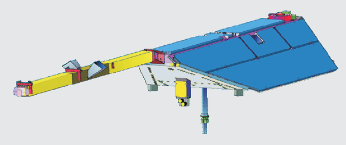
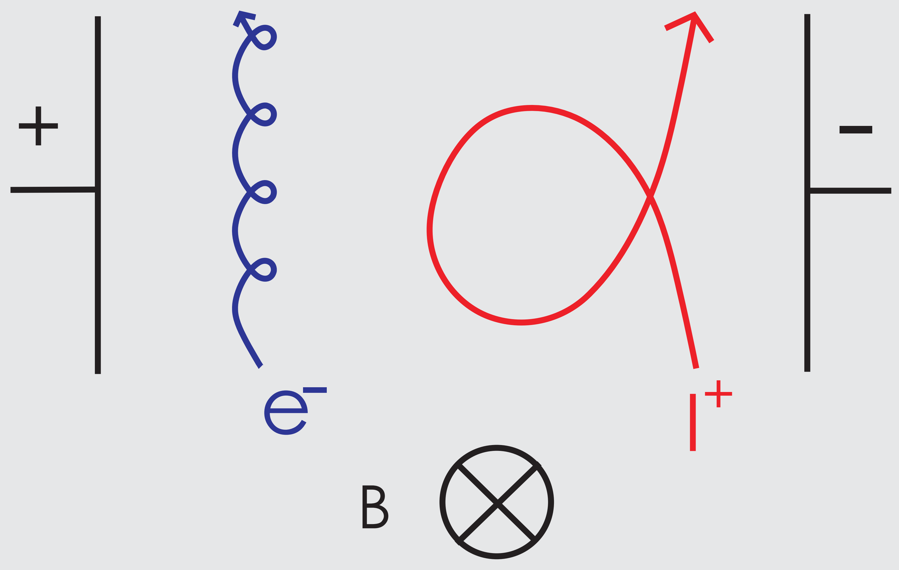
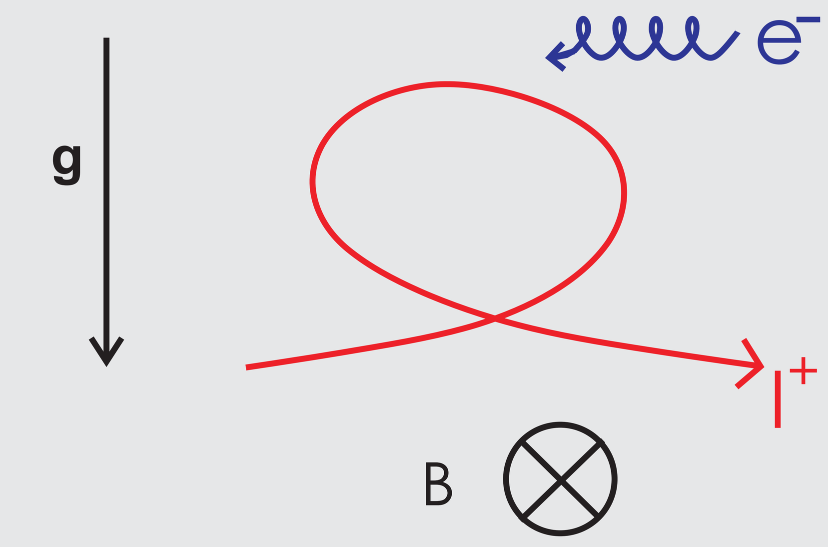


A global gravity-driven electric current system identified in CHAMP satellite magnetic measurements

Stefan Maus and Hermann Lühr



In the upper ionosphere, an electric field applied perpendicular to a magnetic field causes electrons and ions to gyrate around the magnetic field lines and drift into the 3rd direction, perpendicular to the magnetic and the electric field. The gyration is in the opposite sense for electrons and ions, respectively, but they both drift with equal velocity into the same direction, generating no net electric current.



In contrast, if the driving force is a gravity field, electrons and ions still gyrate around the magnetic field lines, but drift into opposite directions, setting up an electric current.

