DUAL IONOSPHERIC RADIAL CURRENT (IRC) AND FIELD-ALIGNED CURRENT (FAC) ESTIMATIONS

The lower pair of the Swarm satellite constellation offers a unique opportunity to determine both radial and field-aligned currents. The horizontal B field components measured by the Swarm A and C satellites at four measurement points, which form a symmetric quad are used to estimate the radial current density. Ampère's law in integral form is used in the case of multiple data points:

\[ j = \frac{1}{\mu_0 A} \int B \, dl \]

Here, the discrete form is applied to solve the ring integral:

\[ j_{\text{inc}} = \frac{1}{\mu_0 A} \left[ (B_1^r + B_1^s) dl_1 + (B_2^r + B_2^s) dl_2 - (B_1^r + B_1^s) dl_1 - (B_2^r + B_2^s) dl_2 \right] \]

Where \( \mu_0 \) is the vacuum magnetic permeability and \( A \) is the integration area

\[ A = \frac{1}{2} (dl_1 + dl_2) (dl_1 + dl_2) \]

Along-track variation, \( B_{\text{inc}} \) is derived from the two subsequent measurements: \( \Delta t = 5s \) corresponding to \( dl_1 (dl_2) = 38 \text{ km} \). Cross-track separation: 1.4° in longitude corresponding to \( dl_1 (dl_2) = 50 \text{ km} \) at 70° latitude.

The field-aligned current (FAC) is obtained from the ionospheric radial current (IRC) projection on the field direction

\[ j_{\text{FAC}} = j_{\text{inc}} \sin I \frac{|I| A}{m^2} \]

where \( I \) is the magnetic field inclination. IRCs and FACs are derived from the low-pass filtered residual B-field data to account for the lateral distance of the satellites (only currents with spatial scale lengths > 150 km are represented). A 3-dB cut-off period of 20 seconds is used (7 seconds filter length) for filtering.

Calculations near the equator and poles
- FACs are not estimated near the magnetic equator for \(|I| < 30°
- FACs and IRCs are not estimated near the poles for latitudes > 86°.

Upward and downward current directions

<table>
<thead>
<tr>
<th>Northern Hemisphere</th>
<th>Southern Hemisphere</th>
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</thead>
<tbody>
<tr>
<td>Upward: +IRC and -FAC</td>
<td>Upward: +IRC and +FAC</td>
</tr>
<tr>
<td>Downward: -IRC and +FAC</td>
<td>Downward: -IRC and -FAC</td>
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</tbody>
</table>

DUAL FAC (IRC) ALGORITHM UPDATES NECESSITY DUE TO SWARM ORBIT EVOLUTIONS

The Swarm L2 dual FAC data product (FAC.TMS.2F) has been impacted by incorrect values due to changes in the orbits of Swarm A and C satellites (described below). An update to the dual FAC algorithm will eliminate these incorrect values and improve the accuracy of current density estimates.

Swarm A and C constellation and orbit evolution
- The mission was launched on 22 November 2013
- The initial constellation was achieved on 17 April 2014 with 1.4° longitudinal separation at the equator between Swarm A and C
- The manoeuvre that slowly reduced the separation in longitude between Swarm A and C started in October 2019 and reached the counter-rotation phase in October 2021
- Orbit raise campaign of Swarm A and C started in May 2022
- As of August 2023, the longitudinal separation at the equator between Swarm A and C is -1.4° again

The equatorial distance and along-track time difference developments between Swarm A and C from 2019-01-01 to 2024-03-15

Dual FAC (IRC) algorithm changes

The following is a set of parameters that will control the automated daily processing and production of CDF data files. The limit parameters for the integration area and time separation determine the time interval that will be ignored during the Dual FAC processing and reprocessing.

In the updated version, the lower area threshold is used instead of restricting through 86° for FACs and IRCs near the poles.