MSS-1 data processing and initial model based on Swarm data

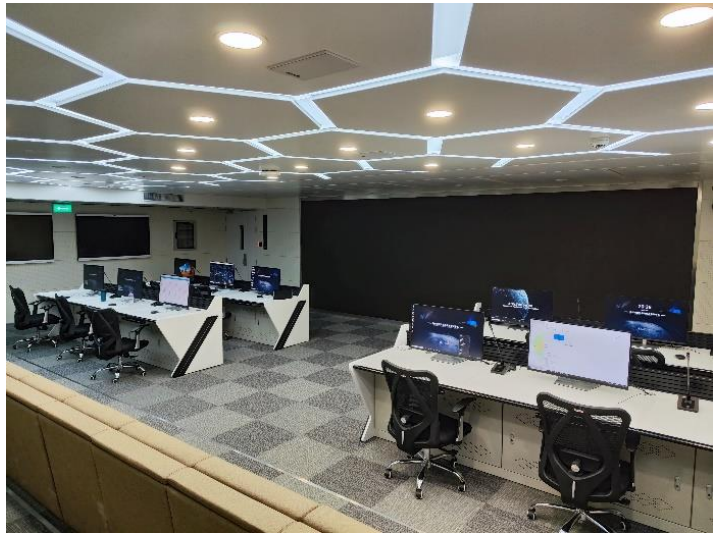
Macao: Yi jiang, Qing Yan, Jiaming Ou
NSSC: Bin Zhou, Bingjun Chen, et al.
DTU: Nils Olsen, John Leif Jørgensen, Chris Finlay, Lars Tøffner-Clausen, Peter Brauer, Jose Merayo, Troelz Denver, Stavros Kotsiaros, et al.
IWF: W. Magnes, A. P. Betzler, et al.
DFH: Shigeng Yuan et al.

Swarm 10 Year Anniversary & Science Conference 2024

MSS-1

Launched on 23rd May, 2023, Jiuquan Satellite Launch Center, China

Launch

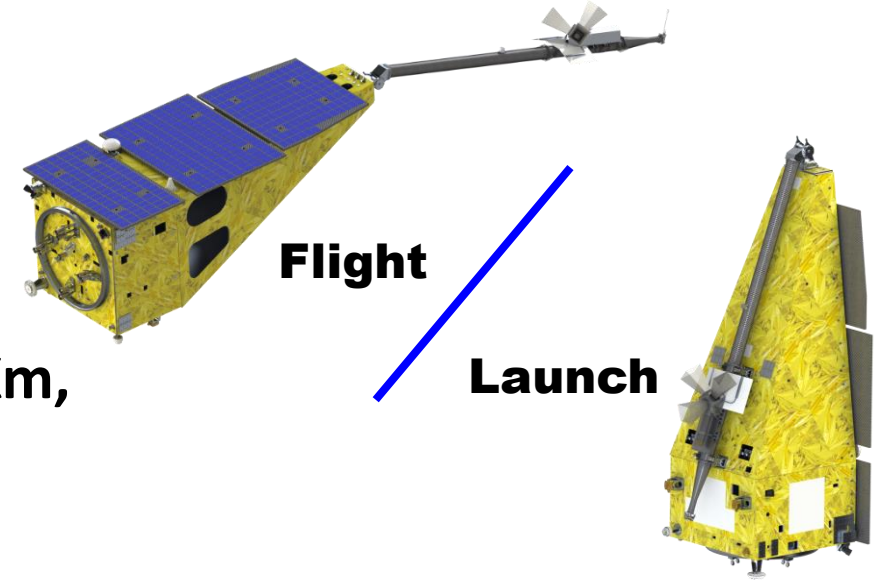


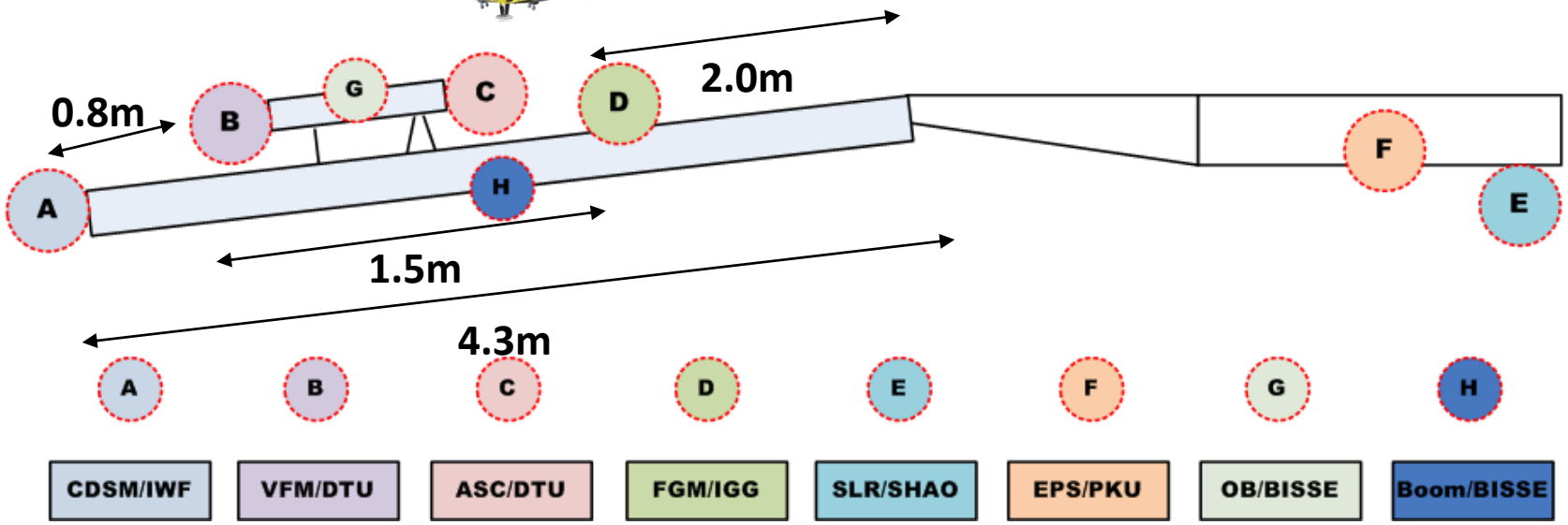
Data centre

Sat	MSS-1A					MSS-1B
Number of orbits around the Earth	About 4900					
Number of data received	422 times					289 times
L0 data	1369.77GB					1720.16GB
	ASC	CDSM	VFM	FGM	Other	
	16.9GB	38GB	42GB	13.2GB		

MSS-1A Satellite

- Orbit
  - Inclination: 41°
  - Height: 450X500Km, nearly circular
- Mass: ~570Kg
- Height: ~9000mm
- AOCS
  - Roll-angle-driven three axis stabilization
  - No magnetic torquers





Inflight Calibration

The calibration model follows Swarm but is slightly different

$$\boldsymbol{B = V \cdot S \cdot (E - b)}$$

b: Offsets $\boldsymbol{b = b_0 + b_{EU} \cdot (T_{EU} - 25)}$

S: matrix for Scale values

$\boldsymbol{S = S_0 + S_{EU} \cdot (T_{EU} - 25) + S_{CDC} \cdot T_{CDC} + S_t \cdot t}$

