SINGULARITIES IN ANNUAL COURSE OF TEMPERATURE IN KATOWICE

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ABSTRACT

In the article, the annual course of average daily temperature in Katowice has been researched, basing on the period 1951-2001. The analysis has been conducted in search of at least 3 day lasting chill waves, as well as heats appearing frequently in the same season of year within the whole examined series of temperature. The annual course of temperature has been approximated with a curve circumscribed by polynomial of fifth degree drawn on the base calculated from the perennial average temperature of each day. The deviations of this temperature from the polynomial have been analyzed.

The author adopted the definition of anomaly described by the term 'singularities' (introduced in 1938 by A.Schmauss in the article entitled 'Synoptische Singularitäten') as the appearance of temperature anomaly, exceeding one standard deviation, for at least 3 consecutive days (calculated from the whole set of deviations). One day breaks within longer courses fulfilling this condition were constantly classified as one temperature anomaly. Positive deviations were defined as the heat waves, and negative ones as the chill waves.

The initial results of the analysis described above reveal the occurrence of 10 periods of cooling (including 3 lasting at least 5 days) and 12 periods of warmth (including 5 lasting at least 5 days) at the border of single standard deviation (0,5ºC) in Katowice. At the border of 1,5 standard deviation (0,75ºC), 2 periods of coolness and 7 periods of warming (including 2 lasting at least 5 days) have been indicated respectively. For the border of standard deviation of 1.8 (0.9ºC), 2 periods of warming (including 1 lasting 4 days) have been indicated.

The analysis shows that the period between 11th March and 19th May is distinguished by the occurrence of the longest chill waves (even up to 12 days) and heat waves (up to 9 days). In the period mentioned above, 22 days are marked by temperatures being lower than average, while 25 days have above average temperatures. August is the most abundant month in heat waves; the number of days with heat is 13, 3 of which are characterized by temperature anomaly of above 0.9ºC higher than the average. An attempt has been made to define which types of circulation influence the generating of big thermal anomalies.

KEY WORDS: polynomial, singularity, southern Poland, temperature

1. Introduction

In the annual course of temperature, there are periods when days with higher or lower than average temperatures occur. The meteorological conditions, which tend to emerge at the same time, or around a particular date in calendar more frequently than it could be out of probability, were described by the term 'singularities', first introduced by A.Schmauss (1938), and then used by other authors (e.g. Glickman 2000), Brier et al. (1963) introduced the term calendaricities to avoid confusion with the mathematical use of the word singularities. Those episodes were observed by people and somehow placed in time by creating folk proverbs (e.g. Buchan 1869, Talman 1919, Glickman 2000). The warmths and coolings couldn't remain unnoticed by meteorologists. Attempts to explain their origins have been made for decades. Various factors influencing these unusually regular changes of temperature have been indicated. Brooks (1946) pointed out dynamics and certain regularities in atmosphere circulation as reasons for the Great Britain. The alternate occurrence of deep lows and highs since October until the beginning of February, and chill waves connected with north-east winds since February until May, are characteristic for the British Isles. In the summer, there are alternate periods of cold north-west and warm south-west winds, as well as periods when frequent highs appear since September until the beginning of October. Similar diagnoses of the events were proposed by Lamb (1966), Godfrey (2002).

There are several methods of researching singularities. Among others, the Fourier's analysis of the annual course of average day temperature may be applied (Godfrey, 2001). The author decided to apply a different method, using high degree polynomial regression curve, which shall be described later. The discovery and then attempt to describe the origins of temperature anomalies begins with anticipating temperature of every day in the examined area. The research has been conducted on the data of synoptic station of IMGW (Institute of Meteorology and Water Management) in Katowice (number WMO 12560). The series of daily temperatures under research covers the period 1951-2001. The paper is concerned with finding at that time all cooling and warming anomalies that appeared, defining their intensity and linking their occurrence with types of circulation every day, distinguished for Poland by Niedźwiedź (2006) in his Calendar of Circulation Types.

