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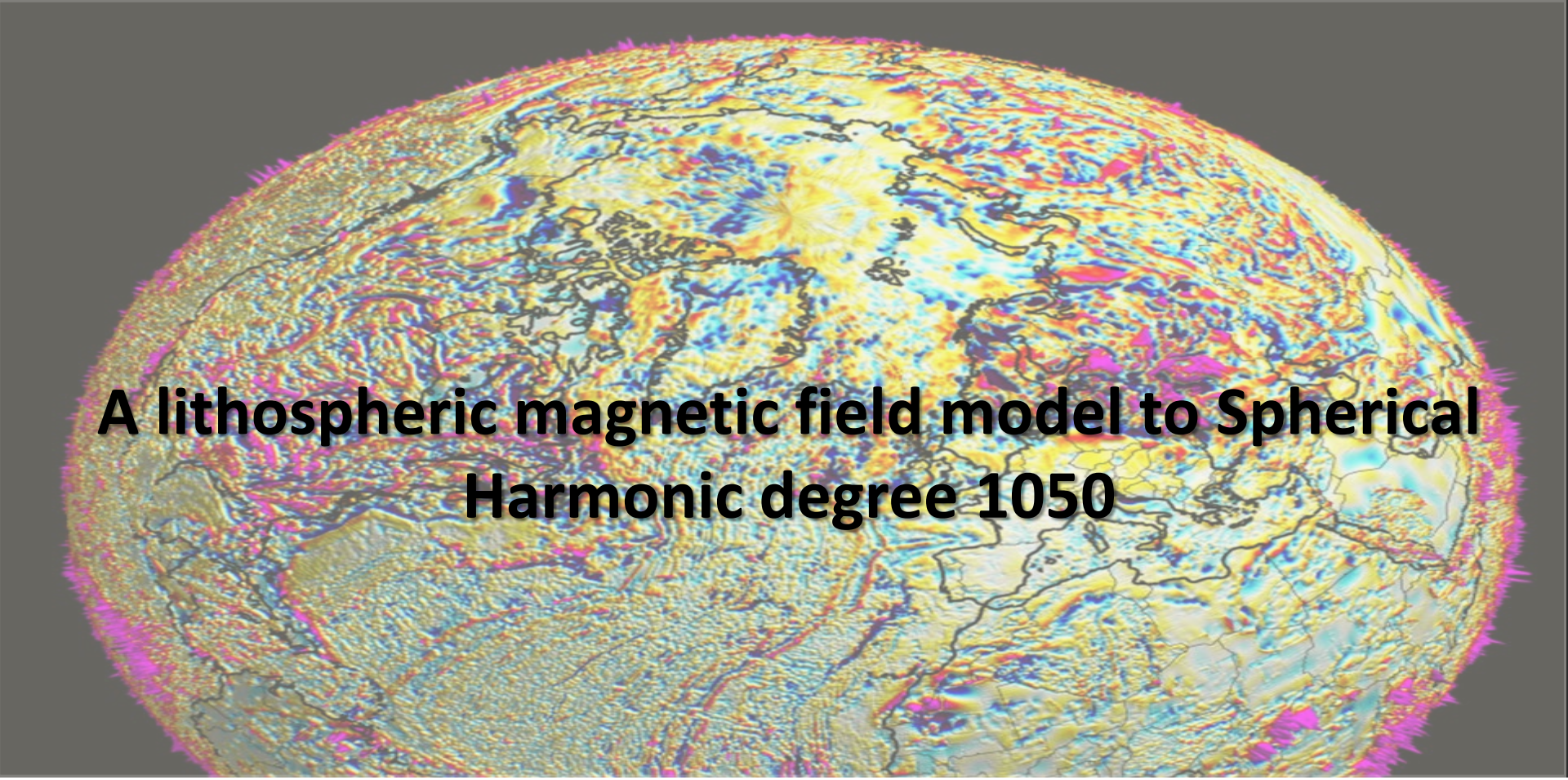

A lithospheric magnetic field model to Spherical Harmonic degree 1050

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Datasets and method

SWARM Measurements

- Level 1b vector and scalar measurements of Swarm A and C between **1st March 2014 and December 31st 2020** (provisional baseline 6).
- Swarm North-South 15s time spacing between measurements along the satellite orbits, following Finlay et al., (2020) and across track gradients.

