Technical University of Denmark

An Equivalent Source Method for Modelling the Lithospheric Magnetic Field Using Satellite and Airborne Magnetic Data

Kother, Livia Kathleen; D. Hammer, Magnus; C. Finlay, Christopher; Olsen, Nils

Publication date:
2015

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):
Kother, L. K., D. Hammer, M., C. Finlay, C., & Olsen, N. (2015). An Equivalent Source Method for Modelling the Lithospheric Magnetic Field Using Satellite and Airborne Magnetic Data [Sound/Visual production (digital)]. 2014 AGU Fall Meeting, San Francisco, CA, United States, 15/12/2014

An Equivalent Source Method for Modelling the Lithospheric Magnetic Field Using Satellite and Airborne Magnetic Data

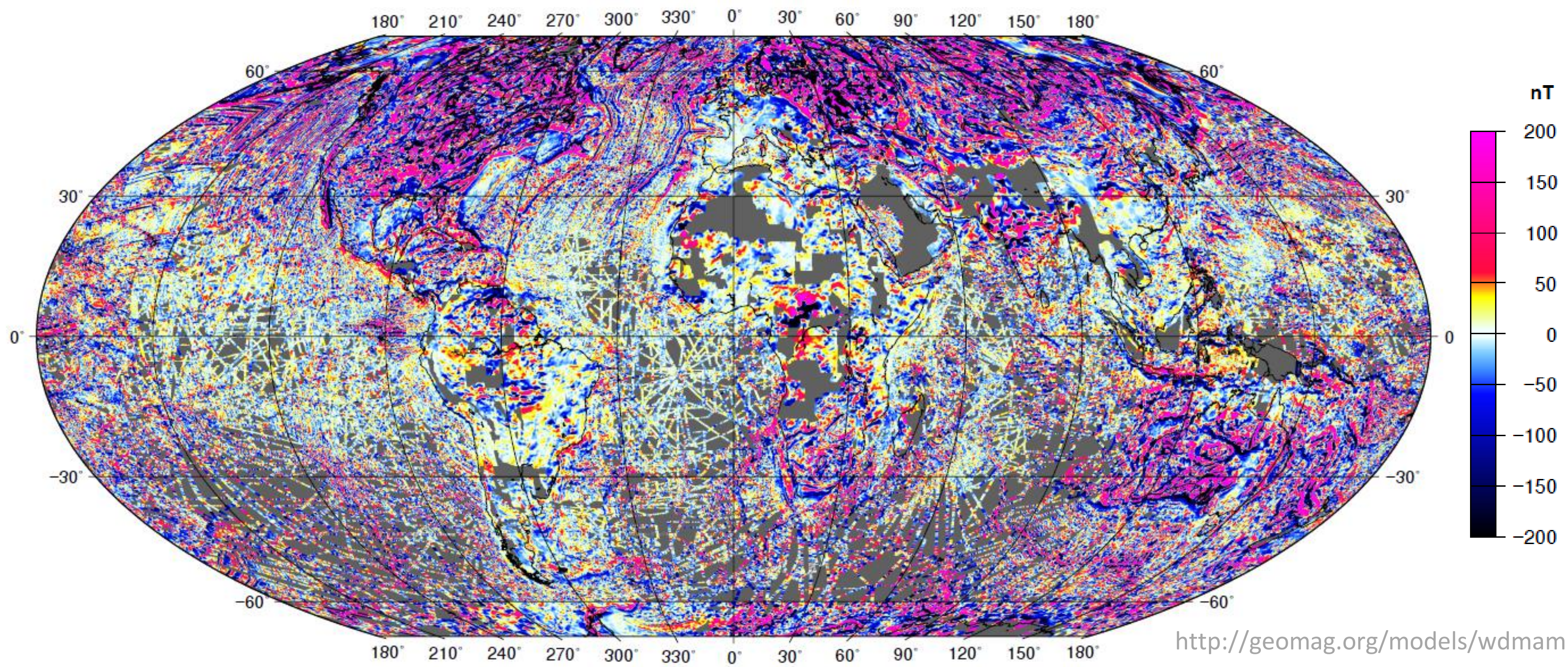
Livia Kother[1], Magnus D. Hammer[2], Christopher C. Finlay[1], Nils Olsen[1]

