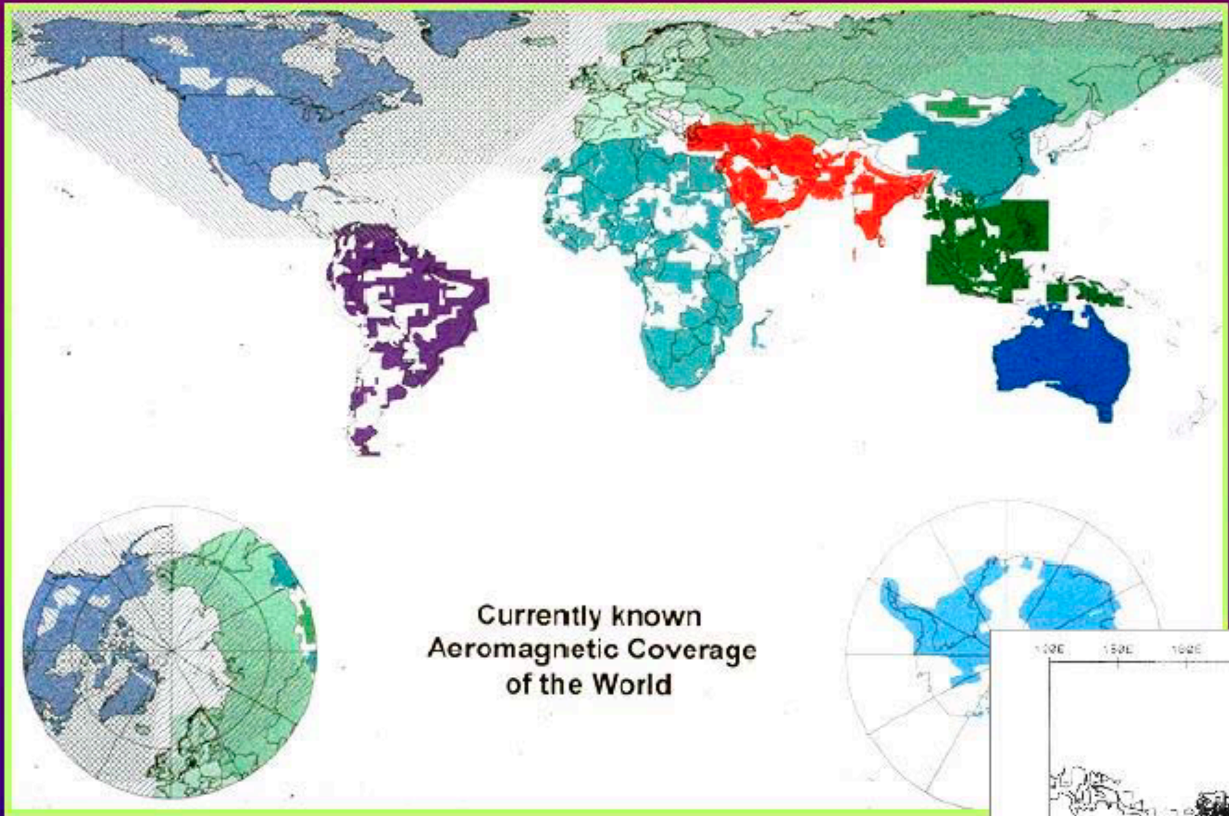
WDMAM project and Compilation of global marine magnetic anomaly data

Takemi Ishihara
Institute of Geology and Geoinformation
Geological Survey of Japan, AIST
t-ishihara@aist.go.jp

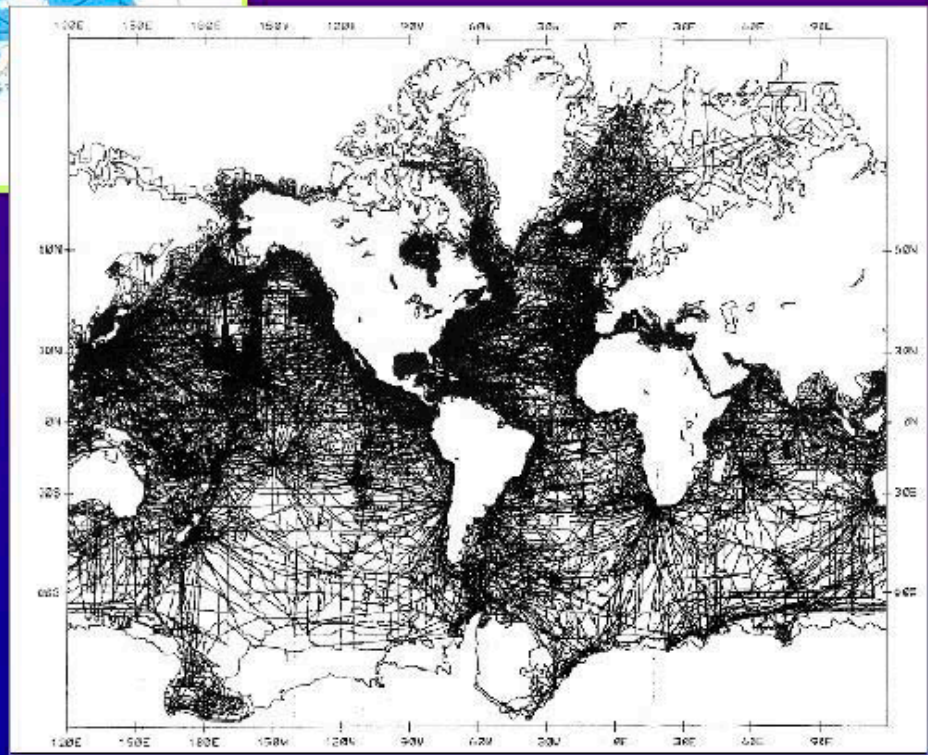
2020/01/28

World Digital Magnetic Anomaly Map (WDMAM) project



The patchwork of detailed aeromagnetic surveys over the continents...

...and the tracks of oceanographic survey vessels across the oceans...



...together make up an enormous but disparate body of data about global magnetic anomalies and, in turn, global geology.

- Reeves, Macnab & Maschenkov, 1998
EOS, Vol 79, No. 28, p 338.

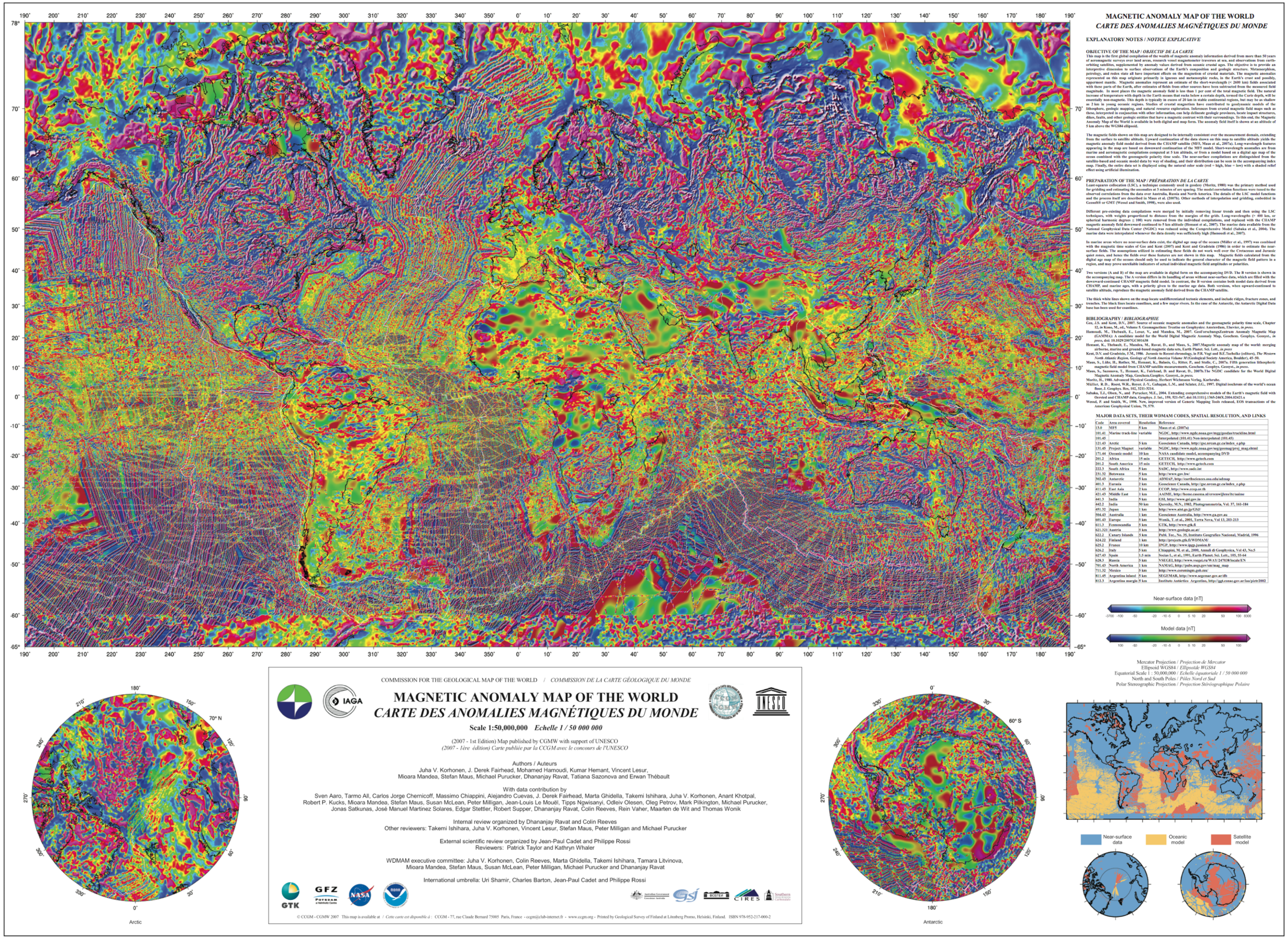
WDMAM

- The WDMAM (World Digital Magnetic Anomaly Map) is an international scientific project under the auspices of IAGA (International Association of Geomagnetism and Aeronomy) and CGMW (Commission for the Geological Map of the World), aiming to compile and make available magnetic anomalies caused by the Earth lithosphere, on continental and oceanic areas, in a comprehensive way, all over the World.
- Various kinds of aeromagnetic, marine and satellite data are merged into a global magnetic anomaly data set.
- The project started in 2003.
- The 1st version of WDMAM was published in 2007.

