Next Generation Gravity Mission (NGGM) scientific outlook

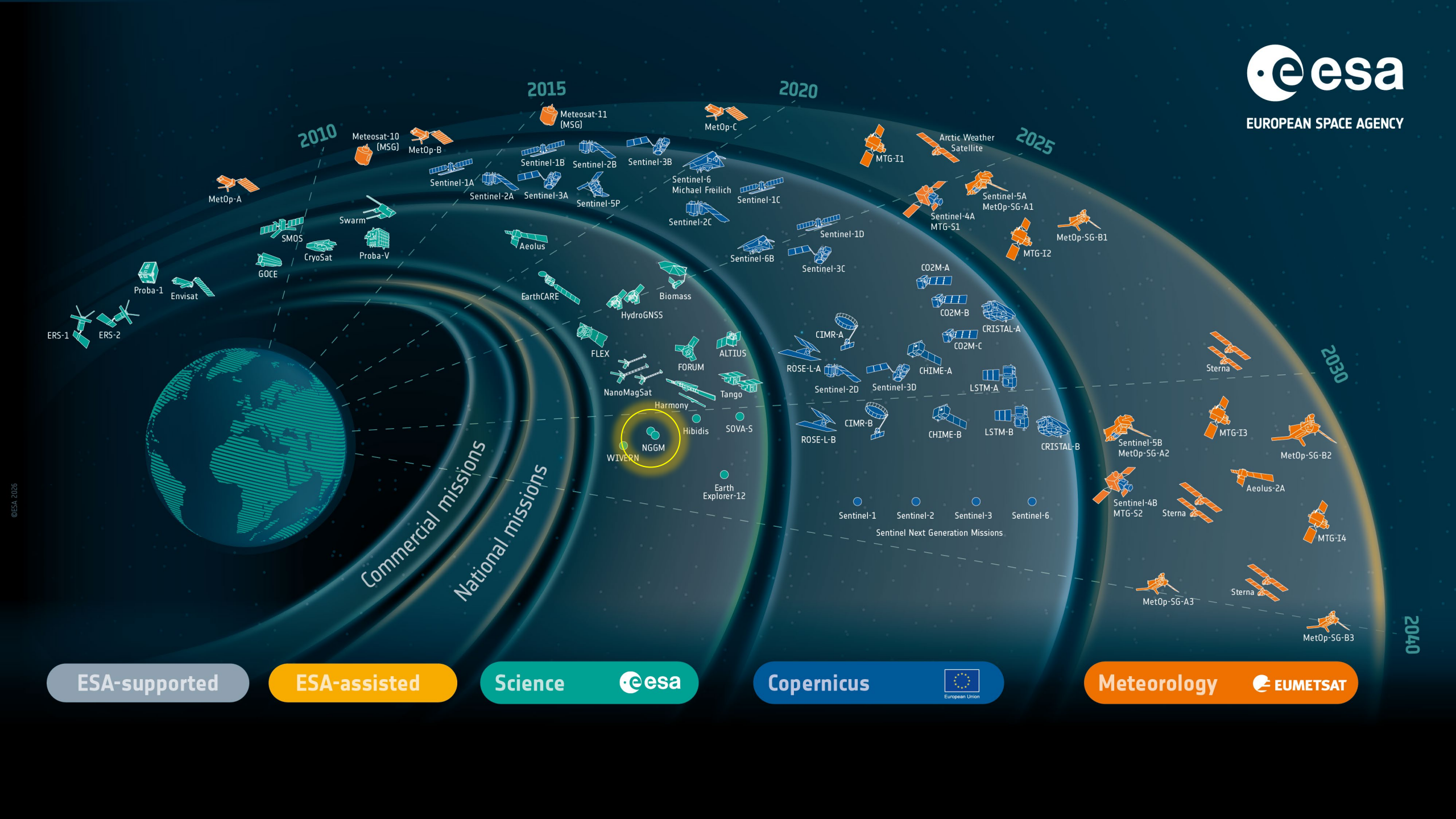
Ilias Daras

NGGM and MAGIC mission scientist

European Space Agency, Directorate of EO Programmes, ESTEC, Noordwijk, The Netherlands

