Applications Program Status; Mass Change Decadal Observable Mission Study

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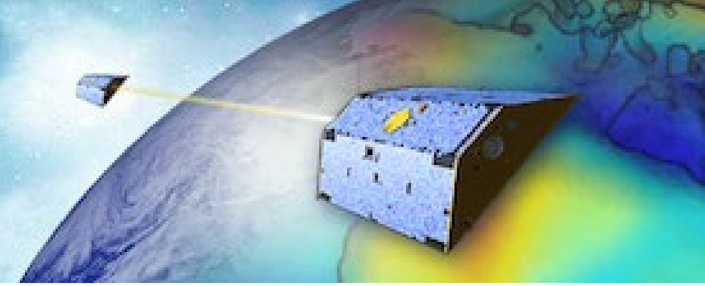
[3]Langley Research Center, Hampton, VA, USA

[4]NASA, Washington, D.C., USA

[5]RTI Innovation Advisors, RTI International, Research Triangle Park, NC, USA

See 'Comments' on each slide for discussion.

MC Applications in the Decadal Survey



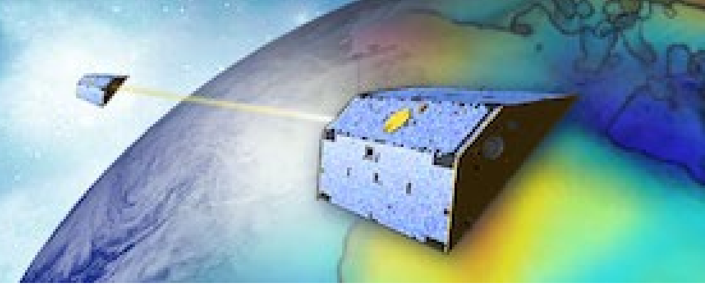
NASA has identified a Mass Change Designated Observable (MCDO) Study Team to develop the next NASA Mass Change satellite mission, as recommended by the National Academy of Sciences' 2017-2027 Decadal Survey for Earth Science and Applications from Space (DS). A key requisite of the MCDO mission is that, in addition to optimizing science objectives and programmatic factors (i.e., as cost and risk), *it must support a range of operational and applied science uses and user communities beyond the research communities.*

This talk will address the activities—past & future —to support applications, applied uses and user communities of existing and future mass change satellite missions. To that end, the following was convened;

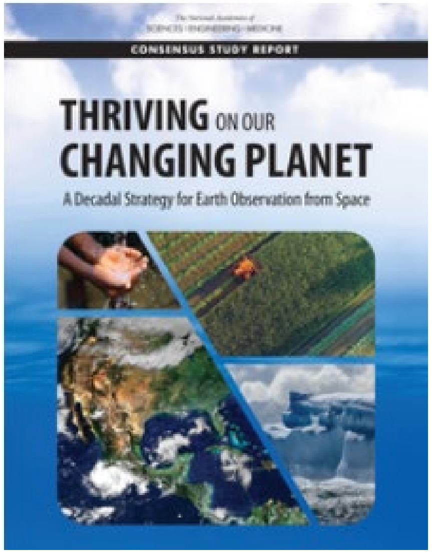
Mass Change Applications Team (MCAT)

- Matt Rodell, GSFC – MCAT Lead
- JT Reager, JPL, GRACE-FO Science Team member
- Carmen Boening, JPL
- Margaret Srinivasan, JPL
- Brad Doorn, NASA HQ
- Rosemary Baize, LARC, and with
- Moline Pandiyan & Kirsten Rieth, RTI

Applications in the MCDO Study



- Primary science objective; Continued measurement of Earth's dynamic gravity field over time
- The 2017 Decadal Survey; Emphasis on applications-oriented science and data products for societal benefit.
- MCAT objectives;
  - Identify existing and potential operational uses
  - Optimize outcomes of and return on NASA's investment
  - Develop a formal program to engage with applied & operational user communities
  - Reach new users and audiences, especially private sector and non-profits.

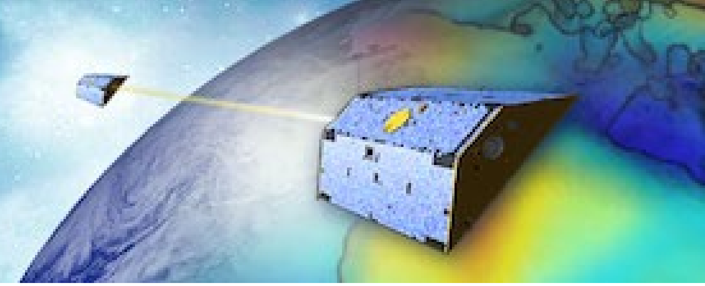


Assessing User Needs

- MCAT Objective: Provide value to a broad audience
- Needs: Data types and format, latency and spatial resolution requirements
- Assessment objective: inform mission design, ground systems, data processing decisions (supported development of a science and applications traceability matrix (SATM)
- Value Framework: Analyze the value of each potential mission architecture based on assessment of provided benefits vs. associated cost and risk (*for more information: Wiese, et al; GSTM2020-36 | Live display program | A.3*)*

**Wiese, D. and the NASA Mass Change Designated Observable Study Team: The NASA Mass Change Designated Observable Study Team, GRACE/GRACE-FO Science Team Meeting 2020, online, 27 October–29 Oct 2020, GSTM2020-36, https://doi.org/10.5194/gstm2020-36, 2020*

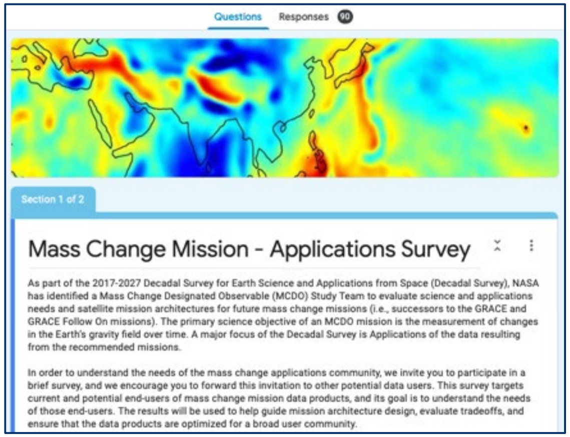
Key Applications Considerations



- **Improved Spatial Resolution**
  - Most heavily populated regions are along coastlines, but GRACE and GRACE-FO total water storage (TWS) uncertainty is larger near coasts.
- **Improved Temporal Resolution**
  - Most water management information (e.g. soil moisture for crop forecasts) needed during critical decision periods are addressing changes within 1 day to 1 week periods.
- **Improved Accuracy**
  - Value is highly variable--Important for some applications (e.g., seasonal snowpack), not for others (e.g., drought monitoring – relative wetness)
- **Value of specific resolution and accuracy improvements are difficult to specify without further study**
  - ➢ OSSE is a potential approach
- **Continuity and length of data record**
  - ➢ Considered very important by end-users

