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Equatorial Electric Fields Derived from Swarm Magnetometer Data

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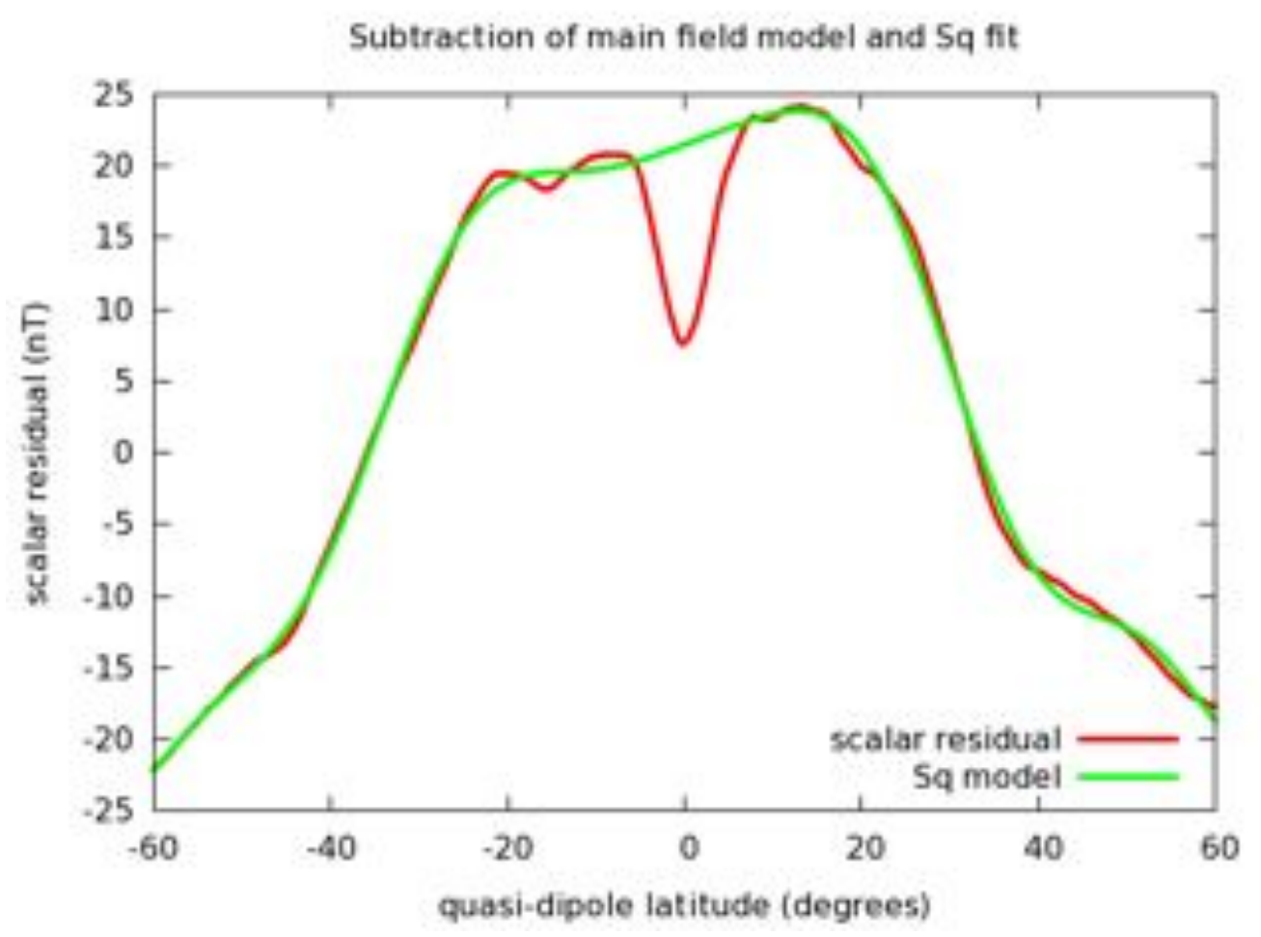
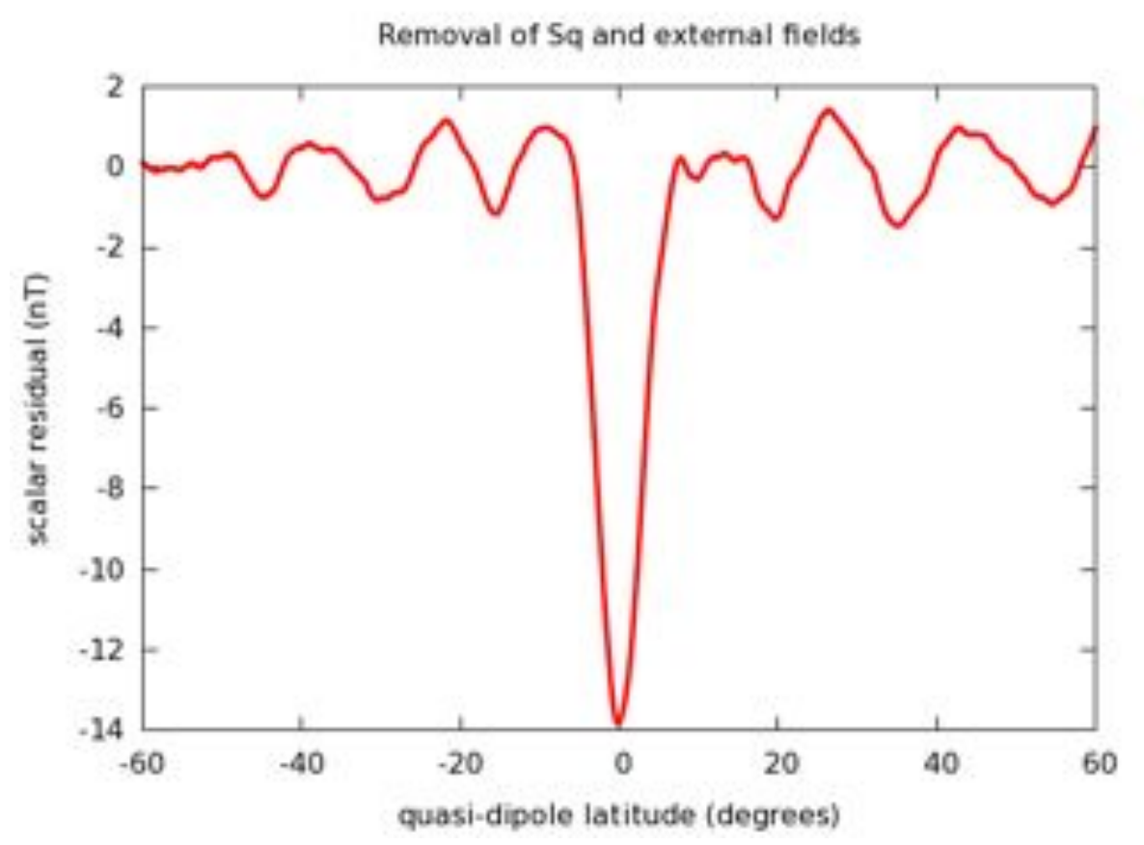
Introduction

