GravityPython: An Open-Source Pipeline for Inversion, Analysis, Assimilation, and Earth System Applications

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Introduction

Next-generation satellite gravity missions such as NGGM and MAGIC are expected to provide unprecedented observations of Earth's time-variable gravity field, offering transformative opportunities for understanding mass transport processes in the global water cycle, solid Earth, cryosphere, and ocean systems. Fully exploiting the scientific potential of these missions requires an end-to-end workflow that ensures methodological consistency from raw sensor data to geophysically meaningful products. Addressing this need, we present an **integrated, open-source scientific platform developed in Python and publicly available on GitHub**. The platform consolidates processing steps across multiple levels of gravity field data, enabling researchers to seamlessly transition from Level-1B observations to high-level geophysical applications.

Overview of our platform (github)

Conclusion and Outlook

1. **This platform offers a community-level, open, and extensible foundation for advancing Earth system studies with current and future satellite gravimetry missions. It aims to enhance transparency, reproducibility, and scientific collaboration in preparation for the upcoming era of high-resolution, high-accuracy gravity field observations.**
2. **The system is under active development, with planned extensions including a fully customizable numerical mission simulator to support the design and performance assessment of next-generation gravity missions.**
3. **You are more than welcome to leave your message or query in our Github discussion forum. We are open to any potential collaboration!**

Reference

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- Yang, F., Schumacher, M., Retegui-Schiettekatte, L., van Dijk, AIJM., Forootan, E. 2025. PyGLDA: a fine-scale Python-based Global Land Data Assimilation system for integrating satellite gravity data into hydrological models. Geosci. Model Dev., 18, 6195–6217, https://doi.org/10.5194/gmd-18-6195-2025
- SAGEA-fluid: a solver for gravitational self-attraction effect, geocenter motion and Earth orientation parameters driven by Earth's surface fluid (under review)