CHAMP measurements

- CHAMP vector and scalar measurements from **January 2001 to September 2010** , and 15s along-track gradients.

All satellite measurements are selected during magnetic quiet days and corrected for the core and the magnetospheric fields with additional filtering by Singular Spectral Analysis independently in polar and mid latitude regions.

Near-surface data

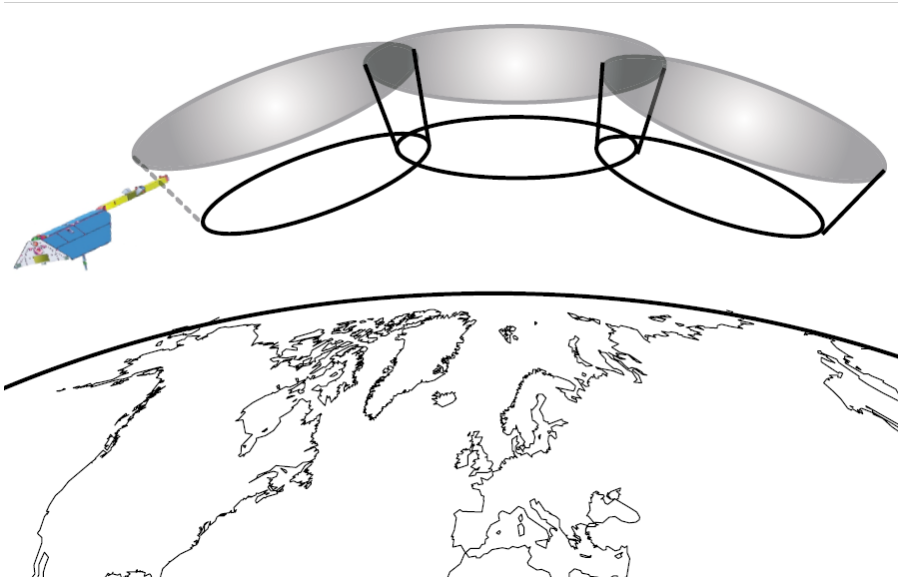
- Resampling of the WDMAM-2 grid (Lesur et al., 2015) available at 5km altitude into a 0.15×0.15 degree cell size cell size grid (15 km spacing) and transformation from the geodetic to the geocentric reference frame.

Inversion

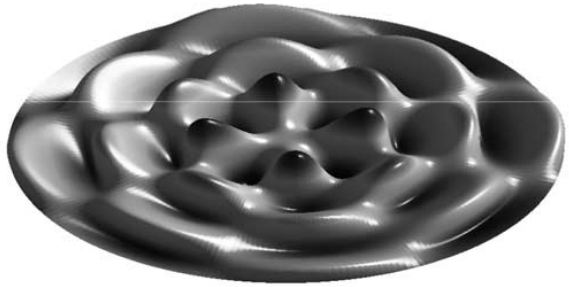
- Model parametrized by 700 independent regional models using the regional R-SCHA inversion technique to 30 km horizontal resolution (Thébault et al., 2013; Thébault et al., 2016)
- Data misfit based on Huber weights and iterative scheme, regularization of the Backus effect for regional models between +-20° geomagnetic latitudes.
- Final representation in terms of spherical harmonics up to SH degree 1100 and released to SH degree 1050.

Datasets and method

Modelling of the vector, scalar and gradient data within spherical caps and relying on regioal potential field analysis (Revised Sphericla Cap Analysis Thébault et al., 2006; Thébault et al., 2013)