The Swarm Level-2 operational equatorial electric field (EEF) product is producing estimates of the EEF for each dayside orbit of all three satellites. The EEF plays a crucial role in E and F region daytime equatorial ionospheric dynamics. It is responsible for driving the equatorial electrojet (EEJ) current system, equatorial vertical ion drifts, and the equatorial ionization anomaly (EIA). The EEF is recovered by analyzing the EEJ signature seen in the Swarm absolute scalar magnetometer (ASM) data. We present first results of Swarm-derived EEJ currents and their corresponding EEF estimates, compare the results between satellites, and validate them against independent ground measurements. Finally, we present measurements of longitudinal gradients in the eastward electric field using near-simultaneous observations from the A and C satellite lower pair.

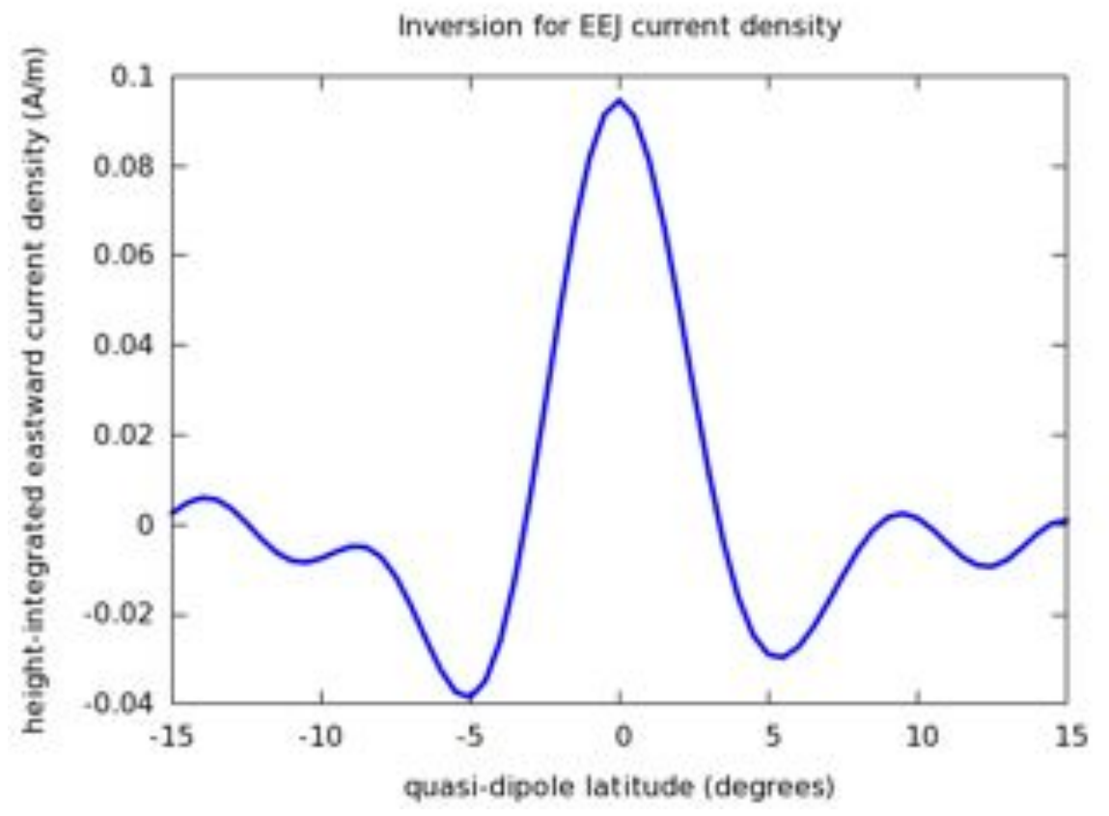
Processing Swarm Magnetometer Data



First, we subtract a main, crustal and external field model from the scalar ASM data for dayside orbits (red). The residual is primarily composed of the EEJ signature, higher-latitude Sq currents, and unmodeled external fields. Then we fit a low order polynomial to the higher latitude data to remove the Sq signal (shown in green).



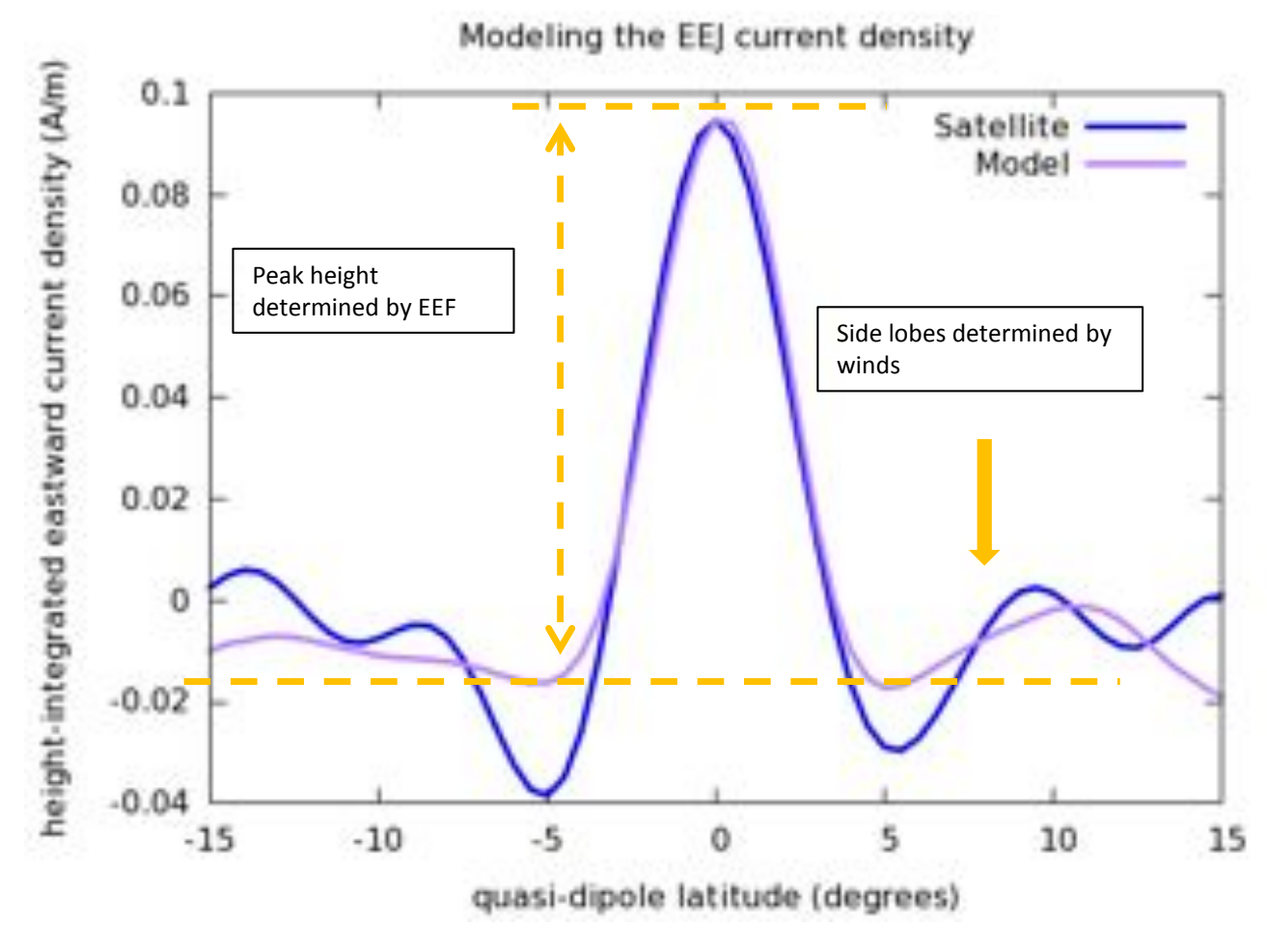
After subtracting the Sq model from the scalar residual, we obtain the curve shown above. The EEJ peak at the magnetic equator is now prominent, in addition to some higher latitude structure primarily due to the neutral winds and external fields.



