Solar cycle variations of the Cluster spacecraft potential and its use for electron density estimations

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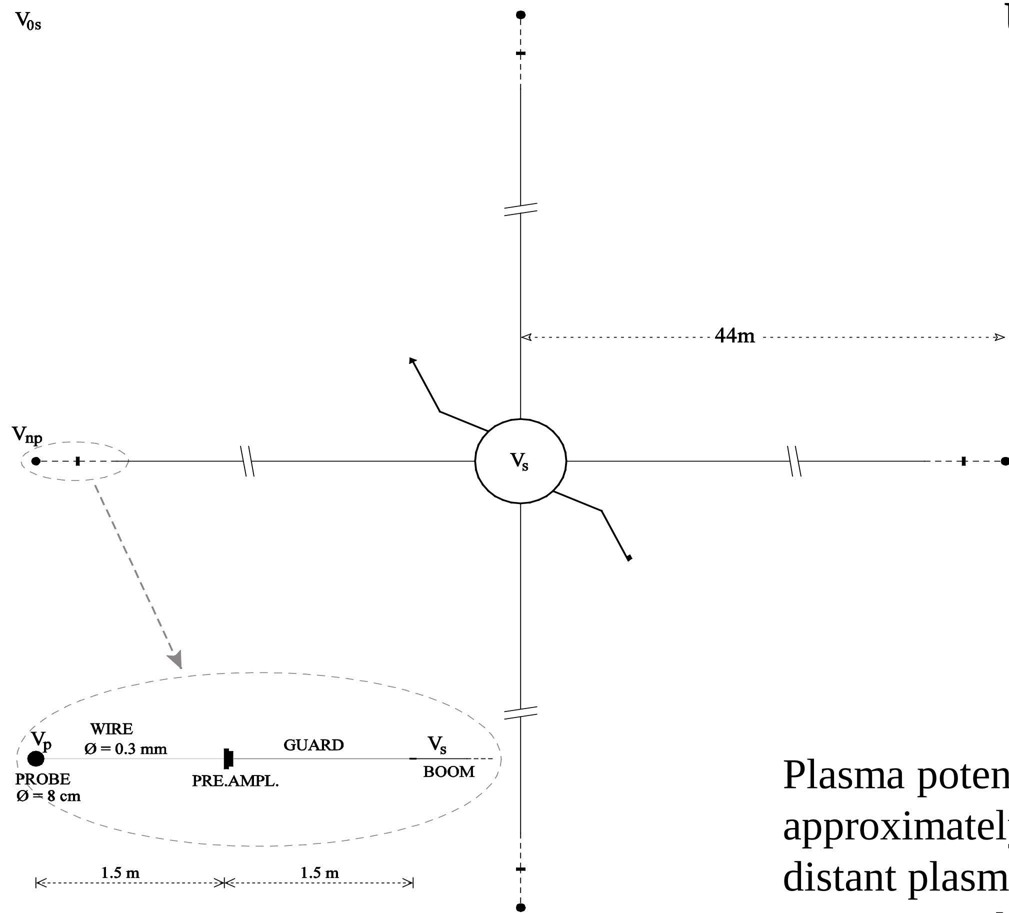
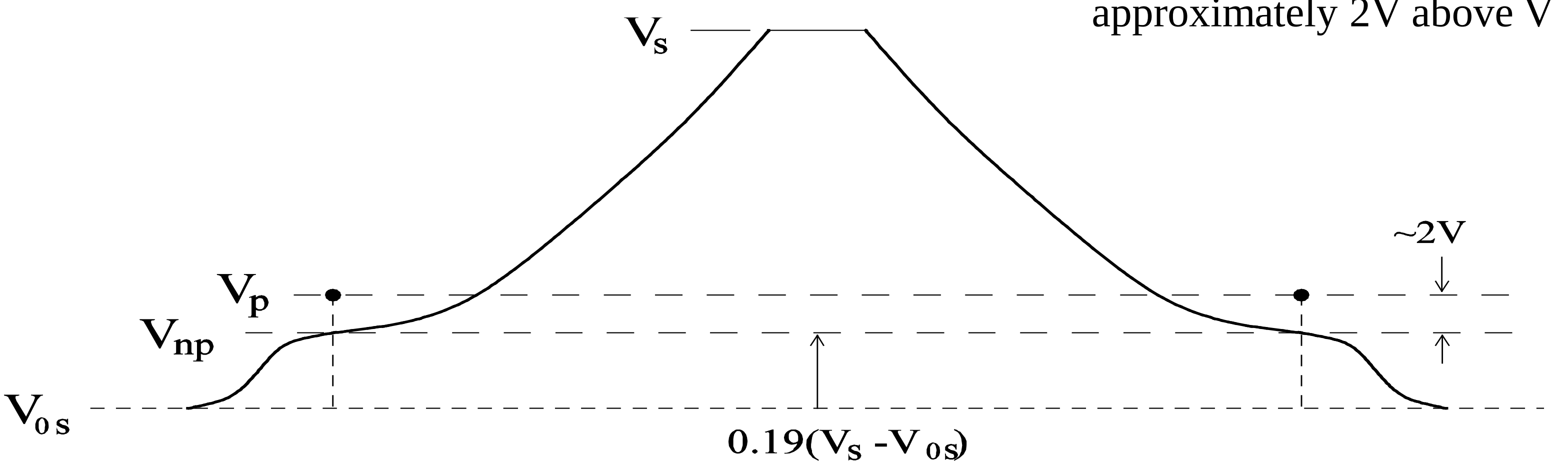


The Cluster spacecraft with EFW booms/ probes

Plasma potential near the EFW probes is approximately 0.19 (V_s –V_{os}) above more distant plasma. The probes are approximately 2V above V_{np} .



