Offset-Tracking as an Effective Tool for Rapid Movements Monitoring

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Key words: displacement monitoring, offset-tracking, glaciers, landslides, SAR images

SUMMARY

Natural-caused terrain movements appear in all parts of the world. However, glaciers movements and landslides are of particular importance because of climate changes issues. Some of these movements are rapid or occur in areas, which are difficult to monitor. Lots of classical surveying methods are difficult to apply in such dynamically changing areas but remote sensing techniques might be a solution to this problem. The aim of the presented study was to investigate the possibilities of applying the SAR offset-tracking technique to monitor fast movements, such as a glacier's velocity or displacement caused by a rapid landslide. In this research, two different areas were studied, the Jakobshavn glacier located in Greenland and the Italian landslide Ponzano. For the first study area, radar images from Sentinel-1 and ICEYE satellite missions were used to determine the glacier's velocity. Values were calculated using the offset-tracking technique for January 2021. For both datasets the results were comparable. However, high-resolution data delivered more detailed information about the glacier movements, especially near the terminus, where the maximum velocity reached almost 41 m/day. The same calculation method was applied for the Italian landslide area to determine displacements that occurred after triggering the rapid landslide. In this case, Sentinel-1 and high-resolution TerraSAR-X (TSX) images were used. Due to the smaller study area, only TSX data delivered reliable results with displacements at the level of over a dozen meters. The resolution of TSX images was 8 times better than in the case of Sentinel-1 data, which made detection of displacement possible. This research proves that the application of the SAR offset-tracking technique can improve the observation of not only glacial but also landslide areas. It might be a useful monitoring method for fast and rapid ground movements. Moreover, it can be considered an effective alternative to the InSAR technique or classic surveying methods, which may be difficult to apply in such areas.

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1. Introduction

Synthetic Aperture Radar (SAR) satellite sensors support observations of the environment since the early ’90s of the 20th century when JERS and ERS-1 satellites were launched. From that time, researchers from all over the world found plenty of useful applications for SAR imagery. They are particularly useful for object detection, classification problems, digital elevation model (DEM) generation or displacements monitoring. A lot of studies show the significance of radar signal features in ice classification (Boulze *et al.*, 2020; Zakhvatkina *et al.*, 2019), soil moisture monitoring (Wang and Qu, 2009), land use classification (Joshi *et al.*, 2016; Qi *et al.*, 2012) or agricultural purposes (Liu *et al.*, 2019). Moreover, due to the possibility of registration data regardless of weather conditions, the SAR imagery became significantly important in the detection of deforestation (Bouvet *et al.*, 2018), oil spills (Migliaccio and Tranfaglia, 2004; Topouzelis, 2008), planes or ships (Han and Chong, 2004; Hwang and Jung, 2018) and much more.

There is also a huge potential for SAR imagery in displacements monitoring. There are some methods that can deliver information about surface movements from radar sensors and they can support classical measurement techniques or replace them in dangerous areas or those with limited access. SAR imagery is successfully used in Differential Interferometry (DInSAR) (Crosetto *et al.*, 2014) or more advanced techniques such as Persistent Scatter (PSInSAR) or Small Baseline Subset (SBAS) InSAR (Osmanoğlu *et al.*, 2016). Each of these techniques uses 2 or more SAR images to determine displacements in a selected period. As an effect, the Line-Of-Sight (LOS) displacements can be calculated, which can be decomposed into a 3D displacement field (Hu *et al.*, 2014). However, one of the limitations of these methods is coherence loss in areas that are changing rapidly. They usually perform best for slow or moderate movements. There are also some algorithms dedicated to the detection of fast movements, developed especially for glacier monitoring. Usually, they are based on the cross-correlation between two SAR images. Two main groups can be distinguished: intensity and coherence tracking methods including such techniques as offset or feature tracking. The offset-tracking method is based on cross-correlation between intensity images. One image is used as a reference and the second one is divided into patches of a selected size. Then for each patch, the corresponding area on the reference image is searched. When the maximum correlation is achieved, the offset between the same regions on both images is calculated (Strozzi *et al.*, 2002). The feature tracking method also looks for similarities between two images, however firstly the individual features such as crevasses or a distinctive pattern of ice have to be identified. Then, the same features are searched on the second image and the distance between them is calculated (Dozier *et al.*, 2008). This method can be applied to both optical and radar images. Tracking methods found plenty of applications in cryosphere monitoring, regardless of the region of the world (Gomez *et al.*, 2019; Jawak *et al.*, 2019; Neckel *et al.*, 2020; Peng *et al.*, 2021; Pritchard *et al.*, 2005; Riveros *et al.*, 2013; Schellenberger *et al.*, 2015). Moreover, few studies are

