The Sun is constantly releasing energy in the form of electromagnetic and particle radiation, which has a tremendous impact on the space environment. The conditions in space caused by the Sun are known as space weather. There are several solar eruptive phenomena that occur within the atmosphere of the Sun and directly affect space weather, such as solar flares or coronal mass ejections. The Sun's activity and related phenomena vary within the 11-year solar activity cycle, which has been tracked since the 18th century. Currently, we are in the maximum of the 25th solar activity cycle, i.e., the period when the Sun is the most active. This will result in an increased occurrence and strength of solar phenomena correlated with increased ionization of the Earth's atmosphere. The ionized region of the upper atmosphere, extending from around 70 km to 1000 km altitude, is called the ionosphere. This solar-driven region is crucial in the complex Sun-Earth relationship, having a significant impact on radio wave propagation.

Commonly used positioning, navigation, and timing services are provided by the Global Navigation Satellite Systems (GNSS). The best-known GNSS system is the American Global Positioning System (GPS), but other global constellations are also available, i.e., the Russian Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS), the European Galileo, and the newest Chinese BDS-3 (operational since July 2020). GNSS data are primarily used to determine the position of users, but they are also used by scientists in various geoscientific applications such as earthquake and tsunami warning systems, volcano deformation, landslide monitoring, etc. Their positioning performance is, therefore, of particular importance. However, GNSS signals are affected by the ionosphere when they propagate from a satellite to a ground receiver. This results in considerable and varying signal propagation delay, causing measurement errors of tens or even more than one hundred meters. Therefore, it is considered one of the main and critical sources of GNSS positioning errors that must be corrected. Mitigation of ionospheric delay in GNSS signals is mainly based on the use of (1) ionospheric models that represent the state of the ionosphere or (2) dual-frequency signals. However, space weather causes changes in the state of the ionosphere, which can result in serious degradation of signals and the deterioration of GNSS performance. Currently, the modernization of GNSS results in the development of new and improved ionospheric models. Moreover, the rapidly evolving GNSS technology, with the emergence of new systems, signals, or processing strategies, raises many new opportunities, and consequently, the necessity to investigate their efficiency and ability to mitigate the adverse effects of space weather. This modernized technology should be particularly assessed during the most adverse space weather events, as these can cause significant degradation of GNSS accuracy and reliability.

The current solar maximum period is associated with an increased occurrence of intense geomagnetic storms. These space weather phenomena can create auroras, but also can cause disruption to GNSS systems through the ionospheric responses. The proposed project will include an analysis of a recent series of intense geomagnetic storms that occurred on 10-13 May 2024. Given that during this event, the most intense geomagnetic storm since 2003 occurred, it is an unusual opportunity to study the space weather effects on satellite systems under the most disturbed conditions that can occur. The proposed project will explore new models and products, as well as modernized satellite signals, providing the current state of the art in GNSS technology. Considering the wide use of GNSS in scientific research and its vulnerability to space weather, the main scientific goal of this project is to provide the scientific community with a better understanding of space weather effects on GNSS performance and thus optimize the use of GNSS data.