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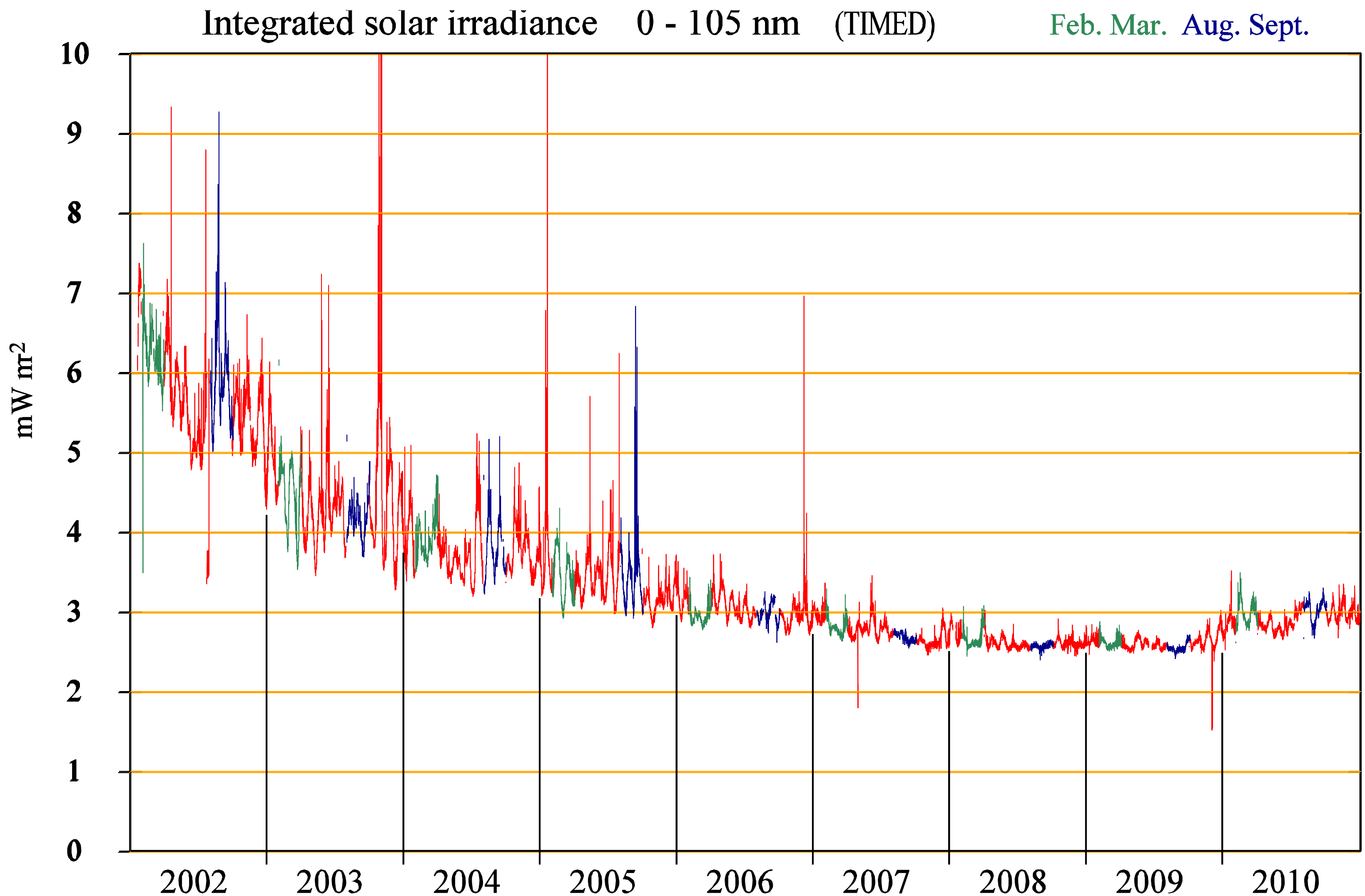


The solar EUV radiation (0–105) nm during the solar cycle from 2002 to 2010 has variations with the solar rotation period. They are more pronounced during solar maximum. A marked drop in the average radiation level has been observed, from near solar maximum to near solar minimum. **Green** parts are for early in the year (solar wind calibrations), and **blue** parts are for early autumn (plasmasheet calibrations).

