UCL DEPT. OF SPACE & CLIMATE PHYSICS
MULLARD SPACE SCIENCE LABORATORY

Cluster Observations of the Electron Low-Latitude Boundary Layer at Mid-Altitudes

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Outline

- Introduction.
- Example showing existence of latitudinally-extended Electron Boundary Layer (EBL) region.
- Multi-spacecraft method for estimation of the EBL size.
- Data set for statistical study.
- Size of the EBL as function of the IMF and solar wind.
- Conclusions.

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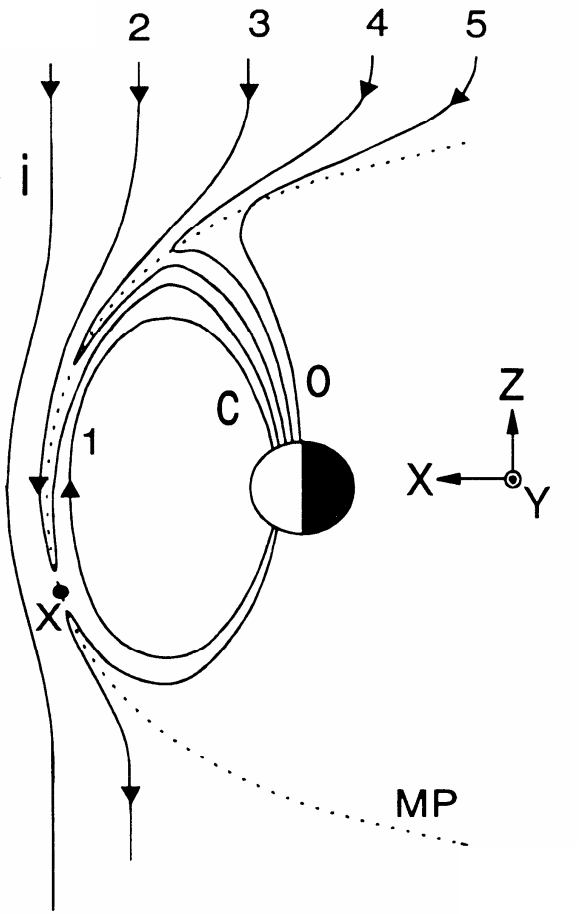
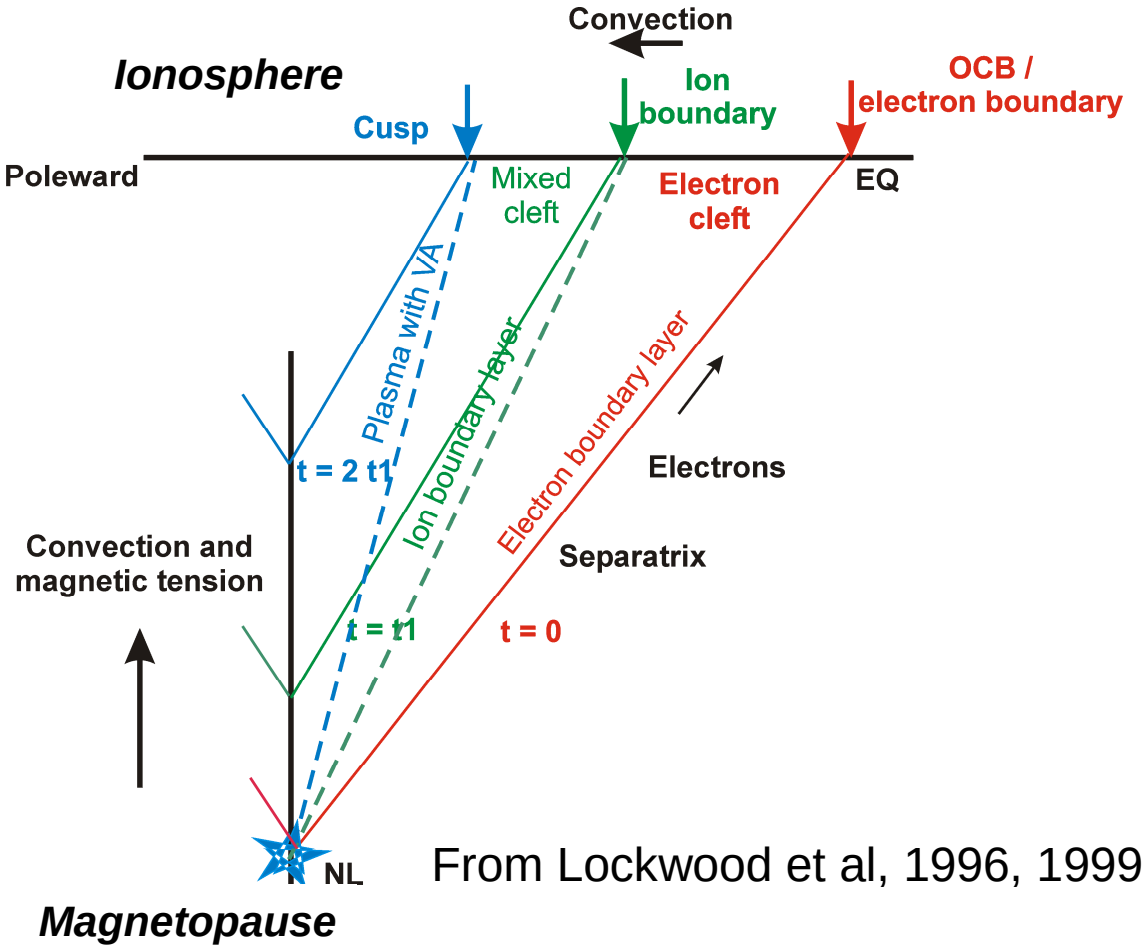
Injection of the magnetosheath plasma