MODEL

The relevant contributions to the current density in the ionosphere are

$$\mathbf{j} = \underline{\sigma}\mathbf{E} + \{n\, m_i\, \mathbf{g} \times \mathbf{B} - k\, \boldsymbol{\nabla}[(T_i + T_e)\, n] \times \mathbf{B}\}\, \frac{1}{B^2} \qquad (1)$$

where $\underline{\sigma}$ is the conductivity tensor, $\mathbf{E}$ is the electric field, n the electron density, m_i the ion mass, $\mathbf{g}$ is the gravitational acceleration, k is the Boltzmann constant, T_e and T_i are the electron and ion temperatures, and $\mathbf{B}$ is the ambient magnetic field with its magnitude B.

1. We assume that the divergent part of the primary gravity-driven current is completely inhibited by an induced electric field. The remaining gravity-driven current is then strictly horizontal, perpendicular to the magnetic field lines, and divergence free.

2 We assume that the magnetic signature of the pressure driven current can then be expressed as a scalar diamagnetic effect, b,

$$b = \frac{nk\mu_0}{B}(T_i + T_e), \qquad (2)$$

which only depends on the local plasma density, ion and electron temperatures and the strength of the ambient magnetic field. The diamagnetic effect, b, represents the local reduction of the magnetic field strength. The corresponding change in the magnetic field vector, $\Delta\mathbf{B}_d$, is then given by

$$\Delta\mathbf{B}_d = b\frac{\mathbf{B}}{B}. \qquad (3)$$

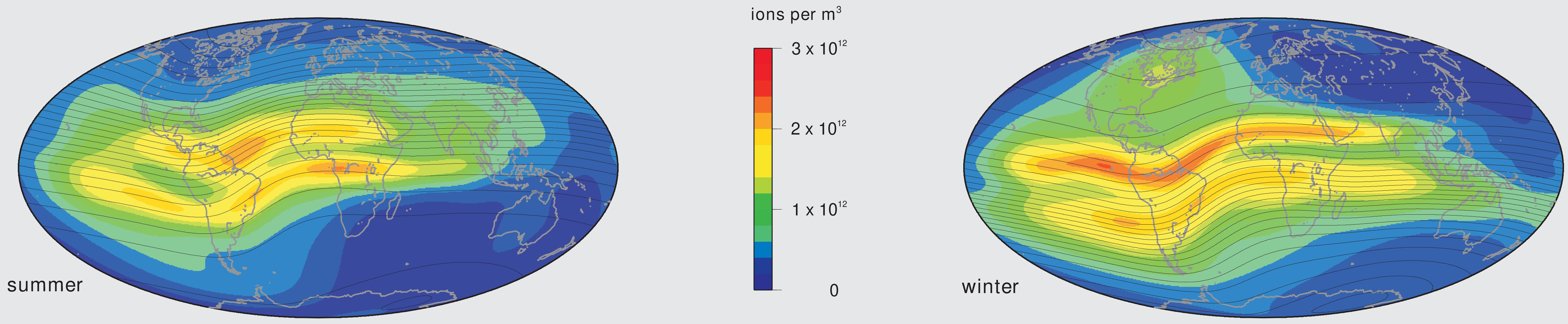


Figure 1. Ion density from the International Reference Ionosphere (IRI) displayed as color maps for a summer (21 June 2000) and a winter day (20 December 2000) for an altitude of 400 km at 18:00 UT. Overlain are the current lines of the nondivergent part of the primary gravity-driven current. A sheet current with a density of 1 mA/m flows eastward between any two neighboring isolines of the stream function.