1. The annual course of temperature

Everyday temperature in Katowice has been calculated as the average temperature for the period 1951-2001 for every day. 29th February has been included within the average for 28th February by averaging these two values. In this way, a series of temperature, which consists of 365 elements representing every day of the year has been obtained. From the established series the annual course of temperature chart has been formed. In order to approximate the course of this temperature in a mathematical way, the author decided to apply high degree polynomial. For this reason, attempts have been made to adjust high degree polynomial regression curves. With the growth of degree of the polynomial, the degree of adjustment of polynomial value to the examined course of temperature grew. With the polynomial degree at 5, polynomial with the best adjustment was obtained. Further increase of the degree did not result in anything more, the coefficient of determination changed very little. At this level the polynomial explained 99.5 % of temperature variations. The received formula went as follows:

$$T_{avD} = (1{,}80834616\,795602\text{e}-11) * \text{n}^5 + (4{,}97143819\,666547\text{e}-09) * n^4 - (1{,}16604730\,428286\text{e}-05) * n^3 + (0{,}00300896\,445187958) * n^2 - (0{,}10690607\,8330132) * n^1 - (1{,}47637393\,101998) * n^0 \quad (1)$$

Where T_{avD} stands for the average temperature of each day and n is the number of subsequent day. The formula is presented in its full shape, as it is essential to be applied so precisely in further analysis of polynomial factors. The least deviations (e.g. roundings) result in values not correlating in any way with values of temperature.

The course of average day temperature and polynomial is presented on picture 1. As can be noticed, the actual course of temperature does not overlap with polynomial values. A number of deviations from the average value (calculated from equation 1) may be observed. The majority of these anomalies have small values, within the limits of acceptable fluctuation, resulting from the length of primary series of data (51 years). However, much bigger deviations lasting several days can be found as well. Precisely these spots should be regarded as days with singularities.

In order to detect these phenomena, the deviation from average value has been calculated for every point of the chart:

$$\Delta t = T_{Avgn} - T_{avgD} \quad (2)$$

Where T_{Avgn} is the average temperature of n-day.

These deviations are the basis for distinguishing between heat and chill waves. This parameter allows finding periods when days of adequately higher and lower temperatures appeared with high frequency. From the set of 365 Δt values standard deviation (SV) has been calculated, giving the value of 0.53ºC, which was then rounded to 0.5ºC. This parameter has been used as a filter for defining particularly warm and cold days. The day when the average daily temperature exceeded the interpolated value by one standard deviation has been set as anomalous day, while cold day stands for the day when the temperature was lower by one standard deviation.

