Multi-Scale Ionospheric Poynting Fluxes Using Ground and Space-Based Observations

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The quasi-static* system

*or: large-scale, DC, big picture, field-aligned currents, convection, etc

What is Poynting flux?
Large-scale Poynting flux

SuperDARN

AMPERE

Polar Poynting flux pattern

\[ E = -\nabla \Phi \]

\[ \delta B \]

\[ S_\parallel = \frac{E \times \delta B}{\mu_0} \]

Polar plots, northern hemisphere

Billett et al. [2023]
The small-scale system
The “everything else” Poynting flux

The ESA Swarm Mission

Electric field

Billett et al. [2022]

Poynting flux

Cumulative PF

 Result

The smaller scales we look at, the more Poynting Flux we see
Statistics across instruments

SuperDARN $E$ and AMPERE $\delta B$ fields:

Swarm $E$ and $\delta B$ fields:

Billett et al. [2021]
Just one problem... the data doesn't agree

SuperDARN $E$ and AMPERE $\delta B$ fields:

Swarm $E$ and $\delta B$ fields:

...why don't these match?

Billett et al. [2021]
Seeing embedded structures

SuperDARN/AMPERE
“large-scale”
Swarm “large-scale”
Swarm “everything else”

So this is the “invisible” Poynting Flux
Upward Poynting flux: Small scales balancing the large?

SuperDARN/AMPERE “large-scale”
Swarm “large-scale”
Swarm “everything else”

"Upward driving on large-scales, balanced by downward driving on smaller scales"

Net = 0

Duskside FACs
Capturing large-scale dynamics is vital for understanding everything else.
Upgrades to SuperDARN Canada radars have recently allowed us to improve temporal resolution sixteenfold.

1-minute narrow beam scanning

3.5-second wide-beam imaging
SuperDARN convection patterns can now update every 3.5s seconds in localised regions

Currently Canada-Greenland only - other SuperDARN radars will make global maps possible soon™

Swarm(s) moves ~27km during one SuperDARN integration. Previously ~900km.

We are very excited about this
Capturing large-scale dynamics is vital for understanding everything else.
Duskside FACs

Electric field

Poynting Flux

Alfvénic?

Look at those magnitudes!

Extra slide: Comparisons

Kp 7+

SuperDARN/AMPERE
“large-scale”

Swarm “large-scale”

Swarm “everything else”
Swarm B: 2014-02-18

SuperDARN/AMPERE "large-scale"
Swarm "large-scale"
Swarm "everything else"

Electric field
Poynting Flux

Dawnside FACs
Duskside FACs
The “full” Poynting flux will contain the perturbation and quasi-static components…
Extra slide: Project CHAMPERE

SuperDARN/AMPERE Poynting Flux

CHAMP Perturbation Neutral Density

Billett et al., 2021