INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr IV/3/2014, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 1487–1498
Komisja Technicznej Infrastruktury Wsi

DOI: http://dx.medra.org/10.14597/infraeco.2014.4.3.113

EXTREME DAILY AIR TEMPERATURES IN POLAND (2000 – 2013)

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Summary

This work concentrates on the analysis of monthly trends of extremes daily temperatures, both minimum and maximum. Analysis was done for the period 2000–2013, based on freely available hourly temperature measurements from 60 Polish stations. Percentiles T_{min10} for minimum and T_{max90} for maximum daily temperature within each month were used as thresholds for selection of extreme temperature values. Count of days with extreme temperatures below/above threshold described every month. Significance of days count trend was analyzed with Mann–Kendall test at the significance level 0.05. For maximum temperatures, significant decreasing trend was found only for 3 station-months. For minimum temperature, 26 significant trends were found and presented in the form of map.

Key words: maximum air temperature, minimum air temperature, trend

INTRODUCTION

The growing interest in extreme weather events, like hurricanes, droughts or floods is a driving force for several scientists. Proper and accurate description of these events requires accurate time series with high temporal resolution. Daily or hourly data series account for the nature of extreme weather events. Minimum and maximum daily temperatures have substantial impact on agriculture (Grajewski 2010; Kępińska-Kasprzak et al. 2011; Kopeć 2009; Yucel et al. 2014; Żarski 2011; Żarski et al. 2012). Also technical infrastructure and people are affected by extreme weather conditions (Bondar-Nowakowska and Rybka 2011; Kossowska-Cezak 2010; Piotrowicz 2009; Twardosz and Kossowska-Cezak 2013).

Several authors made research on extreme temperatures, both in local scale (de Lima et al. 2013; Kejna et al. 2009; Price et al. 1999; Wibig and Głowicki, 2002) and in regional scale (Brázdil et al. 1995; Birsan 2014). In the case of extreme temperature events, dense spatial distribution of monitoring stations can be crucial (Wibig et al. 2014), so not only records length should be considered. For quantitative description of extreme temperature changes, daily maximum (T_{max}) and minimum (T_{min}) of air temperature and the frequency of characteristic days must be recorded and analysed (Bielec-Bąkowska and Piotrowicz 2013; Głowicki 2008; Kaszewski et al. 2012; Kossowska-Cezak 2014; Koźmiński and Michalska 2011)

Extreme temperatures are defined usually as those smaller than 10 percentile or higher than 90 percentile of minimum or maximum daily temperatures respectively (Yan at al. 2002). Fixed methods of temperature classification, with arbitrary temperature thresholds, are also used for some problems (Koźmiński and Michalska 2008; Łaszyca et al. 2013).

MATERIALS AND METHODS

The presented study is based on hourly air temperature data set from 60 stations located in Poland (Figure 5). Collected data covered the period 2000-2013. Source meteorological data in SYNOP format was downloaded from Ogimet web portal. As the reference data, measurements from the period 1951-2006, for 22 stations (Bielec-Bąkowska and Piotrowicz 2013) were used for this analysis: Bielsko-Biała, Chojnice, Hel, Jelenia Góra, Kalisz, Kasprowy Wierch, Katowice, Legnica, Lesko, Łódź, Poznań, Rzeszów, Słubice, Suwałki, Szczecin, Śnieżka, Świnoujście, Toruń, Warszawa, Włodawa, Wrocław and Zakopane. From hourly temperature data, daily extremes (minimum and maximum) were extracted. From those daily series, yearly and monthly statistics were calculated and compared to values from long-term observations (period 1951-2006). From 14-year data series, shorter one (10-years long) was extracted. Finally, comparison was made between two short and one long-term data sets. For every station minimum, mean and maximum of extreme daily values were calculated, and for final statistics data from all 22 stations were expresses as quartile Q1, Q2 and Q3.

Following other authors (Bielec-Bąkowska and Piotrowicz 2013), 10 percentile for minimum temperatures (T_{min10}) and 90 percentile for maximum temperatures (T_{max90}) were chosen as thresholds values for every month and station. All daily extreme temperatures were compared to those thresholds, and days with temperatures below T_{min10} and above T_{max90} respectively, were counted for further analysis.

Significance of extreme temperature trend was analyzed with the nonparametric Mann–Kendall test (Karmeshu 2012). It is a rank-based procedure, especially suitable for non-normally distributed data, widely used for the analysis of trend in climatology. In the present paper, the significance level was fixed at 0.05. The null hypothesis H_0 assumes that there is no trend (the data is independent and randomly distributed).