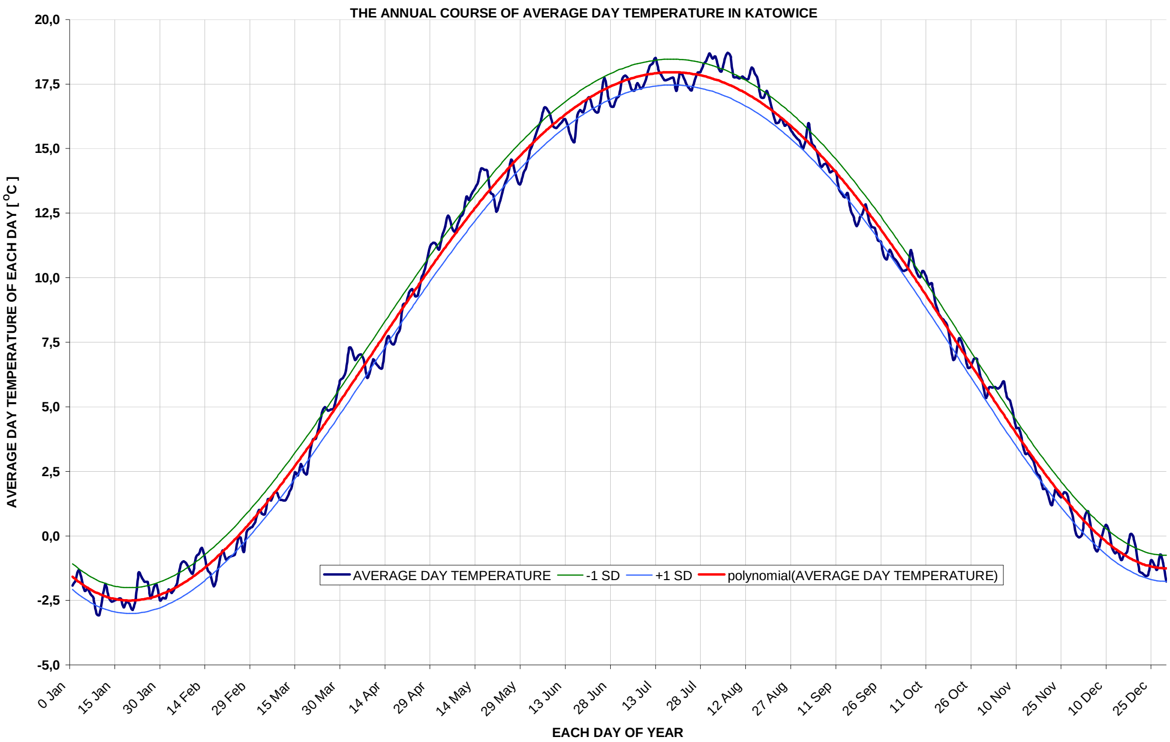

Figure 1. The annual course of temperature at Katowice station juxtaposed with the course of fifth degree polynomial obtained from polynomial regression. The green curve designates values higher by one standard deviation, and the blue one – lower by one standard deviation than average values (red curve).

The period of anomalously warm or cold days lasting or at least 3 days has been defined as singularity. If one-day variation from this rule occurred during a longer series of hot or cold days, this day was also included within one singularity. They were named warm and cold, or positive and negative respectively. For the sake of transparency, they were given chronological order as well, preceded by ‘W’ prefix for warm singularities and ‘C’ for cold singularities. The distinguished episodes are presented in Figure 1 and Table I.

Similarly, the periods with more restrictive conditions (that is, assuming as the border value for indicating hot and cold days the multiplicities of standard deviation) have been marked. Due to attempts, the following multipliers have been set: 1.4, 1.6, and 1.8. This corresponds to the border values at the level 0.7ºC, 0.8ºC, 0.9ºC. The obtained results are in the Table I. As we can observe, there is by far more warm than cold anomalies. At the 0.5ºlevel 10 cold and 12 warm episodes can be distinguished, but on the 0.7ºC border only 3 cold and 7 warm. The 0.8ºC level amounts to only 1 cold and 6 warm anomalies. At the maximum border there are no more cold anomalies, while there are 2 warm ones.

The most significant warm singularity in the region of Katowice (W12) appears since 4th until 10th November, when all 7 days fulfill the minimal anomalous condition, but four of them exceed the value of 0.9ºC. Second in the respect of intensity is W9 lasting 3 days.

The longest lasting cold singularity C2 from 9th to 20th April is the period when closely following days (1 day distance) fulfilling the requirements for cold day even with the higher borders occur, but since these are maximum two-day series, when we increase the borders, the anomaly does not appear again. The following C1 lasts 10 day, but only 3 of them exceed the level of anomaly by 0.7ºC. After increasing the border, this singularity is no longer distinguishable.

xSD=0.5ºC x=1.0							
Warm Singularities				Cold Singularities			
CODE	START	END	N day	CODE	START	END	N day
C1	11 Mar	20 Mar	10	W1	23 Jan	26 Jan	4
C2	9 Apr	20 Apr	12	W2	6 Feb	8 Feb	3
C3	22 May	24 May	3	W3	11 Feb	13 Feb	3
C4	29 May	1 Jun	4	W4	31 Mar	7 Apr	8
C5	15 Jun	17 Jun	3	W5	29 Apr	7 May	9
C6	29 Jun	2 Jul	4	W6	12 May	19 May	8
C7	14 Sep	20 Sep	7	W7	6 Jun	8 Jun	3
C8	26 Sep	29 Sep	4	W8	31 Jul	3 Aug	4
C9	20 Nov	23 Nov	4	W9	6 Aug	8 Aug	3
C10	1 Dec	3 Dec	3	W10	12 Aug	17 Aug	6
				W11	11 Oct	14 Oct	4
				W12	4 Nov	10 Nov	7

xSD=0,7ºC x=1.4							
Warm Singularities				Cold Singularities			
CODE	START	END	N day	CODE	START	END	N day
C1	12 Mar	14 Mar	3	W4	31 Mar	6 Apr	7
C4	1 Jun	1 Jun	3	W6	12 May	19 May	8
C7	17 Sep	19 Sep	3	W8	1 Aug	3 Aug	3
				W9	6 Aug	8 Aug	3
				W10	15 Aug	17 Aug	3
				W11	11 Oct	14 Oct	4
				W12	6 Nov	9 Nov	4

