EGU General Assembly

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Global and local high-resolution magnetic field inversion using spherical harmonic models of individual sources

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Issues of a global magnetic inversion

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- Long-wavelength lithospheric signal is mixed with the core field
- Not enough computer memory for high-resolution inversion
- No possibility of consistent combination with airborne data

Inversion algorithm with tesseroids

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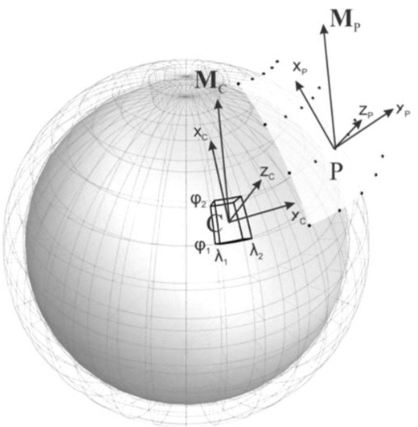
- Calculate the effect of each tesseroid from a crustal/lithospheric model



- Convert the effect in SH model
- Filter SH model of each tesseroid (truncate at degree n =15)
- Solve $\mathbf{d}_{SHC} = \mathbf{A}_{SHC} \cdot \mathbf{x}$

Projected gradient inversion

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- The optimization problem is (from *Lin, 2007*)

$$\min_{x \geq 0} ||\mathbf{A}_{SHC}\mathbf{x} - \mathbf{d}_{SHC}||_2^2$$

- Solution if found by

$$\mathbf{x}^{k+1} = P_{\Omega}\{\mathbf{x}^k - \alpha_k \cdot Grad(\mathbf{x}^k)\},$$

where

$$P_{\Omega}\{\aleph\} = \begin{cases} \aleph & if\ \aleph > 0 \\ 0 & if\ \aleph \leq 0 \end{cases}$$

$$Grad(\mathbf{x}^k) = \mathbf{A}_{SHC}^{\mathrm{T}}\mathbf{A}_{SHC}\mathbf{x}^k - \mathbf{A}_{SHC}^{\mathrm{T}}\mathbf{d}_{SHC}$$

Synthetic induced magnetization model: geometry

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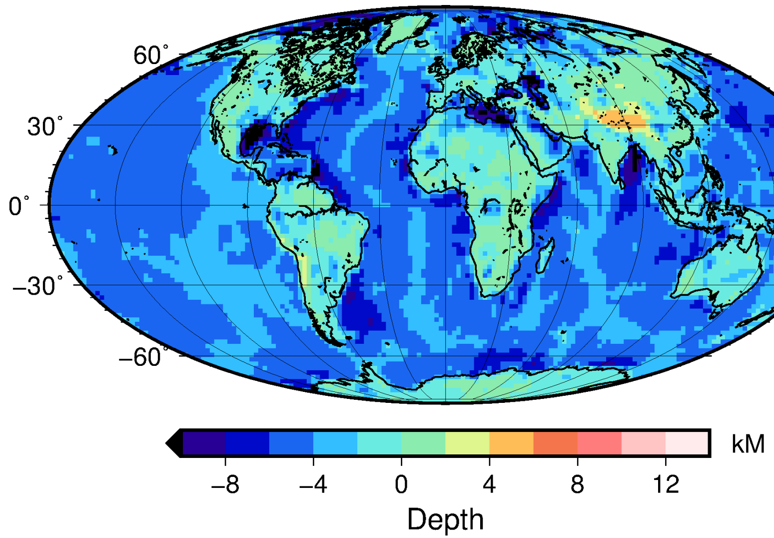

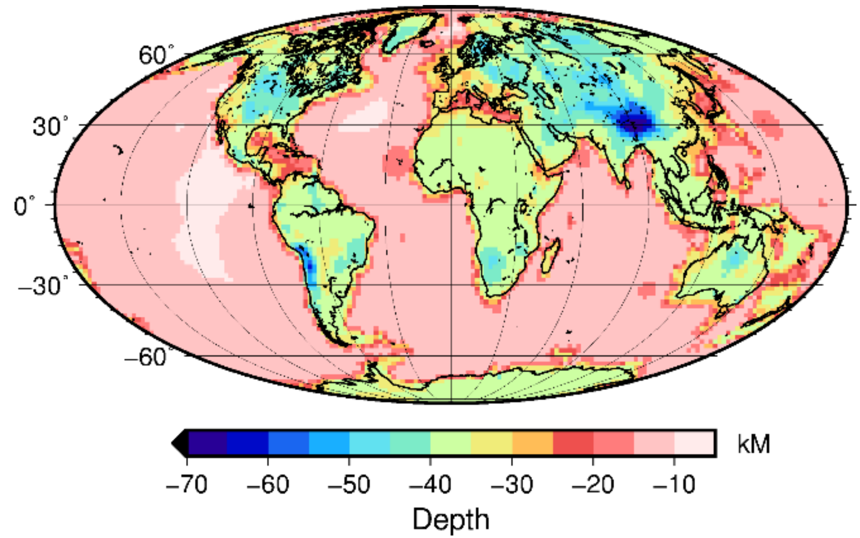

Basement depth taken from CRUST1.0 (*Laske et al., 2013*).