[1] Division of Geomagnetism, DTU Space, Technical University of Denmark
Diplomvej, Building 371, 2800 Kgs. Lyngby, Denmark

[2] Copenhagen, Denmark

Importance of lithospheric magnetic field models

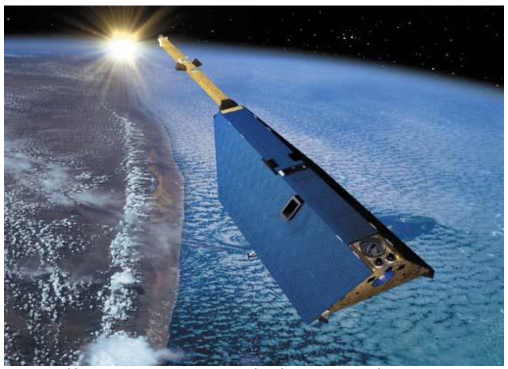
- Lithospheric structure and composition
- Resource exploration
- Directional drilling
- **High resolution models require combination of both satellite and airborne/marine measurements**



http://geomag.org/models/wdmam.html

Applied Geomagnetic Data

Satellite data



http://www.astrium.eads.net/en/programme/champ-cta.html

- CHAMP
- Solar quiet period
- Altitude ~ 300 km
- Global model
- Resolution ~ 400 km

Airborne data

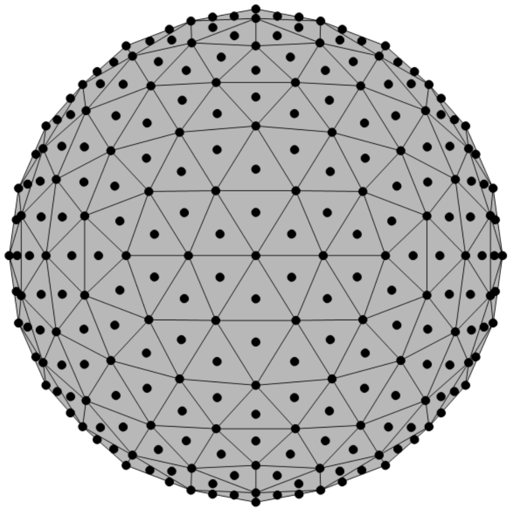
www.ngu.no

- Local surveys
- Norwegian coast
- Local model
- Resolution ~ 5 km

Data combination

- Global field structure defined by satellite data
- Local high resolution data provided by airborne data
- Better description of short wavelength structures

Applied Modelling Method - Equivalent Sources



- Icosahedron grid of magnetic point sources *q*

$$\hat{\Phi}(\mathbf{r}_i) = \sum_{k=1}^{K} q_k \frac{r_k^2}{r_{ik}}$$

$$\mathbf{B}_L(\mathbf{r}_i) = -\nabla\hat{\Phi}(\mathbf{r}_i)$$

- Model values are transferable to spherical harmonic representation

$$g_n^m = \sum_{k=1}^{K} \left(\frac{r_k}{a}\right)^{n+2} q_k P_n^m(\cos\theta_k)\cos(m\phi_k)$$

$$h_n^m = \sum_{k=1}^{K} \left(\frac{r_k}{a}\right)^{n+2} q_k P_n^m(\cos\theta_k)\sin(m\phi_k).$$