From Lockwood et al, 1996, 1999.

Lockwood et al, 1996: LLBL population could be explained by acceleration on the interior Alfvén wave.

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Injection of the magnetosheath electrons

- Wing et al., 1996 modelled penetration of the electrons at low altitudes:
  - The additional parallel electric field between MP and low altitudes should exist to model observed population in the LLBL, mantle and polar rain.
  - This electric field prevents penetration of the electrons and maintains quasi-neutrality.
  - Halo population of the solar wind isn't stopped by parallel electric field and easily penetrates into the LLBL on open field lines, mantle and polar rain.

- Topliss et al., 2001 in 200 events from POLAR found 6 events with clear separate electron and ion boundaries.

- At Cluster: Electron BL have been often observed.

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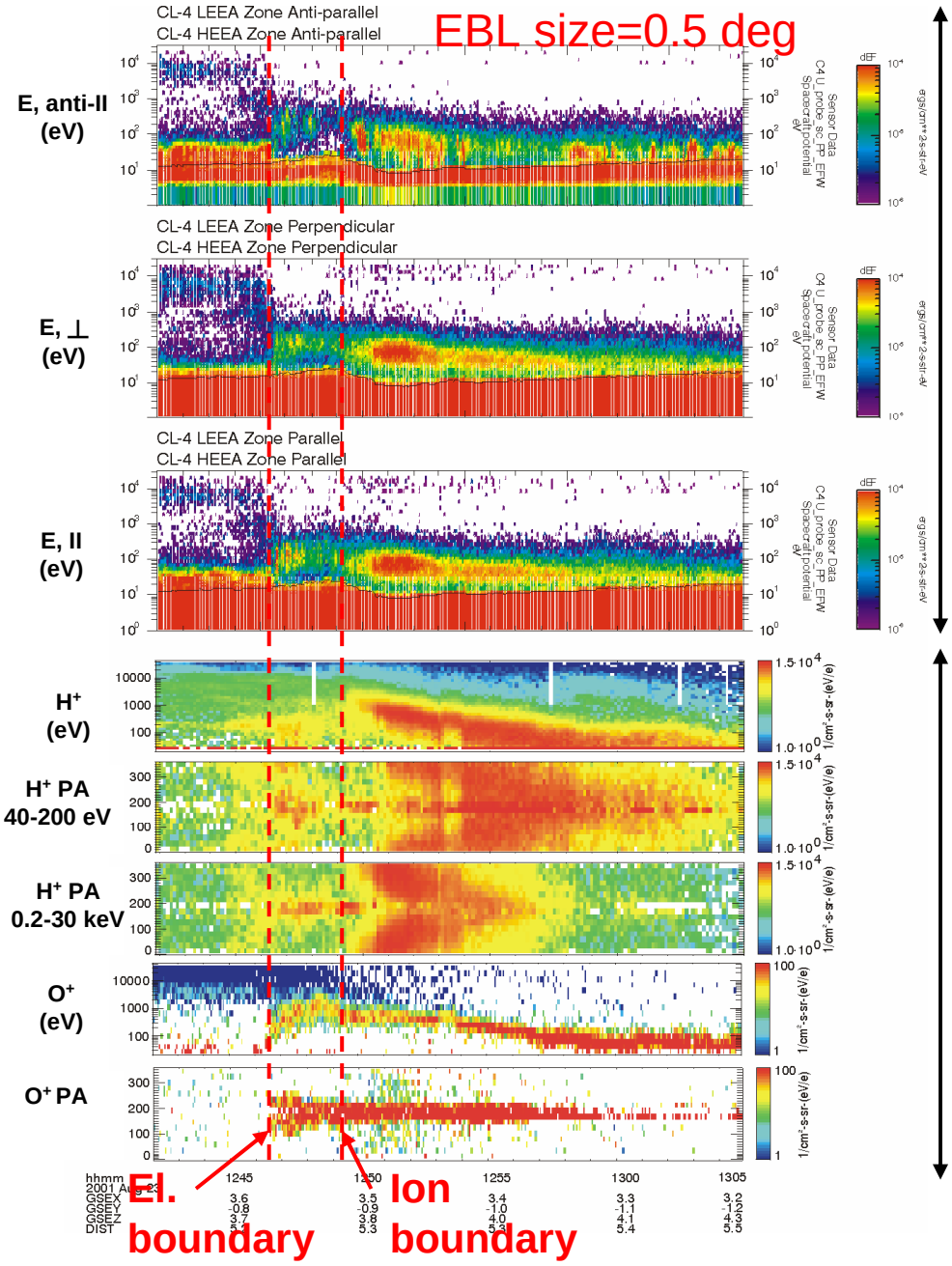