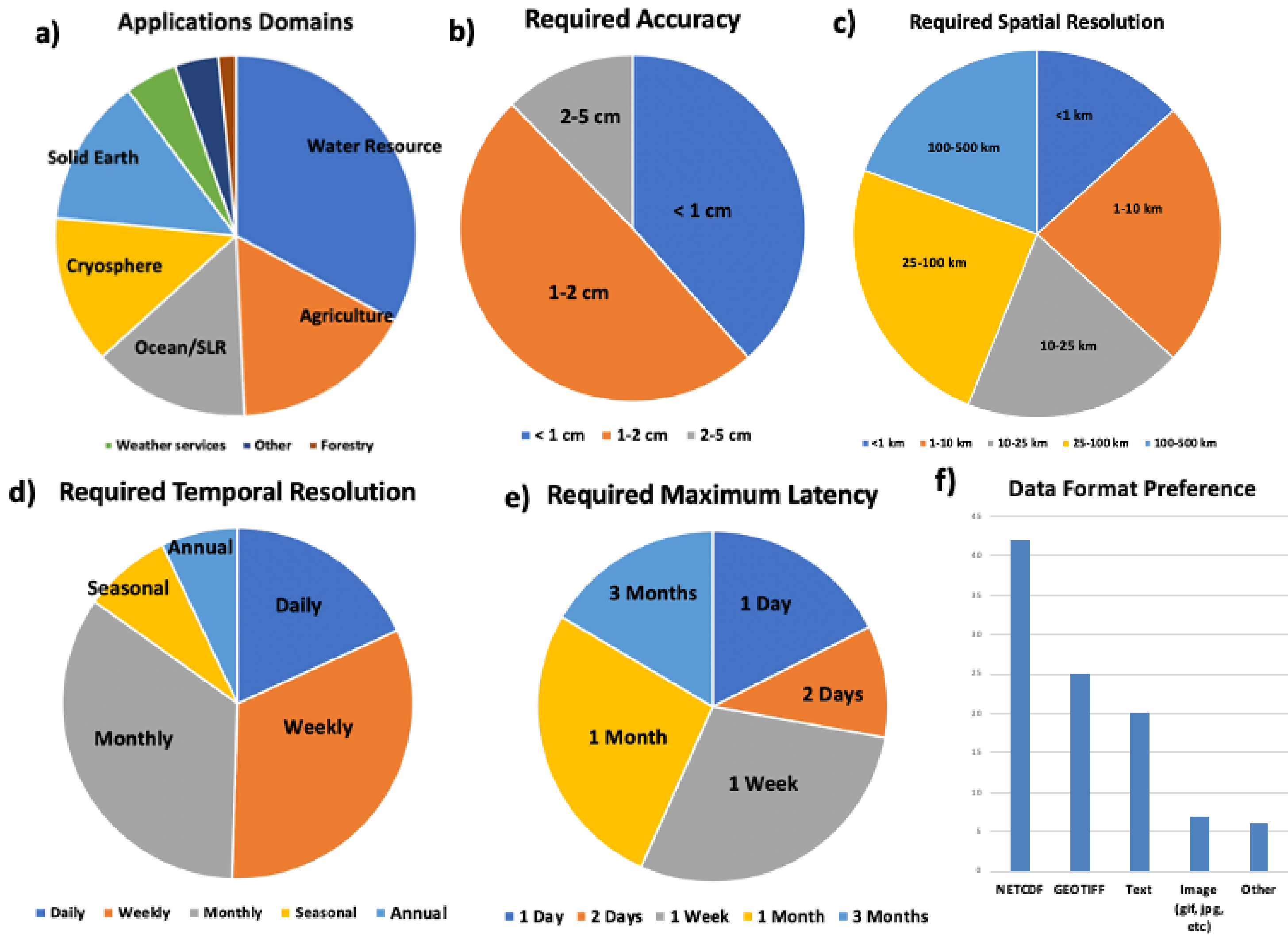
User Engagement Elements

- Leveraging existing work and resources; GRACE Missions Applications Plan
- '[Mass Change Mission Applications Survey](#)';
  - ➢ Sept. 2019-present
  - ➢ Provided important insights into current user communities and their priority needs
  - ➢ Queries resolution and accuracy requirements, data use,and demographic information (to characterize user communities)
  - ➢ Ensure that the MC data products are optimized for a broad user community



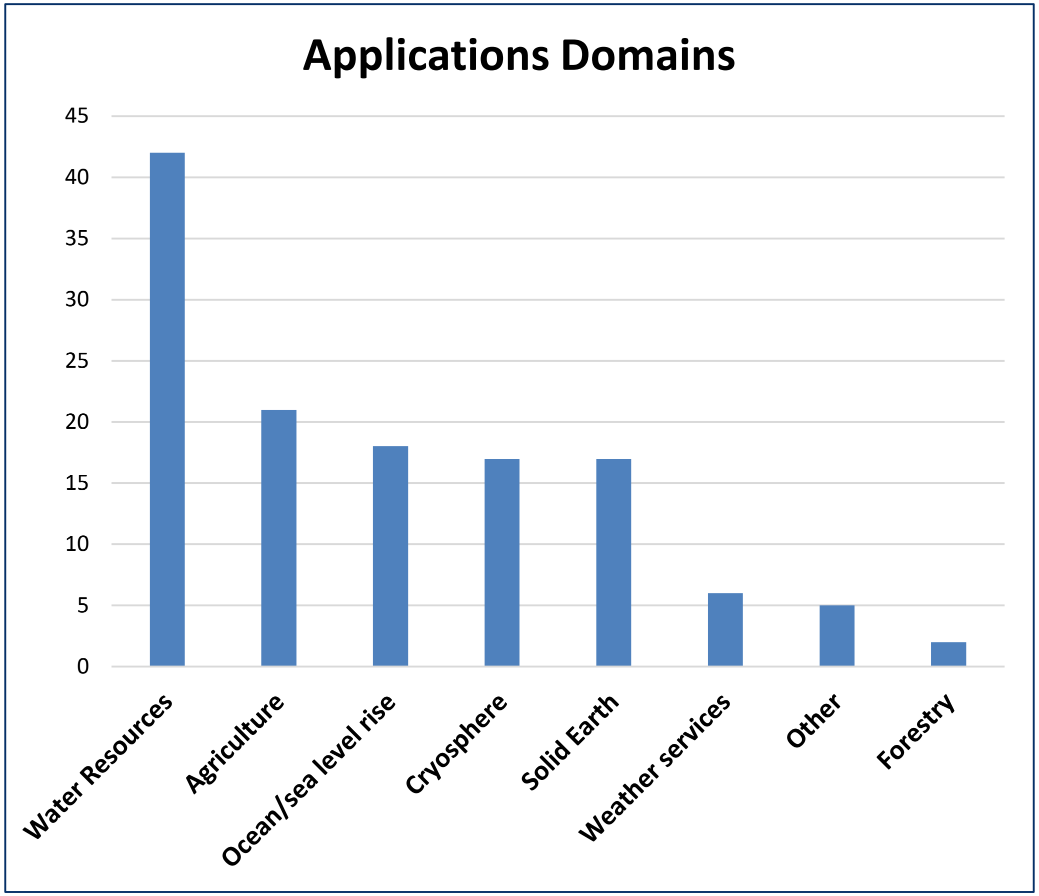
- Identify new users
- Focus groups/workshops to gauge data needs, impact of gravimetric data for new users, and eventually train new users
- Develop Community Assessment Report (CAR) → Maximize benefits for user communities