showing the potential of the methods in mining areas (Huang *et al.*, 2020), post-earthquake areas (Vajedian *et al.*, 2018) or sand dunes (Mahmoud *et al.*, 2020). One of the most important problems connected with the offset-tracking method is its accuracy, which depends on the pixel size of used SAR images and it is usually approx. $1/20^{th}$ of the pixel (Strozzi *et al.*, 2002).
Despite some limitations, the constant development of new radar sensors and easier access to high-resolution datasets allows achieving accuracy at the level of several centimetres. Considering such a level of accuracy and possibilities of more precise detection of an object with smaller sizes, there are showing new ways of using the presented methods. This study's aim is to check the possibilities of observing rapid landslides with the offset-tracking method as their boundaries are much smaller than in the case of glaciers. Moreover, based on calculations performed on glacier and landslides area, the influence of image resolution on the quality and accuracy of detected displacements is investigated. The possibility of using this method in areas affected by rapid landslides will deliver more useful information to improve the modelling process of such events. What is more, the application of the offset-tracking method can support classical interferometry techniques to obtain information about full displacement fields even in areas where the displacement rate varies over time.

2. Study Areas

The research was carried out for two areas with a large speed of movement but the different sizes of extent: Jakobshavn Glacier and Ponzano Landslide (Fig. 1.)

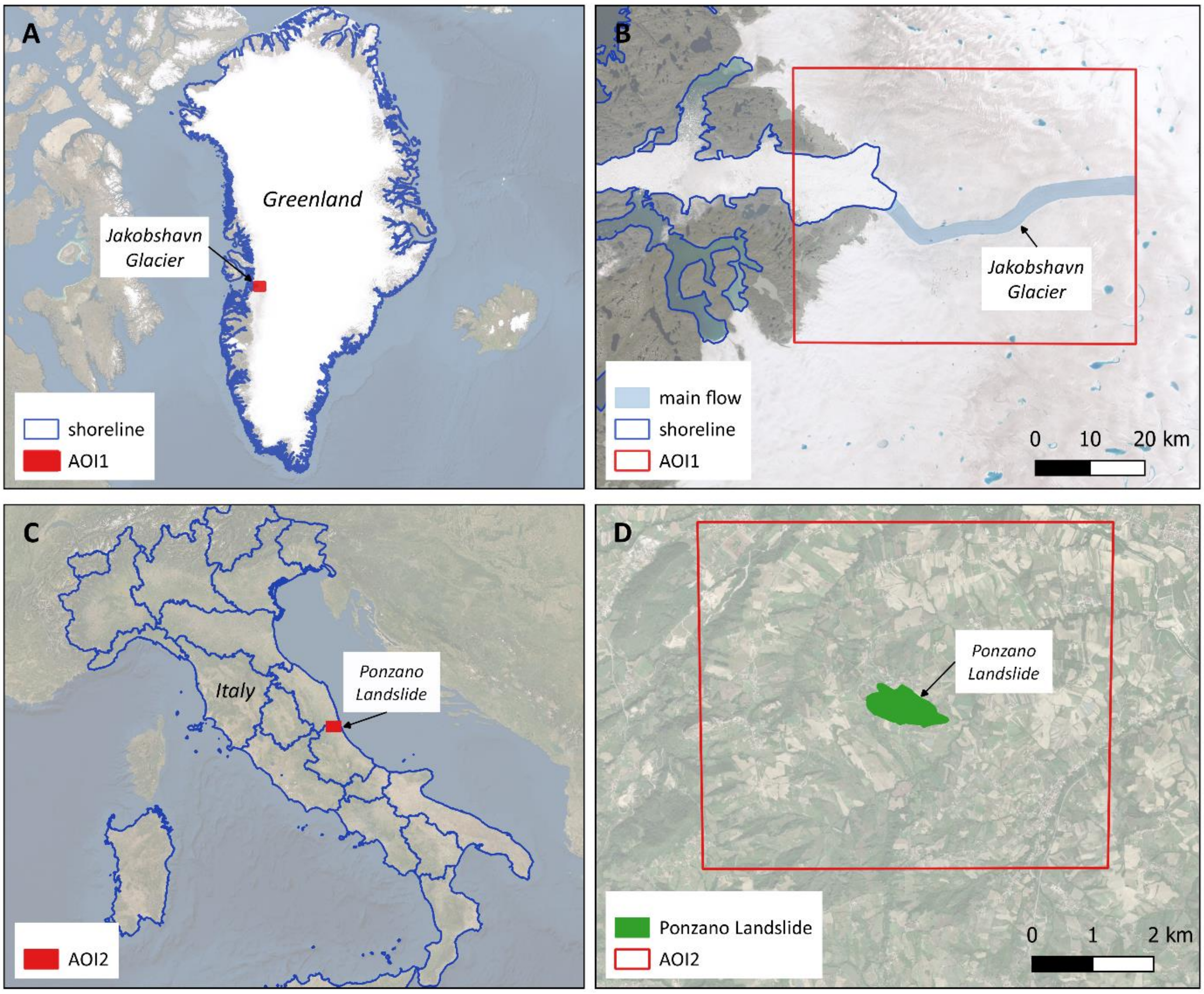

Fig. 1. Location of study areas.