Using cubic B-spline to fit the temporal shrinking

V: matrix for Non-orthogonalities

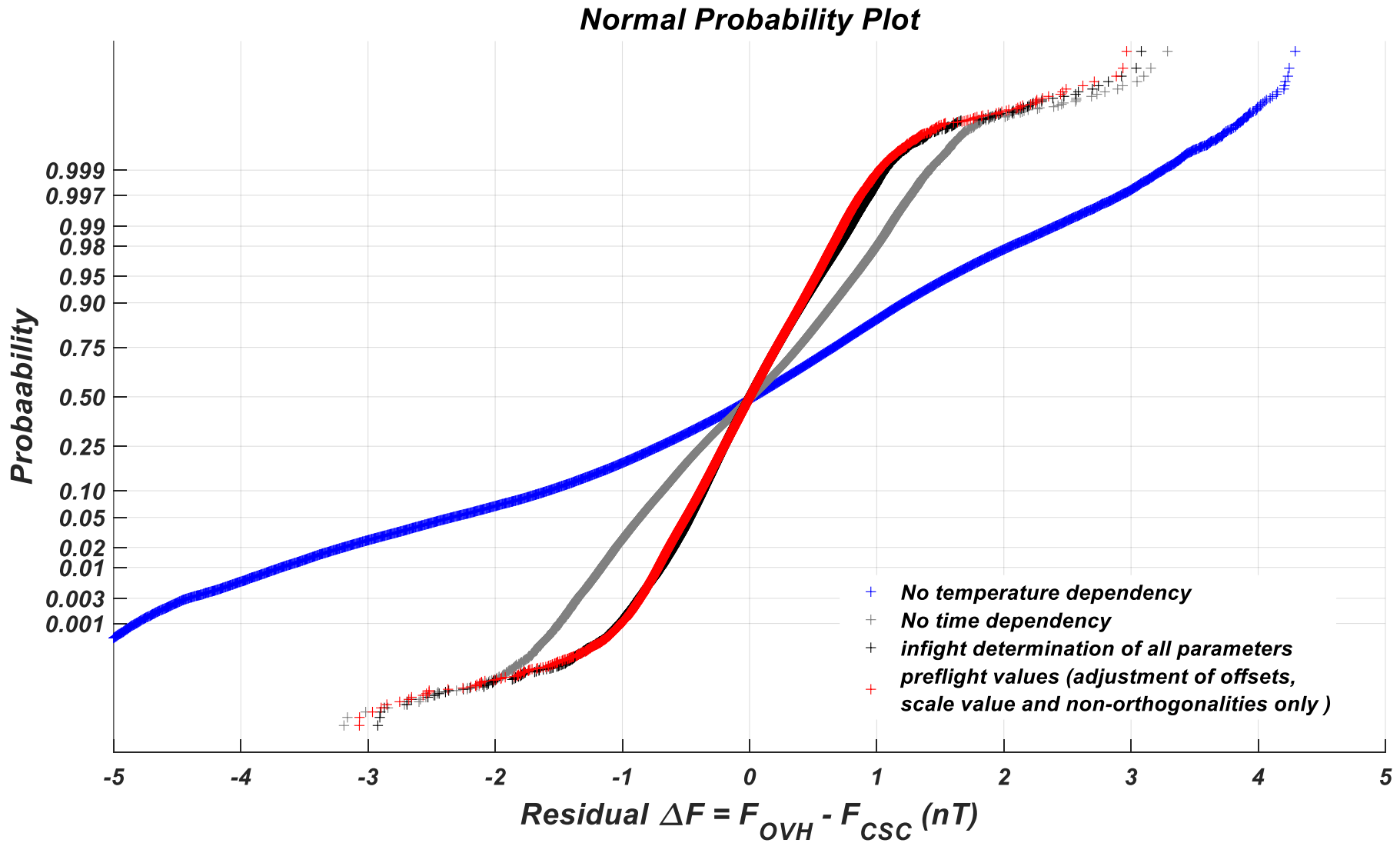
$\boldsymbol{T_{EU}}$*: 25 – 29 °C* $\boldsymbol{T_{CDC}}$*: 0 – 7 °C*

Cofficients

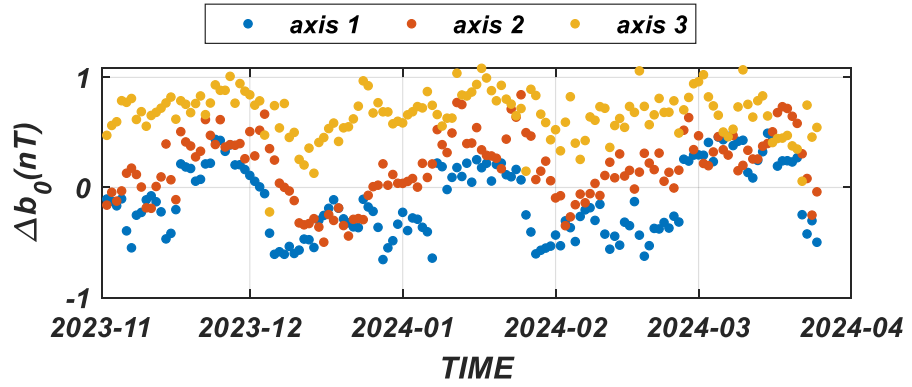
In-flight calibration (2023.11.02 -2024.03.25)		Axis 1	Axis 2	Axis 3
Offsets $b_{0,i}$ (eu)	Pre-flight	-32.694	-37.101	-39.184
	Adjustment	-0.3028	0.3142	0.2769
Scale value $S_{0,i}$ (nT/eu)	Pre-flight	1.00457	1.00433	1.01595
	Adjustment	$-0.18138 \cdot 10^{-4}$	$-1.6222 \cdot 10^{-4}$	$-0.6848 \cdot 10^{-4}$
Non-orthogonalities u_1 (arcsec)	Pre-flight	-134.971	-55.555	-112.833
	Adjustment	-1.89	5.69	-4.69
$b_{EU,i}$ (eu/℃)	Pre-flight	-0.127	-0.065	-0.112
$S_{EU,i}$ (eu/℃)	Pre-flight	3.22e-06	5.071e-06	-0.457e-06
$S_{CDC,i}$ (eu/℃)	Pre-flight	-2.84e-05	-2.84e-05	-2.84e-05

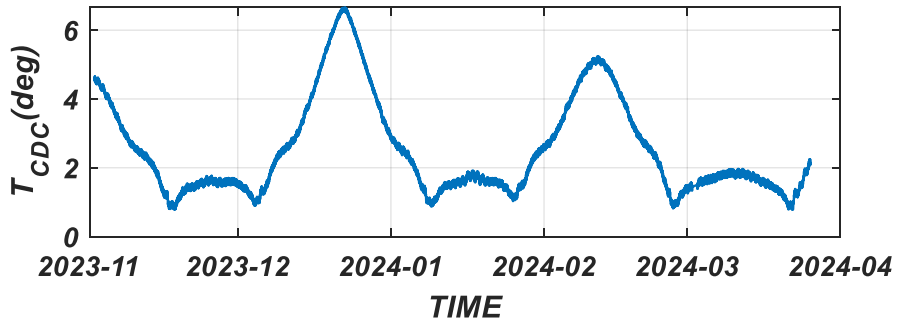
MSS-1 (2023.11.02 -2024.03.25)	Huber-weighted RMS (nT)
No temperature dependency	0.8732
No time dependency	0.455
In-flight determination of all parameters	0.2597
Pre-flight values(adjustment of offset, Scale value and Non-orthogonalities)	0.2573