Example of the EBL

- EBL contains almost isotropic low-dense plasma presumably from the halo solar wind population and uni- or bi-directional short-duration electron beams with high fluxes accelerated at reconnection point.
- EBL coincides with beginning of heavy ion outflow and enhancement of wave activity *[Bogdanova et al, 2004 , JGR]*.

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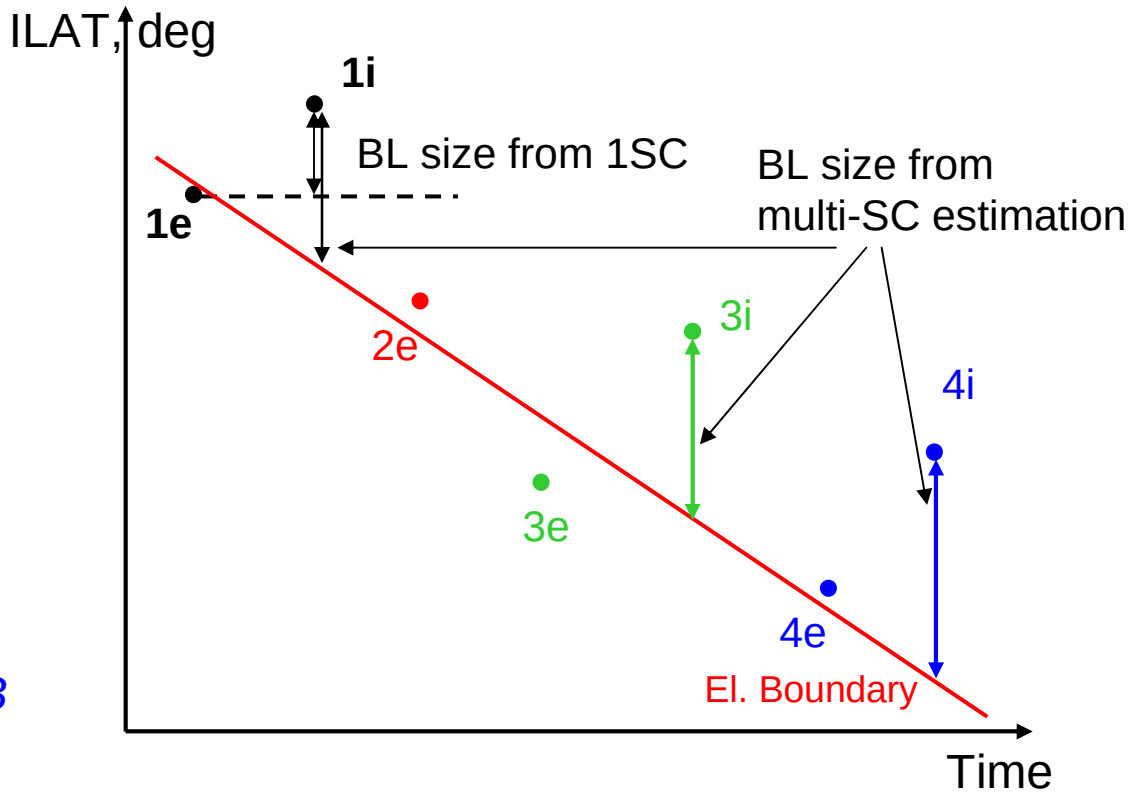
Multi-SC estimation of the EBL size