Moho depth taken from (*Szwillus et al., 2019*)

Discretized by one layer of 2° width tesseroids (16200 tesseroids)

Synthetic induced magnetization model: susceptibility from Hemant

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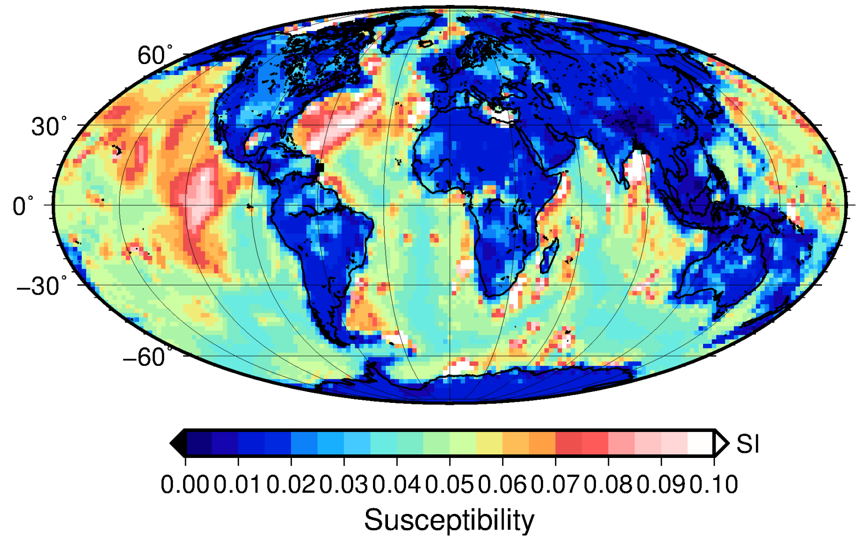
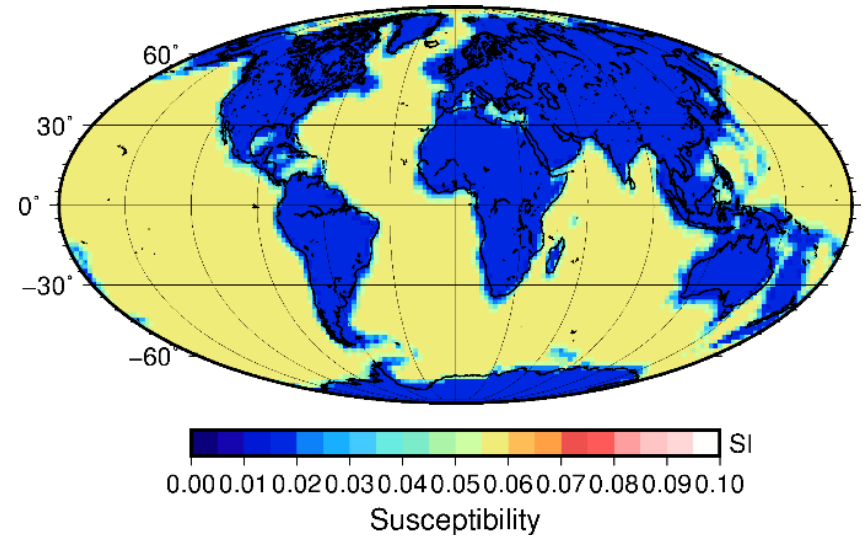


