Interpretation of Ground-Based Magnetometer Measurements During Enhanced Auroral Activity

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Overview

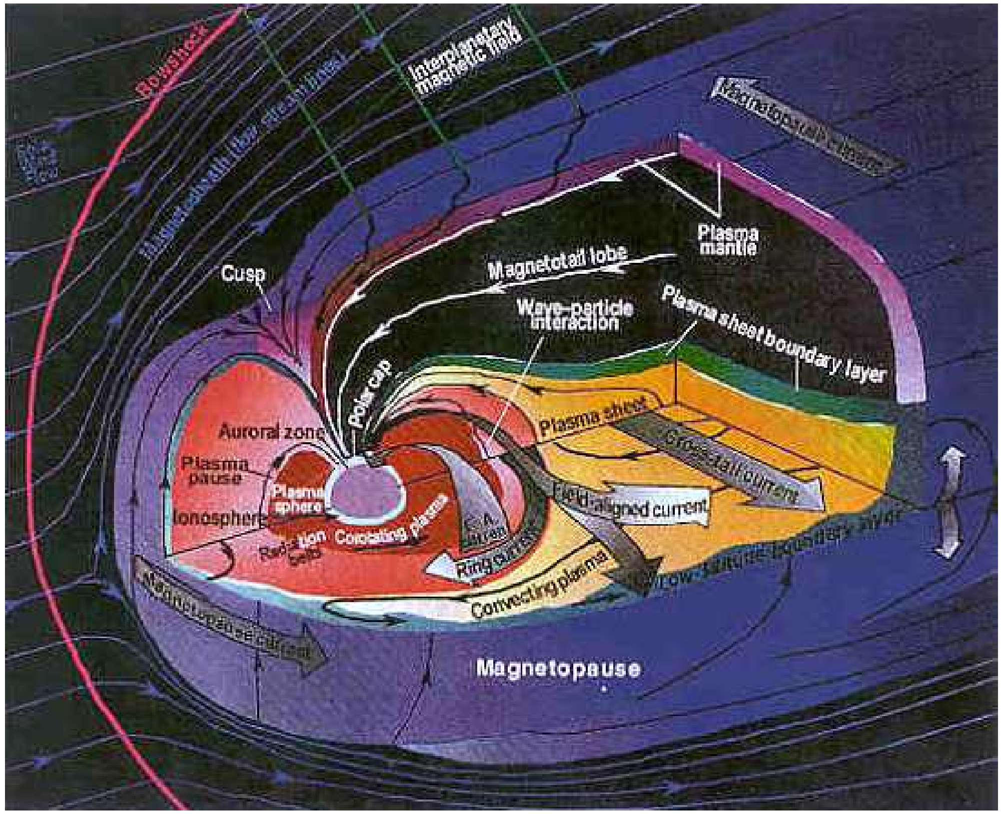
In the current project:

A systematic analysis of the response of the ground-based magnetic field to changes in the parameters of various two current systems was conducted.

For several periods of enhanced auroral activity, the model parameters that provide the *best* representation of the observations were determined by inspection

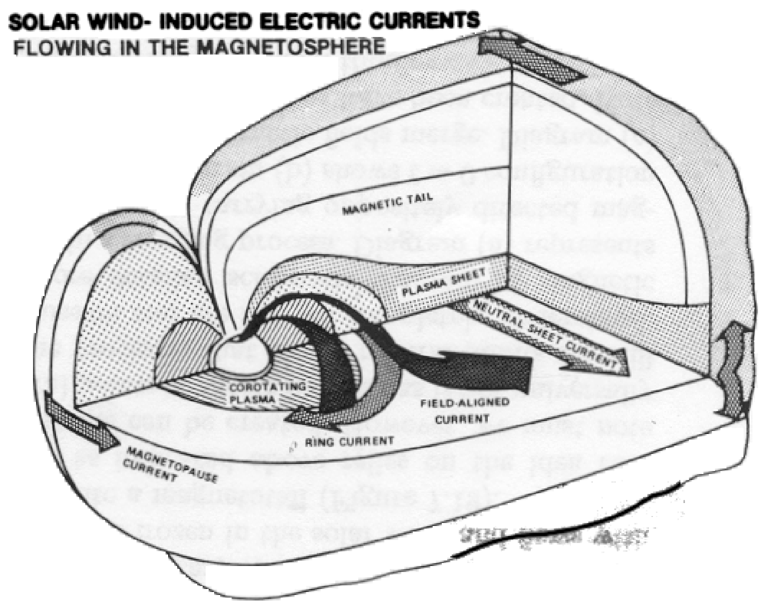
Through the application of Ampere's Law, the model current is used to calculate the distribution of current at approximately 110 km altitude (the altitude at which current flows in the ionosphere). This current distribution is interpreted in the context of UV images from NASA's Polar satellite

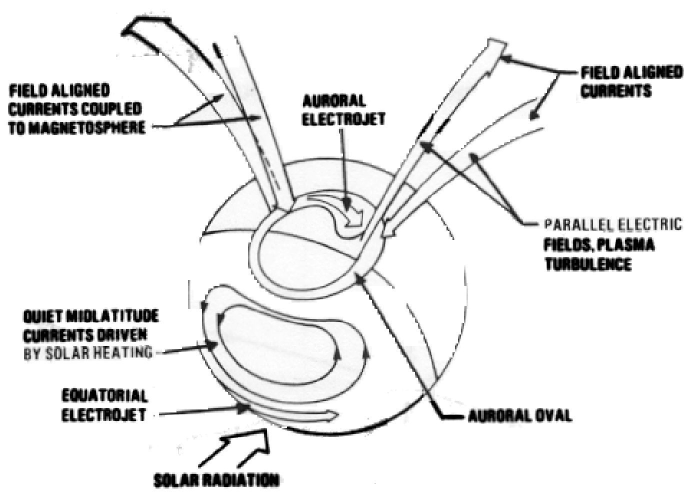
The Terrestial Magnetosphere



A continuous radial flow of plasma known as the soar wind emanates from the Sun. The interaction of the solar wind with the terrestrial magnetic field results in the formation of the magnetosphere (shown above). The Earth resides deep within this protective cavity, which is compressed on the dayside and has an elongated tail on the nightside. In general, the flow of energy proceeds from the solar wind through the magnetospheric boundary to lower altitudes with much of this energy being deposited into the high-latitude ionosphere located approximately 100 km above the Earth.

