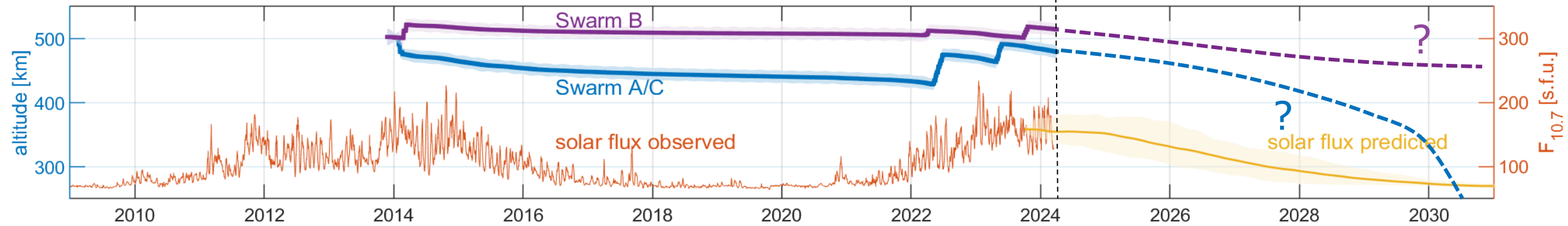
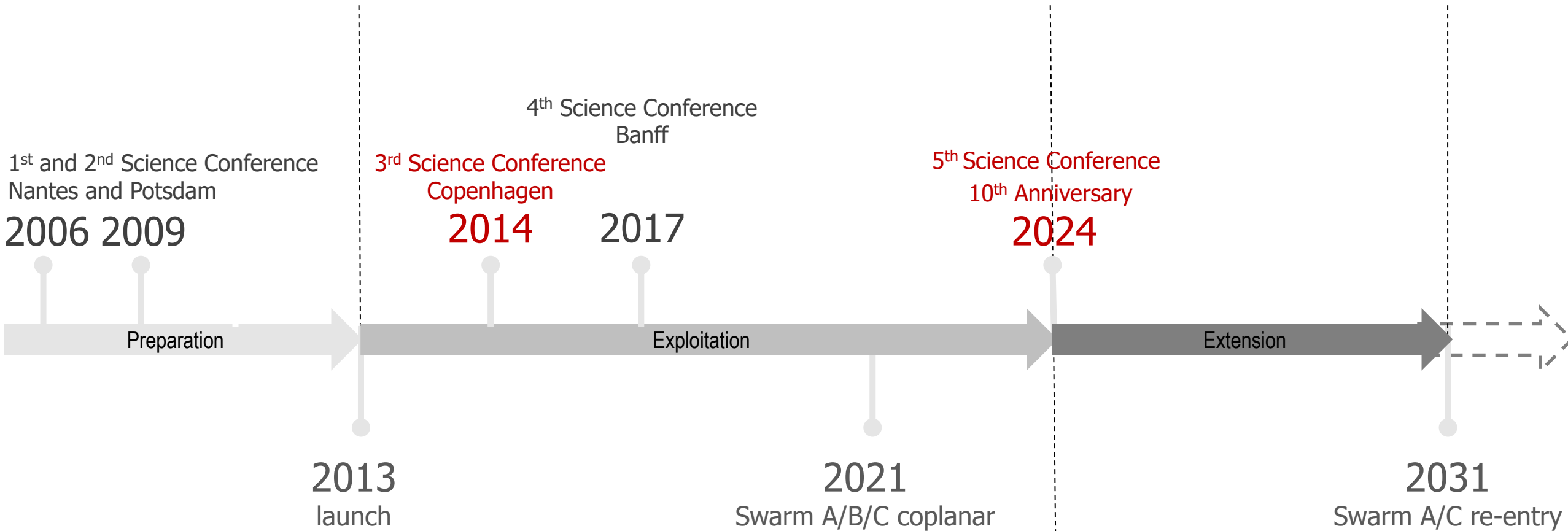




Swarm and beyond Opportunities for the next years

Nils Olsen
DTU Space – Technical University of Denmark
with help from many experts

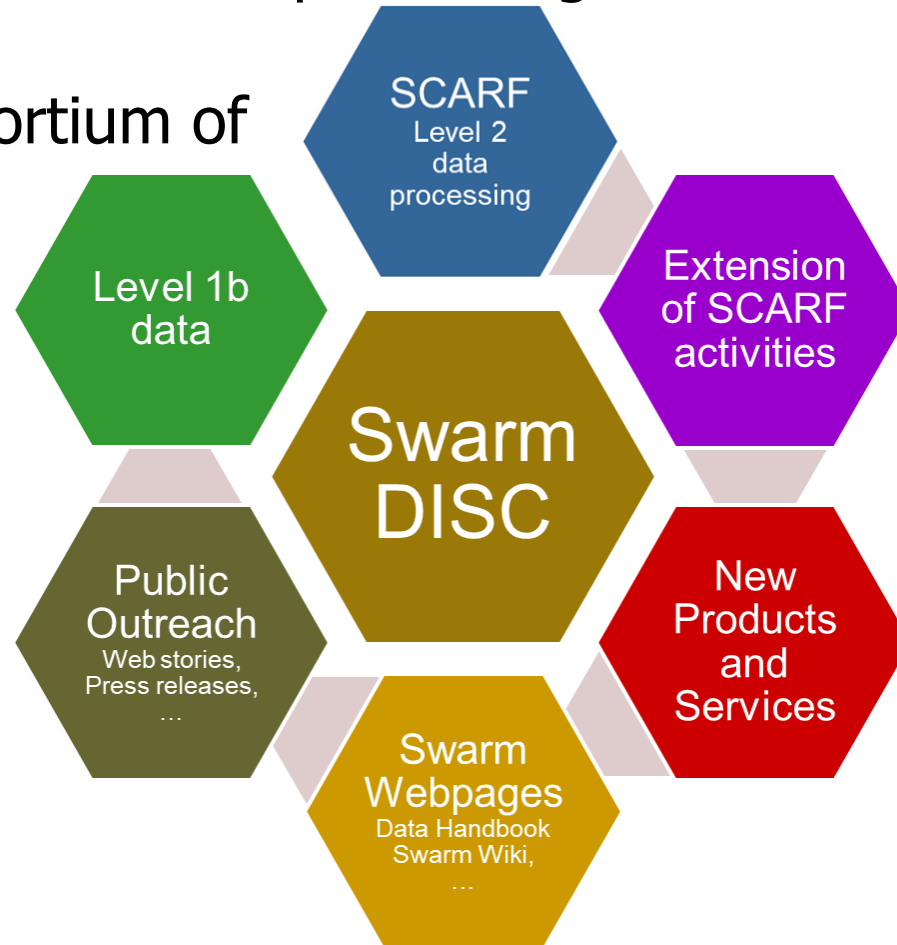
FAST data
Additional satellites
The next years



From SCARF ...