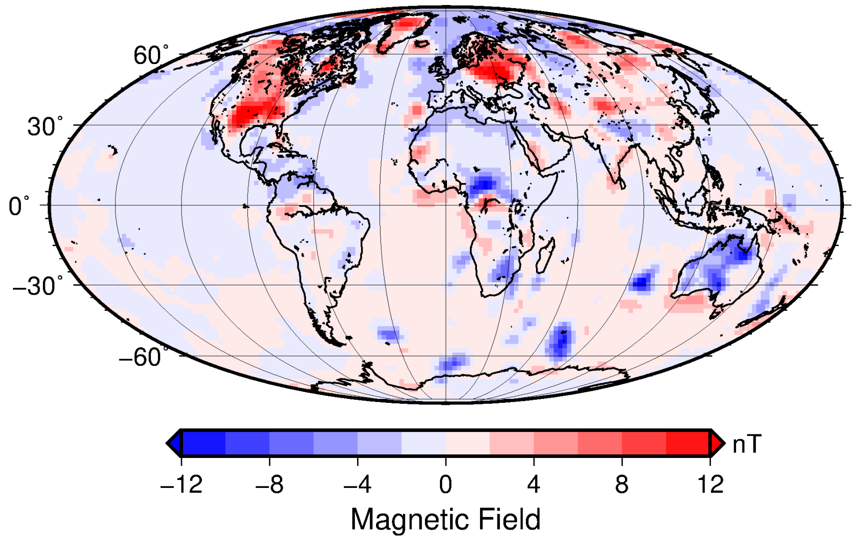


Susceptibility based on Vertically integrated susceptibility model (*Hemant & Maus, 2005*)

Later referred as $\mathbf{x}_{\mathrm{H}}^{0}$ or true model

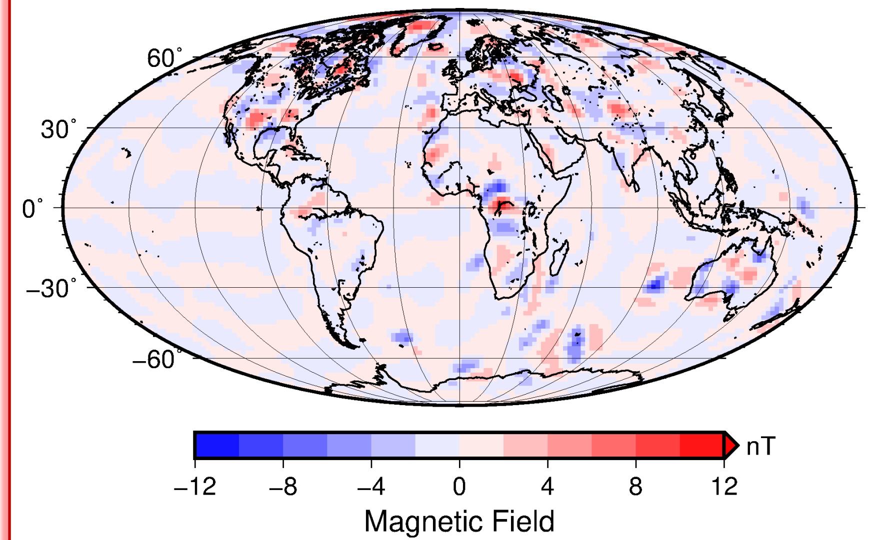
Initial guess $\mathbf{x}_{\mathrm{A}}^{0}$ with averaged susceptibilities from Hemant VIS-based initial guess $\mathbf{x}_{\mathrm{H}}^{0}$ Crustal domain boundaries are taken from age of the oceanic crust map (*Müller et al., 2018*)

Synthetic induced magnetization model: magnetic field



All spherical harmonic degrees from n = 1 to 89

(also field of a true model $\mathbf{x}_{\mathrm{H}}^{0}$)



Truncated model with degrees from n = **16 to 89**

used as observed data for tests

Note removed long-wavelength signal

Inversion: averaged susceptibilities for oceanic and continental crust as an initial guess

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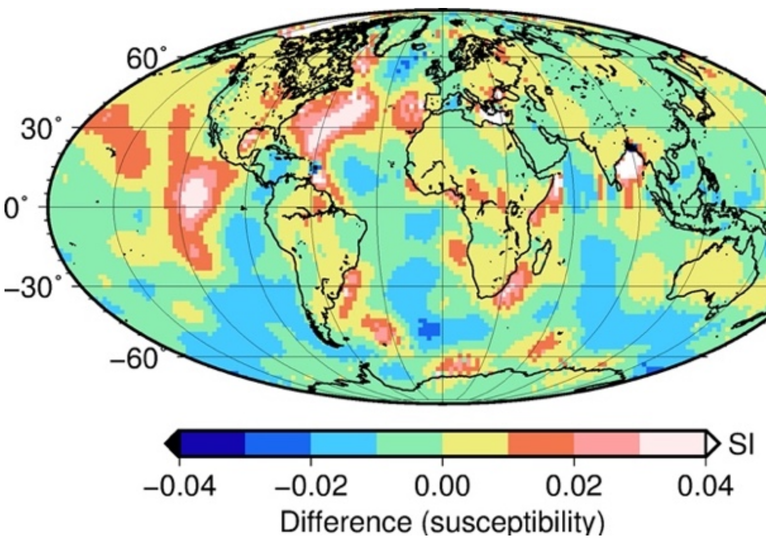