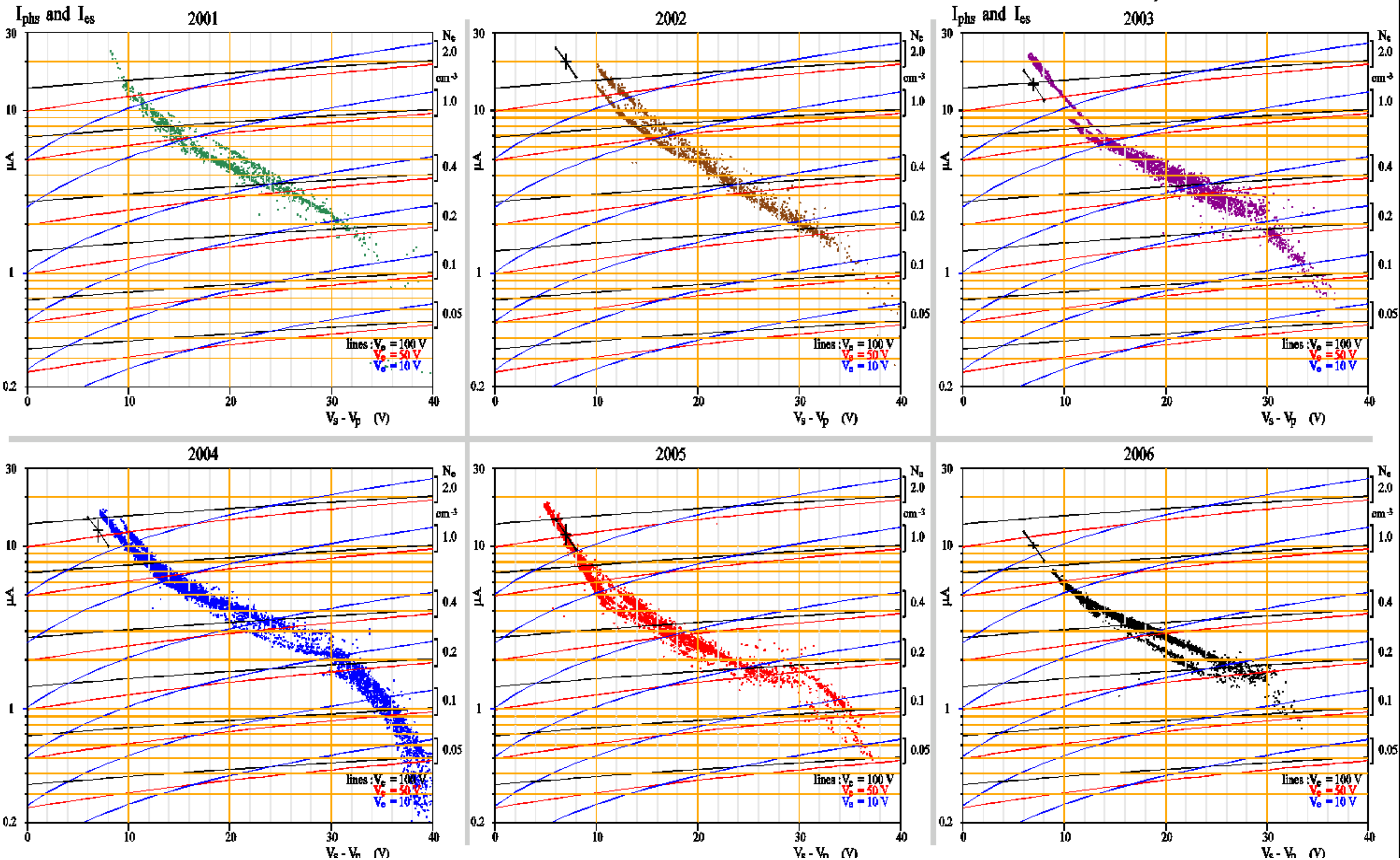
$$I_{es} = C\ N_e\ V_e^{1/2}\ A_s\ [1 + (V_s - V_{0s})/V_e]$$

- I_{es} collected electron current
- $C = 2.68\ 10^{-14}$ A m^3 V$^{-1/2}$
- N_e electron density
- $V_e = k\ T_e\ /e$; (V_e [eV] = T_e [MK] / 11.604508E-3)
- T_e electron temperature
- A_s spacecraft *sphere* area ; (23.5 m^2)
- V_s spacecraft potential
- V_{0s} *(undistrubed)* plasma potential
- V_p probe potential
- I_{phs} emmitted photoelectron current

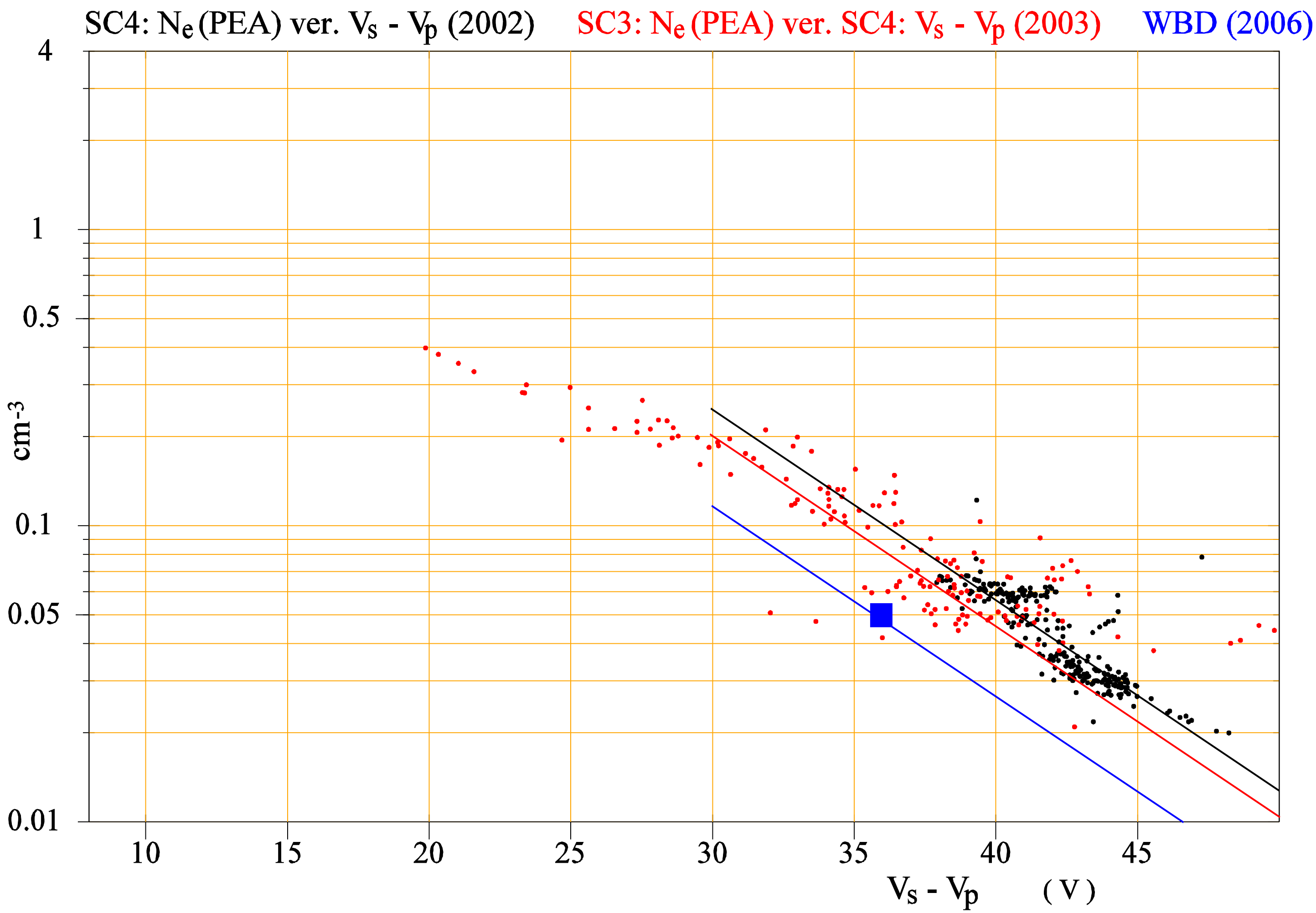
$$(V_s - V_{0s}) = 1.23\ [(V_s - V_p) + (2 +/- 0.5)\ ]$$