2014: SCARF consortium of 6 partners, responsible for Level-2 data processing

2024: Swarm DISC consortium of 35 partners



... to Swarm DISC



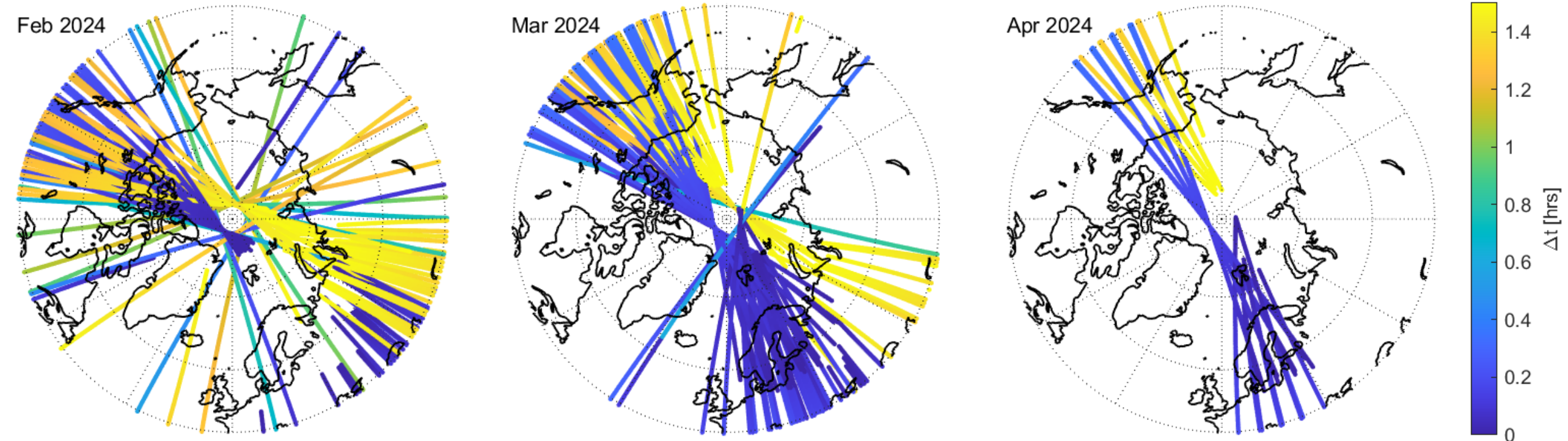
FAST Data Provision (latency < 3 hrs) in addition to OPER data (latency 72 hours)

Improved L1b data latency since 11 March 2024:

“delta” data downlink to obtain most recent data for Europe

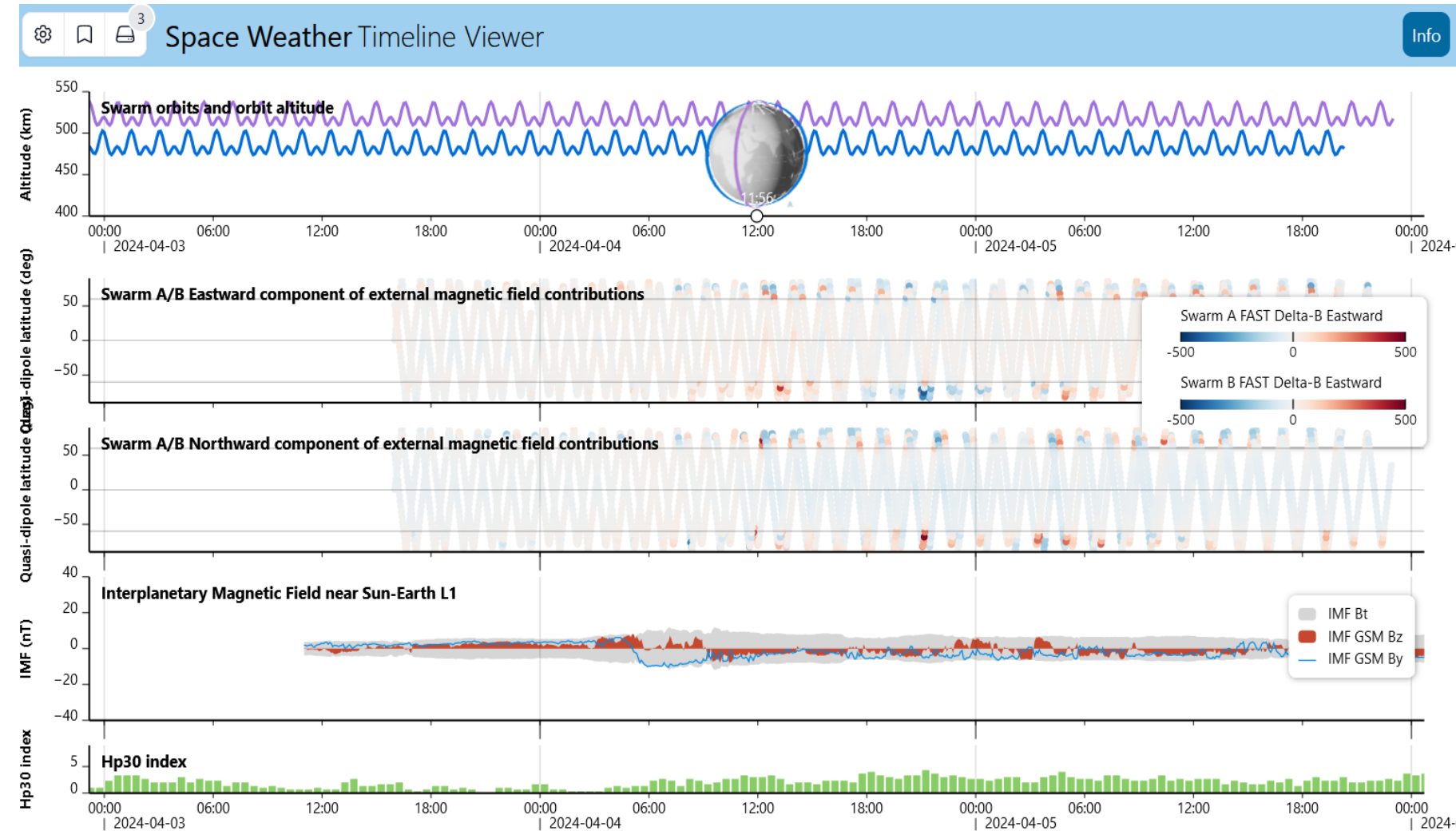
Data available at <ftp://swarm-diss.eo.esa.int/Fast/Level1b> and in VirES/VRE vires.services

Swarm A



FAST (and OPER) Data Visualisation: Space Weather Timeline Viewer

DISC+ Project SWITCH
By Eelco Doornbos, KNMI
<https://spaceweather.knmi.nl/viewer/>