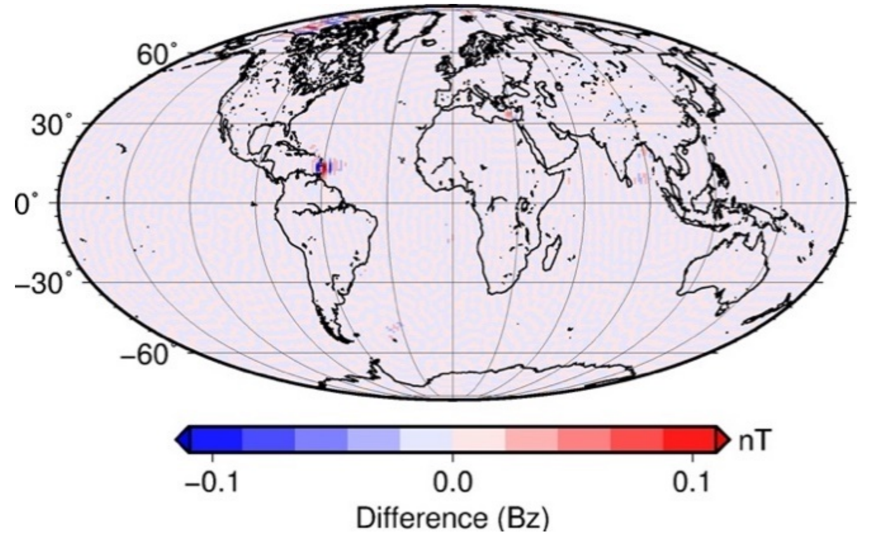

Difference between the true model $\mathbf{x}_{\mathrm{H}}^{0}$ and the inversion result $\mathbf{x}_{\mathrm{A}}^{\mathrm{N}}$

Difference between the observed magnetic field and the field of the inversion result $\mathbf{x}_{\mathrm{A}}^{\mathrm{N}}$, degrees n > 15

Inversion: averaged susceptibilities for oceanic and continental crust as an initial guess ($\mathbf{x}_A^0$)

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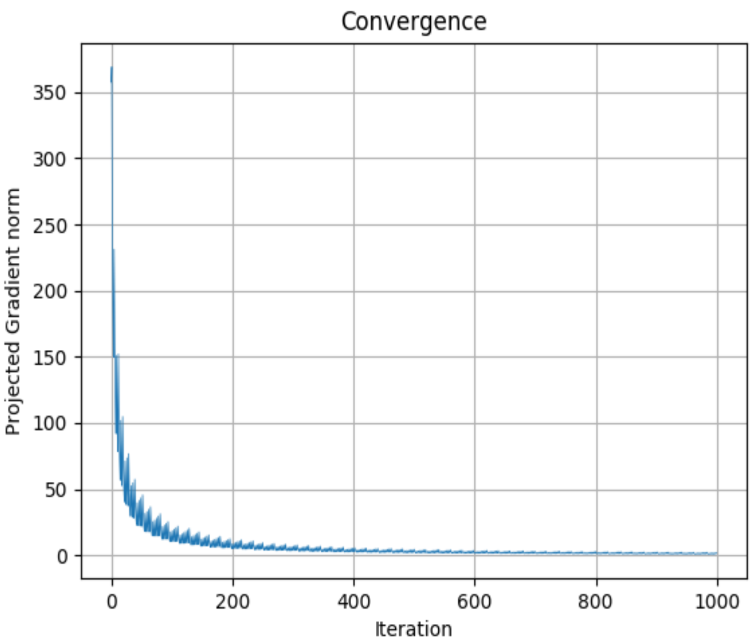
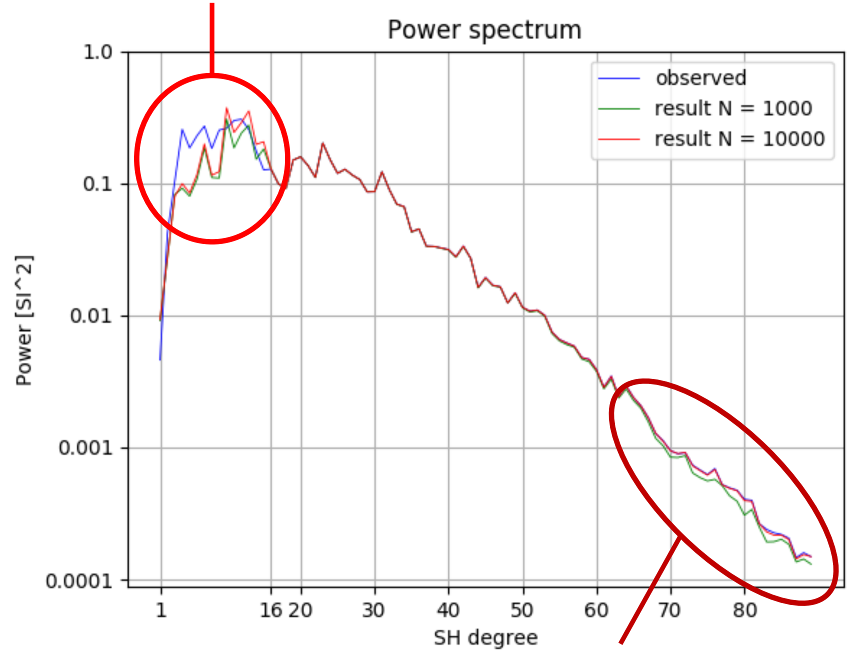