xSD=0.8ºC x=1.6							
Warm Singularities				Cold Singularities			
CODE	START	END	N day	CODE	START	END	N day
C4	29 May	31 May	3	W4	2 Apr	4 Apr	3
				W6	16 May	19 May	4
				W8	1 Aug	3 Aug	3
				W9	6 Aug	8 Aug	3
				W10	15 Aug	17 Aug	3
				W12	6 Nov	9 Nov	4

xSD=0.9ºC x=1.8							
Warm Singularities				Cold Singularities			
CODE	START	END	N day	CODE	START	END	N day
				W9	6 Aug	8 Aug	3
				W12	6 Nov	9 Nov	4

Table I. The juxtaposition of Warm Singularities and Cold Singularities and their lasting time, depending on the assumed border level of temperature anomalies: 0.5ºC, 0.7ºC, 0.8ºC, 0.9ºC. The colours help locate particular singularities at different levels of SD.

C7, which lasts 7 days, includes 3 days with the anomaly above 0.7ºC, and it disappears above this level. The singularity marked as C4 (which lasts from 29th May to 1st June, of which three days since 29th May until 31st May reach the level of temperature anomaly above 0.8ºC) reaches the highest anomalies. It disappears above this level.

2. The types of circulation

The Calendar of Circulation Types according to Niedźwiedź introduces 21 types of circulation, including one undefined, markes as ‘x’. The calendar distinguishes between anticyclonic and cyclonic situations ascribed to eight directions of main air advections, wedges of high pressure, troughs of low pressure, as well as high and low pressure centres.

All anomalies have been analyzed in the light of types of circulation which occurred between 1951 and 2001, included in the calendar of types of circulation mentioned above. Each singularity has been juxtaposed with the number of particular types of circulation. Due to the relatively small amount of days within particular anomalies (each anomalous day includes 51 cases), the year has been divided into winter (November to April) and summer (May to October) half-years. The division is presented in Table II. The numbers have been summarized for particular types of circulation within all the singularities ascribed to each season, leaving the division into cold (November to April) and warm (May to October).

Thanks to this device, it became possible to determine the percentage of specific types of circulation in cool and warm anomalies in the winter half-year. It is presented on picture 2. The analysis indicates that in the winter half-year cold anomalies dominate east, north-east and south-west types of circulation, whether it is anticyclonic or cyclonic. As results from Table II 5, the SEa-type circulation gains the biggest advantage; to a smaller extent, also the NEa, Nc, Na and NEc circulations connected with this singularity. For those types, the advantage is at least 1.5%. The advantage of other prevailing types does not exceed 1%.

Type of Circulation	**Cold Singularities Percentage**	**Warm Singularities Percentage**	**Δ%**
SEa	6,3%	3,8%	2,4%
NEa	3,2%	1,4%	1,8%
Nc	4,1%	2,4%	1,6%
Na	3,7%	2,2%	1,5%
NEc	3,2%	1,7%	1,5%
Ea	5,7%	4,9%	0,8%
Ka	9,1%	8,3%	0,7%
Bc	8,4%	7,7%	0,7%
SEc	3,7%	3,0%	0,7%

Table II. The percentage of prevailing types of circulation occurring with cold singularities in the winter half-year, juxtaposed with the percentage in warm singularities

