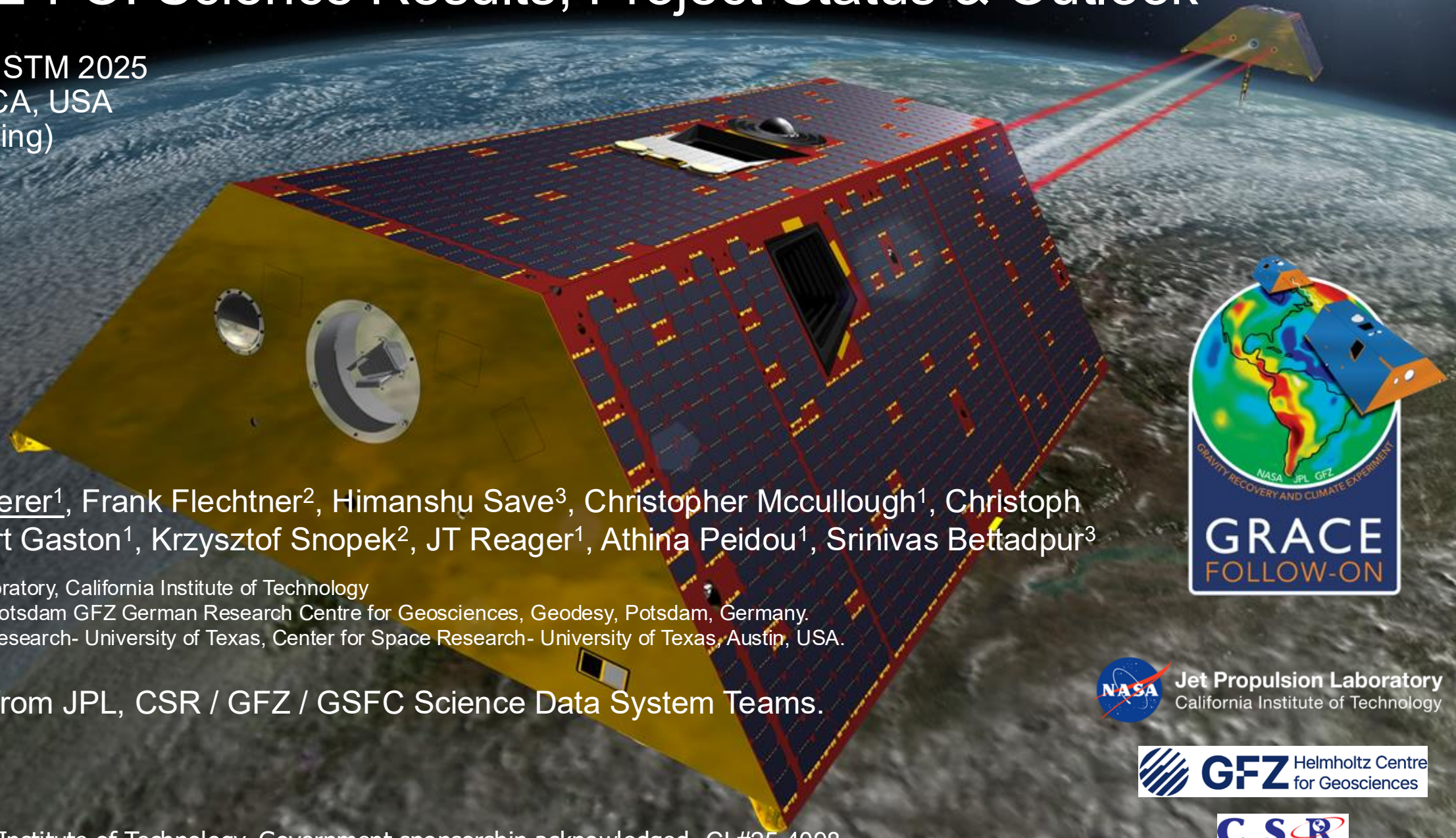
GRACE-FO: Science Results, Project Status & Outlook

GRACE-FO STM 2025
Pasadena, CA, USA
(virtual meeting)



Felix W. Landerer[1], Frank Flechtner[2], Himanshu Save[3], Christopher Mccullough[1], Christoph Dahle[2], Robert Gaston[1], Krzysztof Snopek[2], JT Reager[1], Athina Peidou[1], Srinivas Bettadpur[3]

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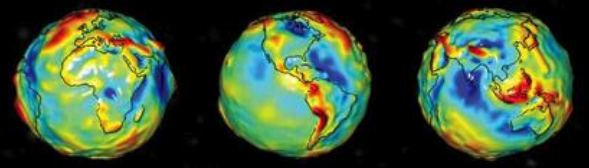
[3] Center for Space Research- University of Texas, Center for Space Research- University of Texas, Austin, USA.