WDMAM, IAGA-Task Group Executives 2005-2007 (WDMAM 2007)

Juha V. Korhonen	co-chairman	juha.korhonen@gtk.fi
Colin Reeves	co-chairman, review organizer	reeves.earth@planet.nl
Dhananjay Ravat	review organizer	ravat@geo.siu.edu
Stefan Maus / Susan McLean	member	stefan.maus@noaa.gov, susan.mclean@noaa.gov
Mioara Mande	member	mioara@gfz-potsdam.de
Michael Purucker	member	purucker@ geomag.gsfc.nasa.gov
Takemi Ishihara	member	t-ishihara@aist.go.jp
Tamara Litvinova	member	tamara_litvinova@vsegei.sp.ru
Peter Milligan	external advisor	peter.milligan@ga.gov.au
Marta Ghidella	external advisor	mghidella@dna.gov.ar

World Digital Magnetic Anomaly Map project
1st version of world map published in 2007



WDMAM Version 2

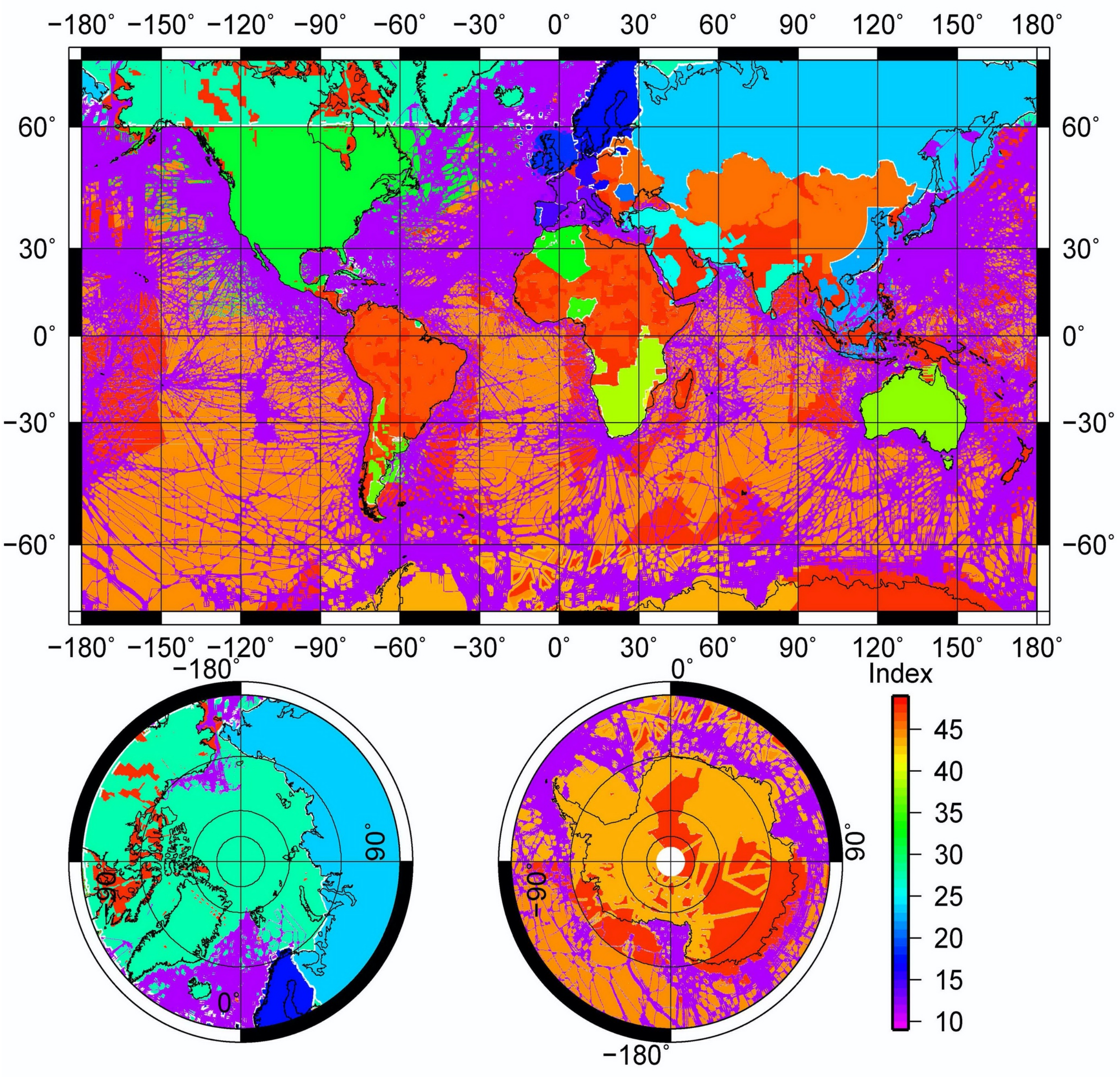
- The 2nd version was published in 2015.
  WDMAM Task Force: J. Dyment (chair), M. Catalan (co-chair),
  A. de Santis, M. Hamoudi, T. Ishihara, J. Korhonen, V. Lesur,
  T. Litvinova, J. Luis, B. Meyer, P. Milligan, M. Nakanishi, S. Okuma,
  M. Pilkington, M. Purucker, D. Ravat, E. Thebault

The compiled map (jpeg format) and grid data set are freely available at http://www.wdmam.org.

Grid data set 3' x 3' (0.05˚ x 0.05˚, about 5 km interval) grid

- Oceanic areas at altitude of 0 km
  marine track line data + magnetic anomaly model
- Continental areas at altitude of 5 km
  merging of various kind of data sets
- Long wavelength components (n=16 to 100) from satellite data
- Satellite data where no aeromagnetic and marine data are available

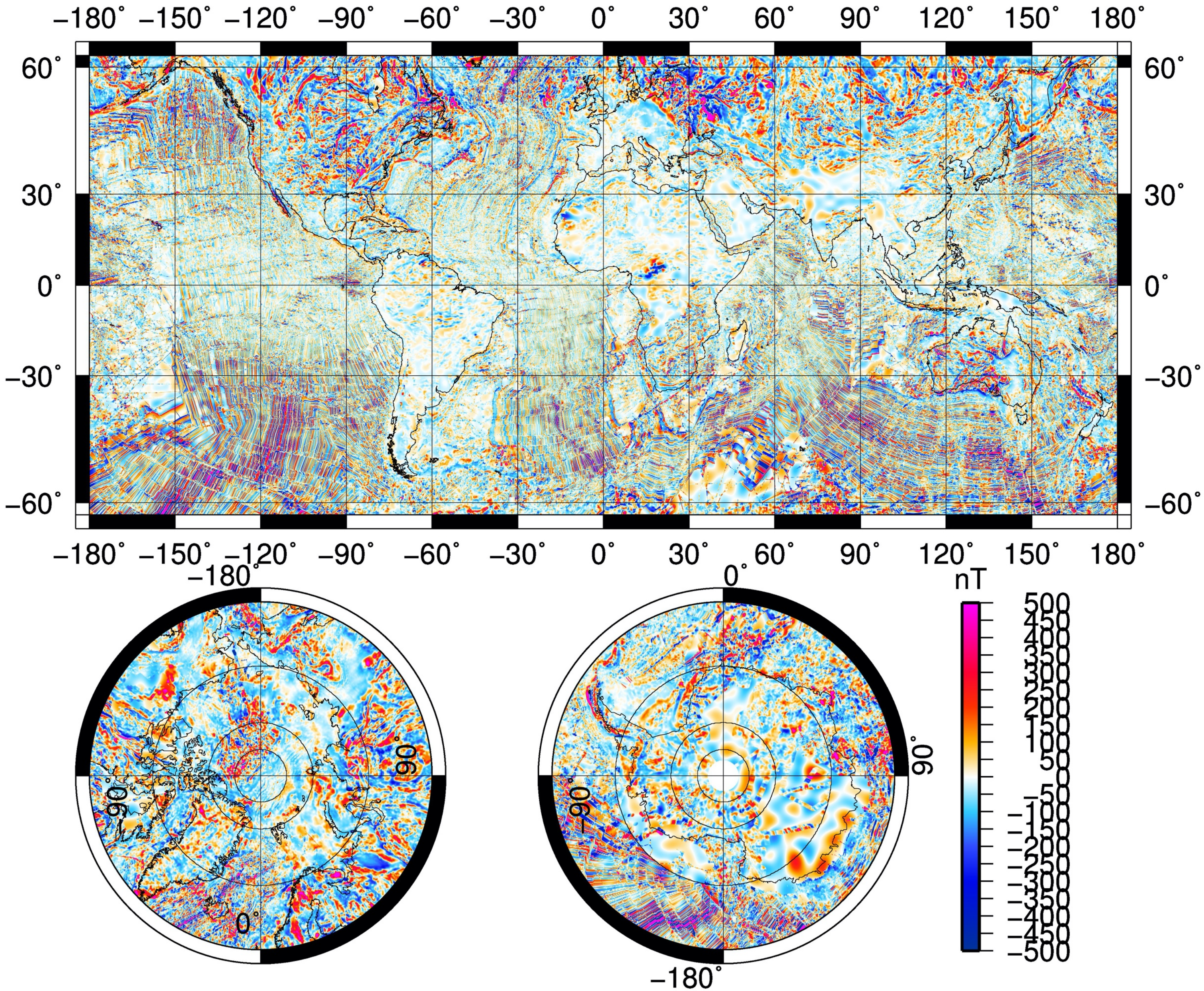
Data sets 11 to 47 used in WDMAM version 2.0



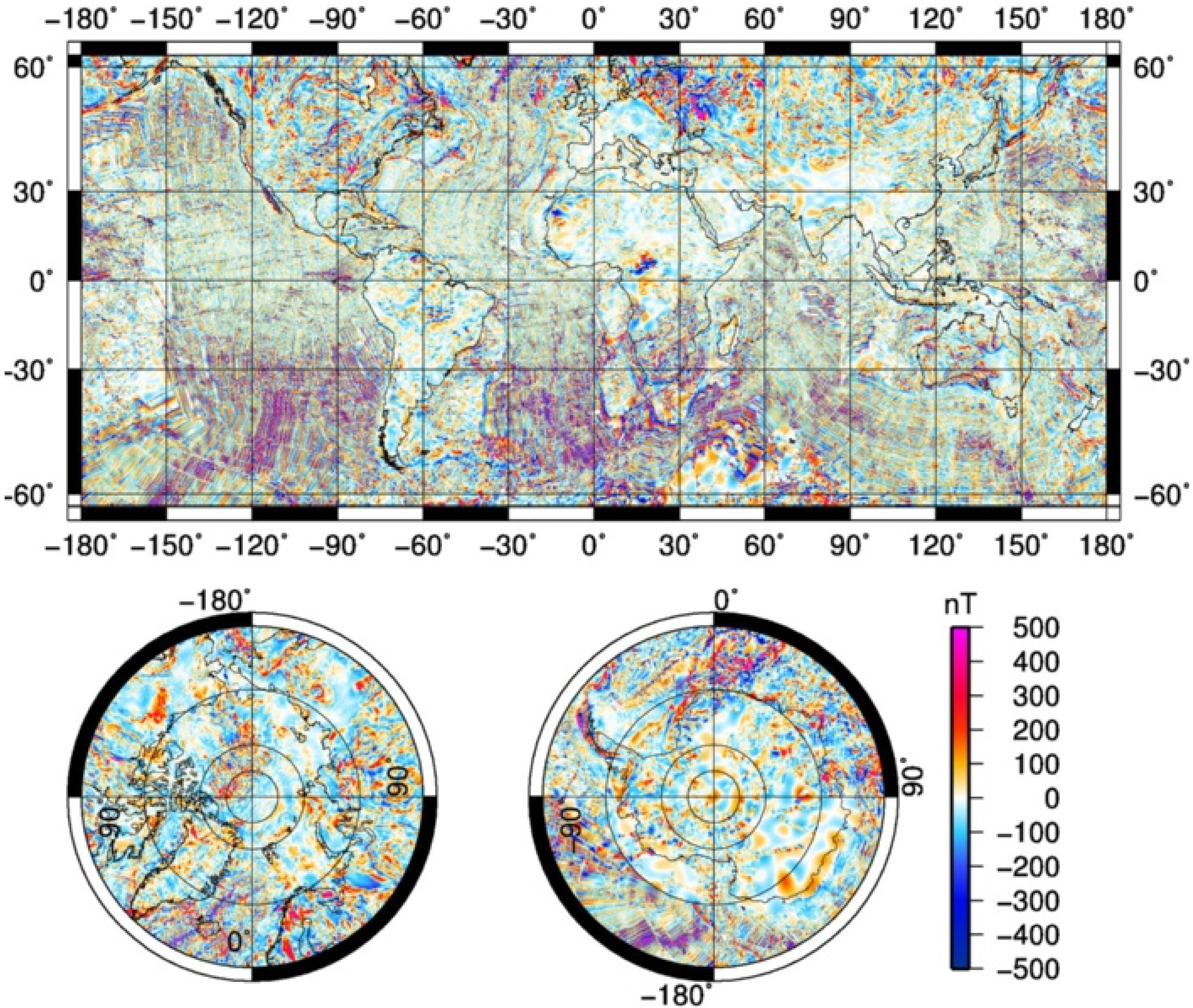
11	Marine data set
12	France
13	Italy
14	Spain
15	Germany
16	Austria
17	Fennoscandia compilation
18	UK
19	Portugal
20	Romania
21	Japan
22	East Asia
23	Russia
24	Djibouti
25	Middle East
26	India
27	Circum Arctic Compilation
28	Guadeloupe
29	French Guiana
30	Bahama/Cuba
31	Nure/Namag
32	Algeria
33	Morroco
34	Nigeria
35	Argentina Shelf
36	Argentina Inland
37	Australia
38	South African Compilation
39	Uganda
40	Mozambique
41	SaNaBoZi (Compilation)
42	Acad_Vernadsky
43	Admap (Compilation)
44	Marine model
45	WDMAM 2007 (grid8)
46	Compilation Getech
47	GRIMM_L120