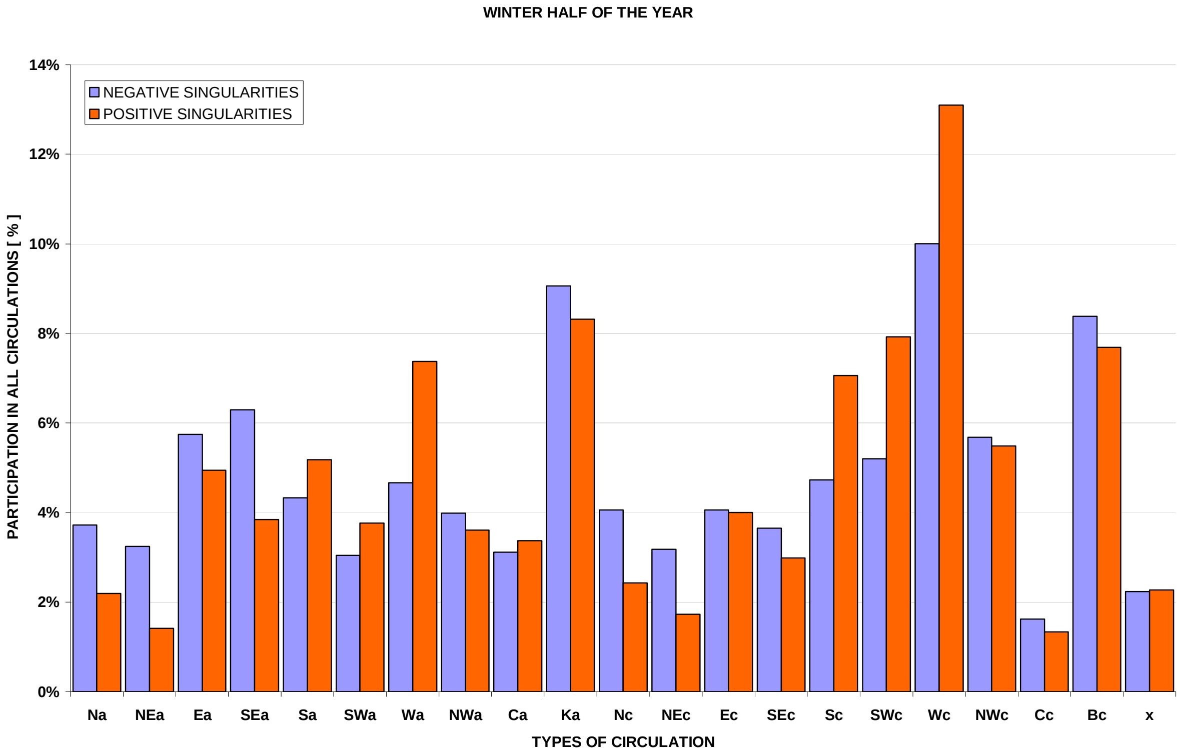

Figure 2. The percentage of types of circulation in cold and warm singularities in the winter half-year. It indicates the dominance of east circulations in shaping negative anomalies as well as west directions in shaping warm anomalies.

In the same period, the types of west and south-west circulation dominate and like before, regardless of their anticyclonic or cyclonic character (Table III).

Types of circulation	**Cold Singularities Percentage**	**Warm Singularities Percentage**	**Δ%**
Wc	10,0%	13,1%	3,1%
SWc	5,2%	7,9%	2,7%
Wa	4,7%	7,4%	2,7%
Sc	4,7%	7,1%	2,3%
Sa	4,3%	5,2%	0,8%
SWa	3,0%	3,8%	0,7%

Table III. The percentage of prevailing types of circulation occurring with warm singularities in the winter half-year, juxtaposed with the percentage in cold singularities.

The Wc-type of cyclonic circulation gains the biggest advantage in creating positive anomalies during the winter half of the year (Figure 2). The SWc and Wa circulations have slightly less influence and the Sc-type of circulation still less. At the same time, the mentioned types have the biggest percentage. These values range from 2.3% for Sc to 3.1% for Wc. Most of other prevailing types of circulation are under 1%. The anticyclonic wedge and cyclonic trough have much impact on frequency, but their influence on warm anomalies is equally high.

In the summer period of year, cold anomalies dominate west and north-west types of circulation. The greatest advantage is gained by NWa circulation, then Na. The Wc and Nc cyclonic circulations have less influence. The Wa anticyclonic circulation from the west reaches domination close to 1%. The situation is presented on Figure 3.

Type of Circulation	Cold Singularities Percentage	Warm Singularities Percentage	Δ%
NWa	6,7%	4,2%	2,5%
Na	5,5%	3,6%	1,9%
Wc	8,0%	6,5%	1,5%
Nc	4,9%	3,4%	1,5%
Wa	5,8%	4,9%	0,9%

Table IV. The percentage of prevailing types of circulation occurring with cold singularities in the summer season, juxtaposed with the percentage in warm singularities.