Next, we invert the magnetic signature seen at satellite altitude, for the eastward currents flowing in the E-region at 110km altitude. This is done by assuming a simple model of line currents spaced 0.5 degrees apart in QD latitude, and inverting the magnetic data for the current strengths.

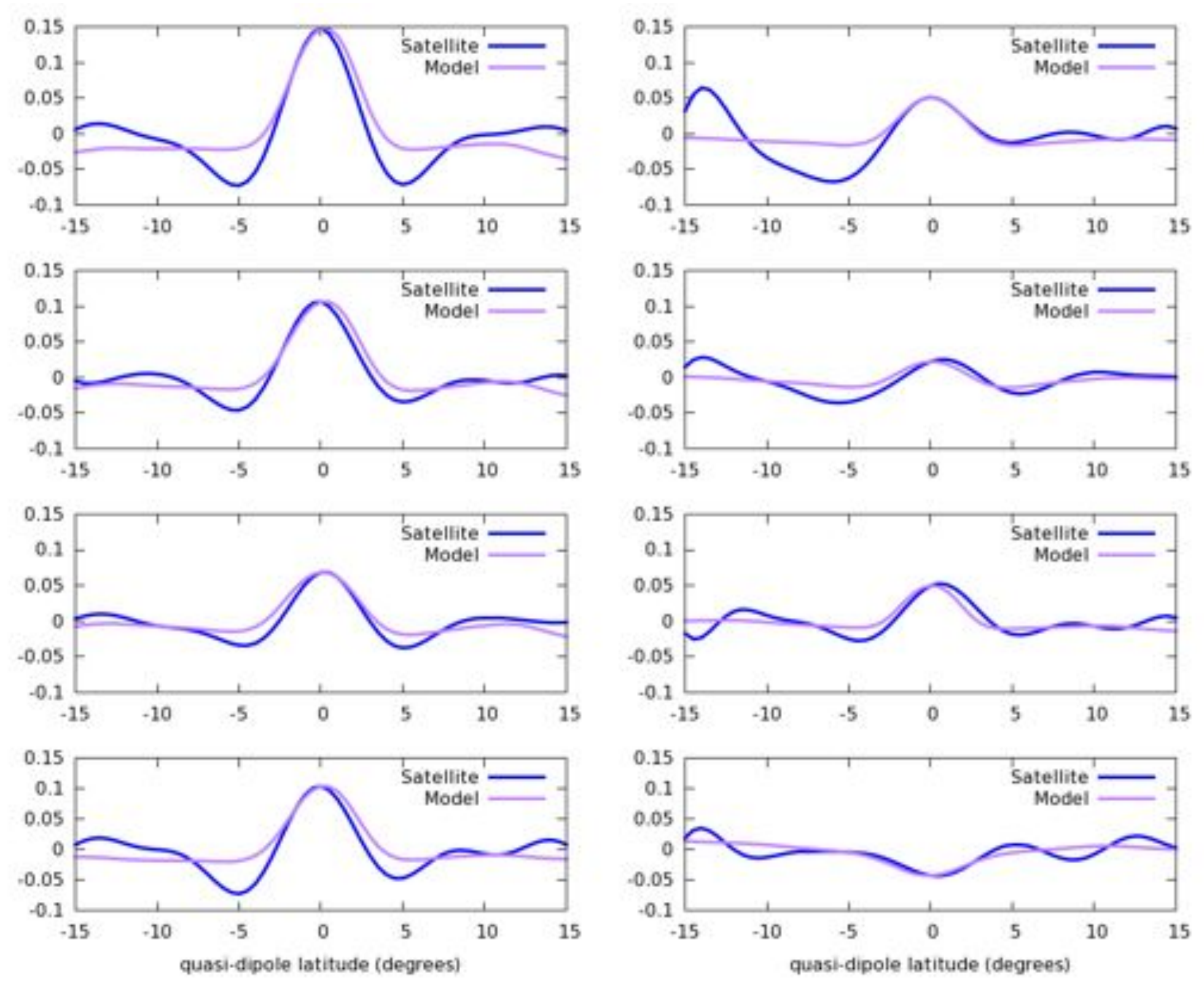
Modeling the Equatorial Electrojet

$$\nabla \times \mathbf{E} = 0$$
$$\mathbf{J} = \underline{\sigma}(\mathbf{E} + \mathbf{u} \times \mathbf{B})$$