WDMAM version 2.0

Lesur et al. (2016)



WDMAM divided by main field strength/45,000 nT



Continents - mainly induced magnetization

Large anomalies
Siberia, North America, Australia, South Africa

Smaller anomalies
Western Europe, China, Central to north Africa, South America
(partly due to lack of detailed data)

Contrast at the Tornquist-Teisseyre line

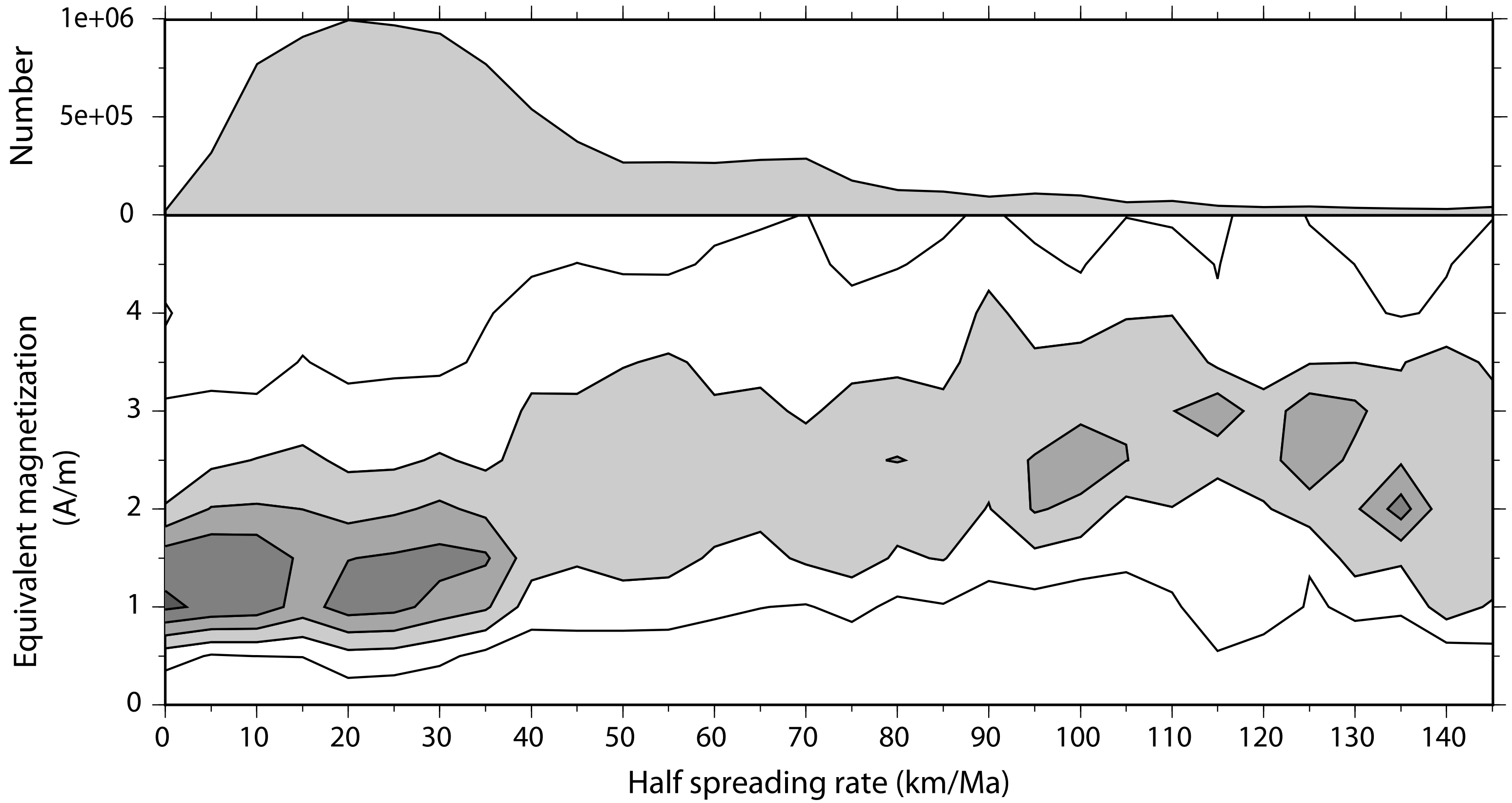
After Lesur et al. (2016)

Oceanic area model - Equivalent magnetization

after Dyment et al. (2015)

(1) about twice stronger for areas formed at fast spreading rate
(2) decreases significantly during the first 10 to 15 Ma,
and slowly increases from 20 to 70 Ma.

Equivalent magnetization versus spreading rate



Equivalent magnetization versus age

after Dyment et al. (2015)

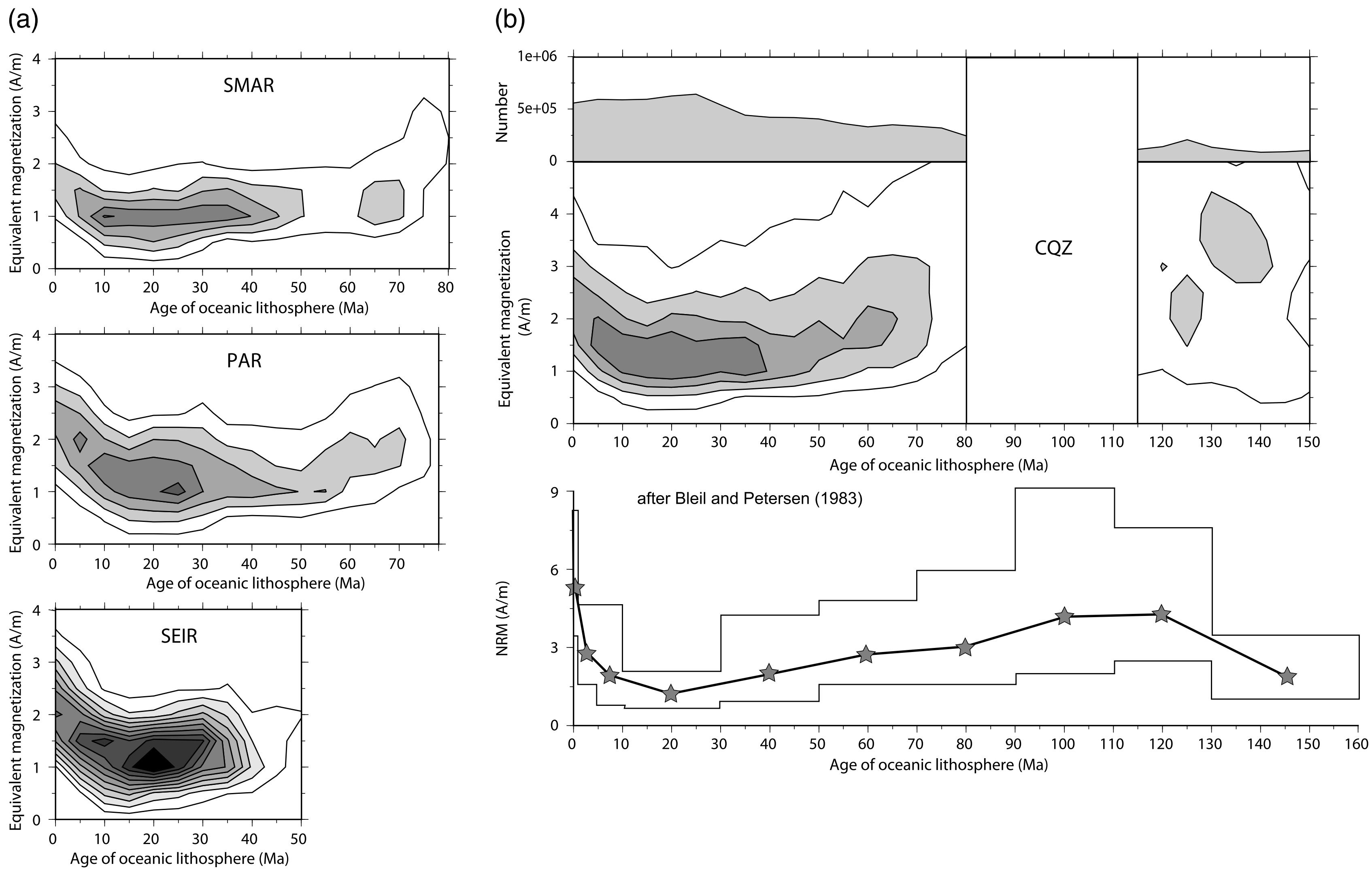


Fig. 3. Equivalent magnetization (assuming a 1 km-thick magnetized source layer mimicking the top of the basement) versus age of the oceanic lithosphere. See text for details on plot constructions. a) For selected areas, not normalized, from top to bottom: the southern Mid Atlantic Ridge and flanks (SMAR, contours every 6000 samples), the Pacific–Antarctic Ridge and flanks (PAR, contours every 8000 samples), and the Southeast Indian Ridge (SEIR, contours every 8000 samples). b) For all dated oceanic areas, normalized for each age to the number of measurements (top), contoured every multiples of 3% (medium), compared to the Natural Remanent Magnetization (NRM) measured on drilled samples (bottom; after Bleil and Petersen, 1983: stars and thick line, average values; thin lines, uncertainties).

