

# SURFACE MONITORING OF LANDSLIDE

47304 KRO

Wielogłowy - Chełmiec rural commune

BY RADAR  
INTERFEROMETRY



# REPORT

Kraków, 31.08.2020

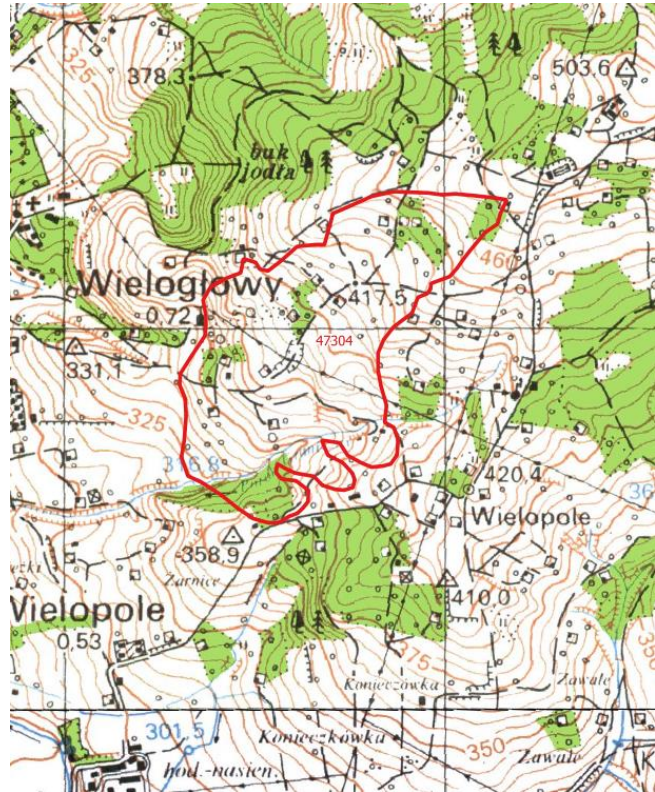
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# 1

## ANALYSIS AREA AND DATA

Area 47304 is located in the Lesser Poland Voivodship in the Nowosądecki Powiat in the commune of Chęłmec in the village of Wielogłowy. The ordinates of the area covered by mass movements at its lowest point are 320 m a.s.l. (the bottom of the Graniczny Stream valley), while the highest point of the studied area rises to a height of about 475 m a.s.l. The geographical coordinates of the central point of the analysed landslide are: 49°40'13.73"N and 20°42'10.10"E. The landslide surface area is 0.394 km<sup>2</sup>



This area has been identified as part of the SOPO project and divided into a periodically active area in its northern part, an inactive area (west of area 43704) and a continuously active area (southeast of the analysed landslide area). The extent of the landslide and the division into activity zones presented on the maps in this report comes from the database of the Landslide Protection System of the Polish State Geological Institute.

This area was subjected to satellite surface monitoring from February 26, 2017 to February 23, 2020. The analysis was made on the basis of analysis of 82 satellite images from the Sentinel-1 satellite by radar interferometry, IPTA technique.

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# RESEARCH METHODOLOGY

InSAR (Interferometric Synthetic Aperture Radar) interferometry is a remote sensing method, the purpose of which is to calculate the phase shift of radar echoes recorded on two independent SAR images, for the same area and in a given time interval. SAR imaging is an active system, i.e. it has its own source of electromagnetic radiation. This makes it possible to record SAR images both during the day and at night, regardless of the weather conditions. The source data in this technique are SAR radar images with high spatial and temporal resolution, covering an area of up to hundreds of square kilometres. An orbiting satellite has a transceiver antenna that records the amplitude and phase of the returning radar waves. The phase is a specific part of the sine wave cycle that gives information about the variable distance of the recorded point from the antenna.

Knowing the wave phase values for two images, it is possible to calculate their difference and, based on it, calculate the phase shift of a given object between these images ( $\Delta r$ ). The phase shift can then be converted to the value of the land movements.