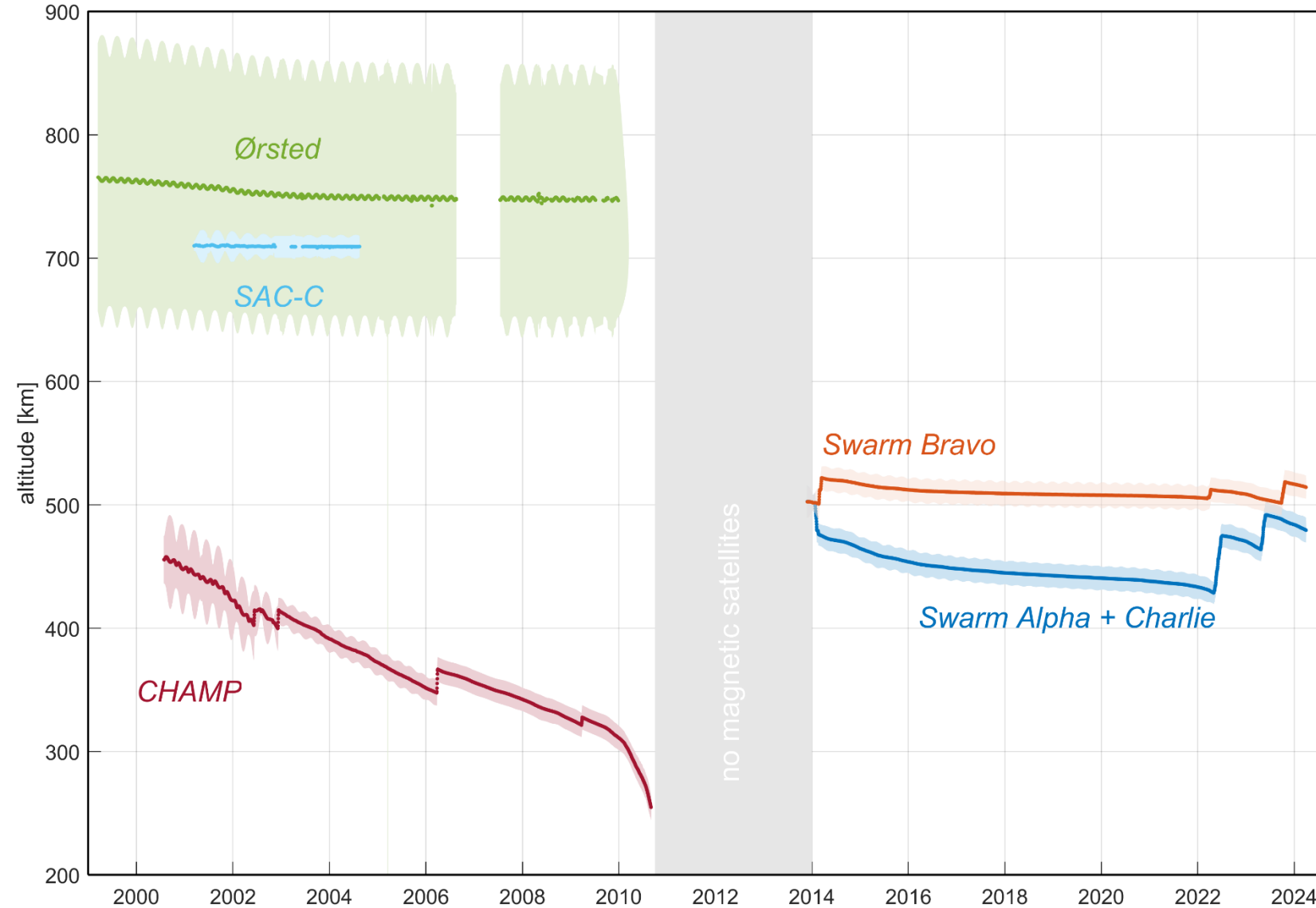
Next: From L1b FAST to L2 FAST

- FAST L1b derived by ESA PDGS and provided at <ftp://swarm-diss.eo.esa.int/Fast/Level1b>
- L2 data will be derived by DISC partners
 - FAST L2 product provision at <ftp://swarm-diss.eo.esa.int/Fast/Level2> – coming soon, starting with FAC will also be available at VirES and in Space Weather Timeline Viewer
 - ... augmented by “on demand determination” (API and/or Web-interface) for *some* products (TBC)

Note: FAST data product determination may not be exactly reproducible, e.g. due to change of auxiliary input data products that are not archived (different from OPER products).

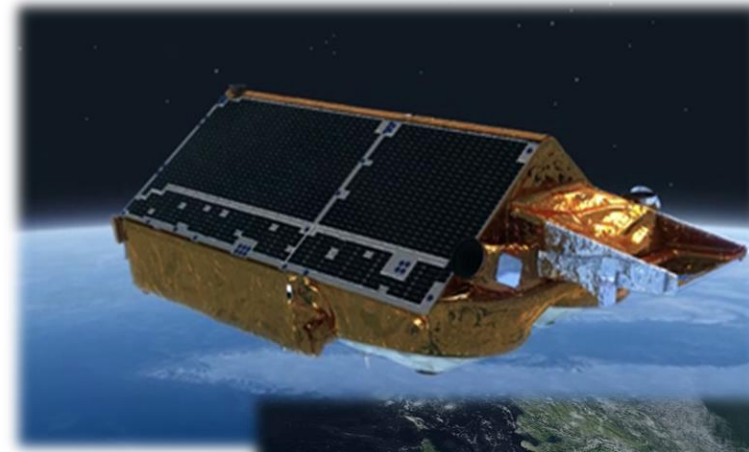
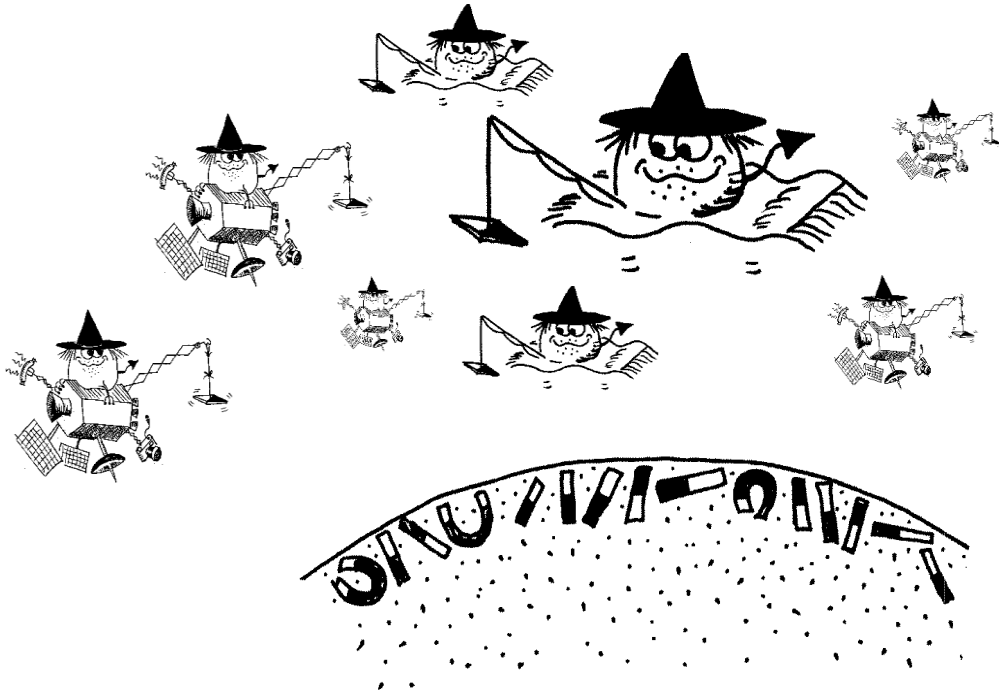
FAST data products not recommended for publications

Swarm-family satellites for exploring Earth's magnetic field

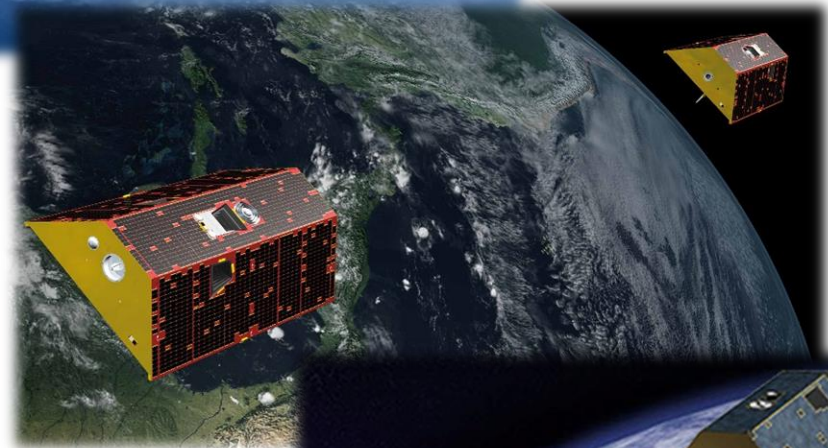


No high-precision magnetic field data are available in the gap between CHAMP and Swarm (Oct 2010 and Nov 2013)