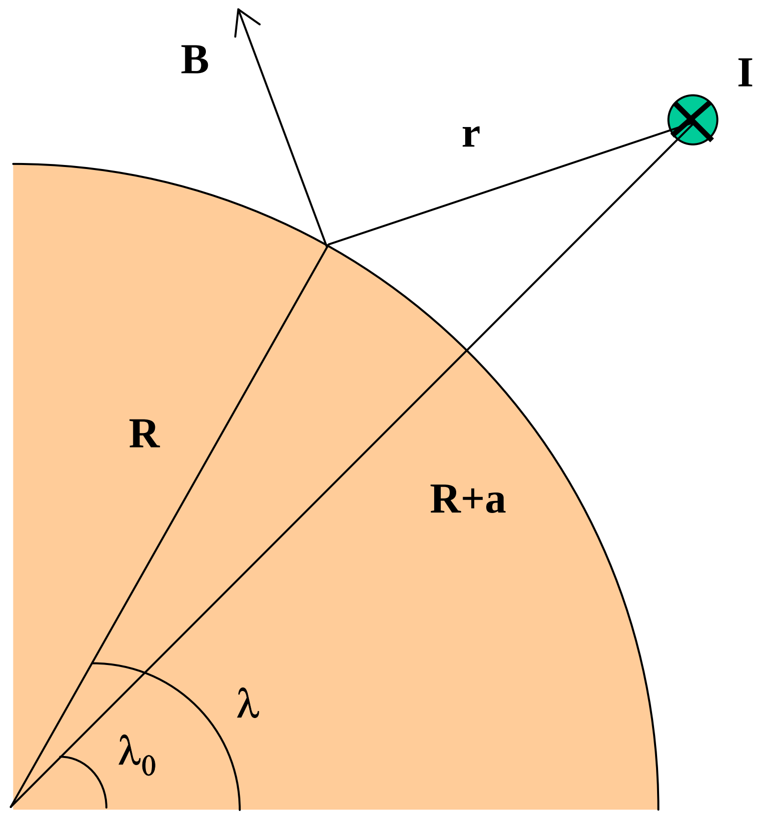
Currents in the Ionosphere and Magnetosphere





Associated with this transfer of energy are electric currents which flow within the magnetosphere (e.g., the tail and ring currents) and along the converging terrestrial magnetic field lines (field-aligned or Birkeland currents). The field-aligned currents close within the high-latitude ionosphere thus coupling the vast regions of the distant magnetosphere to the upper-atmosphere.

Schematic of Model Line Current

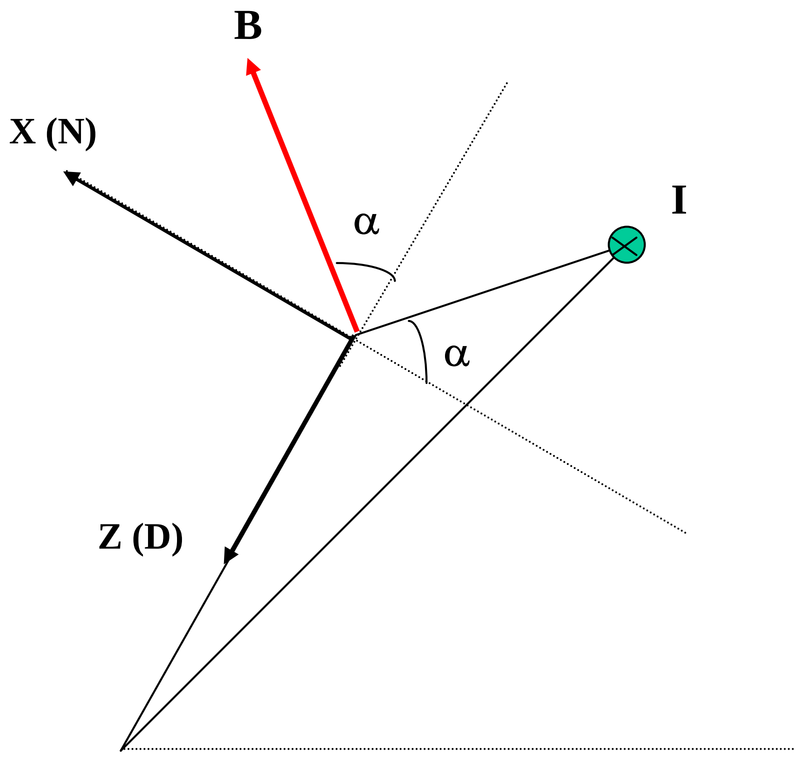


We consider the magnetic perturbation produced at the surface of the Earth by a model infinite line current of strength, I, located at an altitude, a, and latitude, λ_0. The line current is parallel to longitude and is closest to the Earth at the meridian where we wish to evaluate the magnetic field. The strength of the magnetic field produced by the line current is given by:

$$B = \mu_0 I / (2 \pi r)$$

where $r = (R^2 + (R+a)^2 – 2 R (R+a) \cos(\lambda-\lambda_0))^{1/2}$

Magnetic Field Components in Local Coordinate System



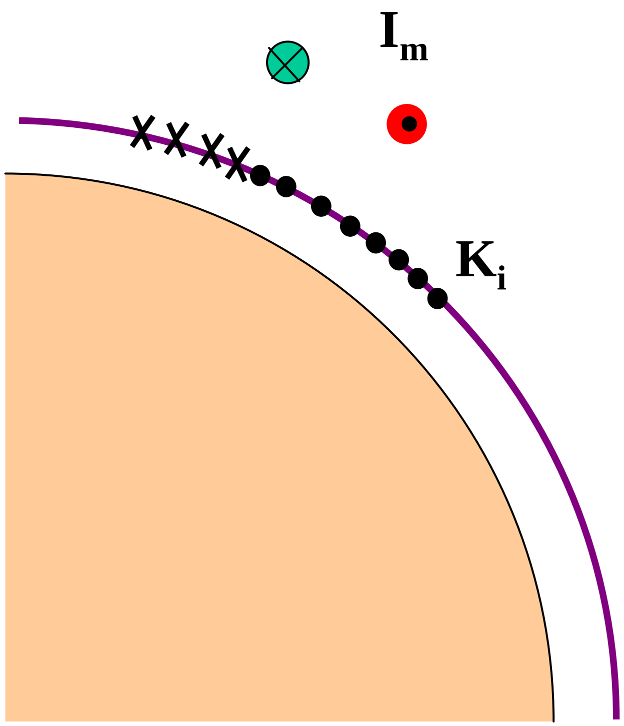
The direction of the magnetic field produced by the line current is such that it encircles the current. We determine the components of the magnetic field, **B,** in the local coordinate system (e.g., x is positive to the North, y is positive to the East, and z is in the downward direction).

$$\alpha = (\pi/180) * \sin^{-1}(((R+a)/r) \sin(\lambda-\lambda_0)) + 90$$

$$B_x = B \sin(\alpha)$$

$$B_z = - B \cos(\alpha)$$

Deriving Ionospheric Current from Model Current



At 110 km altitude: $\mathbf{K} = K_y\,\mathbf{j}$

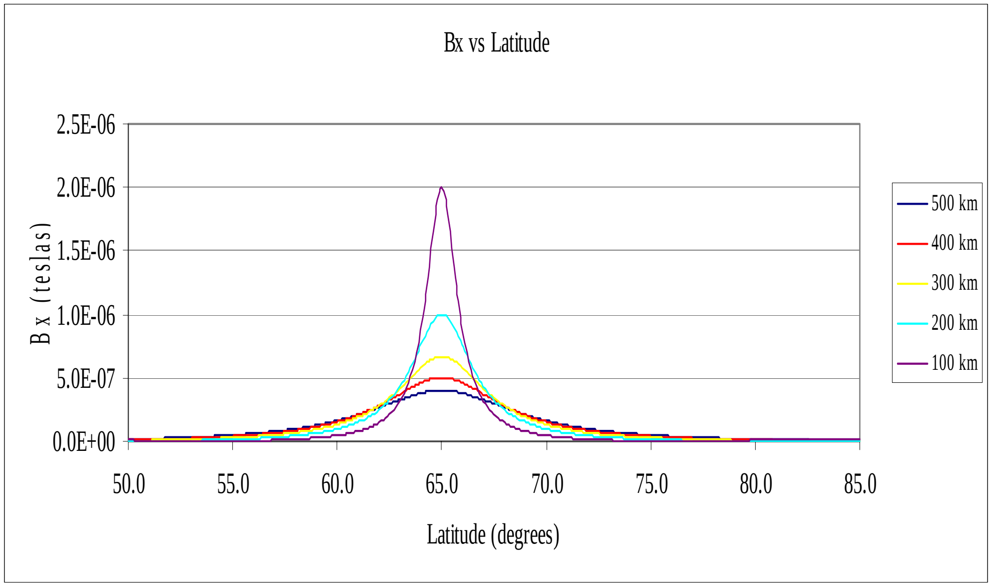
$$\oint \vec{B} \bullet d\vec{l} = \mu_0 I_{enclosed}$$

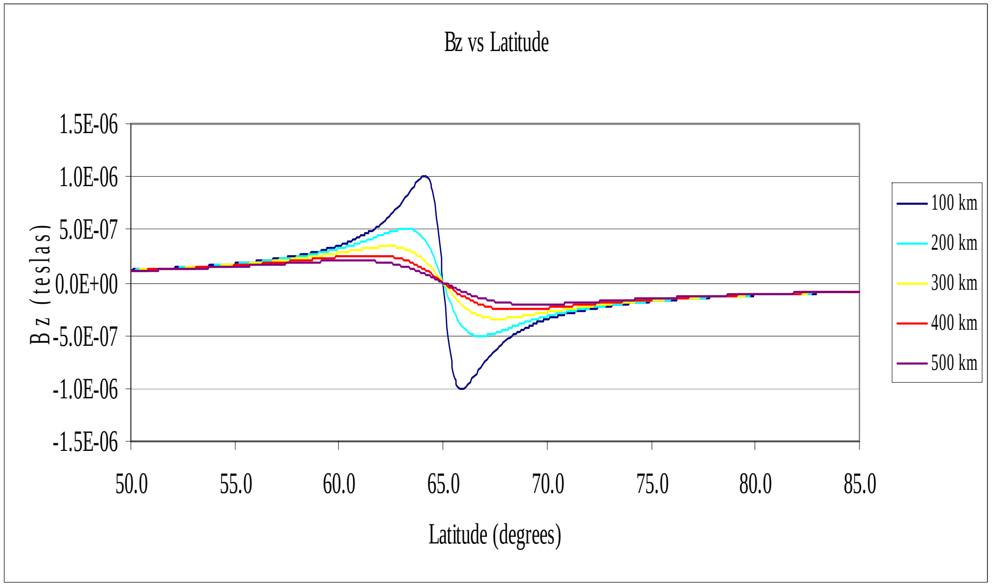
$$\oint \vec{B} \bullet d\vec{l} = \mu_0 K_y l$$