07 September 2026 – ESA Advanced Training Course on Land Remote Sensing

EUROPEAN SPACE AGENCY


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2010
2015
2020
2025
2030
2040
ERS-1
ERS-2
Envisat
Proba-1
GOCE
SMOS
CryoSat
Swarm
Proba-V
MetOp-A
Meteosat-10 (MSG)
MetOp-B
Meteosat-11 (MSG)
Sentinel-1A
Sentinel-2A
Sentinel-1B
Sentinel-3A
Sentinel-2B
Sentinel-5P
Sentinel-3B
Sentinel-6 Michael Freilich
Sentinel-2C
MetOp-C
Sentinel-1C
Sentinel-6B
Sentinel-1D
Sentinel-3C
Aeolus
EarthCARE
HydroGNSS
Biomass
FLEX
NanoMagSat
FORUM
ALTIUS
Harmony
Tango
Hibidis
SOVA-S
NGGM
WIVERN
Earth Explorer-12
MTG-I1
Arctic Weather Satellite
Sentinel-4A MTG-S1
Sentinel-5A MetOp-SG-A1
MTG-I2
MetOp-SG-B1
CO2M-A
CO2M-B
CO2M-C
CRISTAL-A
CIMR-A
ROSE-L-A
Sentinel-2D
Sentinel-3D
CHIME-A
LSTM-A
ROSE-L-B
CIMR-B
CHIME-B
LSTM-B
CRISTAL-B
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-6
Sentinel Next Generation Missions
Sterna
Sentinel-5B MetOp-SG-A2
MTG-I3
MetOp-SG-B2
Sentinel-4B MTG-S2
Sterna
Aeolus-2A
MTG-I4
MetOp-SG-A3
Sterna
MetOp-SG-B3
Commercial missions
National missions
ESA-supported
ESA-assisted
Science
Copernicus
European Union
Meteorology
EUMETSAT
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NGGM and MAGIC

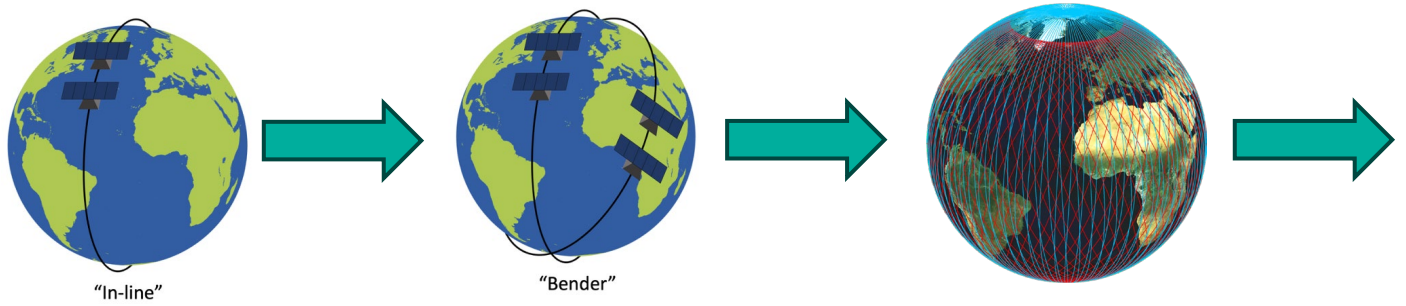
NGGM mission aim[1]

Extend and improve time series of satellite gravity missions by providing ***enhanced spatial and temporal resolution*** *time-varying gravity field measurements with* ***reduced uncertainty and latency*** *to address the international user needs as expressed by IUGG[2] and GCOS[3] and* ***demonstrate operational capabilities*** *relevant for Copernicus.*

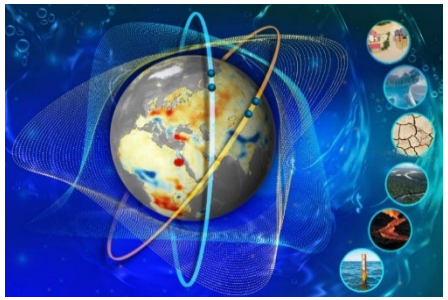
ESA-NASA collaboration on **MAGIC** (Mass Change and Geosciences International Constellation)

MAGIC is the joint concept for collaboration on future satellite gravity constellation that addresses the needs of the international user community. MAGIC is a double-pair constellation to be realized in a staggered manner:

- **Pair 1 (P1) GRACE-C**: NASA/DLR program, near-polar orbit @ ~500 km altitude, global coverage
- **Pair 2 (P2) NGGM**: ESA Mission of Opportunity in FutureEO program (currently in Advance Phase B2), 70 deg. inclined orbit @ ~400 km, controlled altitude, enhanced monitoring
- **MAGIC**: Minimum **4 years** of combined operations with goal to start at 2032