a) Order m=0 and index k=5

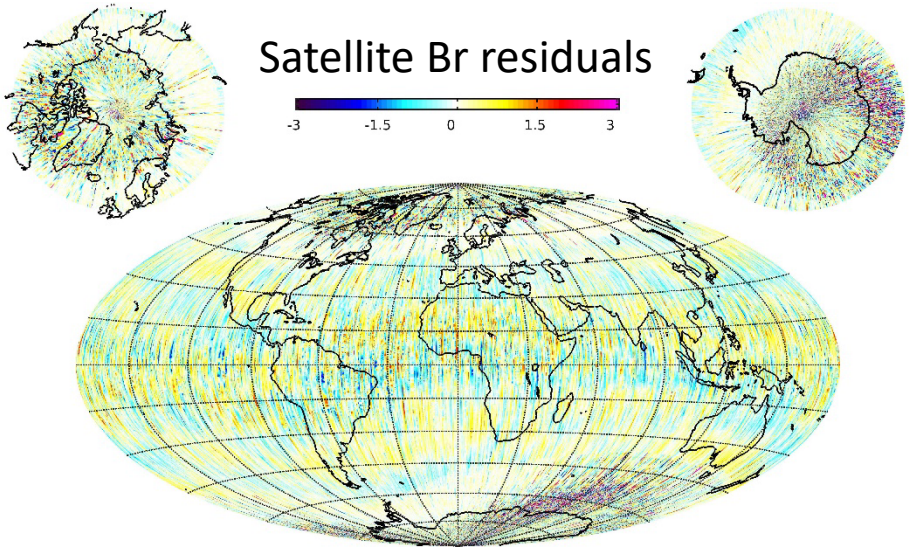


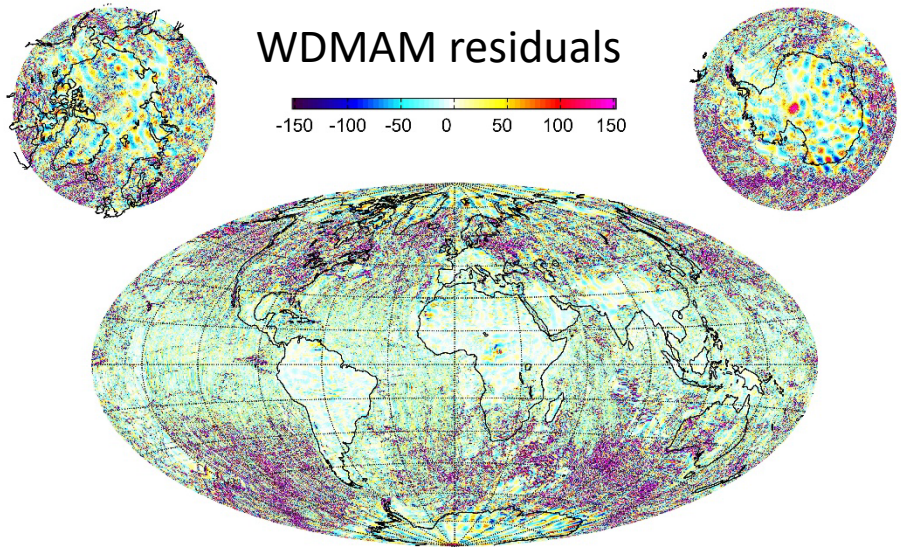
b) Order m=4 and index k=5

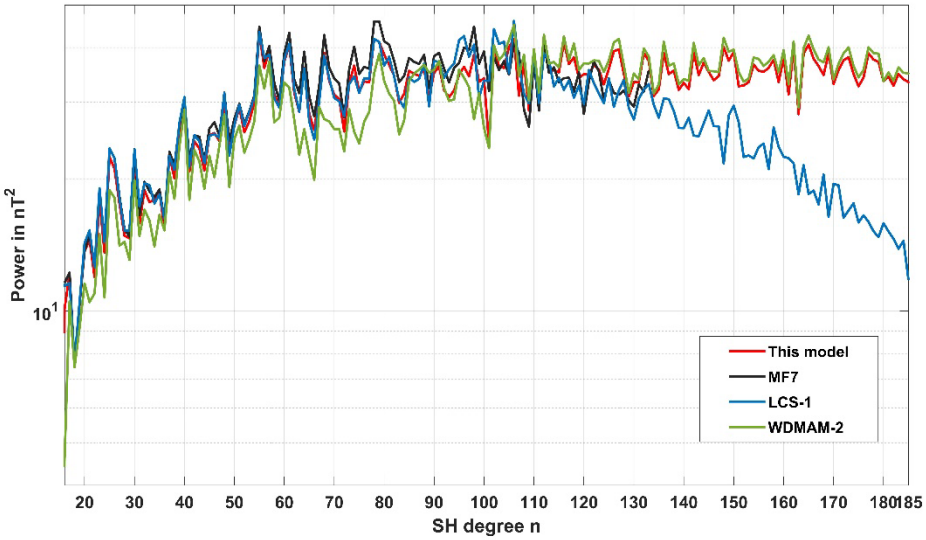
Inversion misfit in nT

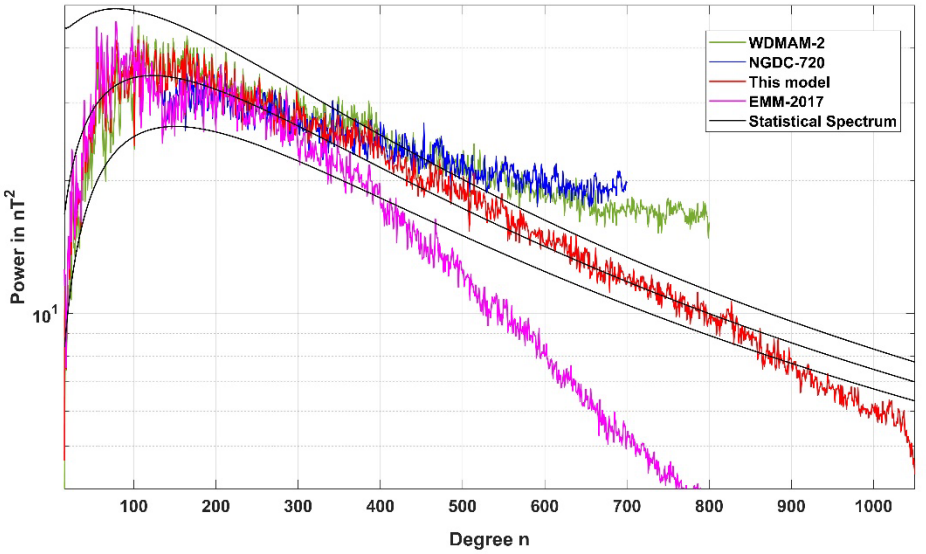
		SWARM			CHAMP			WDMAM	
	N	Mean	rms	N	Mean	rms	N	mean	rms
Fpolar (nT)	3 181 999	0.02	2.91	945 958	-0.76	4.01	588 024	-1.77	22.91
Br,polar (nT)	3 181 999	-0.03	2.43	945 958	0.11	2.58	0	N/A	N/A
Bθ.polar (nT)	3 181 999	0.11	3.58	945 958	0.24	3.71	0	N/A	N/A
Bϕ.polar (nT)	3 181 999	-0.14	3.72	945 958	0.16	3.08	0	N/A	N/A
F non-polar (nT)	4 600 571	0.01	1.2	3 045 208	-0.29	1.45	2 651 976	-2.16	18.51
Br. non-polar (nT)	4 600 571	0	0.91	3 045 208	0.11	1.23	0	N/A	N/A