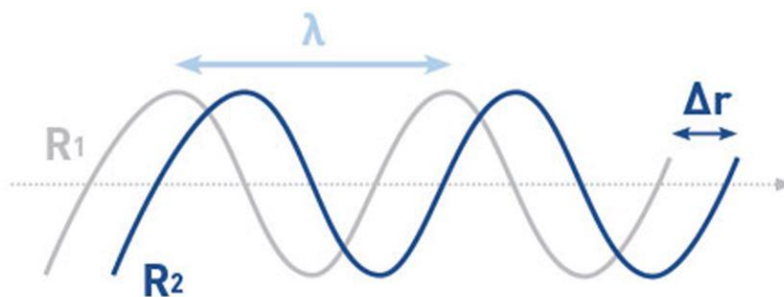


Fig. 1 Visualization of the wave phase shift

One of the most common applications of InSAR techniques is DInSAR (Differential InSAR). It uses two SAR images to calculate the interferogram, i.e. the phase shift image. Then, using a digital terrain model, the topographic component is subtracted and a differential interferogram is calculated that shows movements of the surface of the land covered by SAR images. The disadvantage of DInSAR measurements is the lack of information about local deformations of individual infrastructure objects.

The second method used in the commissioned study is the IPTA technique (Interferometric Point Target Analysis), which uses a set of SAR images between which the phase shift value for each pixel is calculated. In this way, differential interferograms are created. The IPTA analysis is performed only for stable coherent points, i.e. those that are characterised by the invariability of the way the waves are reflected in time. First of all, these are points in built-up areas (mainly on building elements), and their density reaches several thousand points per each km<sup>2</sup>. This method allows calculations of movements for individual objects, also when it is only local deformation. IPTA analyses are carried out for long periods of time, e.g. the whole year. Several or even several dozen SAR images can be used that are recorded periodically every few days (depending on the type of satellite). In this way it is possible to