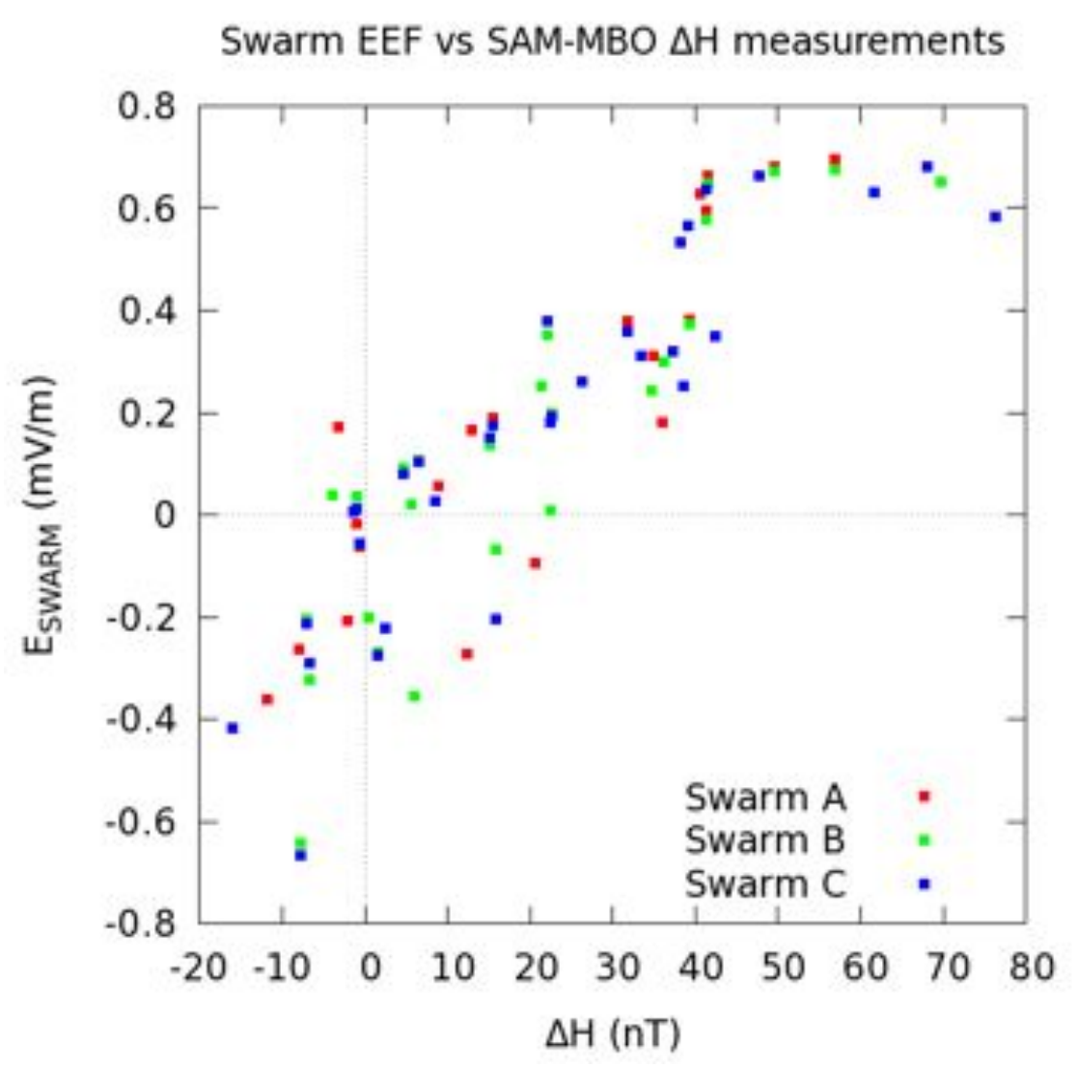


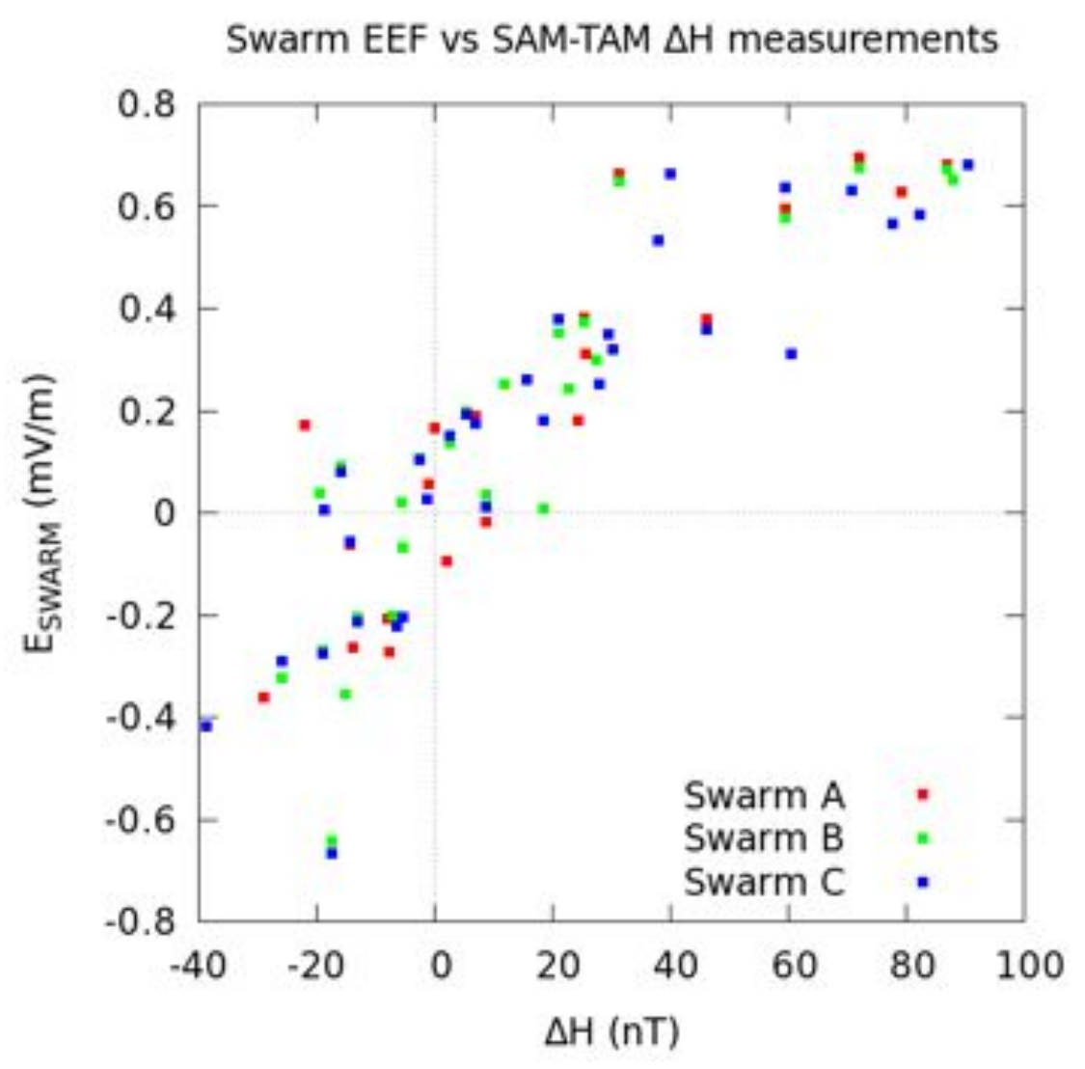
After obtaining the satellite-observed E-region current profile, we then model the EEJ current by solving the governing electrostatic equations, with climatological inputs for the conductivity σ and wind field **u**. The eastward electric field component E_φ is a free parameter in the above equations, chosen to maximize the agreement between the observed and modeled current in a least-squares sense. The equations are solved for each crossing of the magnetic equator on the dayside. A sample of 8 current profiles, measured by Swarm-C in January 2014, with their corresponding model results are shown in the right figure.