Bθ. non-polar (nT)	4 600 571	0.08	1.12	3 045 208	0.12	2.14	0	N/A	N/A
Bϕ. non-polar (nT)	4 600 571	0.02	1.14	3 045 208	0.1	2.06	0	N/A	N/A
δF-AT. polar (nT)	796 122	0.01	0.47	236 490	0.01	0.52	0	N/A	N/A
δF-AT. non-polar (nT)	796 122	-0.01	0.15	761 302	0	0.34	0	N/A	N/A
δBr-AT (nT)	796 122	0	0.25	761 302	0.01	0.32	0	N/A	N/A
δBθ-AT (nT)	796 122	-0.01	0.26	761 302	-0.01	0.29	0	N/A	N/A
δBϕ-AT (nT)	796 122	-0.01	0.23	761 302	0	0.32	0	N/A	N/A
δF-EW. polar (nT)	1 762 358	0.09	0.67	0	N/A	N/A	0	N/A	N/A
δF-EW. non-polar (nT)	1 762 358	0.03	0.42	0	N/A	N/A	0	N/A	N/A
δBr-EW (nT)	1 762 358	-0.01	0.29	0	N/A	N/A	0	N/A	N/A
δBθ-EW (nT)	1 762 358	-0.02	0.33	0	N/A	N/A	0	N/A	N/A
δBϕ-EW(nT)	1 762 358	0.01	0.41	0	N/A	N/A	0	N/A	N/A
Total	**43 922 680**			**19 246 362**			**3 240 000**		

