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A User Needs Assessment for the Next Mass Change Satellite Mission

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ABSTRACT

Planning is underway for development of the next NASA Mass Change satellite mission, as identified in the National Science Foundation's 2017-2027 Decadal Survey for Earth Science and Applications from Space (Decadal Survey). NASA has identified a Mass Change Designated Observable (MCDO) Study Team to evaluate satellite mission architectures that could optimally support a range of science and applications needs of user communities (both research and operational) of future mass change missions (i.e., successors to the GRACE and GRACE Follow On missions). The primary science objective of the MCDO, as identified in the Decadal Survey, is the continued measurement of changes in the Earth's dynamic gravity field over time. The Decadal Survey also emphasizes applications of the mission data products as a major focus, in addition to science outcomes.

Operational use and societal benefit derived from the GRACE and GRACE FO data and information products demonstrate the value of these missions. Applications include drought monitoring, quantification of groundwater depletion, flood prediction, and thermal expansion of the ocean, which contributes to sea level rise, to name a few. In order to effectively identify the observational product requirements of future gravity mission applications data users and to develop actionable objectives for mission design, a Mass Change Mission Applications survey was developed. Information on user needs, current uses, and capabilities derived from the survey have provided insights as to desired or required spatial scales, data latency, data formats, and technical capabilities of the users, as well as how to prioritize tradeoffs. The survey focused on evaluating the needs of a broad range of existing and potential user communities in order to incorporate these needs into mission design and architecture studies that are underway.

The survey comprises general questions about requirements for a given application, and data use and demographic information to help characterize aspects of the user community. Analyses of the survey results are now being used to inform potential mission architecture designs, evaluate tradeoffs, and ensure that the data products are optimized for a broad user community.

DECADAL SURVEY DESIGNATED OBSERVABLES (DO)

In the National Academies of Science' *2017-2027 Decadal Survey for Earth Science and Applications from Space* (Decadal Survey), the variable of mass change in the Earth System was identified as a priority observable, identified as the Mass Change Designated Observable (MCDO). A MCDO study team is charged with evaluating science and applications needs, as well as optimal satellite mission architectures for future mass change missions (i.e., successors to the GRACE and GRACE Follow On missions). The primary science objective of an MCDO mission is the continued measurement of changes in the Earth's gravity field over time. In addition to the core science objectives, a key focus of the 2017 Decadal Survey is the landscape of practical and operational applications of the data and information products that result from the resultant recommended mission(s).

The Decadal Survey prioritized five Designated Observables (DOs) for cost-capped, medium- and large-size Earth observing missions to be launched by NASA in the next decade: Aerosols (A), Clouds, Convection and Precipitation (CCP), Surface Deformation and Change (SDC), Surface Biology and Geology (SBG), and Mass Change (MC). Four study teams (A and CCP were combined) are now defining observational target capabilities and evaluating potential mission instruments and architectures for these DOs. NASA's Earth Science Directorate (ESD) is investigating opportunities to develop observing systems that address these science priorities in partnership with other space agencies and entities.

***Reference**: Bernknopf, R., Brookshire, D., Kuwayama, Y., Macauley, M., Rodell, M., Thompson, A., Vail, P., Zaitchik, B., (2018). The Value of Remotely Sensed Information: The Case of a GRACE Enhanced Drought Severity Index, AMS Weather, Climate and Society, v10, pp. 187-203, DOI: 10.1175/WCAS-D-16-0044.1*

MASS CHANGE APPLICATIONS OVERVIEW

The **Mass Change Applications Team (MCAT)** provides the MCDO Study Team with input into a Science and Applications Traceability Matrix (SATM). The MCAT focus is to identify and communicate with user communities who do and may benefit from new mission data, and to engage with value-added providers. The Decadal Survey identified science and applications priorities (see Table 3.2 at www.nap.edu/read/24938/chapter/6), which includes the 'High Priority' objective, H-4c; "Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations." Applications of future remote sensing missions is, in this context, specifically identified as an objective of the Decadal Survey.

The **needs of applications communities** for a future gravity mission are being assessed and used to inform mission design and data processing decisions through the SATM and a value framework, including:

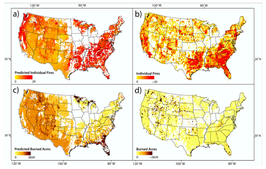
- Leveraging well-developed current and past work and sources for MC applications needs information
- Implementation of a **Mass Change Applications Survey (https://tinyurl.com/MassChangeSurvey)**
- Direct user engagement (i.e., workshops and community meetings)
- Development of a Community Assessment Report (CAR)

The GRACE and GRACE-FO Projects have supported numerous practical and operational applications, including;

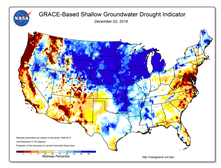
- **Water supply assessments**
- **Drought monitoring and forecasting**
- **Flood vulnerability**
- **Fire risk**
- **Agricultural planning and yield forecasting**
- **Consequences of sea level rise**

SATELLITE GRAVIMETRY APPLICATIONS EXAMPLES

- **GRACE-Based Flood Potential Index, JT Reager and J. Famiglietti** JPL/CalTech (see; tinyurl.com/GRACE-FPI)
- **Sensitivity of US wildfire occurrence to preseason soil moisture , D. Jensen and JT Reager** JPL/CalTech (see; tinyurl.com/GRACE-Wildfire)
- **The Value of Remotely Sensed Information: The Case of a GRACE Enhanced Drought Severity Index, R. Bernknopf and D. Brookshire** (UNM), **Y. Kuwayama and M. Macauley** (RFF), **M.Rodell (GSFC),** A.Thompson and P. Vail **(RFF),** B. Zaitchik **(JHU)** (see; tinyurl.com/GRACE-DSI)