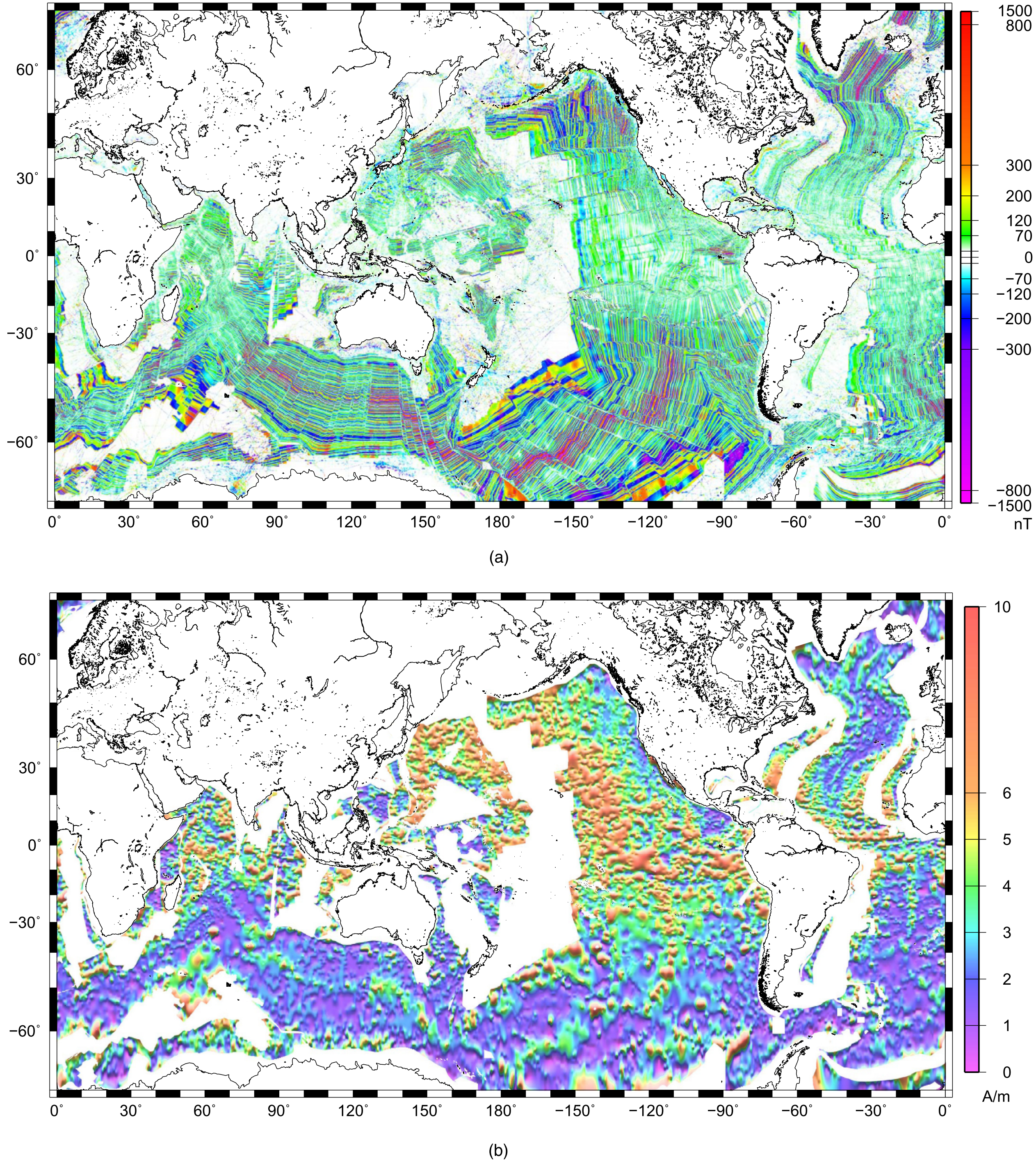


Fig. 2. Final products of our analysis as defined in Fig. 1. (a) The World Digital Magnetic Anomaly Map version 2 at sea level and (b) the equivalent magnetization (assuming a 1 km-thick magnetized source layer mimicking the top of the basement) over oceanic areas.

Oceans – mainly
remanent magnetization

Marine magnetic anomaly model
Magnetization vector
(10 A/m, 1km thick layer
beneath top basement assumed)
from ocean floor age,
geomagnetic polarity time scale
& finite rotation for each plate

Adjust equivalent magnetization
to fit the amplitude variations of
model and real data on sliding
windows of 100 to 400 km
along each track line

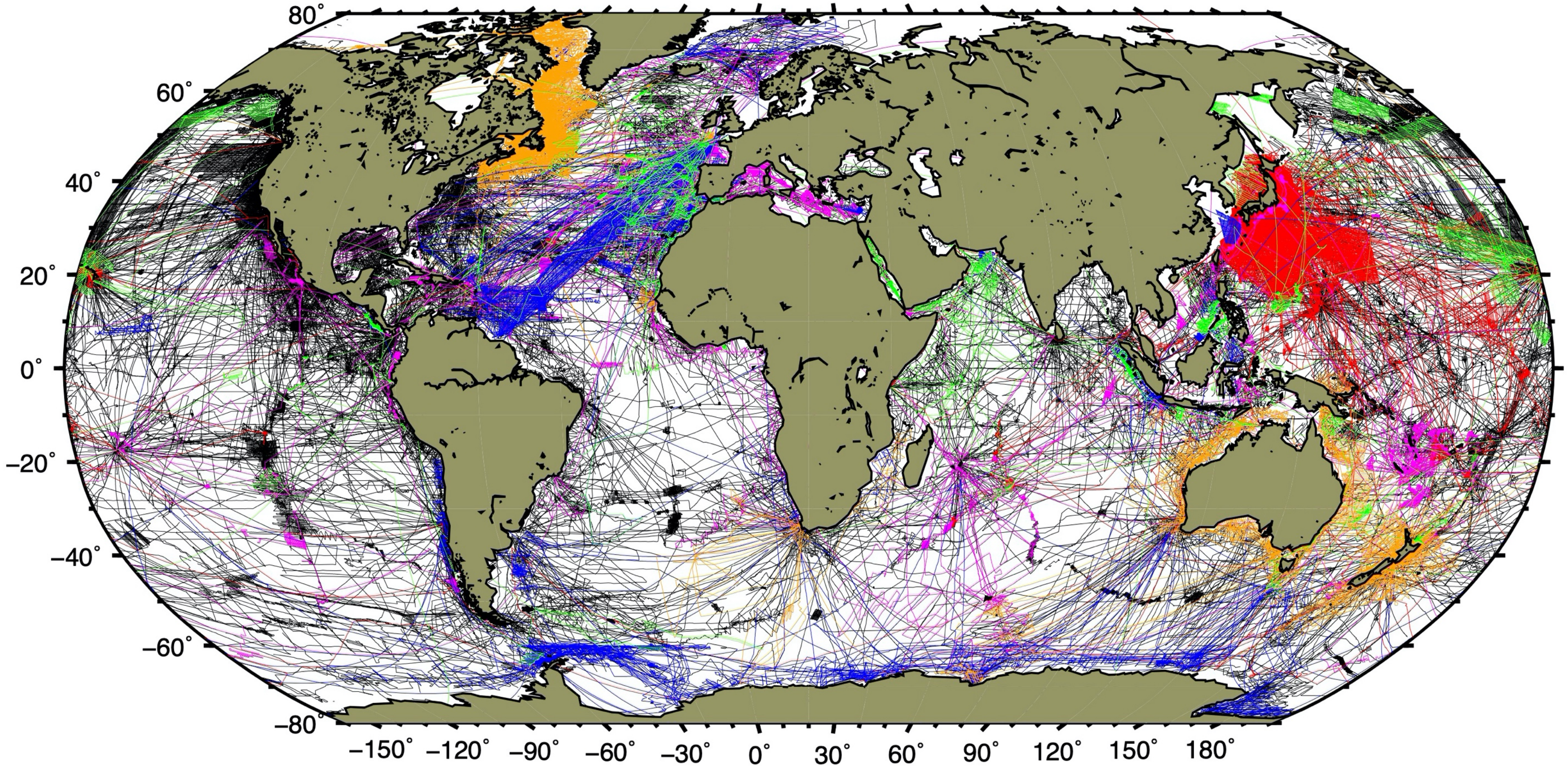
After Dyment et al. (2015)

Compilation of global marine magnetic anomaly data

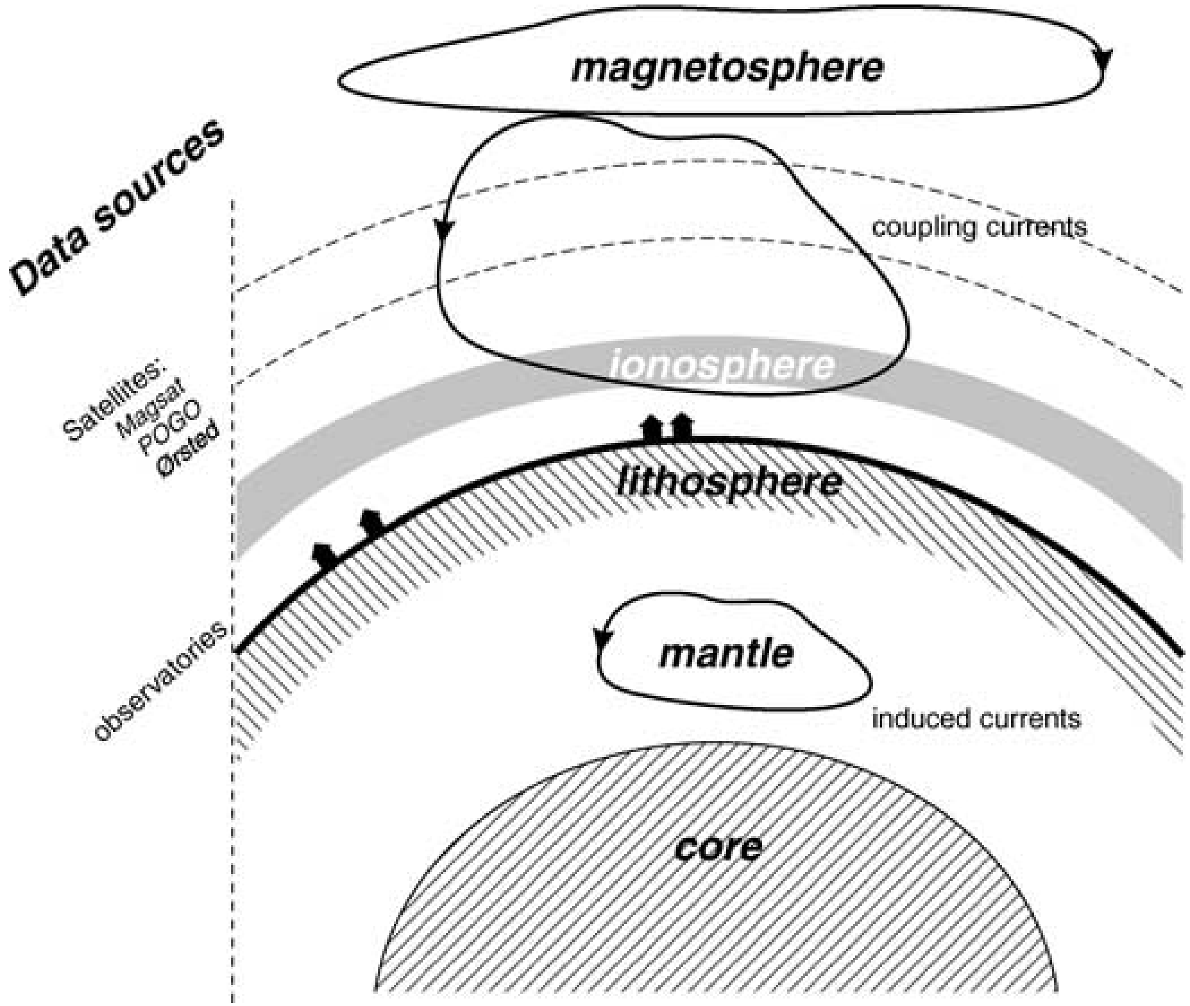
Collected marine data

	Cruises	Records
GEODAS 5.0.10 (Quesnel et al., 2009)	2245	19072440
Global2019	3453	36679884

	Cruises	Records		Cruises	Records		Cruises	Records
US	2102	18164546	Japan	485	4605716	ADMAP I	85	1651670
Canada	93	2787816	France	277	3822592	Netherlands	69	816390
Australia	69	1927098	UK	99	1059249	Spain	11	118938
New Zealand	100	759532	Germany	31	829982	China	3	8798
South Africa	17	58475	Russia	10	53492	Israel	2	15590



3 major components of geomagnetic field



(after Sabaka et al., 2002)