- Divergence-free constraint

$$\sum_{k=1}^{K} q_k = 0$$

Inverse Modelling Scheme

Observed magnetic field data

↓

Removal of core and large-scale magnetospheric sources + data selection

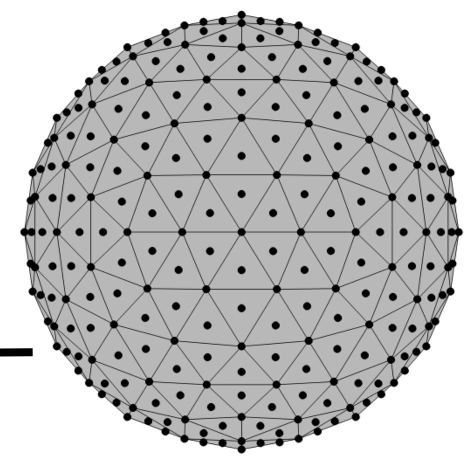
→

Estimate of lithospheric field at measurement location

→

Combination with icosahedron grid of equivalent sources

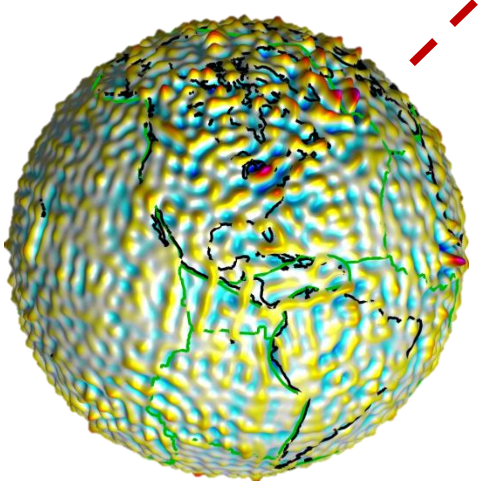