Main goal of this research was to detect existence of a trend, not to describe it quantitatively. Only trend sign was analysed. All monthly station significant trends were collected and presented in the form of a map with corresponding regions, for better visualization.

RESULTS

Threshold values calculated for minimum and maximum temperatures, for the period of 10-years and 14-years, show almost no difference (Figure 1, Figure 2). Differences between 14-year and 56-year periods are also small, but visible. All quartiles (Q1, Q2 and Q3), and minimum and maximum values for three analysed periods, are relatively close to each other. But differences of 1°C are substantial from long-term temperature changes perspective.

Quantitative analysis of differences between percentiles T_{min10} and T_{max90} (Table 1) shows, that for mean values in two shorter periods, T_{min10} estimation error is below 0.35°C, and below 0.1°C for T_{max90}. Those 4 years of difference between two data sets, are at the same time almost 50% increase in record length. So small shift in years may cause major changes in extreme values.

Table 1. Differences of the extreme monthly air temperatures (percentiles T_{min10}, T_{max90}) between the period 2000-2009 and 2000-2013. Q1, Q2, Q3 are quartiles.

	ΔT_{min10} [°C]			ΔT_{max90} [°C]		
Temperature	Q1	Q2	Q3	Q1	Q2	Q3
Min. for station	-0.100	0.000	0.600	0.125	0.300	0.500
Mean for station	0.154	0.271	0.348	-0.042	0.029	0.065
Max. for station	-0.175	0.000	0.000	-0.300	-0.200	0.000

When comparing 14-year observations with 56-year (Table 2), difference of mean values at station in T_{min10} estimation is below 1.4°C, and below 0.35°C for T_{max90}. In this case all quartiles are positive and their values are of the same order.

