Longitudinal Gradients in Field-Aligned Currents as Observed by Swarm

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EGU General Assembly, Session EMRP2.2, May 6, 2020

Outline

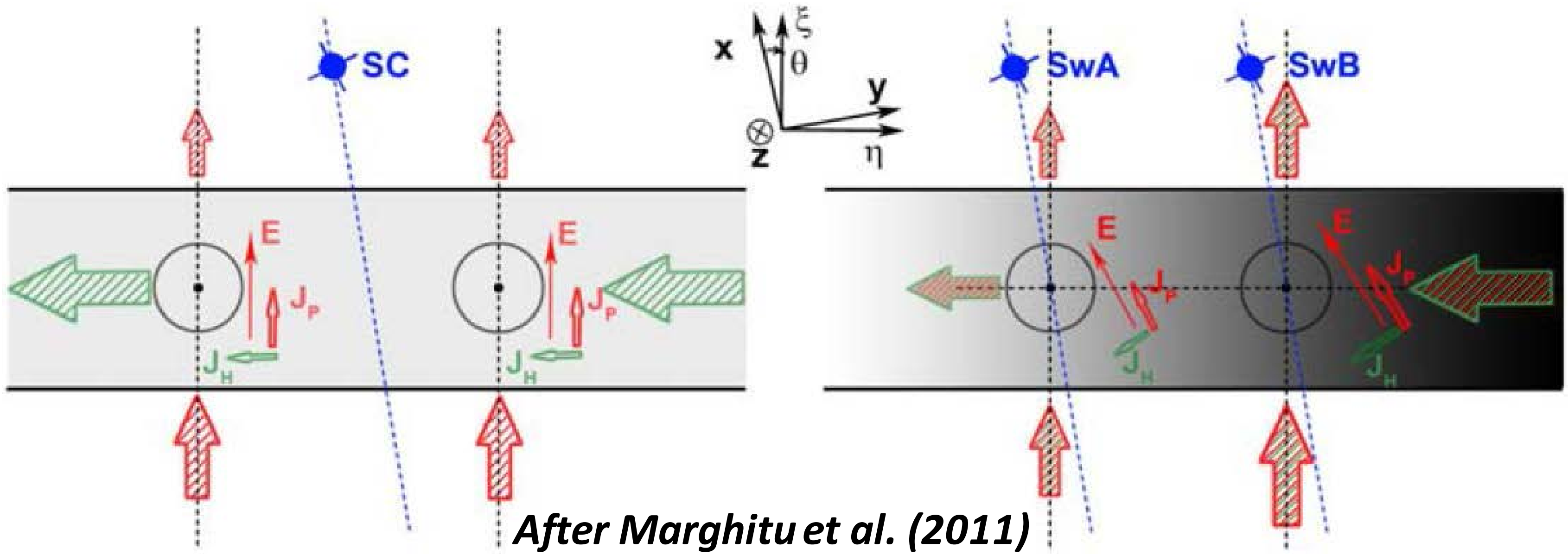
A. Introduction

B. Sample Swarm events of auroral oval crossing

C. Towards a systematic approach

D. Conclusions

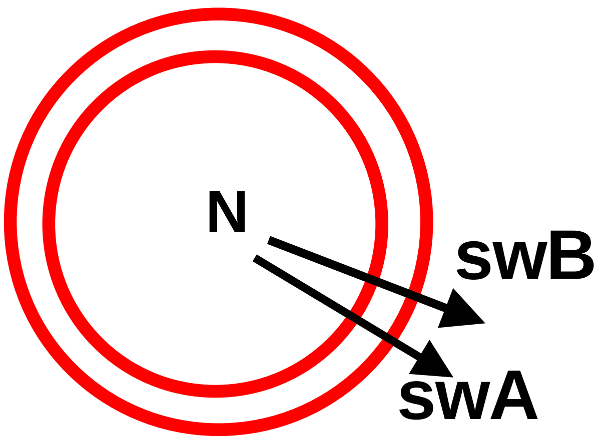
A. Introduction

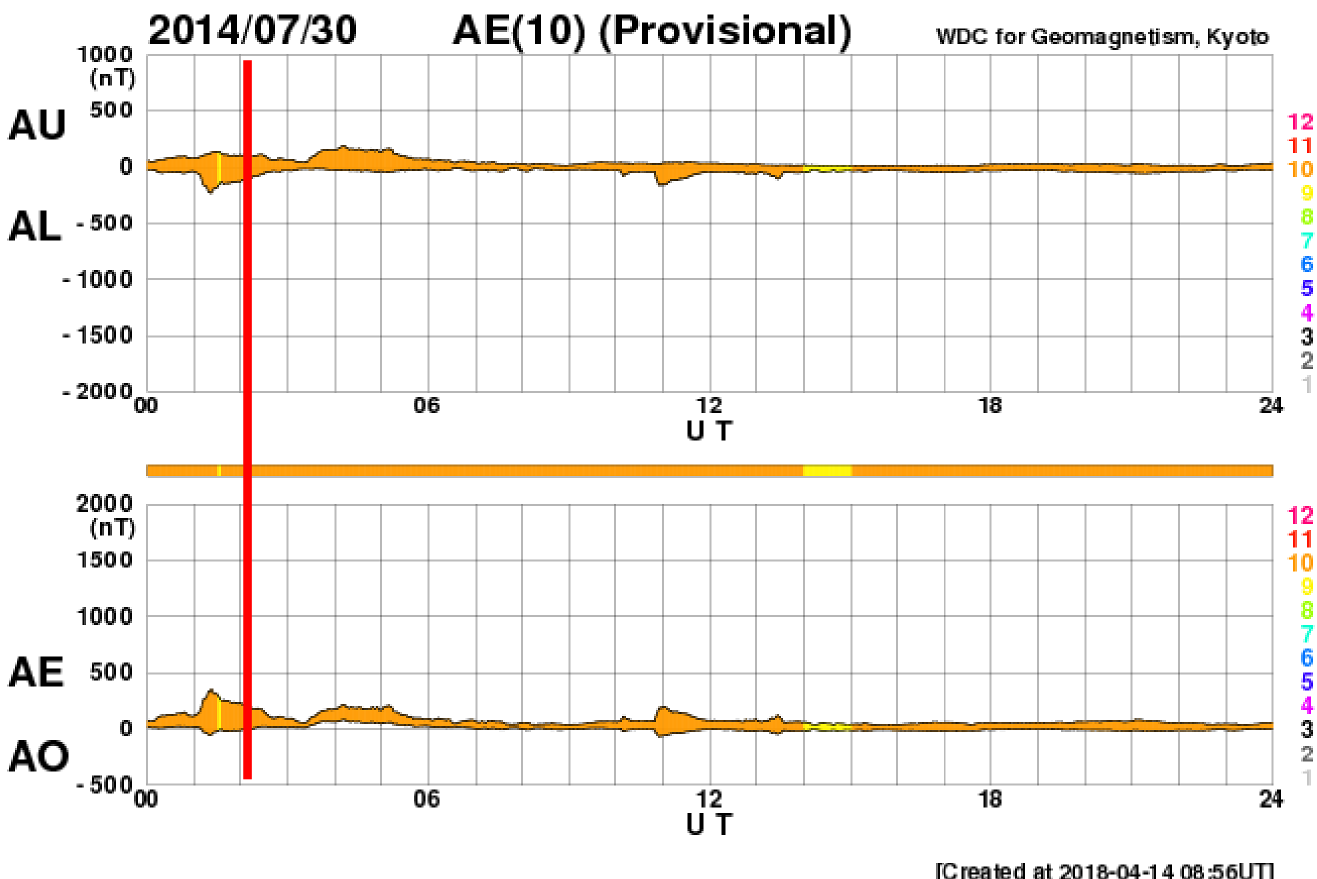


After Marghitu et al. (2011)

- Uniform (left) vs. non-uniform (right) model of the auroral arc or oval, illustrated with the ionospheric footprint of the upward field-aligned current (FAC) region. For simplicity, meridional non-uniformity, always present, is not represented.
- With 2-s/c data properly separated, i.e., by a distance comparable to the longitudinal length scale of the arc or oval, one can check longitudinal (non)uniformity.
- In the non-uniform case, the 1D backbone is still needed, i.e., the longitudinal length scale should be (significantly) larger than the meridional one. When this condition is not met, the structure is 2D and 2 s/c are no longer enough to explore it.
- Here we use data from swA and swB, during the first half year of the operational phase (~May–October 2014), to check longitudinal gradients in the large scale Region 1 / Region 2 (R1 / R2) FAC and address briefly the effect on ionospheric current closure.

