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An Equivalent Source Method for Modelling the Global Lithospheric Magnetic Field

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Summary

We produce a new model of the global lithospheric magnetic field based on 3-component vector field observations at all latitudes from the CHAMP satellite using an equivalent source technique.

Method

A regularized iteratively reweighted least squares algorithm is applied. Data error covariance matrices are implemented, including both the latitude dependence of data error variances σ^2 (Fig.1) and covariances **C** between the vector field components due to unmodelled sources. The regularization norm **R** is defined to be the Euclidean length of the model solution. Our scheme iteratively minimizes:

$$\Theta(\mathbf{m}_k) = (\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{m}_k)^T \mathbf{W}_{k-1}(\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{m}_k) + \lambda \mathbf{R}(\mathbf{m}_k)$$

$$\mathbf{W}_{k-1} = \underline{\underline{\mathbf{C}}}^{-1/2}\underline{\underline{\mathbf{H}}}_{k-1}\underline{\underline{\mathbf{C}}}^{-1/2}$$

Huber weighting ensures a robust solution in the presence of non-Gaussian data errors

$$\underline{\underline{\mathbf{H}}}_{k-1} = min\left(\frac{1.5}{|\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{m}_{k-1}|/\sigma}, 1\right)$$

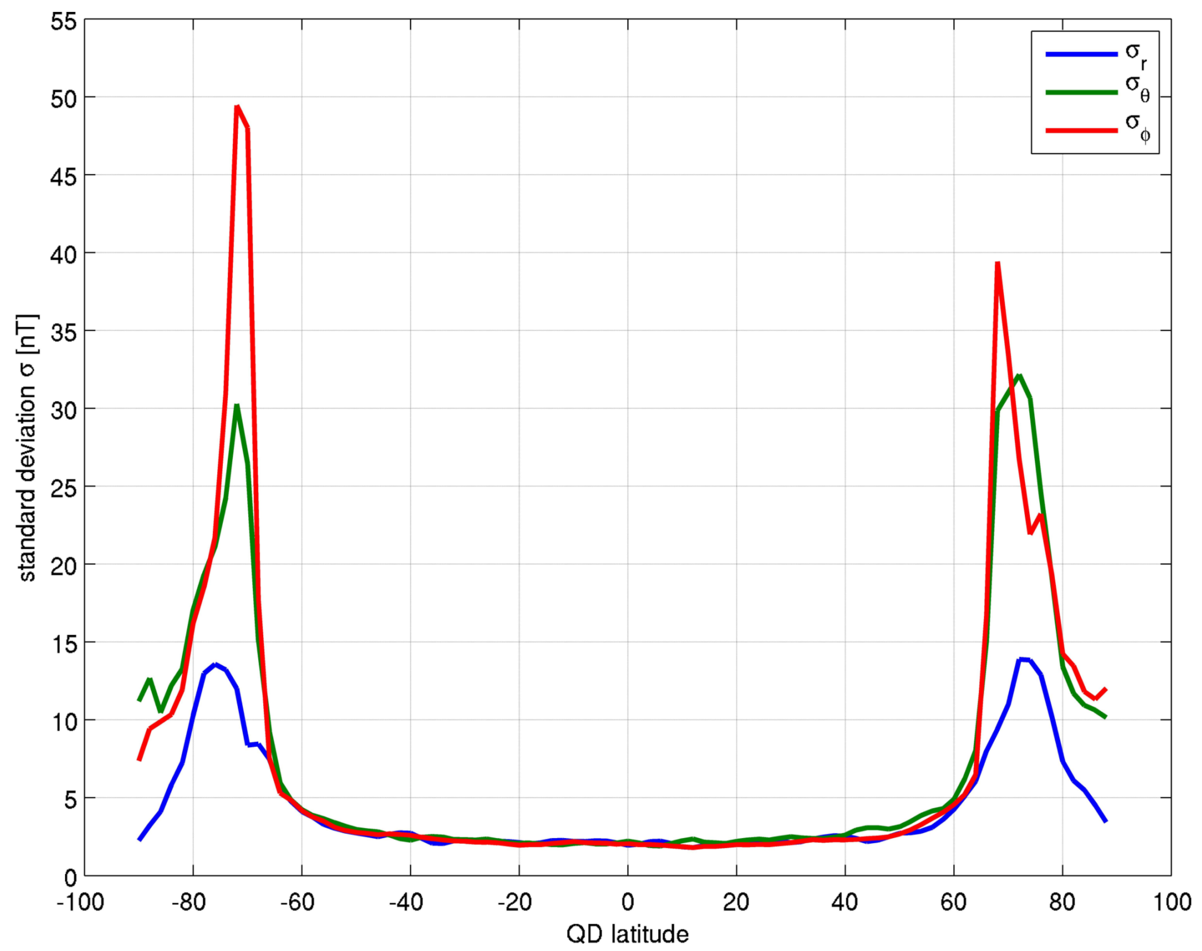

Fig.1: Latitude dependent standard deviations of the assigned errors due to unmodelled sources.