Values of projected gradient $Grad(\mathbf{x}^k)$ at each iteration (up until iteration N=1000)

Major differences in degrees n < 16



Minor differences for lower number of iteration N=1000 for degrees n > 60

Power spectrum of the observed field SHM and power spectrums of the forward calculated SHM of the inversion result $\mathbf{x}_A^N$

Remanent field model

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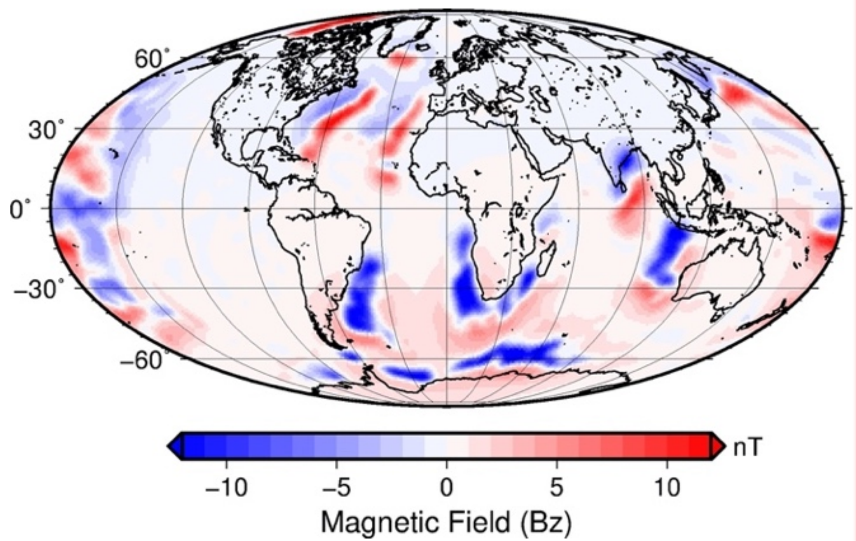
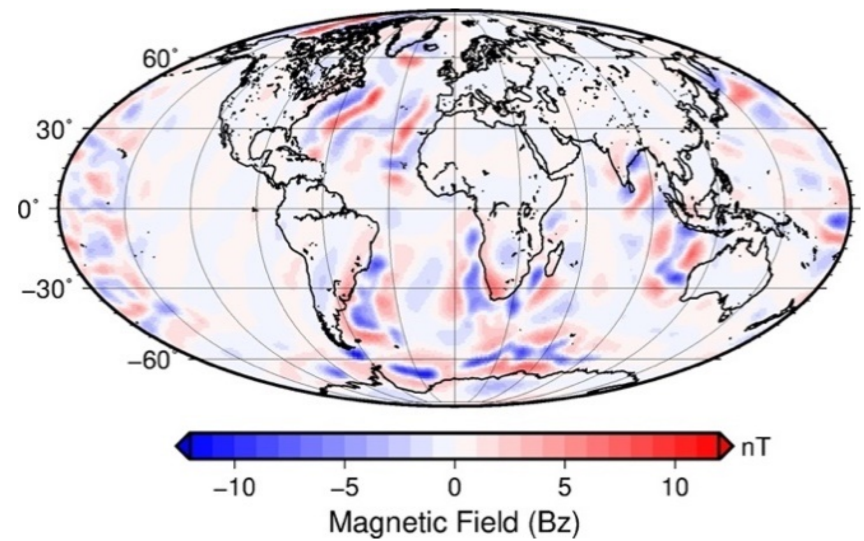