$$I_{es} = I_{phs}$$

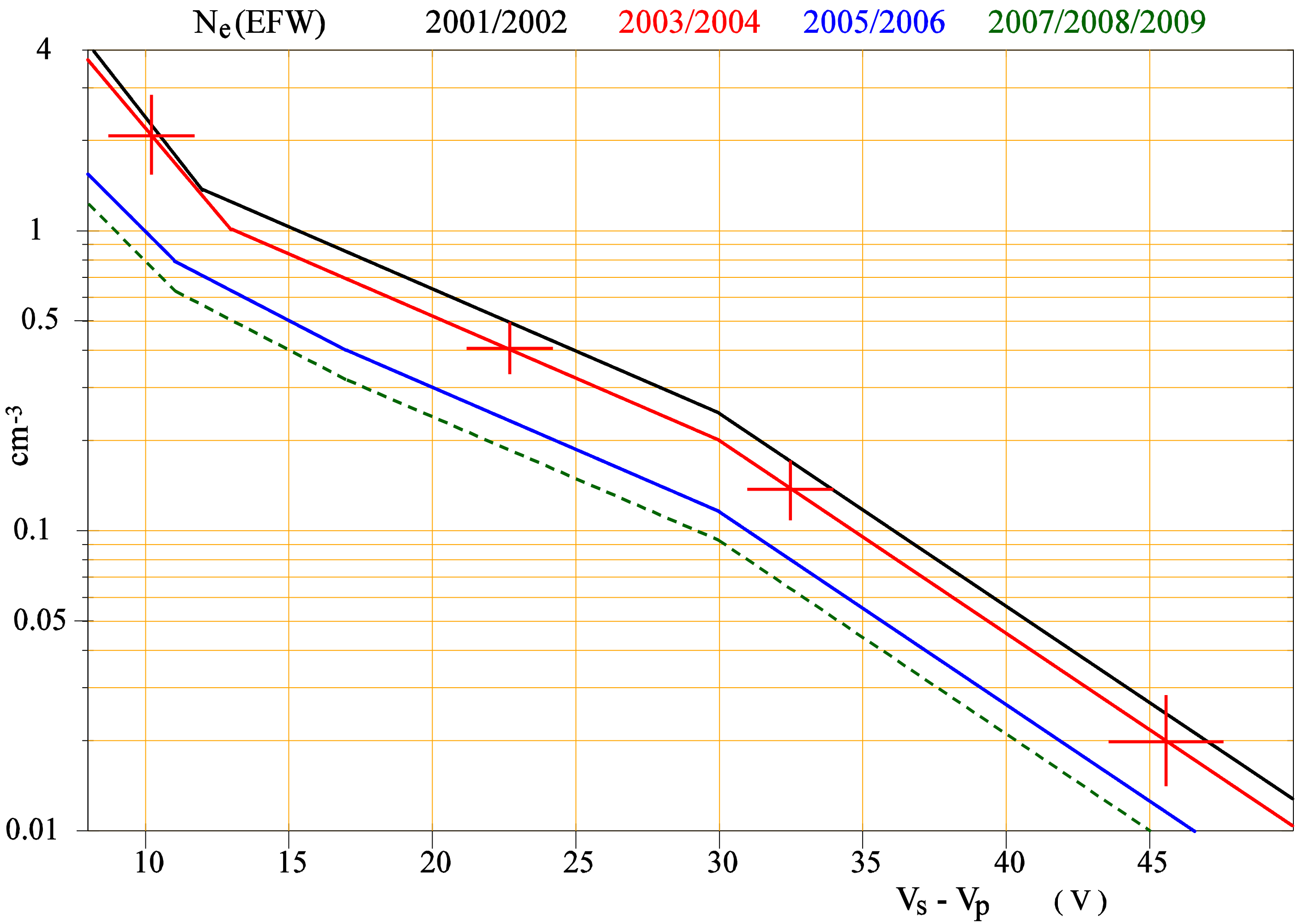
$$I_{phs} = C\ N_e\ (k\ T_e\ /e)^{1/2}\ A_s\ [1 + \{1.23\ [(V_s - V_p) + (2 +/- 0.5)\ \}\ /(k\ T_e\ /e)]$$



