Field-aligned currents associated with multiple arc systems

Jiashu Wu[1], David Knudsen[1], Megan Gillies[1], Eric Donovan[1], Johnathan Burchill[1]

1. Department of Physics and Astronomy, University of Calgary, Calgary, AB, Canada

1. Introduction

The field-aligned current (FAC) system associated with auroral arcs provides important information regarding the generator responsible for multiple arc systems, and presumably for individual arcs themselves. In this study, we have identified two types of FAC configurations in multiple parallel arc systems using ground-based optical data from the THEMIS all-sky imagers (ASIs), magnetometers and electric field instruments onboard the Swarm satellites during the period from December 2013 to March 2015.

Type 1: Each arc is an intensification within a broad, unipolar current sheet and downward currents only exist outside the upward current sheet.

Type2: Multiple arc systems represent a collection of multiple up/down current pairs.

By collecting 12 events for type 1 and 17 events for type 2, MLT dependence, arc number and width, current characteristics are examined in this study.

2. Instrument and Data

THEMIS ASI:

THEMIS ASI consists of 21 cameras covering mid-to high-latitude northern America; it captured 256×256 pixel "white line" images every 3 seconds.

Swarm Constellation:

Consists of 3 identical satellites launched on 22nd November 2013 by the European Space Agency(ESA). One pair of satellites(Swarm A and C) fly side by side at 460km. The third satellite(Swarm B) at 510km. Each satellite is equipped with a magnetometer capable of measurements with up to 50 Hz time resolution with precision greater than 0.1nT. Electric Field Instruments(EFI) provide three-dimensional ion drift velocity and temperature with a pair of thermal ion imager(TII) sensors. A smoothed version of the magnetometer measurements with a resolution of 1Hz and 16Hz Level0 electric field data were used in this study.

3. Studying Conjunction Events

Satellite-aligned keogram(SAK): Similar to a traditional keogram, a SAK is created by extracting the pixels along the path of the satellite passing across the camera from time stacked images.

Field-aligned current(FAC): The FAC $j_{\parallel}$ is calculated according to the single satellite method in *Ritter and Lühr* [2006]:

$$\mu_0 j_{\parallel} = \frac{1}{V_x}\frac{d}{dt}B_y$$

where B_y is the eastern component of residual magnetic field, calculated by subtracting the International Geomagnetic Reference Field(IGRF) model. V_x is the northward component of the satellite velocity. The time derivative is taken in the NEC(north-east-center) frame of the moving satellite.

Type 1: fsmi 20140927 SwarmA

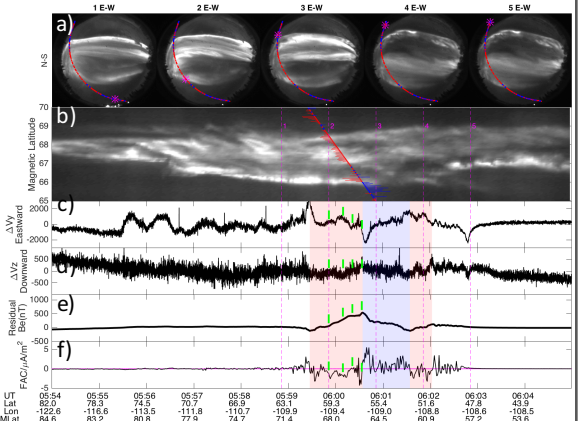


Figure 1. Conjunction of multiple arcs observed by the Fort Simpson ASI and Swarm B with a Type 1 current system on 15 March 2015. (a) Swarm B's path and arcs in the FSIM ASI reference frame are calculated assuming an emission altitude of 110km. Red and blue colors indicate upward and downward FACs. (b) Satellite-aligned keogram of Swarm B as a function of geomagnetic latitude and time. The value of upward (red) and downward (blue) FACs are displayed together with the flight path. (c) Horizontal cross-track (eastward) ion velocity (m/s). (d) Vertical (downward) ion velocity (m/s). (e) East component of residual magnetic field. (f) FACs derived from the single satellite method. The red and blue areas in panels (c)~(f) are large-scale upward and downward FAC regions identified interactively by neglecting small fluctuations. The criterion of $FAC_{up}/FAC_{total}>78\%$ is applied in defining upward current sheets. The positions of arcs are indicated by green lines.