- For 1SC:

Size = $ILAT_{IB}$-$ILAT_{EB}$
Assumption: EB doesn't move

- For more than 1SC:
reconstruction of the EB motion using least square fit to observed points.

Size = $ILAT_{IB}$-$ILAT_{EB\_reconstructed}$
Assumption: linear motion of the EB



• In statistical study we combined events with size estimated from one SC and from multi-SC estimation.

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Statistical study

- Studied size of this region as function of the MLT, ILAT, IMF, solar wind parameters, and geomagnetic activity.

- 3 years of data from north hemisphere mid-altitude cusp crossings by Cluster, 2001-2003. Different SC separation.

- Defined: electron and ion equatorward boundaries of the LLBL/cusp.

- Excluded events with long-lasting positive Bz IMF, events with LLBL on closed field lines and events with unclear boundaries.

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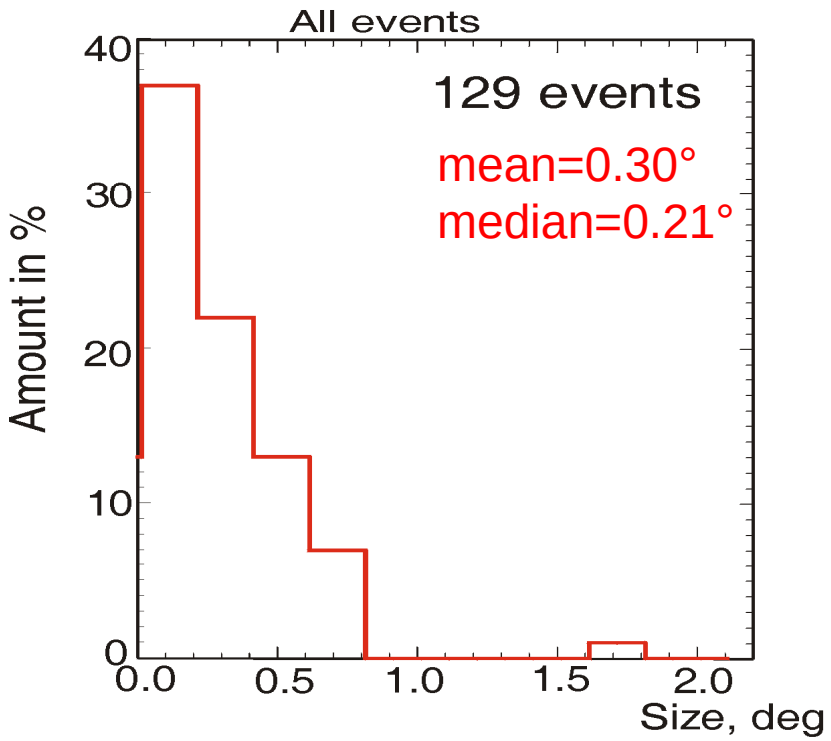
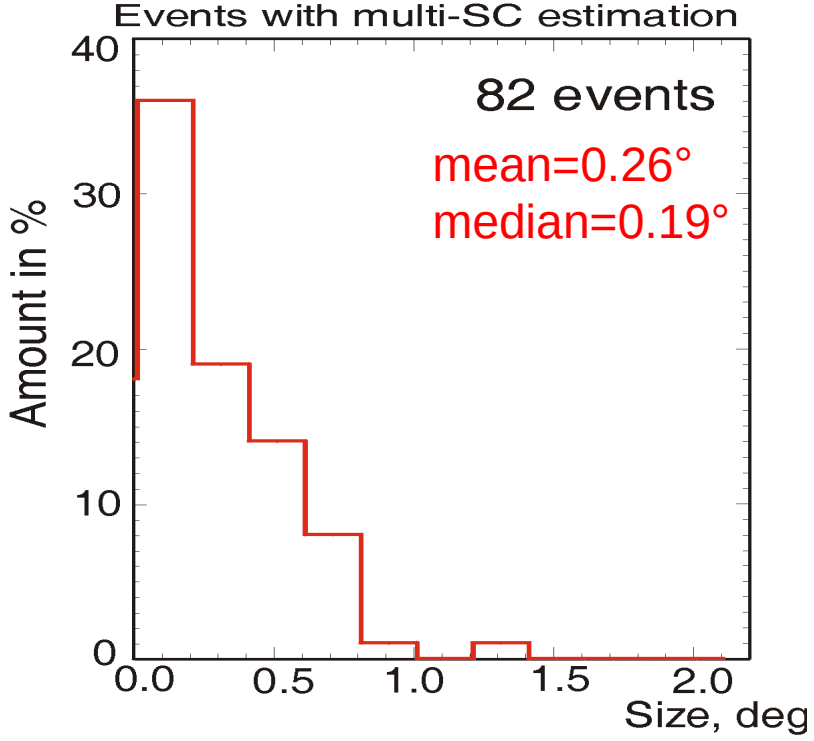
Size of the Electron Boundary Layer