All spherical harmonic degrees from n = 1 to 89

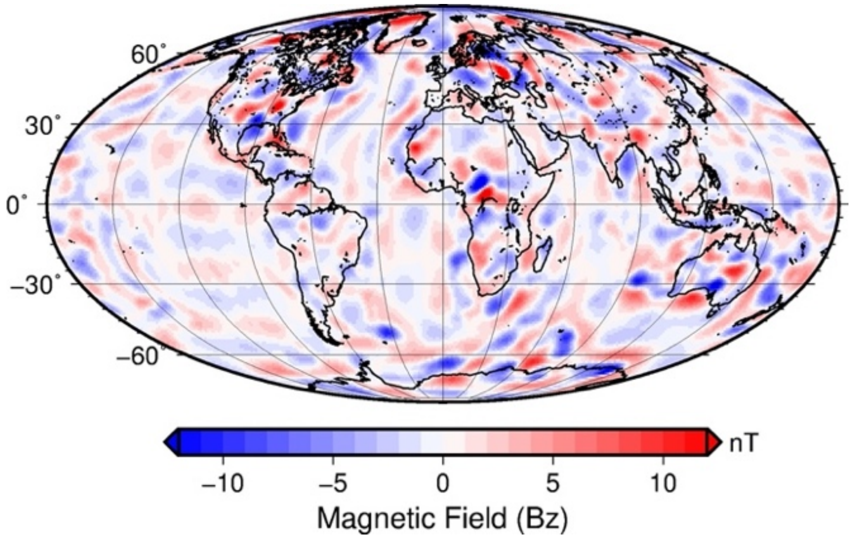


Subtracted from LCS-1!

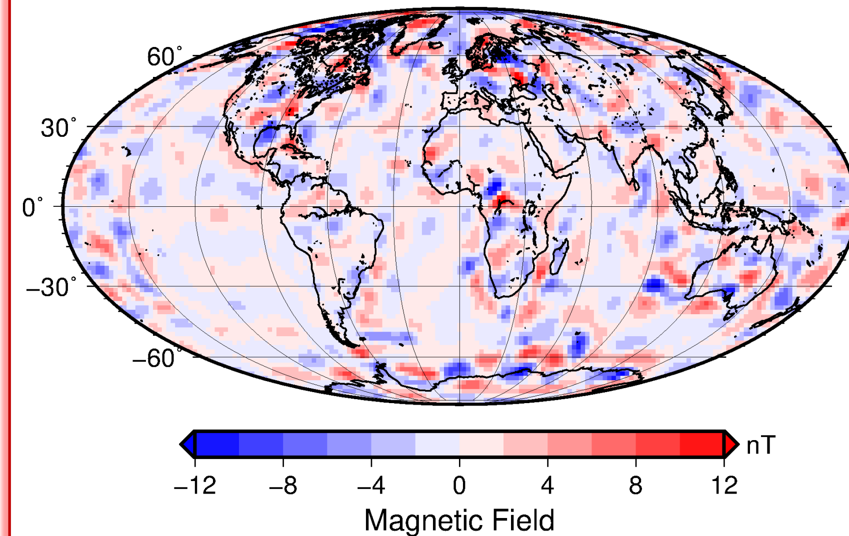
Truncated model with degrees **from n = 16 to 89**

SH model derived from forward calculated Bz grid with 1 degree spacing of *Masterton et al., 2013* remanent magnetization model

LCS-1 without remanent magnetization



Original LCS-1, spherical harmonic degrees **from n = 16 to 89**



Used as observed field

Right: LCS-1 without modelled remanent field, within degrees **from n = 16 to 89**