determine the value of movements for a selected period of time and the velocity of these deformations. The result of IPTA analyses is a spatial set of measuring points for which the values of object movement velocities (usually in the unit of mm/year) along the LOS radar signal incidence line (Line Of Sight) were calculated.

The main parameter describing the possibility, accuracy and, above all, the density of stable PS measuring points for the IPTA analysis is the coherence value for a given area. Coherence is a measure of the consistency of two SAR images. Its value is primarily influenced by two factors: time de-correlation (mainly related to changes in land use or humidity between two images) and the impact of land cover (analysis in forest, swampy and water areas is practically impossible, while in built-up areas - the most effective).

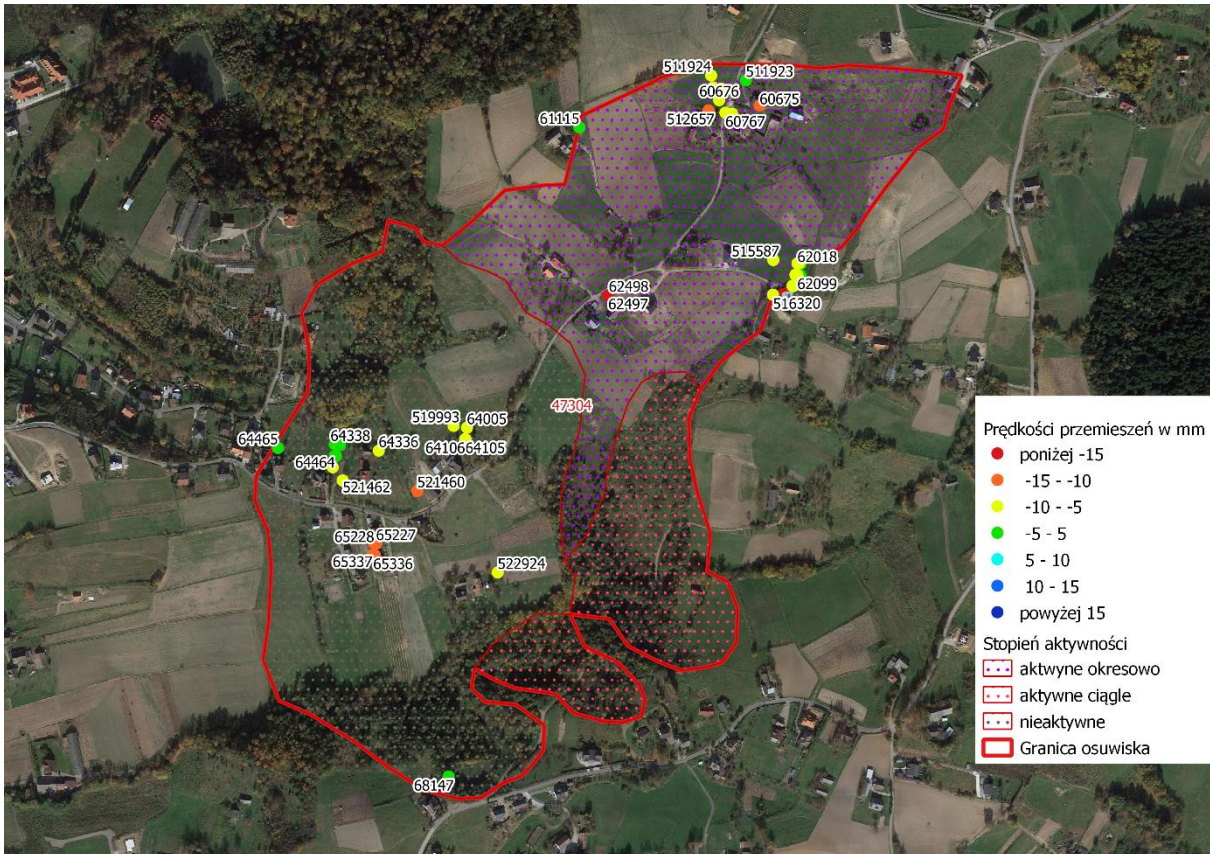
InSAR techniques have been used since the early 1990s (Pratti C., et al., 1994; Hanssen R., 1999; Ferretti A., et al., 2007). The calculation algorithms have been and are being perfected by eminent scientists from around the world. At the beginning of the 21<sup>st</sup> century, the first PS analyses were created (Ferretti A., et al., 2000, 2001). Many scientific articles have also been published that focus on comparing the PS technique