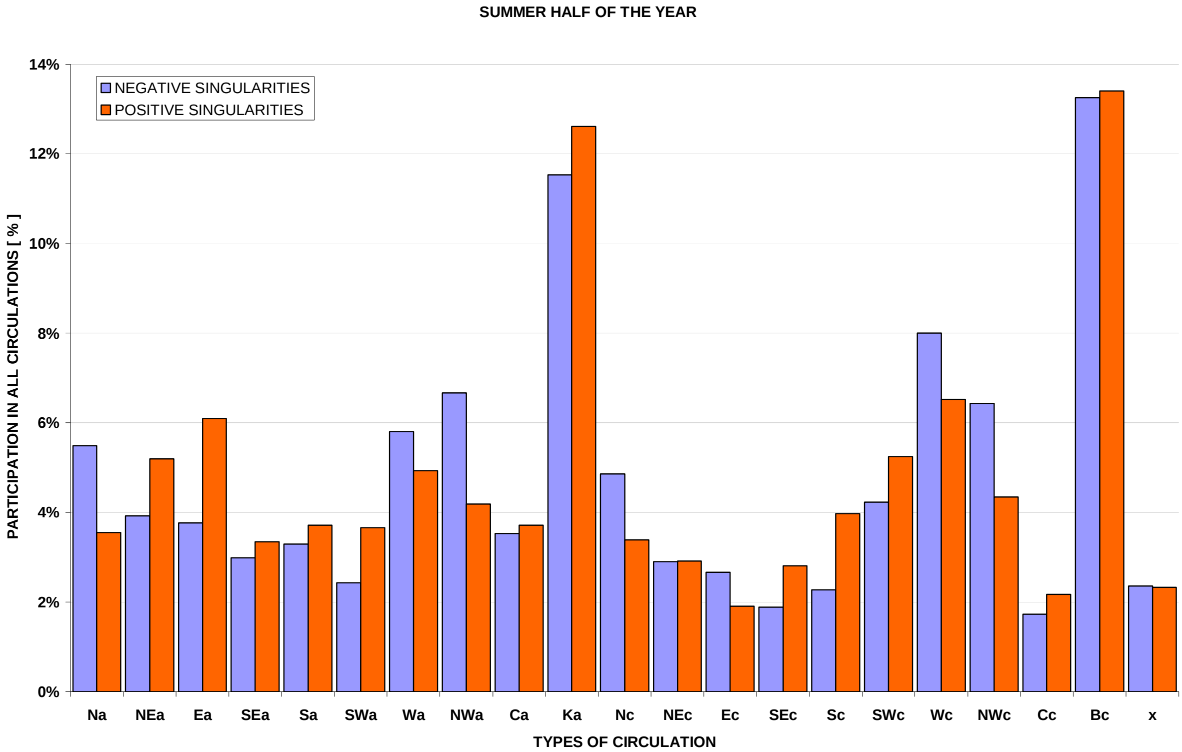

Figure 3. The percentage of types of circulation in cold and warm singularities in the summer half-year. It indicates the domination of west and north-west circulations in shaping negative anomalies, as well as east anticyclonic and south cyclonic circulations in shaping warm anomalies.

Type of Circulation	Cold Singularities Percentage	Warm Singularities Percentage	Δ%
Ea	3,8%	6,1%	2,3%
Sc	2,3%	4,0%	1,7%
NEa	3,9%	5,2%	1,3%
SWa	2,4%	3,7%	1,2%
Ka	11,5%	12,6%	1,1%
SWc	4,2%	5,2%	1,0%
SEc	1,9%	2,8%	0,9%

Table V. The percentage of prevailing types of circulation occurring with warm singularities in the summer season, juxtaposed with the percentage in cold singularities.

In the summer, season warm anomalies dominate in the Ea east anticyclonic and south cyclonic types of circulation. The anticyclonic north-east and south-west circulations have much less influence.

Figures 4 and 5 present the comparison of percentage of particular types of circulation in relation to the period of their occurrence, that is, with the division into summer and winter half-years. High pressure wedges and low pressure troughs noticeably influence the occurrence of warm singularities in the summer. Wc and Ea as well as SWc and NEa have almost by half less influence in their formation.