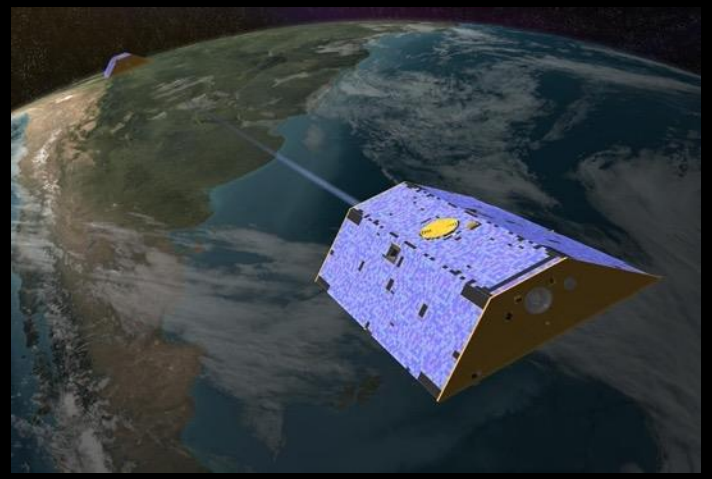
With support from JPL, CSR / GFZ / GSFC Science Data System Teams.

GRACE, GRACE-FO, GRACE-C

A Successful International US-German Partnership Since 2002



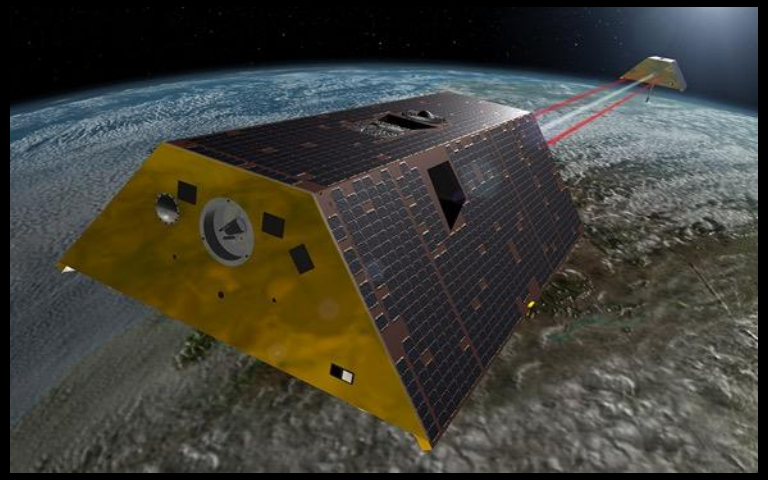
Fundamental geodetic measurements
of global mass changes



2002 - 2017

The ***GRACE*** mission was a collaboration with the German Aerospace Center to measure month-to-month gravity changes.

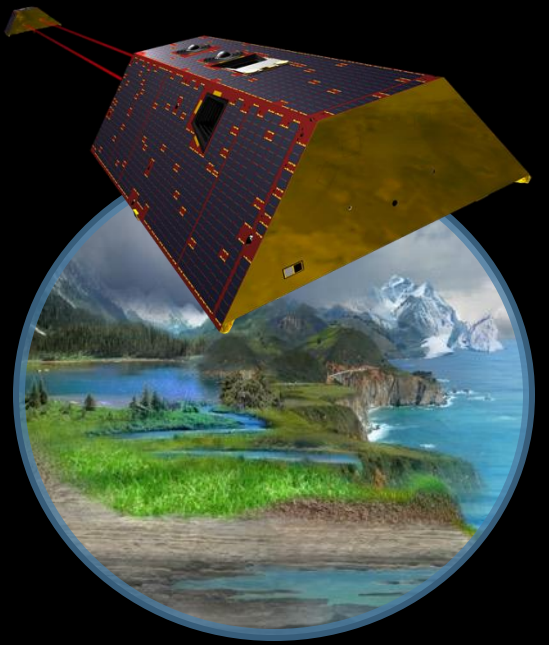
GRACE



2018 - ongoing

GRACE-FO continues the observations, while also demonstrating new laser-ranging interferometry (LRI), in collaboration with the GFZ German Research Center.