- Only 13 % of all events without EBL.
- Size varied between 0° and 2.0°, with median value 0.2°
- Max amount of events with size 0-0.2°, and almost monotonically decreasing of events with increasing of size.
- Accuracy of estimation : +/- 0.1° (due to predicted orbit file).

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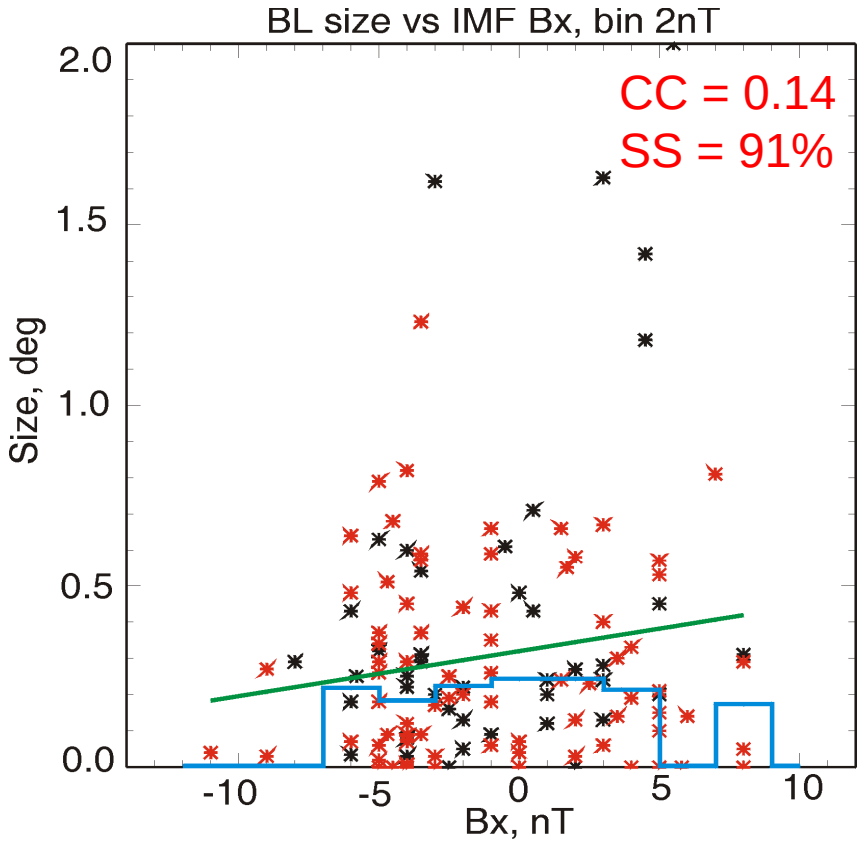
Statistical properties of the EBL size



- Red points – events with MSC size estimation.
- Black points – events with 1 SC size estimation.
- Green line - linear least square fit.
- Blue line – calculation of the median size in the bin, for more than 3 points inside bin.

- Estimated linear Pearson correlation coefficient CC. CC=1 is good correlation.
- Estimated statistical significance of result SS using Student's t-test.