RESULTS

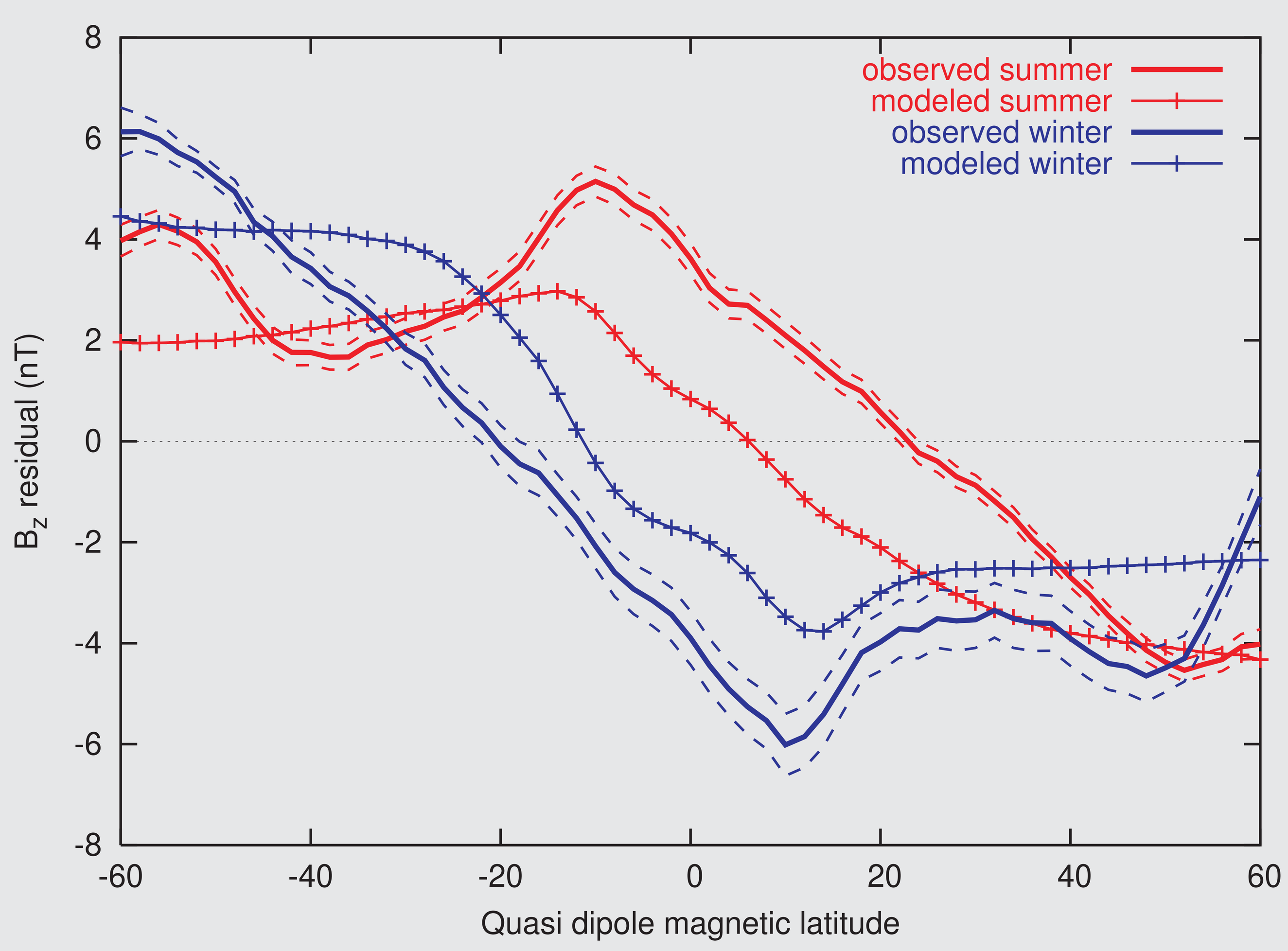


Figure 2. Mean of CHAMP vertical field residuals (positive down) at 20–22 LT, separately averaged for about 600 summer (red) and 700 winter orbits (blue). The standard deviation of the mean is indicated by dashed lines. Also shown are the corresponding predictions of our first order model, including gravity and pressure driven currents. The latter have only a small effect on the vertical magnetic field component, though.