Fire predictive maps for (*a*) individual and (*c*) burned areas (May 2012–Apr 2013), compared to (*b*) actual fire distribution and (*d*) actual burned area for that year for validation, (Jensen, et al, 2018)



Shallow groundwater drought indicator based on GRACE TWS, integrated with other observations using numerical modeling of land, surface water, energy. (nasagrace.unl.edu)

KEY MC APPLICATIONS CONSIDERATIONS

Most practical applications require higher-level products (e.g., changes in individual water storage components as opposed to bulk mass changes) as well has higher spatial and temporal resolutions than can currently be delivered by GRACE-FO. This necessity highlights the importance of advanced data processing and modeling techniques, and data assimilation. Gravimetric data is not a standardized product used in water/natural resource management. As a result, the mission must address how this data will be integrated into water/natural resource management tools (e.g. higher level data products). Examples include;

Improved Spatial Resolution

- e.g. Most heavily populated regions are along coastlines, but GRACE and GRACE-FO TWS uncertainty is larger near coasts.

Improved Temporal Resolution

- e.g. 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

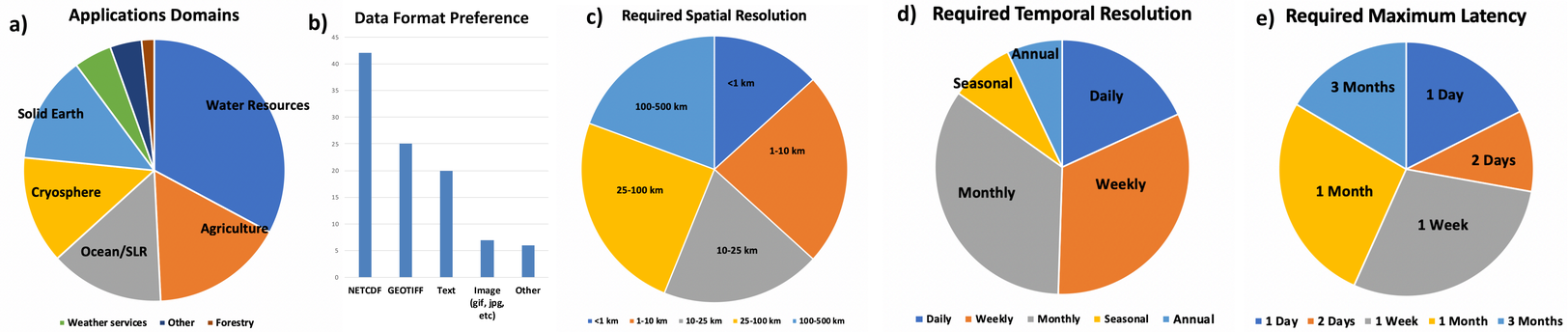
FOR MORE INFORMATION:

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

MCAT Survey; tinyurl.com/MassChangeSurvey

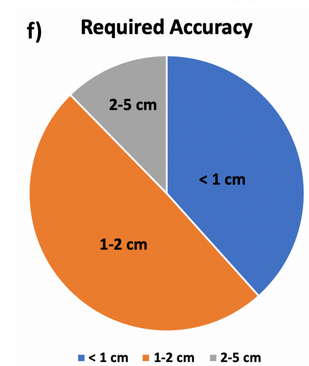
GRACE/GRACE-FO Applications; gracefo.jpl.nasa.gov/applications

MASS CHANGE APPLICATIONS SURVEY FINDINGS – 87 Responses



The MCAT solicited feedback through an open online survey targeted at user communities who may benefit from gravimetric data and information products. These **applications domains (a)** included (but were not limited to) users of GRACE and GRACE-FO satellite mission data, water resource decision makers, ocean and cryosphere data user communities, and other groups. The largest domain is, not surprisingly, water resources (33%), as the hydrologic community is a key constituent of GRACE data use (see applications examples above). However, the ocean (including sea level rise), cryosphere (changes in Earths ice cover), and solid Earth communities collectively comprise 41% of respondents. Agriculture makes up 16%, and weather, forestry and 'other' communities comprise the remaining 10%.

The survey was designed to provide inputs with regards to user needs and desires for Mass Change (MC) observations. Understanding what **data formats (b)** users require will be important in making new mission data products accessible to a broad community. Traditional spherical harmonic format data from the GRACE missions limits users largely to researchers and modelers. Other key variables of interest to users include **spatial (c)** and **temporal (d) resolution, latency (e),** and **accuracy (f)**. More than half of the respondents indicate that spatial resolution of 25 km or less would be desirable. Half indicated that one week latency would be sufficient for their applications, with close to 60% wanting one week or sooner data latency. Accuracy requirements of 2 cm or less are desired by most existing and potential data users (87%) .



Limited user demographic in formation was also collected in order to better understand the general nature of their use, for operational systems or decision-making, for example, and what type of agency they work for (university, federal agency, private industry, NGOs, etc.). The importance of continuity in the MC record and the need to understand and evaluate emerging gravimetric technologies also drove the need to survey these communities. Quantifying the applications communities desires and priorities with respect to the data characteristics listed above, and translating those into performance targets are key inputs into the SATM, and the eventual mission design.

The GRACE and GRACE-FO missions are a collaboration between NASA, the Center for Space Research at the University of Texas, NASA's Jet Propulsion Laboratory, the German Space Agency (DLR), and Germany's National Research Center for Geosciences (GFZ).

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