B. Sample Event on July 30, 2014

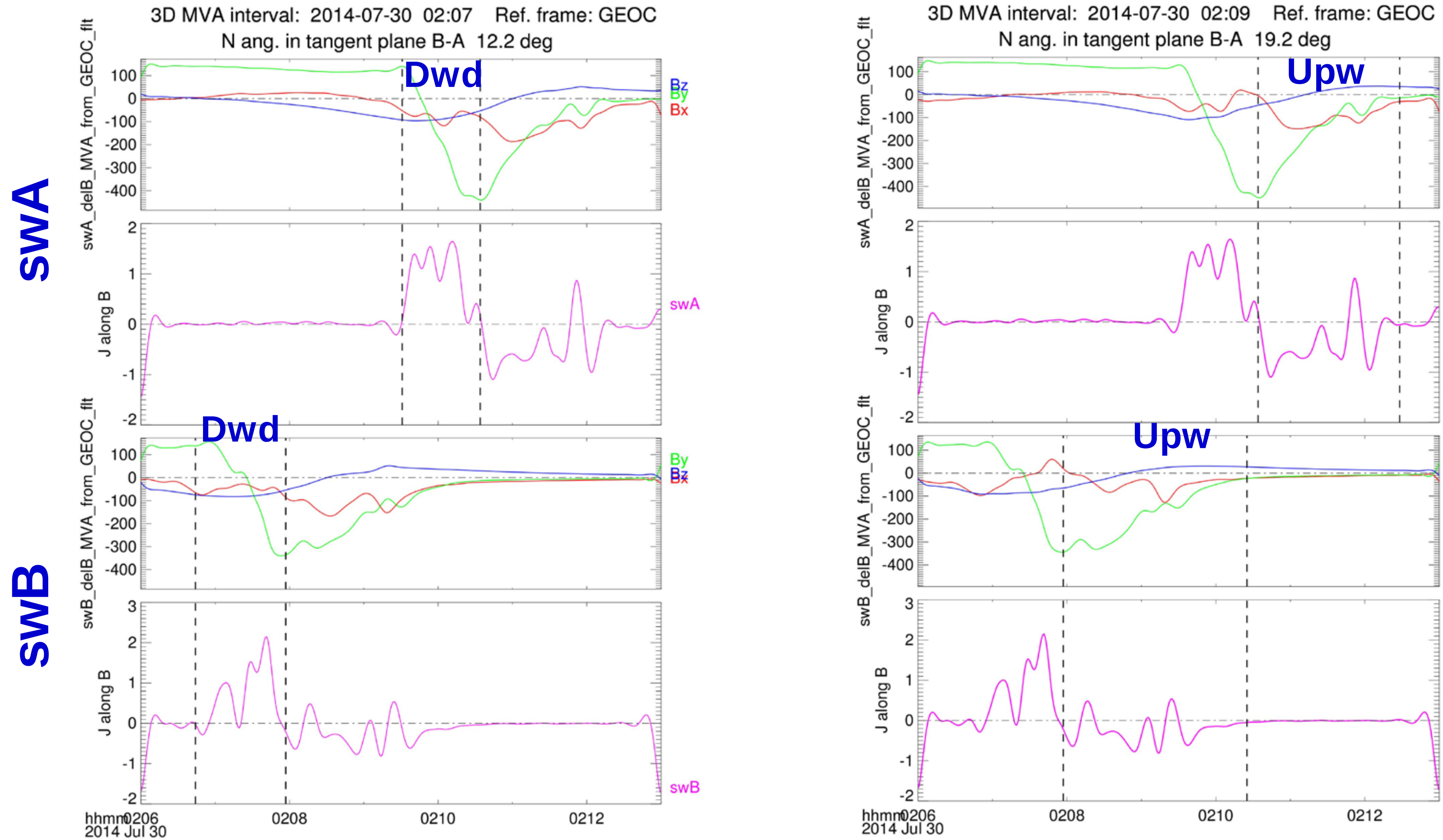




Credit: WDC Kyoto

- **Morning oval crossing, ~5 MLT, during recovery of a weak substorm.**

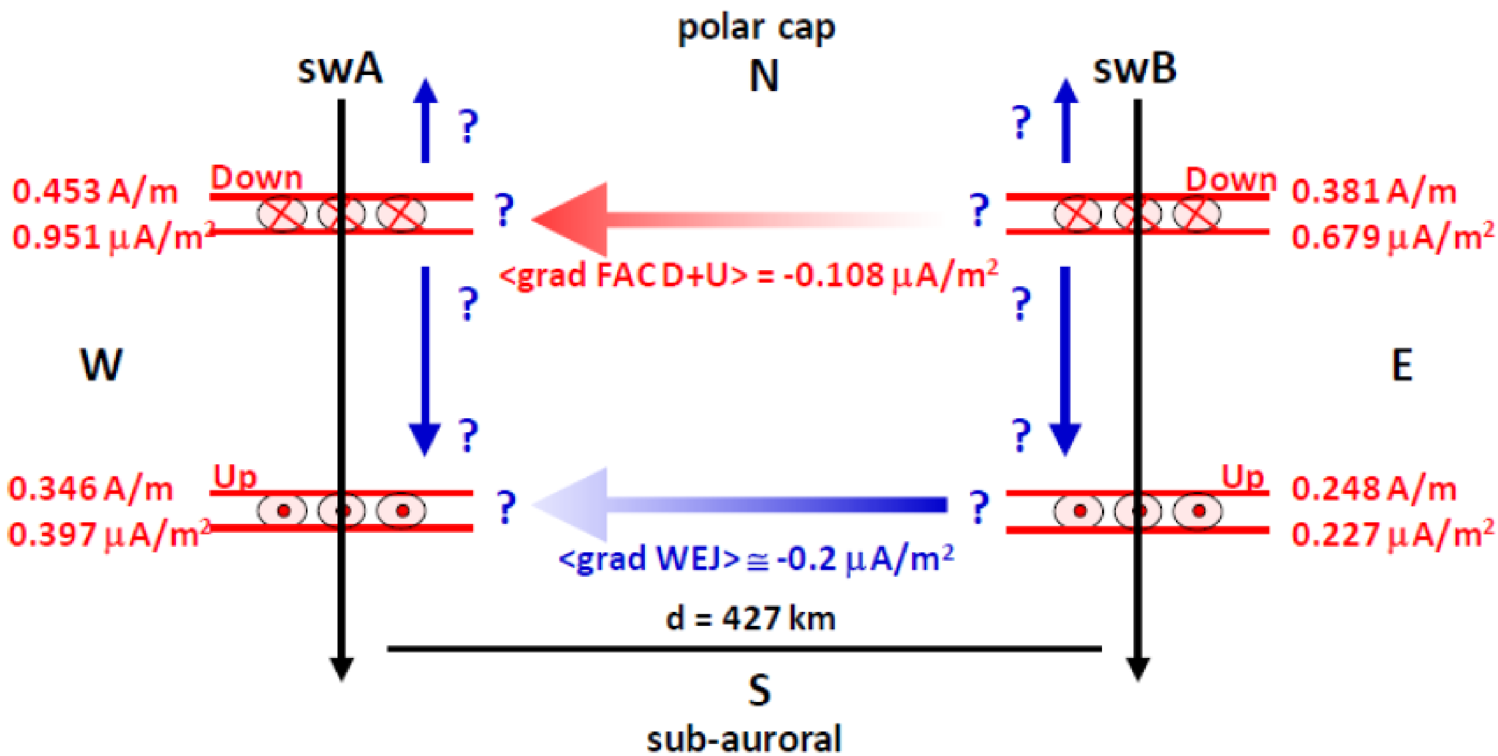
B. Sample Event on July 30, 2014



[swA Sheet D, Ave D, Sheet U, Ave U], [swB Sheet D, Ave D, Sheet U, Ave U], [LGSheet D, U, D+U]

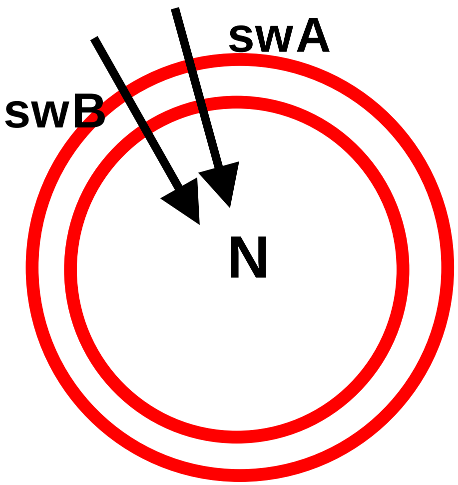
swA Sheet D	Ave D	Sheet U	Ave U	swB Sheet D	Ave D	Sheet U	Ave U	LGSheet D	U	D+U
0.453	0.951	-0.346	-0.397	0.381	0.679	-0.248	-0.227	0.168	-0.230	-0.108
A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	μA/m²	μA/m²	μA/m²