SS ≥ 95 % is a statistically significant result.

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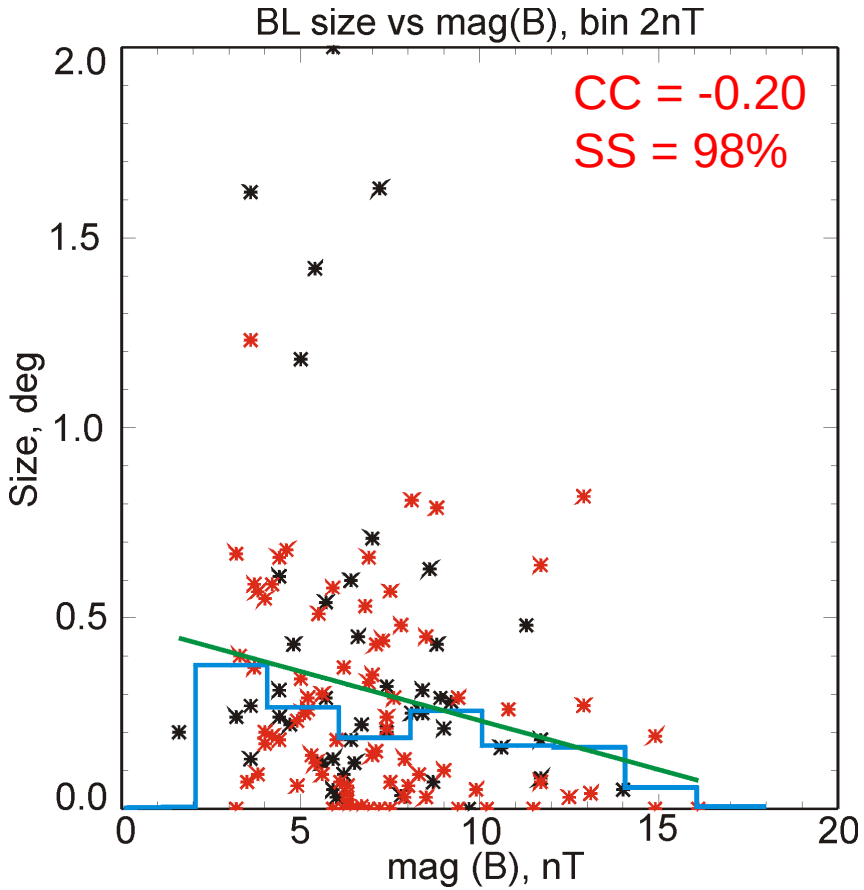
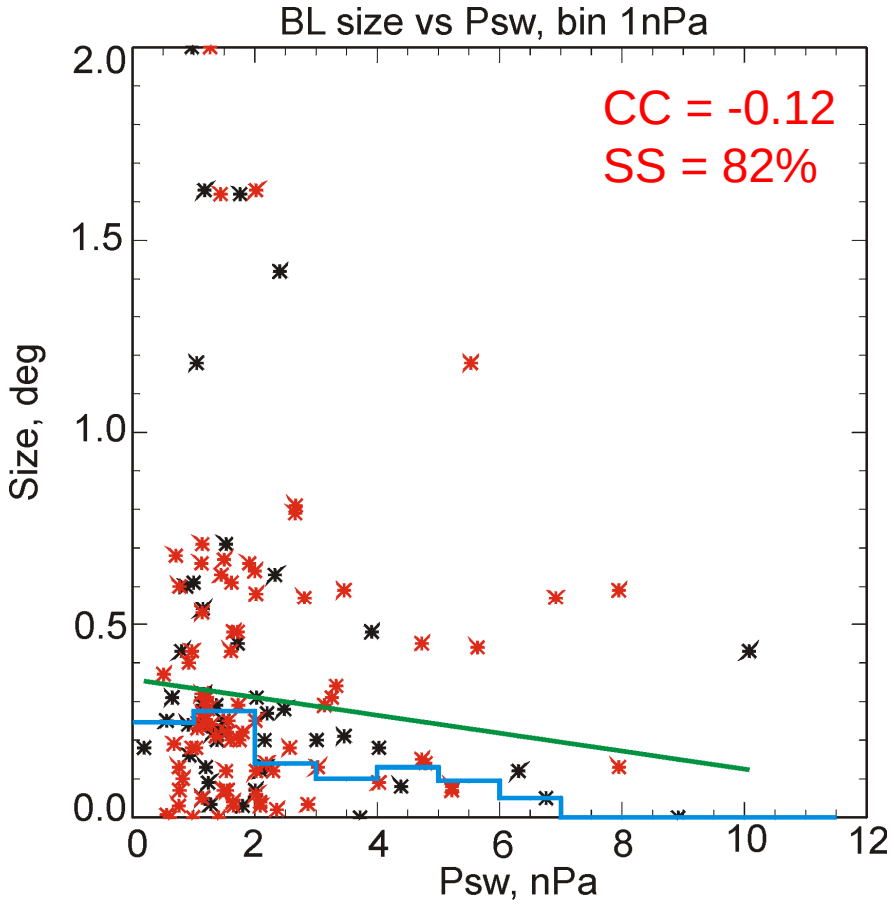
Example of relatively good correlation