2.1 Study area – Jakobshavn Glacier

Jakobshavn is an outlet glacier located in the western part of Greenland which terminates into the Illusat Icefjord. It is also known as Illusat Glacier or Sermaq Kujalleq. Its length exceeds 65 km and it covers an area of 110 000 km^2. The thickness of Jakobshavn reaches approx. 2 km. Because of its large velocities and significant meaning in terms of Greenlandic mass balance, Jakobshavn Glacier has been an object of scientific interest for many years. Due to its record speeds reaching almost 46 m/day in summer in 2012 and 2013 (Joughin *et al.*, 2014), it is an interesting area for testing methods for rapid movement monitoring such as Offset-Tracking.

2.2 Study area – Ponzano Landslide

Ponzano landslide is located the Civitella del Tronto municipality in the northern part of Teramo Province in Abruzzo region. It is a known unstable area that reactivated on 12th February 2017 because of intensive rainfalls and snowmelt. The landslide affected area of about 60 ha and its volume is estimated to be 7 x 10^6 m^3. The landslide area has been stable or slightly moving over several years before its reactivation (Solari *et al.*, 2018). It is a complex formation with two components: rotational sliding in the upper part of a landslide and earth flow in the lower part with a depth over 15 m below the ground (Calista *et al.*, 2019). After triggering in 2017, in only a few days, displacements exceeded 10 m. In the next few months movements slowed down and stopped at the level of max. 65 cm from February to July 2017 (Allasia *et al.*, 2019).

3. Materials and Methods

3.1 Satellite imagery

SAR images from three different sensors were collected for this research: Sentinel-1 (S-1), TerraSAR-X (TSX) and ICEYE. For both areas, open-access datasets from S-1 satellites were collected and compared with high-resolution datasets: ICEYE for Jakobshavn Glacier and TSX for Ponzano landslide (Tab. 1). In the case of S-1 data, Ground Range Detected (GRD) products were selected with a pixel spacing of 10 m x 10 m, acquired in Interferometric Wide swath mode with a resolution of approx. 20 m x 22 m. For the Jakobshavn glacier, additionally, ICEYE GRD products with a pixel spacing of 2.5 m x 2.5 m were used. Images were acquired in Stripmap mode with a 3 m resolution in both directions. TSX images used in the Ponzano area were collected in Stripmap mode with a 3 m resolution. The pixel spacing for Multi Look Ground Range Detected (MGD) products was 1.25 m x 1.25 m.

Table 1. Detailed parameters of SAR images used in the study.

AOI	Date	Sensor	Frequency	Polarization	Pixel spacing [m]	Orbit direction	Swath width	Time baseline
Jakobshavn Glacier	03.01.2021	S-1	5.4 GHz (C-band)	HH	10 x 10	desc	250 km	6
	09.01.2021					desc		
	05.01.2021	ICEYE	9.65 GHz (X-band)	VV	2.5 x 2.5	desc	30 km	4
	09.01.2021					desc		
Ponzano Landslide	12.02.2017	S-1	5.4 GHz (C-band)	VV	10 x 10	asc	250 km	12
	24.02.2017					asc		
	10.02.2017	TSX	9.65 GHz (X band)	HH	1.25 x 1.25	asc	30 km	11
	21.02.2017					asc		

3.2 Offset-Tracking method

Calculation of displacements was performed in SeNtinel Application Platform (SNAP) software with the use of an Offset-Tracking technique (OT). In the first step information about precise orbits was attached to each S-1 image. Afterwards, pairs of SAR images were coregistered based on Copernicus Digital Elevation Model (DEM) with a 30 m resolution. In the next step, an OT procedure was applied for each coregistered pair. The OT technique uses information about the intensity of the reflected signal on both images. The density of the ground control points grid is defined at the beginning. For each point, the offset between master and slave images is estimated in the defined registration window size. If the offset does not meet the correlation threshold standard or exceeds the maximum velocity value, it is removed from the analysis. Next, offsets are interpolated based on valid estimates for the rest of the control points. In the last step, offsets are computed into displacements values and geocoded. This workflow was applied to all sensors (Fig. 2.). Results were compared between the S-1 dataset and VHR SAR datasets for both areas of interest in Quantum GIS (QGIS) software.