MC Applications Survey Findings



2020 Virtual GRACE/GRACE-FO Science Team Meeting, 26-30 October 2020

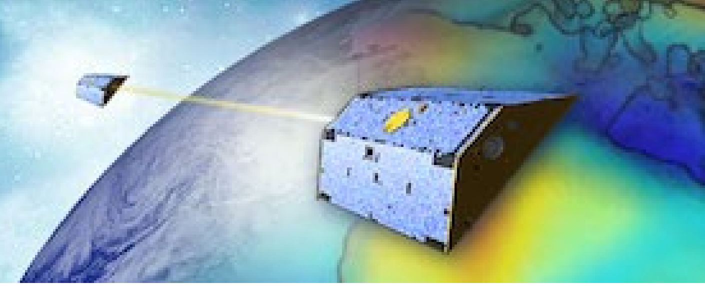
Survey: Applications Domains



Community Assessment Report (CAR)

- Can inform system architecture and component mission design concepts and support trade-off studies
- Outline the scope and potential impacts of the observables for user/applications communities
- Identify key design sensitivities having the greatest influence on the ultimate applications utility of the system, including;
  - Assessment of applications opportunities and importance
  - Characterizations of the Communities of Practice and Potential, including size, discipline and diversity
  - Description of institutions and organizations and their types of decisions
  - Identification of data format(s) the communities are familiar with
  - Assessment of spatial, temporal, and spectral resolution requirements or desires
  - Description of their decisions and actions and how potential products may have impact
  - Assessment of latency needs, format needs and potential operational users with potentially high societal benefit.

Community Assessment Report (CAR)

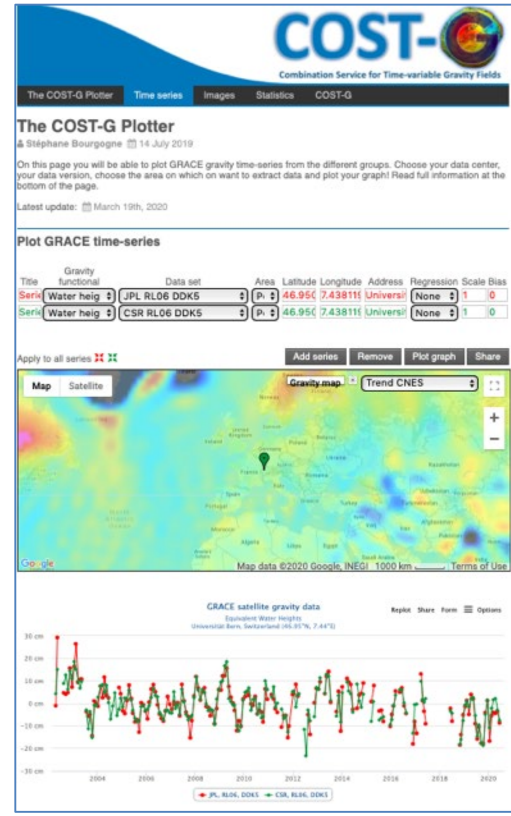


- Results will be presented in support of the mission concept review (MCR)
- Make the project aware of the potential application uses and needs (latency, direct downloads, spatial resolution, data format, repeat frequency, etc.) prior to locking in an observing system architecture and detailed system component designs.
- CAR Results: May 2020
- CAR Table of Contents:
  - Introduction
  - Summary of the Designated Observable
  - Communities of Practice and Potential
  - Characterization/Assessment of Communities
  - Analysis
  - Findings & Implications
  - Appendix
    - Methods
    - References
    - Contacts

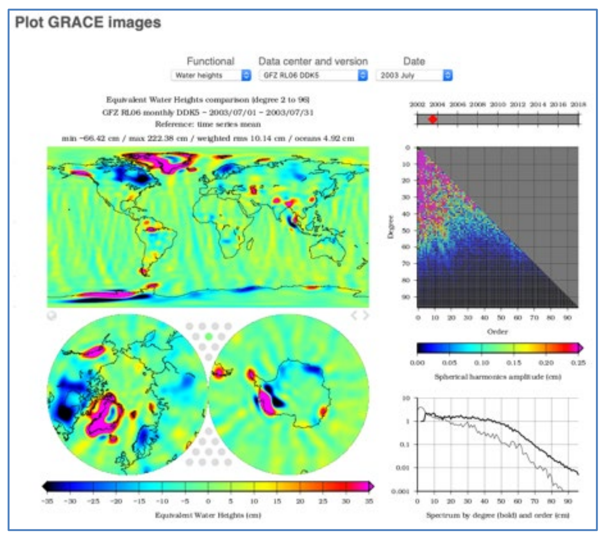
Satellite Gravimetry Data Product Tool

COST-G

The **I**nternational **C**ombination **S**ervice for **T**ime-variable **G**ravity Fields (**COST-G**) is a product center of the International Gravity Field Service (IGFS) and is dedicated to the combination of monthly global gravity field models. COST-G stems from the activities of the former H2020 project European Gravity Service for Improved Emergency Management (EGSIEM).Central Bureau: AIUB; Monthly models so far from AIUB, TU Graz, GFZ, CNES, CSR; open for additional contributorsWebsite: https://cost-g.org



Website: https://cost-g.org
Data & Resources: GRACE, GRACE-FO, SWARM,
Visualization tools
GRACE (and Swarm) Level-2 and Level-3 combined models available @ GFZ´s ICGEM and GravIS portals.
SLR combination maybe another topic.



