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About the phenomen on of subsidence in continental Europe in December 2019 based on the GNSS stations data

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SUMMARY

The research reveals a geodynamic phenomenon in continental Europe in December 2019. The subsidence of GNSS stations lasted from 4 to 10 days. The linearity of the phenomenon spreading from west to east is established. Maximum subsidence reaches near 30 mm, and daily average from up to 5 mm per day. The analysis of the phenomenon is performed as well as maps of its distribution are constructed. Analyzing the reduction of the height of GNSS stations, the relationship between subsidence and the thickness of the Earth's crust is traced. In the future, this phenomenon needs further research and explanation.

Introduction

In recent years, based on the data from GNSS stations the modern kinematic processes of the European continental Earth crust is evaluated. For example, modern kinematic trends of Central European GNSS Research Network (CEGRN) are determined (Zurutuza et al., 2019) as well as diversification of the Earth's crust into smaller structures is performed (Tretyak and Vovk., 2016). In such studies, researchers operate with the data on coordinate displacements for 1 year. This annual distribution allows compensating for the influence of known seasonal phenomena (Tretyak et al., 2012), however, this approach does not allow identifying of special sharp shifts of coordinates that last for several days. Nowadays, geodynamic processes by the distribution are divided into 3 types, namely: global, regional, and local (Tretyak et al., 2015).Global processes are widespread across the planet, and usually are the result of exogenous phenomena, such as changes in the Earth's rotational motion. Regional geodynamic processes are allocated for the special areas, such as the Carpathian-Balkan region (Tretyak and Brusak, 2020). Local geodynamic processes are considered in cities or large industrial facilities, such as GNSS monitoring of Dniester pumped storage power plant (Savchyn & Vaskovets, 2018) or on the territory of a former deposit of potassium saltin Stebnyk, Lviv region where subsidence of the surface is examined (Savchyn et al., 2019). This study examines the geodynamic phenomenon that took place in December 2019 for 4-10 days and affected the height shift of GNSS stations up to 30 mm. Also, it is neither regional nor global phenomena. Authors classify it as continental, as it is widespread throughout the European tectonic structure.

Methods and Theory

Nowadays the daily sharp displacements of the GNSS stations lasting about 10 days are insufficiently studied. No mention in modern studies of such phenomenon on the territory of large tectonic blocks was found. There are a number of reasons. Firstly, to recognize such shifts, it is necessary to work out with short terms of daily solutions of GNSS stations (max. 2-3 months). Secondly, all processing should be carried out in one of the scientific GNSS software such as Bernese, Jipsy, Gamit, in order to avoid averaging, which can smooth the geodynamics phenomena. Thirdly, a significant amount of data should be operated for eliminating the local phenomena or possible equipment failure. This study began after the processing of RINEX-files of permanent stations of the Geoterrace, Ukraine network in the Bernese software. Assessing the changes of the daily solutions of stations, an interesting fact was revealed: standard deviation of the height position of GNSS stations after December 2019 began to grow. The example of the data for 10 stations of Geoterrace stations is shown in table 1.

Table 1 *The accuracy changes of the altitude position of Geoterrace stations before and after December 2019*

GNSS station	Date of installation	Duration of work until 2020, years	Standard deviation of determination of the height position of the GNSS stations			
			Epoch 2019.9, mm	Epoch 2020.1,mm	The difference of standard deviations between epochs (2020.1-2019.9)	
					mm	%
SULP	06.10.2001	18.2	0.96	0.98	0.02	2.25
MYKO	01.10.2012	7.3	0.78	0.88	0.10	13.23
SKOL	05.02.2013	6.9	0.90	0.96	0.06	6.65
BRGN	06.05.2014	5.7	0.83	0.89	0.05	6.43
ZOLH	24.08.2014	5.4	0.83	0.92	0.09	11.37
VLVL	04.06.2015	4.6	0.86	0.93	0.07	8.11
SOKA	31.10.2017	2.2	0.91	0.94	0.03	3.66
NEMR	23.07.2018	1.5	0.84	0.95	0.11	12.56
VYNO	24.12.2018	1.0	0.83	0.92	0.10	11.89
SVLV	09.01.2019	1.0	0.74	0.87	0.13	18.01

As this fact surprised us, detailed attention was paid to the data from GNSS stations this month. Fig. 1 shows a number of daily solutions of the height deviation of GNSS stations of the Geoterrace network in December 2019. From the graphs, it is seen that there started a sharp decline in altitude near 22nd December, which lasts several days and the subsidence of stations remains lower than the previous trend in the future. Accordingly, taking into account these daily solutions, which differ by 2 cm from the conditional previous trend, the overall accuracy of determining the height of the station will decrease.

