On the direction of the Poynting flux associated with equatorial plasma depletions

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Overview

Equatorial plasma depletions (EPD) refer to the large-scale structure of topside Spread F. They are well-known for their adverse effect on radio wave propagation.

Current studies focus on:

- day-to-day variability and forecasting [e.g., Hysell et al., 2018; Yokoyama, 2017]
- effects on GNSS [e.g., Rino et al., 2018; Morton et al., 2018]
- seeding mechanisms [e.g., Rodrigues et al., 2018]

A better understanding of the electrodynamics of EPDs promises to improve their modeling and forecasting.
Overview

Equatorial plasma depletions (EPD) refer to the large-scale structure of topside Spread $F$.

**Local time:** Post-sunset

**Scale:** Few 10s to 100s km.

**Altitude:** Bottomside to 2000 km.

Typical observation of EPD by polar-LEO satellites.
Overview

Why do we care about the Poynting flux $S_{||}$ and its orientation?

$S_{||}$ can characterize dissipation of energy associated with static fields.

$$S_{||} = \frac{1}{\mu_0} (\delta E_\perp \times \delta B_\perp)$$

**Based on theoretical assumptions,**

$S_{||}$ must flow away from the dip equator

[e.g., Bhattacharyya & Burke, 2000; Dao et al., 2013]
Overview

Why do we care about the Poynting flux $S_\parallel$ and its orientation?

Current numerical models follow this configuration [e.g., Aveiro & Hysell, 2013; Yokoyama & Stolle, 2017]

\[
S_\parallel = \frac{1}{\mu_0} (\delta E_\perp \times \delta B_\perp)
\]

\[
j_\parallel = \frac{1}{\mu_0} \left( \frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y} \right)
\]
Do observations agree with such configuration?
Method

Swarm constellation

**Lifetime:** Since November 2013.

**Orbits:** Near-circular polar,  
Alpha & Charlie (445 km); Bravo (512 km).

**Data:** Magnetic field, electron density, ion-drift.

The three parameters must be well correlated (i.e., $|cc| > 0.6$)
Observations

Evidence of interhemispheric Poynting flux (i.e., energy flows from the southern hemisphere to the north.)

\[ S_\parallel = \frac{1}{\mu_0} (\delta E_\perp \times \delta B_\perp) \]

Swarm presents a limited set of electric field data which restricts a climatological analysis of the \( S_\parallel \).

However, valuable information can be obtained from the orientation of the \( j_\parallel \).
Observations

S_{\parallel} \text{ from north to south by assuming a growing EPD (i.e., eastward } \delta E \text{)}

\[ S_{\parallel} = \frac{1}{\mu_0} (\delta E \perp \times \delta B \perp) \]
Observations

\[ S_{||} \text{ from south to north by assuming a growing EPD (i.e., eastward } \delta E) \]

\[ S_{||} = \frac{1}{\mu_0} (\delta E_{\perp} \times \delta B_{\perp}) \]
Seasonal and longitudinal variability of $j_{||}$
(based on almost 5 years of observations)
Seasonal and longitudinal variability of $j_{||}$
(based on almost 5 years of observations)
Seasonal, longitudinal and MLT variability of $j_{||}$
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Seasonal, longitudinal and MLT variability of $j_{||}$
(based on almost 5 years of observations)
$j_\parallel$ close in the hemisphere with the highest conductance

$j_\parallel$ closing around the **southern** foot of EPDs
\( \mathbf{j}_\parallel \) close in the hemisphere with the highest conductance

\( \mathbf{j}_\parallel \) closing around the **southern** foot of EPDs

Pedersen conductance (80 - 300 km, 22 LT) from IRI and NRLMSISE-00 models
Summary

• Observations across EPDs of magnetic and electric fields from the Swarm mission suggest a preference for interhemispheric Poynting flux at LEO altitudes.

• The orientation of the field-aligned currents shows a distinct seasonal, longitudinal, and MLT dependence.

• The use of an extended data set of electric field observations will precisely determine the spatiotemporal characteristics of the Poynting flux.
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Data & information: earth.esa.int/swarm

Invitation:
Poster EQIT01 "Assessment of the plasma and magnetic pressure balance across equatorial plasma depletions."
-Tomorrow, Tuesday 18, 2019-
References