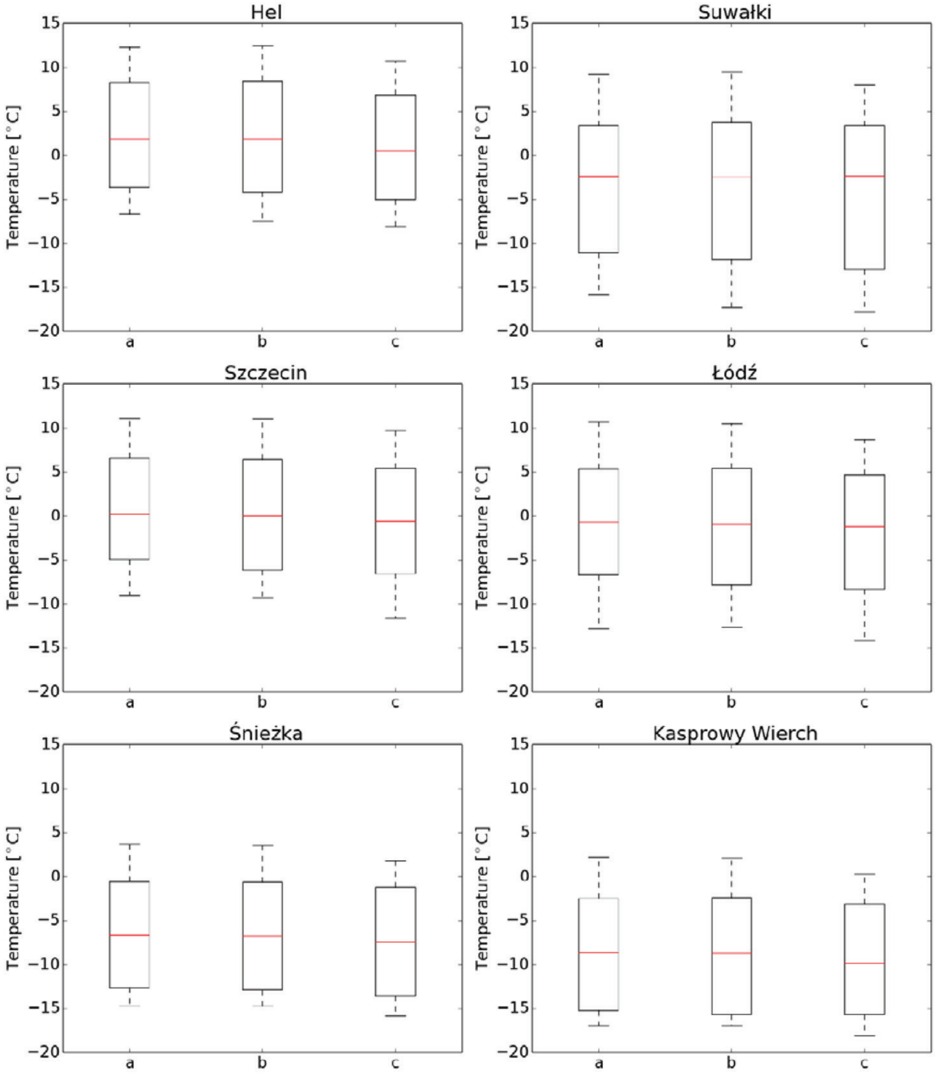

Figure 1. Minimum monthly air temperatures at selected stations; a) for the period 2000-2009; b) for the period 2000-2013; c) adapted after Bielec-Bąkowska and Piotrowicz (2013) for the period 1951-2006.

For threshold values (T_{min10}, T_{max90}) calculated from monthly extremes, only one station had significant trend in number of days below minimum temperature threshold. There was no station with significant trend in number of days above maximum temperature threshold.

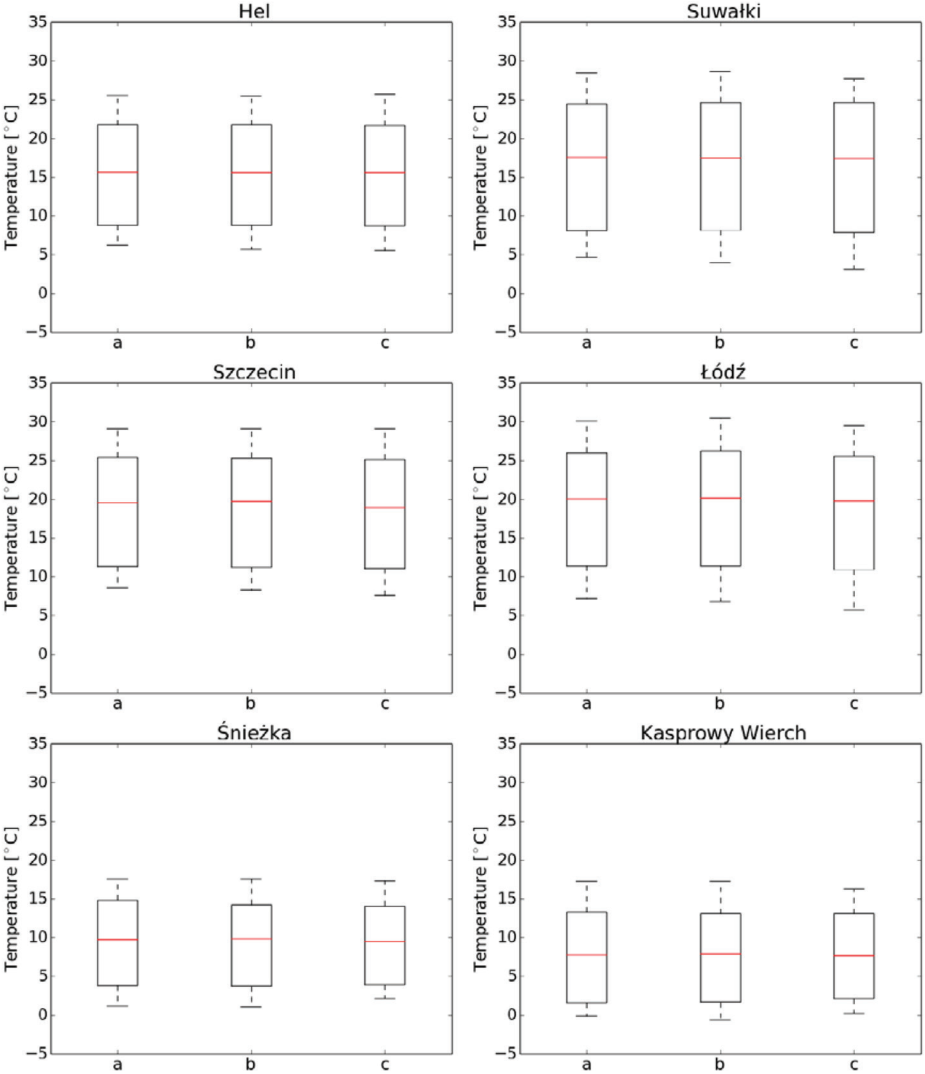

Figure 2. Maximum monthly air temperatures at selected stations; a) for the period 2000-2009; b) for the period 2000-2013; c) adapted after Bielec-Bąkowska and Piotrowicz (2013) for the period 1951-2006.