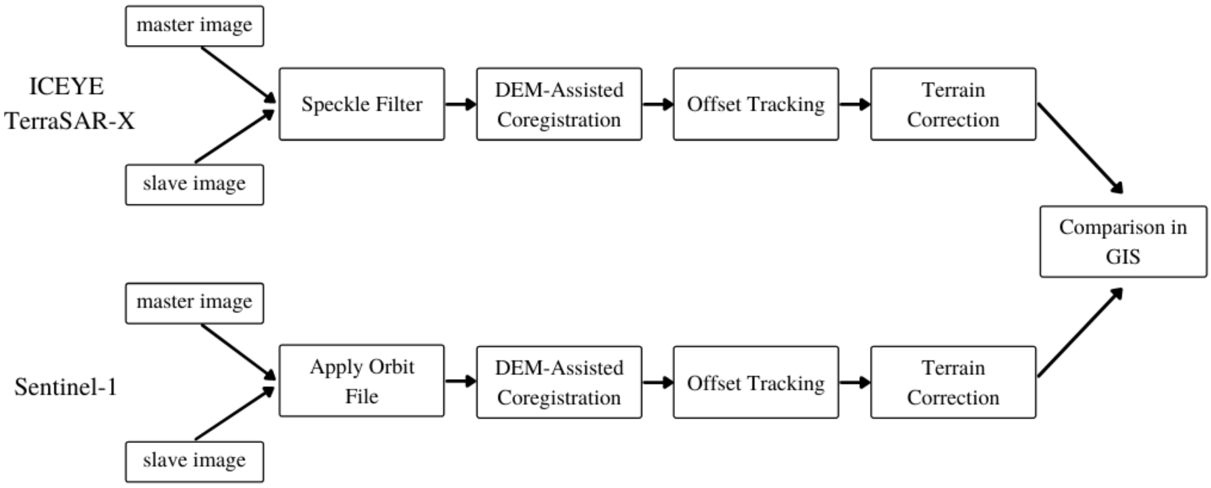

Fig. 2. Processing steps.

4. Results and Discussion

For both areas of interest, the results from the OT technique delivered information about displacement values and velocities. They are presented in form of maps in the following chapter.

4.1 The velocity of the Jakobshavn Glacier

In the case of the Jakobshavn Glacier, the results are represented in form of velocity maps for the S-1 and the ICEYE datasets (Fig. 3.).

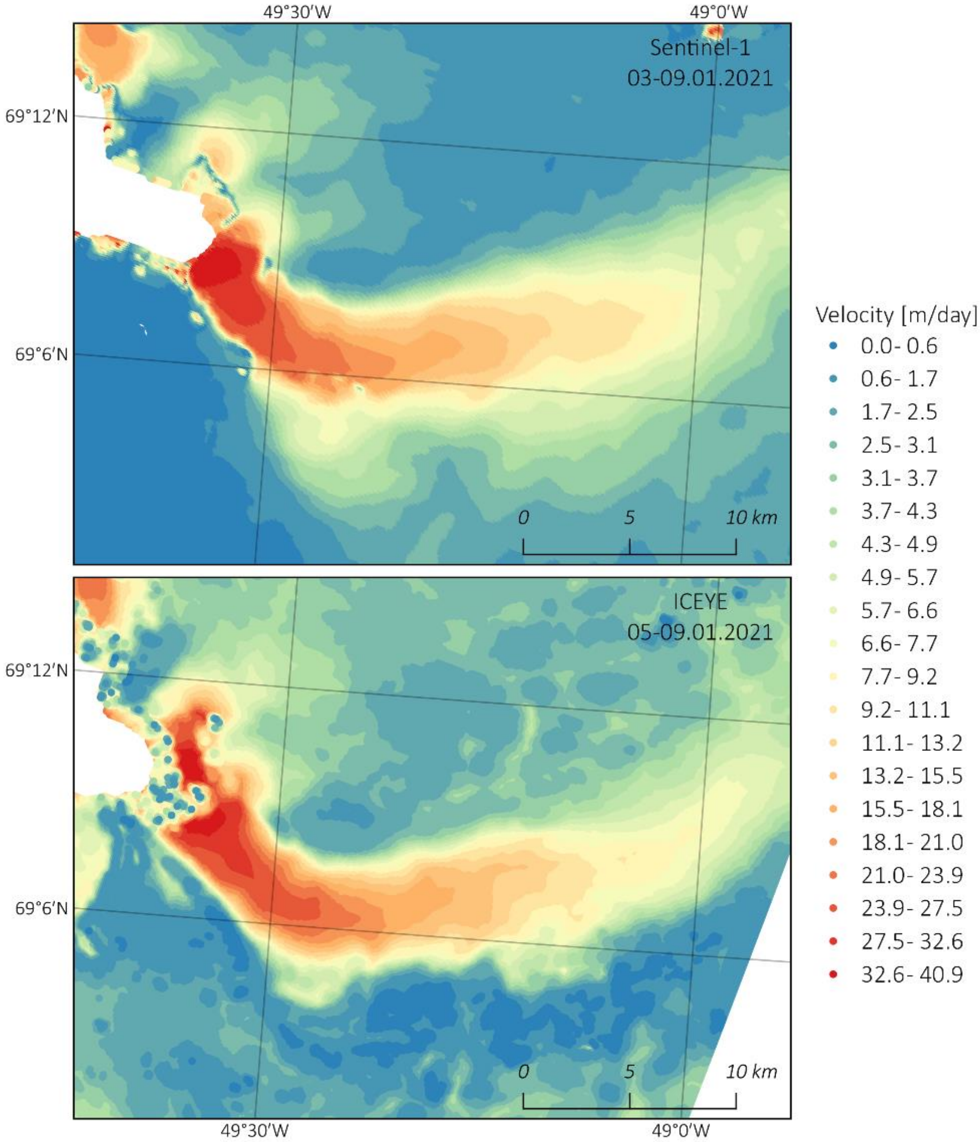

Fig. 3. Velocity maps for the Jakobshavn Glaciers obtained from the S-1 and ICEYE data.