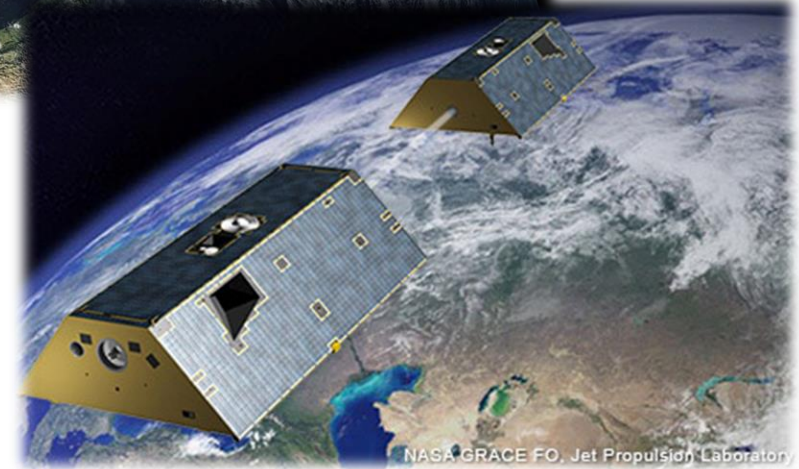
Platform Magnetometer Data



CryoSat-2
since 2010



GRACE
2002 – 2017

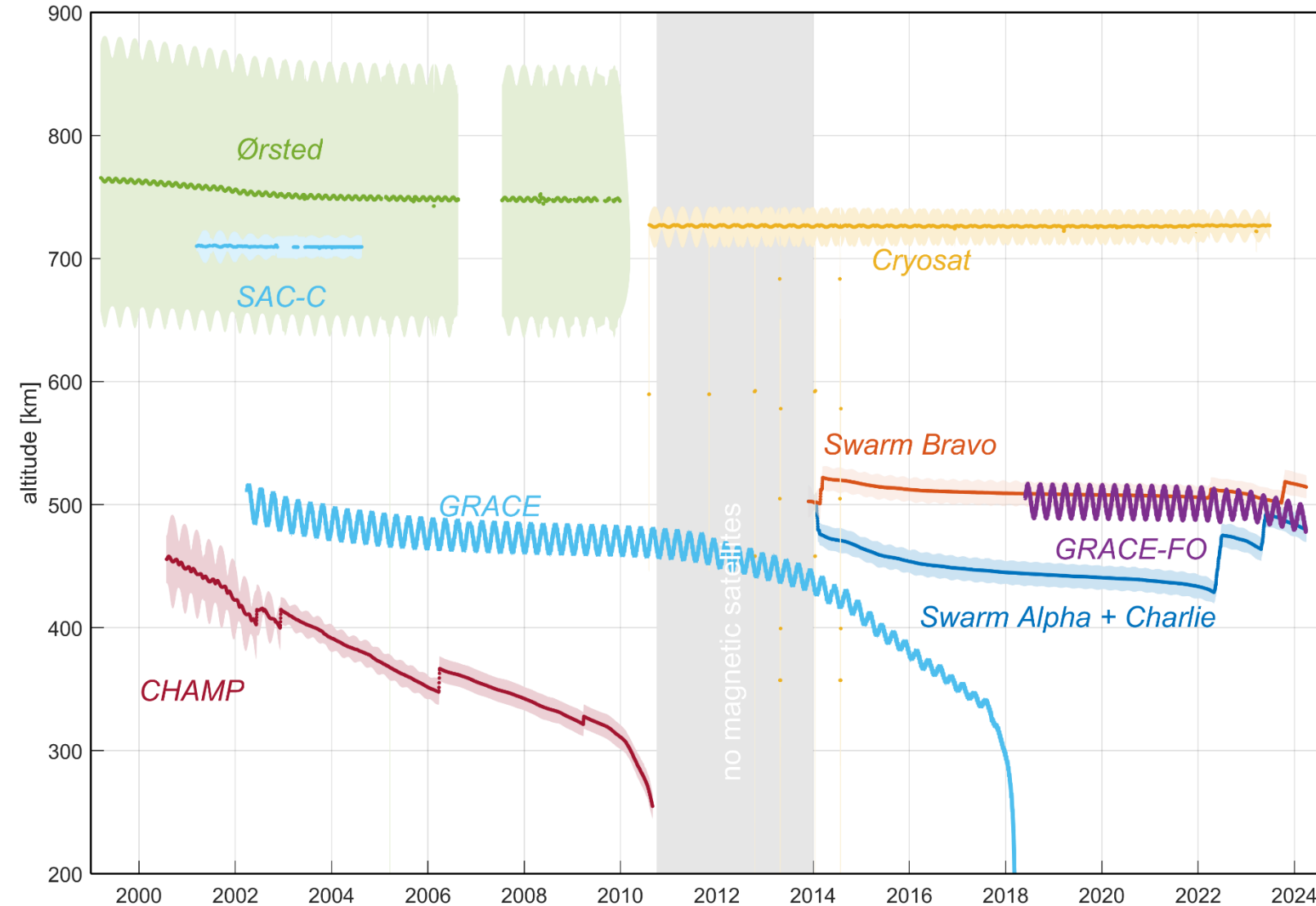


GRACE-FO
since 2018

NASA GRACE FO, Jet Propulsion Laboratory

Data available at <ftp://swarm-diss.eo.esa.int/Multimission>

Swarm-family satellites for exploring Earth's magnetic field

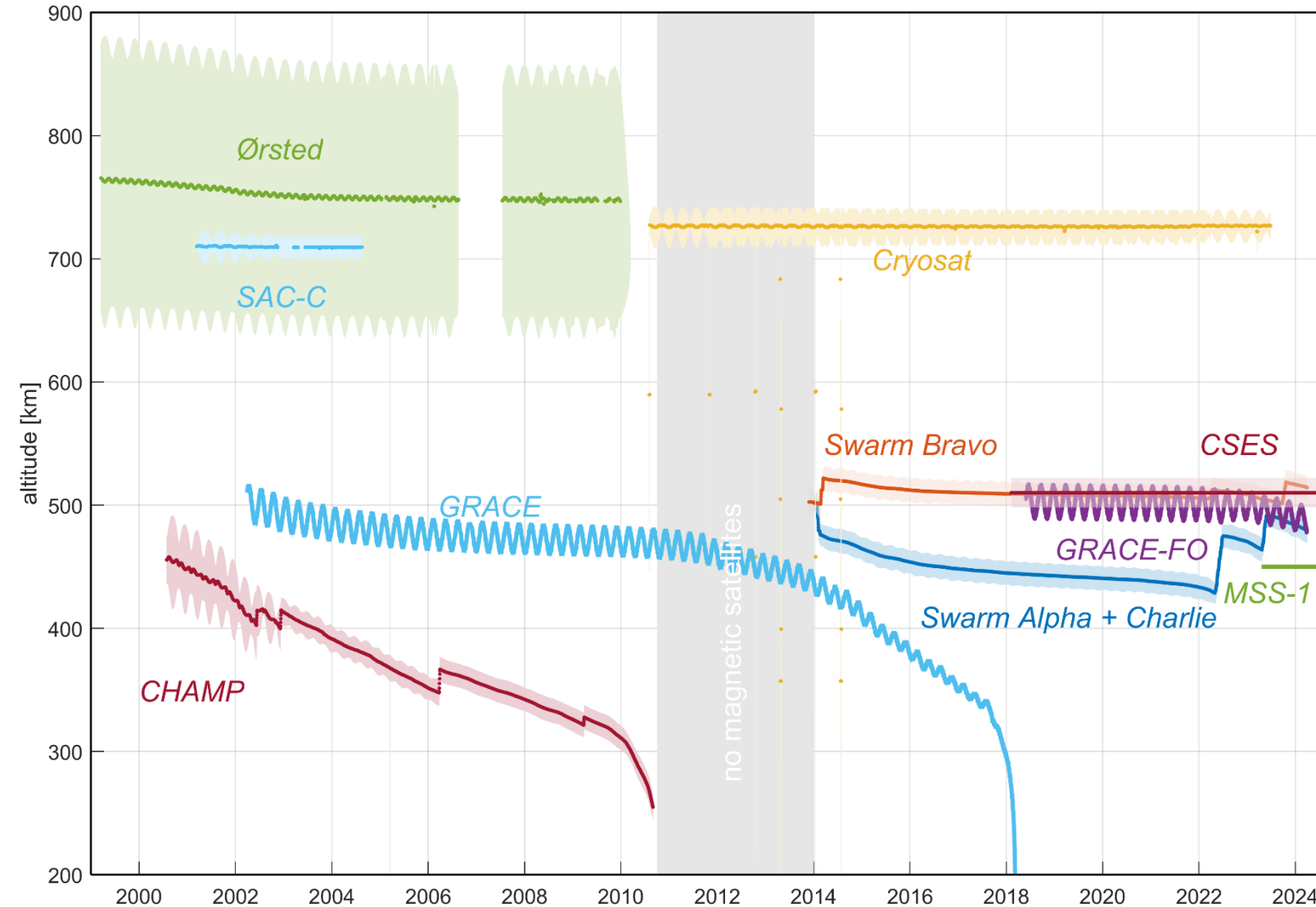


No high-precision magnetic field data are available in the gap between CHAMP and Swarm (Oct 2010 and Nov 2013)

