GROUND MOVEMENTS IN LATVIA IN 2019-2023 ACCORDING TO THE INTERFEROMETRIC SYNTHETIC-APERTURE RADAR METHOD

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Knowledge of ground motion is important for selecting a construction site or monitoring the condition of existing critical infrastructure facilities. Modern technologies (GNSS, InSAR) allow obtaining ground motion data with high accuracy, depending on the receivers used (GPS stations), frequency (radar wavelength in the InSAR method), observation conditions and stability of reflecting objects (InSAR points). Ground motion can be caused by tectonic movements, landslides, erosion, ground dissolution and formation of karst voids, frost heaving, thermal fluxion, earthquakes, anthropogenic activities (mining, construction, pumping of groundwater, oil and gas), groundwater, quicksand, deformations due to moisture cycles. Ground motions can be caused by a combination of factors, making it difficult to understand the root cause of ground movement.

The *Ortho* dataset from the *European Ground Motion Service* (EGMS) used for the ground motion analysis. The dataset based on remote sensing from space using the *Sentinel-1* satellite. This dataset includes ascending and descending calibrated products, which averaged over a common 100 m grid. Ground motion analysis based on InSAR (*Interferometric Synthetic-Aperture Radar*) data performed for the territory of Latvia for the period from 2019 to 2023. An active method used, with the emission of its own signal, its reflection from points on the Earth's surface and recording of the scattered energy by a satellite sensor. Horizontal ground motion velocities in the east-west direction and vertical ground motion velocities measured.

The statistical parameters of the InSAR data array estimated. Areas with anomalous values of ground motion identified. The characteristics of the ground motion velocity given for different objects – swamps and peat bogs, quarries, transport highways, settlements.

Statistical results

The range of surface displacement velocity in the study area in the east-west direction (v_{EW}) varies from –174.7 to + 140.5 mm/year, and for vertical movements (v_{VER}) it varies from – 134 to + 55 mm/year. The average velocity values are – 0.074 mm/year for v_{EW} and for v_{VER} are – 0.490 mm/year. The standard deviations are 2.371 mm/year for v_{EW} and 2.489 mm/year for v_{VER}, respectively. Negative skewness of the distribution of movement velocities v_{EW} (– 0.226) and v_{VER} (– 1.538) is noticeable. The normal distribution function does not perfectly reflect the experimental distribution. A better approximation to the experimental distribution provided by the probability density function based on the *t Location-Scale* and *Non-Parametric* distributions.

Peatlands

The results of ground movement in the area of some peatlands were unexpected. The ground movement speeds in them often have anomalous vertical and horizontal values. The cause of this effect may be the technology of peat collection and storage. Various methods of peat collection used, including cutting peat briquettes. It is possible that individual pieces of peat have good properties for reflecting electromagnetic radiation (EMR). In some cases, for example, in the area of Lake *Lubāna*, there are several peatlands with opposite directions of movement (Fig. 1). The cause of peat movement may be associated with changes in the level of groundwater and greenhouse gas emissions from peat soils [1], i.e. with the so-called “breathing” of the bogs.