GRACE-FO



2028 (planned)

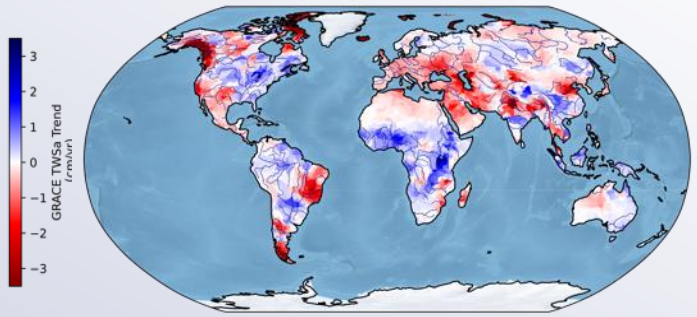
GRACE-Continuity will maintain and expand the foundational mass change measurements of Earth's changing water cycle.

GRACE-Continuity

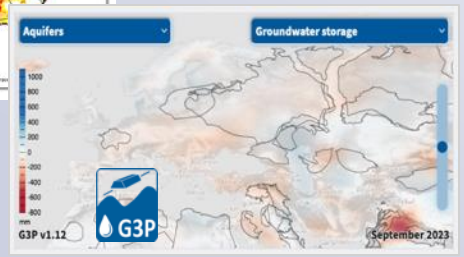
Trillions of unique observations over the last two decades keep an eye on the ever-evolving planet.

Monthly Global Mass-Tracking with *GRACE*-satellites – *Smart Water Meters* for Monitoring Drought & Flood Risks, and Changes to Groundwater, Sea Level and Glaciers

