Today, society relies more and more on GNSS (Global Navigation Satellite Systems) signals and GNSS data across a wide range of industries and critical systems. It is highly important, that satellite navigation signals passing trough the Earth's ionosphere are precariously weak and can easily be damaged or disrupted inside the perturbed ionosphere. The Earth's ionosphere is a highly variable and complex physical system, driven by the Sun's radiation, particles and magnetic fields as well as processes involved in the interaction between the solar wind and the magnetosphere. Ionospheric plasma density irregularities and turbulence lead to a serious degradation of critical systems performance.
The most severe ionospheric irregularities occur primarily in the equatorial region, within a band of 20°S-20°N of geomagnetic latitudes, and at the high-latitude region, above 65° geomagnetic latitude, which include auroral and polar cap regions. These boundaries vary with time of day, season, sunspot number and geomagnetic activity level. At high latitudes, occurrence of the intense ionospheric plasma density irregularities relates mainly to the magnetosphere-ionosphere coupling processes. During space weather events, irregularities occur as a result of significant increase of the auroral particle precipitation and dynamical processes including high-speed plasma convection. Occurrence and motion of the storm enhanced density and tongue of ionization structures and polar cap patches, as well as extension of the auroral oval and equatorward movement and deepening of the main ionospheric trough can result in severe ionospheric gradients and irregularities at high and middle latitudes. Other regular phenomena are the ionospheric irregularities (plasma bubbles) in equatorial region at evening time. The intensity of the equatorial irregularities varies with time after sunset, season (higher occurrence probability in equinoxes than solstices), longitude sectors, solar cycle (increased intensity at the cycle maximum). The ionospheric irregularities at high and low latitudes are produced by different plasma instabilities and plasma processes and they are controlled by different configuration of electric and magnetic fields. Typically, irregularities are generated at the bottomside ionosphere (~100-200 km) and then can reach higher altitudes (>1000 km).

The goal of the project is to specify the main characteristics of ionospheric plasma structures in the Earth's equatorial and high-latitude regions that most adversely impact satellite communication and navigation systems. The equatorial region represents an excellent testing field as intense ionospheric irregularities occur here regularly. The **primary scientific objective** of the project is to improve our knowledge about physics and morphology of the ionospheric plasma irregular structures, in particular its location, life-time, absolute and relative differences between density inside plasma structures and surrounding ionosphere. The **second scientific objective** is to investigate and demonstrate to which extent an integration of independent but compatible modern space-borne observations can support progress beyond the state-of-art in ionospheric irregularities morphology. The **third scientific objective** is to investigate to which intensity the ionospheric irregularities should be developed in order to affect significantly GPS (Global Positioning System) performance onboard LEO (Low-Earth-Orbit) satellites.

To understand physical processes behind the interactions of fields and plasmas within the atmosphere-ionosphere system we will study processes of generation, evolution of the ionospheric plasma density irregularities in equatorial and high-latitude regions using extensive dataset onboard three satellites of the recent ESA's Swarm mission. At the moment only two LEO missions – both being multi-satellite mission, Swarm (orbit altitude H~500 km) and DMSP (H~850 km) – provide actual in situ plasma probe measurements. The ESA's mission Swarm was launched on November 2013, and it consists of three identical satellites - Swarm Alpha, Bravo, and Charlie.

The research project has **interdisciplinary character** as new knowledge on ionospheric irregularities phenomena will be derived from integration of different results based on ideas, concepts and techniques from various disciplines such as computational mathematics, ionospheric imaging, geomagnetic field, GNSS-based spatial navigation, remote sensing and plasma physics.