$$K_y = \frac{2B_x}{\mu_0}$$

The line currents that provide the best representation of the data may be at altitudes significantly above the region where the current flow is a maximum (~110 km). To determine the actual current distribution: 1) The magnetic field produced by the model current system at 110 km is calculated. 2) Using Ampere's Law and the magnetic field determined in part 1, the current density may be determined.

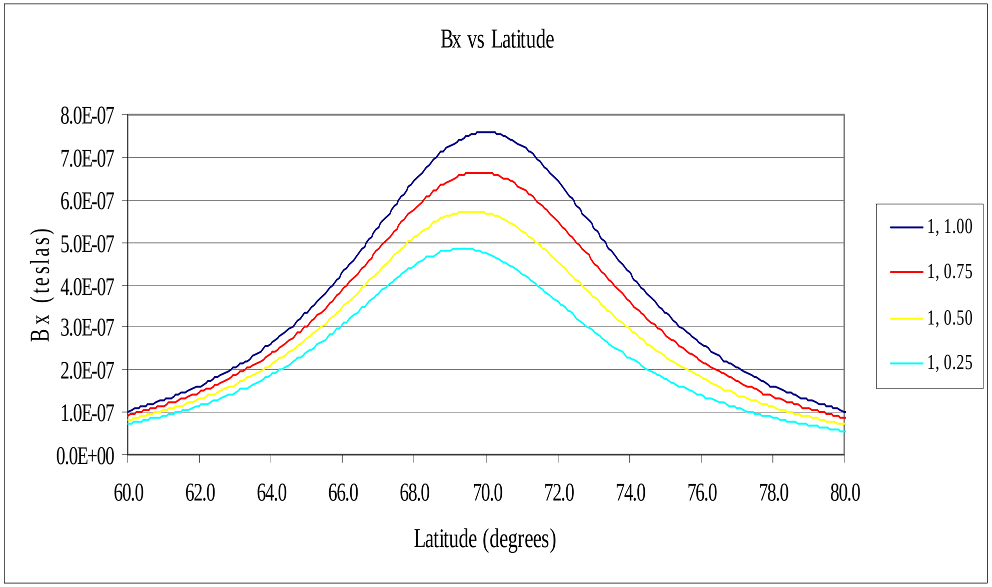
Single Line Current Model: Dependence of B_x and B_z Profiles on Altitude

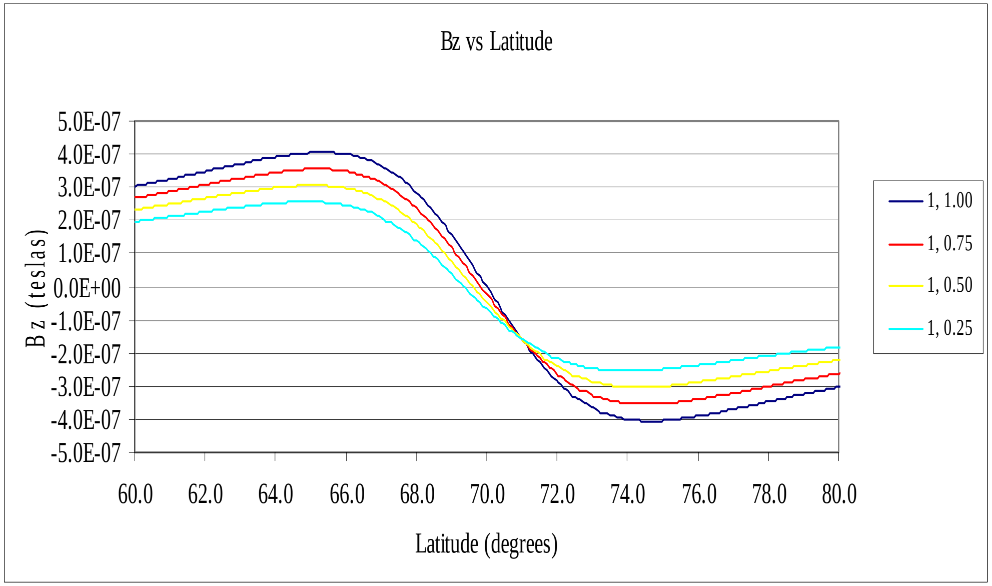




The latitude profiles of the x and z components of the magnetic field produced by a single line current are shown for various altitudes. The signatures clearly broaden with increasing altitude. Thus the altitude of the model current may be adjusted to represent different scale lengths of structures observed in the magnetic latitude profiles.