An initial unregularized (λ = 0) model is derived using 10 iterations. The final model is obtained with 5 further iterations using quadratic regularization and λ = 3E-13.

Equivalent Source Method

The equivalent potential field sources **m** (monopoles) are arranged in an icosahedron grid (Fig.2), consisting of K = 30722 vertices and midpoints, placed at a depth of 100km below the Earth's surface. The derived model can be transformed into a spherical harmonic representation by:

$$g_n^l = \sum_{k=1}^{K} \frac{r_k^n}{a^{n+2}} m_k P_n^l(\cos\theta_k)\cos(l\phi_k)$$

$$h_n^l = \sum_{k=1}^{K} \frac{r_k^n}{a^{n+2}} m_k P_n^l(\cos\theta_k)\sin(l\phi_k)$$

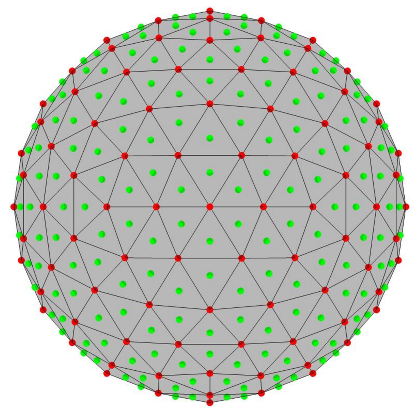

Fig.2: Right: Icosahedron grid with 483 of vertices (red) and midpoints (green). **Left:** The corresponding K equivalent potential field sources **m** can be directly transformed into spherical harmonics of order l and degree n. a = Earth mean radius, (θ,ϕ) = source location.

Results and Outlook

The presented model has a power spectrum that compares well to CHAOS-4, MF7 and CM5 (cf. Poster EGU2014-6883) models to degree n = 100 (Fig.4). Ongoing investigations concern non-quadratic regularization using maximum entropy. Looking forward, we plan to explore local grid refinement options in order to incorporate aeromagnetic survey data.