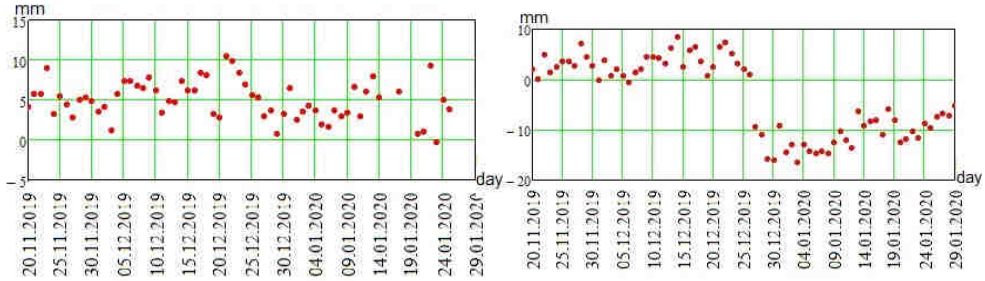

Fig. 1.*A number of daily solutions of height deviation of GNSS stations of Geoterrace network in December 2019(SULP – left, VYNO – right)*

The next step is to establish the territory of the distributionof phenomenon. Examining the time series of GNSS stations of the International GNSS Service (IGS) network, it was found that the rapid altitude reduction is not present in Africa, America, Australia, or East Asia. But it is present in Europe and the extreme limits of the geodynamic process are set.

The extreme western border is Spain, Portugal, Great Britain, because further on the islands in the Atlantic Ocean, the phenomenon is not observed. As mentioned above, at GNSS stations located in North Africa there are also no shifts at the end of December 2019. The northern point, where the phenomenon is observed, is the north of the Scandinavian Peninsula, but further north, GNSS stations that would be operating at this time are not identified.

The eastern border is not clearly identified. In Ukraine, the phenomenon is present in the same way as in Belarus. In Russia, near Moscow and St. Petersburg, the subsidence has also occurred. However, as the data of the Russian permanent GNSS networks are not publicly available, the data are insufficient to clearly establish the eastern border. This indicates that the geodynamic phenomenon is continental.

The daily solutions of GNSS stations of Geoterrace, System Solutions networks (Zurutuza et al., 2019) in Ukraine were processed as well as data from stations in European regions based on the data of NGL (Blewitt et al., 2018), IGS, EUEREF, and SKPOS networks. More than 500 GNSS stations were analyzed. The characteristic drop in altitude at the end of December 2019 is confirmed for all stations.

In order to characterize the phenomenon, the following parameters are selected: The beginning of the process and the corresponding height value, the end of the process and the corresponding height value, the total duration of the phenomenon in days, maximum subsidence, average daily subsidence. Table 2 shows mentioned above data for 10 stations of Geoterrace stations as an example.

In general, on the territory of Europe the process began on 20th of December of 2019 and ended on 01st of January of 2020 (fig. 2,3).The linearity of the phenomenonspreading from west to east is established.Maximum subsidence reaches near 30 mm. Fig. 4 shows daily average subsidence from 2 to 5 mm per day. Analyzing the reductionof the height of GNSS stations, the relationship between subsidence and the thickness of the Earth's crust is traced.

Table2 *Characteristics of the phenomenon of reducing the height (subsidence) of GNSS stations on the example of the Geoterrace network in December 2019*

GNSS station	Beginning of the phenomenon		End of the phenomenon		Characteristics of the phenomenon		
	Date, day. month	Relative height, mm	Date, day. month	Relative height, mm	Duration, days	Max. subsidence	Average subsidence mm/day
SULP	22.12	10.4	30.12	0.8	8	-9.6	-1.2
MYKO	24.12	18.2	30.12	5.0	6	-13.2	-2.2
SKOL	23.12	13.3	30.12	2.9	7	-10.4	-1.5
BRGN	21.12	11.1	30.12	4.9	9	-6.2	-0.7
ZOLH	24.12	8.6	30.12	-2.1	6	-10.6	-1.8
VLVL	23.12	8.3	29.12	-3.2	6	-11.5	-1.9
SOKA	25.12	12.9	30.12	-2.6	5	-15.5	-3.1
NEMR	23.12	14.9	28.12	3.4	5	-11.5	-2.3
VYNO	23.12	7.4	31.12	-15.9	8	-23.3	-2.9
SVLV	25.12	14.2	29.12	-6.1	4	-20.2	-5.1