The spatial extent of detected movements is similar for both SAR sensors. The Jakobshavn glacier terminates into the bay located in the west. the observed velocity is increasing towards the terminus of the glacier as it is approaching closer to the Illusat Fjord. There is a gradual decrease in velocity in direction of the inland part of the glacier. The maximum velocity measured in January 2021 by the ICEYE sensor is almost 41 m/day. In a similar period, the maximum value detected by the Sentinel-1 sensor is less than 37 m/day. Slightly smaller values of movements are measured by S-1 data compared to ICEYE imagery over a whole glacier area. The greatest discrepancies are observed near the glacier terminus and areas located outside the main flow of the glacier. Some small velocities are detected by a high-resolution dataset outside the glacier. Moreover, close to the coastline ICEYE data also deliver information about displacements, whereas it is difficult to detect them using S-1 data. Furthermore, the terminus position and cut-off between glacier and sea-ice are clearly visible on a high-resolution dataset. Because of it, they may deliver more reliable results at borders of the detectable displacements. The obtained displacements values from both sensors are at a reasonable level compared to previous years. The largest velocities were observed in 2012-2013 (Joughin *et al.*, 2014), however, then the Jakobshavn glacier was gradually slowing-down until 2018. In 2019, the trend reversed, and the glacier started to accelerate again, reaching a speed of 34 m/d in the summer (Joughin *et al.*, 2020). Velocities calculated in this study confirm an upward trend in the glacier's velocity. In the last step of comparison, random points over a whole glacier were generated. For each point, pieces of information about velocity from S-1 and ICEYE were selected. A comparison of these values is presented in form of a correlation graph (Fig. 4).

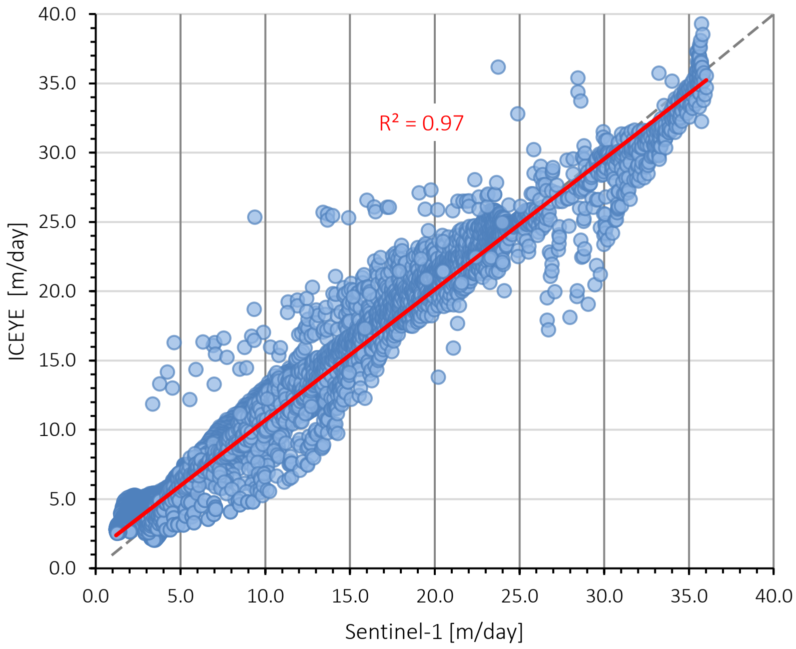

Fig. 4. Correlation plot for velocities obtained from the S-1 and ICEYE datasets for Jakobshavn Glacier.

The graph presents values of the velocity from S-1 at the horizontal axis and displacement rate from ICEYE for corresponding points at the vertical axis. The majority of the points are located near the line presenting function y = x. It means that similar values of velocity are delivered by both sensors. Some points outstand from his trend, however, it is not a significant percentage. The overall correlation coefficient (R^2) is at a high level of 0.97. The correlation is clearly visible but a little underestimation of velocity can be observed in S-1 results compared to a high-resolution dataset.

4.2 Displacements in the area of the Ponzano landslide

For the Ponzano landslide, the main displacements occurred on 12th February and the pace of movement was different in the following days, so the results of calculations are presented in form of a map with a total displacement value (Fig. 5). Despite the application of many processing variants, the dataset from the S-1 satellite did not deliver reliable results, the displacements are presented only for the TSX sensor.