↓



←

Inverse modelling (regularized IRLS algorithm) to determine model values

←



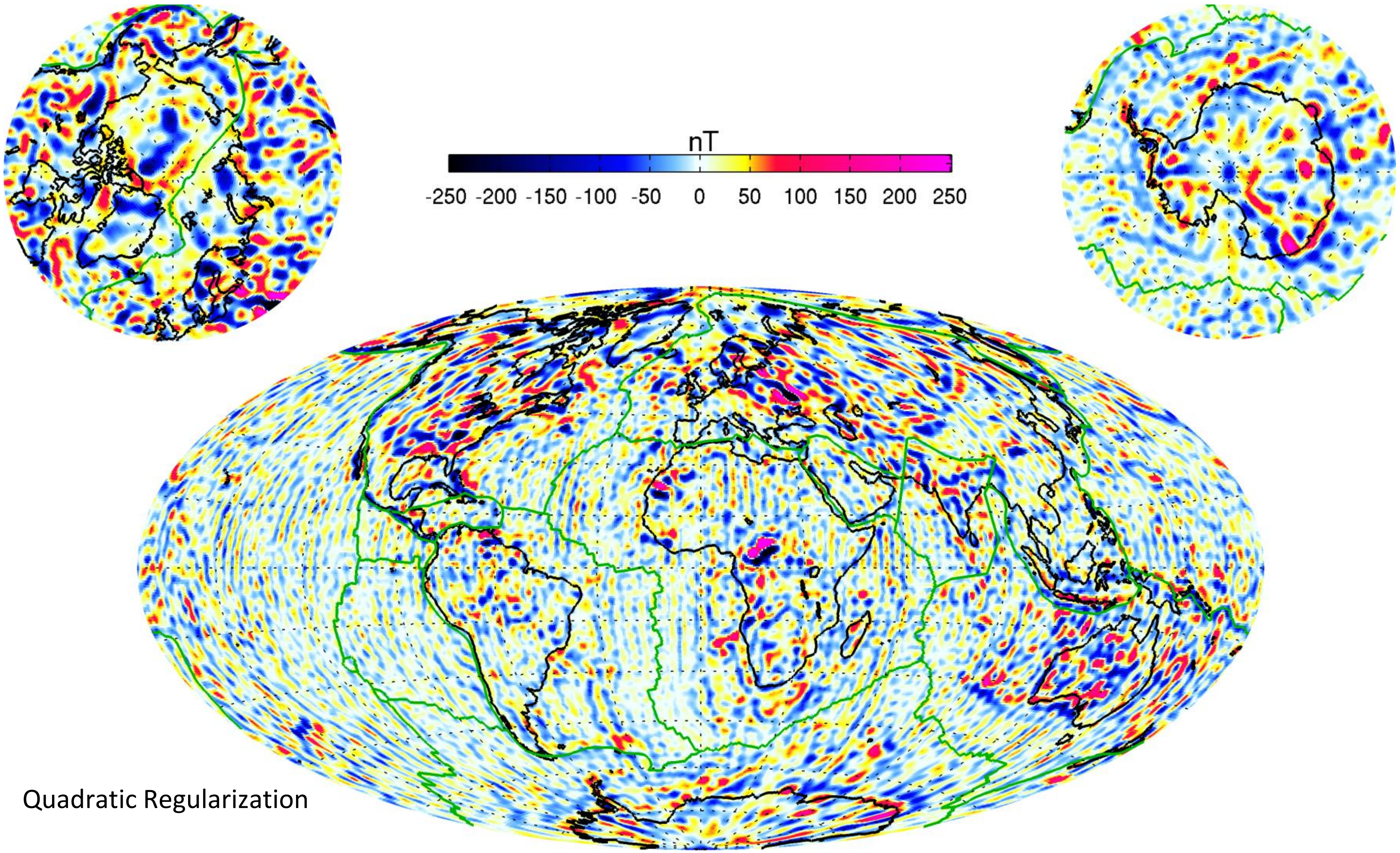
Model Estimation

- Uniqueness problem → regularization

$$\Theta(\mathbf{q}) = (\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{q})^T \mathbf{W} (\mathbf{d} - \underline{\underline{\mathbf{G}}}\mathbf{q}) + \lambda \mathbf{R}(\mathbf{q})$$

