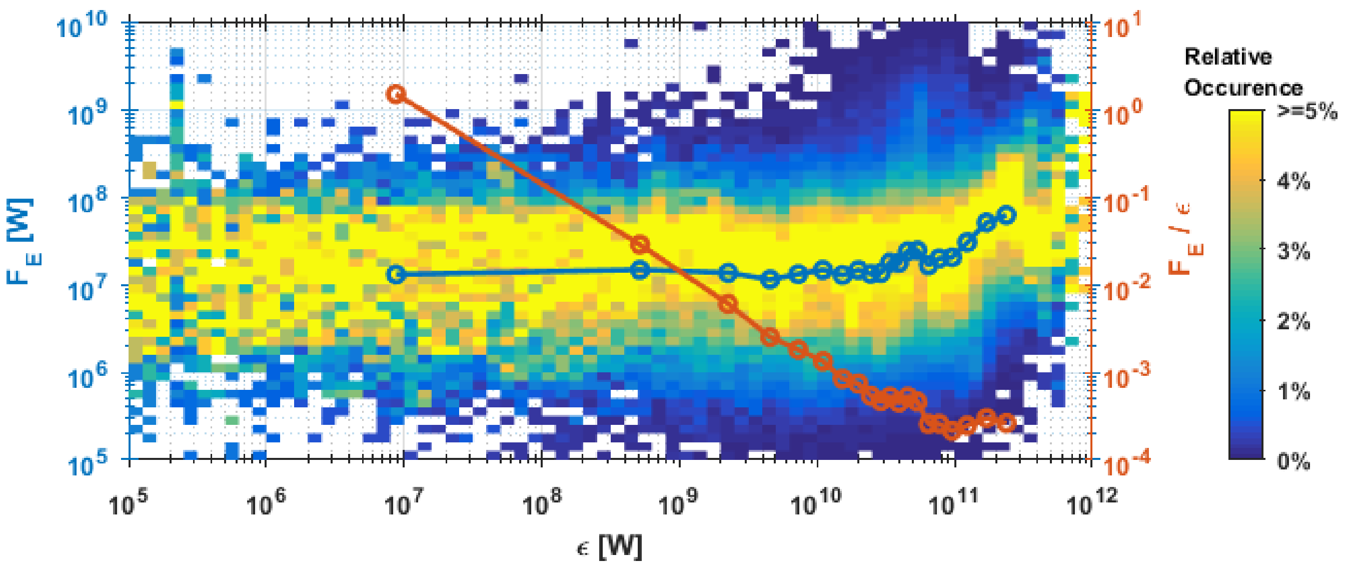
Total Solar Irradiance (TSI)=$1361 W/m^2$ [Kopp and Lean, 2010]

$$A = \pi \cdot (6371 + 1000)^2 km^2$$

$$e_I \sim 10^{-10}$$

From the Solar Wind to the Polar Wind (e_ε)

$$e_\varepsilon \sim 10^{-4}$$



Conclusions

- **When the ε parameter is higher than 10^{10} W, Of the order of 0.1% of the solar wind energy input is transformed to the hemispheric kinetic energy of polar wind outflow.**

- **When the ε parameter is lower than 10^{10} W, the kinetic energy of polar wind outflow is significantly provided by solar illumination.**

- **The energy power provided by the solar wind ranges from 10^7 to 10^8 W. The energy power provided by solar illumination is of the order of 10^7 W.**

Thank you for your attention