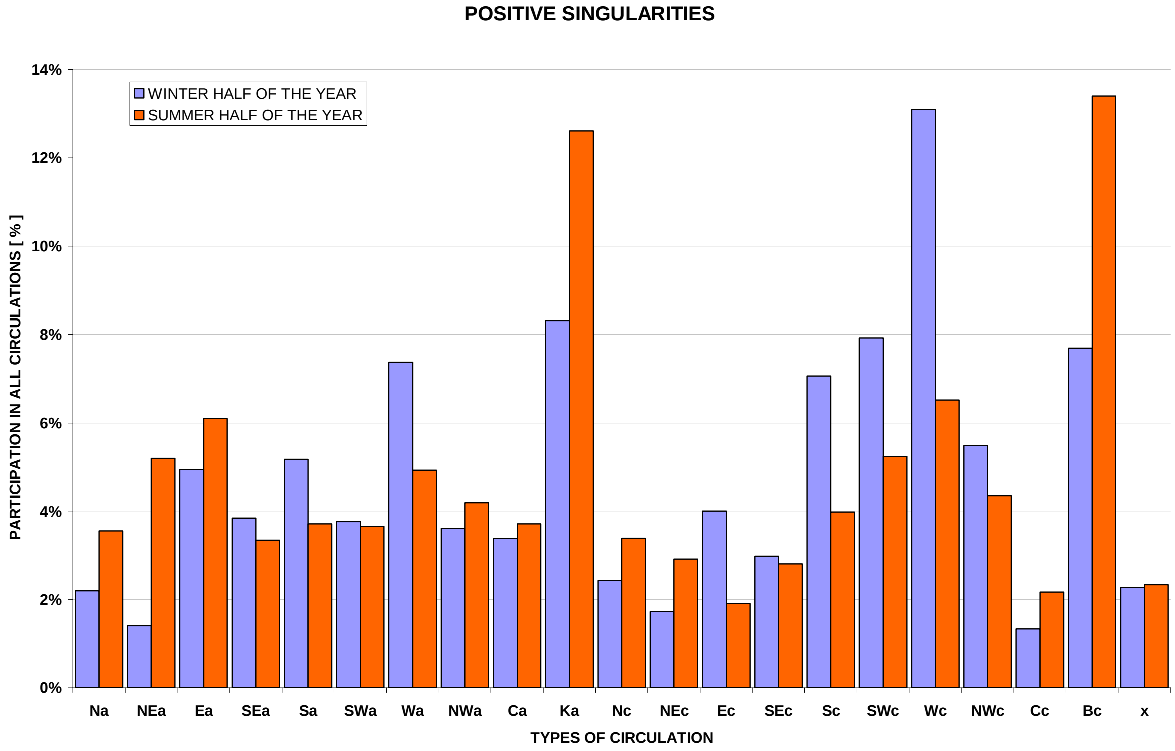

Figure 4. The percentage of types of circulation in generating warm singularities with the division into summer and winter seasons. The high occurrence of wedges and grooves is noticeable in shaping those situations in the summer, as well as Wc circulation in the winter half-year.

Warming episodes in the winter half-year occur mainly during Wc, SWc, Sc and Wa circulations. Also in this case, the appearance of low pressure wedges and high pressure troughs is significant, but their influence in this period is much smaller than it was in the previous case.

Cold singularities in the summer season occur in a similar way to as it was in the case of warm singularities due to wedge and trough; Wc, NWa, NWc, Wa and Na have less influence. The winter period is the west cyclonic circulation, which dominates the forming of anomalies, second with slightly less influence are groove and trough, and then Sea, Ea, NWc.