Swarm-C profiles during January 2014



Validation

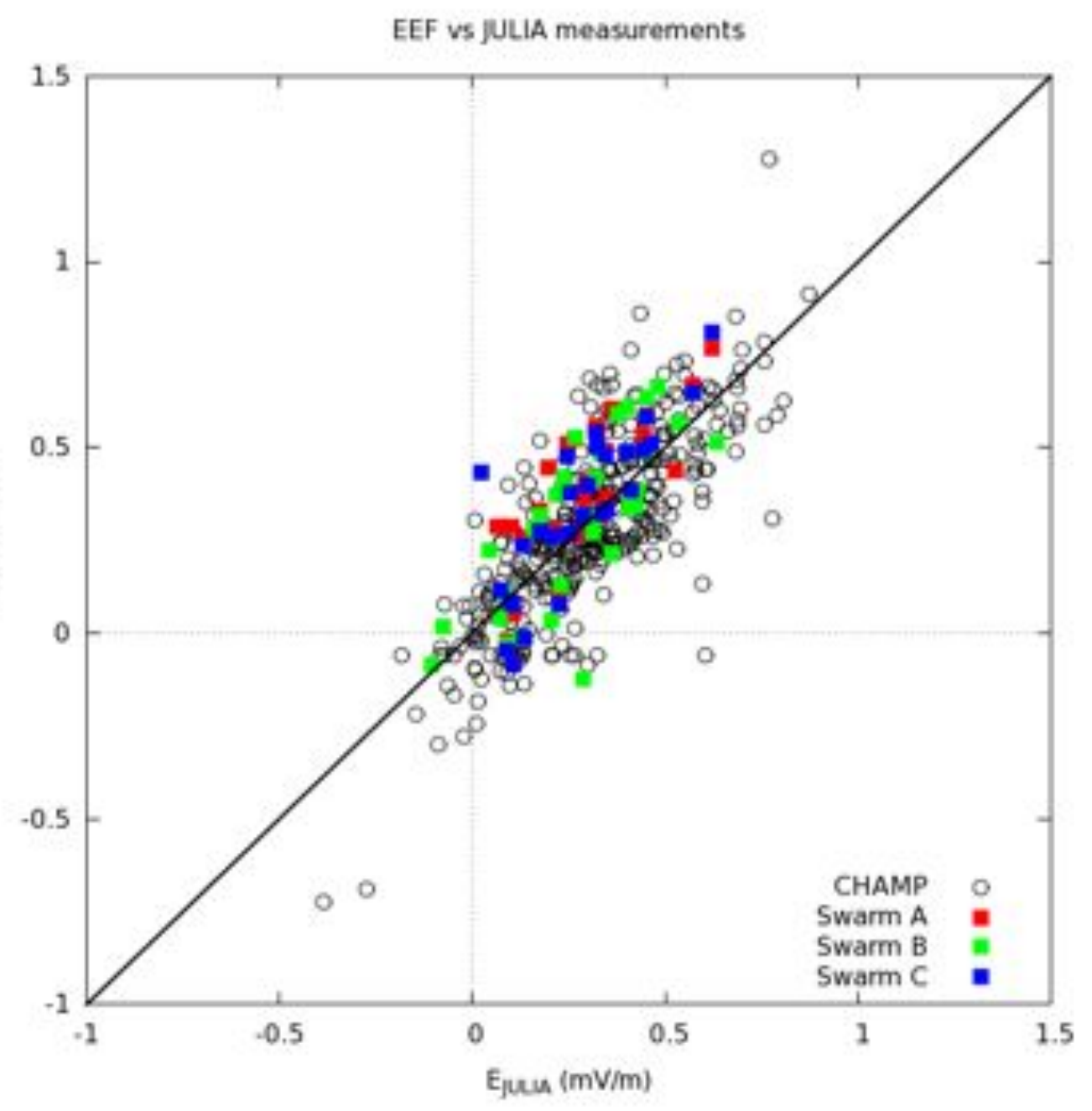




To validate the Swarm electric field chain, first we compare Swarm-derived EEF with ΔH measurements from observatory pairs in West Africa using the WAMNET (West African Magnetometer Network) chain. We find a correlation between the EEF and ΔH of about 80%, indicating the EEF chain is working well in the African sector

Next, we compare the Swarm-derived EEF estimates with measurements from the JULIA (Jicamarca Unattended Long-term Investigations of the Atmosphere) radar near Lima, Peru. JULIA measures vertically drifting plasma irregularities at 150-km altitude, whose vertical drift velocity is proportional to the eastward electric field.