Acknowledgement

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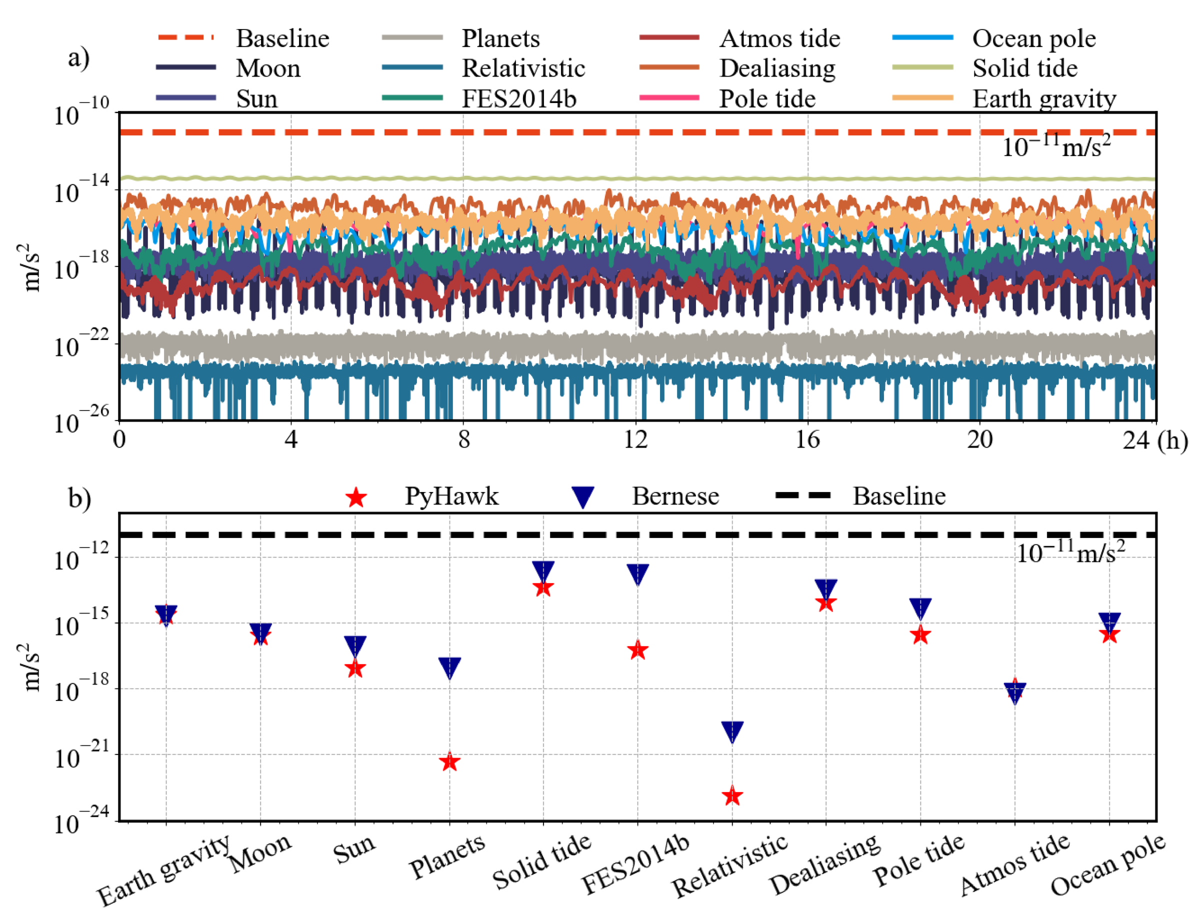
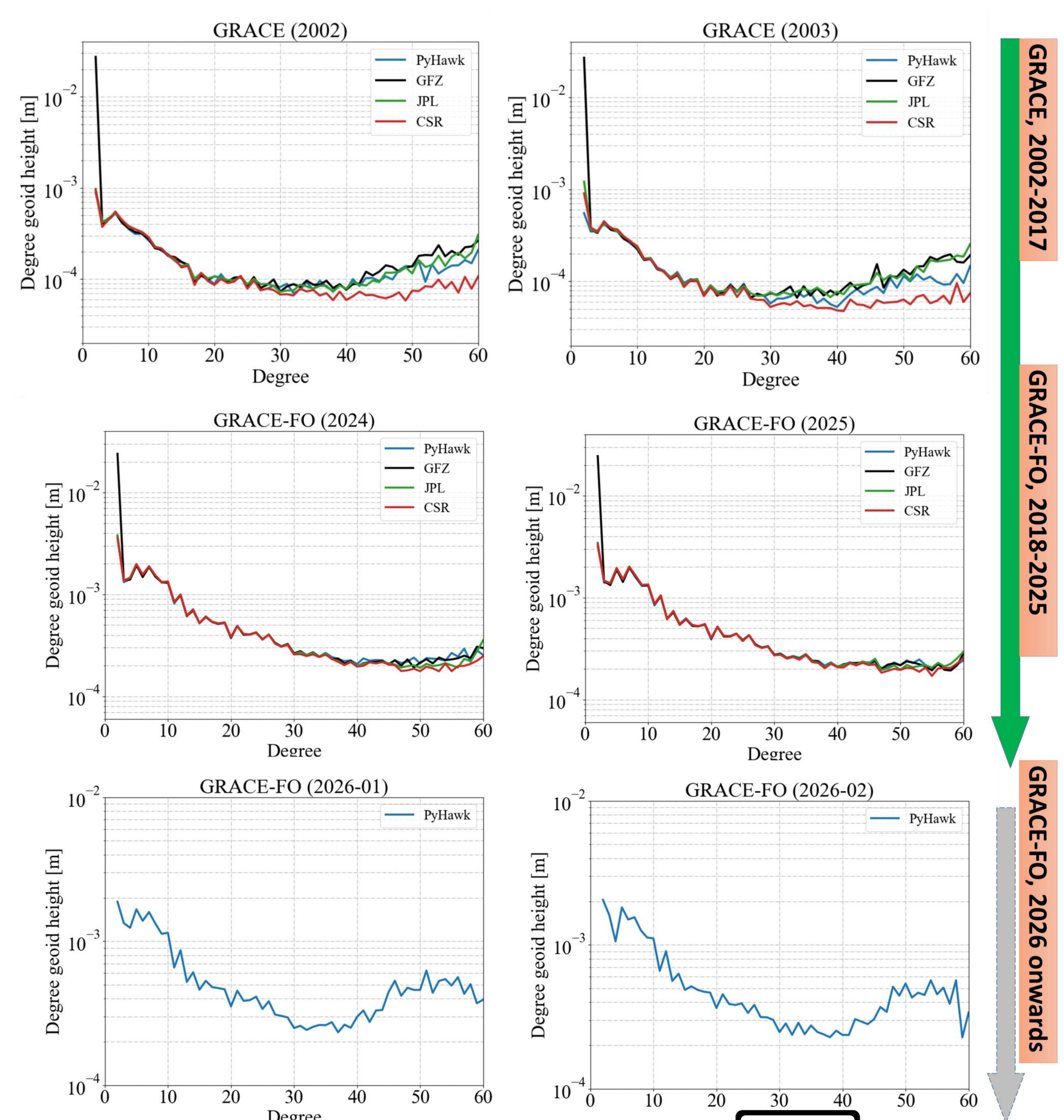
Tool-1: PyHawk