- ✓ **Higher resolutions**
- ✓ **Shorter latency**
- ✓ **Higher accuracy**
- ✓ **Consistency of product quality …**



…new science applications & operational services in anticipation of Copernicus

[1] Daras, I. (Ed), 2023. Next Generation Gravity Mission (NGGM) Mission Requirements Document, Issue 1.0, Earth and Mission Science Division, European Space Agency. https://doi.org/10.5270/ESA-NGGM-MRD-2023-09-v1.0
https://doi.org/10.1007/s10712-015-9348-9

NGGM Primary Objectives (I)

esa
→ THE EUROPEAN SPACE AGENCY



- Measure changes in the AMOC and ACC with an accuracy of 1 Sv for 3-year means







- Improve **ice mass balance** of ice sheets and glaciers and their contribution to sea level change to 0.03 mm/year globally and 0.025 mm/year regionally over the course of a decade
- Improve understanding of unstable **glaciers dynamics**

- Monitor **Terrestrial Water** and **Groundwater Storage ECVs** towards **GCOS** 2022 goal requirements
- Early warning of droughts and flooding potential
- Support water management applications
- Contribute to the closure of water budget at sub-basin scale

NGGM Primary Objectives (II)

esa
→ THE EUROPEAN SPACE AGENCY



- Quantify co-seismic Mw > 8.0, post-seismic Mw > 7.6 gravity changes
- Improve understanding of **deformation processes** during all phases of the seismic cycle.







- Improve the estimation of **Ocean heat uptake** and **Earth energy imbalance** by resolving ocean mass changes < 0.5 mm/yr on decadal time scale
- Improve the closure of **sea level budget** by resolving ocean mass changes < 0.1 mm/yr (0.3 mm/yr) at global (resp. regional) scales and on decadal (resp. bidecadal) time scales

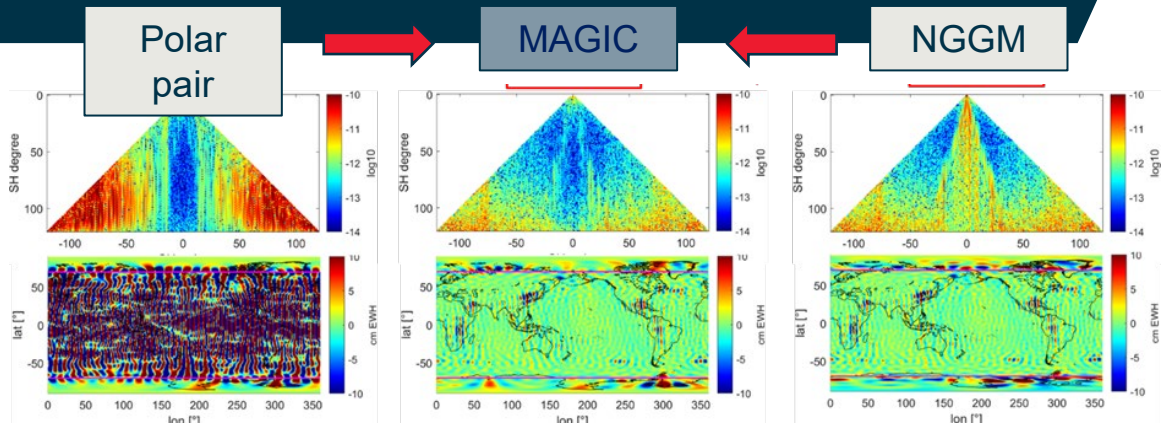
- Improve the unification and closure between regional and national height systems and contribute to the static and time-varying realisation of the **International Height Reference Frame (IHRF)** with 1 cm, for the static part, and 0.1 cm/yr for the time-varying component.