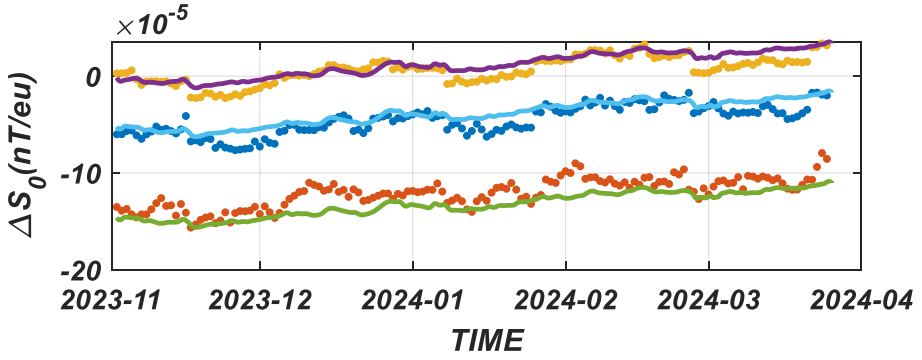
Normal probability plot

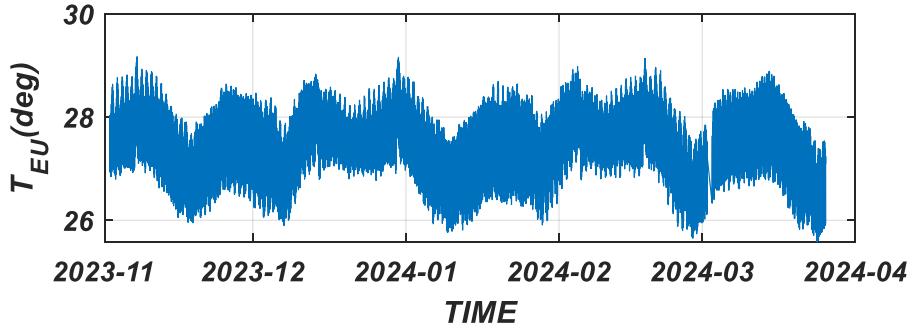


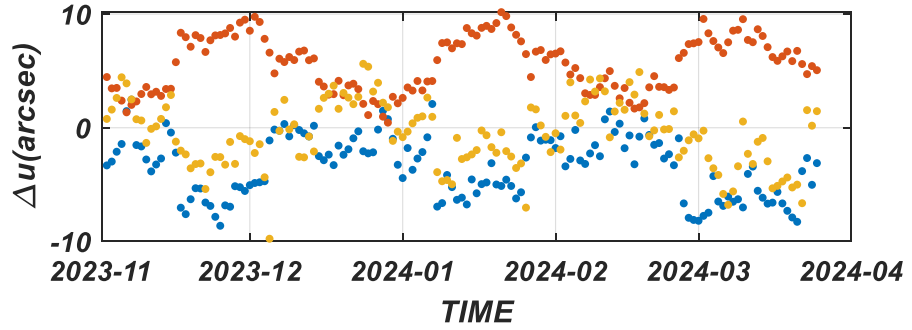
Every day segments

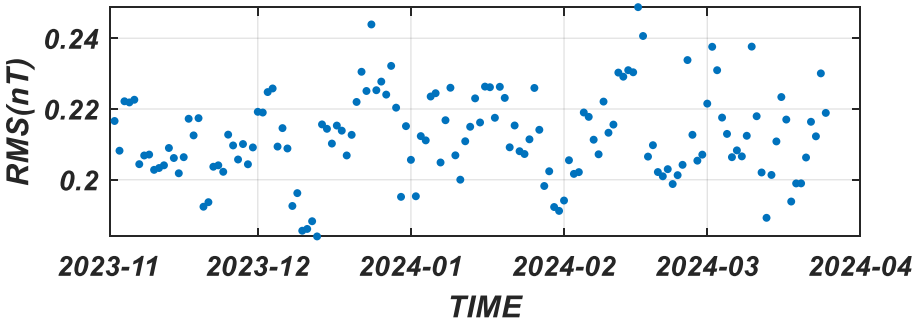












MSS-1 initial field model(MIFM)

- Modelling by Swarm data and MSS data
- Swarm-A data:

From 2023.09.01 to 2024.3.27
41716 vector data at low latitude
20035 scalar data at high latitude

- Swarm-B data:

From 2023.09.01 to 2024.3.27
42275 vector data at low latitude
20139 scalar data at high latitude

- MSS-1 data:

From 2023.11.02 to 2024.3.25
46745 vector data and 46745 scalar data at $\pm 41^\circ$

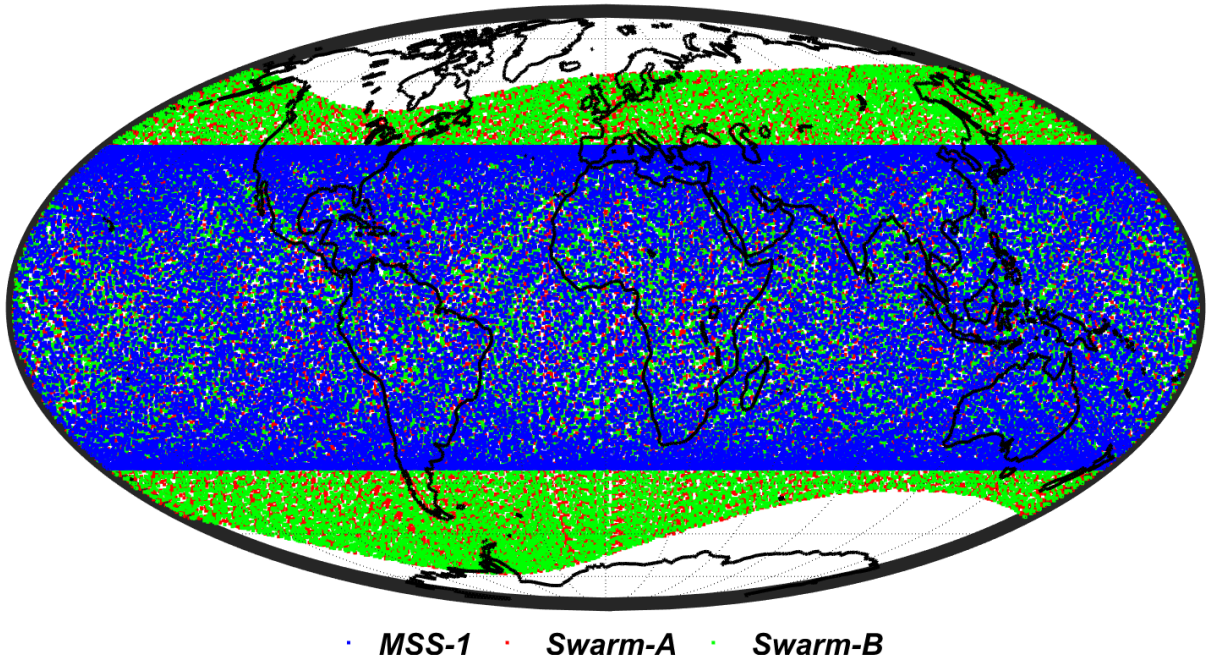
- 40 internal field, 14 secular variation (linear), 2 external field

- Data selection

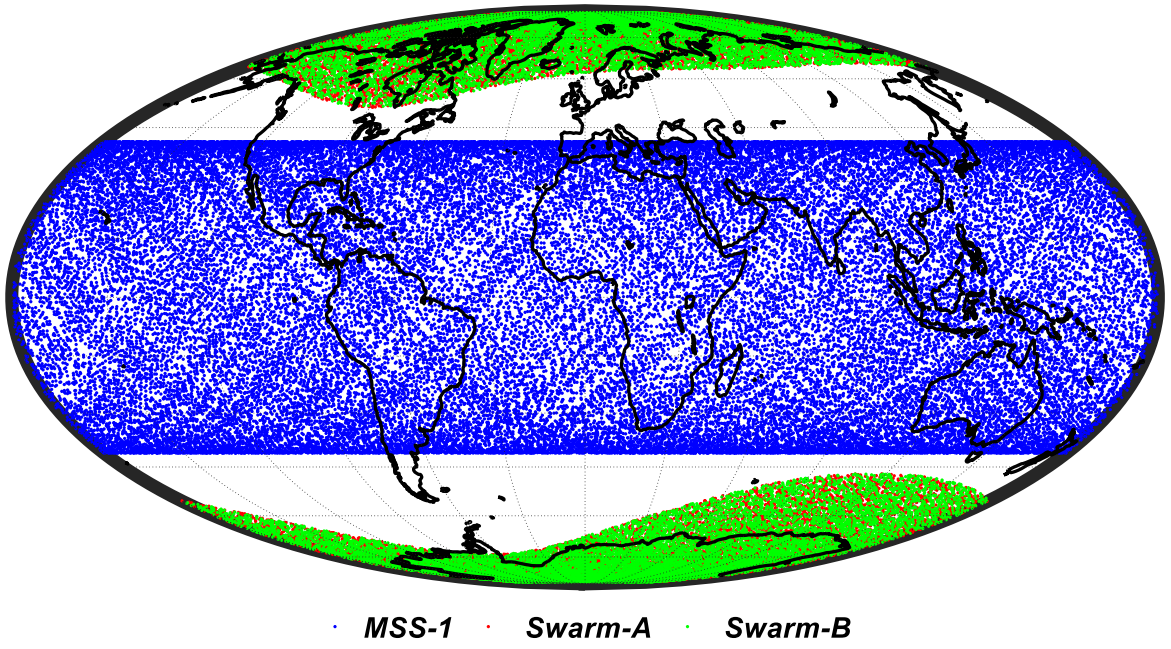
Kp < 2+; |Dst/dt| < 2; Night side (Local time between 18:00 to 6:00)
QD-Latitude < 60 deg for vector data

