Atmospheric scanning? It's already happening!

Whatever our lifestyle, we use location data every day. Our location and the road from point A to point B can be determined on the paper map, but more and more often we use devices that facilitate the selection of the most optimal route and inform about the time of its travel. Navigation in our smartphone or car uses data transmitted by Global Navigation Satellite Systems (GNSS).

The space race launched by the United States and the USSR in the 1960s is still not over. Apart from the American GPS navigation system, Russian GLONASS, European Galileo or Chinese Beidou, there are many commercial satellites in orbits, sent for telecommunications, earth observation or scientific research. According to experts' estimates, in the following years about 300-400 satellites will be launched annually. The signal sent by the satellite to the receiver must pass through the atmosphere. In the lowest layer of the atmosphere, the troposphere, there is most water vapour. This causes that the satellite signal received by a dense network of terrestrial receivers or receivers located in low orbits is bent and delayed. The measure of tropospheric delay is a valuable and relatively low-cost source of information about the current state of the atmosphere for weather services.

In the case of ground stations, the delay is determined as an integrated value for the satellite-receiver pair. For this reason, it is difficult to determine the water vapour content at particular tropospheric altitudes. In space, on the other hand, for the satellite-receiver pair, the delay is determined in a high vertical resolution profile. These profiles, although they cover almost the entire Earth, are characterized by low horizontal resolution. Limitations in the use of GNSS information in meteorology can be overcome by using GNSS tomography. As with computed tomography, which is used to diagnose pathogenic changes, GNSS tomography provides a three-dimensional image of the water vapour content of the atmosphere. In this case, part of the troposphere above the dense network of GNSS receivers is divided into small boxes, voxels, in which, using ray tracing algorithms, the length of the GNSS signal crossing the voxel is determined. On this basis, the integrated delay value is spread over the model voxels. Despite the dense network of ground-based stations and the large number of satellites transmitting the GNSS signal, some of the voxels remain empty, i.e. the GNSS signal does not pass through them. This effect can be mitigated by integrating information from ground and space receivers into the tomographic model.

The idea of integrating space and ground observations triggers the need to expand the functionality of the tomographic model and to develop satellite signal tracking algorithms. At the same time, due to the continuous development of ground stations and satellite constellations, it is necessary to simulate the operation of the model for future infrastructure. The integrated tomographic model can then be used to determine altitude and monitor the planetary and urban boundary layers. The height of the planetary boundary layer affects, among other things, the night-time inversion of the temperature and, consequently, pollution of the ground layers of air masses. Within the urban boundary layer, which is located above urbanized areas, the variation of meteorological parameters is related to the microclimatic properties of the observation site.

Recent studies have shown a positive influence of observations from the tomographic model on short-term weather forecasts. As predicted, the integrated tomographic model will be able to provide very accurate water vapour data for local, regional and global weather services. Thus, through improved techniques of assimilation of tomographic data, the possibility of forecasting severe weather phenomena, such as the development of storm cells or intense rainfall, will be intensified.