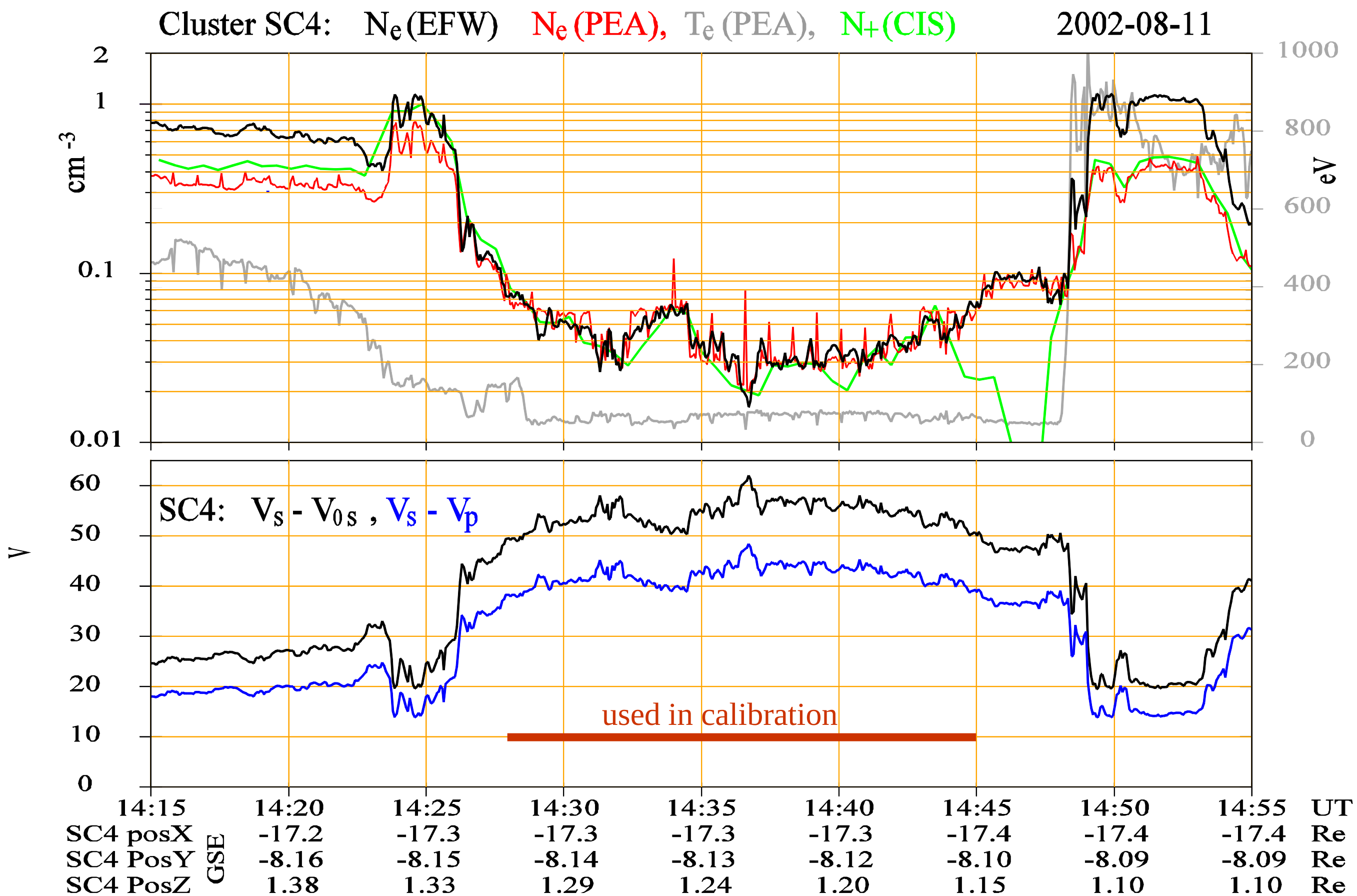
I_{phs} as a function of V_S-V_P from calibrations with PEACE in the plasmasheet and plasmasheet boundary layer. The blue, red and black lines are calculated values of I_{es} versus V_S-V_P , for selected values of N_e and V_e. Electron densities as a function of V_S-V_P can be estimated from the crossings of scatter plots and coloured lines.



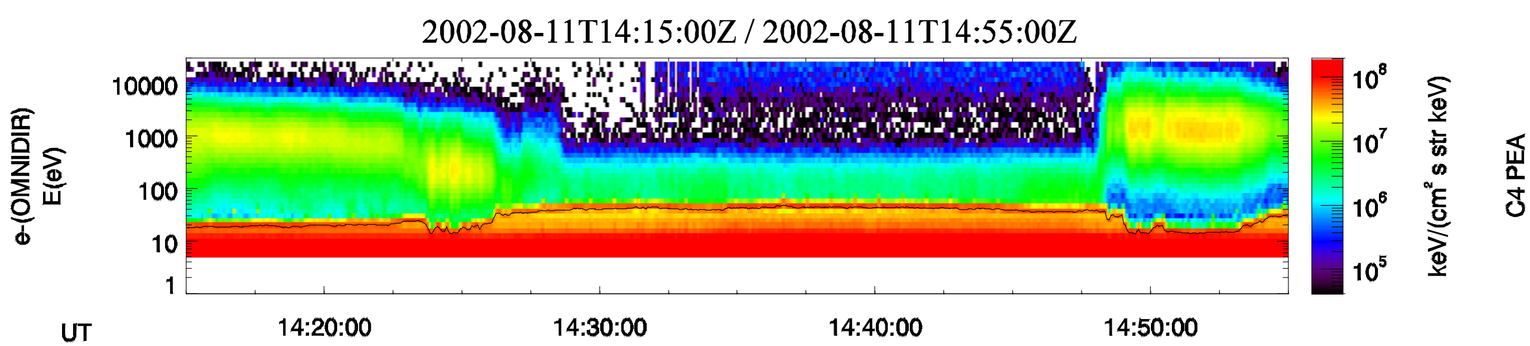
In the autumn of 2003 all Cluster spacecraft were separated by a few hundred km. This opened for the possibility to get N_e based on PEACE full spectrum measurements during ASPOC operations on C3, and at the same time get V_S-V_P from C4 with no ASPOC operations. The **red** dots are the result of such measurements during selected periods. The **black** dots are from a particular event on C4, 2002-08-11 14:28 - 14:45 UT, in the lobe. The **blue** square is a calibration with WIDEBAND from 2006.



$N_e = N_e$(EFW) for the months of August-September 2001/2002, 2003/2004 and 2005/2006. Ne(EFW) 2007/2008/2009 has been added on the basis of the finding that variations of I_{phs} follow variations of the solar EUV radiation. The error bars marked on the red curve for 2003/2004 are nearly the same for the other periods. Error bars include spread of photoelectron escape current due to solar EUV variations during solar rotations, spread due to the range of V_e of (10–100) V, used in calculating $I_{es}=I_{phs}$.