- Dependencies as expected. Also seen in the median values.

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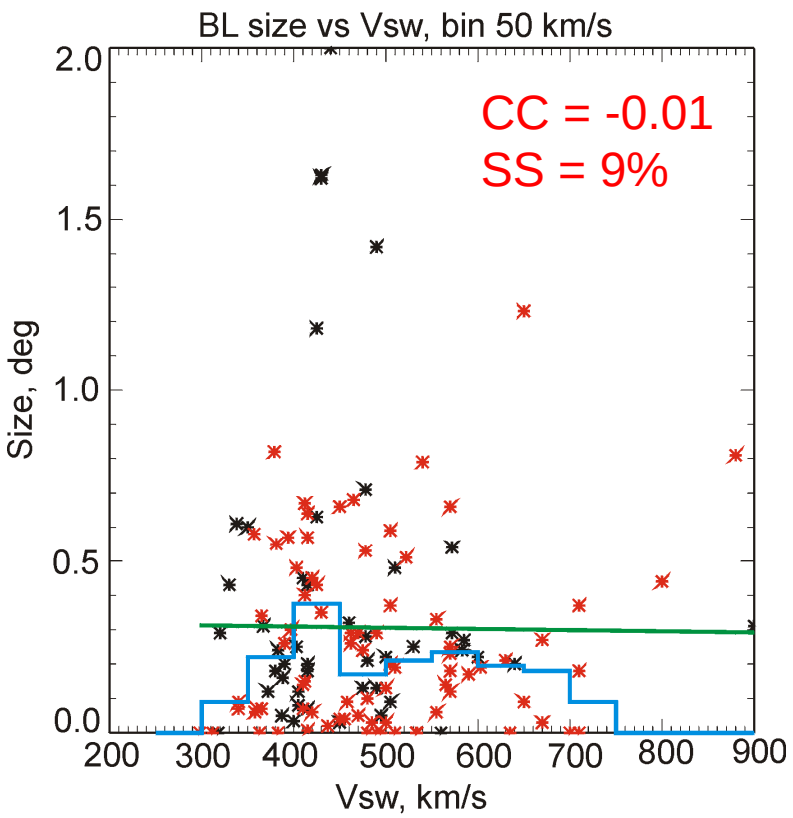
Example of poor correlation



Variable	CC	SS
IMF mag(B)	-0.20	98%
IMF B_X	0.15	91%
ILAT	0.14	89%
K_p	-0.14	89%
P_{sw}	-0.12	82%
MLT	0.09	69%
N_{sw}	- 0.09	69%
IMF B_Y	-0.05	43%
IMF B_Z	0.05	43%
mag(CA)	-0.03	27%
V_A	-0.04	35%
V_{sw}	-0.01	9%

Statistically significant

Dependency in the median values

If we will consider events only with multi-SC size estimation and with small distance between SC, correlation coefficient will increase, but significance will decrease.