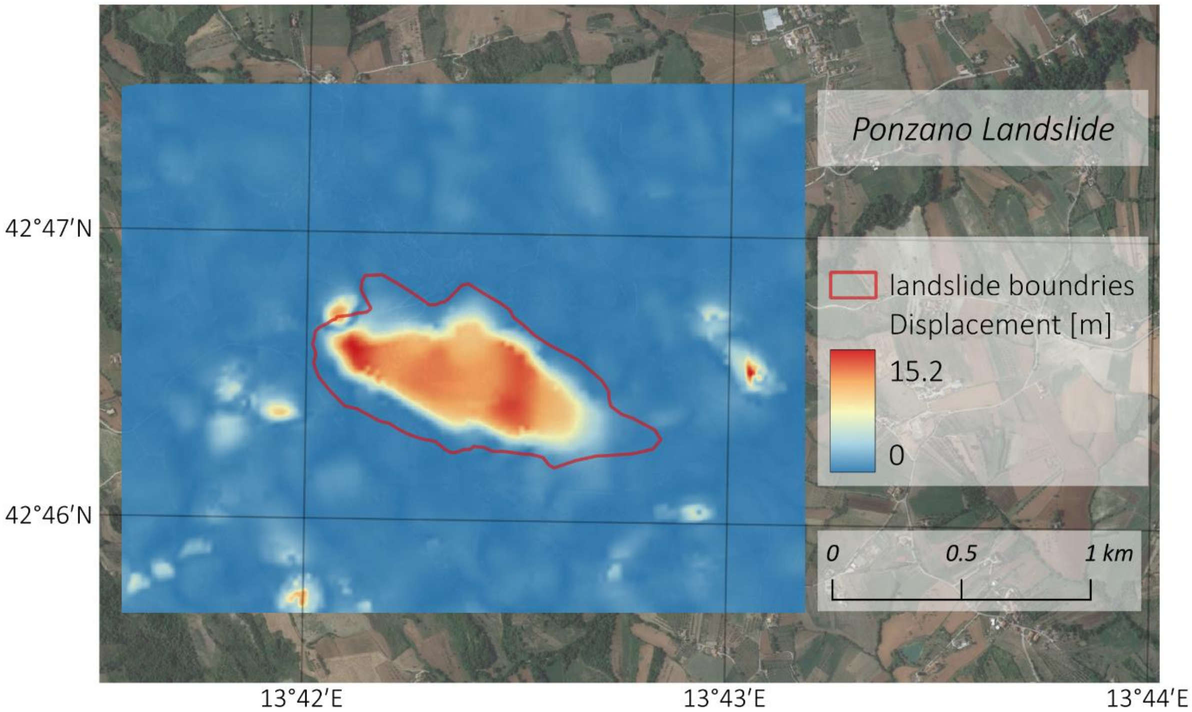

Fig. 5. Displacement map for Ponzano Landslide from the TSX data.

The maximum displacement observed between 10th and 21st February 2017 reached 15.2 m. The most significant movements occurred inside landslide boundaries reported by the International Programme on Landslide (International Programme on Landslide, 2017). The highest values appear in two regions: the upper part and the mid-to-lower part, slightly below Villa Carosi. The displacement pattern reflects the boundaries of a landslide. Only in the northern part extent of displacement is smaller than landslide borders. Outside these boundaries, there are no significant displacements. There are some small speckles that present values higher than 0 but they may result from the noise in SAR datasets. Displacement extent and values also show a high correlation with the results from UAV imagery (Calista *et al.*, 2019). However, direct comparison between these results is impossible because of significantly different time baselines.

5. Conclusions

An application of the OT technique to glacier and landslide areas and a comparative analysis of the results from Sentinel-1 and high-resolution ICEYE or TSX data showed that this calculation method can be successfully used in various areas, regardless of the size and the value of displacement. The OT method is usually applied in glacier areas, and it was developed mainly for this purpose. However, in case of rapid landslides, especially those where displacements did not change significantly look of the land cover, the application of this technique might be successful. Research carried out on the Jakobshavn glacier showed that usage of higher resolution images can deliver more reliable results, mainly in the borders of detected movement extent. These observations showed that application on a high-resolution dataset may enable observation of movements for smaller objects such as the Ponzano landslide. Test carried out on S-1 and TSX images showed that with the use of high-resolution imagery it is possible to detect rapid movements in landslide areas with high accuracy. A comparison of the extent of detected movements with the landslide boundaries and UAV results from the different research group showed that obtained results are reliable. Taking into account the current quick development of new SAR sensors with increasing resolution of the products, such knowledge opens up new possibilities in the monitoring of rapid movements. The OT technique can deliver information about the displacement in areas where in-situ measurements may be difficult or dangerous. Knowing the displacement values and pattern may also enhance knowledge about the formation of such landslides and their mechanism. Such results may also support the analysis of the displacement field in areas where only LOS or vertical movements could be detected from the classical interferometric (InSAR) approach.