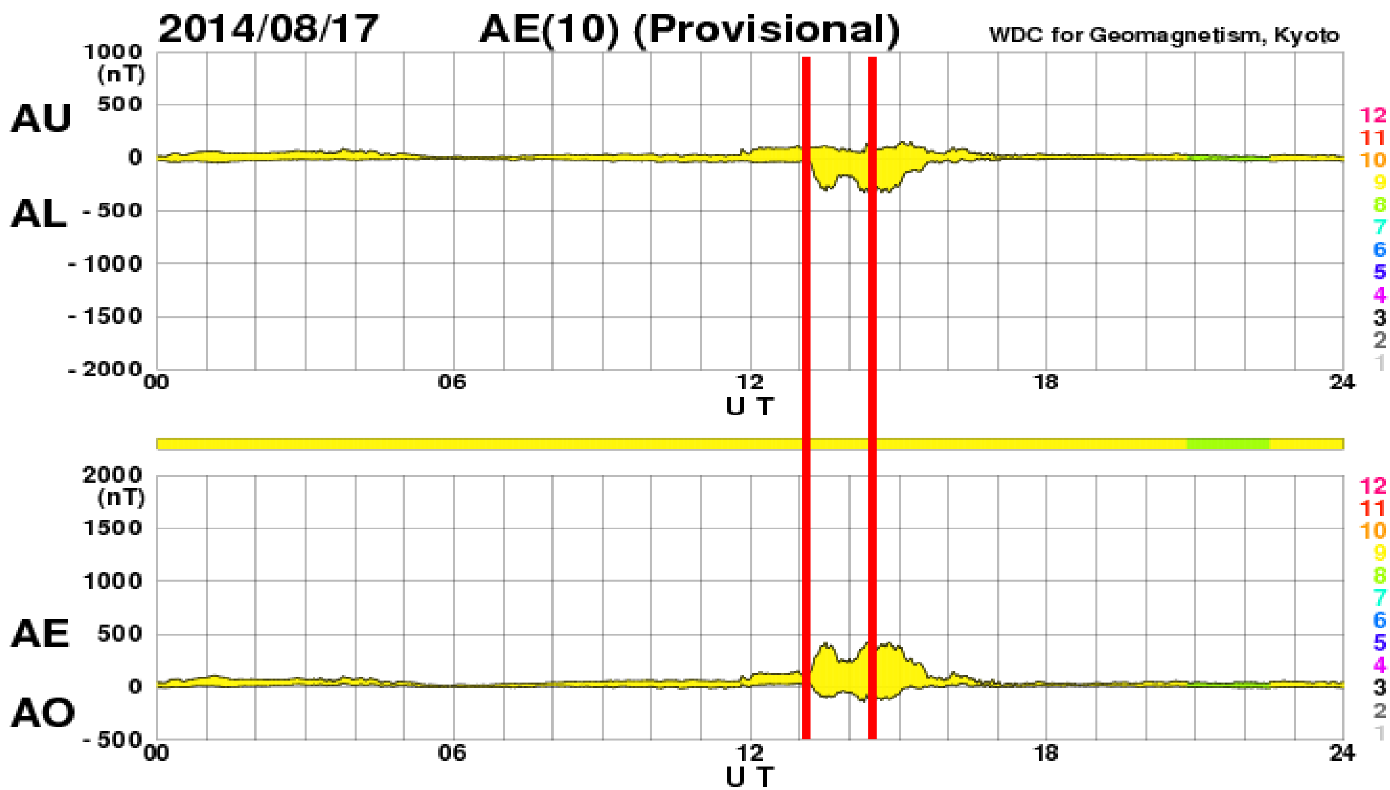
B. Sample Event on July 30, 2014



- **The schematics summarizes the results of the FAC analysis and indicates by question marks uncertainties related to meridional vs. longitudinal FAC closure.**
- **The large scale westward electrojet (WEJ) might be fed by excess R1 dwd FAC (not balanced meridionally) at its poleward boundary, and feed R2 upw FAC at its equatorward boundary (based on examination also of electric field data, not shown).**
- **A close investigation by ALADYN technique (*Marghitu et al., JGR, 2004, 2009, 2011*), not detailed here, indicates that the most likely configuration in this case consists of:**
  - **divergence free, meandering electrojet, as observed in the morning sector during recovery;**
  - **customary meridional FAC closure, with excess dwd FAC leaking into sunlit summer polar cap.**