SH model derived from forward calculated Bz grid with 1 degree spacing

Inversion: $\mathbf{x}_{\mathrm{H}}^{0}$ as an initial guess

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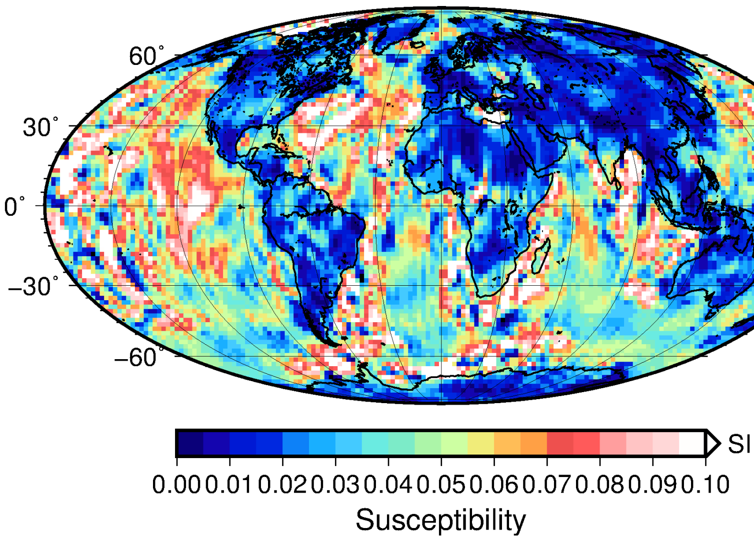
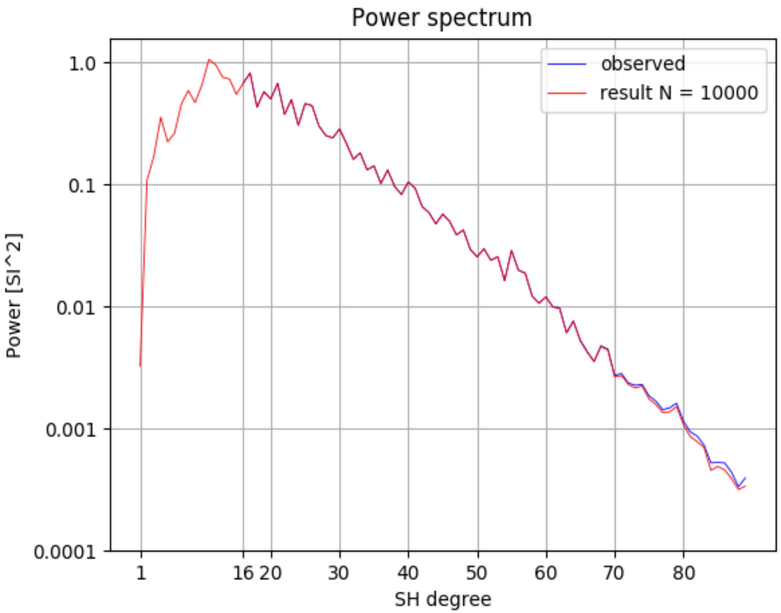


LCS-1 inversion result after N=10000 with a model $\mathbf{x}_{\mathrm{H}}^{0}$ as an initial guess



Power spectrum of LCS-1 and power spectrum of the forward calculated spherical harmonic model of the inversion result $\mathbf{x}_{\mathrm{LCS}}^{\mathrm{N}}$ after N = 10000 iterations

Field at the airborne altitude

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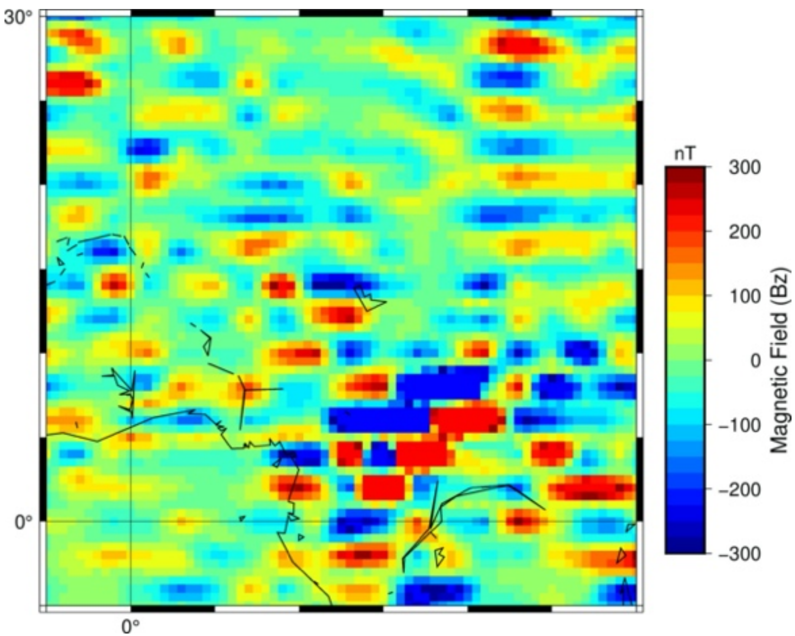