Considering threshold values at monthly base for every station, several significant relations were found. From 60 stations, only 3 had one month in year with significant trend in maximum temperatures – Resko, Jelenia Góra i Śnieżka

(Figure 3). All of them had at the same time one month with significant trend in minimum temperatures. Decrease in number of days with maximum temperature was always in February. For Resko and Śnieżka, this corresponded to increase of days with minimum temperature in May. As conclusion – both extreme temperatures (min./max.) at those three stations decreased.

Three stations had two months with increased or decreased number of days with extreme temperatures (Figure 4). Tarnów with increasing number of days and Ostrołęka with Suwałki with decreasing number of days. Tarnów had more days with extreme temperatures (more cold and more hot days), while Ostrołęka with Suwałki had less.

For additional 14 stations, there was just one month per station, with significant trend in minimum temperature. Most of the stations (10) had decreasing number of days with temperature below T_{min10}. The most trend-affected month was September, with 7 stations with decreasing number of days for minimum temperatures. All 20 stations with significant trend are shown on Figure 5. For better perception, the surrounding region is assigned to each station.

Table 2. Differences of the extreme monthly air temperatures (percentiles T_{min10}, T_{max90}) between the period 2000-2013 and 1951-2006. Q1, Q2, Q3 are quartiles.

	ΔT_{min10} [°C]			ΔT_{max90} [°C]		
Temperature	Q1	Q2	Q3	Q1	Q2	Q3
Min. for station	0.950	1.400	1.675	0.400	0.550	0.800
Mean for station	0.942	1.129	1.350	0.160	0.267	0.321
Max. for station	1.500	1.800	1.975	0.600	0.850	1.075

DISCUSSION AND CONCLUSIONS

Differences in threshold values of T_{min10} and T_{max90}, for records of different length, are caused by substantial difference in length itself, but another explanation can be shift in recorded values. This increase of temperature was found also by other authors (Bielec-Bąkowska and Piotrowicz 2013). From statistical point of view, 14-years of observations is very short period for long-term analysis, but can be used to trace short term changes in extreme daily temperatures. Even in short temperature records, significant trends can be found. Minimum daily temperatures increased between period 1951-2006 and 2000-2013 by about +1°C (Table 2) for 22 analysed stations. Similar gradient (about +1°C/30 years) was presented by other authors (Bielec-Bąkowska and Piotrowicz 2013; Żarski et al. 2010).