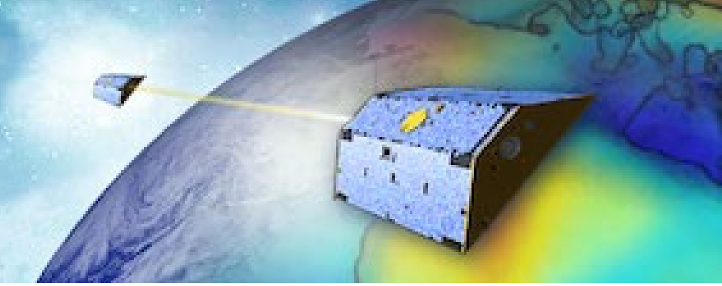
Source: cost-g.org

Satellite Gravity Applications Examples

- GRACE and GRACE-FO measurements already support numerous practical applications
  - Water resources assessments
  - Drought monitoring and forecasting
  - Flood vulnerability
  - Fire risk
  - Agricultural planning and yield forecasting
  - Consequences of sea level rise

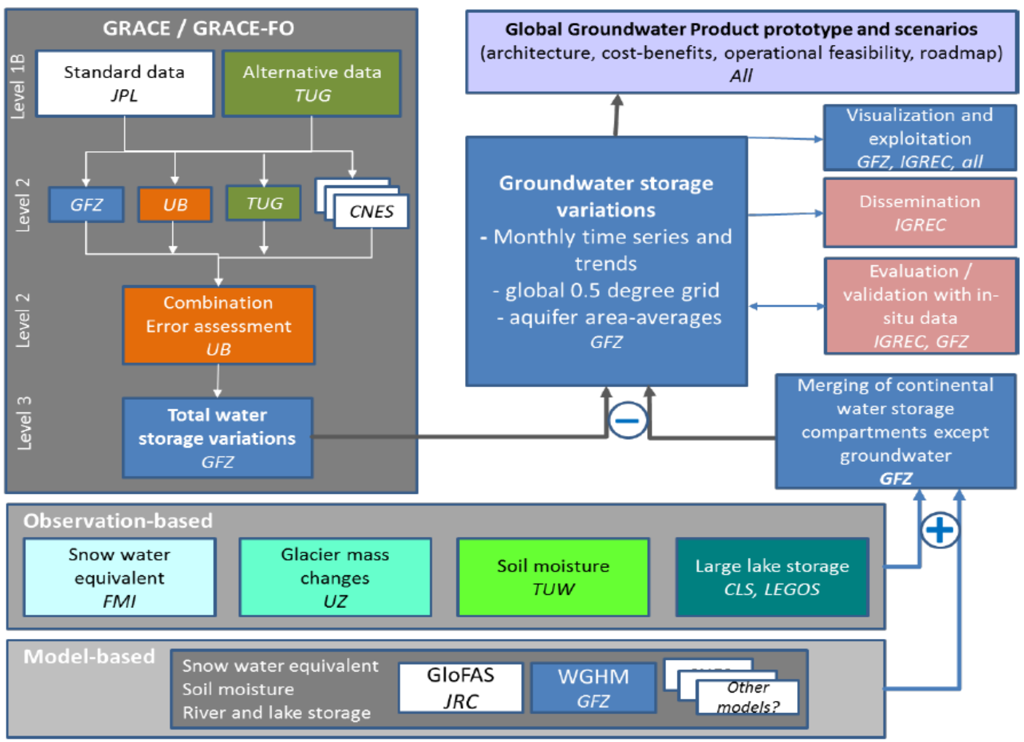
Examples of use of gravity measurements to support societal needs follows

Satellite Gravimetry Applications



Europe planning for a Gobal Gravity-based Groundwater Product (G3P)

Funded by EU within Horizon 2020



GFZ leads EU funded project „Global Gravity-based Groundwater Product (G3P, 2020-22).

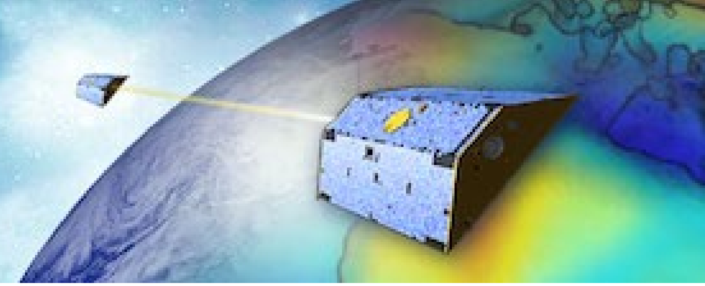
G3P will integrate the Essential Climate Variable groundwater as new product into Copernicus Services.

For this, GRACE and GRACE-FO gravity data will be combined with other operational Copernicus products such as soil moisture or surface water.

US and European groundwater services complement each other as different in-situ and model data will be used (Cal/Val activity).

2020 Virtual GRACE/GRACE-FO Science Team Meeting, 26-30 October 2020

Satellite Gravimetry Applications



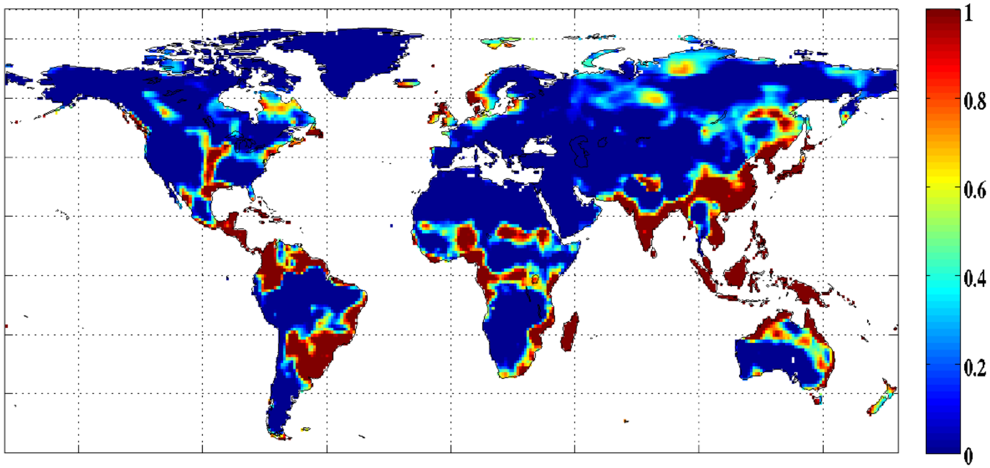
GRACE-Based Flood Potential Index

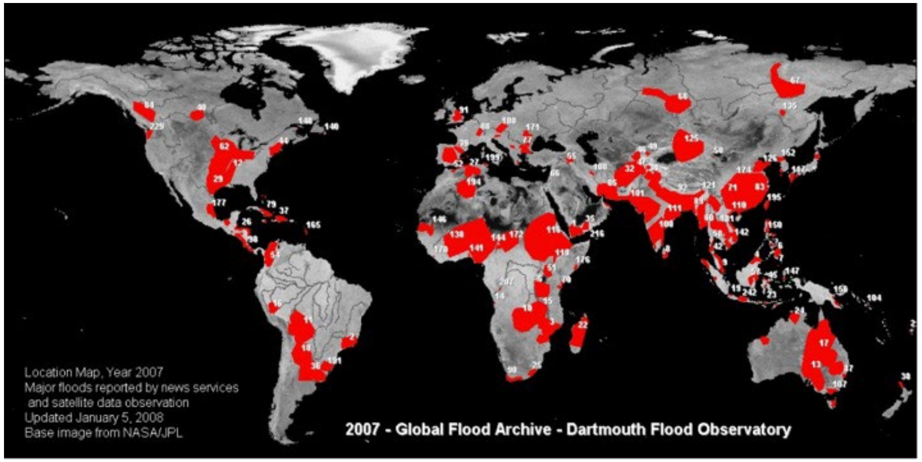
J. Reager (JPL, GRACE-FO ST member), J. Famiglietti (U. Saskatchewan)

Flood potential based on GRACE-estimated current vs. maximum storage and precipitation (GPCP)

Right: Comparison of GRACE-predicted floods (top) and reported floods (bottom) from the Dartmouth Flood Observatory, for 2007.