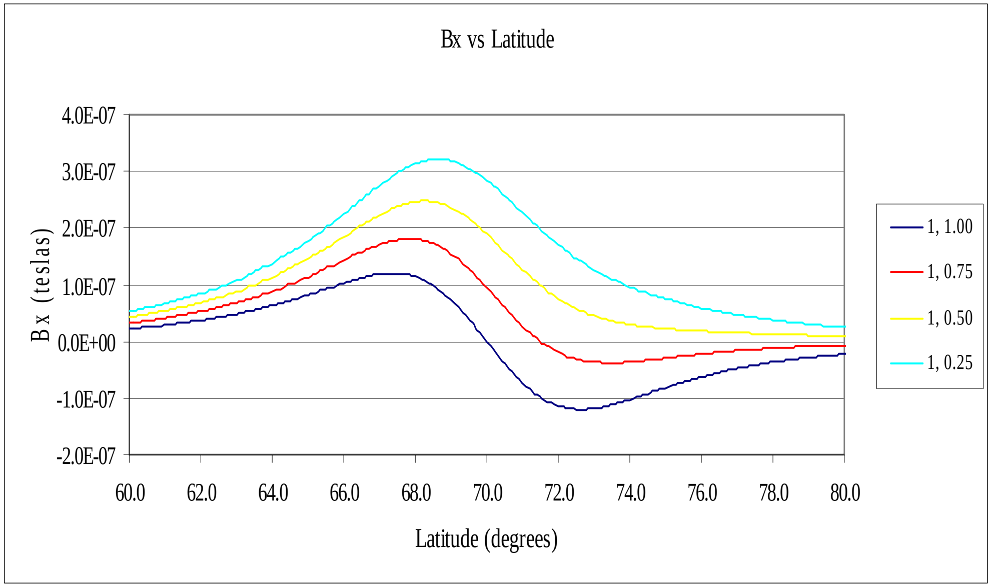
B_x and B_z Profiles for Two Parallel Line Currents of Varying Relative Strength

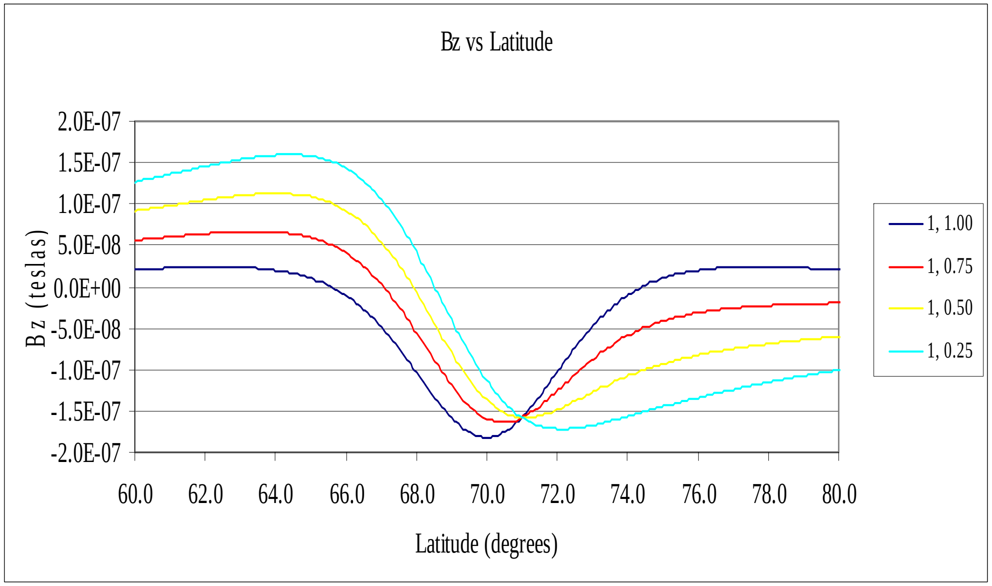




For a system of two currents, we investigate the effects of varying the relative strength between the currents while holding the other parameters constant. Each current flows eastward at an altitude of 500 kilometers. One current occurs at a latitude of 69 degrees, the other occurs at 71 degrees. The strength of both currents is measured in MegaAmps and indicated in the legend. The equatorward current is held constant while the strength of the poleward current is systematically decreased.

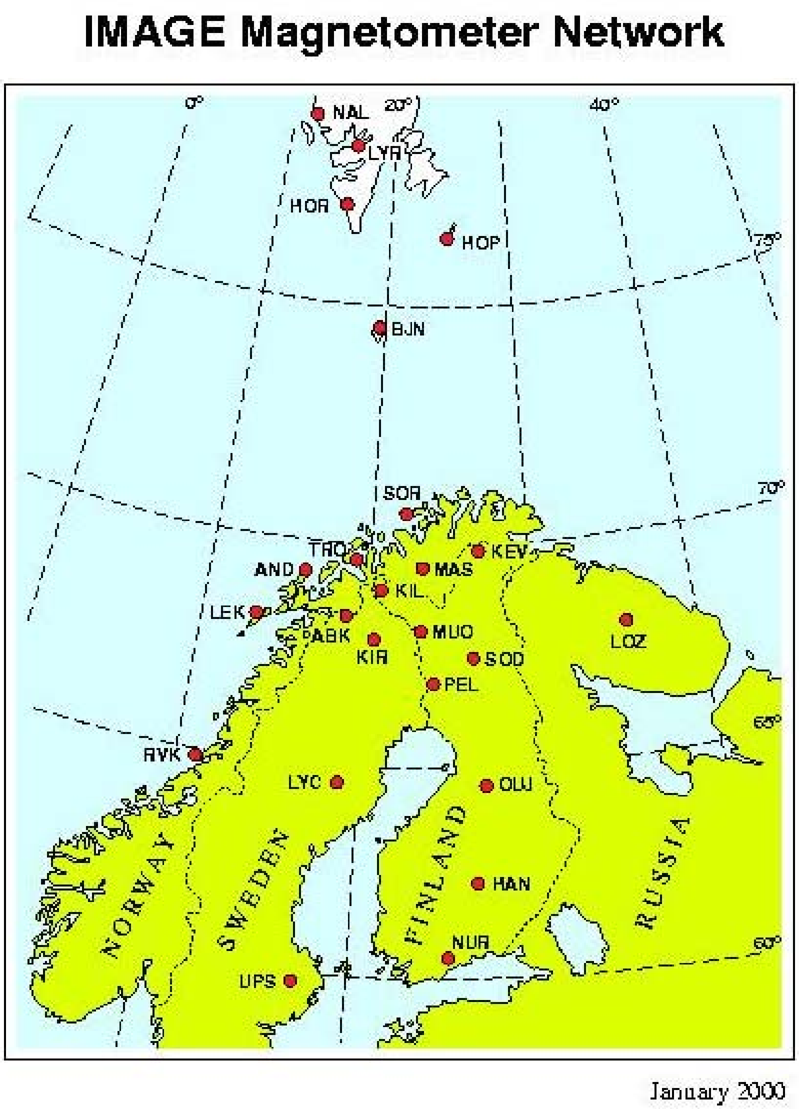
B_x and B_z Profiles for Two Oppositely Directed Line Currents of Varying Relative Strength





