Earth's Gravity Field Evolution (EAGLE)

Observations of the **time-variable Earth's gravity field** describe the redistribution of environmental masses in the Earth system, including changes in **land hydrology, ice, ocean, and atmosphere**. These observations provide essential insights into the global water cycle, changes in ocean surface currents, mountain, and polar ice mass loss, large-scale underground droughts, sea-level rise, surface load displacements, as well as many other environmental processes. The variations of the Earth's gravity field directly influence **the Earth's rotation**, in particular, pole coordinates and **length of the day** variations from intra-annual to decadal and secular scales.

Two satellite missions, **GRACE and GRACE Follow-On,** have revolutionized the observations of mass transport within the Earth system. However, GRACE was **launched in 2002**; thus, there is **very little information about temporal Earth's gravity field changes before this date**. Moreover, GRACE was initially designed for five years, and after 2010, substantial problems related to the power supply occurred, resulting in missing data. GRACE FollowOn entered the science phase in January 2019, which is **16 months** after decommissioning its predecessor; therefore, the observations of the Earth's gravity field are discontinuous, with many gaps between 2010 and 2019.

Fortunately, GRACE and GRACE Follow-On are not the only missions that can be used to recover the Earth's gravity field variations. For the recovery of the mass redistribution processes in the large scales, we may employ precise **Satellite Laser Ranging** (SLR) observations to past, present, and future **geodetic satellites**, such as LAser GEOdynamics Satellites (LAGEOS-1/2), LAser RElativistic Satellites (LARES-1/2), Ball Lens In The Space (BLITS), as well as Ajisai, Starlette, and Stella. **Since the 1980s**, Starlette, Ajisai, and LAGEOS have been **observed on a regular basis by the globally distributed network of laser stations** providing range measurements with **the accuracy of several millimeters**. Since the beginning of the 1990s, many active **low Earth orbiters (LEO)** have been equipped with **precise Global Navigation Satellite System (GNSS) receivers**, allowing for precise orbit determination and thus for the gravity field recovery.

The primary goal of this study is to derive long-term models of the longest wavelengths of the Earth's gravity field changes using integrated observations from SLR observations to geodetic satellites, inverse methods based on GNSS station coordinates, LEO satellites equipped with GNSS receivers, GRACE data, and geophysical models. We will focus on the long-term evolution of the Earth's oblateness term, low-degree gravity field changes, geocenter motion, with geophysical interpretations and implications.

The currently available models of the Earth's gravity field variations start in 2002 with the launch of the GRACE mission with many gaps after 2010. Many groups provide the series of geocenter coordinates or oblateness term based on various data and satellite and ground-based techniques; however, no common geocenter products are available to the users.

In this project, the temporal, integrated, multi-satellite models of the Earth's gravity field will be derived and analyzed **starting from the 1980s**. We will not only derive and assess the temporal models of the Earth's gravity field, but also we will **evaluate the interactions** between the **gravity** field, Earth **rotation**, **geocenter** motion, the standard **gravitation parameter GM**, and the **anomalies in satellite motions** for the **seasonal and secular temporal scales**. We will employ passive satellites, active satellites, and station coordinates based on three GNSS systems: GPS, GLONASS, and Galileo for the inverse methods of low-degree gravity field recovery. All of those constitute fundamental insights into the processes in the fluid and solid layer of the Earth system and have utmost meaning for all high-accurate satellite missions for the Earth observations and measurements.