Electrojet estimates from mesospheric magnetic field measurements

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Key Points:

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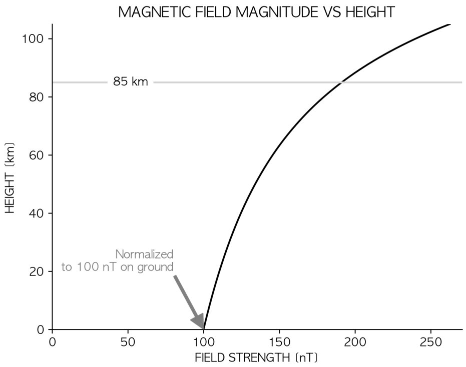

Figure 1. Altitude variation of ΔB, assuming spatial structure of electrojet is similar to field-aligned currents. Normalized to 100 nT on ground.

Abstract

Suggested EGU abstract:

The auroral electrojet is traditionally measured remotely with magnetometers on ground or in low Earth orbit. The long distance, more than 100 km, means that smaller scale sizes are not detected. Because of this, the spatiotemporal characteristics of the electrojet are not known. Recent advances in measurement technology give hope of remote detections of the magnetic field in the mesosphere, very close to the electrojet. We present a prediction of the magnitude of these disturbances, inferred from the spatiotemporal charecteristics of magnetic field-aligned currents. We also discuss how a constellation of small satellites carrying the Microwave Electrojet Magnetogram (MEM) instrument (Yee et al., 2020), could be used to essentially image the equivalent current at unprecedent spatial resolution.

Plain Language Summary

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1 Introduction

Electrojet traditionally measured from ground + later satellites. Disadvantage: Distance > 100 km, which removes fine scale structures. ⇒ electrojet spatial structure is not known

New techniques available (EZIE (Yee et al., 2020)+ maybe sodium laser measurements (Kane et al., 2018)), which offer the potential to distinguish between different fine-scale structures in the electrojet.

1.1 Prediction of mesospheric magnetic field disturbance magnitudes

Use (Gjerloev et al., 2011) FAC-based spectrum to make synthetic equivalent current that has the same magnetic power spectrum. Use standard radial dependence to calculate structure and magnitude of magnetic field below ionosphere. The result is a theoretical prediction of the average magnitude of the magnetic field perturbations as function of altitude (or distance from electrojet current sheet). The point is to quantify the added benefit of measuring at 85 km compared to ground.

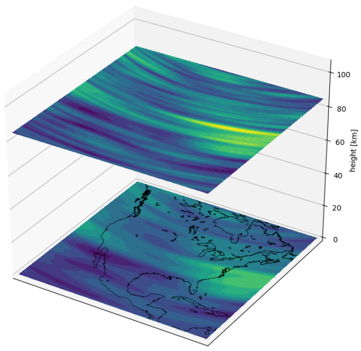

Figure 2. Contour plots of magnetic field of a random electrojet with similar spatial structure (spatial power spectrum) as FACs, shown at 85 km and on ground. (probably merge this figure with fig 1 - and add panel with (Gjerloev et al., 2011) power spectrum).

2 Resolving electrojet using mesospheric magnetic field measurements

Point: Demonstrate / quantify increased capability in determining electrojet structure with meospheric measurements compared to ground

Subsections:

1. EZIE mission concept
2. Test simulation
3. Electrojet inversion

2.1 EZIE mission concept

Description of mission: Grid, time resolution, precision (basically going from spectrum to B + error)

Limitations of look direction

2.2 Test simulation

Description and plots of MHD simulation and snapshot(s) that we will use.

Description of the simulated data: How is the (perfect) MHD output used to produce measurements on grid with noise / uncertainty etc. Much of this is covered in (Yee et al., 2020)

Description of ideal figures ($\boldsymbol{J}_{eq}^{ideal}$ and $\boldsymbol{J}_{H}^{df}$): $\boldsymbol{J}_{eq}^{ideal}$ is the equivalent curent at 110 (?) km altitude calculated with perfect knowledge about the magnetic field at 85 km. What we would get if we had no noise, and perfect spatial coverage. $\boldsymbol{J}_{H}^{df}$ is the divergence-free part of the horizontal current. $\boldsymbol{J}_{eq}^{ideal}$ and $\boldsymbol{J}_{H}^{df}$ are expected to be very similar, but not exactly: $\boldsymbol{J}_{eq}^{ideal}$ does not have spatial structures < distance to electrojet, and it has contributions from magnetospheric currents. $\boldsymbol{J}_{H}^{df}$ has all spatial scales of the MHD simulation, and no contribution from magnetosphere.

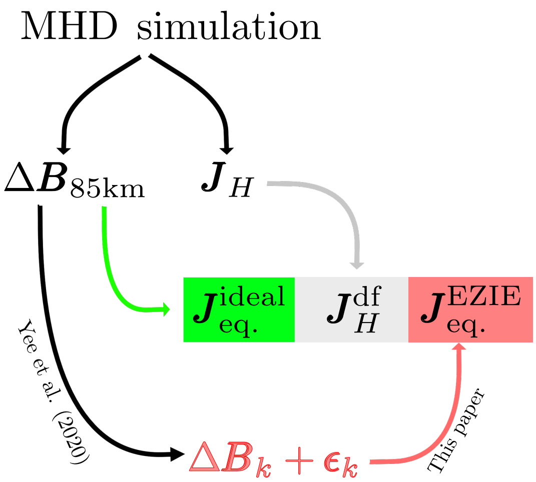

Figure 3. PRELIMINARY FIGURE: Schematic to illustrate what is done in this paper: Calculate equivalent current based on realistic measurements from EZIE, and compare the result to 1) equivalent current calculated from an ideal distribution of perfect measurements of $\Delta\boldsymbol{B}$ at 85 km, and 2) the divergence-free part of the horizontal ionospheric currents.

2.3 Electrojet inversion

Description of algorithm - this is the main section of the paper describing the details of the inversion. Rough description:

- Input: Magnetic field at 85 km on a grid - defined by satellite orbit, 4 viewing directions, and sampling frequency/integration time. Three magnetic field components with different errors every direction - and correlated errors so we can not use least squares techniques directly
- Technique: Place divergence-free spherical elementary current systems (SECS) (Amm, 1997; Vanhamaki & Juusola, 2020) on a grid (details tbd) and find the amplitudes that fit the measurements. Several MHD model snapshots should be used to find an optimal grid + regularization parameters.
- With known divergence-free SECS amplitudes, plot the divergence free current and compare to the ideal currents discussed above

3 Discussion

3.1 Effect of weighted volume emission

Can we merge/combine the inversions: Instead of spectrum → magnetic field → equivalent current, we do spectrum → equivalent current.

use probabilistic inversion methods?

3.2 Effect of uncertainties in measurement location

There is an uncertainty in the location of the measurements (where the emission comes from). What is the corresponding uncertainty in electrojet estimate? This probably requires different inversion methods. (related to previous subsection...)

3.3 Effect of temporal variations

In this paper we work with snapshots of MHD model. What are the effects of time variations?

Acknowledgments

Enter acknowledgments, including your data availability statement, here.

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