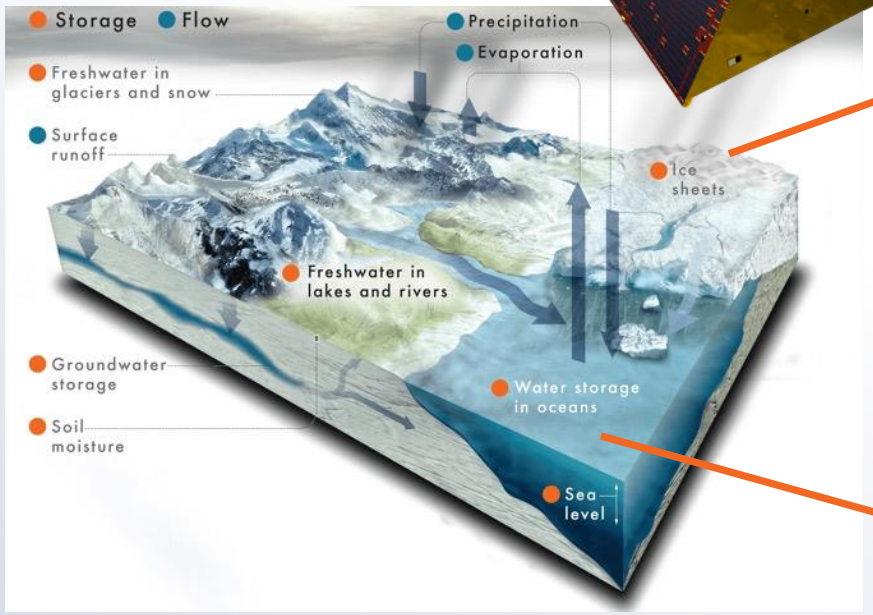
Groundwater & Soil Moisture



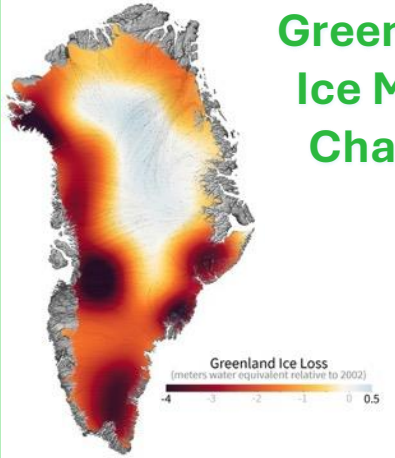
Drought Risk & Flood Potential



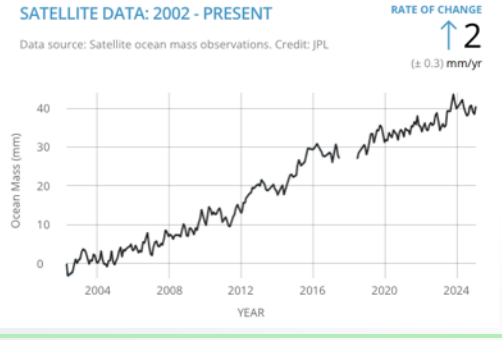
Earth's Water Cycle



Greenland Ice Mass Change

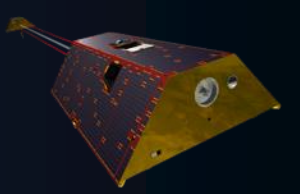


Sealevel Change

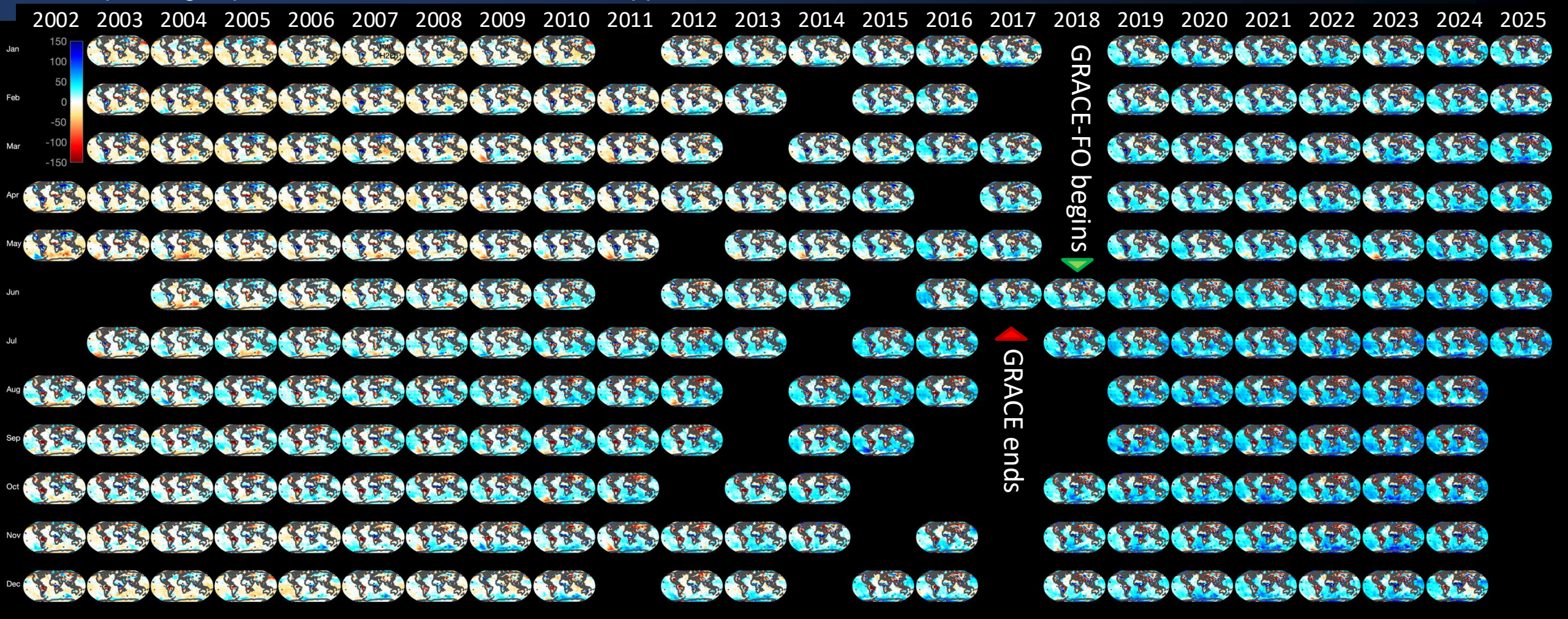


The GRACE-missions are vital for advancing scientific knowledge of Earth's evolving water cycle and systems.
They provide valuable data in support of meeting water resources needs & security for thriving economies & societies.

GRACE and GRACE-FO: 23+ years of Scientific Discoveries and Expanding Societal Applications



- Continuous science data collection & processing in 2024/2025
- Since mission start, delivered 85 monthly gravity/mass change data sets at a level consistent with GRACE (see Level-2 talks in this session)
- Expanding impactful science results & societal applications



Mission Updates since last STM (10/2024)

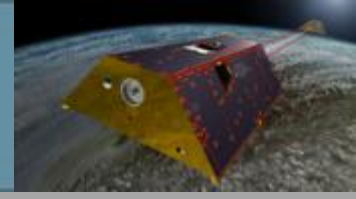
- Programmatic & Mission Updates
- Science Data Performance & Quality
- Near-term Plans & Outlook

GRACE-FO is healthy and delivering high-value science & applications data!