Type 2: gill 20140428 SwarmA

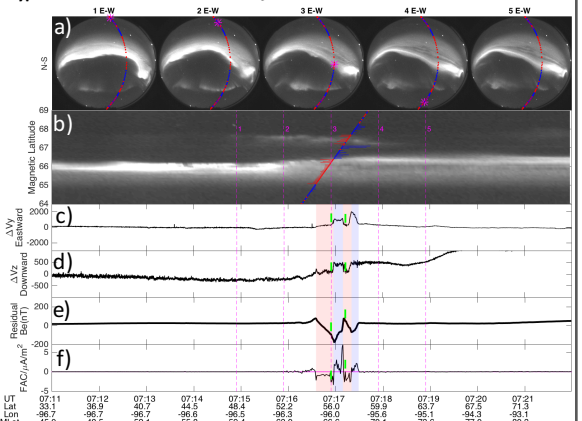


Figure 2. Conjunction of multiple arcs observed by the Gillam ASI and Swarm A with a Type 2 current system on 28 April 2014.

4. Statistical Results

4.1. MLT dependence

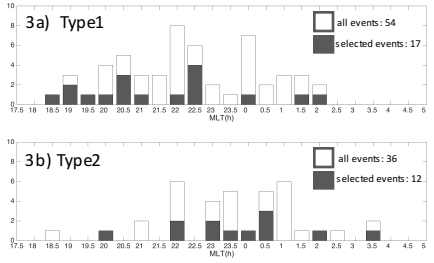


Figure 3. Histograms displaying MLT dependence of all events(90) and selected events(29). To be selected, events must have identifiable arc numbers and clearly structured FAC. For selected events, arc number, width of arcs, total current ($\int j_{\parallel}\,dx$) and width of current sheet are calculated.

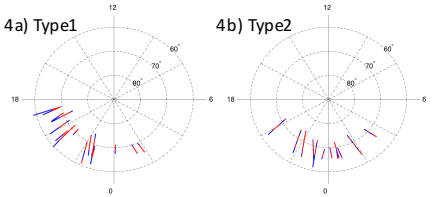


Figure 4. MLT dependence of selected events in a MLT-MLAT polar diagram. Red and blue colors indicate upward and downward current regions identified as in panels c)~f) of Figures 1 and 2.

- Type 1 events are mainly located between 22-23MLT. The current pattern is generally consistent with the Region 1 and Region 2 FAC system.
- Type 2 events are mainly located around midnight. Typically 2 pairs of up/down currents are occurred in each event.

4.2. Arc number VS. upward current characteristics

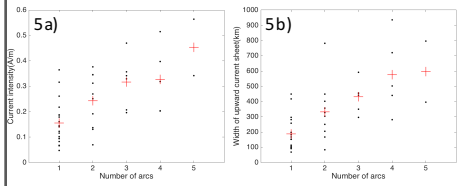
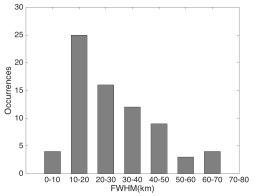


Figure 5a). Relation between arc number and total current $\int j_{\parallel}\,dx$ (A/m) . Figure 5b) Relation between arc number and width of upward current sheet(km).

- Upward currents with more arcs embedded have larger intensities and widths.

4.3. Arc width

Figure 6. Histogram of Gaussian full widths at half maximum(FWHM) for all optical arcs in selected events.



- Characteristic width of multiple arcs in this study is consistent with the mean width of stable arcs (18km±9km) in *Knudsen et al.*[2001].

5. Conclusion

We identified two types of field-aligned currents (arcs located in one upward current sheet and in up/down current pairs) in multiple arc system and examined the statistical characteristics of arcs and currents.

- Type 1 events are mainly located between 22-23MLT. Type 2 events are mainly located around midnight.
- Upward currents with more arcs embedded have larger intensities and widths.
- There is no significant difference between the characteristic widths of multiple arcs and single arcs.

Two multiple arcs models have been proposed:

- Knudsen (1996): Drifting unipolar FAC sheets are susceptible to spatial structuring in the form of our Type1 current.
- Atkinson (1970): Multiple arcs resulting from feedback interactions between ionosphere and magnetosphere have multiple FAC pairs.

The results in this study provide specific constraints on theory of multiple auroral arcs generation.

6. References

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