

## BRIEF DESCRIPTION OF CRYOSAT-2 MAGNETOMETER DATA CALIBRATION METHOD AND CONTENT

This document provides a brief description of Cryosat-2 magnetometer data calibration and data description. For more details please refer to Olsen, N., Albin, G., Bouffard, J. et al. Magnetic observations from CryoSat-2: calibration and processing of satellite platform magnetometer data. *Earth Planets Space* **72**, 48, 2020 (<https://rdcu.be/b3u4h>).

The calibration of ESA Cryosat-2 magnetic field data is performed in the following way:

- For each of the three magnetometers we estimated monthly values of the 9 calibration parameters (3 offsets, 3 scale values, 3 non-orthogonalities) and 3 Euler angles. We also determined a correction for the magnetic effect of magneto-torquer (described as a 3 x 3 matrix that transform from the magneto-torquer currents  $I_{MTQ}$  to the magnetic field disturbance  $dB_{FGM}$ ); this correction matrix is the same for all data (all months). In addition, the magnetic effect due to currents from the two solar array is described in the same way (co-estimating 2 x 3 parameters that are the same for all months). The effect of battery currents and the dependency of the offsets on sensor temperature  $T_{FGM}$  (3 parameters) is also accounted for; also this effect is the same for all months. And finally we co-estimate non-linear effects, to account for the "cross-talk" or "transverse" effect between the fluxgate magnetometer sensors by estimating 3 non-linear terms ( $B_1$  depends on  $E_1^2$ , and  $B_3$  depends on  $E_2^3$  and  $E_3^2$ , where  $E$  is the sensor output and  $B$  is the magnetic field component after calibration).
- The 9+3 "basic" (monthly) calibration parameters are regularized in such a way that their month-to-month variation is smooth. In total this yields 1224 calibration parameters: 12 x 100 months = "basic" calibration parameters plus 24 parameters that are constant for the whole period (9 ( $I_{MTQ}$  dependency) + 3 ( $T_{FGM}$  dependency) + 3 ( $I_{Battery}$  currents) + 2 x 3 (2  $I_{solar}$  array currents) + 3 (non-linearities) = 24 parameters). The month-to-month variation of the offsets vary up to +/- 8 nT, scale values by up to +/- 300 ppm, and non-orthogonalities and Euler angles by up to +/- 0.02 degrees (corresponding to +/- 72 arcsecs).

The ESA Cryosat-2 magnetic field data description is the following:

- The format of the CDF files is Swarm-like, but the data are given separately for each of the three magnetometers, thus there is  $B_{NEC1}$ ,  $B_{NEC2}$  and  $B_{NEC3}$  and similarly  $B_{FGM1}$ ,  $B_{FGM2}$  and  $B_{FGM3}$ .  $B_{mod\_NEC}$  is the CHAOS-6 model field (core, crustal plus magnetosphere and induced).  $q\_error$  is an attitude quality flag (derived when merging data from the three star trackers); good vector data have  $q\_flag < 40$  or so. If you work with vector data in the NEC-frame it is recommended that you only use data for which  $q\_error < 40$  or so.



**References:**

1. Olsen, N., Cryosat Magnetometer Data Calibration - and a first attempt of their scientific exploitation, 8<sup>th</sup> Swarm Data Quality Workshop, 8 – 12 October 2018, Frascati, Italy.
2. Olsen, N., et al., Exploring Earth from space – Towards a true swarm of magnetic satellites, Living Planet Symposium 2019, 13 – 17 May 2019, Milan, Italy.
3. Olsen, N., On the Calibration of Cryosat-2 Magnetometer Data, Platform Magnetometer workshop, 21-22 May 2019, Potsdam, Germany.