NGGM contribution to MAGIC

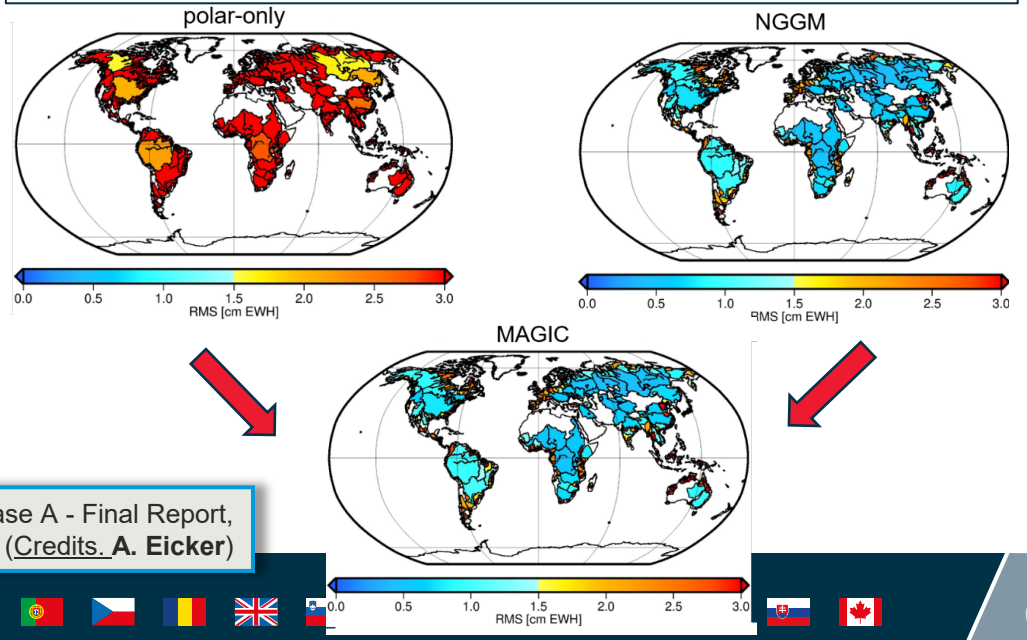
- **GRACE-C** ensures continuity and global coverage.
- **NGGM** enables enhanced sensitivity and pre-operational capabilities
- Simulations reveal **NGGM** contributes **>90%** to the **MAGIC** Level-2a ***mission performance*** over the areas below 70°
- **NGGM orbit control** provides homogeneous ground-track coverage, ensuring uniform ***consistency of product quality*** over time, compensating for the variable quality of polar pair products

→ prerequisite for NGGM and MAGIC **pre-operational capabilities**

- **NGGM** ***improved product latency*** enables the generation of **novel** fast-track sub-weekly products for both NGGM and MAGIC → **Early warning applications**
- For **hydrological applications**, mostly in river basins in the lower to mid latitudes (i.e., below 70° degrees latitude) NGGM provides a leap in the improvement of gravimetry derived water products.



RMSD of basin averages using Level-2a 5-day product at 400km spatial resolution

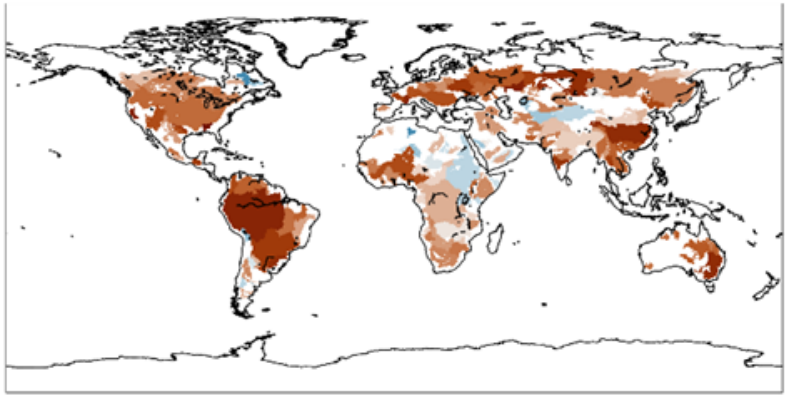


Reference: ESA NGGM/MAGIC – Science Support Study During Phase A - Final Report, https://www.asg.ed.tum.de/iapg/magic/documents/ (Credits. **A. Eicker**)

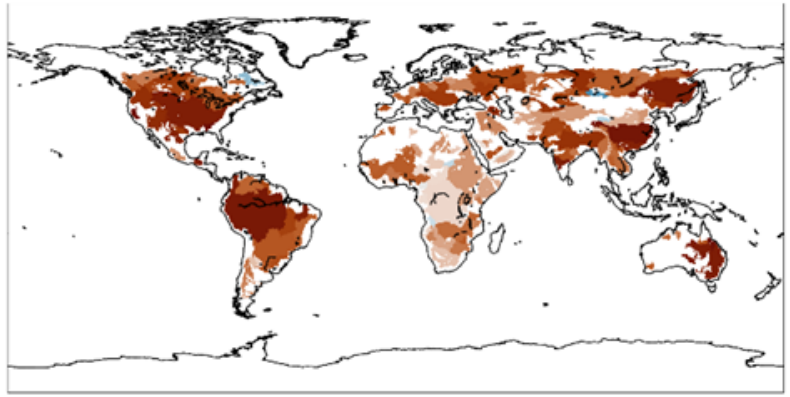
NGGM and MAGIC – Drought monitoring applications

