Open Source Science for ESO Mission Processing Study

Identify a system architecture that meets the ESO mission processing objectives, supports open science, enables system efficiencies, and promotes earth-system science.

Workshop #1
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Mass Change
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Program Scope

What is Mass Change? Mass change is the **mass redistribution** in the Earth system at various time scales.

Why we care? Global observations of water and ice mass transport at monthly to decadal time scales are critical for understanding the climate system and investigating its changes. **Interactions between the different climate system components involve mass variations** in continental surface and sub-surface water storage (rivers, lakes, ground water, snow cover, polar ice sheets and mountain glaciers), as well as the mass redistribution within and between ocean and atmosphere.

How is measured? The Decadal Survey dedicated a section on the use of **satellite gravity to understand Mass Change** (Box 3.7, p.108), providing an overview of the GRACE - twin satellite pair measuring their distance - enabled accomplishments and the insight provided by monthly maps and contributed to:

- process understanding
- quantifying changes in ice sheets/ mountain glaciers & water losses in lakes and aquifers
- begin to monitor decadal trends associated with climate change

Satellite-to-Satellite Tracking provided 2 decades of observations of Mass Change - GRACE 2002 to 2017, GRACE-FO 2018 launch. MC new mission will continue & improve observational record.

GRACE & GFO Science Team (5 competitions), Research elements in several disciplines (hydrology, cryo, ESI), applied science (water resources), MEaSUREs.

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Vision for Open Science

SMD defines open science as a **collaborative culture enabled by technology** that empowers the open sharing of data, information, and knowledge within the scientific community and the wider public **to accelerate scientific research and understanding.**

Please address the following questions and provide any insights you consider relevant to the Study:

- *How does open-science fit within your program objectives?* Optimize effectiveness of the research funding, advance science understanding with the use of mission data, extend the user base and applications
- *What investments are you making towards open-science and what are the expected outcomes?* Broad science team solicitations (5 to date), broadly advertise science team meetings annually (international), open community forums (e.g. AGU), monitoring of data usability and downloads.
- *What barriers exist across NASA that inhibit participation to open-science? (please consider factors such as institutional policies, cultural landscape, technical restrictions, and intellectual property).*
    - Extremely high skill required in data processing, small community of experts globally
    - Multi-disciplinary nature of core observation (geophysics) vs application disciplines (e.g. Hydrology)
    - Mission data no release until 5 and 6 months after IOC - level 1 and level 2 respectively

Vision for Mission Data Processing

We define a Mission Data Processing System (MDPS) as the set of algorithms, software, compute infrastructure, operational procedures, documentation, and teams to automatically process raw instrument data through to science quality data products. This includes the software tools that support the development of the processing algorithms and validation and analysis of the processed data.

Please consider mission data processing in the context of your program and address the following questions:

- *What does it mean for mission data processing systems to support open science?* **Allow unrestricted access of data and tools to broad users**
- *What does it mean for mission data processing systems to enable earth system science?* Enable **easy access** to broad users and allow **diversity of research and applications**
- *What does it mean for mission data processing systems to be efficient?* Provide the research community and other users **validated standard mission products - avoid duplication** of product development
- *What opportunities does NASA have for advancing mission data processing systems?* Allow **flexibility** to infuse new technologies AND enable optimal observable development and future observing system evolution (future double satellite pair vs single pair).

Facilitate interfaces with other agency and international mission partners and international services (e.g. operational services)

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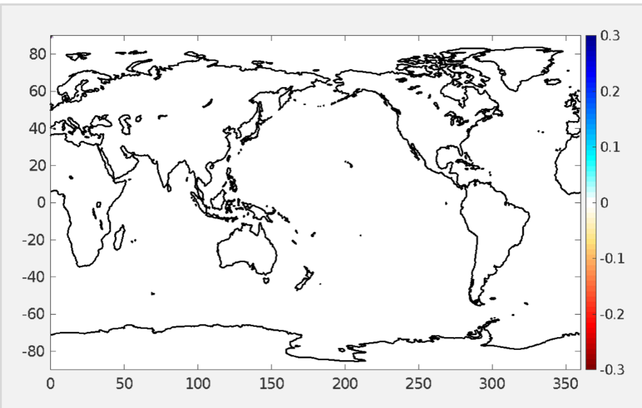
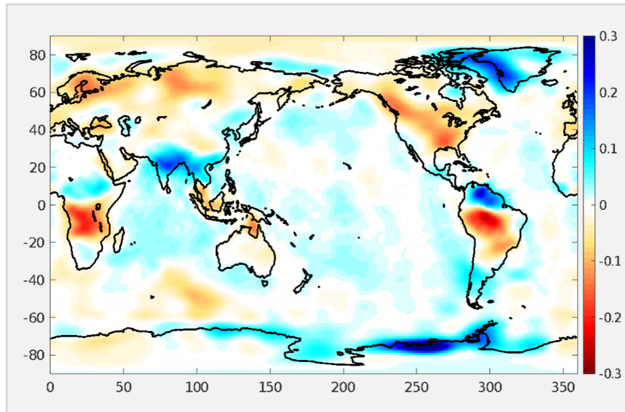
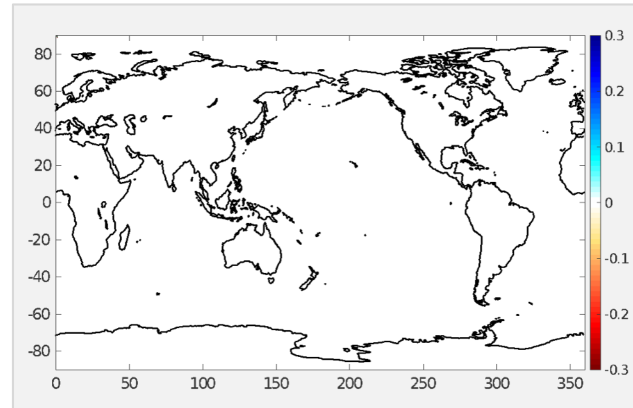
‘Stripes’ in the monthly gravity field