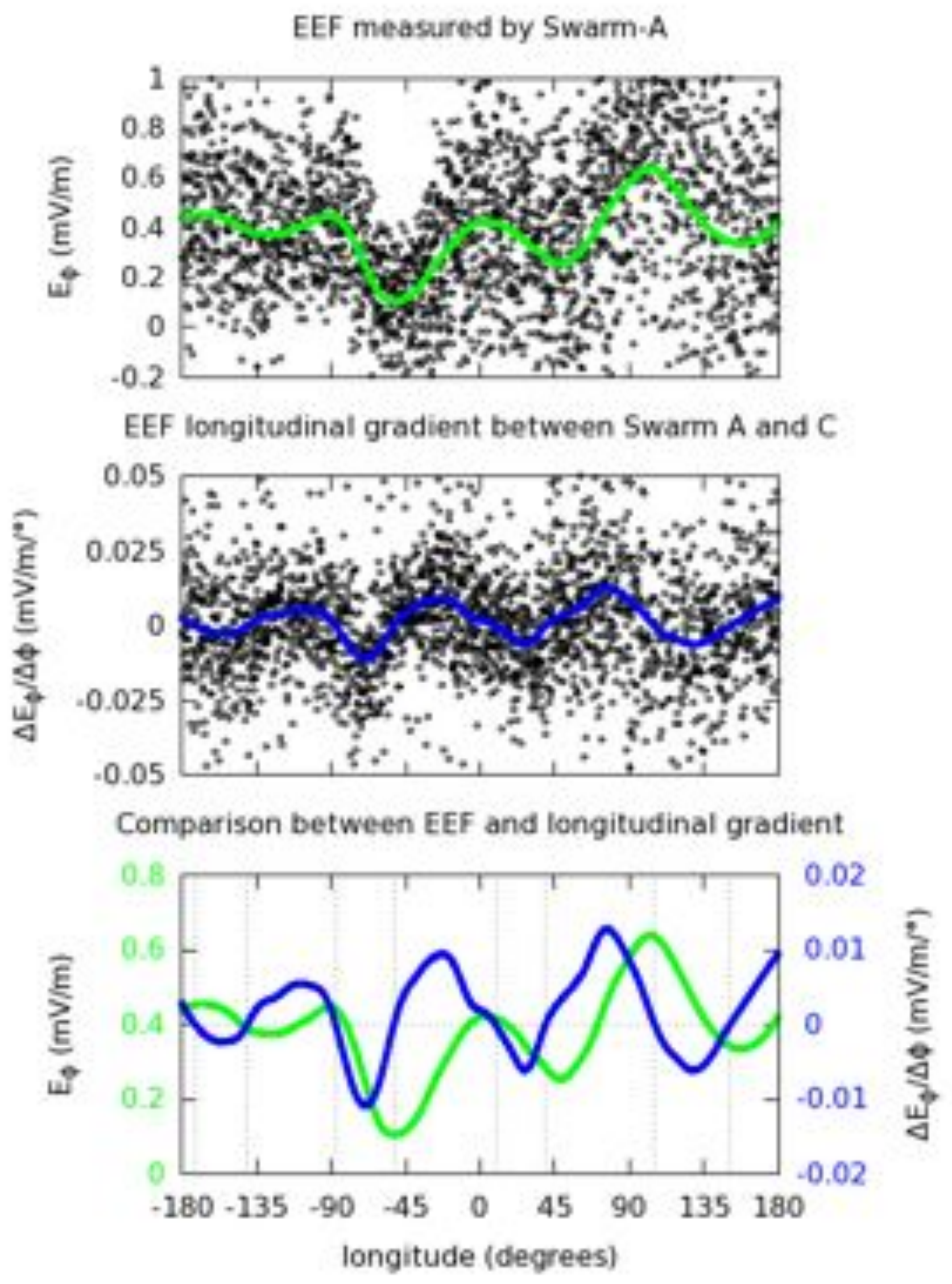
We define simultaneous measurement events as when the satellite flies over JULIA within 10 degrees longitude and within 5 minutes of the JULIA measurement. We find very good agreement between the satellite-derived EEF and JULIA (right).



Satellite	Correlation
CHAMP	0.78
Swarm-A	0.80
Swarm-B	0.75
Swarm-C	0.82
Swarm-All	0.78

Table 1: Correlations of satellite-derived EEF with JULIA measurements

Longitudinal Gradients



We find that the Swarm EEF chain is able to measure east-west gradients in the equatorial electric field using near-simultaneous measurements from the lower satellite pair. While there is not currently enough data to view the full local-time / seasonal behavior of the EEF and its east-west gradient, we find the generally expected longitudinal wave-4 structure due to the neutral tidal winds in the EEF (top). In the middle panel, we plot the gradient between the A and C satellites and again find a wave-4 structure. The bottom panel shows that generally the gradient curve (blue) represents the longitudinal derivative of the EEF curve (green).

SUMMARY

- **Swarm satellite scalar magnetometers are measuring low-noise signatures of the EEJ current on the dayside**
- **Swarm EEF estimates have been validated against ground measurements in 2 longitude sectors**
- **Swarm EEF chain is capable of measuring longitudinal gradients in the EEF**

References:

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