For a system of two currents, we investigate the effects of varying the relative strength between the currents while holding the other parameters constant. Each current is located at an altitude of 500 kilometers. One current occurs at a latitude of 69 degrees and is directed eastward, the other occurs at 71 degrees and is directed westward. The strength of both currents is measured in MegaAmps and indicated in the legend. The equatorward current is held constant while the strength of the poleward current is systematically decreased.

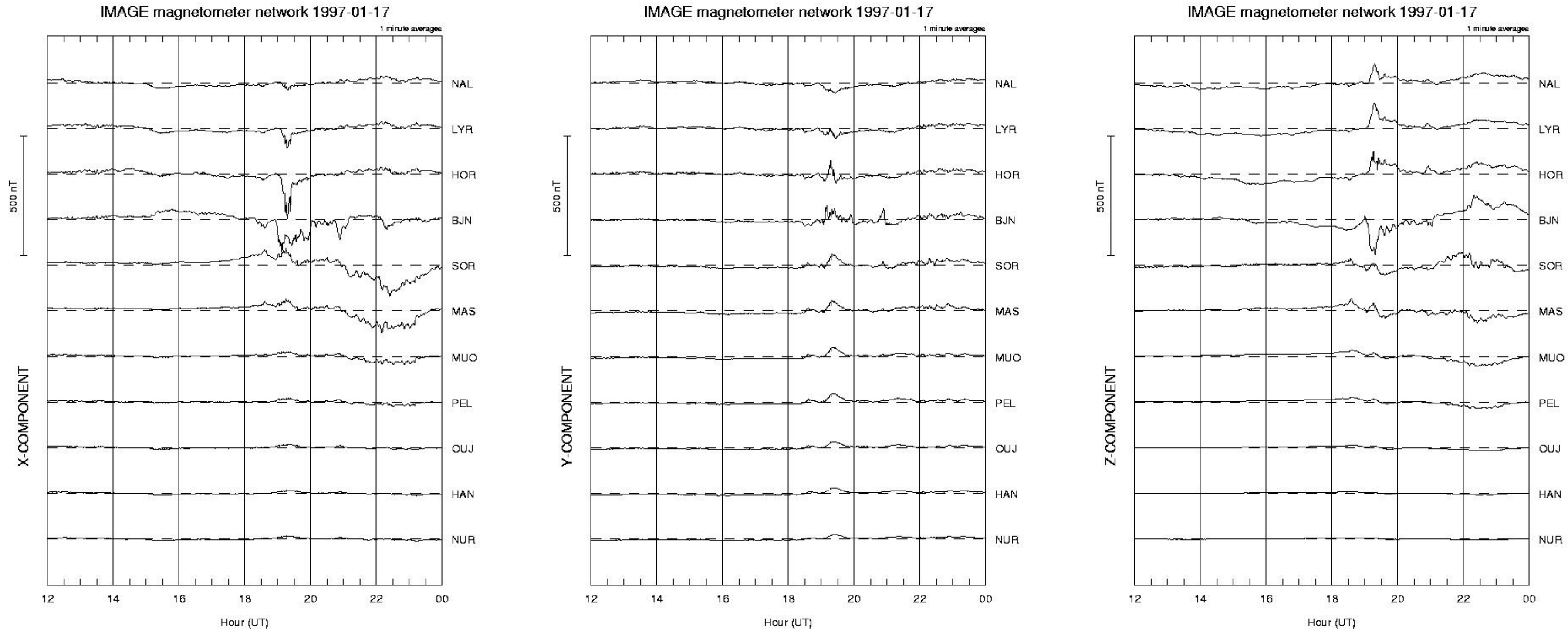
IMAGE Magnetic Observatories



Location of magnetic observatories comprising the IMAGE magnetometer network. Each station provides continuous measurements of the three components of the magnetic field at the surface of the Earth. We will use data obtained from stations that run approximately along a line from NAL to NUR.