Main field

Self-excited dynamo

in the liquid outer core

External field

Currents in the ionosphere

and magnetosphere

Anomaly

Lithospheric Magnetization

Sources and variations of the 3 components of geomagnetic field

Component	Source	Spatial Variation	Temporal Variation
Main field	Outer core	Long wavelength Spherical harmonic degree ~< 15	Secular variation (~> 1 year)
External fields	Ionosphere & Magnetosphere	Long wavelength	1 hour to 1 year
Anomalies	Lithosphere	Short wavelength Spherical harmonic degree ~> 16	No variation

New leveling method

Ishihara (EPS, 2015) modified

to correct temporal variation due to external field

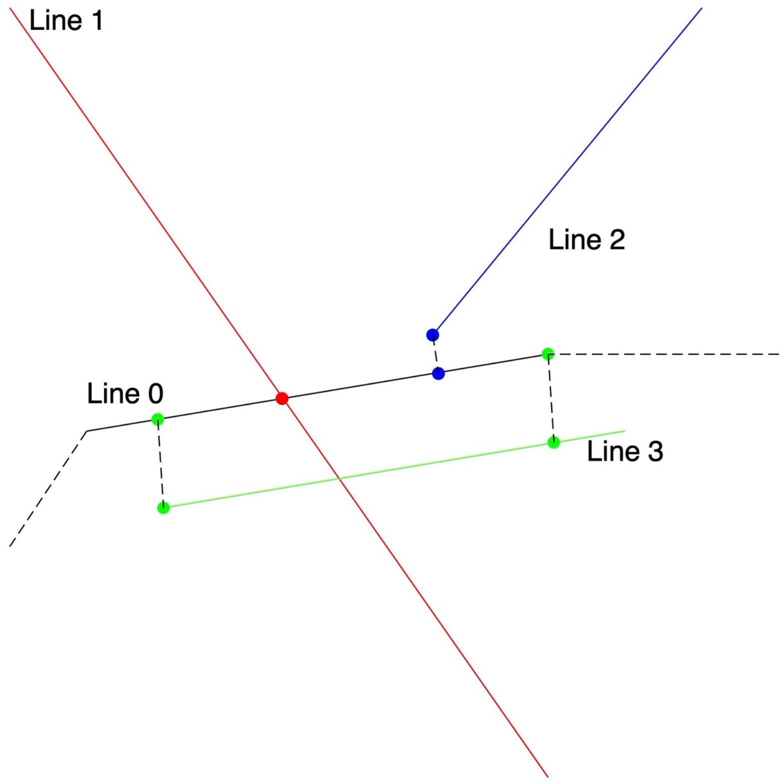
Ship's track is divided into straight lines. Crossover point or nearest points between each line pair is considered. Combination of weighted differences from neighboring line values and low-pass filtering. Weight of the anomaly difference between the nearest points is given as function of their distance, and the leveling correction is obtained by low-pass filtering of the weighted anomaly differences along the ship's track.

$$\mathbf{c_i = \sum_k G(t_k - t_i) \sum_j W(d_{jk}) (c_j + a_k - a_j)/\{\sum_k G(t_k - t_i) \sum_j W(d_{jk})\}}$$

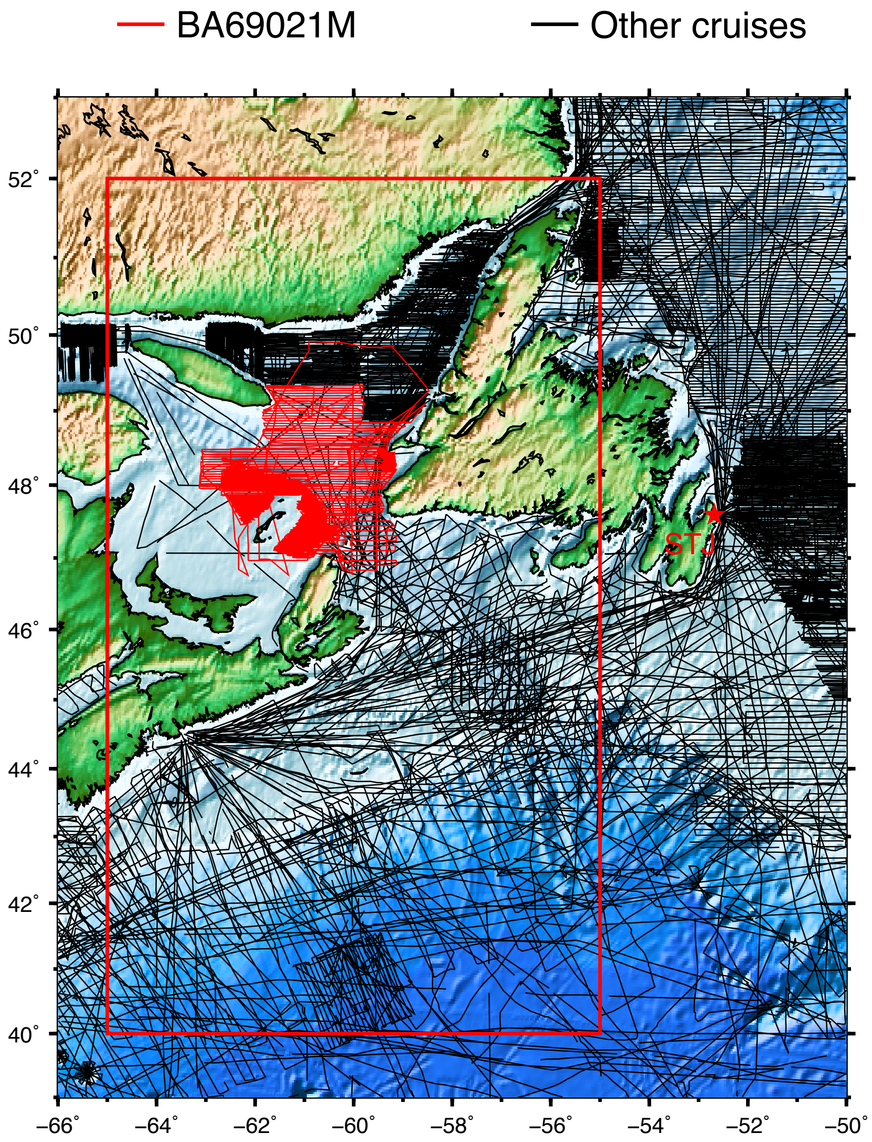
$\mathbf{W(d_{jk})}$: **weight function of distance between j-th and k-th points**

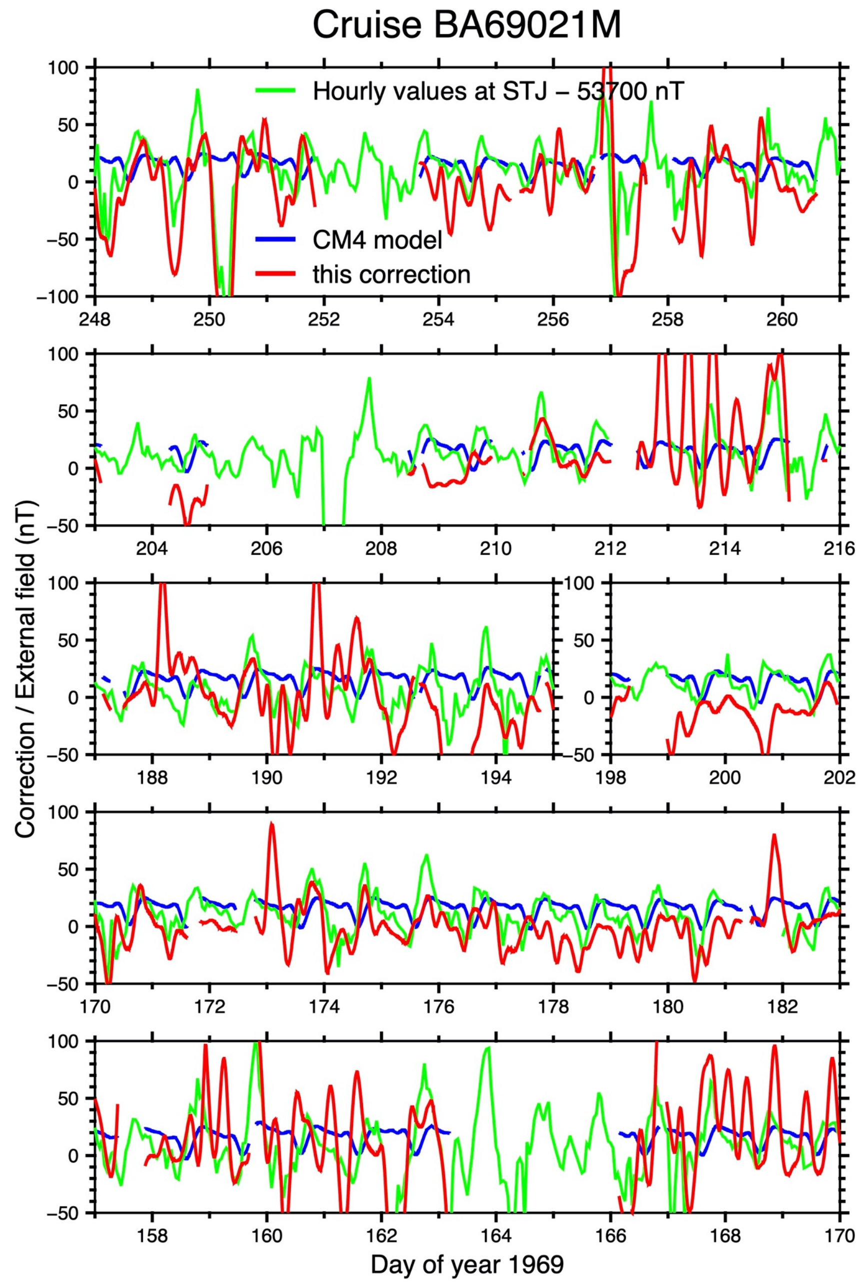
$\mathbf{G(t_k - t_i)}$: **Gaussian filtering function of time difference between k-th and i-th points**

Correction $\mathbf{c_i}$ is obtained by iterated calculation.