with ground-based geodetic methods (Wei-Chia Hung, et al., 2011; Crosetto M. et al., 2009). They confirmed millimetre accuracy per year for techniques using PS points. In this study, the accuracy of determining the value of vertical movements by the IPTA method was assumed to be +/- 2 mm per year.

All SAR image analyses were carried out by experienced SATIM employees with a university degree in geology, geodesy, remote sensing and computer science.

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# MAP OF MEASURING POINTS

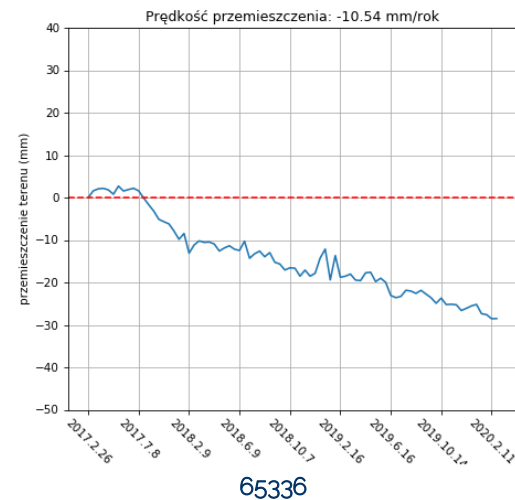
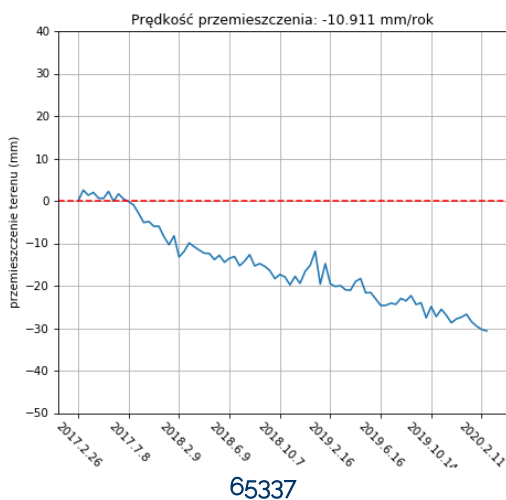
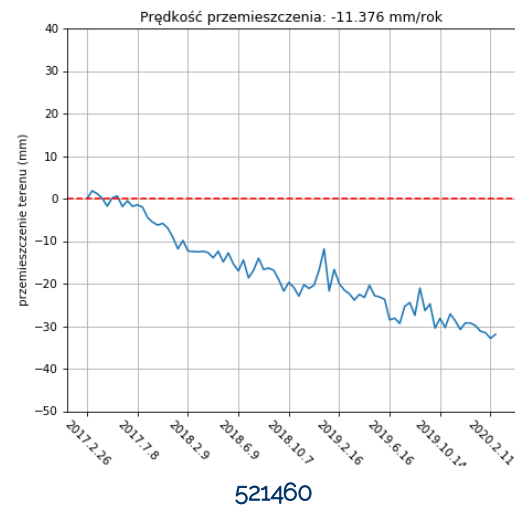
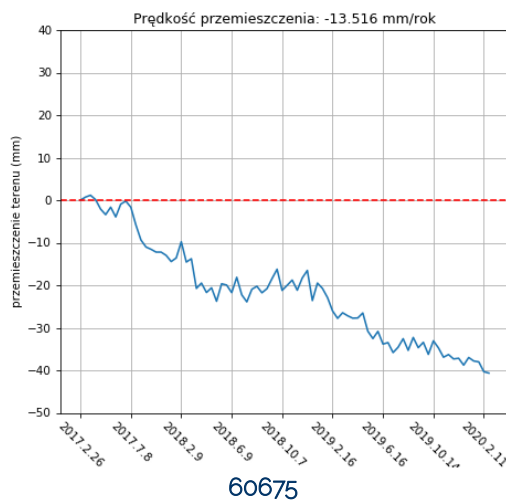
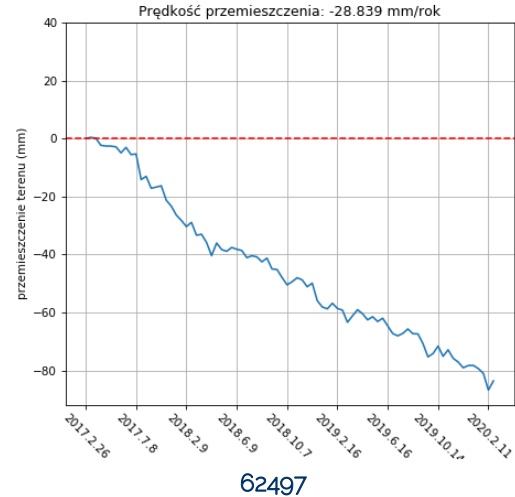
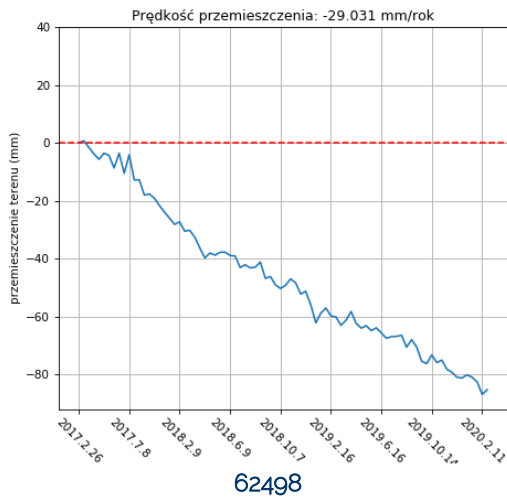


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## SELECTED MEASURING POINTS