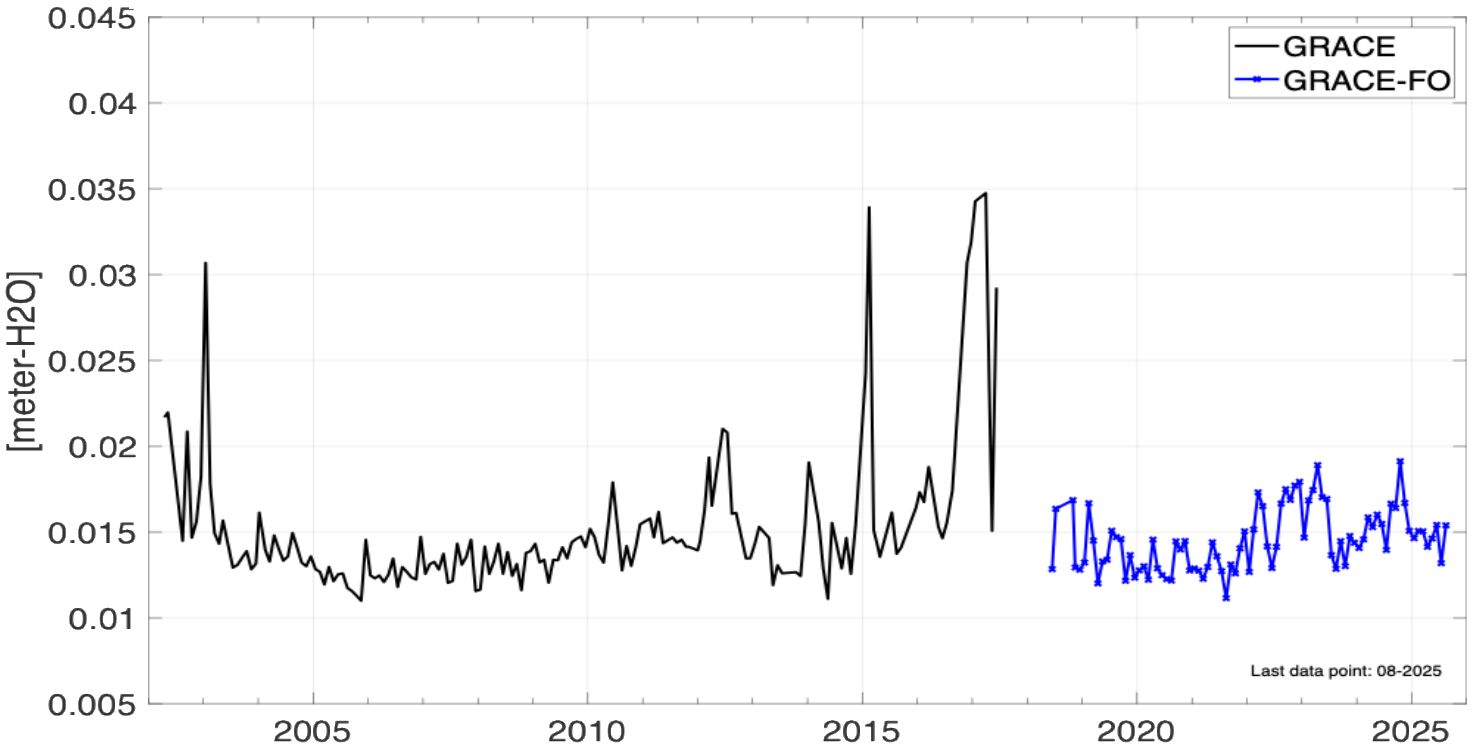
Mission Updates since last STM (10/2024) / part I

- GRACE-FO is in its 3rd year of the 3-year '*Extended Mission*' phase (through Sep'26)
- GFZ: Mission operations at GSOC are secured by GFZ funding through Dec-2029; this will enable extension of the GRACE-FO time series and 1 year cross-calibration with GRACE-C
- JPL/NASA will go through the NASA Senior Review process to renew the mission extension (proposal call expected towards end of 2025 / early 2026)
- NASA Senior Review:
  - We will need to demonstrate continued excellent science and applications value
  - Please communicate to the project team any end-user & stakeholder engagement that show how GRACE-series data is is used for water / drought / fire / resources / hazard management & mitigation
  - Previous NASA *Senior Review* results can be found here: https://science.nasa.gov/earth-science/operating-missions/

The data record between GRACE and GRACE-FO is mostly of consistent quality and information content over 23 years.