Data distribution

Vector data



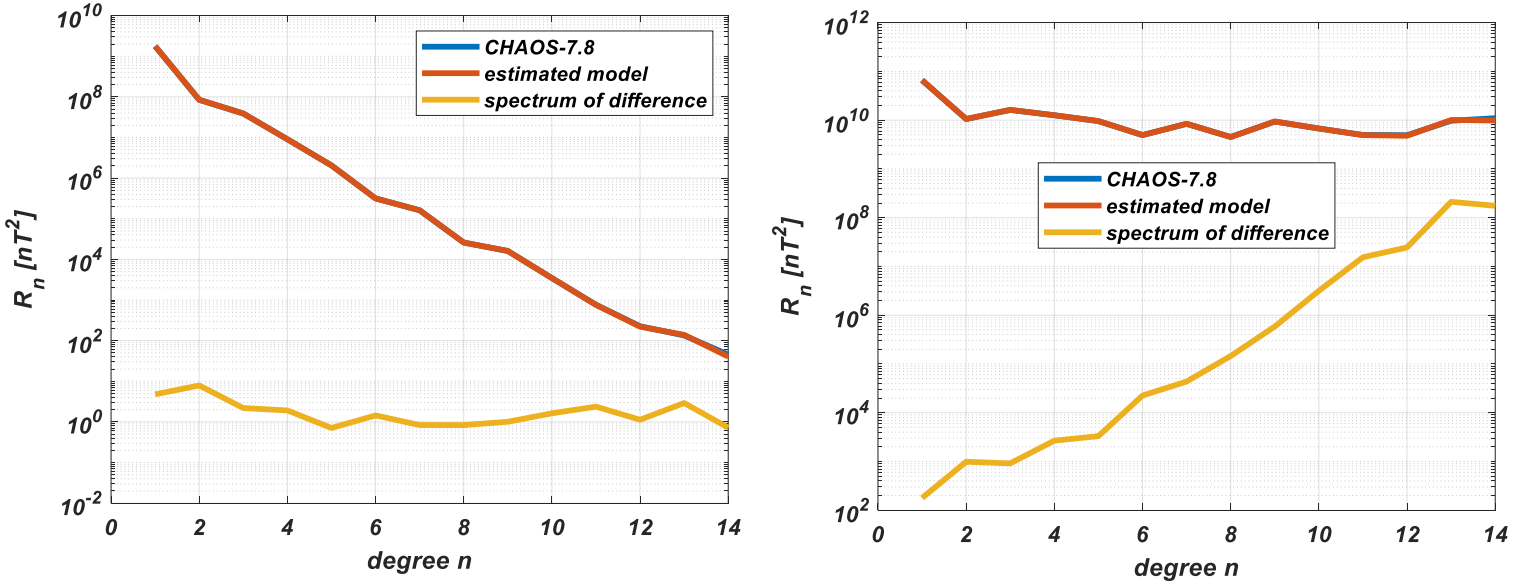
Scalar data



RMS and Power Spectra

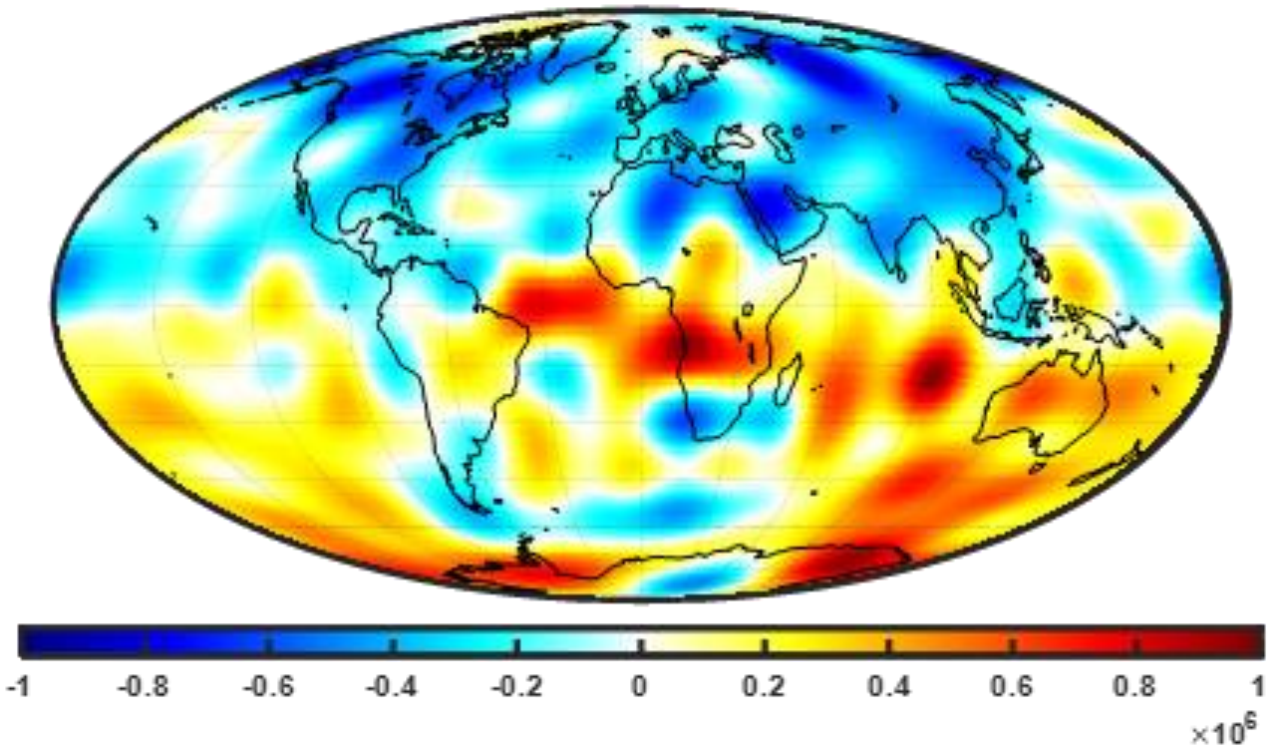
Huber weighted RMS (nT)	F	B_r	B_theta	B_phi
Swarm-A	7.53	2.26	3.00	3.41
Swarm-B	8.01	2.45	3.11	3.53
MSS-1	2.18	2.64	3.01	3.74
Total	4.98	2.46	3.04	3.56

power spectra at surface (left) , CMB (right)

