Water temperature and the occurrence of ice phenomena are among the fundamental characteristics of rivers, influencing the course of many physical, chemical, and biological processes. They determine the physical properties of water (e.g., its density), the content of dissolved gases (e.g., oxygen), and the rate of chemical reactions. Ice phenomena transform the hydrodynamic conditions in river channels (e.g., by altering flow velocity), also affecting processes such as erosion, transport, and accumulation. The presence of ice modifies the spatial distribution of these processes, increasing their spatial heterogeneity. The thermal regime and ice cover of rivers also play an important role in the functioning of river ecosystems. In the case of water temperature, this is due to the fact that most aquatic organisms are ectothermic animals, whose body temperature depends on the surrounding environment. Ice, on the other hand, exerts mechanical effects on aquatic organisms, which can either improve or worsen habitat conditions in a given section of the river. Water temperature and the presence of ice are also of great importance to human activities. Temperature variability affects the suitability of river water for industry and energy production, can alter its quality (e.g., by influencing the development of microorganisms), and impacts the abundance and species composition of fish. Ice phenomena, meanwhile, can negatively affect river infrastructure and cause ice-jam floods. At the same time, in colder regions of the world (e.g., Alaska), frozen rivers are sometimes used as transportation routes.

In many regions of the Earth, since the second half of the 20th century, an increase in river water temperature and a decrease in the frequency and extent of ice cover have been observed. The main causes of these changes are rising air temperatures associated with climate change and human activities, including thermal pollution emissions and the operation of reservoirs. The increase in air temperature leads to higher water temperatures and reduces the conditions favorable for freezing, which affects the development of ice phenomena. The operation of dam reservoirs reduces the frequency of ice occurrence in the lower reaches of rivers while increasing its accumulation upstream of the dam. This results from limited ice migration along the river, the warming of water downstream of the reservoir (during winter), and changes in the flow regime caused by dam operations.

Due to the complexity of the processes involved, the temporal and spatial variability of water temperature and ice phenomena remains poorly understood. The main research limitations stem from the low density of monitoring networks and the poor quality of available data, which hinders the analysis of long-term changes. An additional challenge is separating the influence of climatic factors from the effects of human activity, including the operation of dam reservoirs. Satellite remote sensing offers the potential for a better understanding of these phenomena, enabling detailed studies of river thermal regimes and ice cover over large stretches. Particularly promising are machine learning techniques, which make it possible to quantitatively distinguish the impact of dam reservoirs on river temperature and ice cover from the effects of climatic conditions.

The aim of the proposed project is to integrate ground-based measurement data, satellite data, and machine learning methods to investigate in detail the temporal and spatial changes in ice cover and thermal patterns of the Vistula River – one of the longest rivers in Europe. The project will utilize archival measurement data, results from field measurements conducted by the author, as well as satellite data from the Landsat and Sentinel-2 constellations. The collected data will be subjected to statistical and spatial analysis using advanced data analysis tools such as Google Earth Engine, which allow for the processing of large satellite datasets. Using machine learning techniques and satellite data, the impact of the Włocławek dam reservoir on changes in the ice regime upstream and downstream of its location will be assessed.

Based on an innovative methodology, the planned project will determine how water temperature, as well as the extent and duration of ice phenomena, have changed over recent decades, and what mechanisms have been responsible for these changes. The analyses will identify which factors and to what extent influence the transformation of the thermal and ice regime of rivers in both time and space. The project will also contribute to the development of methodologies for studying river thermal conditions and ice cover using satellite data and machine learning techniques.