REFERENCES

Allasia, P., Baldo, M., Giordan, D., Godone, D., Wrzesniak, A. and Lollino, G. (2019), “Near Real-Time Monitoring Systems and Periodic Surveys Using a Multi Sensors UAV: The Case of Ponzano Landslide”, *IAEG/AEG Annual Meeting Proceedings, San Francisco, California, 2018 - Volume 1*, Vol. 1 No. 2, pp. 303–310.

Boulze, H., Korosov, A. and Brajard, J. (2020), “Classification of sea ice types in sentinel-1 SAR data using convolutional neural networks”, *Remote Sensing*, Vol. 12 No. 13, pp. 1–20.

Bouvet, A., Mermoz, S., Ballère, M., Koleck, T. and Le Toan, T. (2018), “Use of the SAR Shadowing Effect for Deforestation Detection with Sentinel-1 Time Series”, *Remote Sensing 2018, Vol. 10, Page 1250*, Multidisciplinary Digital Publishing Institute, Vol. 10 No. 8, p. 1250.

Calista, M., Miccadei, E., Piacentini, T. and Sciarra, N. (2019), “Morphostructural, meteorological and seismic factors controlling landslides in weak rocks: The case studies of Castelnuovo and Ponzano (northeast Abruzzo, central Italy)”, *Geosciences (Switzerland)*, Vol. 9 No. 3, available at:https://doi.org/10.3390/geosciences9030122.

Crosetto, M., Crippa, B., Biescas, E., Vega, T., Biescas, E., Monserrat, O., Agudo, M., *et al.* (2014), “Land deformation monitoring using SAR interferometry: State-of-the-art LAND DEFORMATION MEASUREMENT USING SAR INTERFEROMETRY: STATE-OF-THE-ART”, available at: https://www.researchgate.net/publication/262186921 (accessed 12 April 2022).

Dozier, J., Raup, B.H., Andreassen, L.M., Bolch, T. and Bevan, S. (2008), “Remote Sensing of Glaciers”, *Remote Sensing of the Cryosphere*, pp. 397–410.

Gomez, R., Arigony-Neto, J., De Santis, A., Vijay, S., Jaña, R. and Rivera, A. (2019), “Ice

dynamics of union glacier from SAR offset tracking", *Global and Planetary Change*, Elsevier, Vol. 174 No. January, pp. 1–15.
Han, Z. and Chong, J. (2004), "A review of ship detection algorithms in polarimetric SAR images", *International Conference on Signal Processing Proceedings, ICSP*, Vol. 3, pp. 2155–2158.
Hu, J., Li, Z.W., Ding, X.L., Zhu, J.J., Zhang, L. and Sun, Q. (2014), "Resolving three-dimensional surface displacements from InSAR measurements: A review", *Earth-Science Reviews*, Elsevier, June.
Huang, J., Bai, Y., Lei, S. and Deng, K. (2020), "Time-Series SBAS Pixel Offset Tracking Method for Monitoring Three-Dimensional Deformation in a Mining Area", *IEEE Access*, Institute of Electrical and Electronics Engineers Inc., Vol. 8, pp. 118787–118798.
Hwang, J.I. and Jung, H.S. (2018), "Automatic ship detection using the artificial neural network and support vector machine from X-Band Sar satellite images", *Remote Sensing*, MDPI AG, Vol. 10 No. 11, p. 1799.
International Programme on Landslide. (2017), "Report - Ponzano landslide", available at: https://iplhq.org/report/ponzano-landslide/ (accessed 15 April 2022).
Jawak, S.D., Kumar, S., Luis, A.J., Pandit, P.H., Wankhede, S.F. and Anirudh, T.S. (2019), "Seasonal Comparison of Velocity of the Eastern Tributary Glaciers, Amery Ice Shelf, Antarctica, Using SAR Offset Tracking", *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. 4 No. 2/W5, pp. 595–600.
Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jepsen, M.R., *et al.* (2016), "A Review of the Application of Optical and Radar Remote Sensing Data Fusion to Land Use Mapping and Monitoring", *Remote Sensing 2016, Vol. 8, Page 70*, Multidisciplinary Digital Publishing Institute, Vol. 8 No. 1, p. 70.
Joughin, I., E. Shean, D., E. Smith, B. and Floricioiu, D. (2020), "A decade of variability on Jakobshavn Isbræ: Ocean temperatures pace speed through influence on mélange rigidity", *Cryosphere*, Copernicus GmbH, Vol. 14 No. 1, pp. 211–227.
Joughin, I., Smith, B.E., Shean, D.E. and Floricioiu, D. (2014), "Brief communication: Further summer speedup of Jakobshavn Isbræ", *Cryosphere*, Vol. 8 No. 1, pp. 209–214.
Liu, C., Chen, Z., Shao, Y., Chen, J., Hasi, T. and Pan, H. (2019), "Research advances of SAR remote sensing for agriculture applications: A review", *Journal of Integrative Agriculture*, Elsevier, 1 March.
Mahmoud, A.M.A., Novellino, A., Hussain, E., Marsh, S., Psimoulis, P. and Smith, M. (2020), "The Use of SAR Offset Tracking for Detecting Sand Dune Movement in Sudan", *Remote Sensing 2020, Vol. 12, Page 3410*, Multidisciplinary Digital Publishing Institute, Vol. 12 No. 20, p. 3410.
Migliaccio, M. and Tranfaglia, M. (2004), "Oil spill observation by SAR: A review", *USA-Baltic International Symposium*, Institute of Electrical and Electronics Engineers Inc., available at:https://doi.org/10.1109/BALTIC.2004.7296831.
Neckel, N., Zeising, O., Steinhage, D., Helm, V. and Humbert, A. (2020), "Seasonal Observations at 79°N Glacier (Greenland) From Remote Sensing and in situ Measurements", *Frontiers in Earth Science*, Frontiers Media S.A., Vol. 8, p. 142.
Osmanoğlu, B., Sunar, F., Wdowinski, S. and Cabral-Cano, E. (2016), "Time series analysis of InSAR data: Methods and trends", *ISPRS Journal of Photogrammetry and Remote*