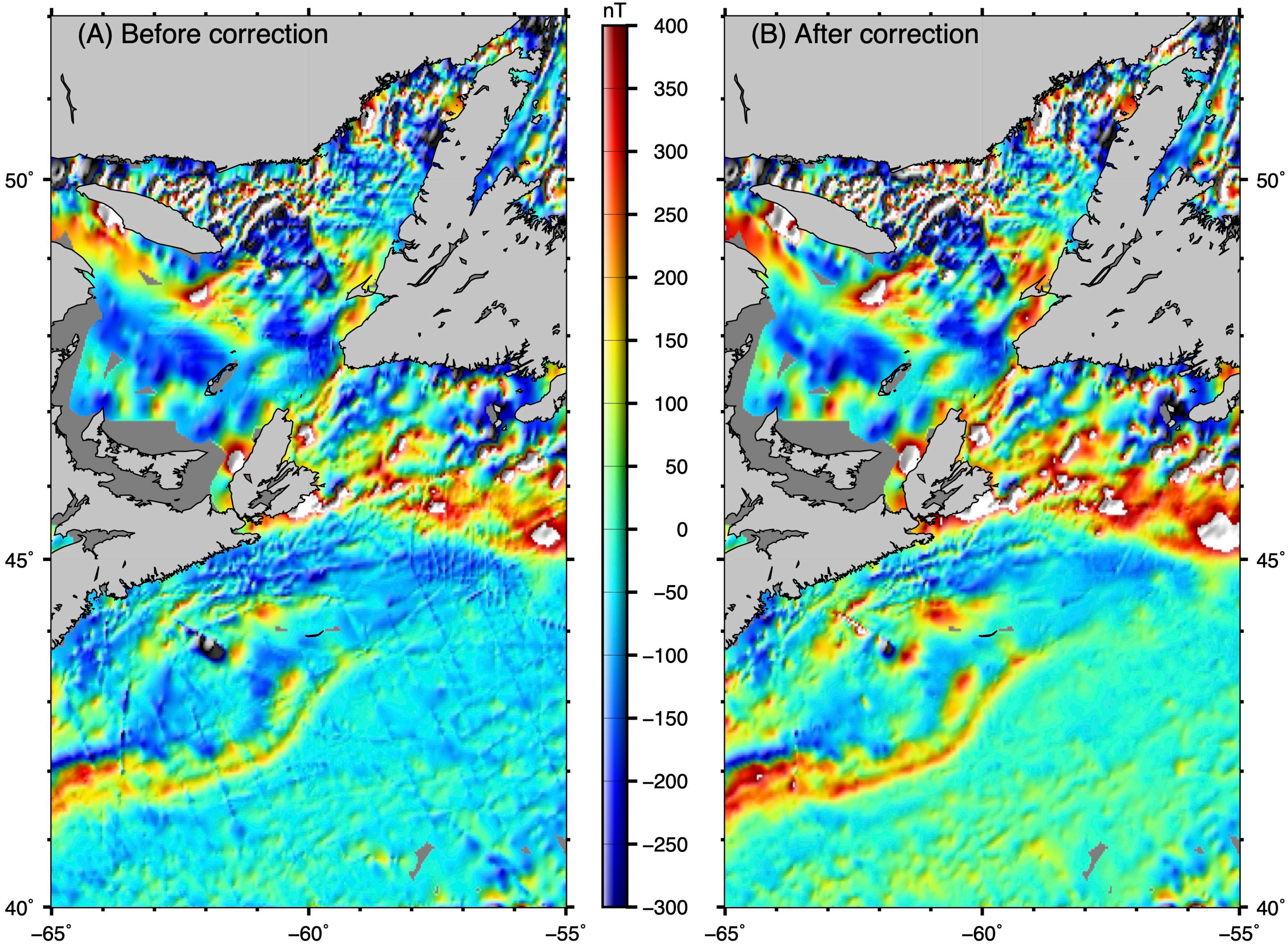


Gulf of St. Lawrence

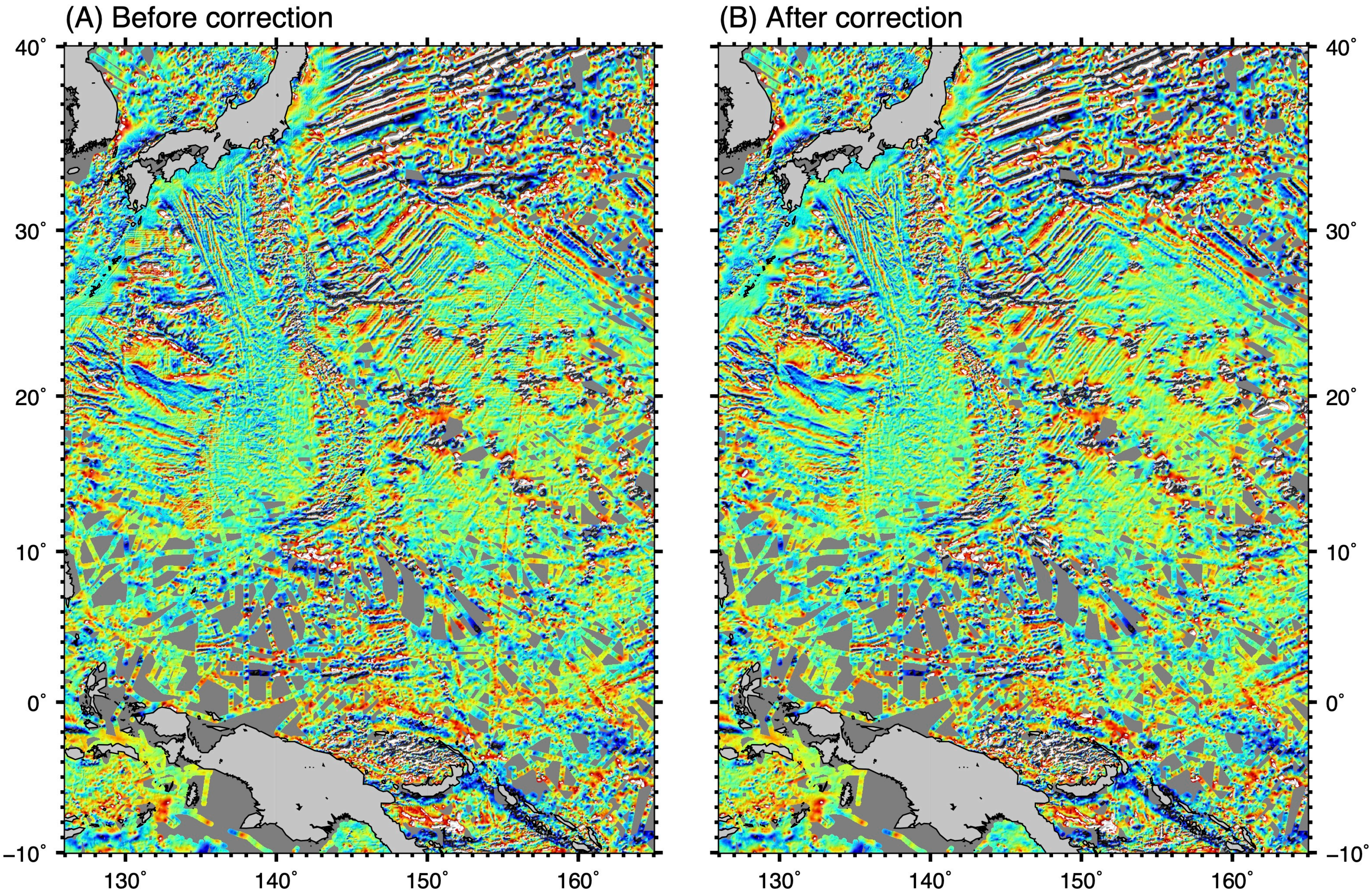




Gulf of St. Lawrence, NW Atlantic Ocean

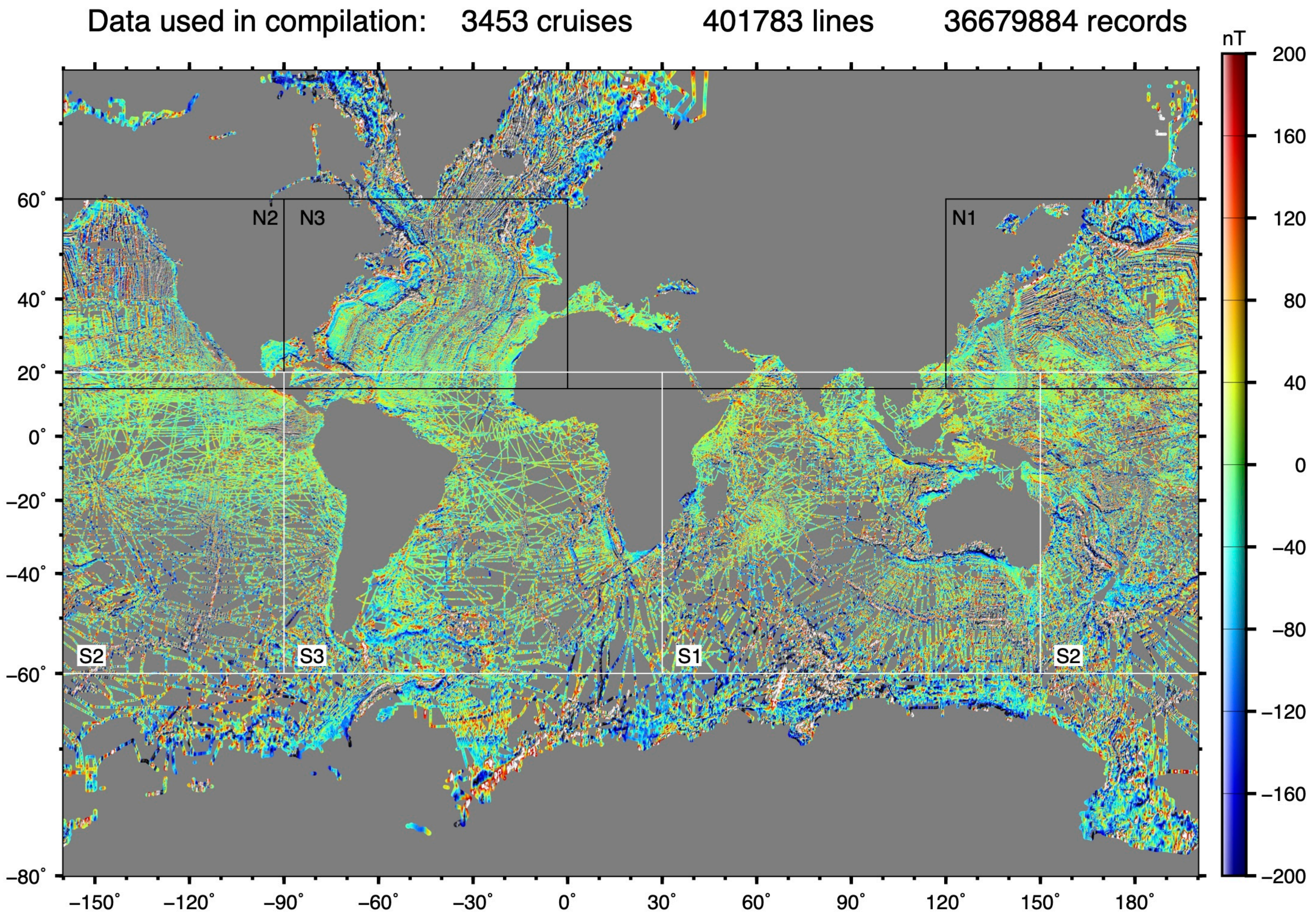


Philippine Sea and NW Pacific Ocean

