Planet Earth is very dynamic and restless. Various processes occur on its surface, e.g., processes related to tectonic plate motions, volcanisms, ice melting, eustatic sea level rise, etc. Sometimes, these processes cannot be observed directly, thus, we use indirect observations. For instance, the ice mass depletion can be assessed using the observations of the Earth's flaterring (oblateness) parameter (when the ice sheets on poles expand or decrease the Earth becomes more or less 'flattened'). Earth's flattering cannot be measured directly, because we are not able to drill a hole through the entire planet from a pole to its center. However, we are able to determine an accurate value of Earth's flattering parameter through observing the anomalies in the satellite motion. The Earth's flattering causes a precession of orbital plane that depends on satellite altitude and inclination of satellite orbital plane with respect to the equator. Observing anomalies of satellite motion with respect to nominal trajectories allows us to determine the value of Earth's flattering parameter with a very high accuracy. The observations of the planet Earth must be extremely precise since every additional millimeter in the sea level or every single centimeter in the Greenland's icy surface play a crucial role for the future of our planet, which is indeed our home.

Precise orbit determination constitutes, thus, an indispensable element in studying the planet Earth, because the accuracy of the satellite trajectory determination substantially influences the accuracy of parameters derived from satellite observations. Precise orbit determination is typically based on two observations types, i.e., on microwave observations (e.g., satellite navigation systems such as GPS, GLONASS, Galileo) or based on laser distance measurements (Satellite Laser Ranging, SLR). SLR observations do possess many advantages related to their high accuracy at a level of a few millimeters and related to their insensitivity to many systematic error sources as opposed to microwave observations. SLR measurements are free of ionosphere delays, satellite clock offsets, phase ambiguities, as well as the variations of the antenna phase center offsets. On the other hand, SLR measurements are limited by the atmosphere, because the satellites can be tracked only under almost cloudless conditions. Considering the aforementioned aspects, the best results unaffected by systematic errors can be obtained through the integration of laser and microwave satellite observations.

The principle of SLR observations is the measurement of the time interval between a transmission and a reception of a laser pulse at an SLR station after being reflected by the retroreflectors installed on satellites. By multiplying this time interval by the speed of light we obtain the double distance between an SLR station and a satellite. The measured distances have to be corrected by some effects related to atmosphere delays, satellites' center-of-mass corrections or range biases. The SLR contribution to science is unique and essential due to providing the remarkable orbit accuracy of geodetic satellites and due to the precision of laser observations at a level of a few millimeters. Considering these aspects, SLR has an exceptional potential in establishing global networks and deriving geodetic parameters of the supreme quality. SLR observations observations significantly contribute to the determination of precise satellite orbits, to the definition of the origin of the reference frame (geocenter coordinates), the global scale, the gravitational constant, and low-degree spherical harmonics of the Earth's gravity field (especially the oblateness term). SLR became an exceptional contributor to the space geodesy in particular after the launch of the first two SLR-designed geodetic satellites, i.e., Starlette in 1975 and the LAser GEOdynamics Satellite (LAGEOS) in 1976. SLR allowed defining a global terrestrial reference frame, observing Earth rotation parameters and the Earth's long-wavelength gravitational potential with a previously unprecedented accuracy. SLR confirmed the theory of the drift of tectonic plates and allowed defining the precise value of one of the fundamental values in physics and astronomy, i.e., the gravitational constant. The SLR solutions are able to recover the ice mass loss differences in Antarctica or the melting of the Patagonian glaciers. This is possible, because the dynamic orbits of SLR satellites carry implicit information about the holistic Earth's gravity field. Melting processes of the polar ice shields are an important contributor to mass transport mechanisms and global variations of the mass balance, and they constitute a sensitive indicator of climate change. Reliable estimates of mass trends, which are fundamental to answer the question if they are accelerating or not and to quantify the contribution of the ice mass depletion to eustatic sea level rise can be supported by SLR, because SLR can provide precise information about the longest wavelengths of the Earth's gravity field.

The accuracy of current SLR solutions is, however, limited by deficiencies in the background models which are applied in the SLR solutions. Two of the most crucial factors limiting the accuracy of SLR solutions are related to the modeling of the troposphere delays, in particular unmodeled horizontal gradients of the troposphere delay, and to the systematic effects, especially range biases at SLR stations. The goal of this project is to improve the modeling of horizontal and vertical gradients of the troposphere delay and to investigate the systematic effects at the SLR stations in order to increase the accuracy of the SLR solutions and to improve the consistency between SLR and other space-geodetic techniques, namely Global Navigation Satellite Systems (GNSS), and Very Long Baseline Interferometry (VLBI). The horizontal gradients are neglected in the current SLR solutions. This neglect leads to an error source that contributes up to 50 mm of delay at low elevation angles for the SLR observatory in Herstmonceux, which has a climate that is influenced mainly by its close proximity to water resulting in the weather being normally damp and subject to frequent changes. Yarragadee, which is situated on the south-western coast of Australia, is a very important station in the SLR network because it produces a very large number of observations and is one of only three operational core stations in the Southern Hemisphere. The Indian Ocean lies 50 km to the west of the station, and as a result, the ocean has a significant influence on the horizontal gradients of troposphere delay around Yarragadee. In Zimmerwald, which is stationed near Bern in Switzerland, the varying topography (altitudinal spread of more than 4000 m) is one of the main factors that affect the climate. In the north direction from the observatory, the Bernese Highland is situated, whereas in the south direction there are the highest Alps, which cause the horizontal gradients in the troposphere delays of SLR observations. Also, for a majority of the most important SLR stations the significant horizontal gradients are expected.

In the view of the challenges mentioned above, following problems will be addressed within the framework of this project: Quality improvement of the SLR solutions and the SLR-derived parameters through modeling horizontal and vertical gradients for the troposphere delay, as well as the improvement of the consistency between SLR and GNSS solutions through using similar mapping functions and horizontal gradients in troposphere delays, investigating systematic range biases for SLR stations, and validating and estimating center-of-mass corrections for LAGEOS and LARES satellites. The enhanced modeling of troposphere delays shall improve all SLR-derived products, e.g., the quality of precise satellite orbits, the realization of the scale and the origin of the International Terrestrial Reference Frame, the quality of SLR-derived Earth rotation parameters and the SLR-derived temporal variations of the low-degree gravity field coefficients, which are associated with large-scale mass transport in the system Earth. As a result, the enhanced realization of the reference frame will allow us to study with a better accuracy the processes related to climate change, such as the eustatic sea level rise and melting of the polar ice shields.