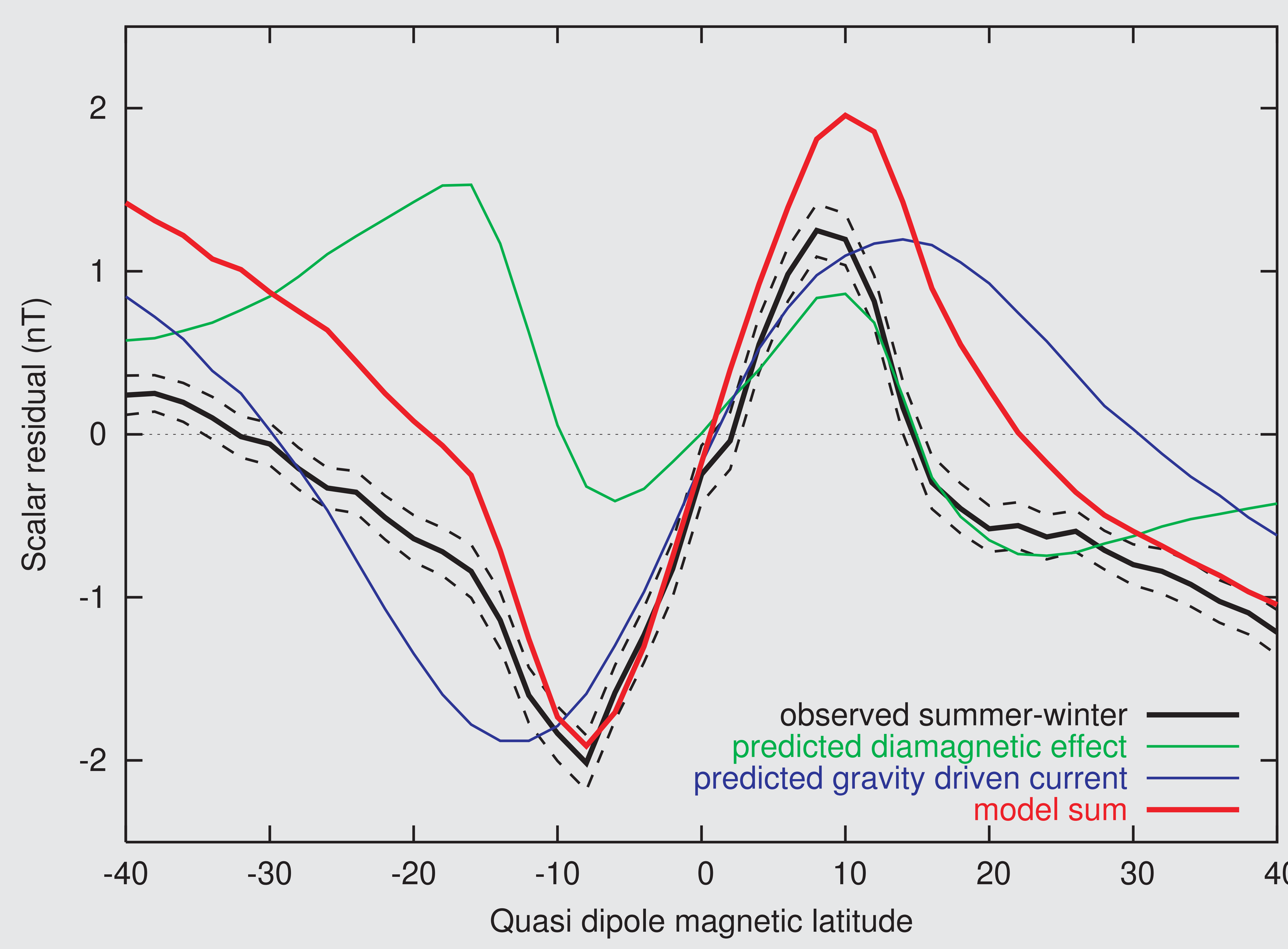


Figure 3. Observed seasonal difference (black) between the means of CHAMP magnetic field intensity residuals at 20–22 LT for the same summer and winter orbits as in Figure 2. The standard deviation of the mean of the observed seasonal difference is indicated by dashed lines. The colored curves show the corresponding predictions from our first-order model for pressure (green) and gravity (blue) driven currents. Both effects contribute significantly to the intensity of the field. The sum of both predictions (red) is in good agreement with the observed seasonal variation (black).

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