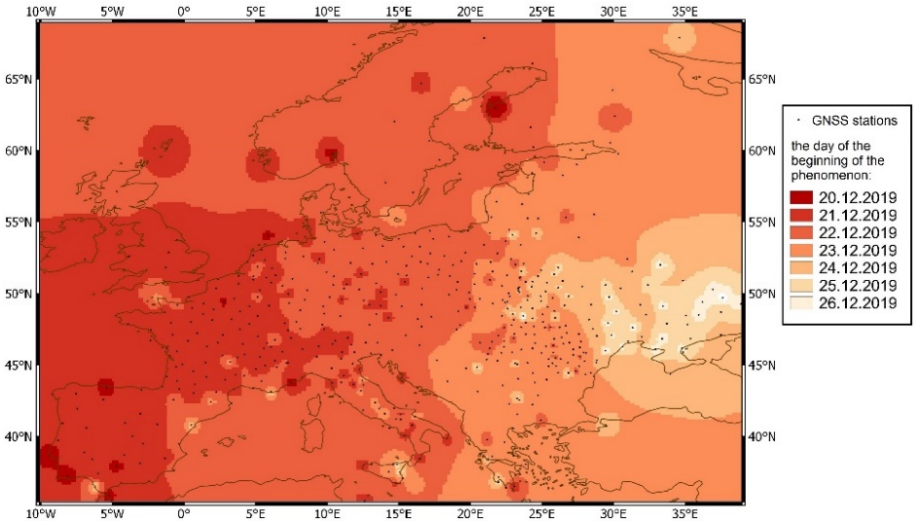

Fig. 2.*The beginning of the geodynamic phenomenon in Europe*

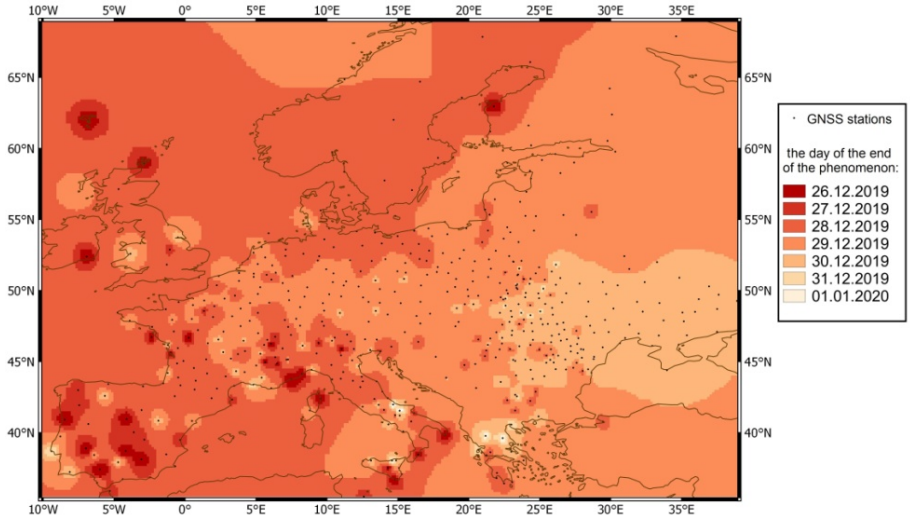

Fig. 3.*The end of the geodynamic phenomenon in Europe*

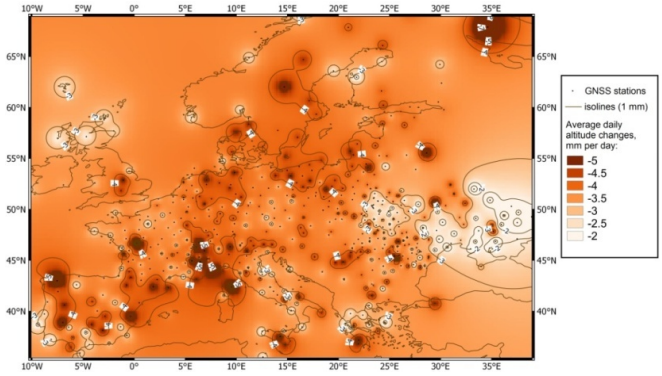

Fig. 4.*Daily averagesubsidence in Europe during the geodynamic process*

Conclusions

The research reveals a geodynamic phenomenon in continental Europe in December 2019. The subsidence of GNSS stations lasting 6-10 days is investigated. The analysis of the phenomenon is performed as well as maps of its distribution are constructed. The linearity of the phenomenonspreading from west to east is established. Maximum subsidence reaches near 30 mm, and daily average from up to 5 mm per day. Analyzing the reducing the height of GNSS stations, the relationship between subsidence and the thickness of the Earth's crust is traced.In the future, this phenomenon needs further research and explanation.

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