CryoSat-2 and GRACE help to fill this gap, for improved study of the dynamics of Earth's core field

Swarm, CryoSat-2, and GRACE-FO provide simultaneous data for improved time-space separation of external sources

Swarm-family satellites for exploring Earth's magnetic field



No high-precision magnetic field data are available in the gap between CHAMP and Swarm (Oct 2010 and Nov 2013)

CryoSat-2 and GRACE help to fill this gap, for improved study of the dynamics of Earth's core field

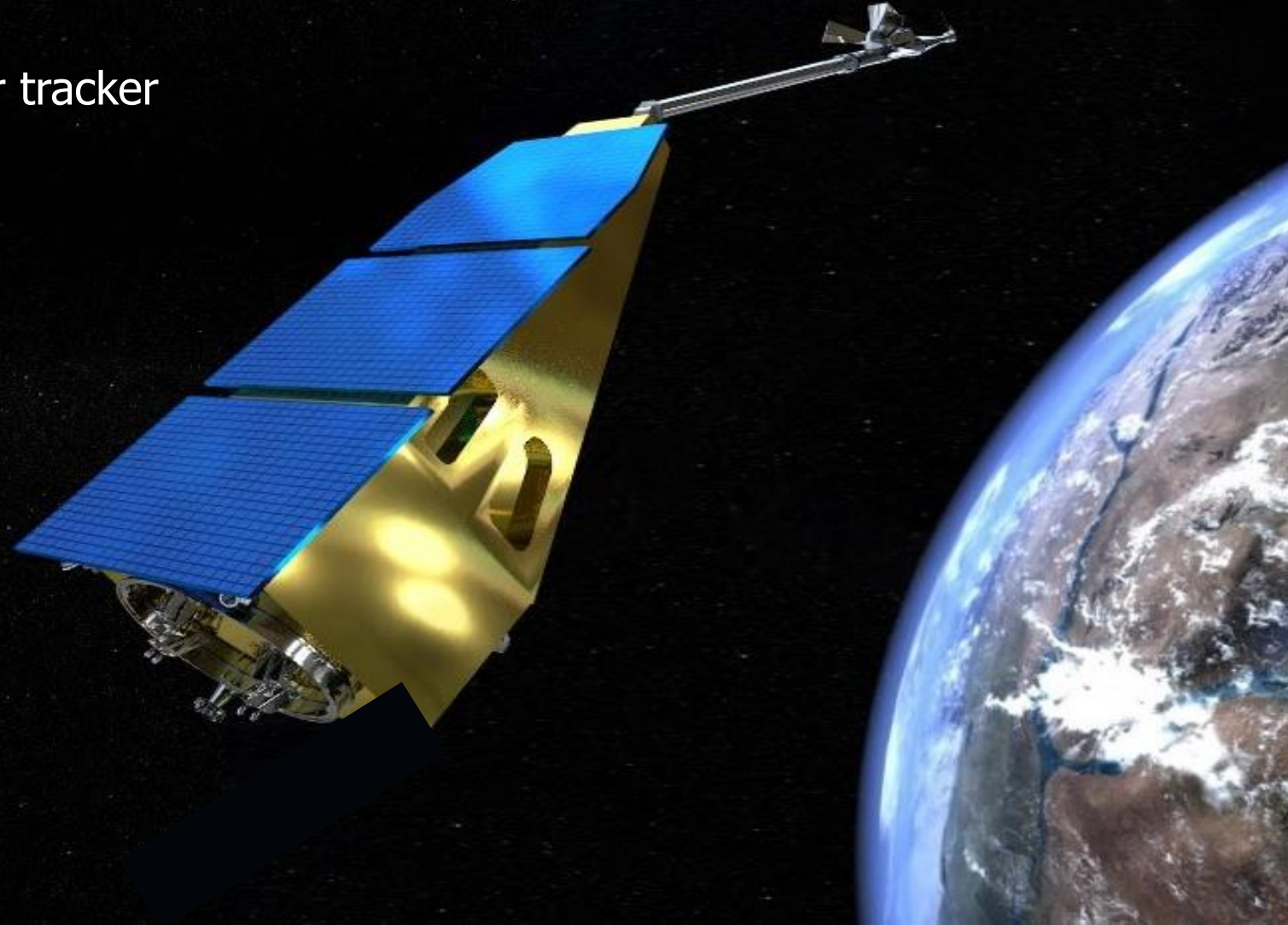
Swarm, CryoSat-2, and GRACE-FO provide simultaneous data for improved time-space separation of external sources

... plus high-precision magnetic data from CSES (only *F*) and MSS-1 (*B*)

The Future (1)