Assessment of the extended model

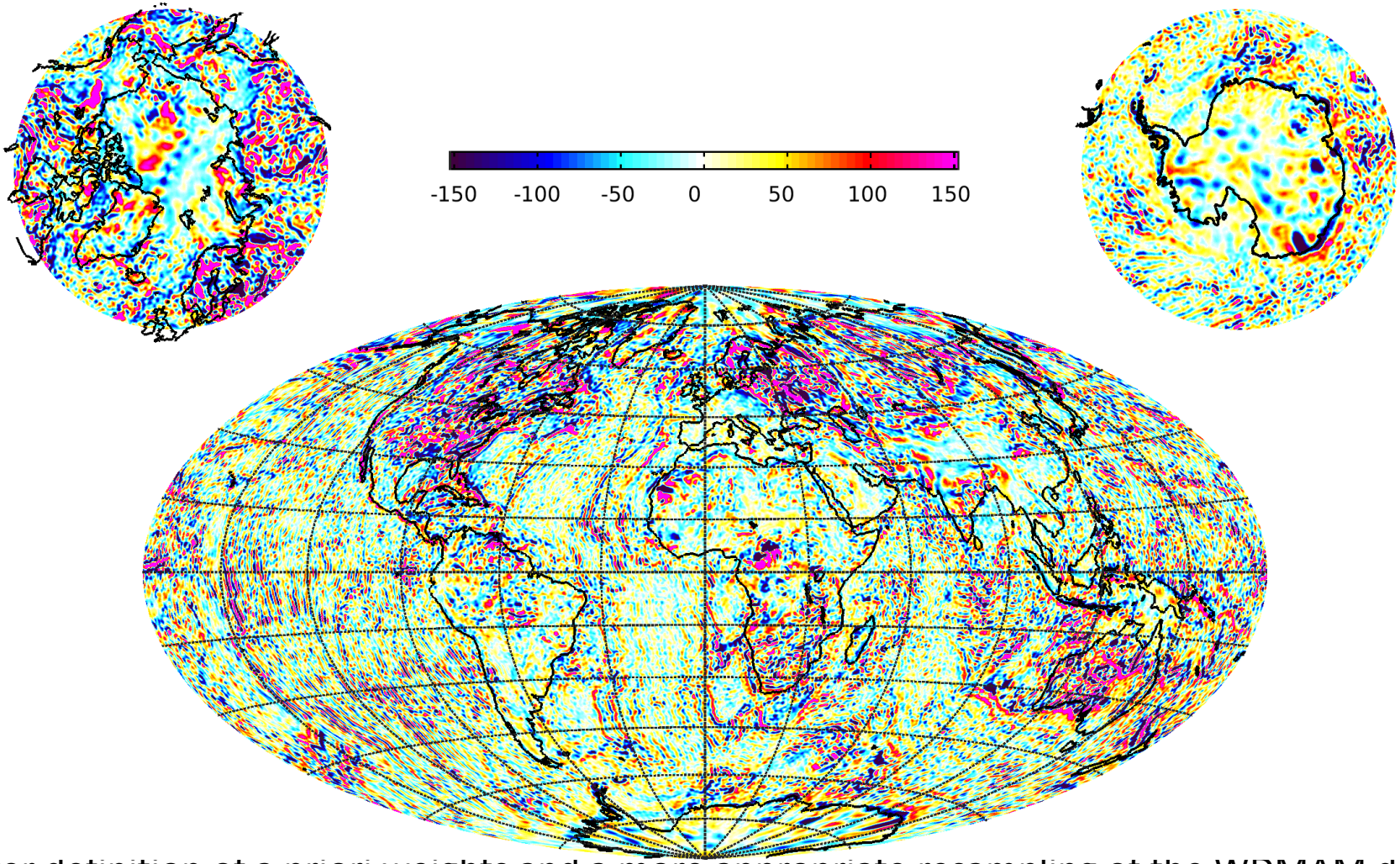






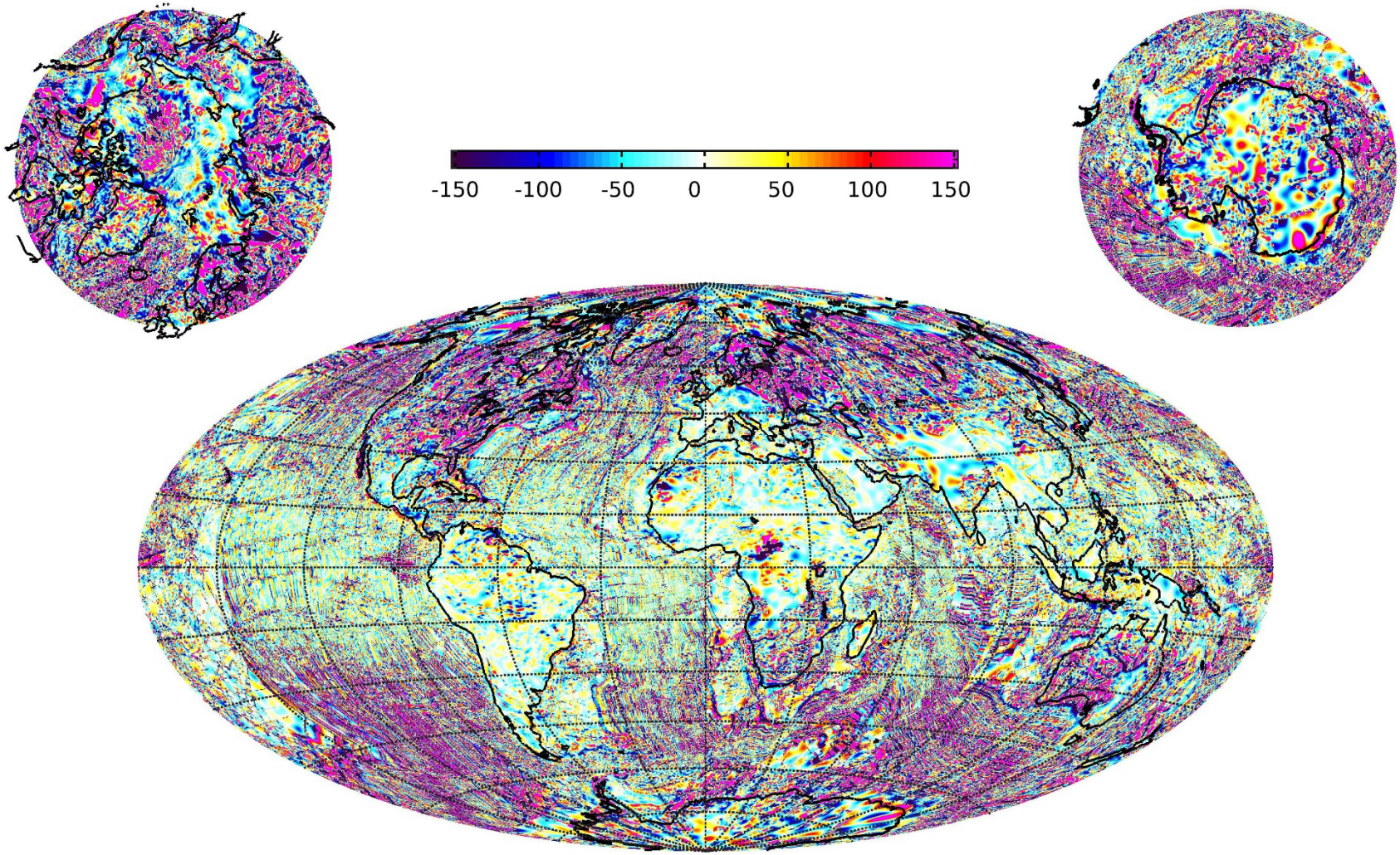


Previous generation expanded to SH degree 350 (released to SH degree 300 in July 2020)



A better definition of a priori weights and a more appropriate resampling of the WDMAM data allowed addressing some of the generation 1 numerical instabilities.