PyHawk inverts GRACE/FO and future-mission Level-1B measurements into time-variable gravity field solutions. It implements state-of-the-art dynamic orbit determination, variational inversion, stochastic modeling, designed to be easily extendable for upcoming mission concepts.

Benchmark tests of PyHawk

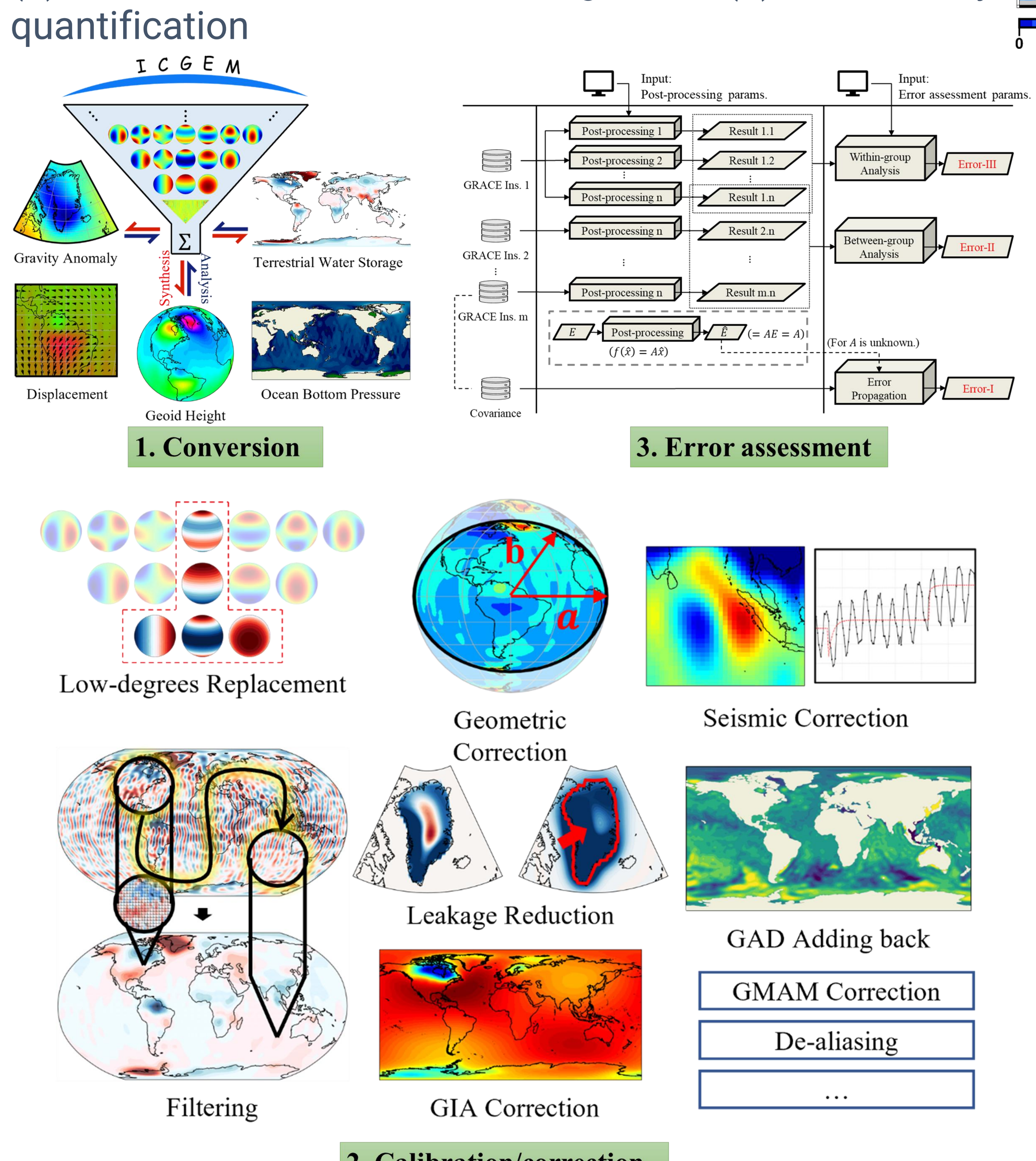


Monthly gravity recovery (2002-2026) using PyHawk



Tool-2: SAGEA

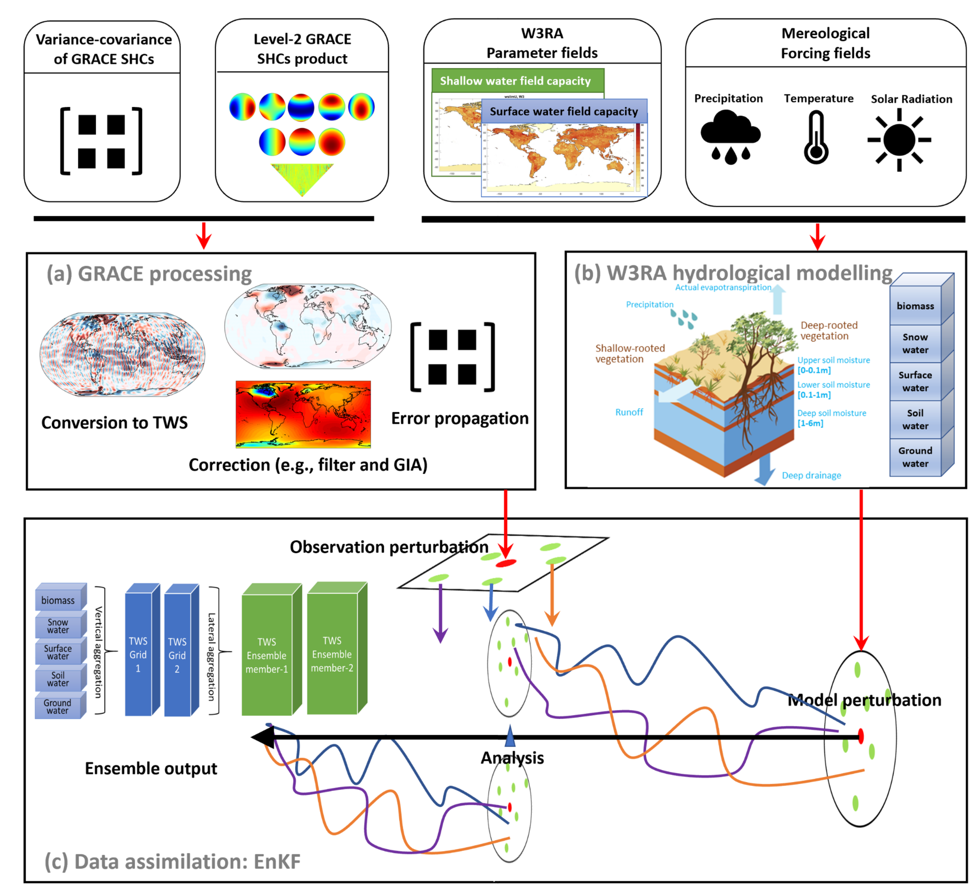
SaGEA enables systematic post-processing of Level-2 spherical harmonic solutions, including (1) conversion, (2) correction such as filtering, and (3) uncertainty quantification