Efficiency in NASA mission data system - validated processing, high level of expertise (no duplication efforts)







‘Raw’ mapping of gravity field to surface mass anomalies:

- Strong ‘correlated errors’ in the N-S direction
- ‘classical’ spherical harmonic solutions

Postprocessing:

- Remove striping
  - Empirical De-correlation filter
  - Spatial smoothing (300 km)
  - Potential to attenuate real signal

‘Mascon’ data processing:

- Rigorous Bayesian inversion with a priori constraints
- Highest signal-to-noise ratios
- State-of-the-art, well established

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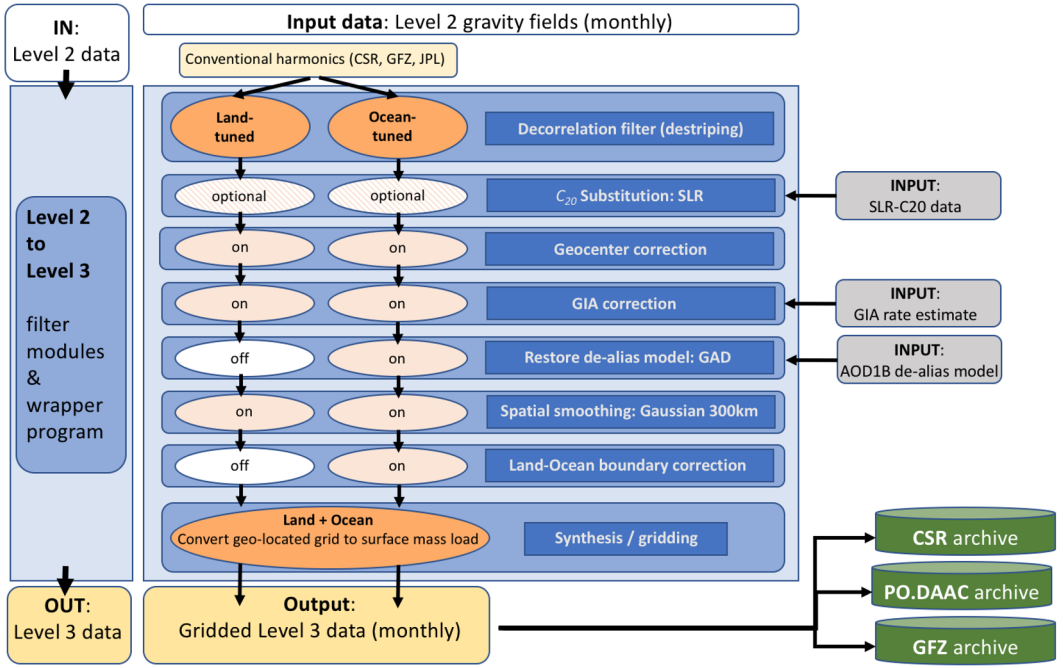
Mass Change from Gravity Measurements - GRACE & GFO

The calculation of Earth surface mass changes from the gravity potential changes requires the application of various steps to account for a number of different processes including the removal of correlated and random errors, glacial isostatic adjustment (GIA), and other background model corrections (Equivalent Water Height).

Key processing:

- De-aliasing, removing sub-monthly variations (ocean+atm.)
- Gridded land & ocean data calculated separately
- Mass concentration blocks “mascons” use of domain-optimized filters



77% of users download downloads are level 3&4 mission data from PO.DAAC

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Guidance for the Study

The goal of this study is to identify a MDPS system architecture (description of the components of a system and how they behave and interact) that 1) meets the ESO mission processing objectives, 2) supports open science, 3) enables system efficiencies, and 4) promotes earth-system science. The System Architecture Working Group (SAWG) is tasked to conduct this study.

Do you have any specific guidance for the SAWG?

- Recommend the use of principles and science needs provided in the previous pages in the development of the system architecture and implementation to ensure the presented needs are met.

Do you have any recommendations for the study steering committee?

- Develop and implement the equivalent of “Market Research” approach. In implementing the open science approach, the pilots should go on to unquestionably demonstrate the stated goals are met i.e. **accelerate scientific research and understanding *and expanding applications. The established metrics should be used to demonstrate increase in research, e.g. for NASA funded investigators research output (publications etc) significantly increases, and non-NASA funded investigators demonstrate research output.**

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