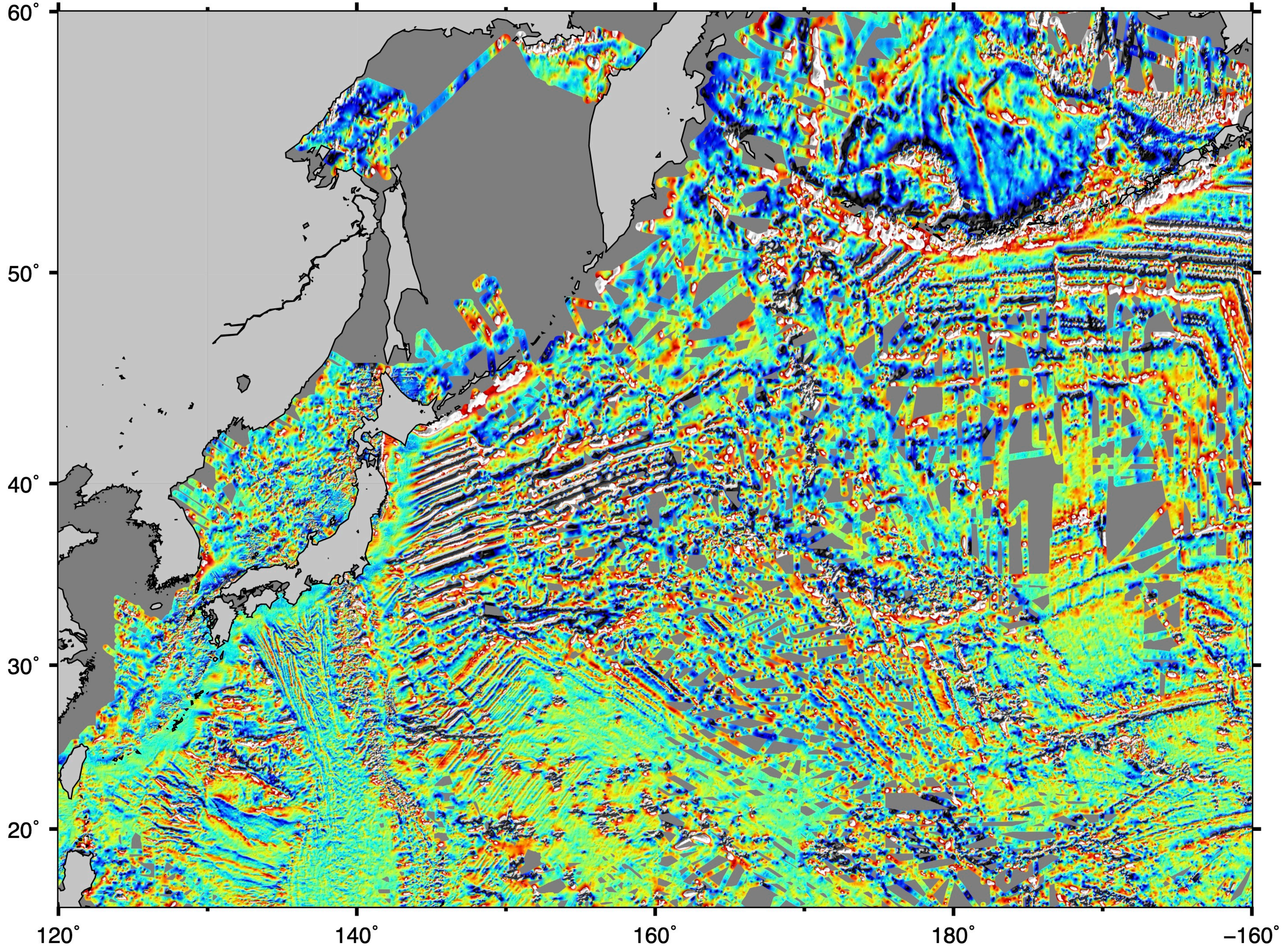


Global marine magnetic anomaly map after leveling correction

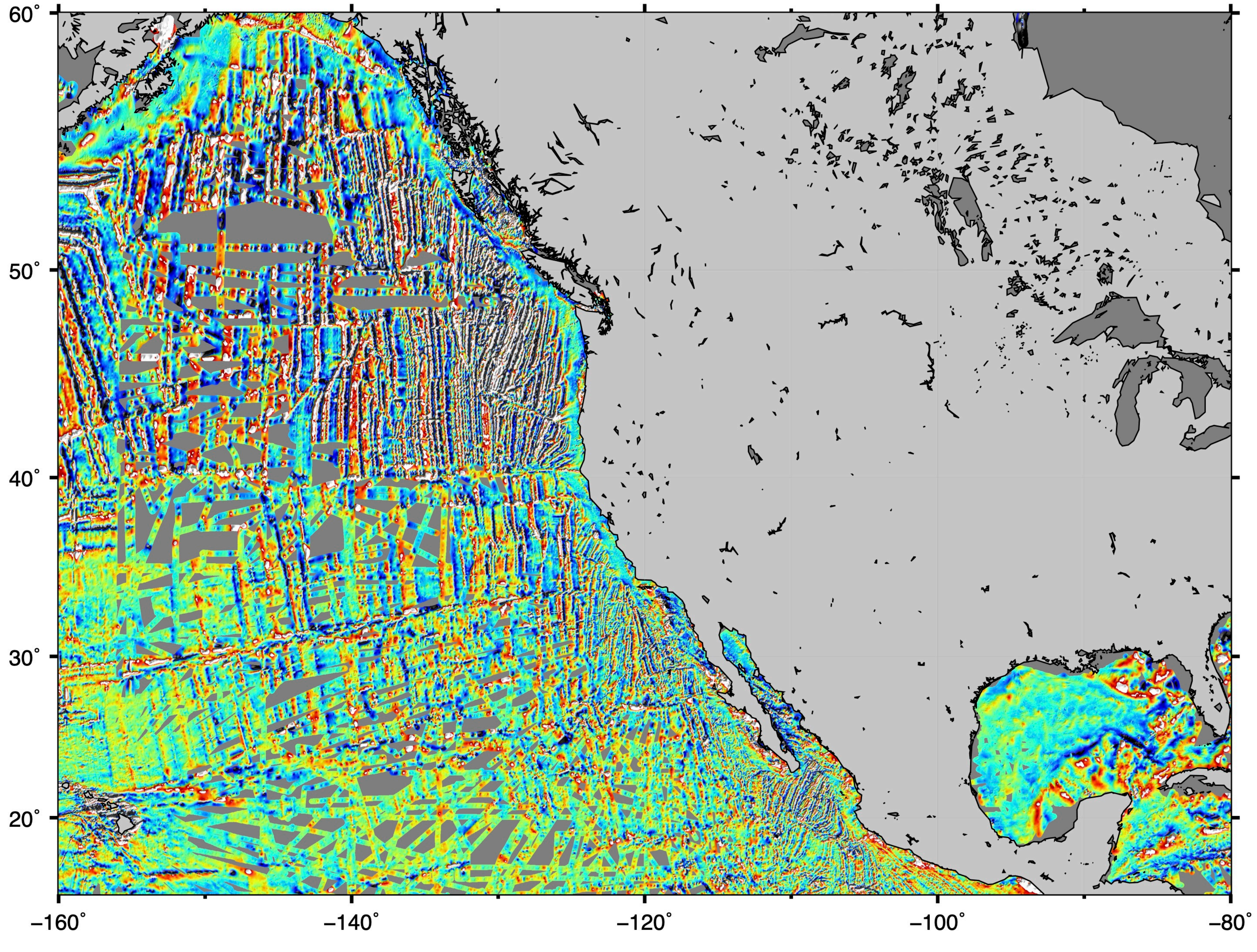
rms COD: 79.5 nT (before correction)
45.6 nT (after correction)
Total NO of CODs =806466