Measuring point ID	Land movements [mm]												Total	
	2017				2018				2019					2020
	Quarter 2	Quarter 3	Quarter 4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 1		
62498	-10.5	-2.33	-8.84	-14.62	-2.8	-9.93	-6.9	-5.33	-6.24	-7.93	-5.78	-4.02	-85.22	
62497	-5.55	-8.63	-7.13	-14.58	-2.76	-9.33	-7.99	-5.23	-6.13	-8.03	-2.98	-5.29	-83.63	
60675	-8.31	-6.07	-3.04	-5.57	-0.1	-3.4	1.57	-1.8	-6.8	-6.67	-0.82	-1.65	-42.66	
521460	-0.22	-5.62	-6.39	-7.28	1.36	1.9	-7.37	-3.58	-6.31	0.07	-5.37	-1.87	-40.68	
65337	-1.84	-0.21	-4.91	-5.76	-1.75	-7.32	4.93	-7.02	-4.27	3.36	-4.48	-2.65	-31.92	
65336	0.43	-1.43	-4.97	-5.63	-1.52	-5.21	3.14	-5.76	-3.66	0.59	-3.38	-3.25	-30.65	
522927	0.17	-1.62	-4.92	-5.24	-1.64	-5.48	3.76	-5.39	-3.97	0.39	-3.35	-2.99	-30.28	
65228	1.11	-2.03	-5.66	-4.86	-0.67	-6.24	3.45	-5.4	-3.99	-0.21	-1.86	-2.8	-29.16	
65227	2.17	-2.29	-6.09	-4.27	0.19	-6.79	2.83	-5.2	-4.15	-0.03	-1.91	-2.98	-28.52	
512657	2.04	-2.09	-2.86	-1.28	-4.9	0.81	-1.3	-8.1	-8.51	2.17	-1.52	-1.02	-26.56	
519993	-0.41	-2.43	4.24	-7.24	1.84	-4.67	-1.27	-3.64	0.67	-5.25	-4.1	-0.55	-22.81	
516320	-1.24	-5.23	0.63	-0.87	-1.77	-1.38	-4.77	-5.38	-0.77	-1.79	2.25	-0.96	-21.28	
60572	3.77	-3.01	-3.06	-0.33	-4.7	3.23	-1.3	-8.64	-5.97	3.53	-2.37	-2.09	-20.94	
521462	0.25	-1.69	-2.59	-3.5	-1.75	-1.36	-3.23	-4.71	-0.6	-1.83	0.52	-0.1	-20.59	
60676	2.77	-2.59	-3.7	-0.35	-3.45	2.6	-1.53	-8.42	-7.76	4.04	-0.61	-1.3	-20.3	
62189	-2.12	-1.34	0.31	-0.33	-2.13	-2.01	-3.2	-6.6	-1.32	-2.31	2.38	-1.1	-19.77	
64005	2.02	0.53	-2.99	-6.23	4.14	-6.48	-1.15	-0.95	2.85	-5.36	-1.83	-3.72	-19.17	
62099	0.26	-2.25	-0.05	-0.54	-1.47	-2.16	-3.23	-6.37	-1.32	-1.57	0.79	-0.69	-18.6	
62100	0.75	-2.36	0.03	-0.01	-1.77	-1.87	-3.15	-6.5	-0.84	-1.78	0.32	-0.46	-17.64	
62017	1.14	-2.39	-0.28	-1.19	-0.43	-2.02	-3.64	-5.87	-1.65	-1.25	0.51	-0.57	-17.64	

# 5 GRAPHS FOR SELECTED MEASURING POINTS



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# SUMMARY AND EVALUATION OF RESULTS

During this monitoring for area 47304: Wielogłowy - Chetmiec, 45 stable measuring points were generated. The landslide in the period from February 26, 2017 to February 23, 2020 was characterised by land movements of even  $-29.031$  mm/year (measuring point ID = 62498), with the average annual land movement velocities for all measuring points amounting to  $-7.862$  mm/year.

Measuring points were generated in urbanised areas that are located in the western, northern, eastern and central parts of the landslide area. In each of these parts, without any exceptions, there are land movements.

The highest land movement velocity in the western area is  $-13.516$  mm/year with an average of  $-7.068$  mm, which means that in the period from February 26, 2017 to February 23, 2020, this area in some places could have moved at least by  $-40.66$  mm.

In the northern landslide area, the highest movement velocities were  $-12.602$  mm/year, while the average movement velocity for this area is  $-7.394$  mm/year

On the other hand, in the eastern part of the area, there was the maximum of  $-8.648$  and the average movement velocity of  $-6.738$  mm/year, respectively, which corresponded to the average value recorded in the entire measuring period of  $-13.779$  mm.

The highest movement velocities throughout the entire measurement period were recorded in the central part of the landslide, and amounted to  $-83.616$  mm and  $-85.208$  mm for measuring points 62497 and 62498, respectively.

Detailed movement velocities for each measuring point analysed on each satellite imaging can be seen in the attached XLSX file and the SHP file.