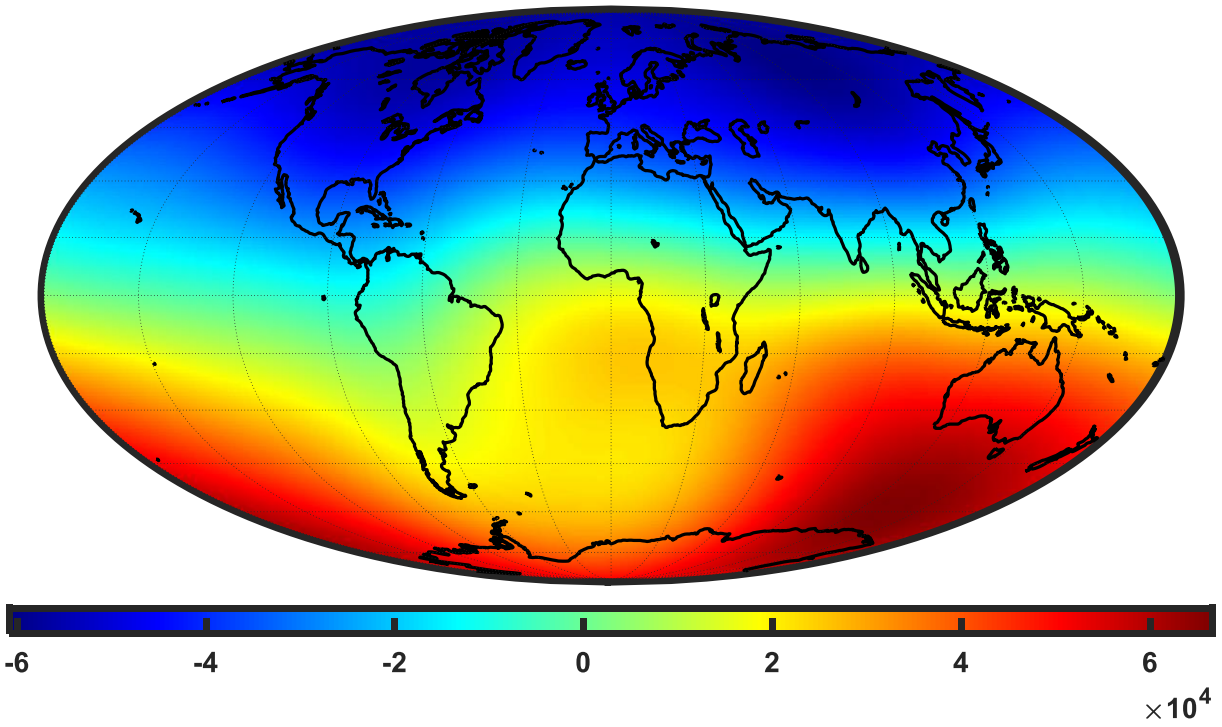


Map

Br at CMB, degree up to 14

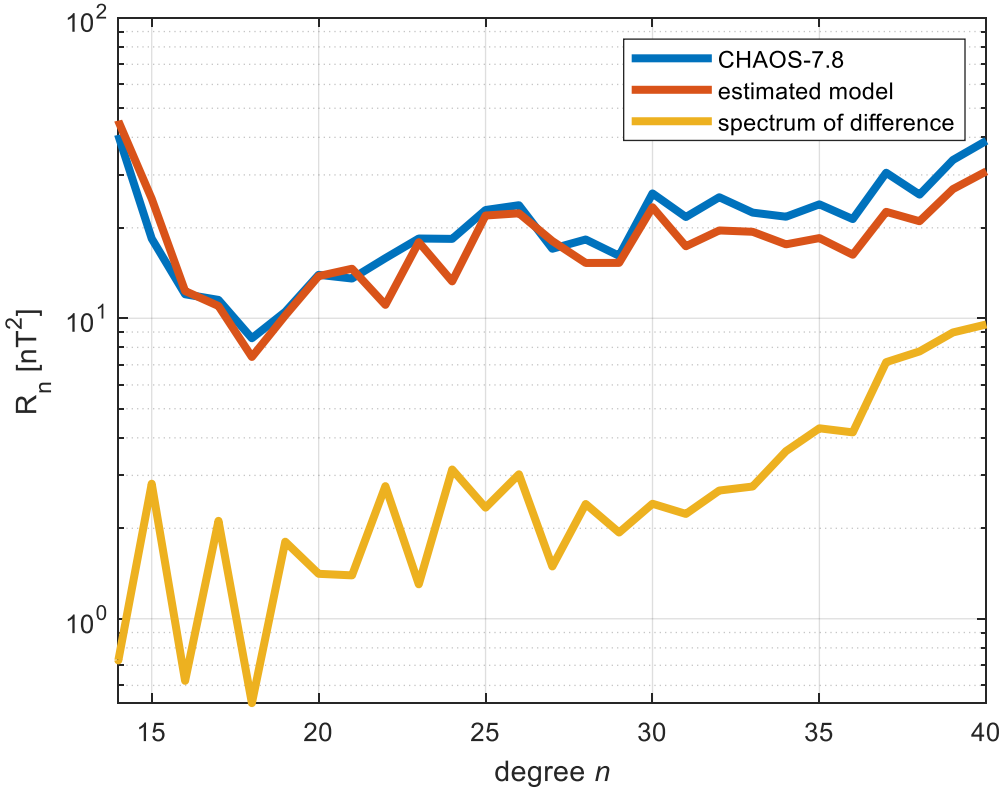


Br at surface, degree up to 14

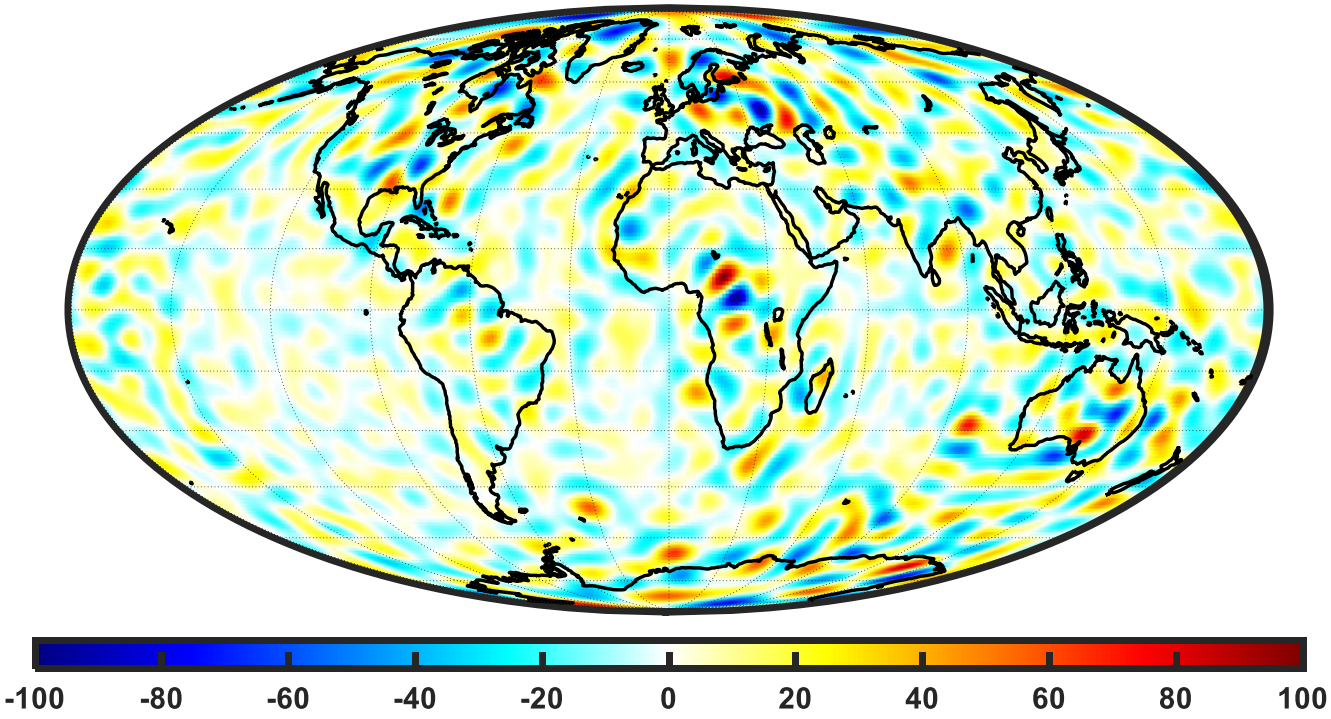


Crust field (14 – 40 degree)

