British Geological Survey
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GEOSPACE

# Spherical Elementary Current representation of ionospheric equivalent currents: results from a test model.


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**The auroral electrojet, and associated current systems are an important source of the magnetic field observed on the ground, and in space. In main magnetic field modelling we'd like to minimise the influence of such non-uniform current systems. This is usually done using careful data-selection based on indices. Ionospheric equivalent currents derived independently from the ground and the CHAMP satellite have been shown to be in good agreement (Ritter et al. 2004). This offers the possibility of a non-index based data selection technique e.g. by estimating the ionospheric current density as a function of time and space using ground based observatory data, and then selecting suitable time intervals for modelling. We present the results of our implementation of fitting Spherical Elementary Current Systems (SECS) to a model of the auroral electrojet based on a simple line-current.**

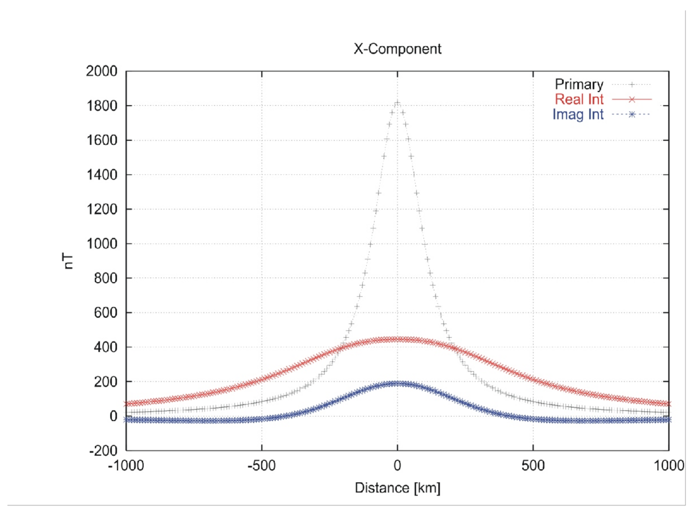

## 1. Spherical Elementary Current Systems (SECS)

SECS can be used to estimate ionospheric equivalent currents from the magnetic field (e.g. Amm & Viljanen, 1999; Ritter *et al.* 2004). We use divergence free SECS for the ground-based magnetic field (e.g. Pulkkinen, 2003). The pole of a SECS is placed at each node in a grid (which need not be regular) covering the region of interest. The SECS are linearly related to the magnetic field ($\underline{B}$) via a set of scaling factors ($\underline{I}$, the amplitude of a current element), viz.

$$\underline{B} = \underline{IT}$$

The matrix $\underline{T}$ contains the geometric relation between the elementary currents and the ground magnetic field. The linear inverse problem (determining $\underline{I}$) is usually under-determined as there are more current elements than there are measurements. Therefore, we employ Singular Value Decomposition to determine the unknown scaling factors.

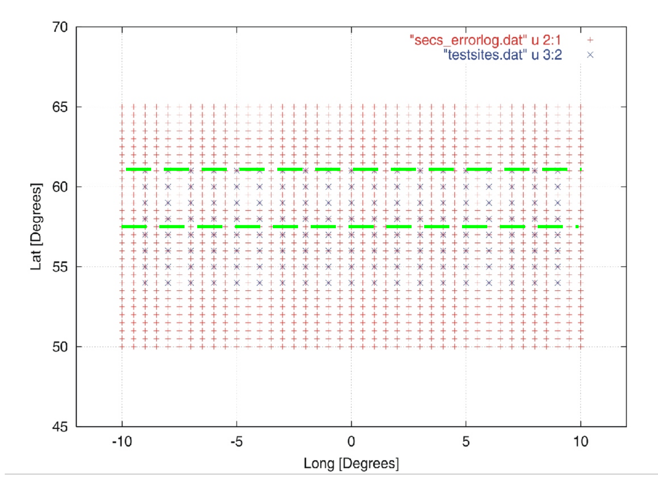
## 2. Line Current Test Model

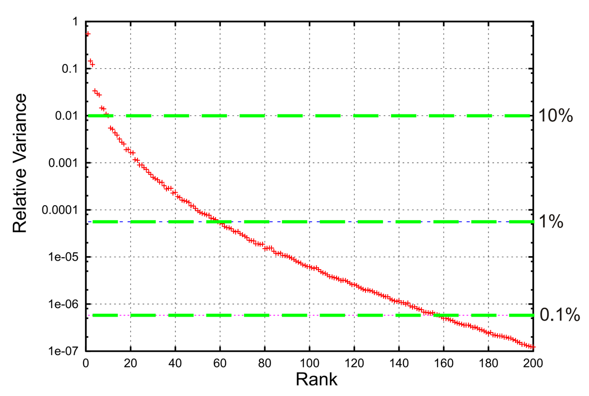



We model the auroral electrojet using a line current.

**Left:** the *X* (North) component of the ground magnetic field with distance from the electrojet centre is shown. Both the primary external field (black crosses) and the real (red stars) and imaginary parts (blue stars) of the secondary internal field calculated using the Complex Image Method (e.g. Boteler & Pirjola, 1998) using a resistive Earth model are shown.

**Right**: The test grid comprises a set of 1271 elementary current systems, placed at a height of 110 km in a regular grid (-10º to 10ºE, 50º to 65ºN; red crosses), with a grid spacing of 0.5º. Amplitudes of the current elements were determined using all components of the magnetic field at the 152 'model' measurement sites (blue stars). The green dashed line shows the two electrojet locations we will consider.