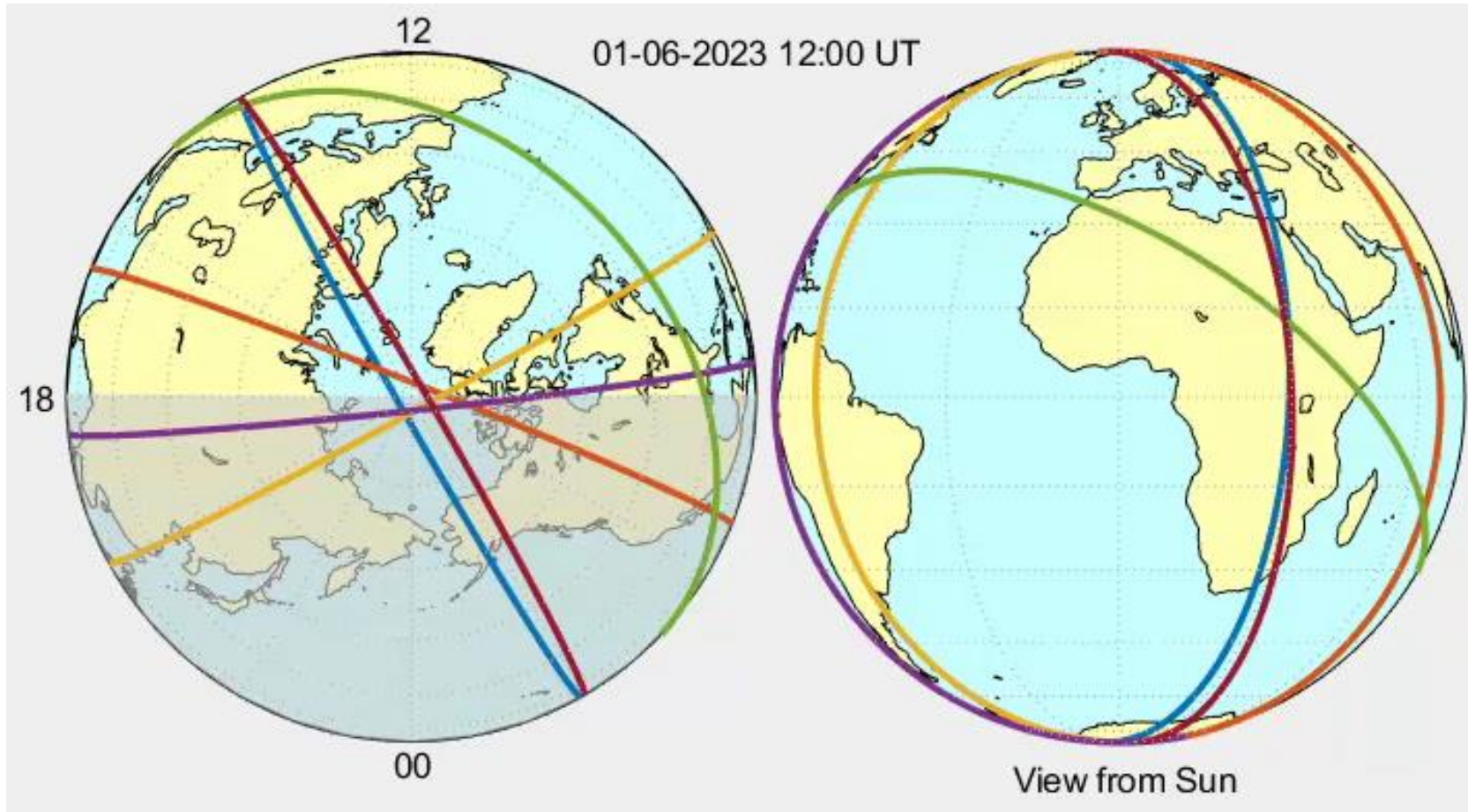
MSS-1: First Macau Science Satellite

- Launched on 21 May 2023
- 450 km altitude, 41° inclination
- Vector and scalar magnetometers, star tracker
- Ongoing commissioning of satellite



see talk by Keke Zhang

Local Time Evolution



Swarm A/C

change in LT of 2.73 hrs/month
all LT in 4.4 months

Swarm B

change in LT of 2.61 hrs/month
all LT in 4.6 months

CryoSat-2

change in LT of 1.50 hrs/month,
all LT in 8.0 months

GRACE-FO A/B

change in LT of 0.59 hrs/month,
all LT in 20.2 months

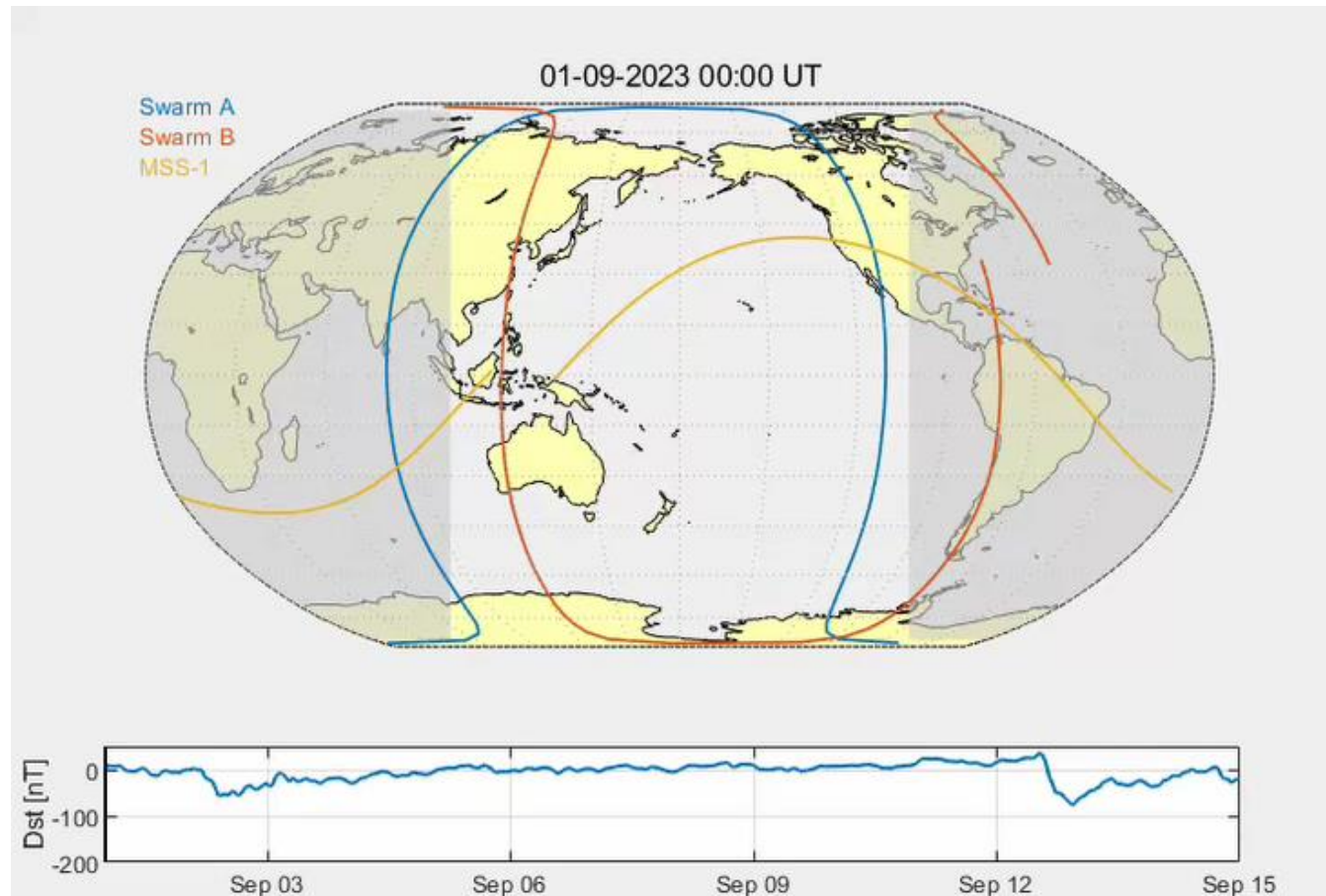
CSES

fixed LT at 02/14

MSS-1

change in LT of 13.9 hrs/month
all LT in 26.3 days

Improved Local-Time description of (non-polar) external fields



Models of core and lithospheric field are presently degraded by external magnetic field contributions – they are the main error source in geomagnetic field modelling.

Improved description of the time-space structure of magnetospheric fields

- Scientific case: the “quiet time ionosphere and magnetosphere”
- ... will in return improve models of core and lithospheric field ...
- ... and improve determination of 3D mantle conductivity

The Future (2)

NanoMagsat Constellation

- 3 cubesats (16u) at 575 km initial altitude
- Two satellites at 60° inclination, one near-polar
- Vector and scalar magnetometers, star tracker plasma instrument (Langmuir probe)
- Approved for implementation as an ESA Scout mission