A passage of C4 from the plasmasheet to the boundary layer, and further to the lobe, provides a good opportunity to obtain a calibration of N_e(EFW). PEACE measurements of N_e are based on a complete electron energy spectrum, and the mean electron energy (grey curve in upper panel) is just below 50 eV.



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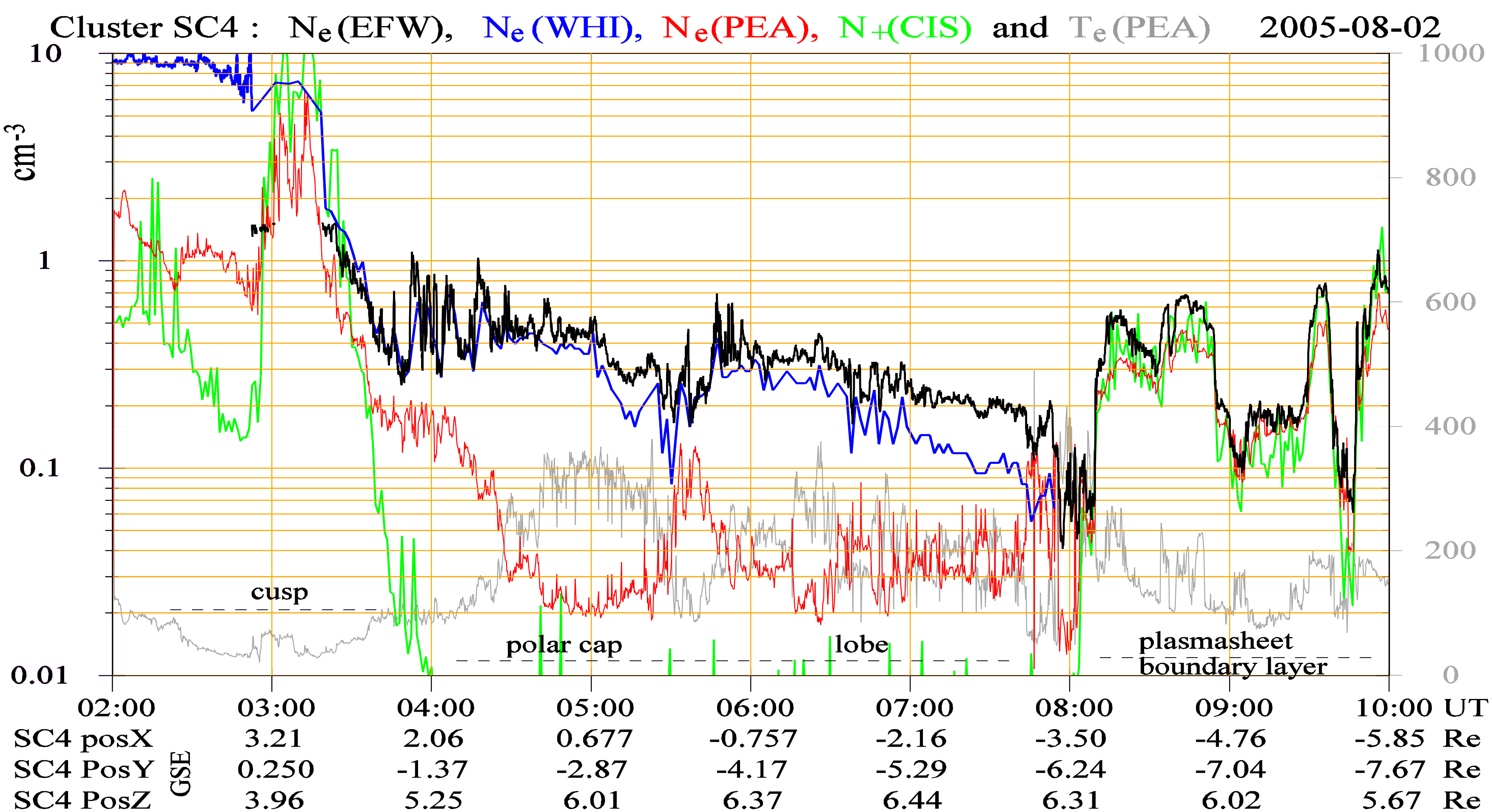
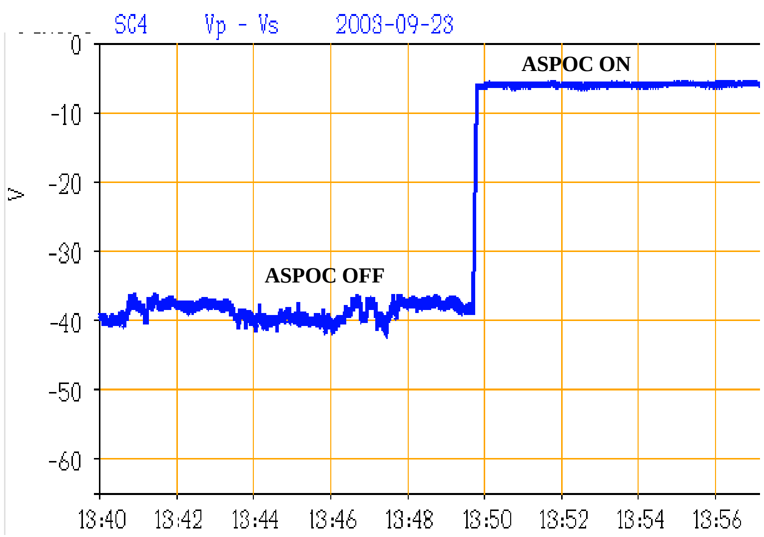
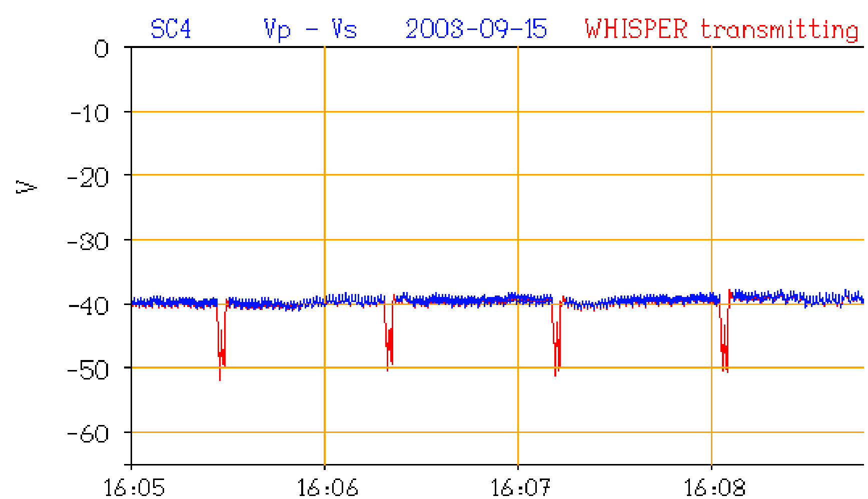