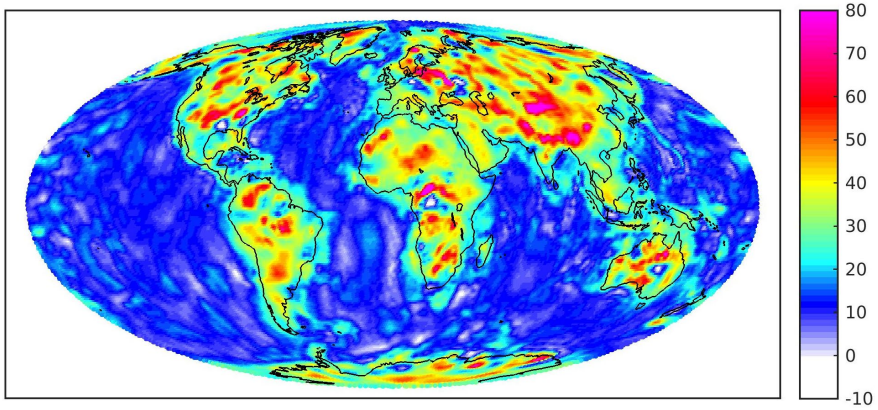
This model, expanded to SH degree 1050



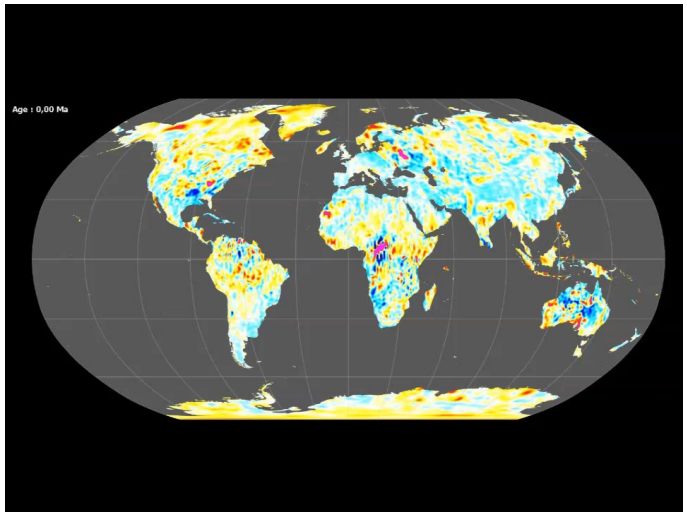
Thébault, E., Hulot, G., Langlais, B., & Vigneron, P. (2021). A Spherical Harmonic Model of Earth's Lithospheric Magnetic Field up to Degree 1050. *Geophysical Research Letters*, *48*(21), e2021GL095147.

Geophysical Inferences, some examples

1) **Hybrid statistical and deterministic inversion for the magnetic crustal thickness (in preparation)**