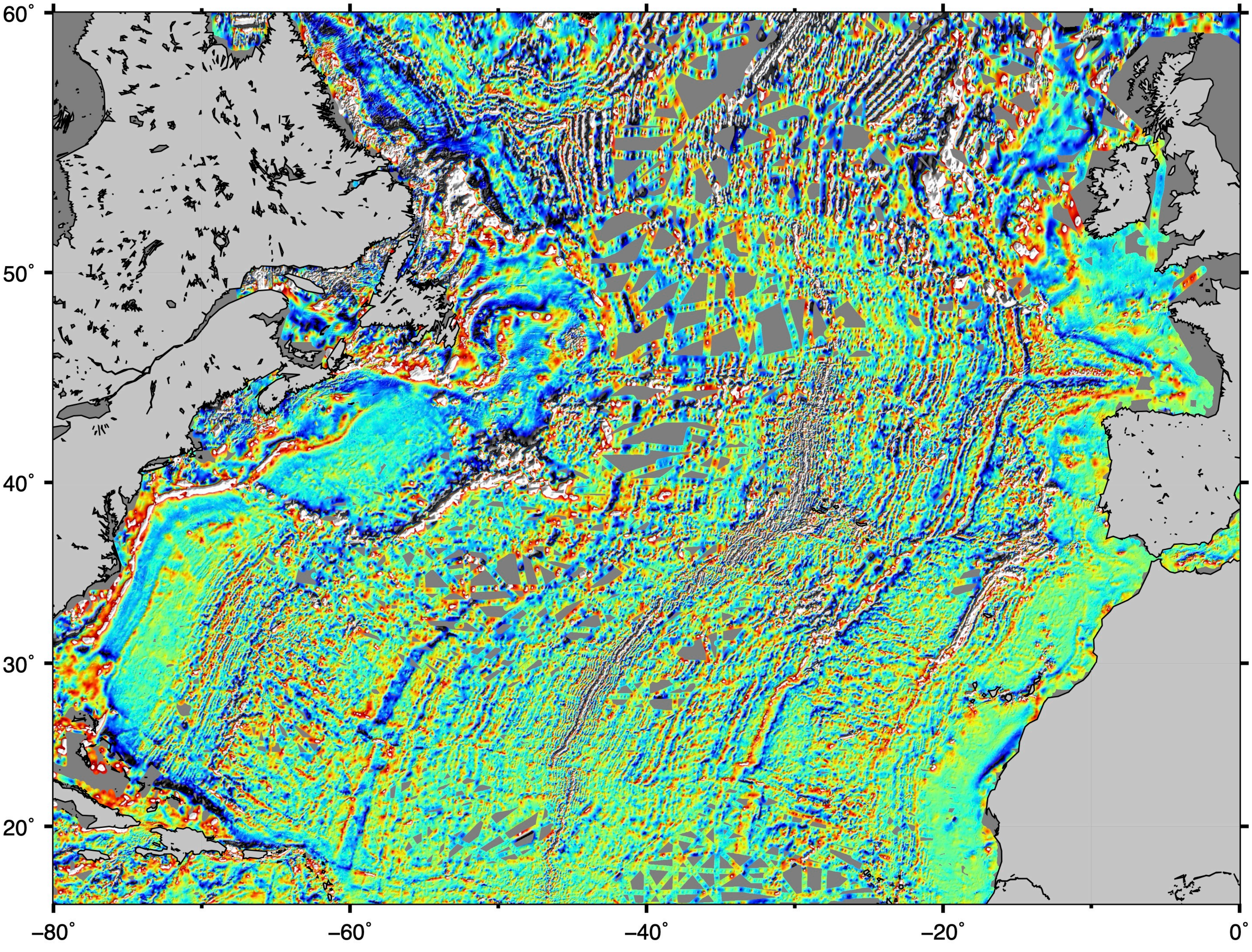
N1: Northwest Pacific Ocean



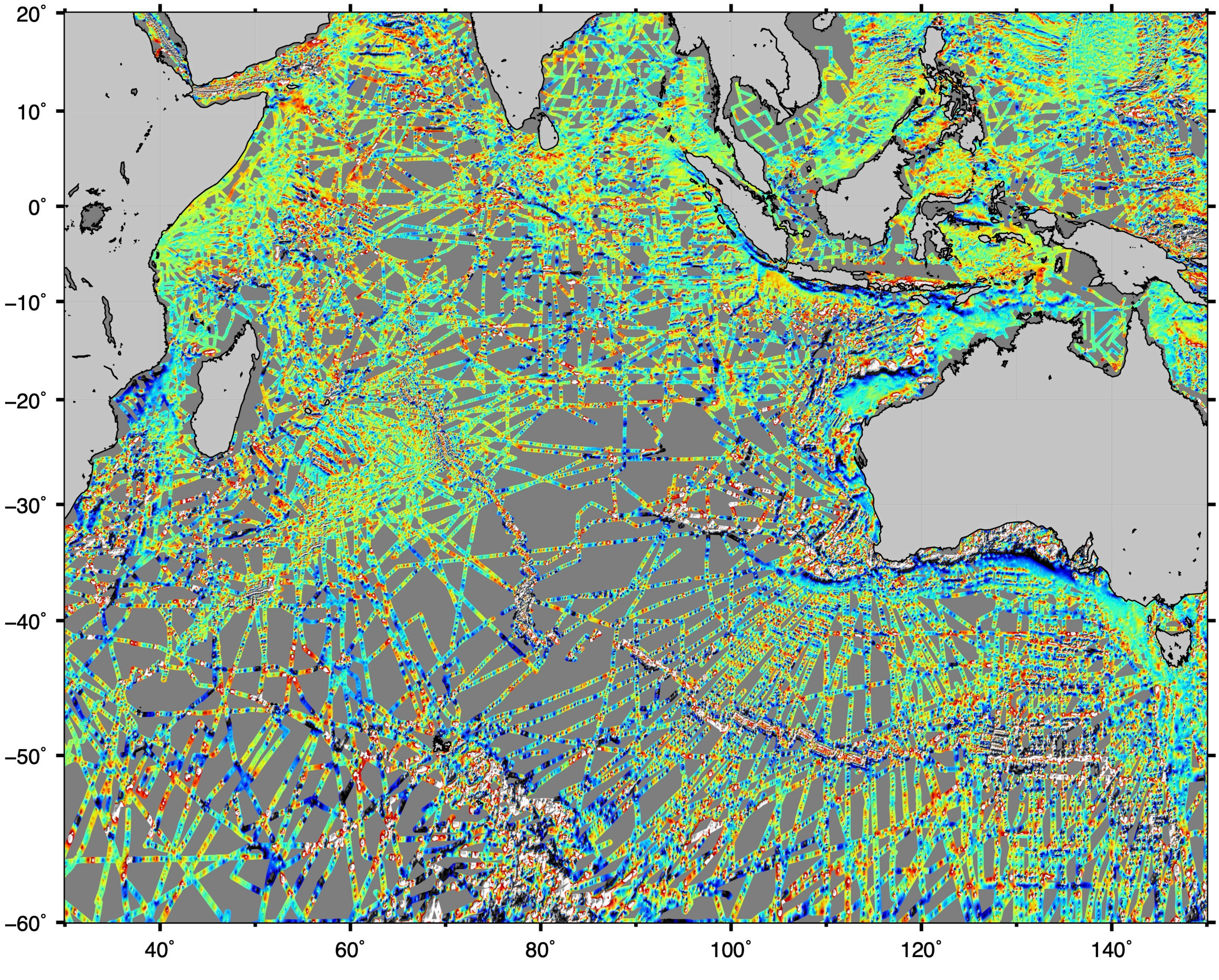
N2: Northeast Pacific Ocean



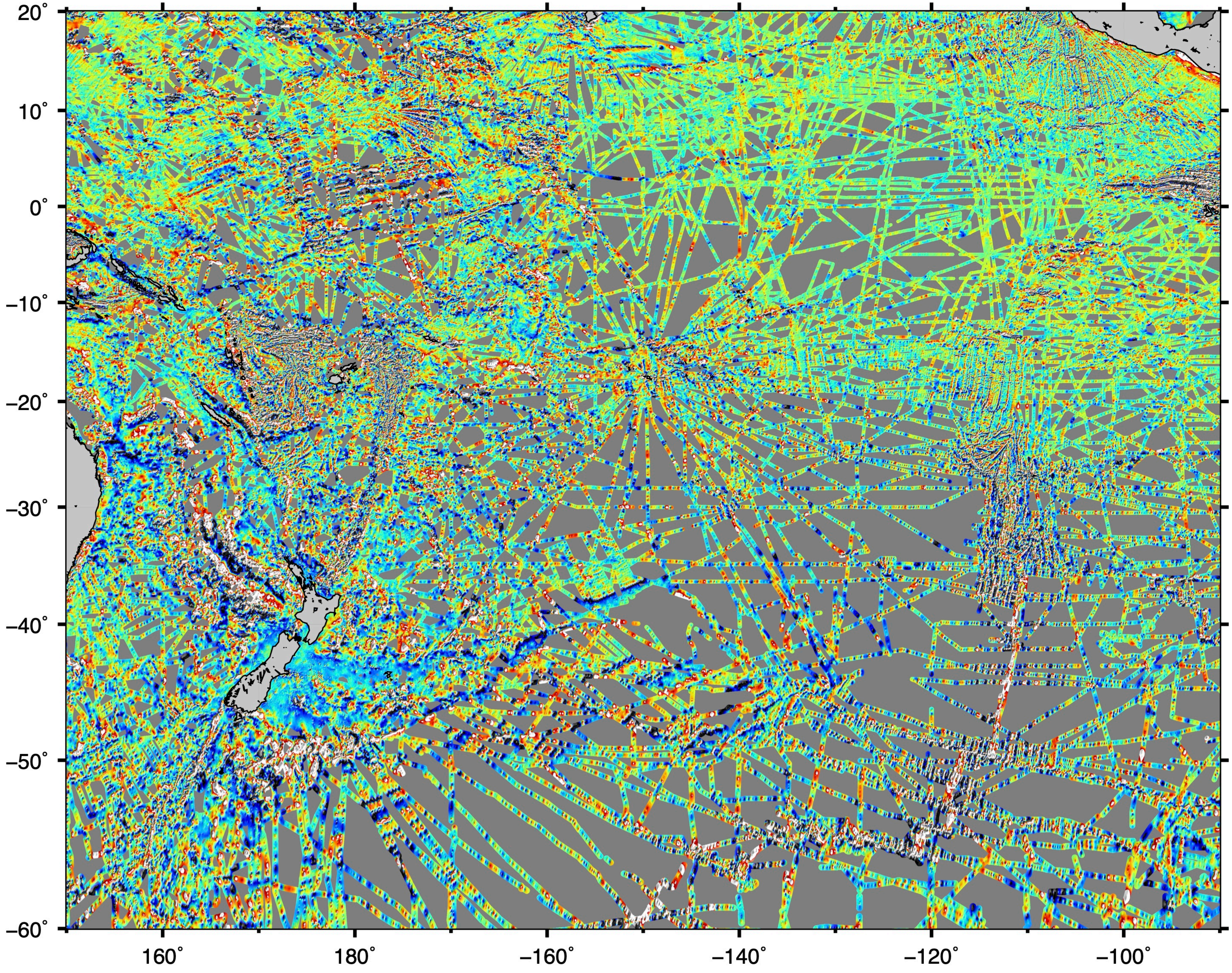
N3: North Atlantic Ocean



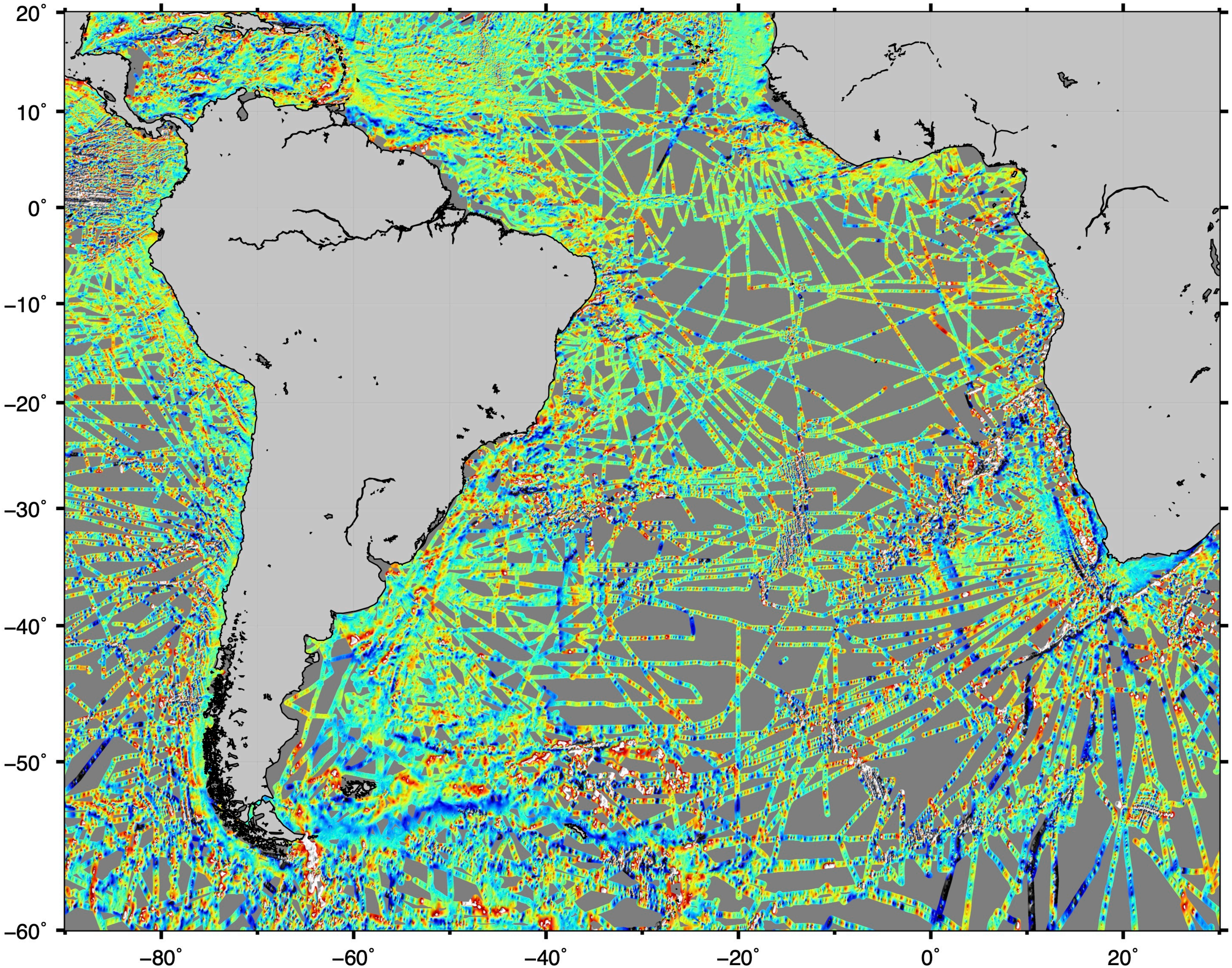
S1: Indian Ocean



S2: South Pacific Ocean



S3: South Atlantic Ocean



References

Dyment, J., Y. Choi, M. Hamoudi, V. Lesur and E. Thebault (2015) Global equivalent magnetization of the oceanic lithosphere. *Earth and Planetary Science Letters*, Vol. 430, 54-65.

Ishihara, T. (2015) A new leveling method without the direct use of crossover data and its application in marine magnetic surveys: weighted spatial averaging and temporal filtering. *Earth, Planets and Space*, 67-11 DOI 10.1186/s40623-015-0181-7.

Lesur, V., M. Hamoudi, Y. Choi, J. Dyment and E. Thebault (2016) Building the second version of the World Digital Magnetic Anomaly Map (WDMAM). *Earth, Planets and Space*, 68-27 DOI 10.1186/s40623-016-0404-6.

Lesur, V., M. Rother, F. Vervelidou, M. Hamoudi and E. Thebault (2013) Post-processing scheme for modelling the lithospheric magnetic field. *Solid Earth*, Vol. 4, 105-118.

Quesnel, Y., M. Catalan and T. Ishihara (2009) A new global marine magnetic anomaly data set. *Journal of Geophysical Research*, Vol. 114. (B04106) DOI 10.1029/2008JB006144.

Reeves, C., R. Macnab and S. Maschenkov (1998) Compiling all the world's magnetic anomalies. *EOS, Transactions of the American Geophysical Union*, Vol. 79, 338.

Sabaka, T., N. Olson and R. A. Langel (2002) A comprehensive model of the quiet-time, near-Earth magnetic field: phase 3. *Geophysical Journal International*, Vol. 151, 32-68.

Sabaka, T., N. Olson and M. E. Purucker (2004) Extending comprehensive models of the Earth's magnetic field with Orsted and CHAMP data. *Geophysical Journal International*, Vol. 159, 521-547.