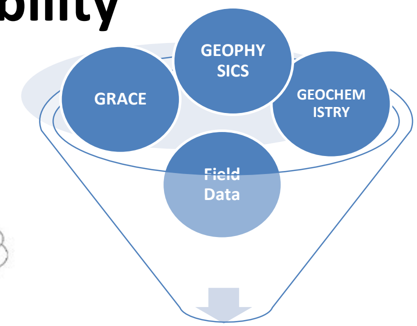
Details provided in *Reager and Famiglietti (2009), Geophys. Res. Lett., 36, L23402.*



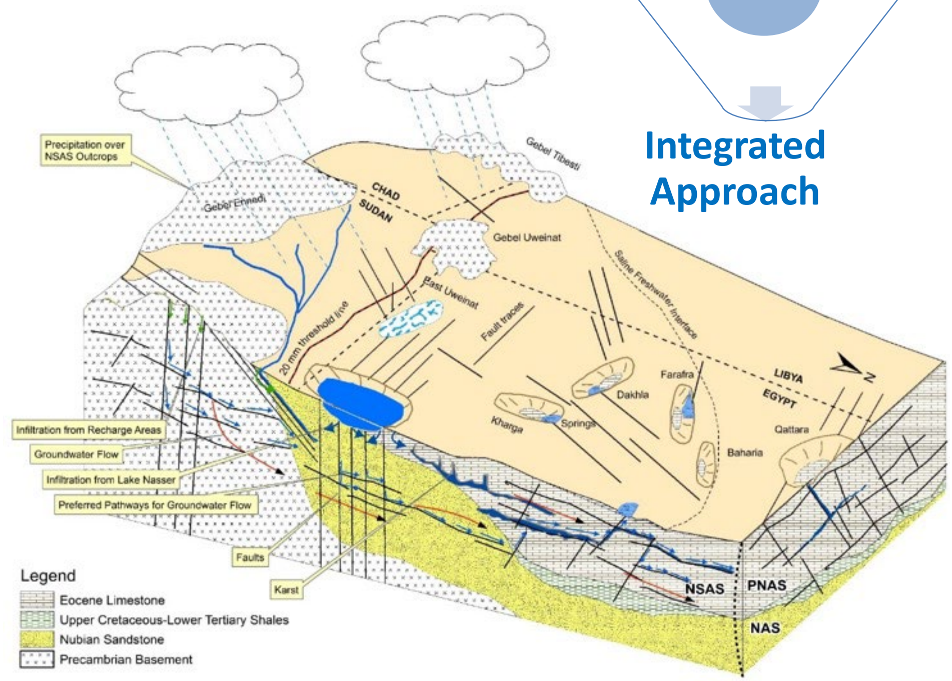


Rapid response of deep aquifers to climate variability

Mohamed Sultan
Western Michigan University



- Test area: The Nubian Sandstone Aquifer System (NSAS) in NE Africa
- Northern subbasins (N Kufra and Dakhla) respond to GRACETWS variations over source areas (lake Nasser/ppt in southern subbasins): negative trends in dry period & positive trends in wet period despite negligible precipitation in both periods
- Explanation: NSAS recharged by infiltration from Lake Nasser and from precipitation in the south & rapid groundwater flow from source areas along network of faults and karst



K.Abdelmohsen, M.Sultan, H.Save, etal., What can the GRACE seasonal cycle tell us about lake-aquifer interactions?, Earth-Science Reviews (2020), https://doi.org/10.1016/j.earscirev.2020.103392

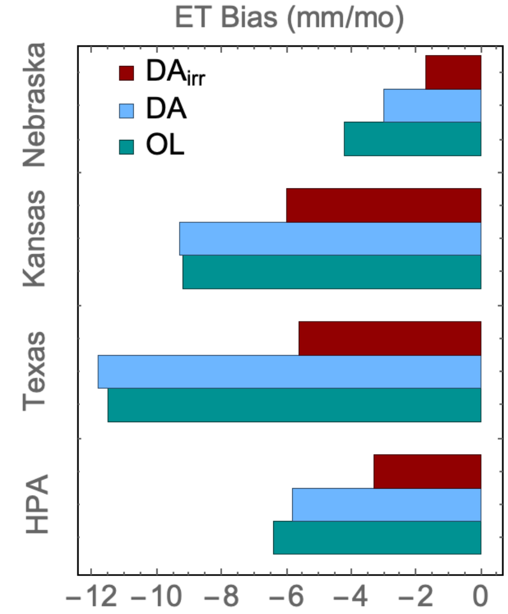
Abdelmohsen, K., Sultan, M., et al., 2019, Response of deep aquifers to climate variability, Science of the Total Environment, DOI: 10.1016/j.scitotenv.2019.04.316.

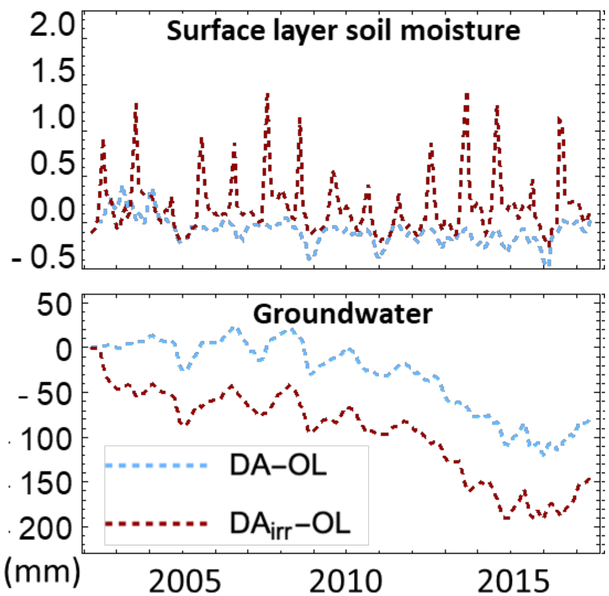
Satellite Gravimetry Applications

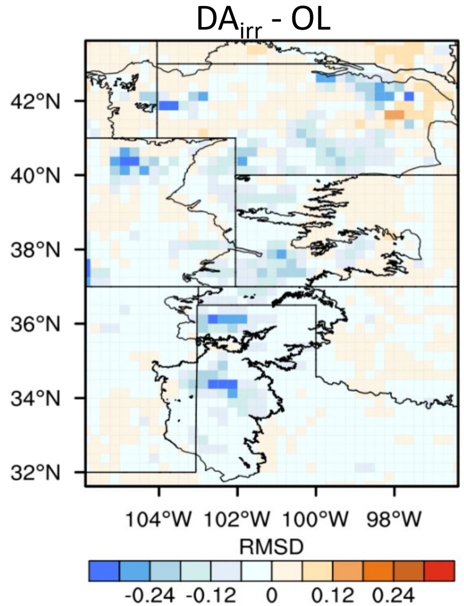
GRACE improves simulation of water storage and fluxes in the High Plains in the presence of irrigation water withdrawal