see talk by Gauthier Hulot

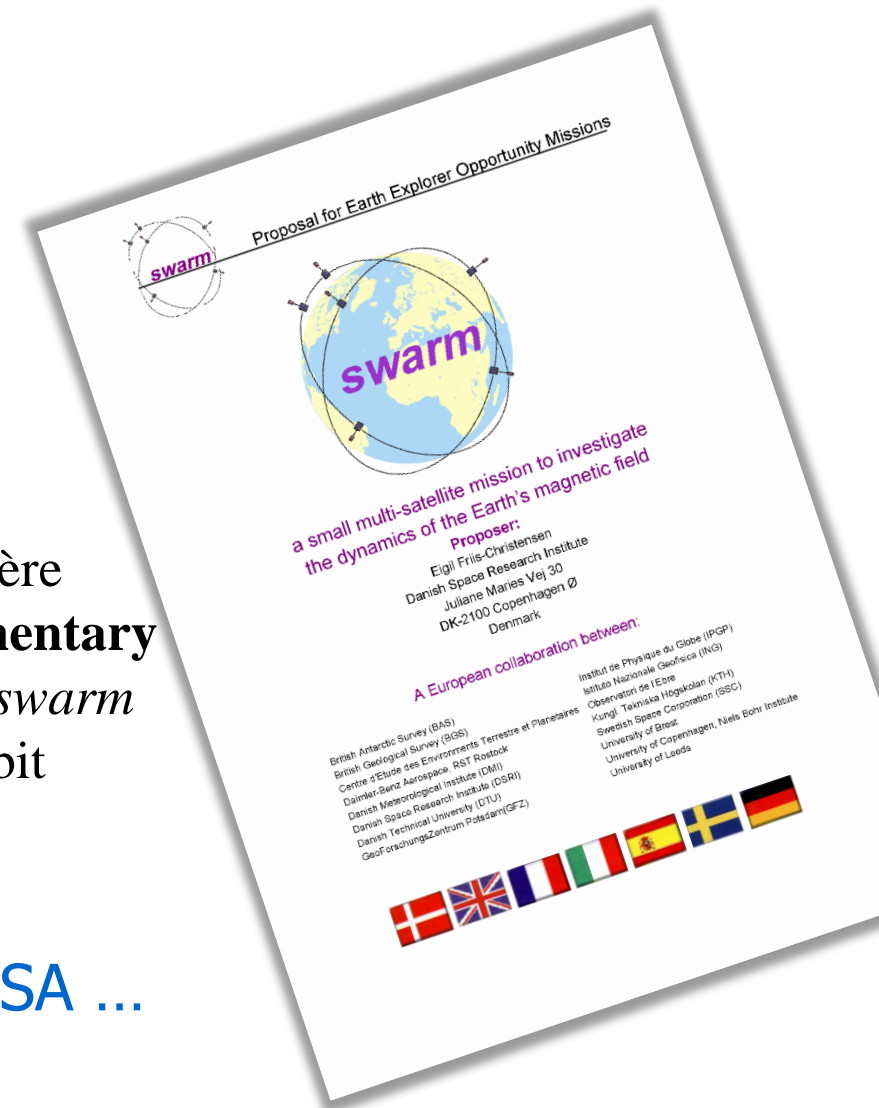
The original *swarm* concept

First proposal to ESA in 1998: 6+1 = **7 satellites** !

- 6 polar orbiting satellites in two orbital planes
- ... and a 7th low inclination satellite
(French contribution, "Ampère satellite")

"In the framework of the *swarm* mission, the scientific team of the Ampère project proposes an evolution of the Ampère concept toward a **complementary mission** to the basic *swarm* concept: We propose to use the flight spare *swarm* satellite as the **low inclination** (< 50 degree) low altitude (< 400 km) orbit Ampère implementation."

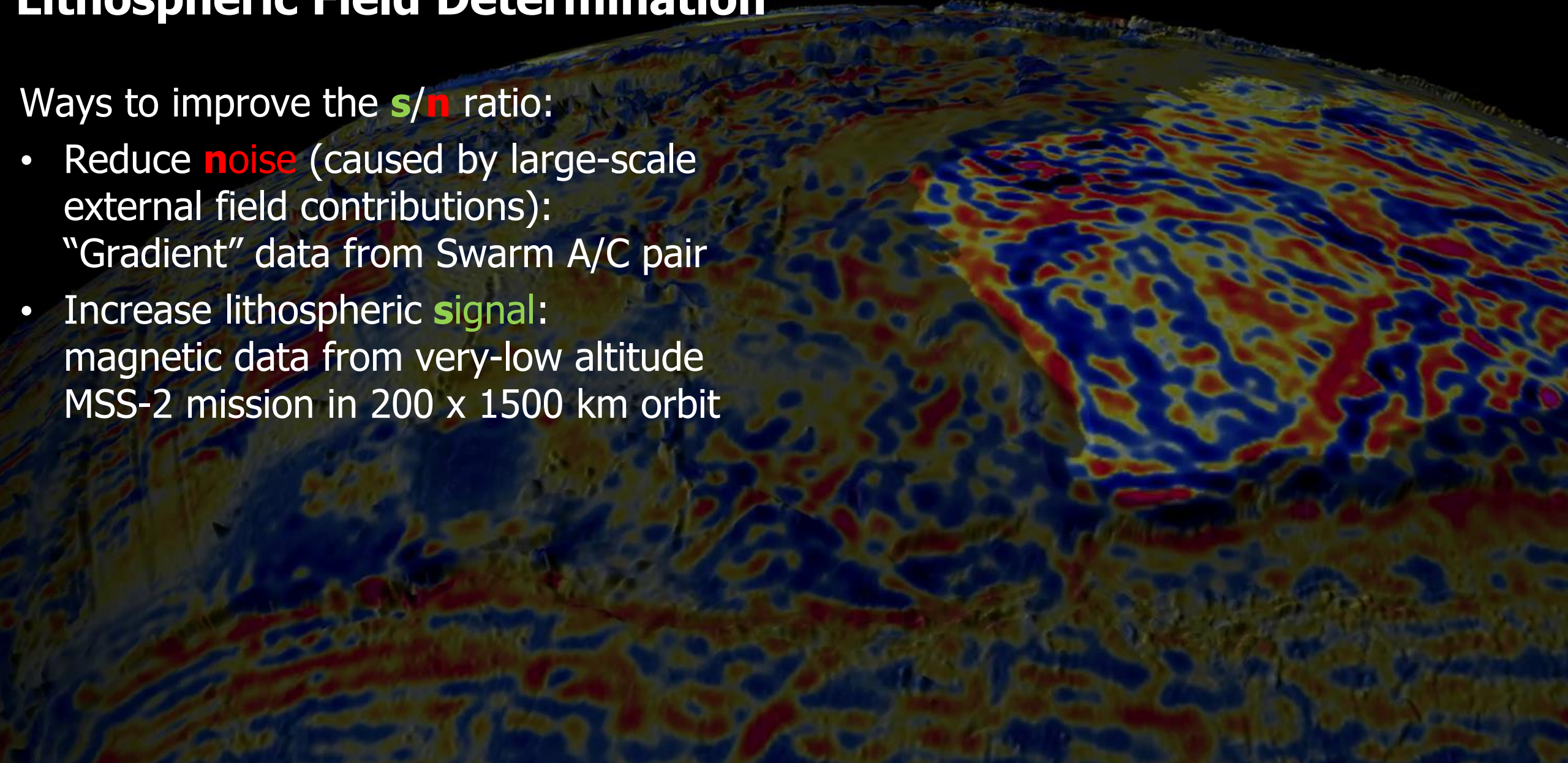
- The low-inclination satellite was not implemented by ESA ...
... but with MSS-1 and NanoMagsat we finally get it!