Mission Updates since last STM (10/2024) / part II)



- Ocean RMS – a fundamental error metric – remains stable
- Enabled continuous 'wide pointing' mode in since Jul-2023; benefits:
  - Reduced leaks / increased lifetime
  - Improved L2 / L3 data quality through better ACC data calibration
  - Accelerometer 'hybrid-transplant' is stable, can deal effectively with higher-drag environment
- No major issues with operations, spacecraft & science instruments (see MOS / SOM reports for details)
- Only modest increases in GRACE-FO errors despite very high solar activity / drag since late 2021
- Solar Cycle 25 is still high, but has likely entered its declining phase

Project Science Data System Level-2 talks from JPL, GFZ, CSR & GSFC will further detail the data performance and advances made.

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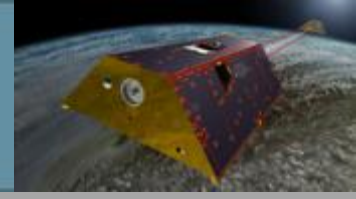

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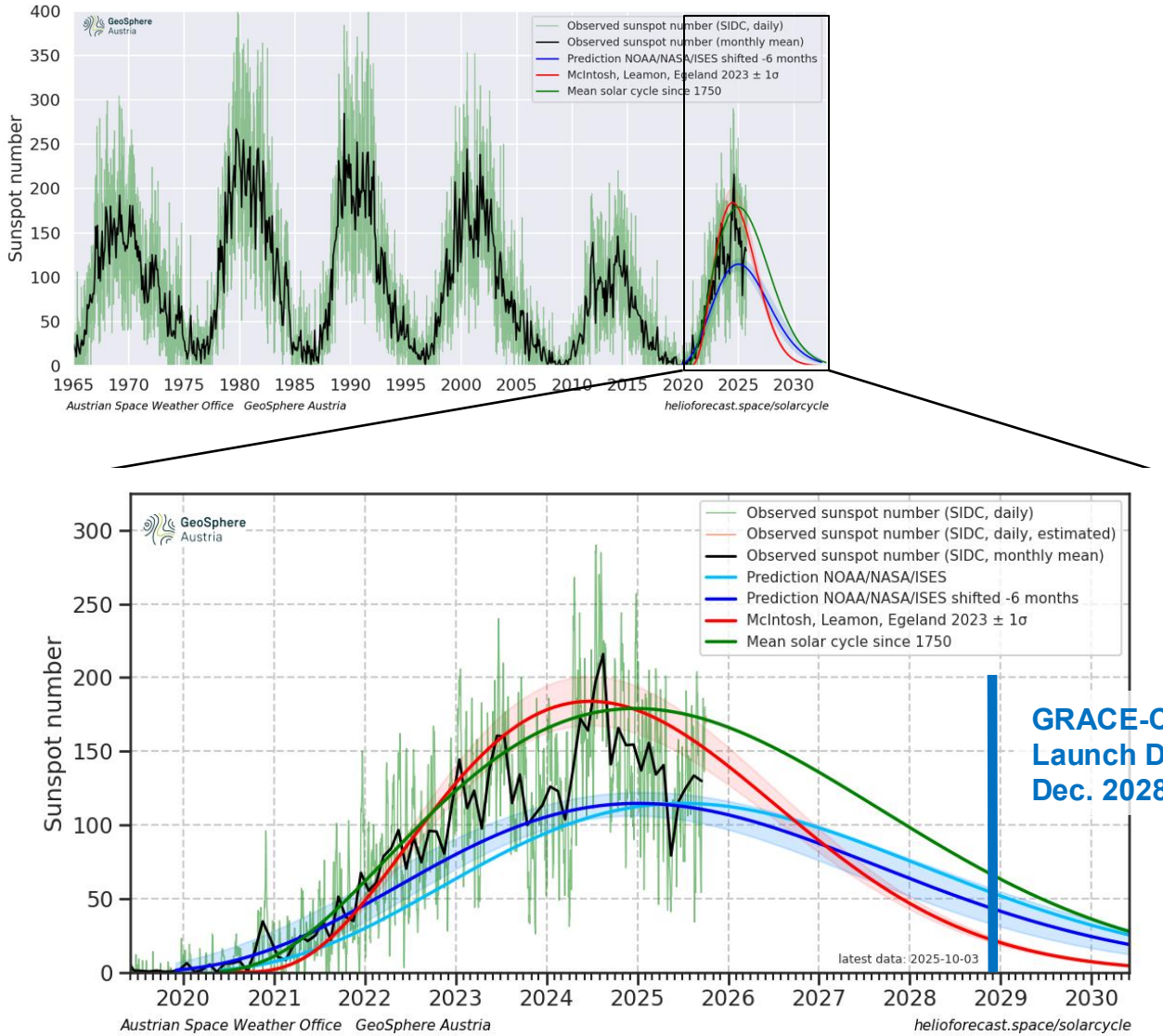
Operational Outlook: Solar Cycle #25 has peaked – higher drag environment will persist as satellites altitude declines