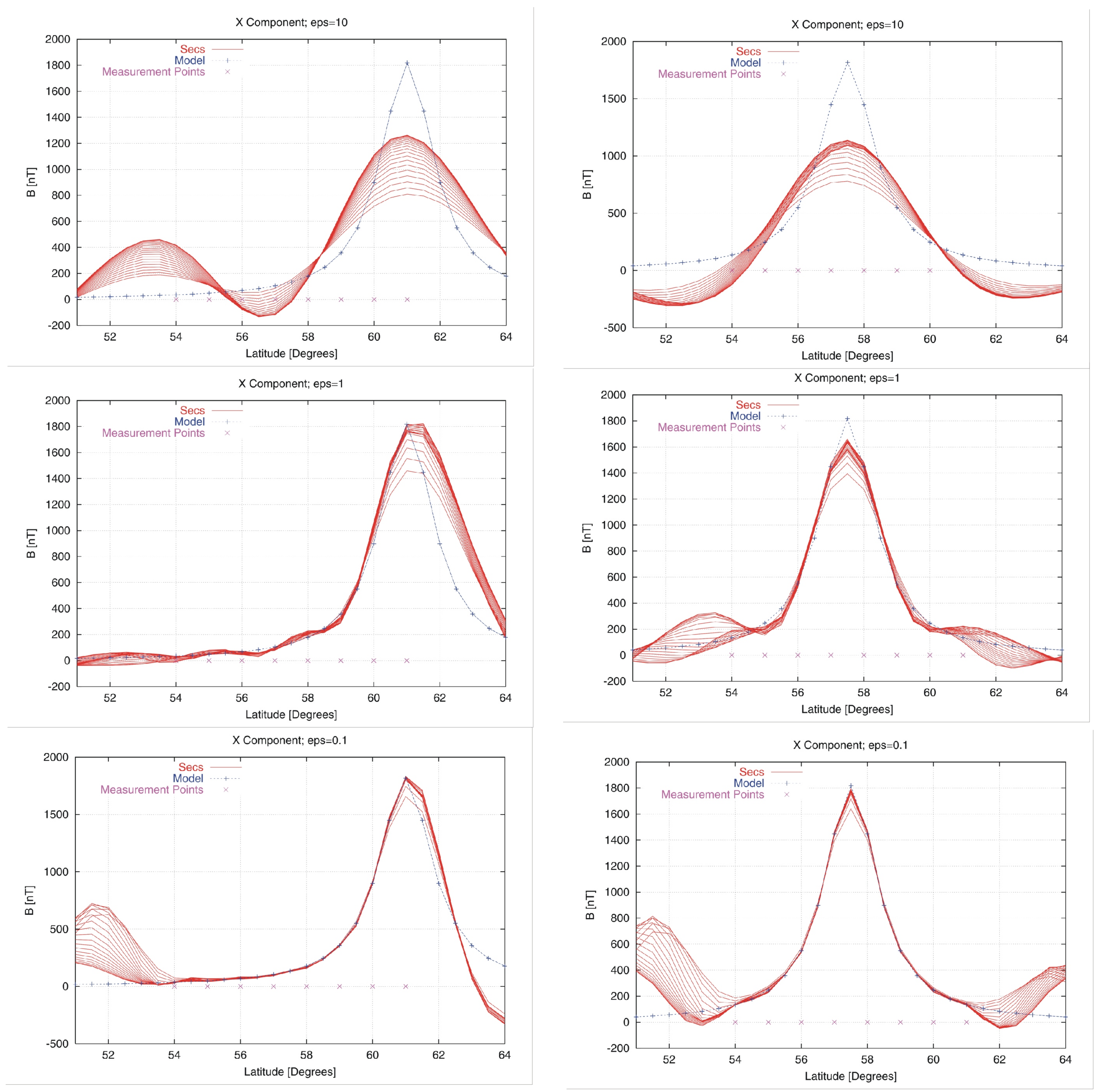




Singular Values Decomposition (SVD) is employed to calculate the SECS scaling factors using least-squares. We consider three solutions which correspond to ignoring all singular vectors whose magnitude is less than 10%,1% and 0.1% of the largest singular value.

**Left**: The relative variance described by each of the singular vectors decreases rapidly. The three threshold values of 10,1,0.1% are also shown.

## 3. Results

We show results for the X-component only; the results are similar for all components. The left hand column is for a line-current which is located at the Northern end of the test measurement array; the right-hand column shows the results when the line-current is located in the middle of the measurement array. The RMS misfits (calculated only within the measurement array) for both electrojet scenarios are similar; for the 10, 1 and 0.1% thresholds the RMS misfits are 240, 70 and 13 nT respectively. However, there is a trade off between the resolution and stability; as the resolution improves (we include more singular vectors) edge affects appear e.g. large side-lobes. The side-lobes are asymmetric for the mid measurement array electrojet: we think this could be due to modelling the electrojet using a Cartesian current system, but this requires further investigation.




## 4. Summary and Future Work

(1) Within the model test-site array there is good agreement between the magnetic field from the line-current model and that of the ionospheric equivalent currents.

(2) The overall RMS misfit does not depend strongly on the position of the electrojet with respect to the test measurement array.

Further tests will be conducted using more realistic ionospheric currents system such as an electrojet with finite width and length (e.g. Boteler and Pirjola, 1998). Thereafter, we will implement SECS using measured data from a measurement array comprising the UK and northern Europe. We do not account for induction in the Earth; this will lead to an over-estimate of the ionospheric current density which increases with distance from the electrojet centre (e.g. Pulkkinen and Engels, 2005). Therefore, an important aspect of future work will be including the effect of the induced field on the determined ionospheric equivalent currents, and establishing the resultant impact on the estimated ionospheric current density.

## References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