A task for Swarm during next solar minimum: Lithospheric Field Determination

Ways to improve the **s/n** ratio:

- Reduce **noise** (caused by large-scale external field contributions):
“Gradient” data from Swarm A/C pair
- Increase lithospheric **signal**:
magnetic data from very-low altitude
MSS-2 mission in 200 x 1500 km orbit



The Future (3)

MSS-1: First Macau Science Satellite

- Launched on 21 May 2023
- 450 km altitude, 41° inclination

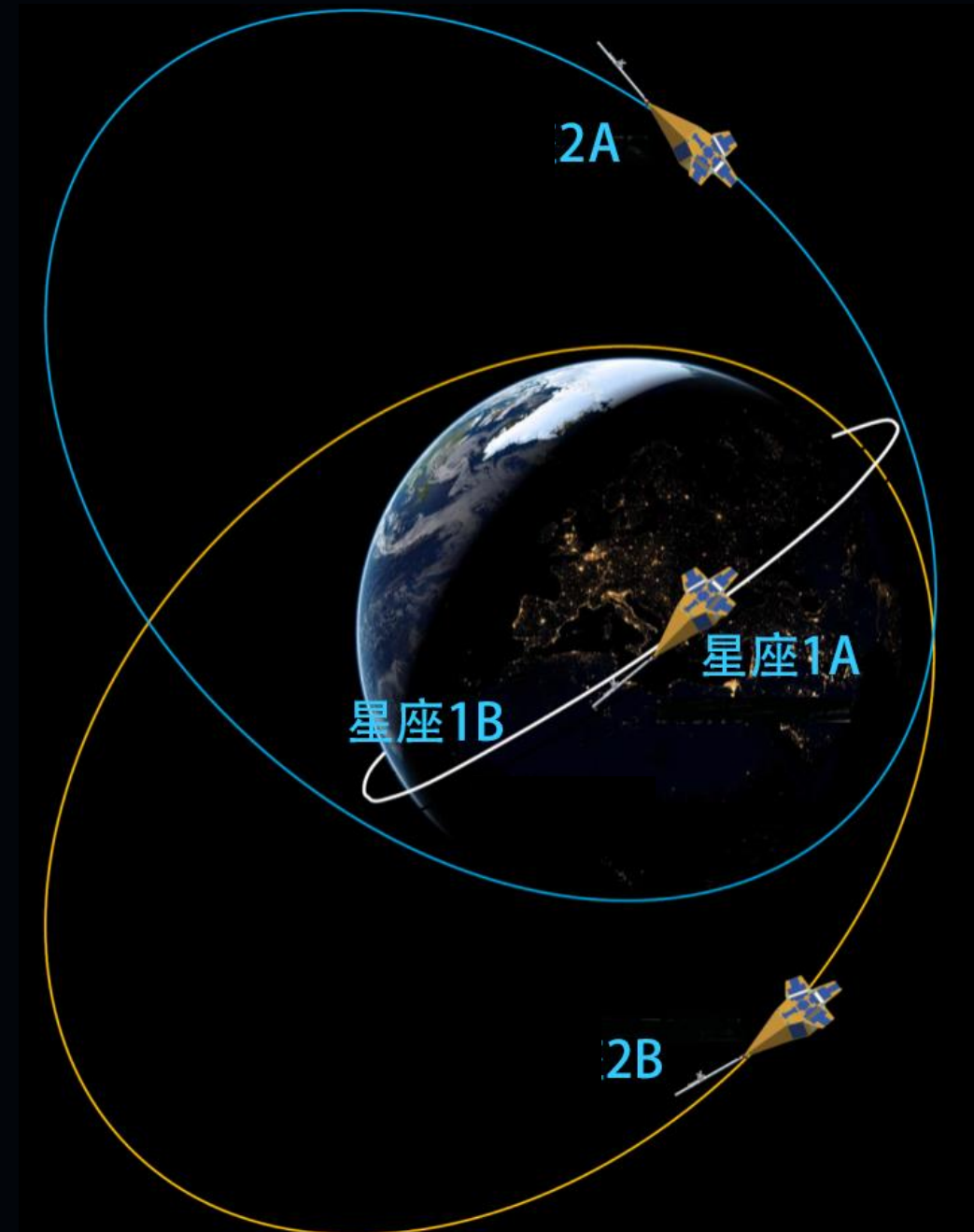
NanoMagsat Constellation

- 3 cubesats (16u) at 575 km initial altitude

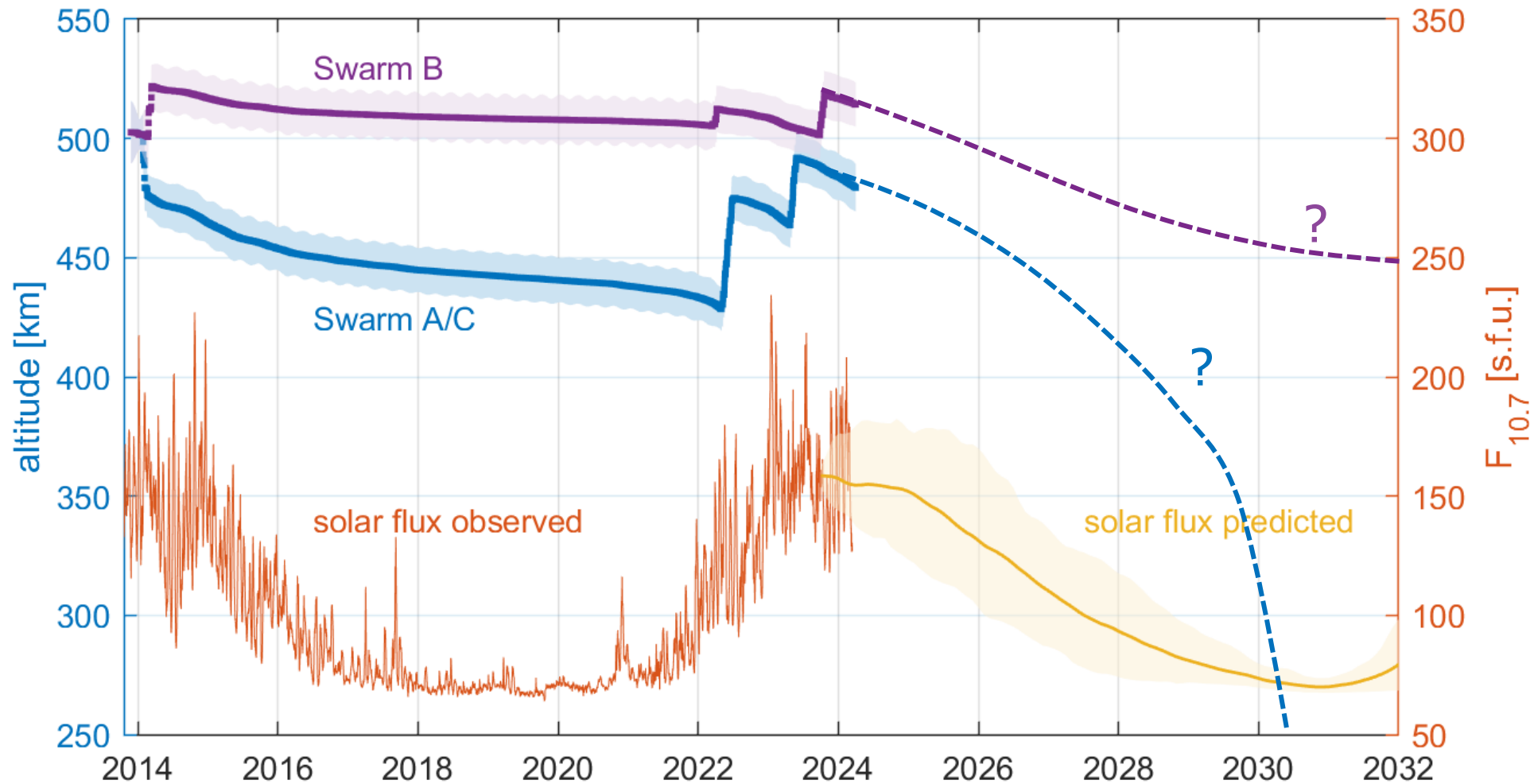
MSS-2: Low altitude Second Satellite Pair

- In preparation for launch in 2026+
- < 200 x 1500 km elliptical polar orbit
- Vector and scalar magnetometers, star tracker

see talk by Keke Zhang



Preparing for the next years of Swarm



Outlook: Swarm and Beyond

- With Swarm, MSS-1, NanoMagSat and MSS-2: the future of satellite magnetometry is bright ... for the next 5-10 years
- Continuation of international and inter-agency collaboration ...
... following the spirit of the Ørsted, CHAMP, Swarm science communities
- Operational satellite for monitoring Earth's magnetic field based on NanoMagSat concept? Future ESA Sentinel mission?