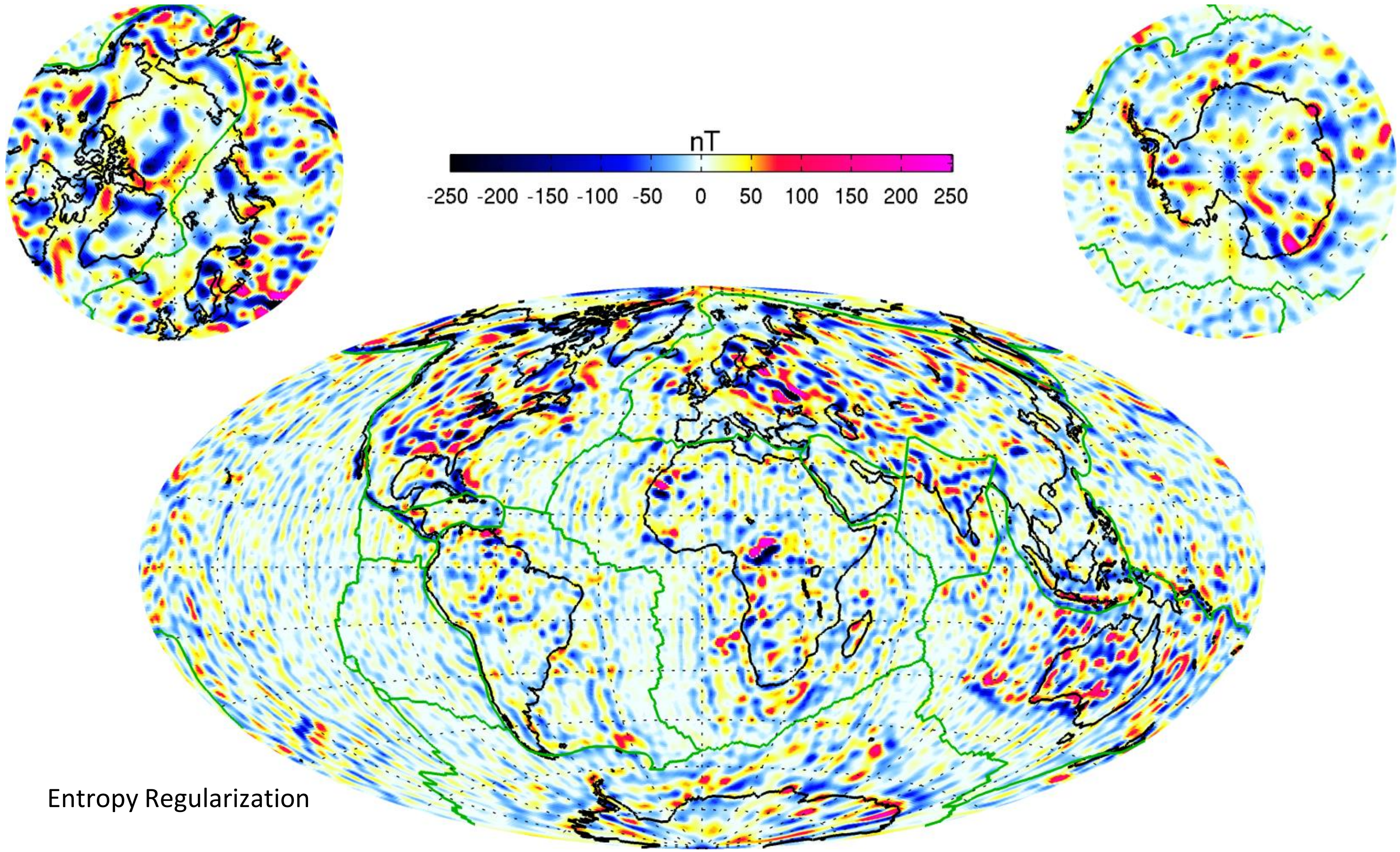
$$\mathbf{W} = \underline{\underline{\mathbf{C}}}^{-1/2} \underline{\underline{\mathbf{H}\mathbf{C}}}^{-1/2}$$