In August 2005 C4 passed the northern cusp, the polar cap – lobe, and entered the northern plasmasheet boundary layer. There is good agreement between EFW and WHISPER for the higher densities, but an increasing difference for lower electron densities. PEACE measures part of the electron spectrum above approximately 40eV, and underestimates the density. The high electron energies will in some cases cause a small overestimate of N_e(EFW), but not enough to explain the difference with WHISPER. N_e(EFW) is in good agreement with N_e(PEACE) when the electron mean energy is near 100eV in the boundary layer after 09:00UT.

- Ne(EFW) is calculated from probe potential
- 5 samples/second
- 10 years with data

- Restrictions:
  - EFW probe potensial is ~8 - ~68 Volt
  - EFW is not sweeping
  - ASPOC ion current is off
  - WHISPER is not transmitting
  - EDI beam current < 80 μA





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Data Base (ASCII format)

CLUSTER:

Time ISO [UT]	**Spaceraft** number 1, 2, 3, 4	Spacecaft **position** X, Y, Z (GSM) [Re]	**V_s-V_p** (median verage) [V]	**N_e(EFW)** **(median average)** **[cm-3]**	**B** (FGM) X, Y, Z [nT]	**E** (EFW) X, Y [mV/m]	**N_i** (CIS) H+, He++, O+ [cm-3]	**T** (CIS) perp [eV]

V (CIS) X, Y. Z [km/s]	**E** (EDI) X, Y, Z [mV/m]	**V** (EDI) X, Y. Z [km/s]	**N_e**(PEA) $[cm^{-3}]$	**T** (PEA) perp [eV]	**V** (PEA) X, Y. Z [km/s]	**J_e_low**(RAP) $[1/(cm^2$ s sr)]	**N_e**(WHI) [cm-3]	**gse_gsm** [degrees]

Beam Current (EDI) GDU2 [nA]	Spacecraft **mapping** LT, MLT, Inv.Lat [h], [h], [deg]	**Esigma**(EFW) (standard dev.) [mV/m]	**Equality** (EFW) quality mask	Stat0 (EDI) **quality** flag

SOLAR WIND (OMNI):

B (IMF) X, Y, Z (GSM) (GSM) [nT]	**V** X, Y , Z (GSE) [km/s]	**N_p** [cm-3]	**T** [eV]	**Psw** (flow pressure) [nPa]	**E** [mV/m]	**BSNpos** X, Y, Z (GSE) [Re]	**Clock Angle (IMF)** Angle , Sector [1..8] [mV/m]	**BiasVector** Stability of IMF (> 0.96)	**Plasma** **Beta**

SUN:

0 – 105 nm (TIMED satellite) $[W / m^2]$	**10.7 cm** Solar radio Ottawa (1AU) [s.f.u.]

GEOMAGNETIC:

AE index [nT]	**DST index** [nT]	**PCN index** Polar Cap index (Thule)