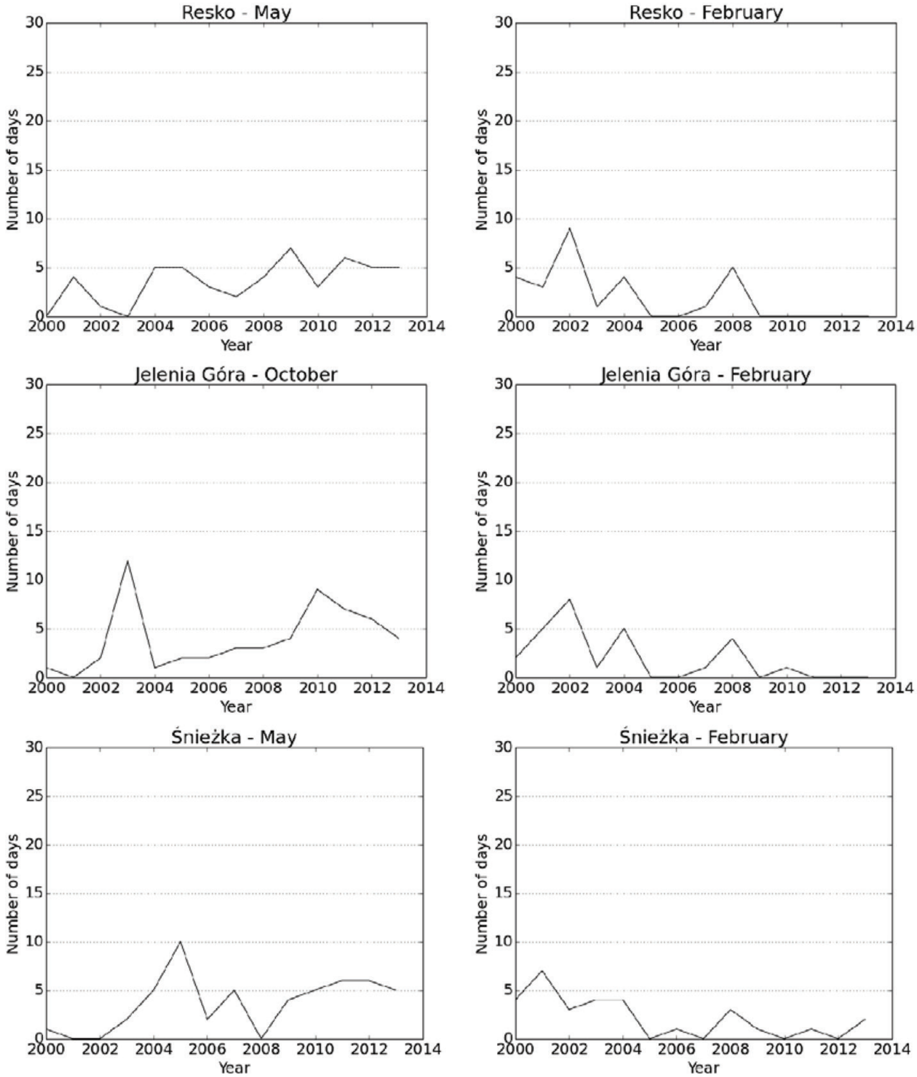

Figure 3. Selected significant trends in number of days with daily extreme temperatures below/above monthly percentiles T_{min10} (left column) and T_{max90} (right column) respectively.

Spatial extent of extreme temperature changes is consistent. Regions with decreasing number of days, with extremely low temperatures, are located in eastern-north and central part of Poland (Figure 5). Regions with increasing number of those days are much more scattered and located in north-west, west and south-east.