Types of circulation	Positive singularities		Negative singularities	
	Winter	Summer	Winter	Summer
Na	2,2%	3,6%	3,7%	5,5%
NEa	1,4%	**5,2%**	3,2%	3,9%
Ea	4,9%	**6,1%**	**5,7%**	3,8%
SEa	3,8%	3,3%	**6,3%**	3,0%
Sa	5,2%	3,7%	4,3%	3,3%
SWa	3,8%	3,7%	3,0%	2,4%
Wa	**7,4%**	4,9%	4,7%	5,8%
NWa	3,6%	4,2%	4,0%	**6,7%**
Ca	3,4%	3,7%	3,1%	3,5%
Ka	**8,3%**	**12,6%**	**9,1%**	**11,5%**
Nc	2,4%	3,4%	4,1%	4,9%
NEc	1,7%	2,9%	3,2%	2,9%
Ec	4,0%	1,9%	4,1%	2,7%
SEc	3,0%	2,8%	3,7%	1,9%
Sc	**7,1%**	4,0%	4,7%	2,3%
SWc	**7,9%**	**5,2%**	5,2%	4,2%
Wc	**13,1%**	**6,5%**	**10,0%**	**8,0%**
NWc	5,5%	4,3%	**5,7%**	**6,4%**
Cc	1,3%	2,2%	1,6%	1,7%
Bc	**7,7%**	**13,4%**	**8,4%**	**13,3%**
x	2,3%	2,3%	2,2%	2,4%

Table VI. The comparison of percentage of particular types of circulation occurring during cold warm singularities.

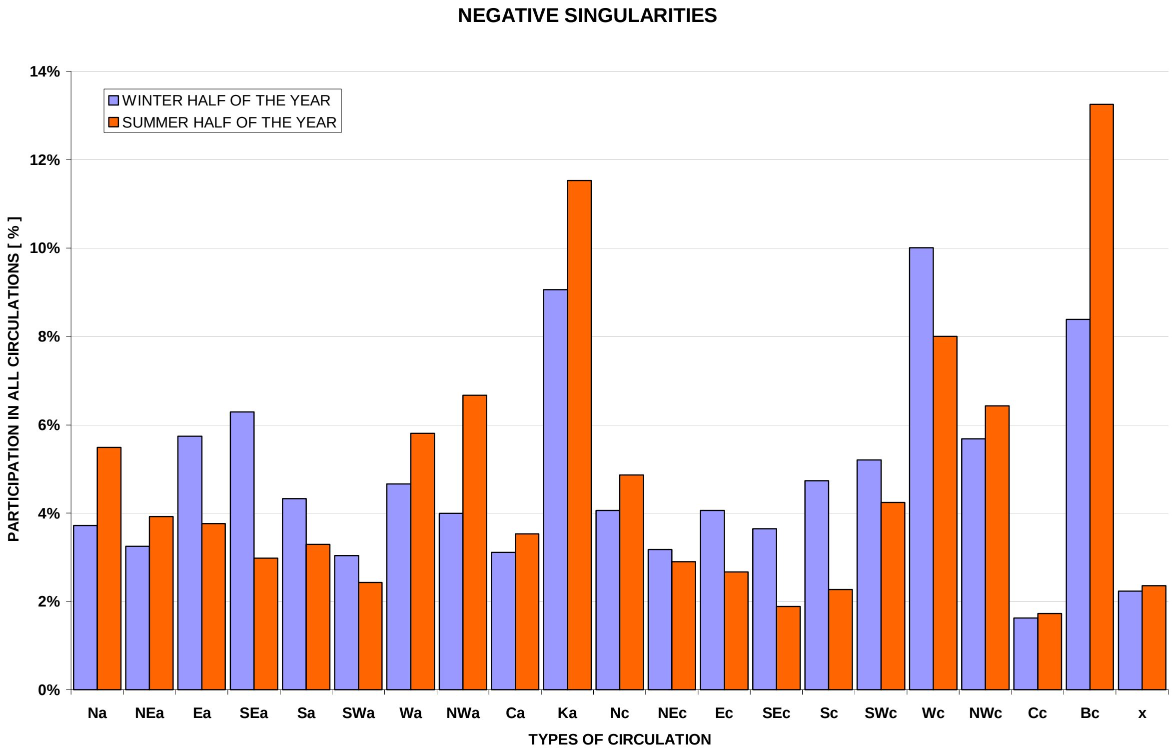

Figure 5. The percentage of types of circulation in generating cool singularities with the division into summer and winter half-years. There is a noticeable occurrence of wedges and troughs in creating these situations in the summer, as well as Wc circulation in the winter period.

The overall look allows stating that the west circulation is the main reason for generating singularities in the winter season in Katowice and the surroundings. It is the circulation which is most important for the anomalies under research. The summer half-year is distinguished by the domination of cyclonic trough in the recorded anomalous days.

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