Drought Severity Index (DSI) correlation using TWSA from data assimilation

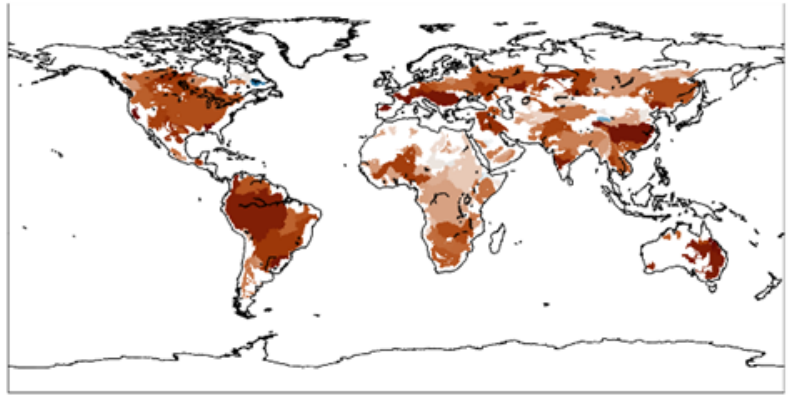
GRACE-C

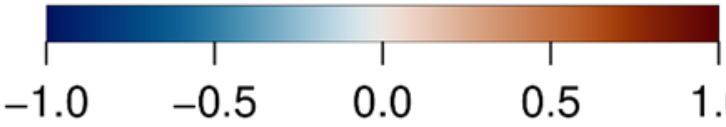


NGGM



MAGIC





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ESA NGGM and MAGIC Science and Applications Impact study (SING study, https://www.esa-sing.org/)

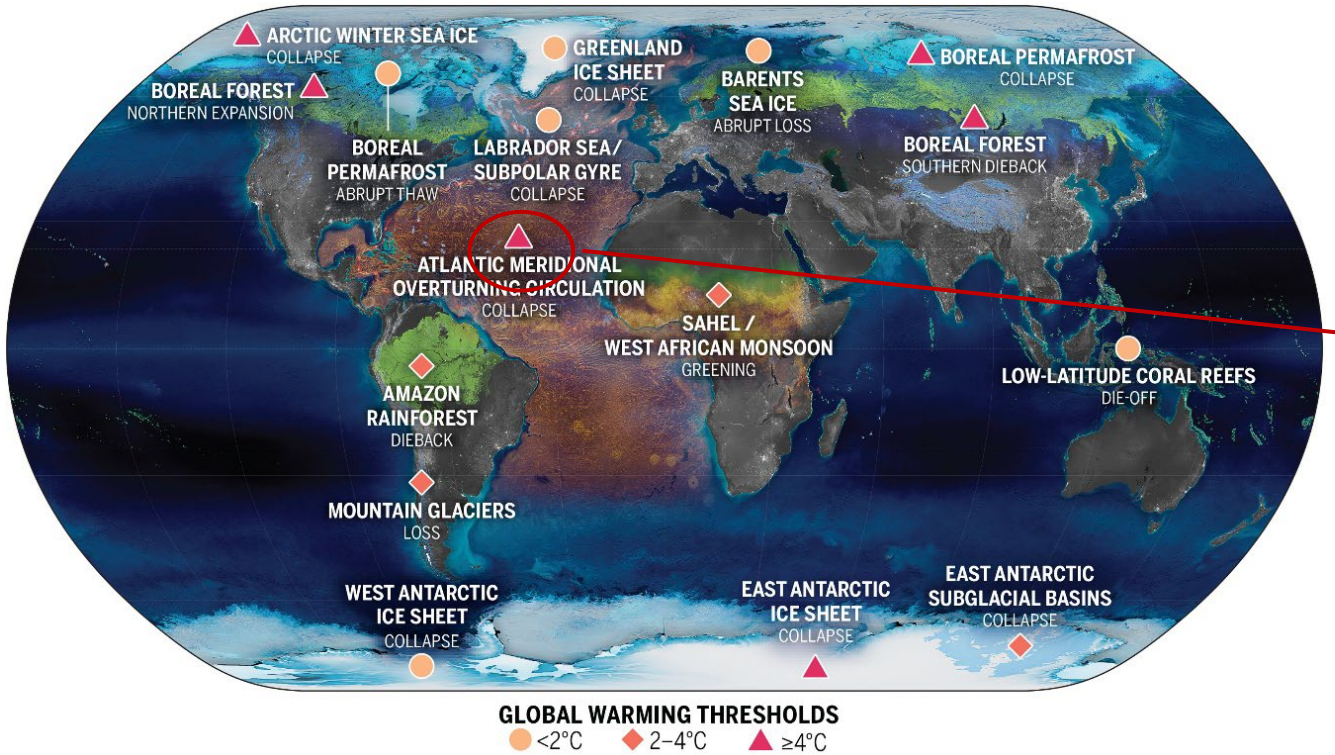
Global **improvement** versus **GRACE-C**-like for TWSA monitoring of dry and wet extremes on monthly scales