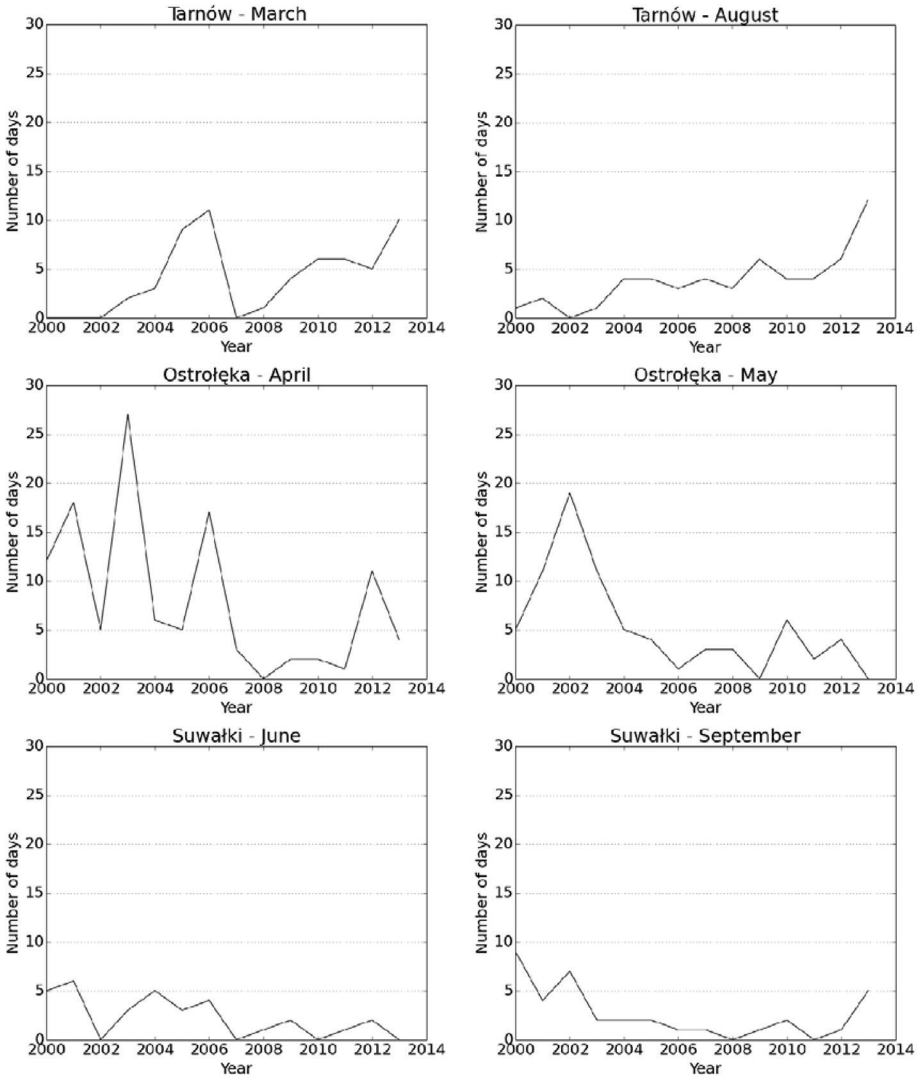

Figure 4. Significant trends in number of days with daily extreme temperatures below monthly percentiles T_{min10}. Only stations with more than one month of significant trend.

Years 2002, 2003 and 2007 were found as exceptionally hot summers (Twardosz and Kossowska-Cezak 2013), and years 2000-2010 as the hottest in last six decades (Wójcik and Miętus 2014). Presented in this paper analysis of trends didn't confirmed that. This can be caused by fact, that observation period overlaps entirely those events.

Monthly thresholds for detection of extreme temperatures, provide larger number of significant trends (at the level of 0.05), compared to temperatures averaged over the whole year. It was proven, that even relatively short observations (10-15 years), can be useful for short term trends detection. In this case however, temporal thresholds decomposition is the key issue.

Presented method of analysis, with freely available source of data, can be used for tracing changes of extreme temperatures not from long-term, but human perception perspective.

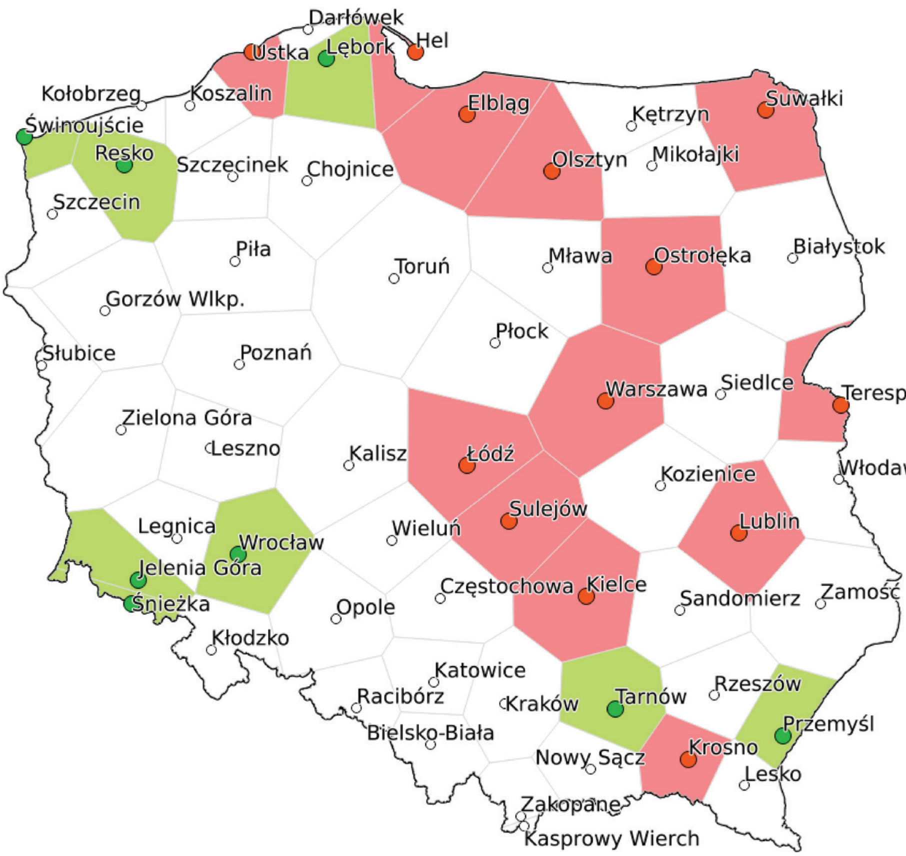

Figure 5. Stations with at least one month of significant trend in minimum daily temperature change. Trend based on days with daily temperature below monthly T_{min10} (green – more days, red – less days).

This research was financed within Ś-1/174/2014/DS, task 2. Data kindly provided by SatAgro.pl project.

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