B. Sample Events on Aug. 17, 2014

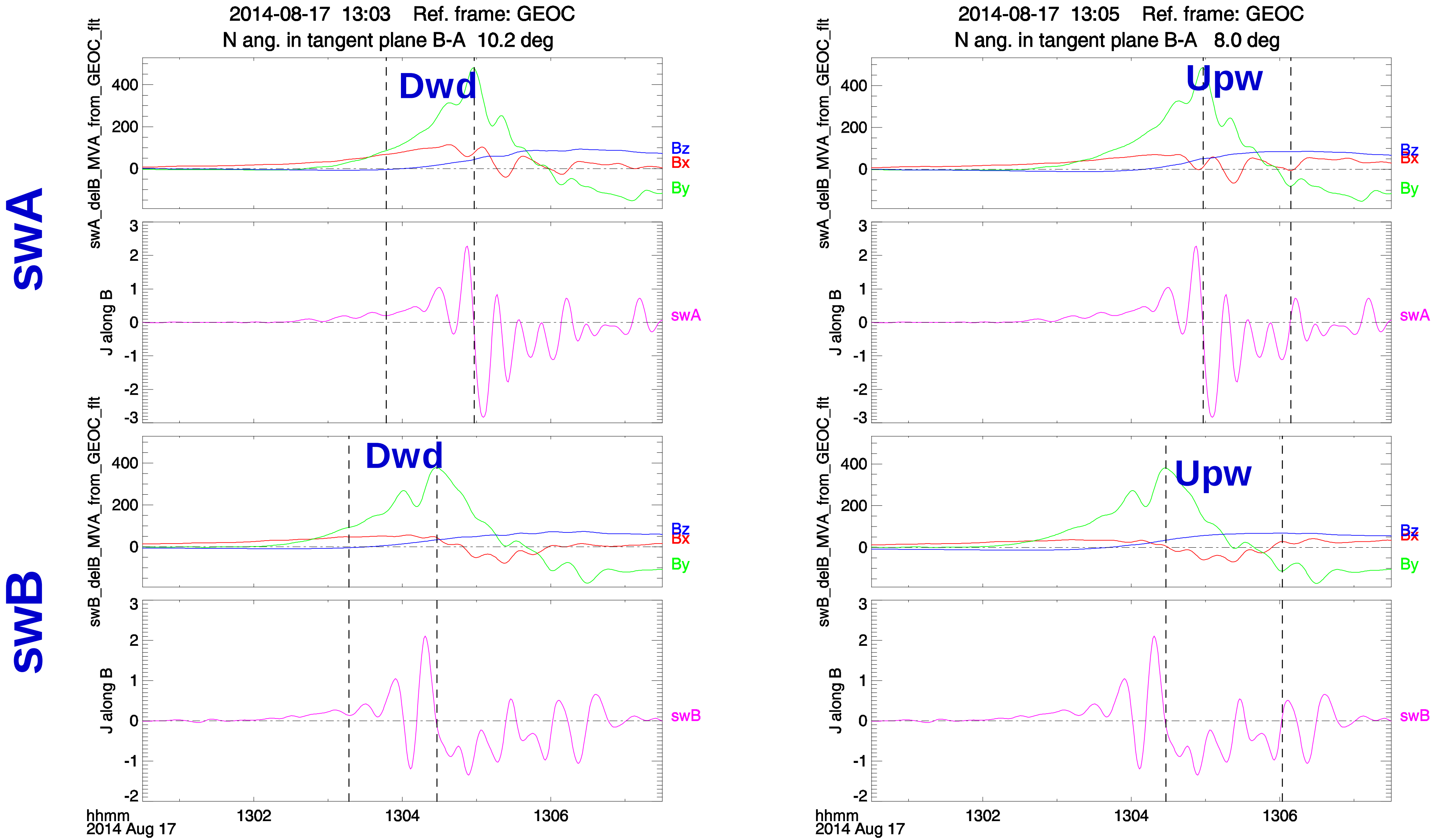




Credit: WDC Kyoto

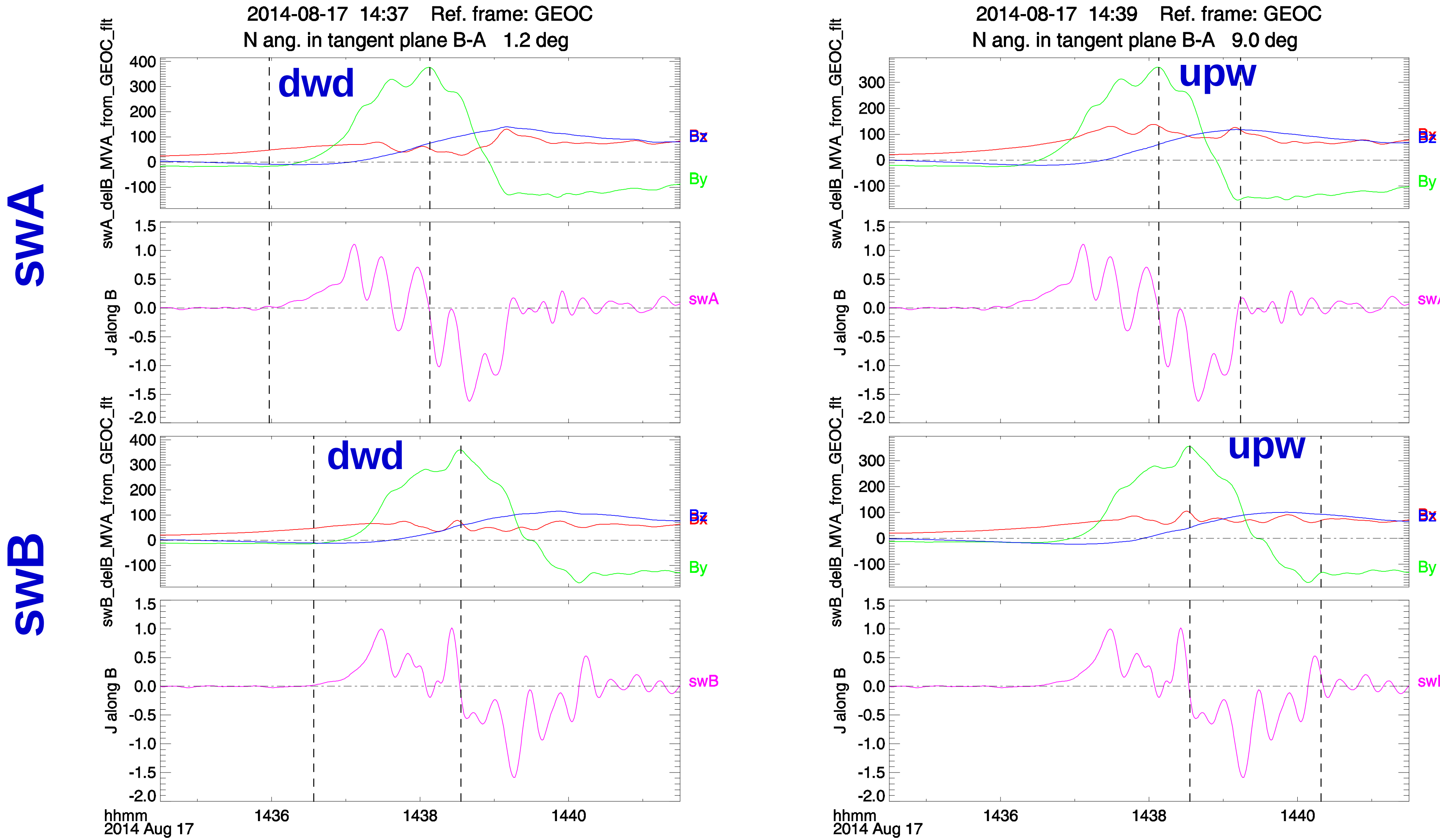
- Post-noon oval crossings, ~13 MLT, two consecutive orbits, just before the onset of a weak to moderate substorm and near the maximum of second expansion.
- Events selected on the dayside because of better 1D, sheet-like FAC backbone (in particular for the second event).
- More work needed on the night side, which is also closer related to the substorm process.