Wanshu Nie, Ben Zaitchik,
Johns Hopkins University

- GRACE TWS data is assimilated into the Noah-MP in the presence of groundwater extraction for irrigation
- Assimilating GRACE without irrigation produces biased increments, while simulating irrigation without GRACE allows for model error
- Combining GRACE-DA and irrigation shows the overall best performance for water storage components and evapotranspiration







Nie, W., Zaitchik, B. F., Rodell, M., Kumar, S. V., Arsenault, K. R., Li, B., & Getirana, A. (2019). Assimilating GRACE Into a Land Surface Model in the Presence of an Irrigation-Induced Groundwater Trend. Water Resources Research, 55(12), 11274-11294.

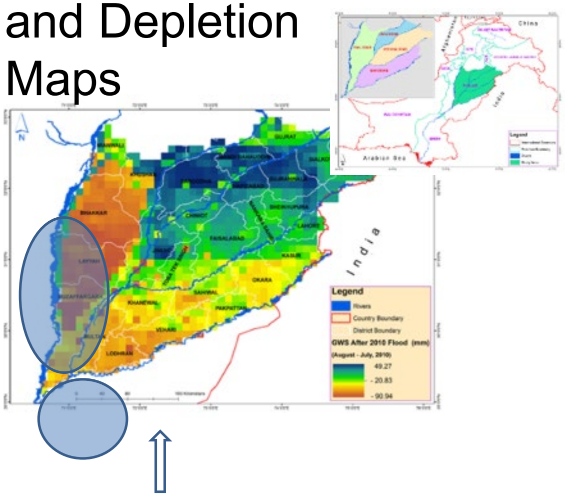
Satellite Gravimetry Applications

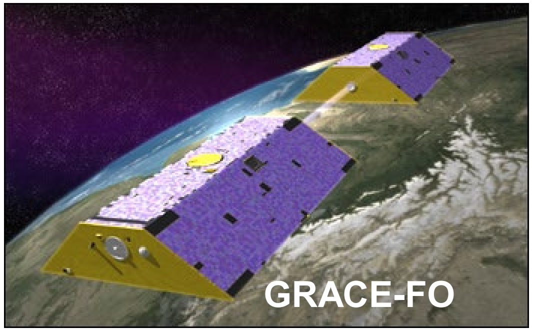
Smart Irrigation Can Be Smarter

Faisal Hossain, University of Washington

- GRACE/Landsat TIR-based irrigation tool
- Developed & funded by U. Washington
- SMS texting on how much to irrigate based on crop water demand and weather forecast
- In 2019 for 100,000 farmers India, Bangladesh, Pakistan – 10,000 USD/yr (operational costs), not sustainable to scale to 130 million potential users in the region
- GRACE-FO satellite + Landsat can help prioritize regions where farmers should get the SMS message ‘free’ or at a subsidized cost
- Farmers in areas with rapid groundwater depletion can be prioritized (more outreach, extension)
- This will give those regions ‘breathing space’ to build the groundwater stock
- More info; https://www.youtube.com/watch?v=vaONVVii6fE

Recharge and Depletion Maps

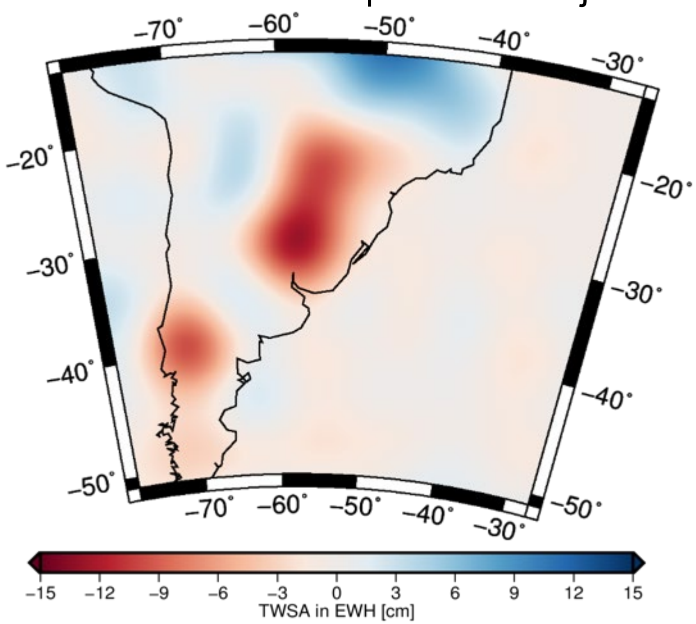


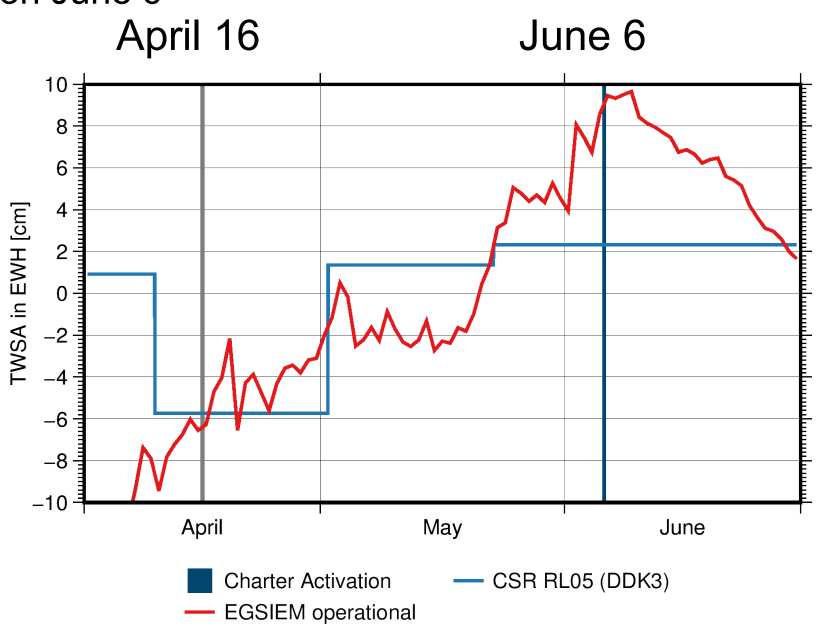


Near Real Time Hydrological Service

Adrian Jäggi*, Adreas Kvas, Frank Flechtner
*Astronomical Institute, University of Bern

