

## **Spatial and seasonal variations of the urban heat island in the Górnośląsko-Zagłębiowska Metropolis based on satellite data**

Higher temperatures in cities compared to surrounding areas are a result of the Urban Heat Island (UHI) phenomenon. In the context of contemporary climate change and ongoing urbanization, UHI is particularly significant as it exacerbates the effects of global warming by heat wave intensification within urban areas. UHI is considered a hazardous phenomenon at a local scale due to being risky for health and, in extreme cases, a threat to the city inhabitants lives during the summer. In other seasons, the presence of UHI is often perceived positively. However, the benefits of winter UHI (e.g., reduction in mortality due to hypothermia) are disproportionate when compared to the negative effects of Surface Heat Island (SHI) during summer. Therefore, UHI spatial identification is essential for the implementation of adaptive measures in the most problematic parts of the city. Although the Górnośląsko-Zagłębiowska Metropolis (GZM) is one of the most urbanized and densely populated regions of Poland, studies on UHI were rarely conducted. Hence, the main goal of this doctoral dissertation is to recognize the surface urban heat island (SUHI) structure in GZM from seasonal perspective based on satellite data. The "structure" refers to the spatial variability, composition, and intensity of SUHI.

The analysis, conducted based on Landsat satellite data, revealed that SUHI in the central part of GZM has an archipelago-like structure due to the polycentric structure of the metropolis (publication no. 1). In the summer season, the Surface Heat Island (SHI) covered between 15,4% and 16,4% of GZM (depending on the date) and 70% of the SHI area consisting of discontinuous urban fabric and industrial and commercial areas. Strongly heated agricultural areas were also included in the SHI. Thus, an essential part of the research was to propose an index for the surface urban heat island (LCL SUHI). After excluding strongly heated non-urban areas, the SHI extent decreased from 2,9% to 2%. Depending on the date, Surface Cold Island (SCI) in GZM accounted for 12.2% to 19.4%. The structure of SCI was more fragmented and mainly included forests and water bodies. Furthermore, permanent SHI (9% of GZM) and permanent SCI (3,6% of GZM) (occurring in the same places regardless of the date) were identified. Precipitation, occurring the day before the recording of one of the analyzed satellite images caused a weakening of the cooling efficiency of vegetation, primarily coniferous forests. As a result, it led to a significant reduction in the permanent SCI extent.

The SUHI is influenced by the characteristics of urban surfaces, therefore the next research objective concerned determining land cover changes from 1990 to 2018 and the SUHI structure changes from 1986 to 2021 in GZM (publication no. 2). The largest increase was found for impervious surfaces – by 4.8%, while the largest decrease – by 3.7% for agricultural areas due to the transformation of these areas into urbanized ones. A comparison of satellite images taken in different years, but at similar times and under comparable meteorological conditions, revealed the SUHI expansion in GZM from by 0,6% to 4,3%. The main reason for the SUHI expansion was the increase in the share of impervious areas within the GZM. Regardless of the changes in spatial extent, an increase in the mean land surface temperature of

all land cover types analyzed was noted, in line with the ongoing climate change trends. Despite the increase in the mean land surface temperature, the intensity of SUHI decreased by as much as 3,4°C due to the higher rate of increase in the SCI land surface temperature within GZM. It is important to note that this situation was caused by the agricultural drought that has been going on in Poland since the 1990s, which, combined with the rising temperature due to global warming, has led to a weakening of the cooling effect of the vegetation creating the SCI.

UHI is considered a dynamic phenomenon, manifested by high daily and seasonal variability. Due to the fact that the seasonal variability of SUHI has not been previously studied for the Polish agglomeration, it was decided to fill this gap in the literature. Additionally, the seasonal variability of SHI was analyzed separately for urban and non-urban areas. In most seasons, urban SHI was located primarily in the central, most urbanized part of the metropolis, with its extent fluctuating throughout the year from a peak in summer to a minimum in autumn, which resulted from the annual vegetation cycle. The growing season also played a key role in the seasonal variability of non-urban SHI, which in winter and autumn was slightly more than 1% greater than urban SHI. During winter, both urban and non-urban SHI were mainly located in the western part of GZM, corresponding to the distribution of snow cover, which was least present or completely absent in the lowest-lying western regions of the metropolis. Throughout the year, approximately 80% of urban SHI consisted of discontinuous urban fabric and industrial and commercial areas. However, the effective contribution of these two classes in SHI varied depending on the season. Although there is a small share of continuous urban fabric and dumps in the GZM (approximately 1,1% in total), their potential capability to intensify SHI is considerable. Non-urban SHI was mainly composed of agricultural areas (from 57,5% to 85,8%, depending on the season). For the first time, both permanent SHI (occurring in the same areas each season) and seasonally specific SHI (appearing only in a given season) were identified. Permanent urban SHI covered 3% of GZM, mainly consisting of industrial and commercial sites, discontinuous urban fabric, and dumps. In contrast, over 63% of seasonally specific urban SHI in winter, summer, and autumn was covered by discontinuous urban fabric, while approximately 13% comprised industrial and commercial areas. Non-urban SHI was almost exclusively a seasonal phenomenon, as evidenced by the marginal contribution of permanent SHI to the GZM area (0,4%). Non-irrigated arable lands contributed most to the development of seasonally specific non-urban SHI.