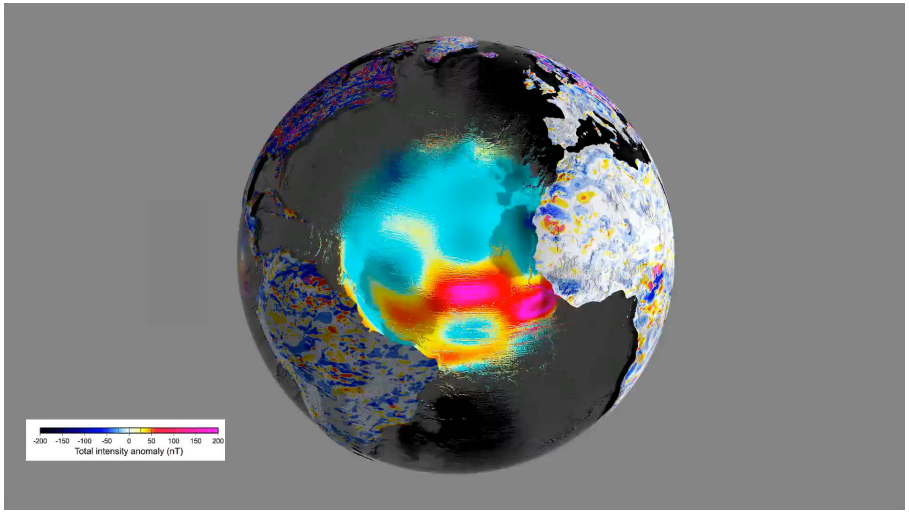


2) **Continental reconstructions**



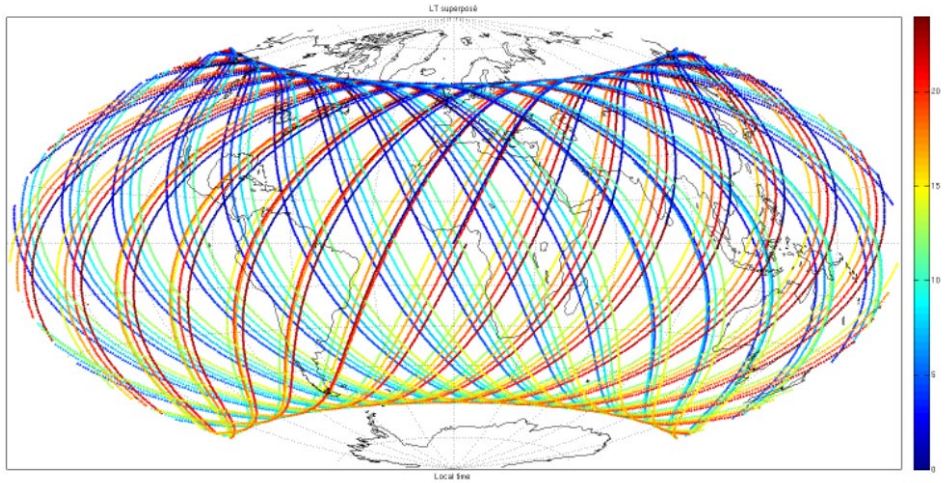
3) Better space and time windows for the core field

Investigation of the crustal field space and time contaminations at the Core Mantle Boundary (external collaborations with 4D Earth ESA project – N. Gillet et al.)

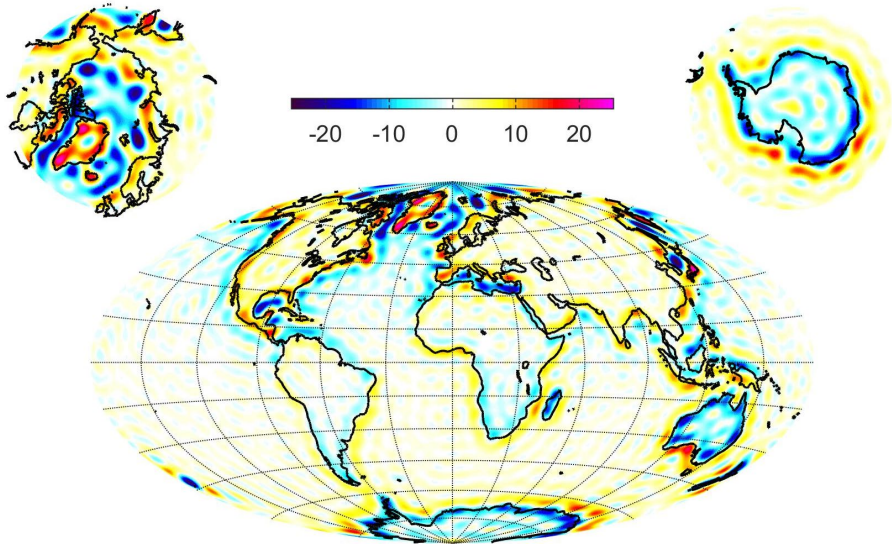


Next steps to improve the field model

- Continuing the optimization of the gradients to better highlight the geological/geophysical structures.
- Increase the internal resolution of the local basis functions (still some converging problems at very high equivalent SH degrees).
- Incorporate latest Swarm data calibration and the forthcoming WDMAM 3.0



Combine cumulated Swarm and NanoMagsat future measurements (Hulot et al., LPS22)



Radial field predicted for the Continent/ocean boundaries for n> 15

Summary

We derived a lithospheric field model from a joint combination of 8 years of vector, gradients, and scalar Swarm measurements, 9 years of vector and scalar CHAMP measurements (2001-september 2010), and a subset of the WDMAM-2 scalar anomaly grid. The SH model is currently derived to about 40 km resolution.

Current and forthcoming developments

We are currently preparing the algorithm to process NanoMagsat measurements for better internal/external field separations.

Optimization of directional gradients to extract tiny but structured signals.

The model is being transformed using analytical and statistical relationships in order to infer the **magnetic crustal thickness** (Thébault and Vervelidou, 2015; Vervelidou and Thébault, 2015), the estimated **apparent susceptibility maps**, **relationships with gravity field** models at all scales, **continental reconstructions** at all scales, **crustal field contamination** into the static and time varying core field signal at the CMB (Thébault et al., 2009; Hulot et al., 2009), incorporation of estimated errors for **geodynamo data assimilation** (Fournier et al., 2020) etc…

This magnetic crustal field model does not only provides a nice map. Its predictions can be used to characterize (or better characterize) geophysical fundamental processes from the surface down to the core.

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