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Birkeland currents associated with Jupiter's auroras

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Abstract

Jupiter's incomparably bright auroras, and the overwhelming influence that this rapidly rotating planet has on its voluminous magnetosphere, led to the expectation that powerful sheets of magnetic field-aligned electric currents (Birkeland currents) would be found in association with the bright auroras that appear over Jupiter's polar regions[1]. We present an extensive analysis of magnetic field perturbations measured during Juno's transits of Jupiter's polar regions, and thereby demonstrate the existence of Birkeland currents associated with Jupiter's auroral emissions. We characterize the magnitude and spatial extent of the currents and we find that they are weaker than anticipated, and filamentary in nature. A significant asymmetry is observed between the field perturbations and the current associated with the northern and the southern auroras.

1. Introduction

Juno is the first mission to the giant planet Jupiter well positioned to explore the polar magnetosphere, sampling Birkeland currents and particle distributions that power the solar system's most spectacular auroras. Subsequent to orbit insertion in July 2016, the Juno spacecraft has maintained a near-polar orbit, passing over both polar regions in close proximity to the planet every $\sim \mathbf{53}$ days, as it continues mapping the planet's magnetic and gravitational fields. From this vantage point Juno's complement of science instruments gathers in-situ observations of magnetospheric particles and fields while its remote sensing infrared and ultraviolet spectrographs and imagers map auroral emissions[2].

2. Jupiter's Birkeland currents

Extended analysis of Juno's magnetic field observations over Jupiter's polar regions has revealed magnetic field perturbations associated with Birkeland currents. The magnetic field perturbations (largely confined to the azimuthal component, δB_ϕ) are obtained from Juno magnetic field vector observations after removing the planetary magnetic field estimates using JRM09 model[3]. The perturbations are found in transit across magnetic field lines mapping to the auroral oval and are compared with contemporaneous images of ultraviolet (UV) emissions[4], with red representing emissions from deeper in the atmosphere and white emissions with less atmospheric absorption (Figure 1). The perturbations

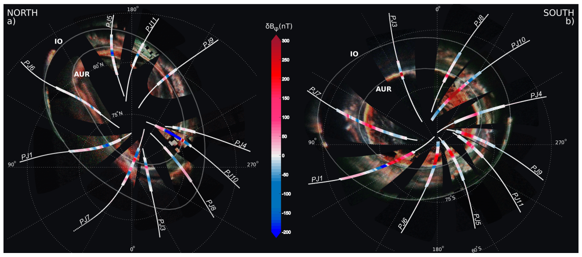

Figure 1: Comparison of observations of magnetic field perturbations (δB_ϕ) associated with Jupiter's auroras with contemporaneous images of ultraviolet (UV) color ratio (depth of emission with red representing the deepest) for each traversal (PJ1 to PJ11) over Jupiter's polar regions.

are highly correlated with the UV auroral emissions with emissions from greater depths associated with more intense magnetic perturbations. A significant asymmetry between the field perturbations associated with the northern and the southern auroras is observed. The southern aurora is associated with stable and consistent regions of mainly negative (equatorward of the main auroral oval) and positive (poleward of the main auroral oval) perturbations whereas the northern aurora is associated with significantly more dispersed and dynamic perturbations with alternating polarities suggesting filamentary structures of the electrical currents. One of the most intense magnetic field perturbations occurred during PJ6 and is described in detail, compared to contemporaneous images of the UV aurora, and modeled assuming i) static semi-infinite current sheets (Figure 2a,b) and ii) spatially confined current sheets responsible for the perturbations (Figure 2c,d). We find, that the model with more spatially confined current sheets (per Figure2c,d) matches the observed trends and magnitudes very well suggesting that the assumption of uniform semi-infinite current sheets is too simple and Juno crossed spatially variable localized currents with a more complex filamentary structure. Based on Juno's observations of magnetic perturbations we calculate the total current flowing into Jupiter's ionosphere and we find a mean total current of 24 MA for the

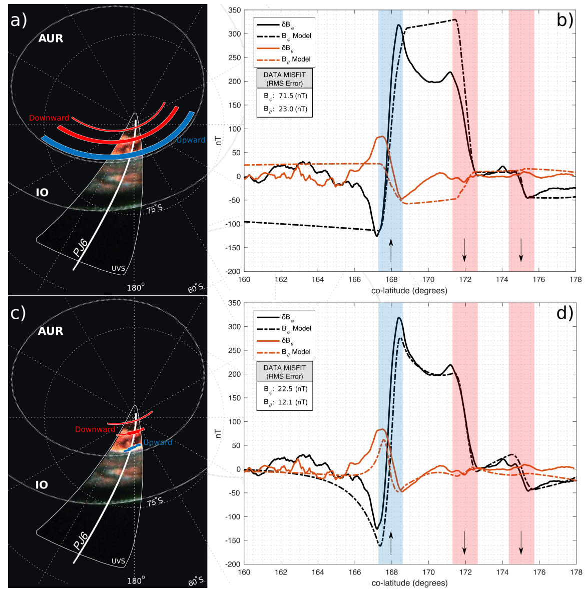

Figure 2: Models of Birkeland currents assuming semi-infinite current sheets (a,b) and longitudinally confined and co-latitudinal dynamic currents (c,d).

north and 58 MA for the south. The exact reason for this asymmetry is under investigation.

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