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Conclusions

- We have looked at EBL containing low-dense electrons and no magnetosheath ions.
- EBL coincides with enhancement of wave activity and heavy ion outflow *[Bogdanova et al, 2004, JGR].*
- EBL was observed in 87% of mid-altitude cusp crossings by Cluster. This result is very different from Topliss, 2001.
- With Cluster we can use multi-SC techniques to estimate size of the EBL and try to test the Lockwood/Wing models.
- Size of the electron-dominated BL:
  - varies from 0° to 2.0° ILAT with median 0.2°.
  - depends on combination of various parameters.
  - anti-correlates with magnitude of the IMF. As expected, 98% significance of correlation.
  - anti-correlates with solar wind dynamic pressure and Kp index, correlates with ILAT. As expected, 82-89% significance of correlation, dependences also seen in median values.
  - no correlations with MLT, N_{SW}, IMF B_Z and B_Y, IMF CA, V_{SW} and estimated $V_{A.}$

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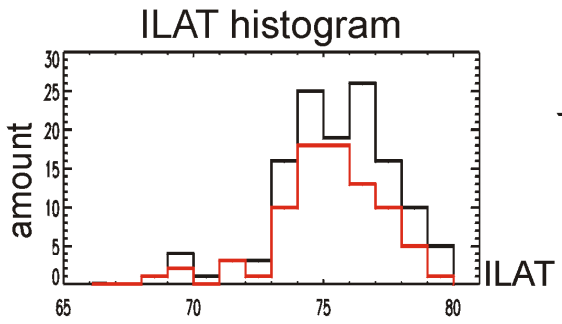
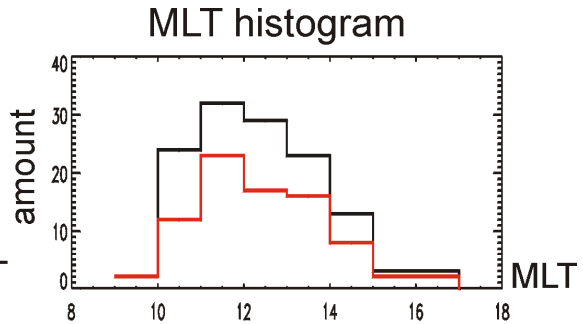
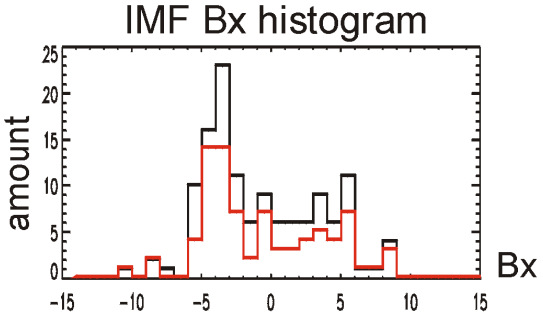
Data Set-Boundary Position

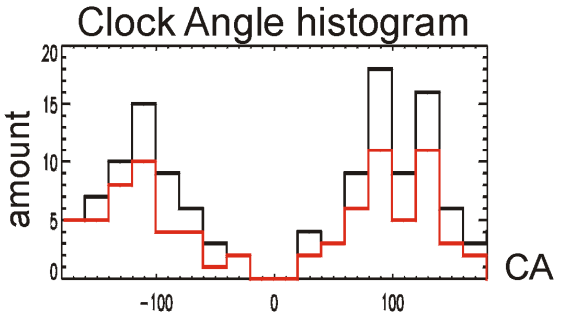
Position: ILAT and MLT



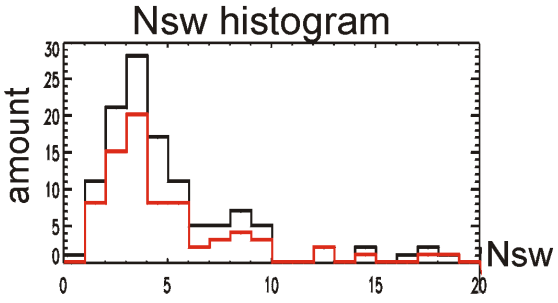


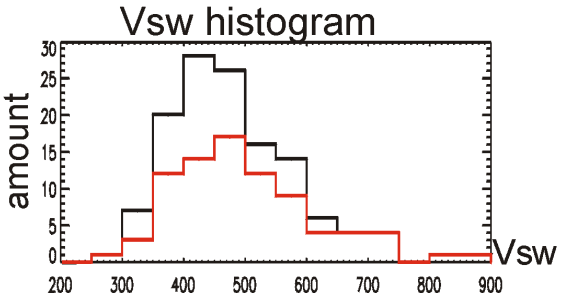
IMF conditions: IMF Bx and clock-angle CA
CA=arctg(By/Bz)





Solar wind parameters: Nsw and Vsw





- Plots based on position of the equatorward boundary of the electron injections. Black line –all events, red line – events with estimation from multi-SC techniques.

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