Sensing, Elsevier, Vol. 115, pp. 90–102.

Peng, Y., Li, Z., Xu, C., Zhang, H. and Han, W. (2021), "Surface Velocity Analysis of Surge Region of Karayaylak Glacier from 2014 to 2020, in the Pamir Plateau", *Remote Sensing*.

Pritchard, H., Murray, T., Luckman, A., Strozzi, T. and Barr, S. (2005), "Glacier surge dynamics of Sortebræ, East Greenland, from synthetic aperture radar feature tracking", *Journal of Geophysical Research: Earth Surface*, Blackwell Publishing Ltd, Vol. 110 No. 3, p. F03005.

Qi, Z., Yeh, A.G.O., Li, X. and Lin, Z. (2012), "A novel algorithm for land use and land cover classification using RADARSAT-2 polarimetric SAR data", *Remote Sensing of Environment*, Elsevier, Vol. 118, pp. 21–39.

Riveros, N., Euillades, L., Euillades, P., Moreiras, S. and Balbarani, S. (2013), "Offset tracking procedure applied to high-resolution SAR data on Viedma Glacier, Patagonian Andes, Argentina", *Advances in Geosciences*, Copernicus GmbH, Vol. 35, pp. 7–13.

Schellenberger, T., Dunse, T., Kääb, A., Kohler, J. and Reijmer, C.H. (2015), "Surface speed and frontal ablation of Kronebreen and Kongsbreen, NW Svalbard, from SAR offset tracking", *Cryosphere*, Vol. 9 No. 6, pp. 2339–2355.

Solari, L., Raspini, F., Del Soldato, M., Bianchini, S., Ciampalini, A., Ferrigno, F., Tucci, S., *et al.* (2018), "Satellite radar data for back-analyzing a landslide event: the Ponzano (Central Italy) case study", *Landslides*, Landslides, Vol. 15 No. 4, pp. 773–782.

Strozzi, T., Luckman, A., Murray, T., Wegmüller, U. and Werner, C.L. (2002), "Glacier motion estimation using SAR offset-tracking procedures", *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 40 No. 11, pp. 2384–2391.

Topouzelis, K.N. (2008), "Oil Spill Detection by SAR Images: Dark Formation Detection, Feature Extraction and Classification Algorithms", *Sensors 2008, Vol. 8, Pages 6642-6659*, Molecular Diversity Preservation International, Vol. 8 No. 10, pp. 6642–6659.

Vajedian, S., Motagh, M., Mousavi, Z., Motaghi, K., Fielding, E.J., Akbari, B., Wetzel, H.U., *et al.* (2018), "Coseismic deformation field of the Mw 7.3 12 November 2017 Sarpol-e Zahab (Iran) earthquake: A decoupling horizon in the Northern Zagros Mountains inferred from InSAR observations", *Remote Sensing*, Vol. 10 No. 10, available at:https://doi.org/10.3390/rs10101589.

Wang, L. and Qu, J.J. (2009), "Satellite remote sensing applications for surface soil moisture monitoring: A review", *Frontiers of Earth Science in China 2009 3:2*, Springer, Vol. 3 No. 2, pp. 237–247.

Zakhvatkina, N., Smirnov, V. and Bychkova, I. (2019), "Satellite SAR Data-based Sea Ice Classification: An Overview", *Geosciences 2019, Vol. 9, Page 152*, Multidisciplinary Digital Publishing Institute, Vol. 9 No. 4, p. 152.

BIOGRAPHICAL NOTES

M.Sc. Magdalena Łukosz is currently a PhD student at AGH UST in Cracow, conducting research in areas of ground movements with the use of SAR (Synthetic Aperture Radar). Having earned her Engineering degree in Geodesy and Cartography in 2019, she decided to specialize in Geoinformation and Mining Surveying during her master's studies, which ended in 2020. She is the principal investigator in two projects, testing possibilities of using high-resolution

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