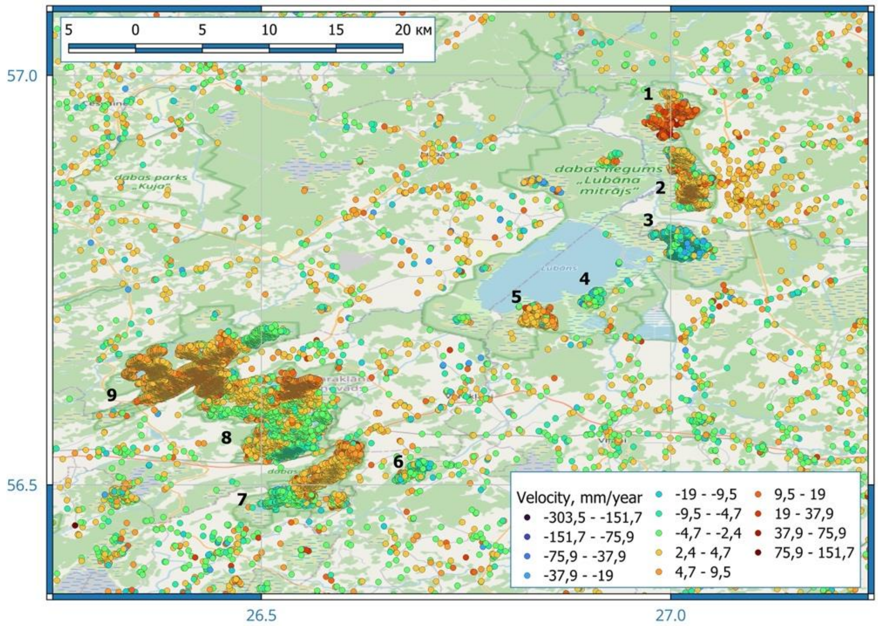

Fig. 1. Horizontal ground movement velocities in the east-west direction in the area of Lake *Lubāna*.

Quarries

Some industrial quarries have also proven to be good objects for reflecting EMI. The most probable reason for this is the removal of the upper, loose layer of Quaternary deposits, under which denser rock deposits are located, most often Devonian. Deposits of dolomite, limestone and gypsum represent these rocks. A typical example is the *Kūmas* quarry, where limestone mined, or the *Salaspils* quarry, where gypsum mined.

Transport highways

Transport highways are good objects of EMR. First, these are railways and, to a lesser extent, highways. For example, sections of the railway in the *Bolderaja* area, in the direction to the north and to the northeast, with a length of 2.9 km and 1.8 km, respectively, are sinking at velocities from 4.7 to 21.3 mm/year.

Populated areas

The largest number of good objects (InSAR points) of EMR are located in populated areas. Such objects are roofs of buildings, roads, concrete structures and other objects characterized by good reflective properties for EMR. The largest subsidence areas have a complex, mosaic shape and randomly distributed in Riga and its environs. The velocities of ground subsidence within these areas vary from – 2.5 to – 27.0 mm/year. The most intense subsidence areas are located along the railway on the right bank, as well as in the southern part of *Kundziņsala*. The rest of the territory of Riga is mainly characterized by uplift with rates from 0 to 5 mm/year.

Comparison of the results of the EGMS (2019-2023) and PanGeo (1992-2000) projects

The *PanGeo* project was carried out within the framework of the 7th Framework Program of the European Union from 2011 to 2013. The objective of the project was to assess geological hazards in support of the *Copernicus* program (formerly GMES - *Global Monitoring for Environment and Security*). These assessments are based on the collection of environmental data via *the European Space Agency* (ESA) satellites, as well as other data from the *European Environment Agency* (EEA). Ground stability layers created within the *PanGeo* project. This product is based on the joint processing of InSAR data, geological information and information on geological, tectonic hazard factors from European geological services. The vertical movement velocities used to identify geological hazard polygons.

Geological assessments based on the integration of the above data performed for Riga and Liepaja for the period from 1992 to 2000 for Latvia. Reflections for 64,116 InSAR points obtained in the territory of Riga. 57 geological hazard polygons were identified [2]. The main features for identifying the polygons were the concentration of InSAR points. According to the *PanGeo* project data, the central part of Riga, bounded by *Sarkandaugava* to the north and *Krišjāna Valdemāra* and *Duntes* streets to the south and east, has a predominant subsidence trend. In the southeast from this area, in the center of Riga, InSAR points with positive velocity predominate.

The EGMS project results for the *Ortho* dataset of this area of Riga and the time interval from 2019 to 2023 do not show this uplift. In addition, the *Ortho* dataset results do not reflect the extreme values of vertical velocities for other polygons identified in the *PanGeo* project (1992 - 2000). The *PanGeo* project results characterize tectonic movements better than EGMS project with Orto dataset.

References:

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