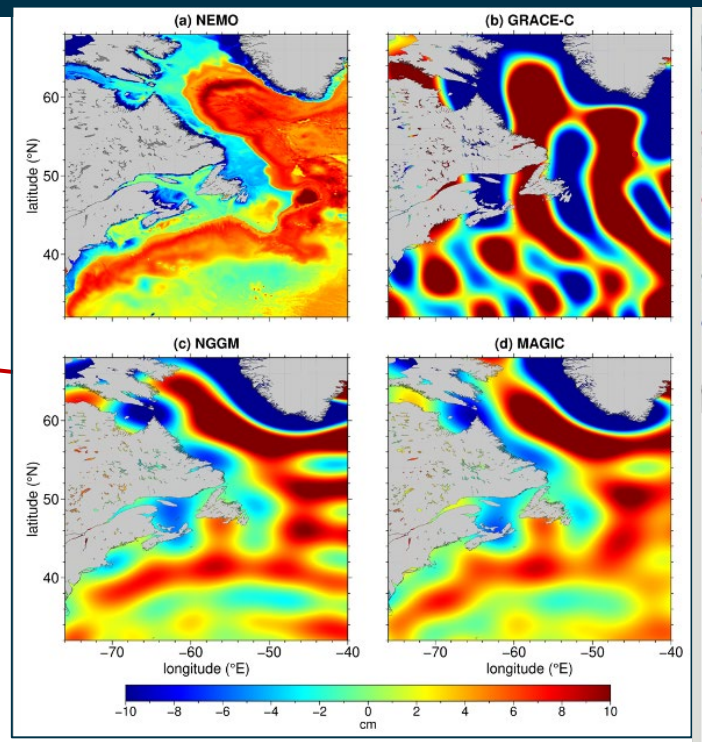
NGGM 69%

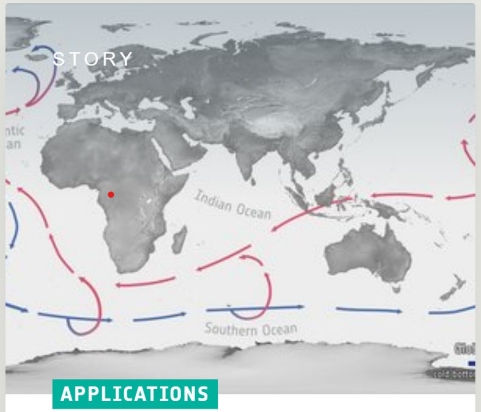
MAGIC 75%

Improve drought monitoring and prediction through global and regional assimilation of satellite gravity data in hydrological models

NGGM / MAGIC and AMOC Tipping Point







APPLICATIONS

New ESA gravity mission to detect weakening ocean conveyor

26/06/2025 4436 VIEWS 45 LIKES

READ →

- AMOC variability leaves a distinct ocean bottom pressure (OBP) signature along the western boundary of the North Atlantic.
- This signature is obscured by noise with a GRACE-like mission.
- Simulated NGGM data captures OBP variability on the western boundary with much greater fidelity.
- MAGIC's ability to resolve this crucial OBP signal, and enable robust AMOC monitoring from space, hinges on NGGM's improved noise characteristics.

ESA web story:

Credits: ESA SING study (University of Bristol)

University of BRISTOL

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ESA NGGM and MAGIC Science and Applications Impact study (SING study, https://www.esa-sing.org/)



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NGGM
SCIENCE AND APPLICATIONS WORKSHOP 2027



24-26 May 2027 | Carcassonne, France

https://www.nggm2027.org/ *(under construction)*

Contact: **ilias.daras@esa.int**