Novel view on the study of glacier kinematics in the context of global climate change

Magdalena A. Łukosz

The rapid civilization development taking place in recent decades and the increase in consumption meant that more and more people talk about **global climate change**, which is constantly accelerating and is visible in more and more corners of the world. One indicator of the progress of global climate change are **glaciers** and their condition. Increasingly, you can hear about the increase in temperature of both air and water, which means that glaciers, both mountain and flowing into the sea, are losing their volume. The melting of glaciers that leave the seas is **increasing global ocean levels**, which in turn is **flooding coastal areas**, including large cities. On the other hand, the melting of mountain glaciers causes the threat of their fragments tearing off, increased number of avalanches or disruption of the local water management. Moreover, the formation of rivers or lakes on the surface of glaciers or just below them additionally leads to the destabilization of the glacial tongue. Consequently, numerous gaps are created, the calving process of the glacier is accelerated, and the speed of the glacier itself is increased by facilitating its sliding. Since **ice-covered areas exist on almost every continent of the Earth**, and their condition and behaviour have an impact on our environment, monitoring such areas continuously and understanding the processes taking place in such areas is essential.

Due to the large areas of areas threatened by climate change, often difficult access to them, as well as the speed of mass movement, classical measurement techniques, such as GNSS networks, tacheometry or laser scanning are not always able to provide information about the scale of movements. For this reason, **remote sensing techniques** are used, often based on the use of satellite imagery. For years, optical images have allowed the observation of changes taking place in the environment, while **satellite synthetic aperture radar (SAR)** are particularly useful in the context of determining terrain displacements, which allow the determination of their size with an accuracy of single mm. For large-scale movements such as glacier advancement, the radar interferometry tool does not always reliably determine the displacements. The changes happen too abruptly and often the radar signal changes too much. For this reason, the most frequently used method in such areas is the **Offset-Tracking** technique, based on changes in pixel intensity. It allows finding pixel areas with a similar reflection of the radar beam on a pair of radar images, thanks to which it is possible to determine the distance between such areas. However, this method requires the determination of several parameters during calculations, including e.g., the knowledge of maximum speeds or determination of the mesh density of points for which the displacement will be determined. Therefore, some of the information contained in SAR data can be lost through averaging, and the use of data from different sensors that are constantly appearing on the market can make it difficult to unambiguously compare the results. In order to analyse the full scale of movements in glacial areas, it is also helpful to include observations from **differential interferometry (DInSAR)**, which additionally allows the detection of smaller-scale and vertical movements. By using these techniques together, it is possible to get a complete picture of the glacier and analyse changes in the dynamics of movement over time.

The development of artificial intelligence in recent years has also revolutionized the possibilities of analysing satellite imagery. Research to date has mainly focused on combining **Machine Learning (ML) tools** with optical sensor products. First of all, artificial intelligence is used to detect various objects or areas exposed to natural hazards in satellite images. Machine learning, due to its ability to recognize patterns that are often invisible to the human eye, can prove to be a useful tool for analysing SAR data. Its use may allow for the creation of **a new method allowing for the identification of the displacement field** based on radar imagery. Moreover, the use of artificial intelligence may allow the extraction of information that is difficult or almost impossible to detect using classical computational methods. The development of a new method may allow **a better understanding of the phenomena occurring in our environment due to climate change**. Knowledge on this subject will allow for better determination of potential causes and effects of glacial movements, as well as for the detection of local anomalies within the glacial field.