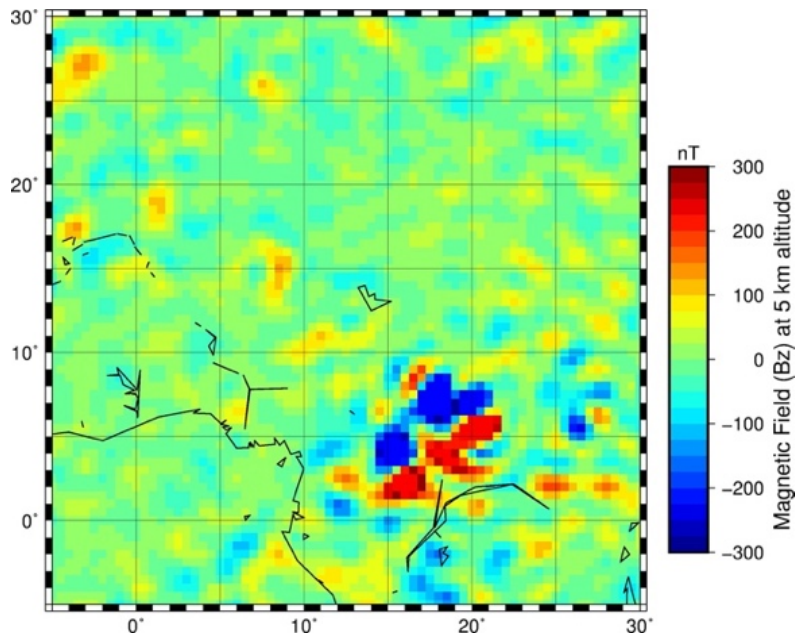

Magnetic field of the <u>tile</u> inversion result and LCS-1 at the airborne altitude

LCS-1 calculated at 5 km altitude.

Improvement in results

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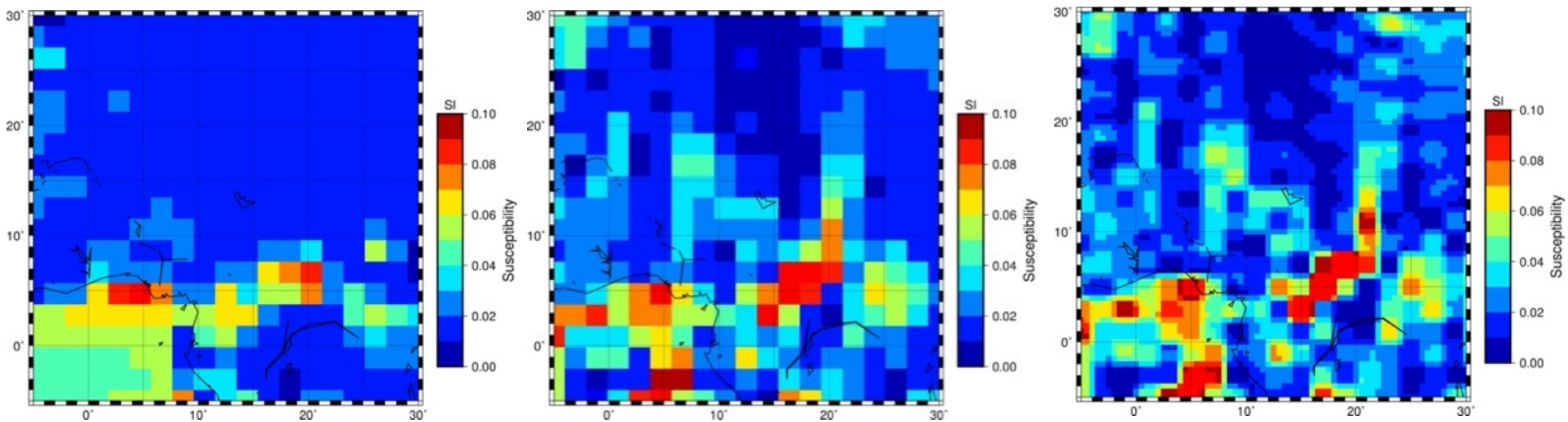

Susceptibility models for Bangui area in Africa

Initial guess $\mathbf{x}_{\mathrm{H}}^{0}$

Inversion result $\mathbf{x}_{\mathrm{LCS}}^{\mathrm{N=10000}}$

Tile inversion result with resolution of 0.5 degrees

Summary

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- Method for global magnetic inversion with tesseroids and spherical filtering was implemented (software is available here)
- Algorithm is scalable and can be used to utilize airborne data
- More a-priori constraints (initial guess) are necessary to produce realistic long-wavelength lithospheric field
- Methodology can be used to merge gap between airborne and satellite data
- **Paper (*Baykiev et al., 2020*) about the topic of this presentation is available in open-access here.**