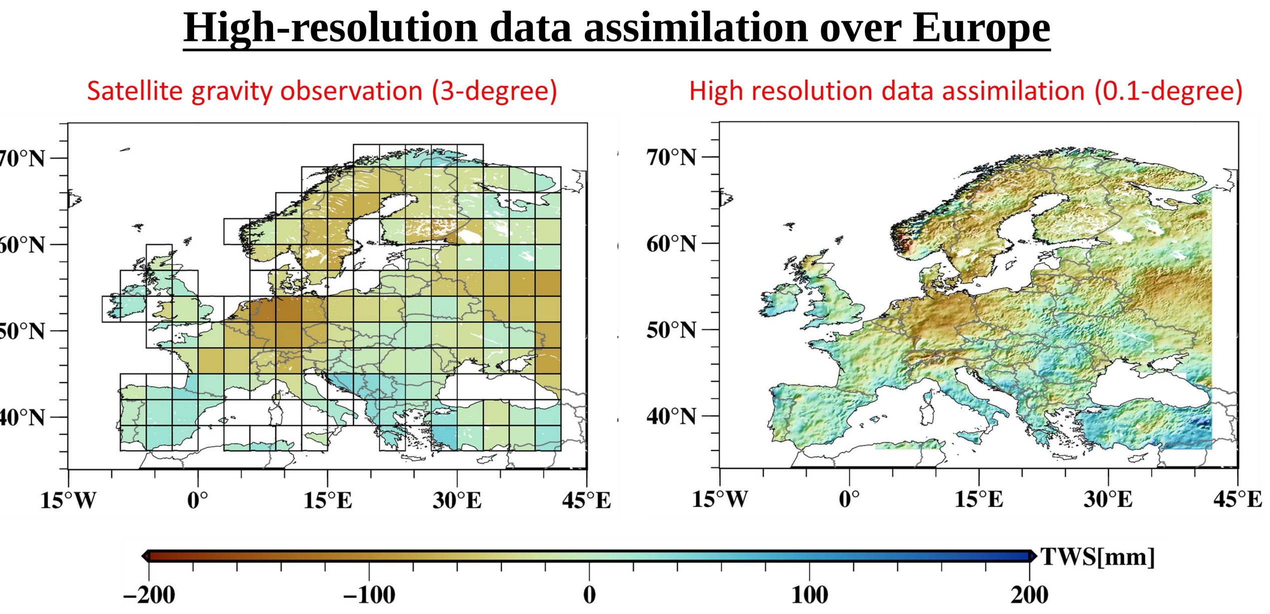
Tool-3: PyGLDA

PyGLDA incorporates gravity-derived Level-3 products into a hydrological model through a global sequential data assimilation system. This component provides improved estimates of terrestrial water storage anomalies and their subcomponents (soil moisture, groundwater, snow), offering new opportunities for hydrological analysis, drought monitoring, and water resource assessment.