B. Sample Events on August 17, 2014: 13 UT



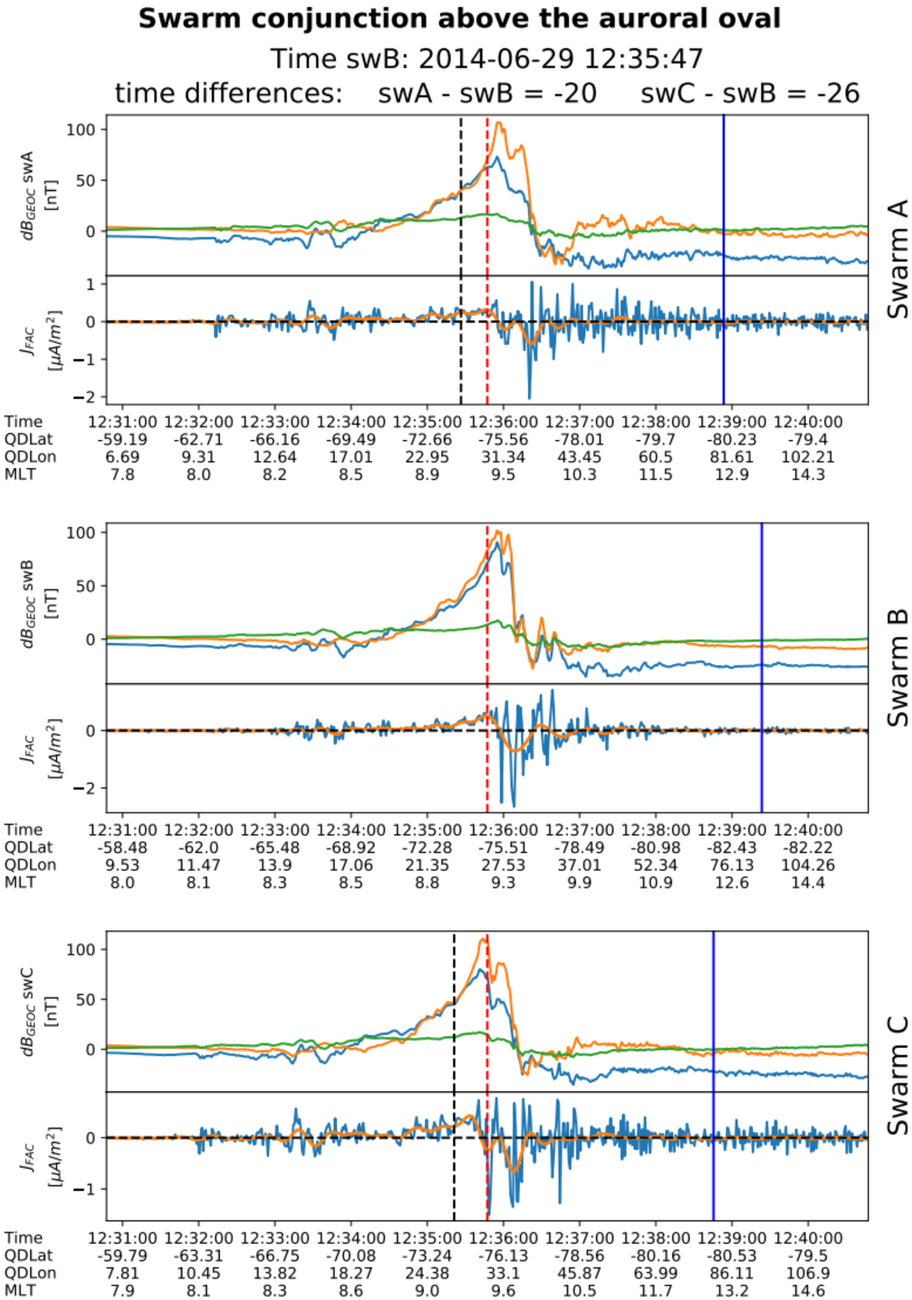
[swA Sheet D,	Ave D,	Sheet U,	Ave U],	[swB Sheet D,	Ave D,	Sheet U,	Ave U],	[LGSheet D,	U,	D+U]
0.298	0.561	-0.451	-0.827	0.226	0.415	-0.395	-0.547	0.255	-0.199	0.057
A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	μA/m²	μA/m²	μA/m²

B. Sample Events on August 17, 2014: 14.5 UT



[swA Sheet D,	Ave D,	Sheet U,	Ave U],	[swB Sheet D,	Ave D,	Sheet U,	Ave U],	[LGSheet D,	U,	D+U]
0.318	0.320	-0.405	-0.800	0.298	0.328	-0.391	-0.482	0.054	-0.035	0.016
A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	A/m	μA/m²	μA/m²	μA/m²	μA/m²