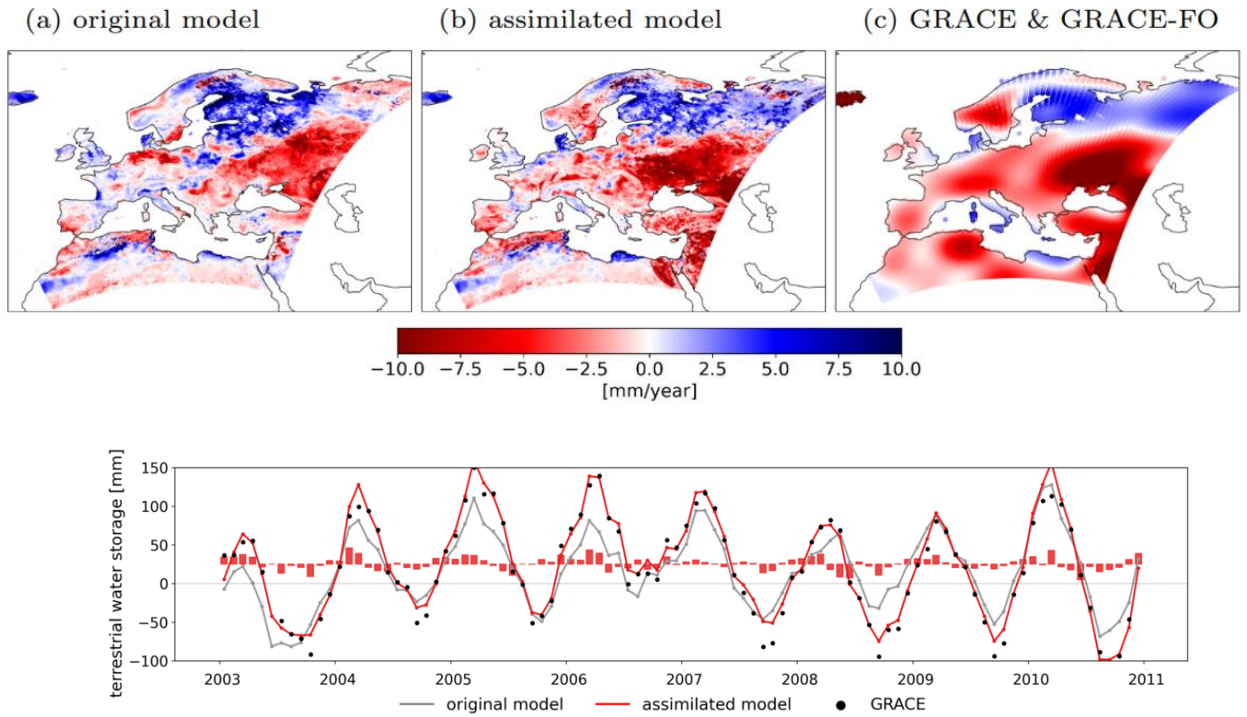


- While SC25 activity is declining, drag is also higher due to declining orbit altitude.
- No orbit raises currently planned.
- See SOM & GSOC reports for further details.

(https://helioforecast.space/solarcycle)

The GRACE-missions provide valuable data in support of meeting water resources needs & security for thriving economies & societies.

Satellite gravimetry improves land surface model simulations



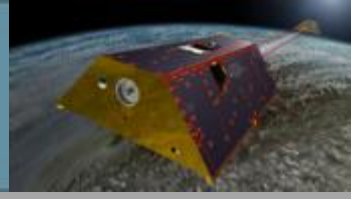
Total water storage changes in the Dnipro catchment area (Credits: Anne Springer).

- GRACE-series data improve the representation of the water cycle in coupled Earth System Models.
- Both the *trends and the extremes* are better captured in the case of GRACE/-FO assimilation.
- This optimized Earth system model & data assimilation make it possible to assess the impact of human activities on the European climate, such as changes in land use or irrigation practices.
- Provides actionable information at stakeholder-level spatial scales.