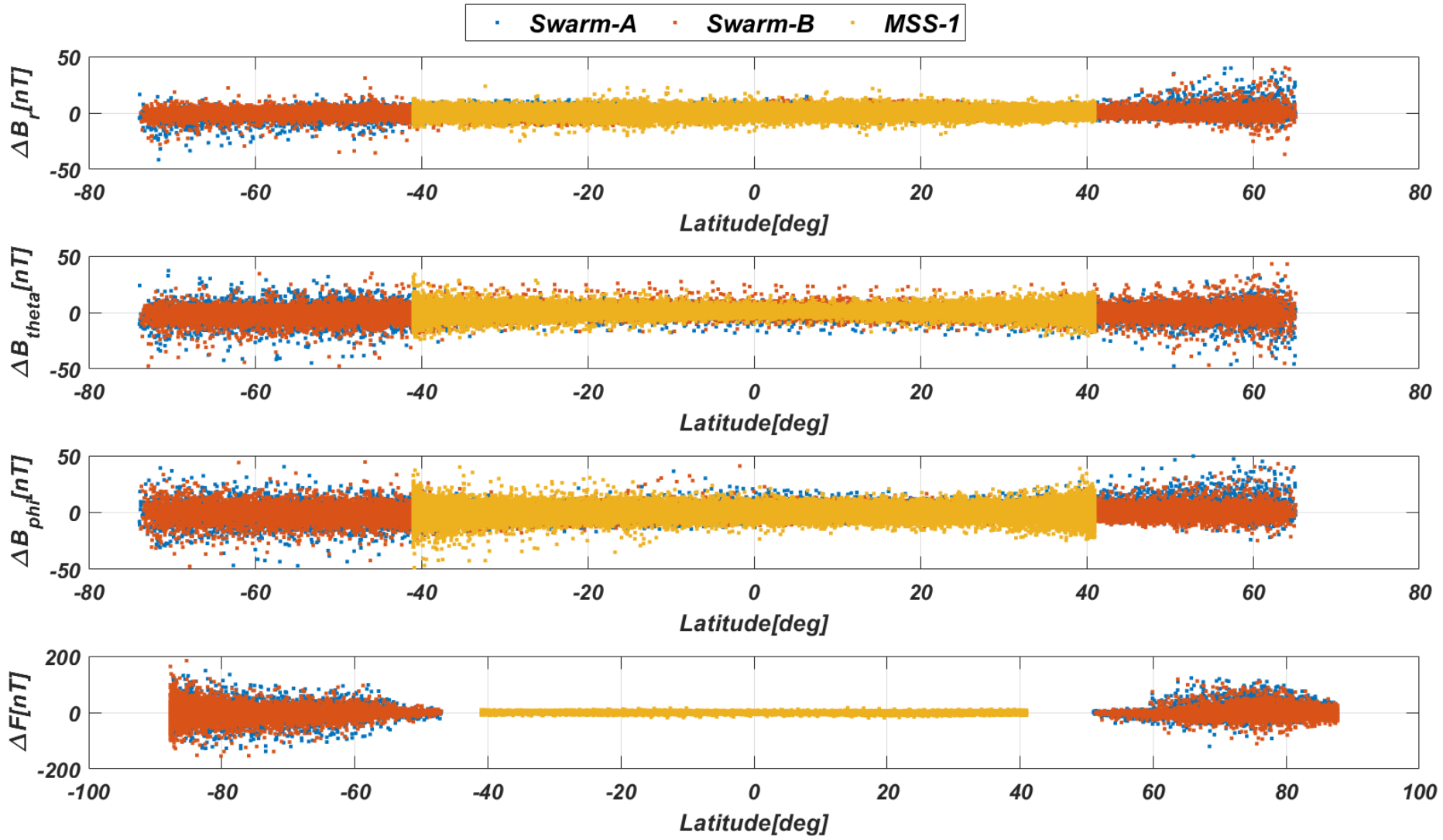
Power Spectra



Br at surface



Residual


Swarm-A
Swarm-B
MSS-1
ΔB_r[nT]
ΔB_theta[nT]
ΔB_phi[nT]
ΔF[nT]
Latitude[deg]

Euler angle

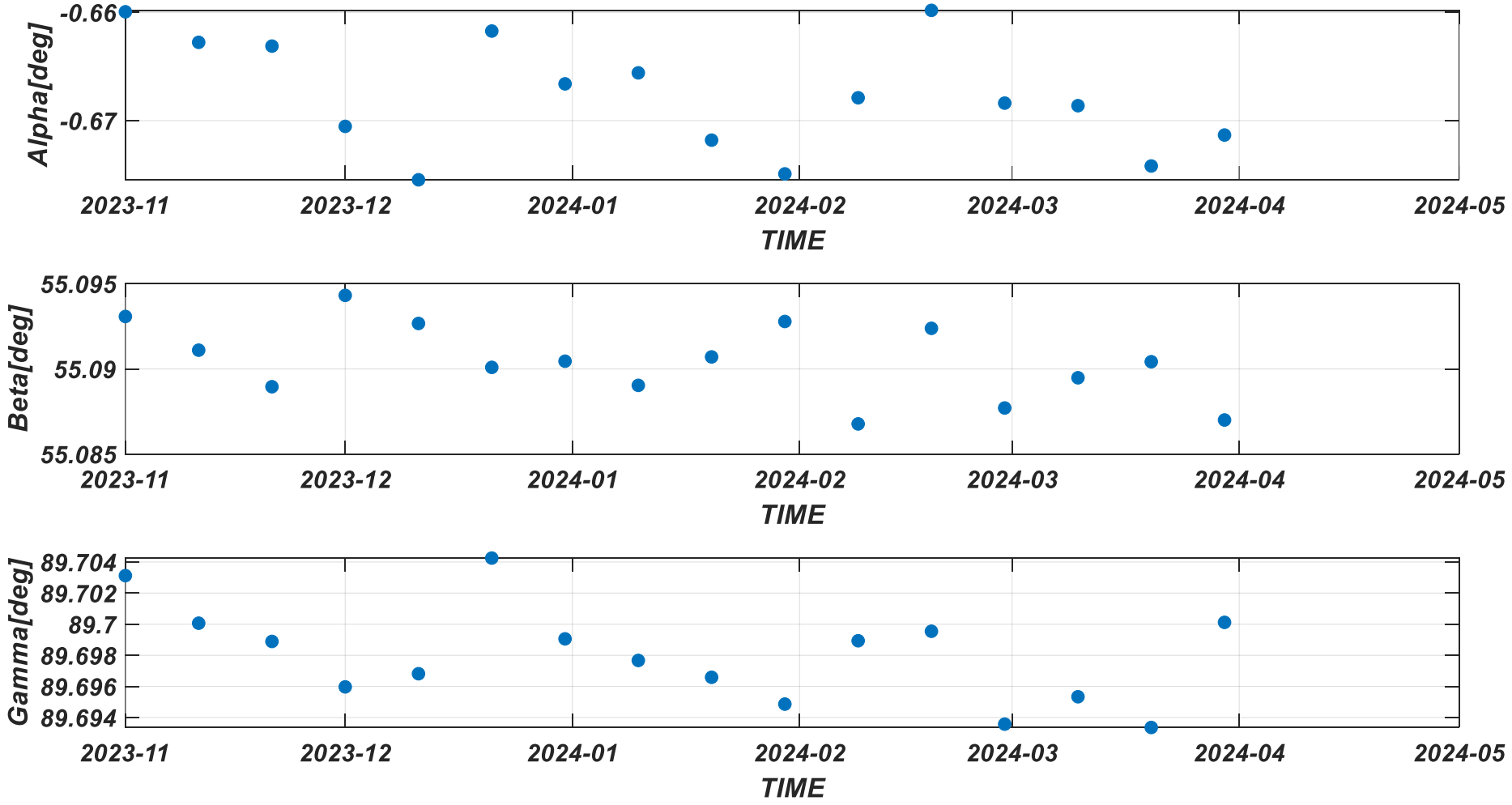
Estimated Euler angle every 10 days

Pre-flight Euler angle:

alpha = -0.6578

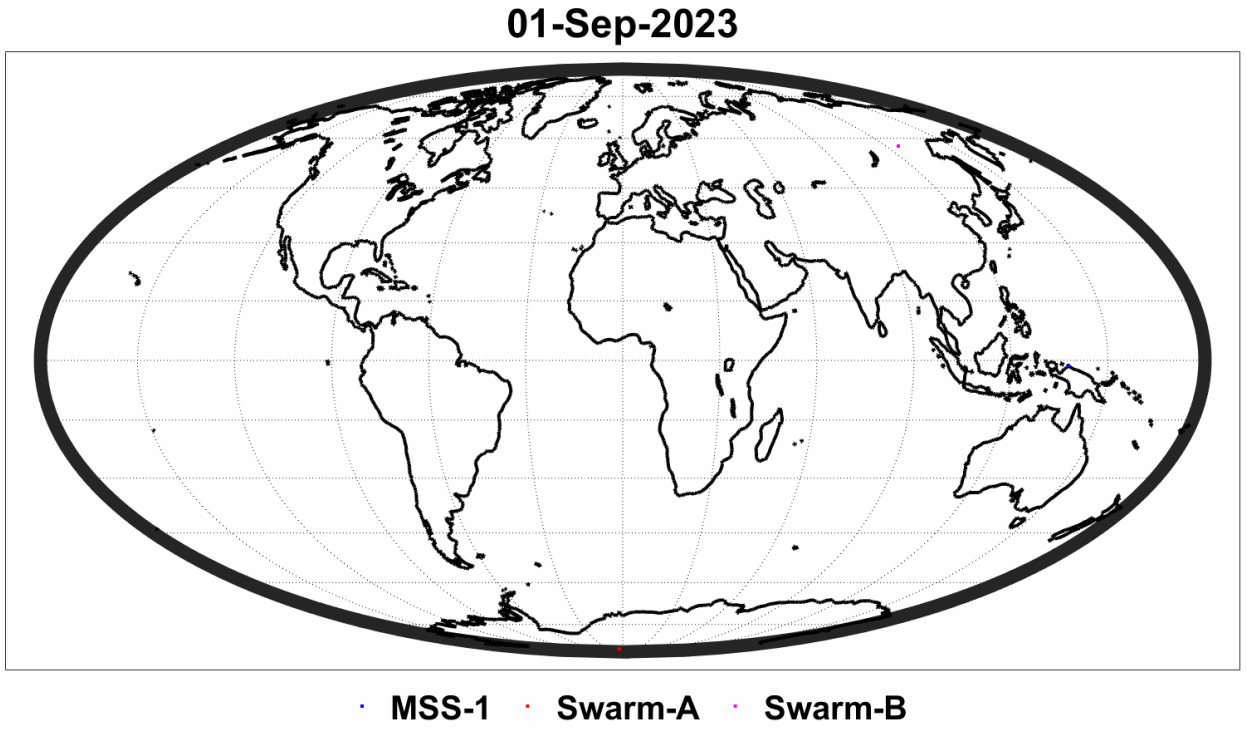
beta = 55.0966

gamma = 89.7122

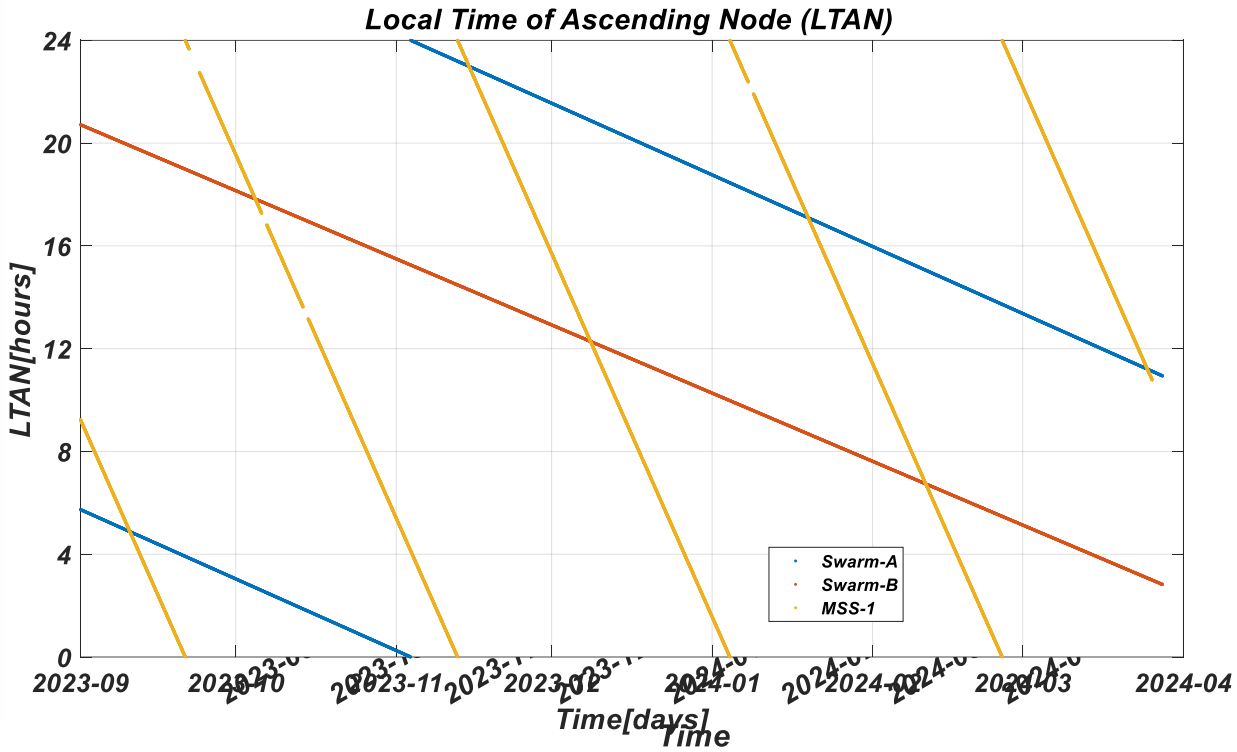


MSS-1A and Swarm

Orbit

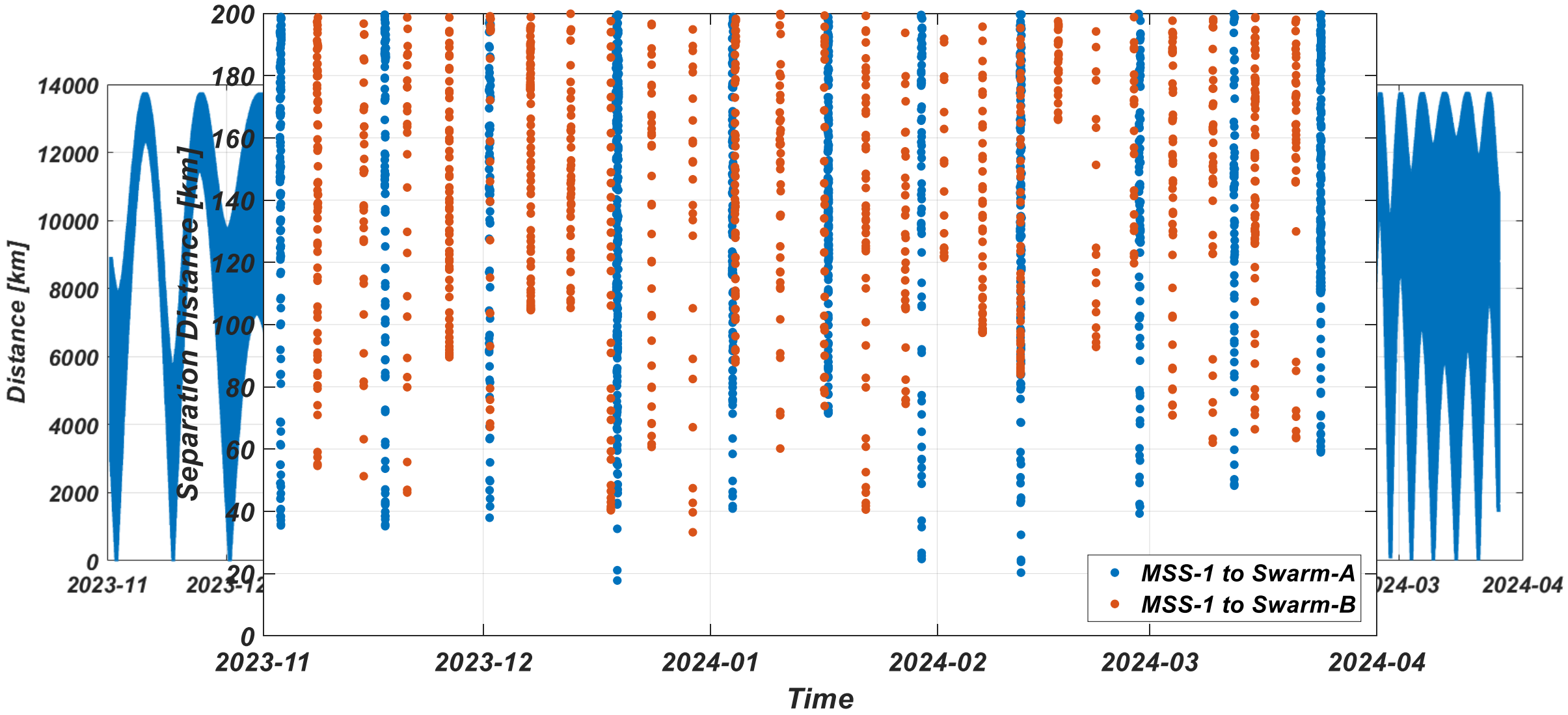


Altitude

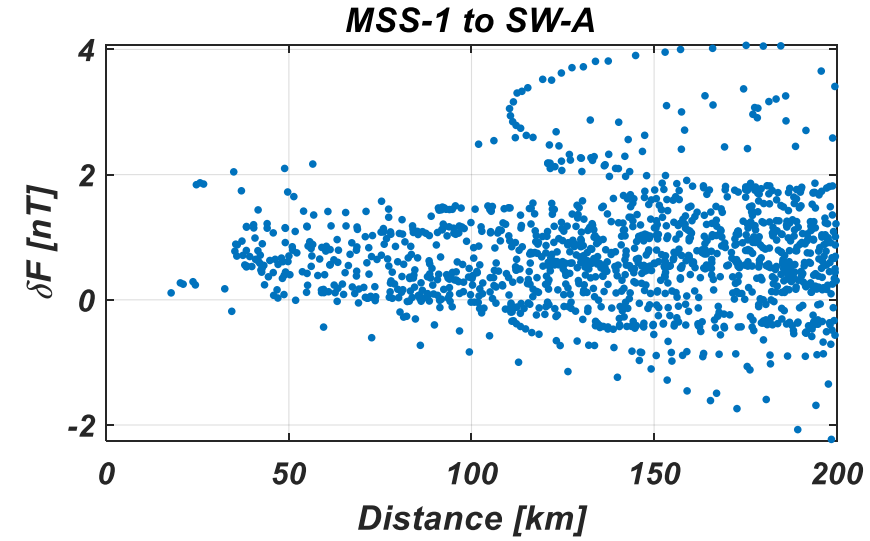


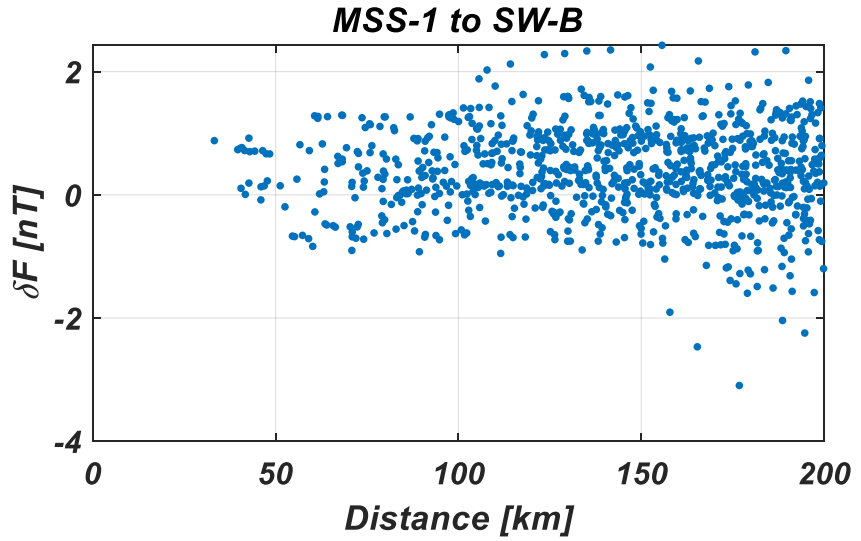
MSS-1 covers all LT within about 26.3 days

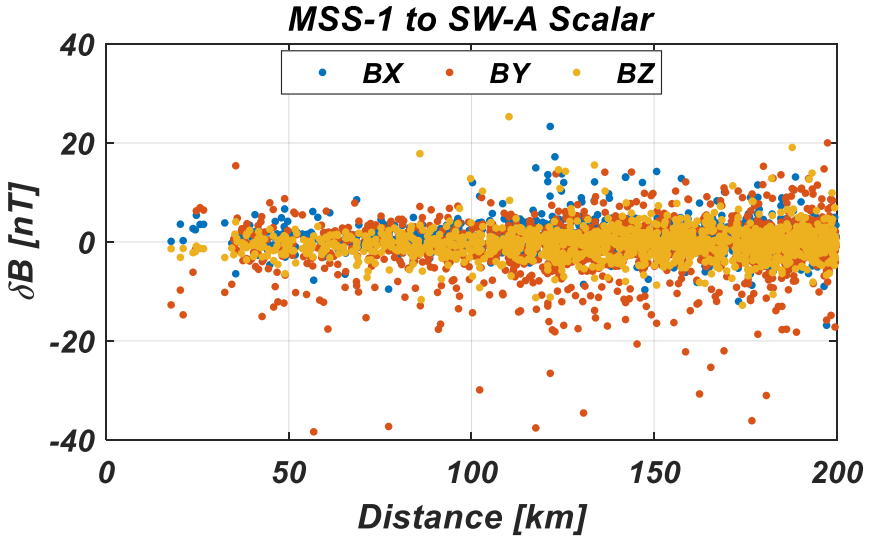
Distance between MSS-1A and Swarm

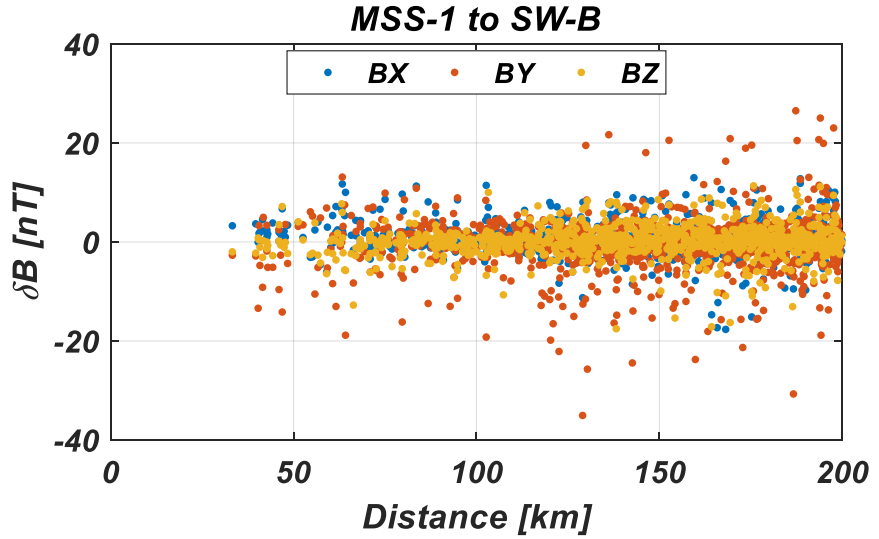


MSS-1A and Swarm









Residual between MSS-1 and Swarm

$\delta Fsw = Fsw - CHAOS$

$\delta Fmss = Fmss - CHAOS$

Data from 2023.11.02 to 2024.03.25

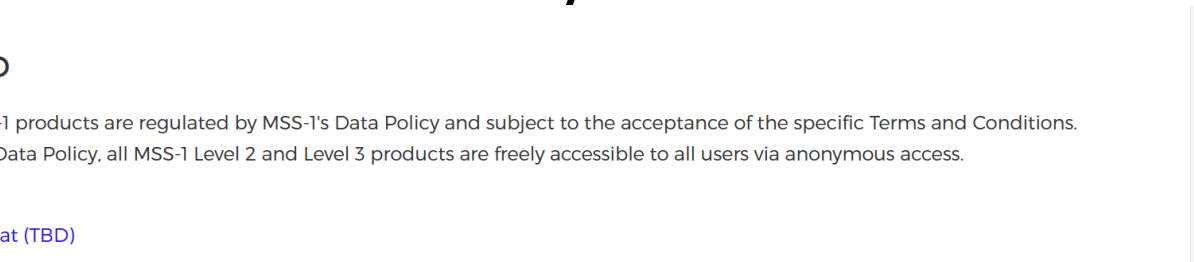
For more comparisons of scalar data, see Xandi's poster: **Comparison of scalar magnetic field data of CSES, MSS and Swarm satellite**

Conclusion and next work

- MSS-1 data is good, the Huber-weighted RMS for in-flight calibration is about 0.256nT.
- The quality of MSS-1 magnetic data at least as good as Swarm. Two data sets have very good consistency.
- All these results can still be improved. We can do better.
- Hope MSS-1 can do some contribution for IGRF-14.
- Still have some details needs to be checked to determine the current best method of data process, e.g. attitude combination, roll angle and regularization for non-orthogonalities, etc.

Hope all work will be completed soon !!

Data and more information: https://mss.must.edu.mo/



Thank you