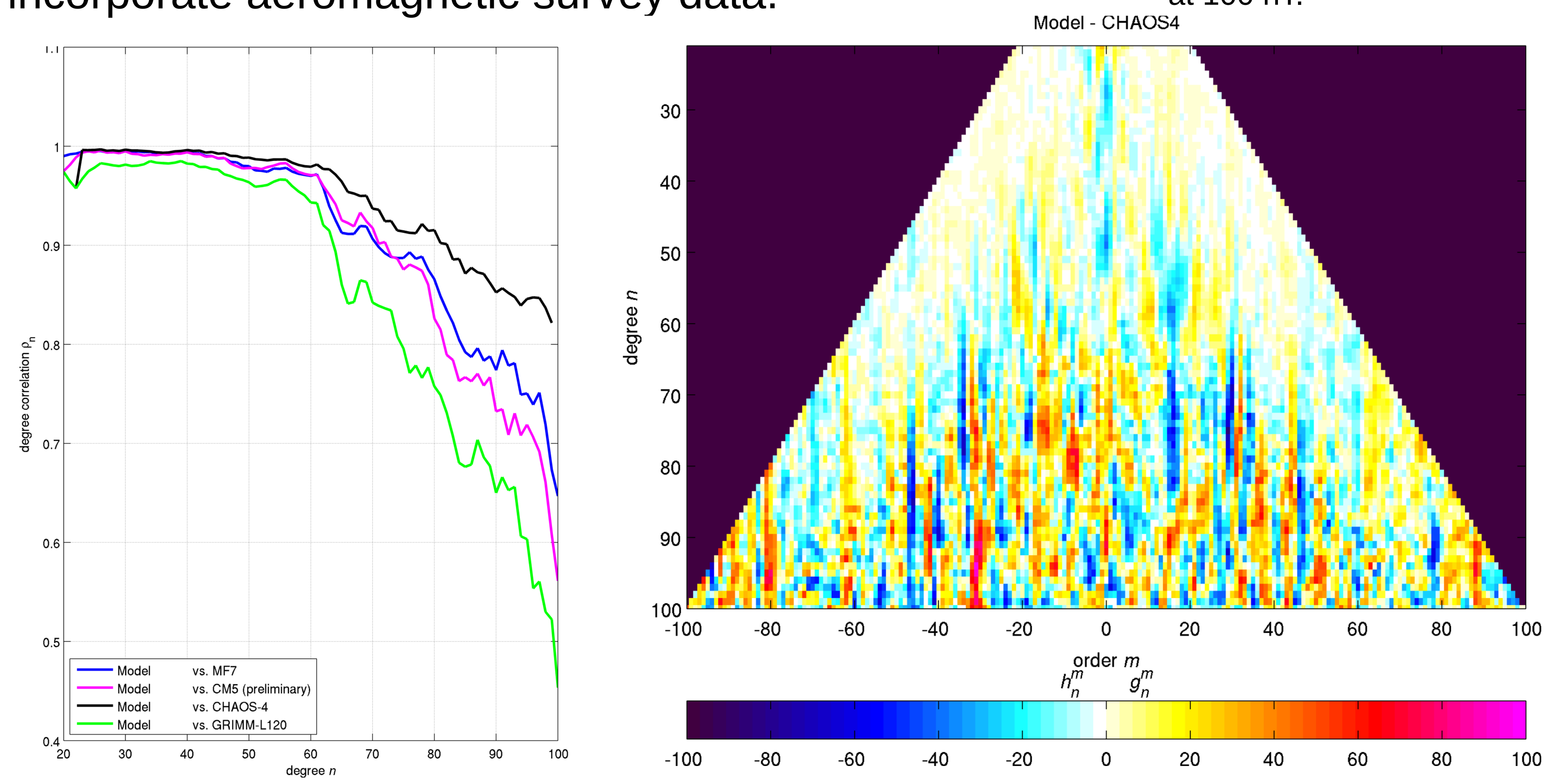

Fig 3 left: Final model degree correlation with CHAOS-4, MF7, GRIMM-L120 and CM5. **right:** Sensitivity matrix between final model and CHAOS-4. The scale saturates at 100 nT.

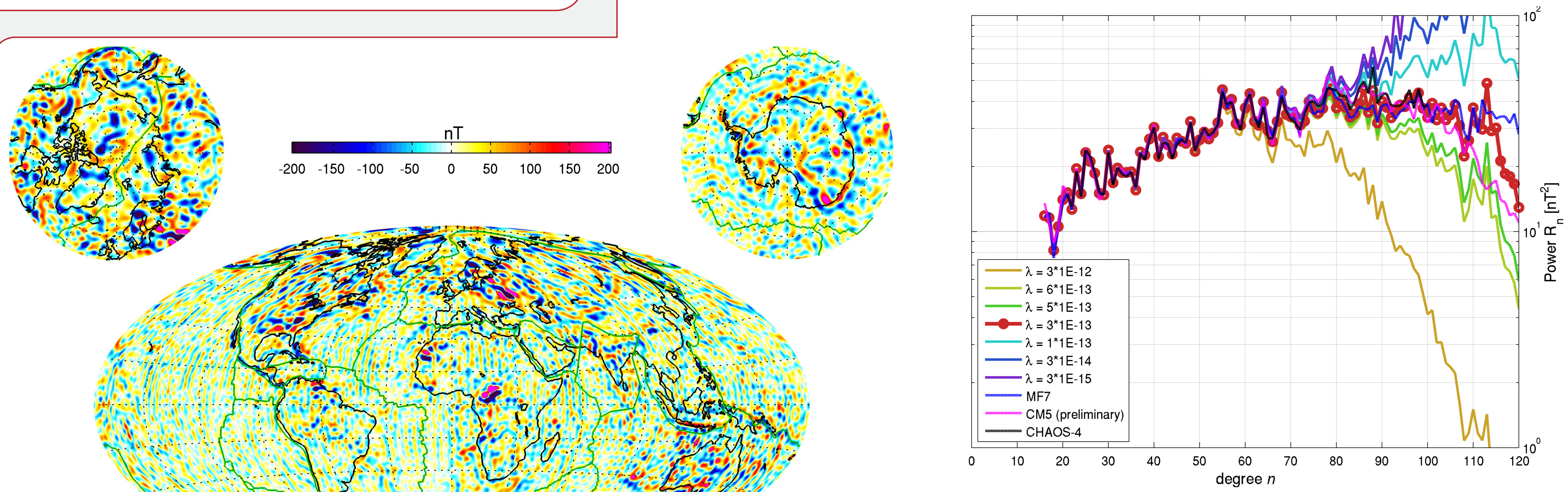

Fig 4 left: Modelled lithospheric radial magnetic field at the Earth's surface for degree n = 16-180. The scale saturates at 200 nT. **right:** Power spectrum for MF7, CM5 and CHAOS-4 models in comparison to model results with different regularization damping values. The chosen model is represented by the red line.