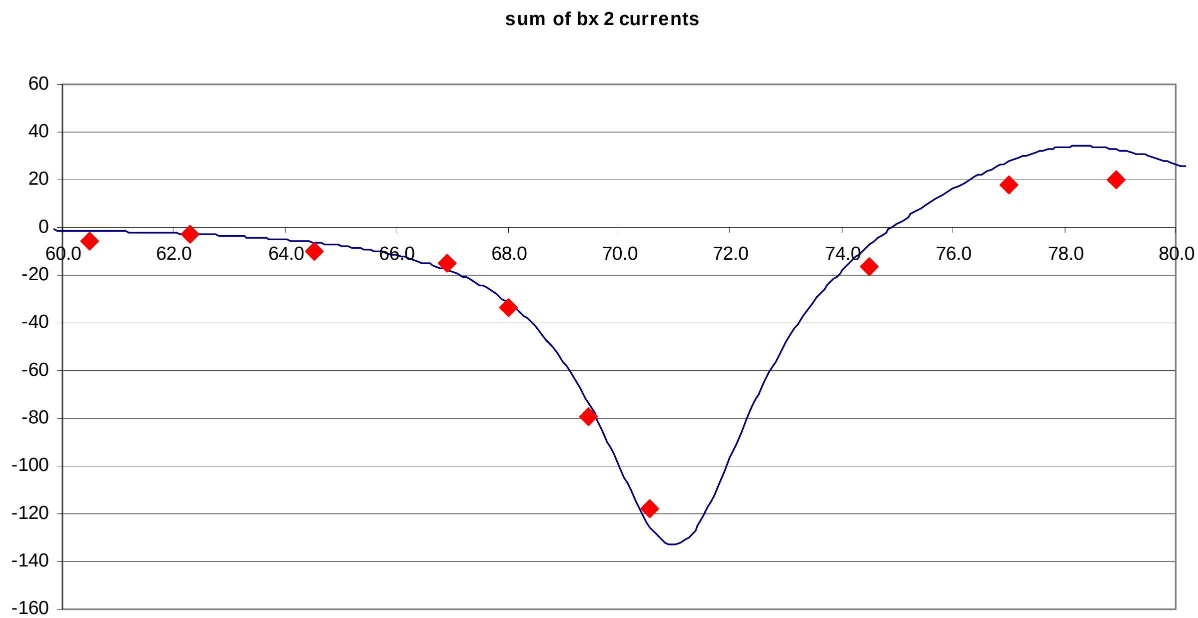
We would like to acknowledge the institutions participating in IMAGE for making this data available (http://www.geo.fmi.fi:80/image).

Magnetic Field Observations: 17 January 1997

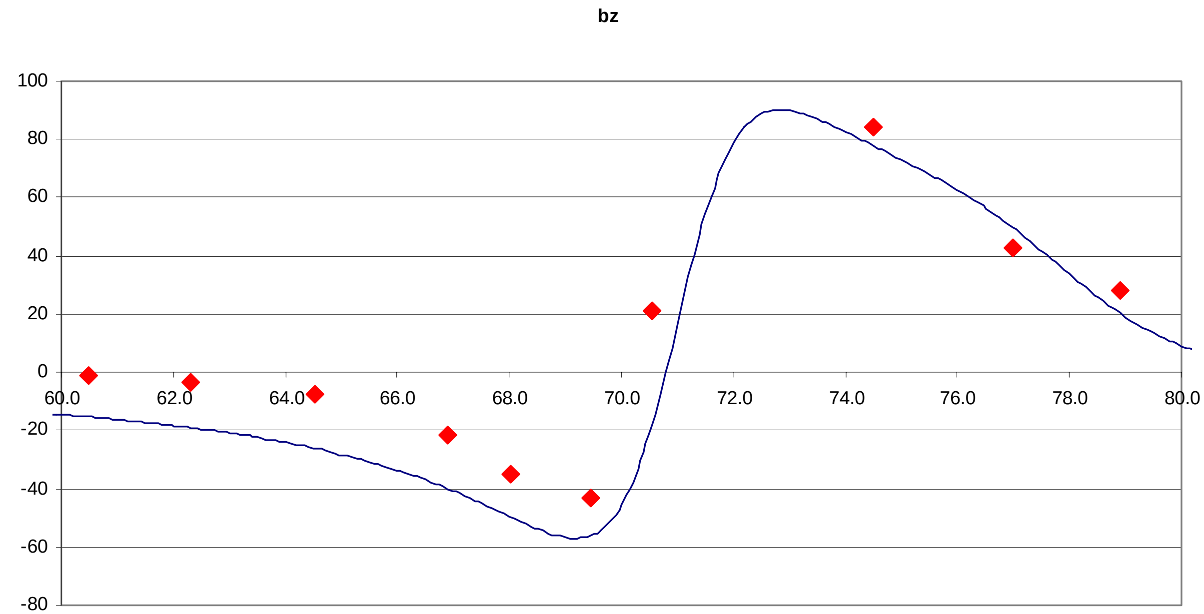


Magnetograms for 17 January 1997 12 to 24 UT. The North (left), East (middle), and Down (right) components of the magnetic field are shown as a function of time for 11 stations running from NAL at the northern extreme (top) to NUR at the southern extreme.