Anne Springer, University of Bonn
https://www.globalwaterstorage.info/en/satellite-gravimetry-improves-land-surface-model-simulations

globalwaterstorage
SATELLITE MONITORING - GRAVITY MISSIONS

The GRACE-missions provide *valuable* data in support of meeting water resources needs & security for thriving economies & societies.



Natural Hazards
https://doi.org/10.1007/s11069-025-07499-3

ORIGINAL PAPER

An economic impact assessment of the use of earth observation information in flood hazard communication

Richard Bernknopf[1] · Yusuke Kuwayama[2] · Benjamin Zaitchik[3] · Matthew Rodell[4] · Augusto Getirana[4] · Andrea Thorstensen[5] · Samiha Shahreen[6]

Received: 17 September 2024 / Accepted: 21 June 2025

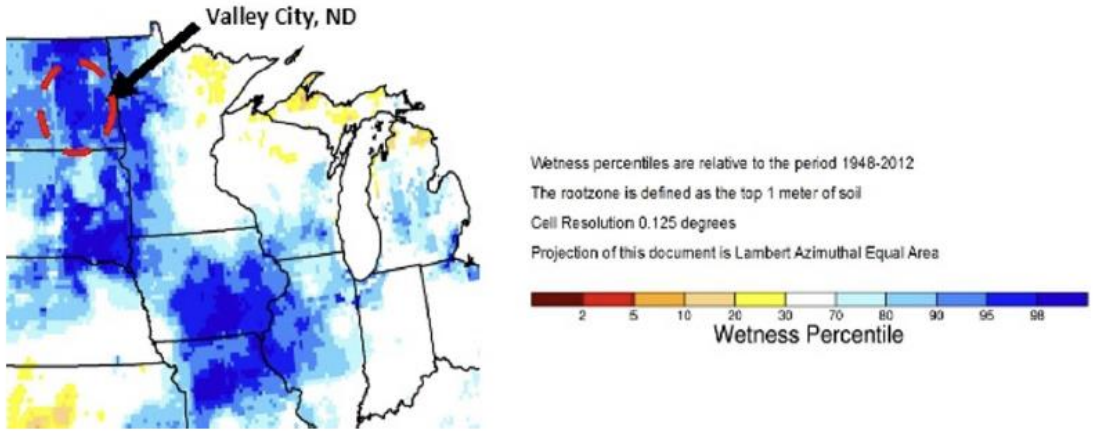


Fig. 3 GRACE – based root zone soil moisture drought indicator 2/28/2011 (https://nasagrace.unl.edu)

Case Study:
2011 spring season Sheyenne River, ND

- A retrospective study quantified the economic value of improved forecast with an experimental empirical soil moisture adjustment from GRACE
- Flood hazard forecasts are critical information to reduce disaster impacts.
- Improved operational flood forecasts can lead to timelier, more cost-effective pre-flood mitigation decisions.

'Value of Information' analysis findings:

- Flood protection decisions could have been made 5 days earlier and mitigation costs could have been reduced.
- Observed increases in extreme dry/wet events provide an opportunity for impactful lower-latency products.

GRACE-FO Mission Status - Summary

- Achievements 2024/2025:
  - Uninterrupted collection of high-impact gravity, mass change & GPS-RO observations, producing excellent science results & applications across all Earth system domain & extending the GRACE data record
  - SDS team is well-along reprocessing G & GFO for Release 7 (RL-07)

- Outlook & Plans:
  - Continue with nominal spacecraft operations
    - wide-pointing mode for now with LRI in diagnostic mode
  - Deliver RL07 reprocessed data for GRACE (Dec'25) and GRACE-FO (Spring'26)
  - Fuel budget and orbit decay outlook is favorable for overlap with NASA / DLR *GRACE-Continuity* mission, targeted to launch 12/2028
  - JPL Project Team is preparing to respond to the NASA '26 Senior Review call and submit a proposal for Mission Extension through '29 (overlap with GRACE-C)

Please keep sending us your latest and greatest papers, presentations & results!

Backup

GRACE-FO: SDS Data Product Status

- Steady delivery of:
  - L-1 (weekly bundles)
  - L-2 + L1B-ACX (monthly)
  - L-3 (monthly)
  - L-4 (monthly)

- SDS data portals:
  - GFZ ISDC
    - https://isdc.gfz-potsdam.de/grace-fo-isdc/
  - JPL PO.DAAC
    - https://podaac.jpl.nasa.gov/GRACE-FO