Developed at TU Graz and GFZ
Kalman filter approach: solution stabilized by introducing spatio-temporal correlations, stochastic information from long time series of geophysical models
Operational test run April-June 2017 at DLR´s Center for Satellite Based Crisis Information (impacted by degraded GRACE data quality)
Follow-up project at GFZ funded by DLR (1 year starting October 2019)
Example: Operational GRACE daily NRT solutions during the Uruguay Flooding 2017 led to activation of International Charter on Space and Major Disasters on June 6



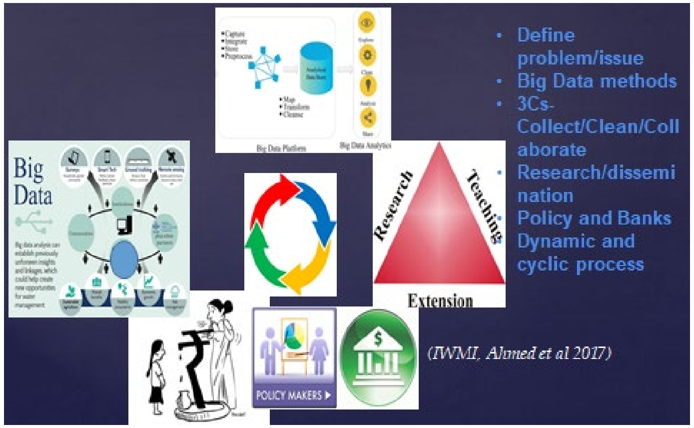


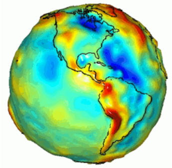
Satellite Gravimetry Applications

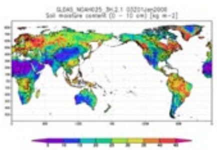
India – Holistic assessment of water resources

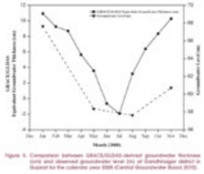
Pennan Chinnasamy
Indian Institute of Technology-Bombay, India

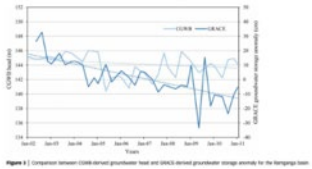
- Develop physically based holistic frameworks
  - Mass balances (identify data products for closing water budgets)
  - Socio—economic drivers (Satellite Data (SD) as secondary/proxy data)
  - Anthropogenic stressors
- Paradigm shift in framework
  - Satellite Data (SD) based Big Data Analysis
  - Higher spatial and temporal SD resolution
  - Dynamic feedback/checking using SD data
- Satellite data augmenting observation data

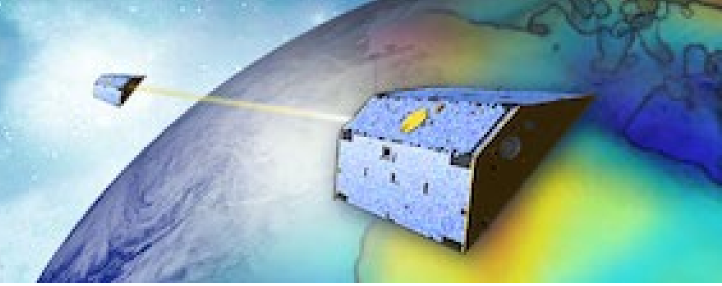








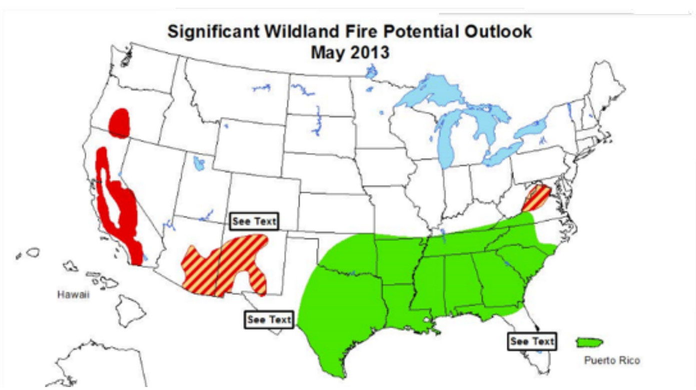


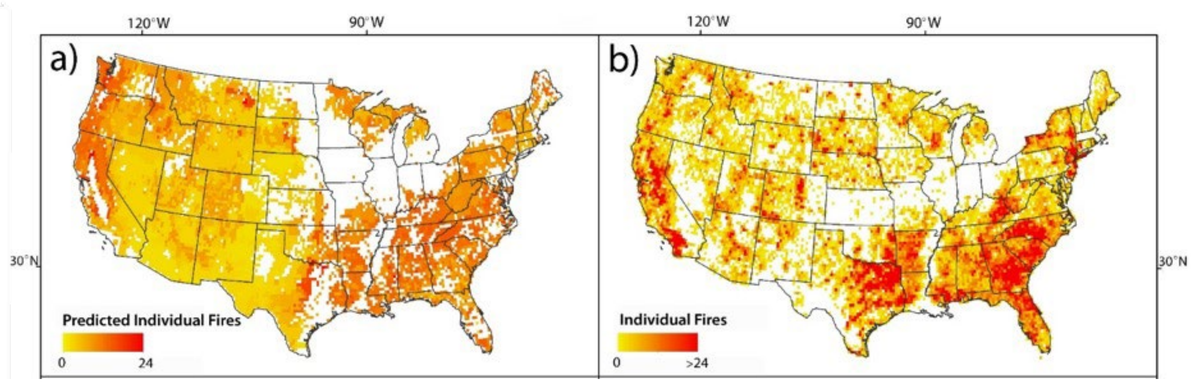


Sensitivity of US wildfire occurrence to preseason soil moisture

Daniel Jensen and John Reager (GRACE-FO Science Team member), JPL

- Goal: Filling a gap in operational fire risk management by building a new tool around NASA Earth observations.
  - Global fire risk prediction system
  - Data product and web tool
  - Guidance on priority observation and mitigation targets for the future





Jensen, D., ***Reager, J. T.,*** *Zajic, B., Rousseau, N., Rodell, M., & Hinkley, E. (2018). The sensitivity of US wildfire occurrence to pre-season soil moisture conditions across ecosystems. Environmental research letters, 13(1), 014021.*