Model Result: CHAMP Data

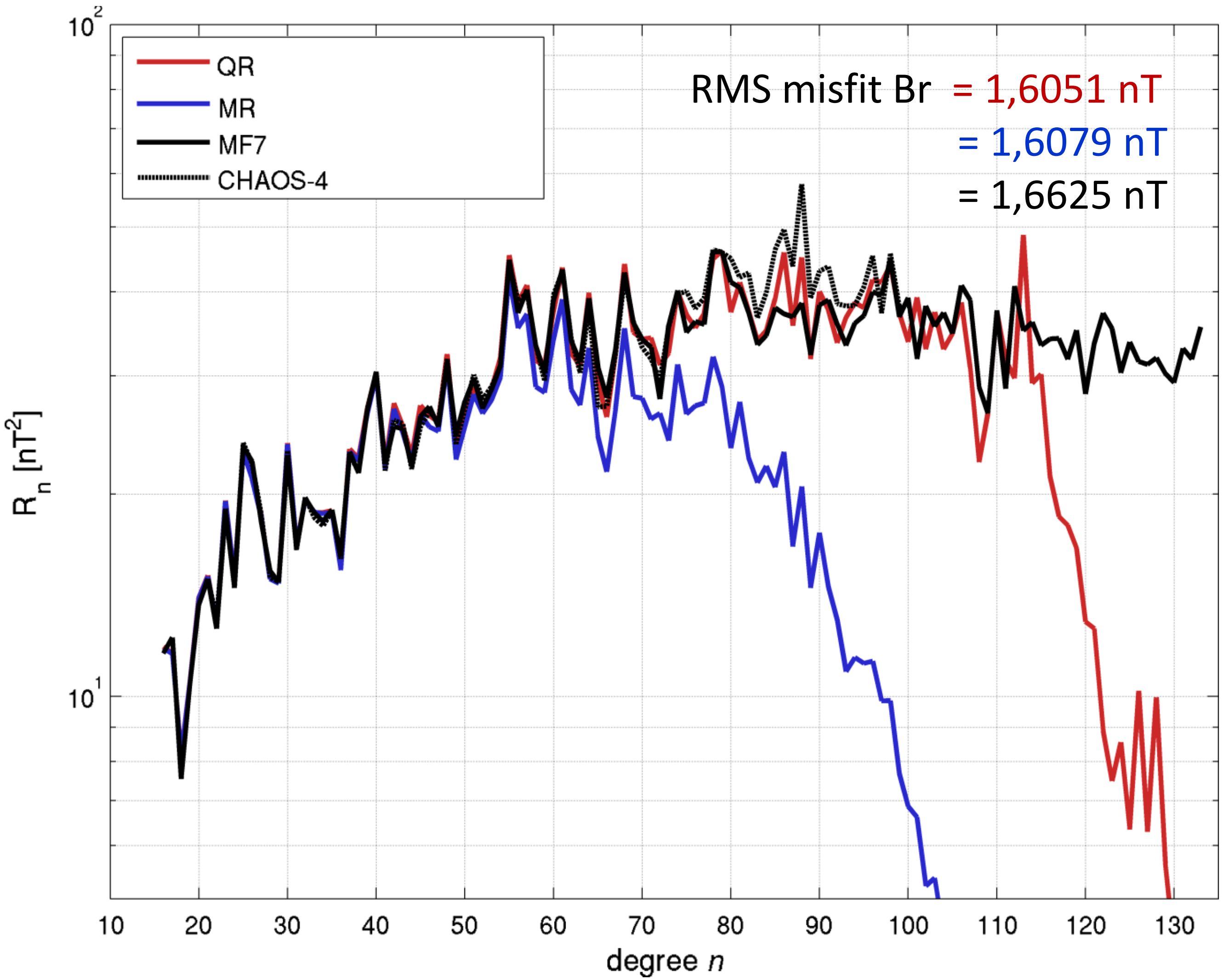


Quadratic Regularization

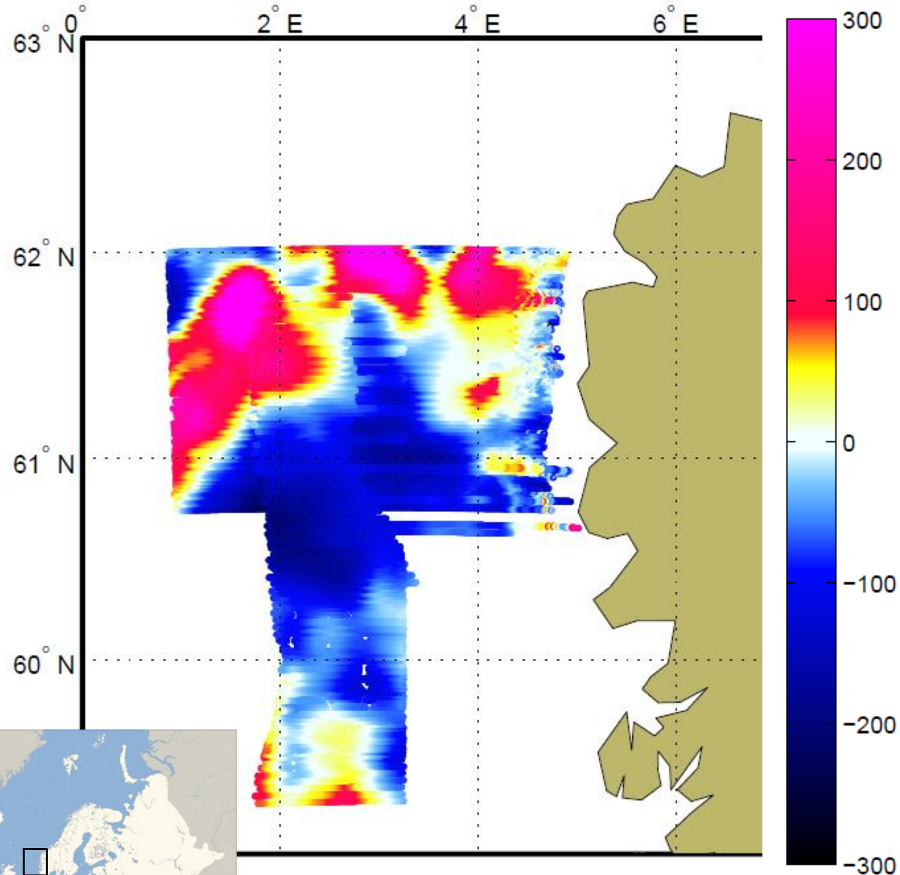
Model Result: CHAMP Data

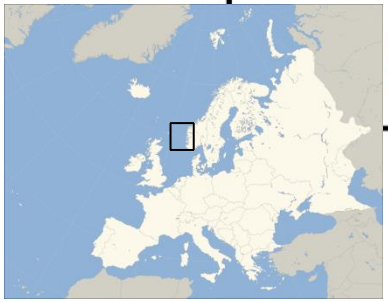


Model Result: CHAMP Data



Model Result: Airborne Data





Aeromagnetic survey data are
kindly provided by NGU

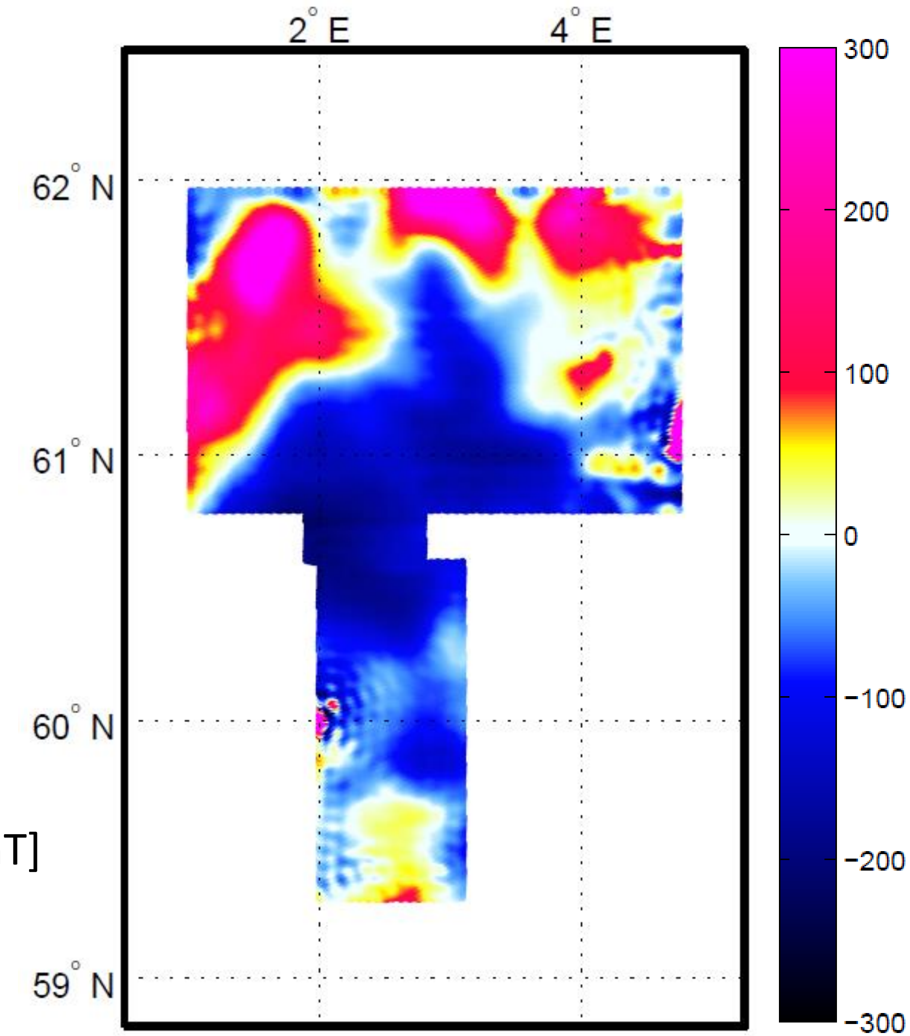
Survey 1 - Viking

Year:	1993
Sensor elevation:	150 m
Line spacing:	0.5 – 2 km

Survey 2 - Fairey

Year:	1971
Sensor elevation:	500 m