Structure

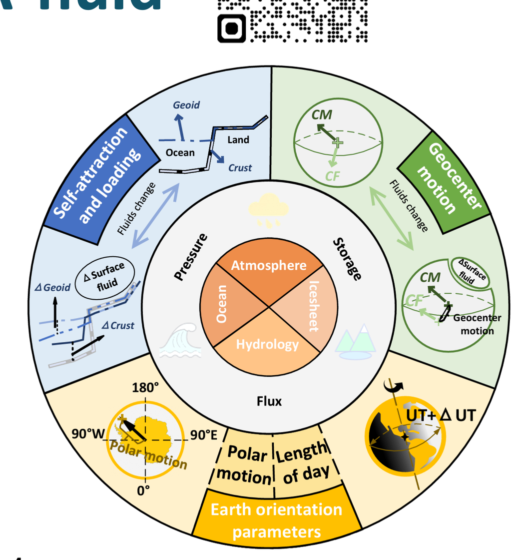


High-resolution data assimilation over Europe

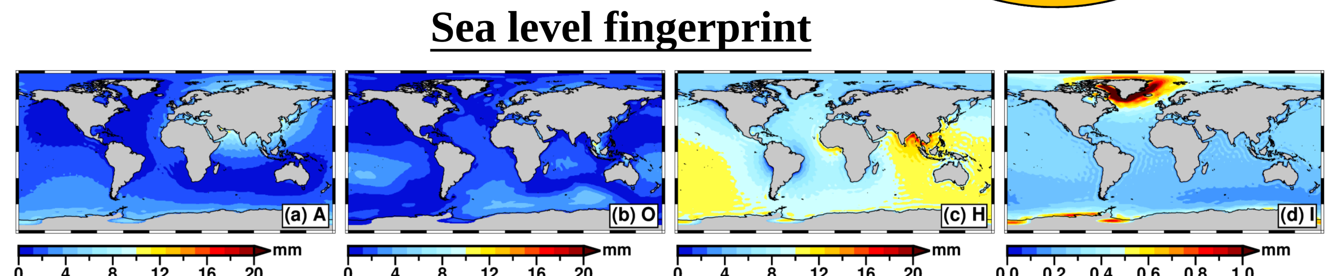


Tool-4: SAGEA-fluid

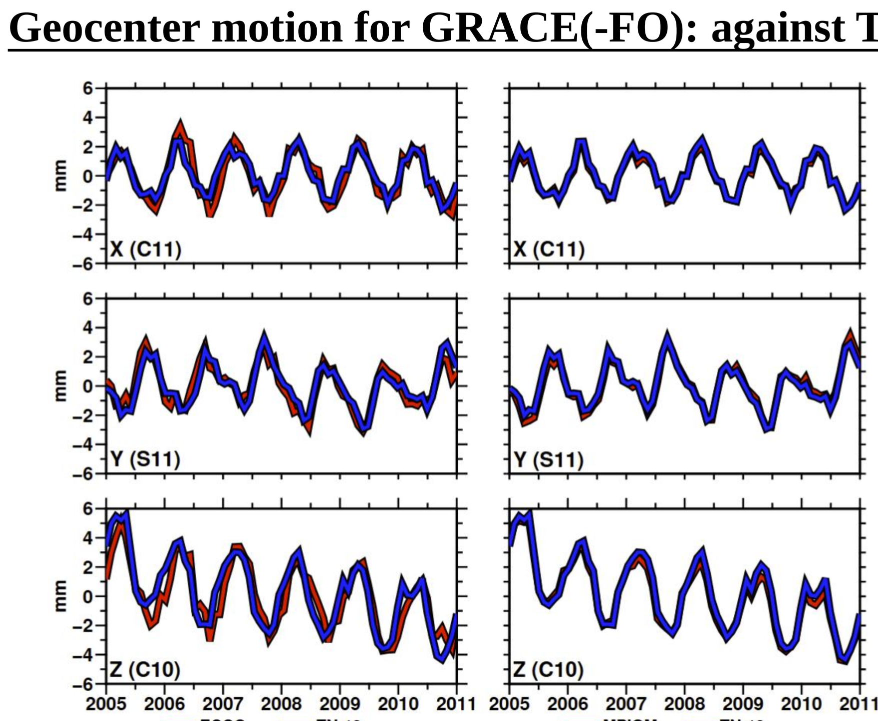
SaGEA-Fluid computes a wide range of geophysical corrections driven by atmospheric, oceanic, hydrological, and cryospheric mass redistributions, including self-attraction and loading (SAL), geocenter motion, and Earth orientation parameter (EOP) variations.



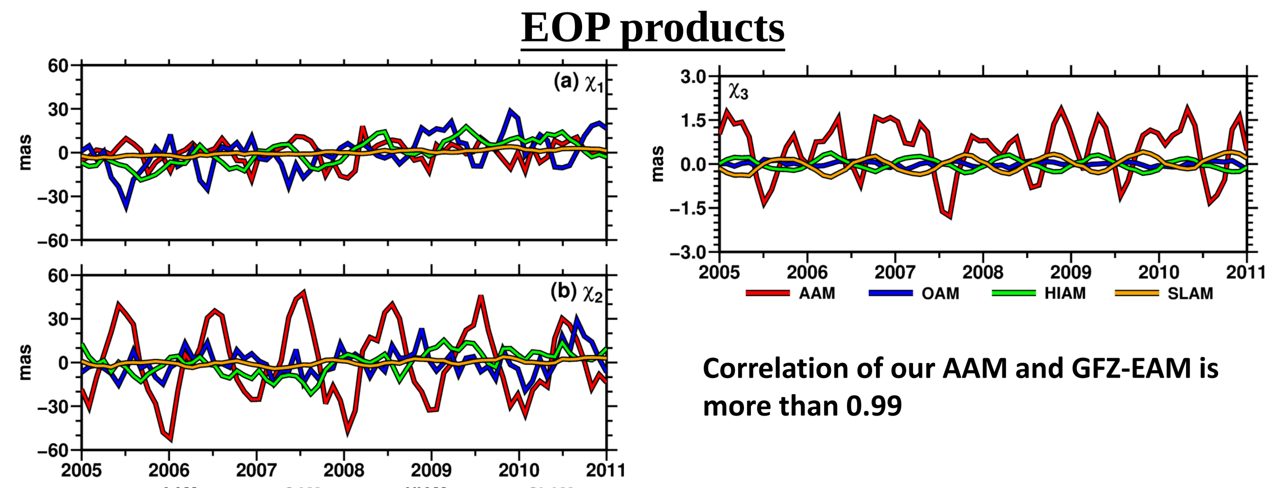
Sea level fingerprint



Geocenter motion for GRACE(-FO): against TN13



EOP products



Correlation of our AAM and GFZ-EAM is more than 0.99