Satellite Gravimetry Applications

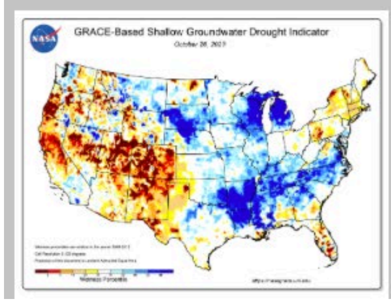
Drought Monitoring and Early Warning

Brian Wardlow and Mark Svoboda

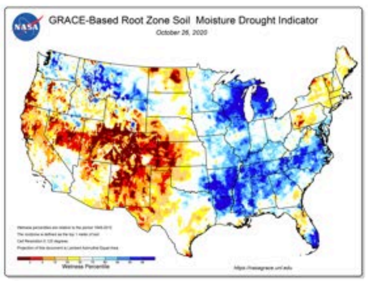
Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska-Lincoln

National Drought Mitigation Center (NDMC), University of Nebraska-Lincoln

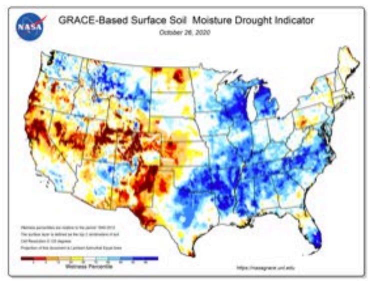
Groundwater Percentile



Root Zone Soil Moisture Percentile

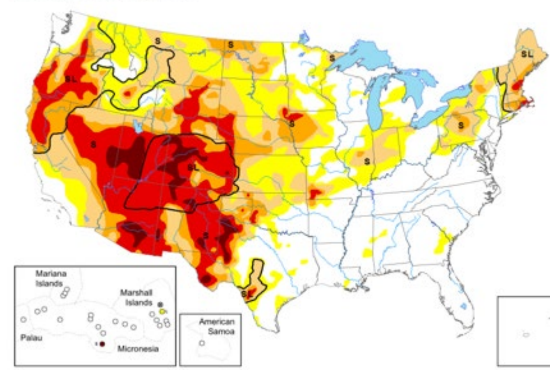


Surface Soil Moisture Percentile



Map released: October 22, 2020

Data valid: October 20, 2020



Operational **NASA GRACE Terrestrial Water Storage (TWS) drought anomaly products** have been developed at NASA/GSFC for the continental U.S. and globally, filling a key information gap in drought monitoring for subsurface soil moisture and groundwater conditions, which traditionally been provide by a limited number of *in situ* measurements or hydrologic models.

Products integrated into the ***U.S. Drought Monitor (USDM)***, which is tied to several federal and state-level drought disaster programs, as well as ***national and regional drought monitoring systems in other parts of the world*** (e.g., Brazil and Greater Horn of Africa) in collaborative work between NASA and the National Drought Mitigation Center (NDMC) and Center for Advanced Land Management Information Technologies (CALMIT) at the University of Nebraska-Lincoln.

https://nasagrace.unl.edu

European Gravity Service for Improved Emergency Management (EGSIEM)

Adrian Jäggi*, Adreas Kvas, Frank Flechtner

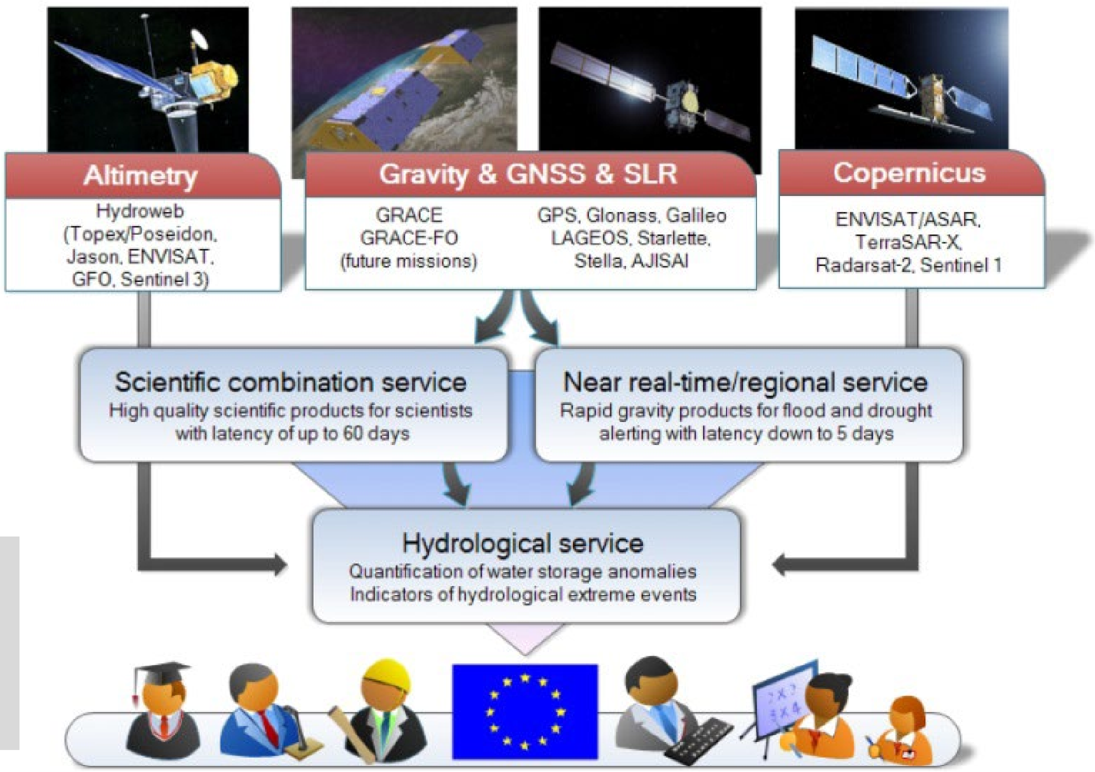
*Astronomical Institute, University of Bern

EGSIEM was funded by EU Horizon2020 2015-2017 (Lead AIUB plus various European partners (GFZ, TU Graz, CNES, DLR, …)

Tasks: Develop prototypes of three different services to

1) Combine monthly time-variable gravity field models of different analysis centers
2) Derive NRT (max. 5 days delay) mass transport products
3) Develop wetness indices to be used for flood prediction

Jäggi, A., Weigelt, M., [Flechtner, F.](), [Güntner, A.](), et al. (2019): European Gravity Service for Improved Emergency Management (EGSIEM) - from concept to implementation. - Geophysical Journal International, 218, 3, 1572-1590. https://doi.org/10.1093/gji/ggz238



FOR MORE INFORMATION:

MCDO; science.nasa.gov/earth-science/decadal-mc

MCAT Survey; tinyurl.com/MassChangeSurvey

GRACE/GRACE-FO Applications; gracefo.jpl.nasa.gov/applications