Line spacing:	2 – 7,5 km

Model Result: Airborne Data



Modelled values [nT]
at Earth surface

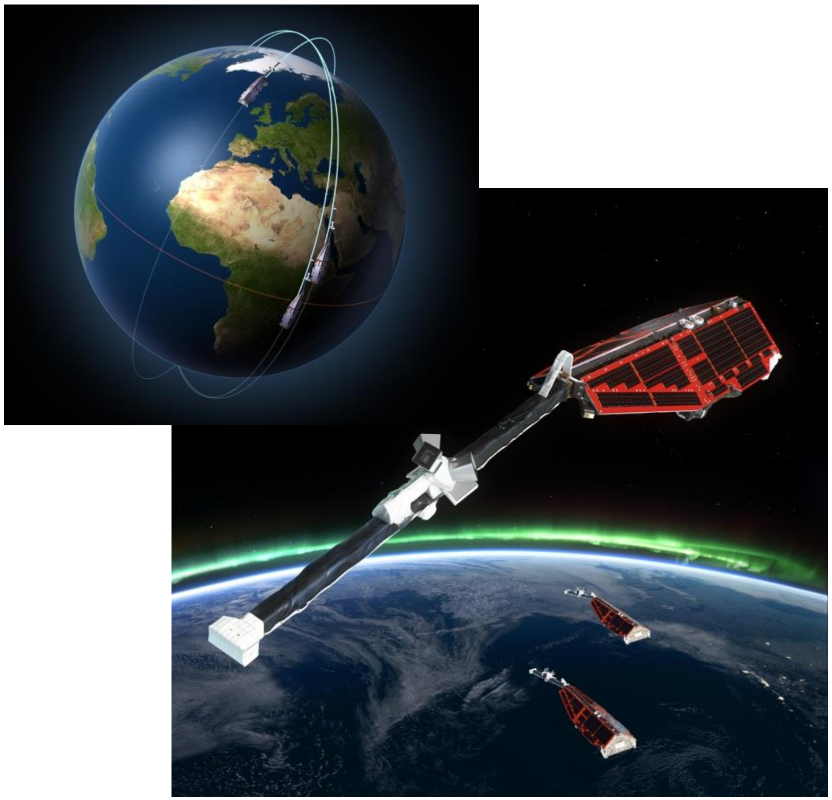
Conclusion

- Lithospheric field modelling based on equivalent potential field source estimation
- Robust, regularized, least squares estimation scheme
- Successful tests using satellite data on a global scale and local airborne data

Advantages of the method:

- ➢ Combined local and global applications are possible
- ➢ Model regularization can be easily implemented
- ➢ Downward / upward continuation
- ➢ Method is not sensitive to polar gap problem

Swarm mission



www.esa.int

Launched: 22th Nov 2013

Mission duration: 4yrs

Orbit: 2 satellites orbit side-by-side at an initial altitude of 460 km, decaying naturally to 300 km; the third satellite orbits at about 530 km

Instruments: Vector field magnetometer, absolute scalar magnetometer, electric field instrument, accelerometer, GPS receiver, startrackers and laser retroreflector