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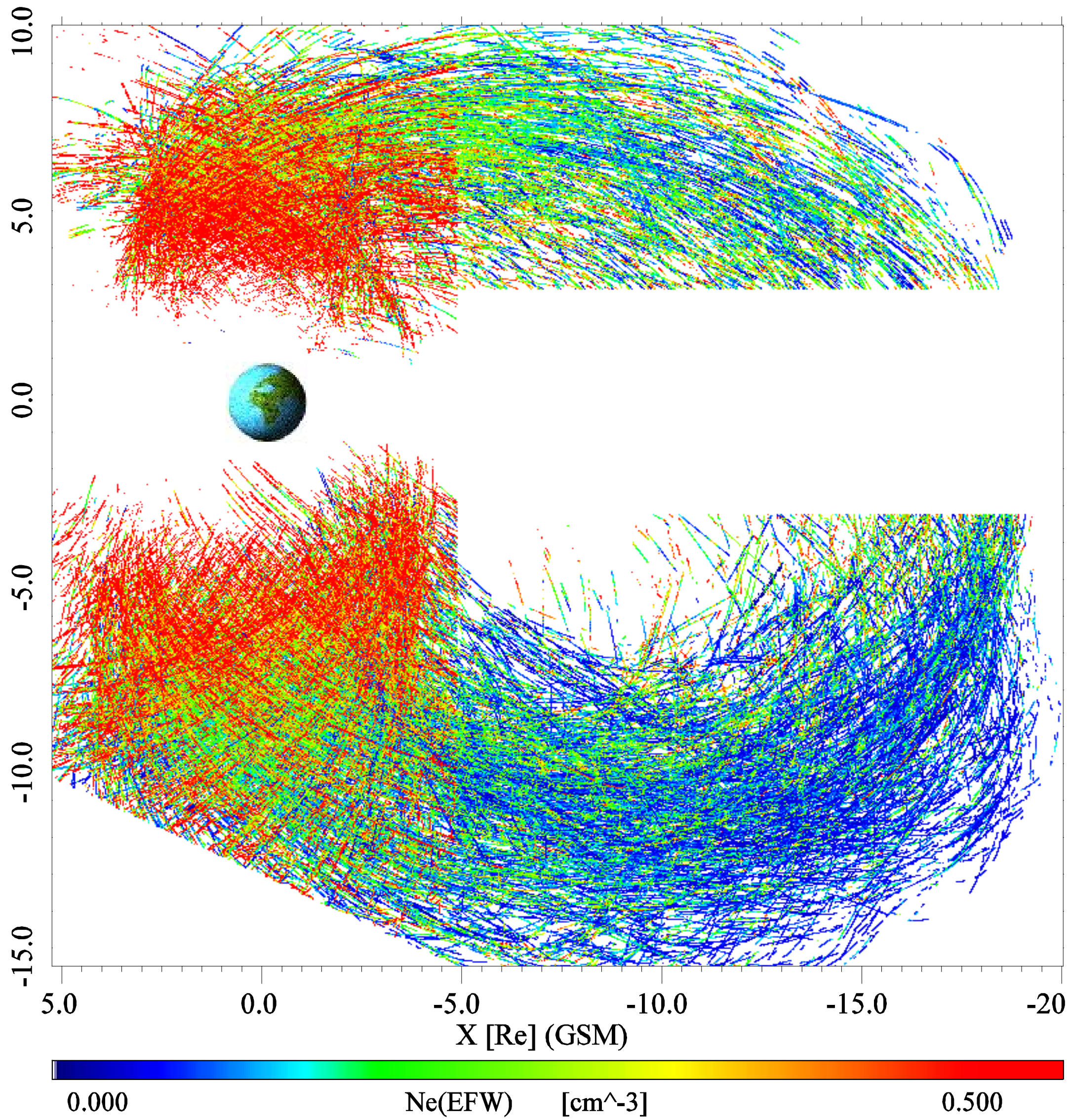
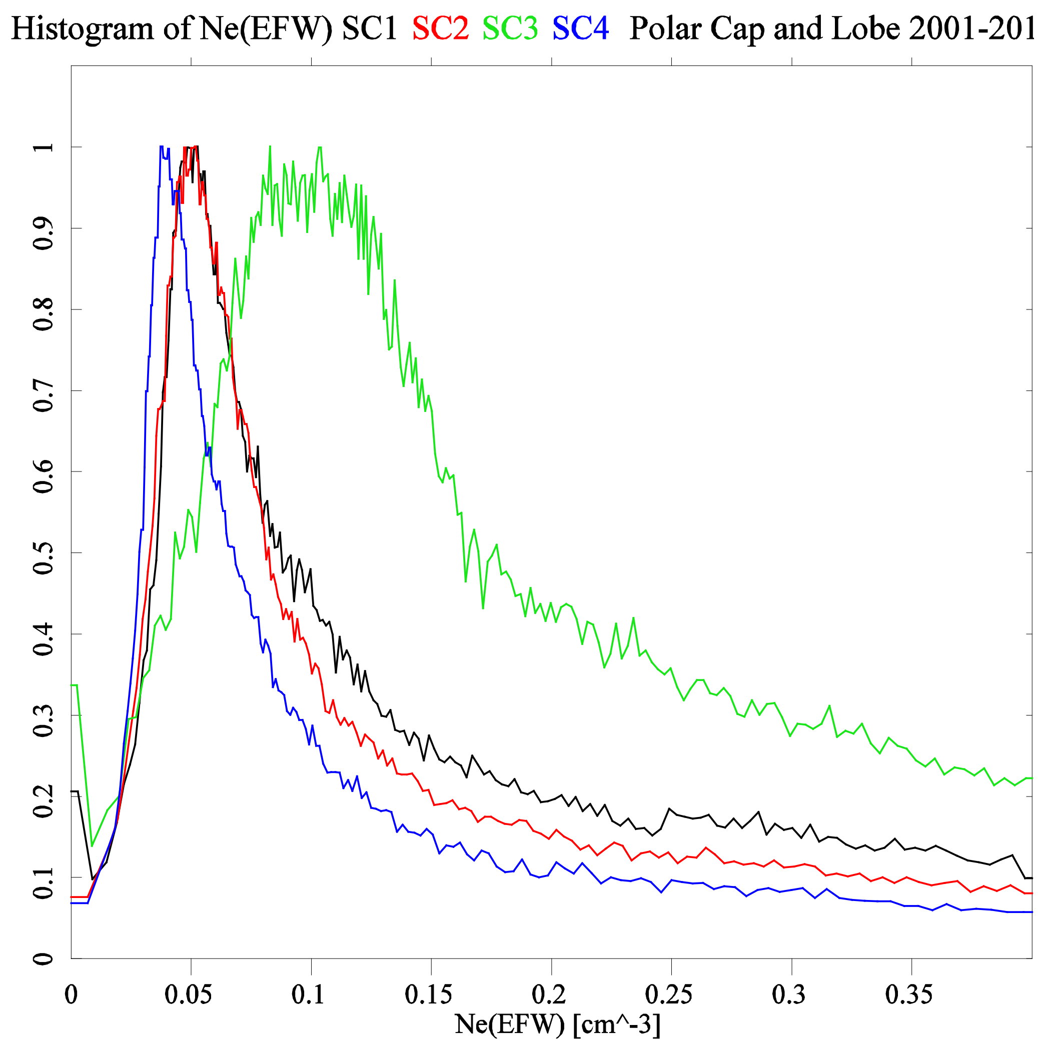
N_e(EFW) SC1, SC2, SC3 and SC4 Polar Cap and Lobe 2001-2010




Histogram of Ne(EFW) SC1 SC2 SC3 SC4 Polar Cap and Lobe 2001-201
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Ne(EFW) [cm^-3]