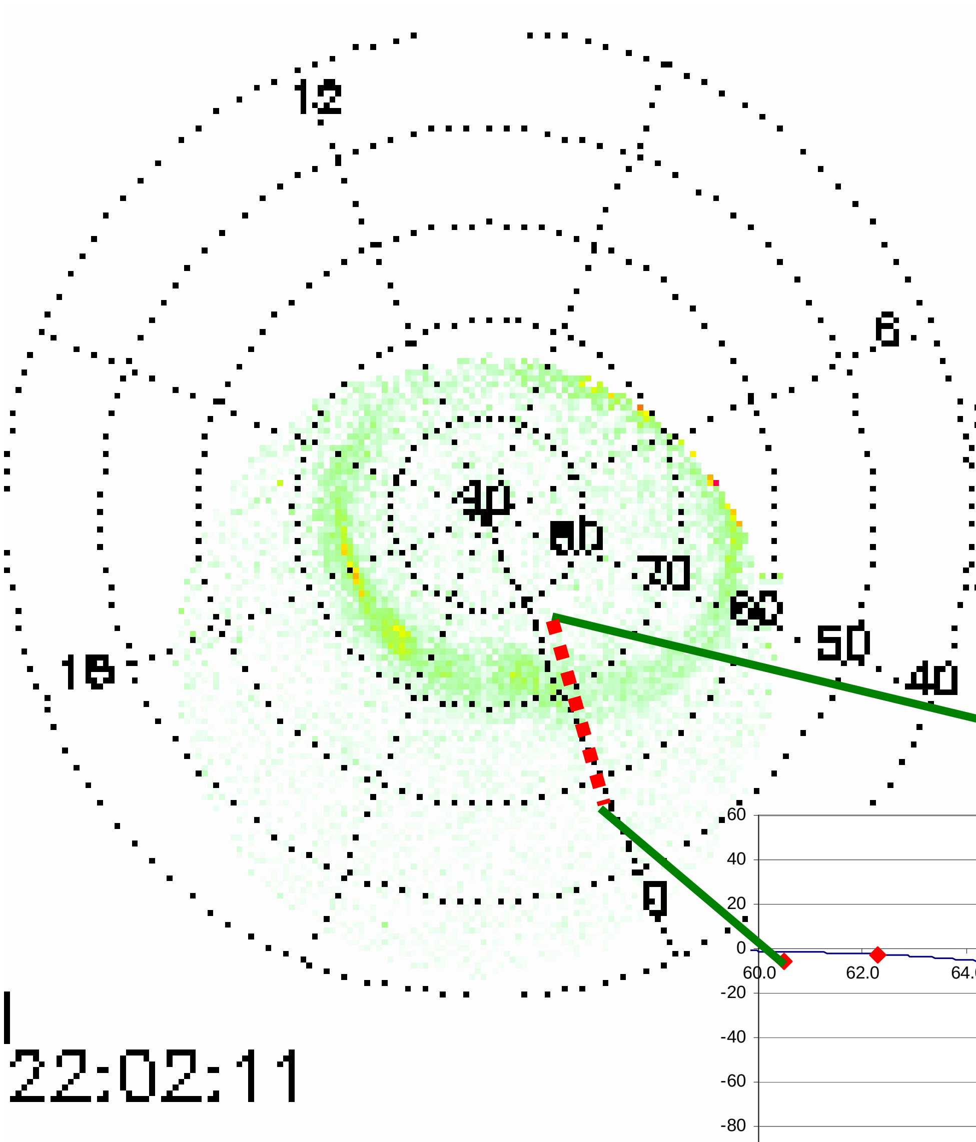
B_x



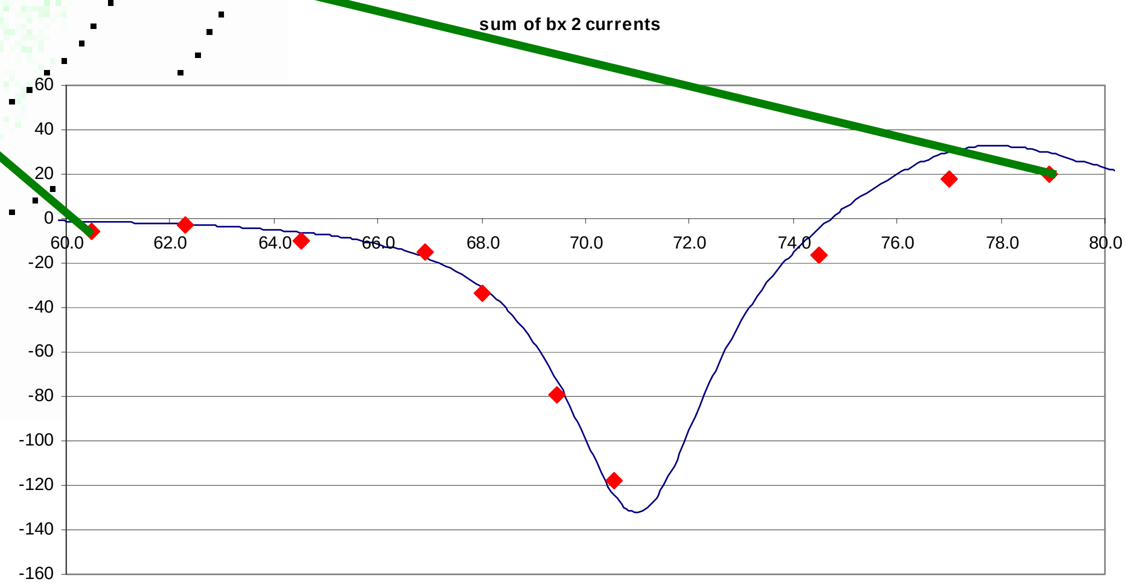
B_z



A comparison of our model to ground-based magnetometer data recorded on January 17th, 1997. Red points are data points and the blue line is the model's prediction.



Comparison of Simultaneous Observations of Ground-Based Magnetic Perturbation and Auroral Emissions 17 January 1997 ~22:02 UT



Summary

Ground-based magnetic field measurements from the Scandinavian Peninsula are interpreted in terms of a simple model of horizontal ionospheric currents.

Magnetic field signatures are compared to satellite observations of auroral emissions.

Future Work

- **Magnetic field and auroral emissions will be examined for several additional cases.**
- **Comparison of magnetic and auroral signatures in time will be used to infer a relationship between auroral enhancements and excited current systems.**
- **The current distribution at ionospheric altitude will be determined from the model current and compared to auroral emissions.**