C. Towards a Systematic Approach: Event Selection

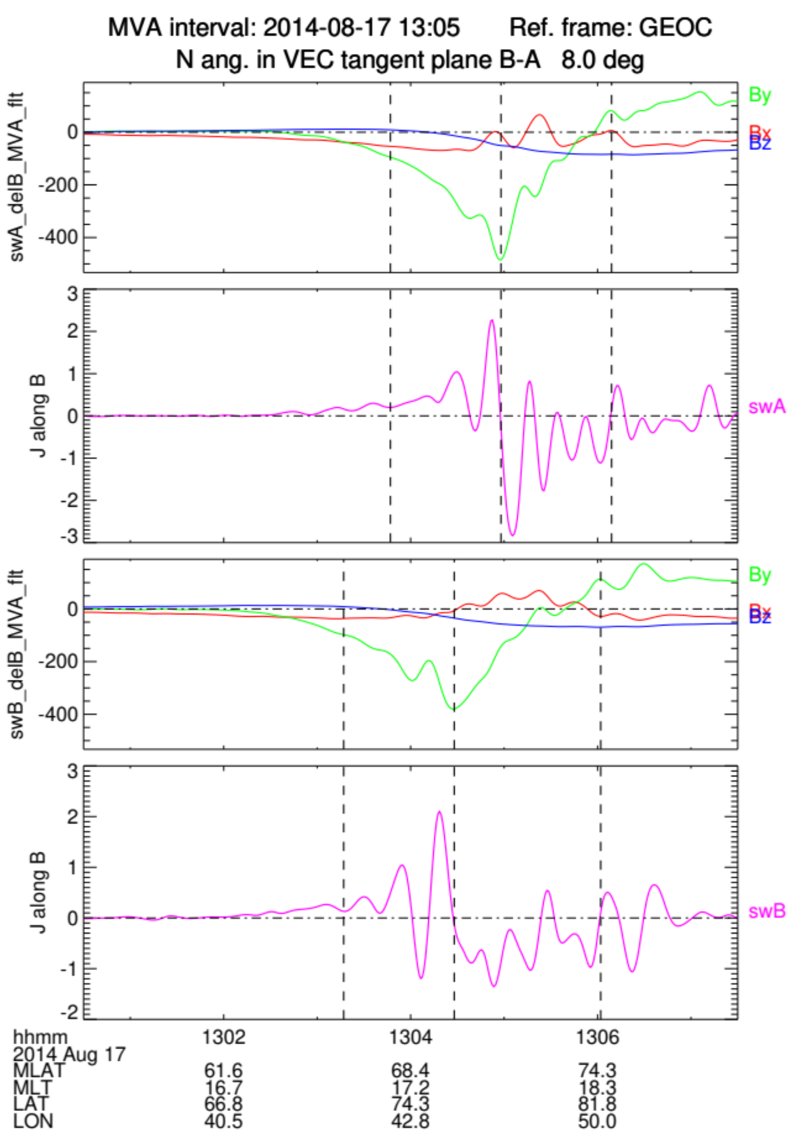


The different orbital velocities of Swarm upper and lower satellites results in latitude alignment for ~ 4 or 5 auroral oval (AO) crossings every other 6 days

Using an automatic procedure to find AO and requiring small time lags between magnetic profiles (< 30 s) a roughly 130 conjunction events have been identified between May and Oct 2014

The angular separation of swB and swC/swA orbital planes varies between 5° and 11° (~ 200 – 450 km longitudinal separation at 70° latitude) while all the magnetic local times are covered

C. Towards a Systematic Approach: Computation of Longitudinal Gradients



The intervals of upward and downward current sheets are selected manualy from individual dB and J profiles

One concentrates on the large scales => magnetic data are low-pass filtered

The algorithm takes into account the inclination of FAC sheet

Output example

```
First current branch
====================
AO average LAT, LON from swA and swB    80.63  189.80   79.87  198.43
AO average MLAT, MLT from swA and swB   75.73    7.90   76.17    8.33
average distance between satellites [km]      174.9
integrated current, swA and swB [A/m]     0.450    0.613
thickness from swA and swB [km]           256.4     271.1

Second current branch
=====================
AO average LAT, LON from swA and swB     78.44  192.92   77.83  200.54
AOl average MLAT, MLT from swA and swB   74.42    8.39   74.94    8.79
average distance between satellites [km]       187.8
integrated current, swA and swB [A/m]    -0.556    -0.718
thickness from swA and swB  [km]          237.1    175.7

Longitudinal gradients
=====================
First branch [mA/km]    -0.931
Second branch [mA/km]    0.858
```

D. Conclusions

- Swarm data from the first half year of operation (about May to October 2014, when swA and swB were separated by a few 100 km when aligned with the auroral oval), can be used to explore longitudinal gradients in the large scale R1 / R2 FACs.
- Longitudinal gradients in the large scale upward and downward FACs, separately, are not unusual, but apparently less frequent in the total FAC, indicating that respective variations are correlated, preserving in general meridional closure.
- When the longitudinal gradient of the total FAC is significant, a closer exploration is needed, to check whether the excess FAC couples to the electrojet current and/or leaks into the polar cap (in particular, the summer, sunlit polar cap).
- The FAC coupling to the electrojet can be analyzed by using the ALADYN technique, which helps to fully resolve the ionospheric current closure. For a weak substorm recovery event, examined closer, it turned out that apparent electrojet divergence was most likely not coupled to FAC, but related to the electrojet meanders.
- Exploration of more events is needed to check longitudinal gradients in FAC during the various stages of the substorm cycle. Methodology and tools were developed towards a systematic investigation, to make full use of the Swarm event statistics (>100 events in May – October 2014).

Acknowledgement. ESA Contract SIFACIT, C4000118383.