Changes in Precipitation in Poland in the 21st Century in the Light of Quantile Classification

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Abstract. The study aims to analyze the variability of the precipitation character of seasons and years at selected stations in Poland in the 21st century. The work includes six meteorological stations located in specific regions of Poland. The precipitation character of years and climatic seasons was determined using quantile classification, based on the values of 10, 30, 70, and 90% quantile of the empirical distribution of seasonal and annual precipitation. 1971-2010 precipitation data (normal period) were applied to calculate the quantile values. In spring (MAM), the highest frequency of precipitation anomalies was recorded in Wroclaw station. In the 21st century, precipitation of only one spring period was classified as normal at this station. Seven springs were dry or very dry, and 11 were wet or very wet. The most stable seasonal precipitation in spring was observed in Suwalki station. In the years 2001-2019, the twelve spring seasons had normal rainfall. Three spring seasons in Suwałki were classified as dry or very dry and five as wet or very wet. In the summer season (JJA) Szczecin and Wroclaw recorded a high frequency of precipitation anomalies. At each of these stations, 15 summer seasons were characterized by abnormal rainfall. The frequency of rainfall anomalies in the summer season was the smallest in Suwałki, where ten seasons with abnormal rainfalls were recorded, including three seasons with low or very low rainfall and six seasons with high or very high rainfall. In the autumn season (SON), precipitation was more stable in western and central Poland, where the number of seasons with abnormal precipitation ranged between 9 in Szczecin and Wroclaw to 10 in Lodz. In Lublin, on the other hand, as many as 15 seasons with abnormal rainfall was recorded in the 21st century. In the winter season of 2001-2019, rainfall amounts of unusual nature dominated at all stations, with the frequency being higher at these located in eastern Poland. The analysis of annual sums of precipitation showed that most years were abnormal in terms of precipitation, with a higher frequency of precipitation anomalies at stations located in the eastern part of the country.

1. Introduction
Climate change observed since the 1950s [1] is becoming a major challenge for national economies. The effects of changes in air temperature mainly impose on the rulers the need to take actions to mitigate them and adapt the functioning of many areas of the economy to new climate conditions. This is no different from changes in precipitation, which is the main source of drinking water. In Poland [2], trends
in precipitation changes are not unambiguous. Increase trends in total precipitation are observed in northern Poland, while in southern Poland there are some symptoms of a decrease in total precipitation.

The aim of the study is to analyse changes in the precipitation character of seasons and years in the 21st century in selected stations in Poland. The observed changes in the sum of seasonal and annual precipitation [2] should result in an increased frequency of wet and extremely wet periods in northern Poland and increased frequency of dry and very dry periods in southern Poland. To determine the precipitation characteristics of the above mentioned periods, the quantile characteristic of precipitation [3] was used, in which the assignment of the period to particular classes is based on the values of quantiles 10, 30, 70, and 90% of the empirical distribution of seasonal and annual precipitation from the normal period 1971-2000 (Table 1). The quantile precipitation classification has the advantage over other classifications [4, 5] because it uses positional measures that can be applied to describe statistical series with arbitrary distributions, not only normal.

| Quantile   | Characteristic of the period | Class |
|------------|-----------------------------|-------|
| >90.00     | extremely wet               | +2    |
| 70.01 – 90.00 | wet                      | +1    |
| 30.01 – 70.00 | normal                  |       |
| 10.01 – 30.00 | dry                      | -1    |
| ≤10.00     | extremely dry              | -2    |

The values of quantiles were calculated on the basis of homogeneous series of daily precipitation of the normal period 1971-2000 from six stations, representing characteristic landscapes (figure 1). Values of quantiles 10, 30, 70 and 90% of winter precipitation sums were calculated on the basis of data from December 1971 to February 2001.

The analysis of the results focuses on the precipitation character of the seasons and years of the period 2001-2019. Winter 2001 covers the months December 2001-February 2002 and winter 2019 covers the period December 2019-February 2020.
2. Results and discussion

2.1. Winter precipitation

The ranges of the normal winter precipitation (DJF), determined based on data for the years 1971-2000, ranged from 66.3 - 95.8 mm in Wroclaw to 96.3 - 123.5 mm in Szczecin (table 2). Extremely low precipitation is the one whose seasonal sum does not exceed 45.6 mm - 64.9 mm at the stations in Wroclaw and Suwalki respectively. Extremely high precipitation sums are those that exceed values from 109.8 mm in Lublin to 141.3 mm in Szczecin.

Table 2. The values [mm] of the 10th, 30th, 70th and 90th quantile of Winter (DJF) precipitation totals in selected meteorological stations in Poland, 1971-2000

| Station | Quantile |
|---------|----------|
|         | 10%      | 30%      | 70%      | 90%      |
| Szczecin| 63.97    | 96.21    | 123.57   | 141.30   |
| Wroclaw | 45.69    | 66.24    | 95.80    | 117.44   |
| Torun   | 50.96    | 76.23    | 99.93    | 110.29   |
| Lodz    | 56.72    | 89.69    | 114.81   | 127.54   |
| Suwalki | 64.94    | 86.24    | 108.74   | 138.15   |
| Lublin  | 60.42    | 75.60    | 102.01   | 109.84   |

Table 3. Quantile classification of winter (DJF) precipitation totals in selected stations in Poland, 2001-2019

| Year | Station |
|------|---------|
|      | Szczecin | Wroclaw | Torun | Lodz | Suwalki | Lublin |
| 2001 | +2       | +2      | +2    | +2   | +1      |        |
| 2002 | -2       | -1      | -2    | -2   | -1      |        |
| 2003 | +1       | +2      | +1    | +2   | +1      | +2     |
| 2004 | +1       | +2      | +2    | -1   | +2      |        |
| 2005 | +2       | +1      | +2    | +2   | +2      |        |
| 2006 | +1       | +2      | +2    | +2   | +2      |        |
| 2007 | +1       | +1      | +1    | -1   | -1      |        |
| 2008 | -1       | -1      | -1    | -1   | -1      |        |
| 2009 | -1       | -1      | -1    | -1   | -1      |        |
| 2010 | +1       | +1      | +1    | +1   | +1      | +1     |
| 2011 | +2       | +1      | +2    | +1   | +1      |        |
| 2012 | +1       | +2      | +1    | +1   | +2      |        |
| 2013 | -1       | -1      | -1    | -1   | -1      | +1     |
| 2014 | +1       | -1      | +1    | +1   | +1      |        |
| 2015 | -1       | +1      | +1    | +1   | +1      | +2     |
| 2016 | -1       | +1      | -1    | +1   | +1      | +2     |
| 2017 | -2       | -1      | -1    | +1   | +1      | -1     |
| 2018 | +1       | +1      | +2    | +2   | +1      | +2     |
| 2019 | +1       |        | +2    | +2   | +1      | +2     |
In the 21st century, the analysed stations were dominated by anomalous rainfall (Table 3). A certain transient character of the precipitation conditions is noticeable. At stations located in western Poland (Szczecin, Wroclaw) anomalous seasons intertwined with normal seasons. Between 2001 and 2006 the winter seasons were generally normal or wet and extremely wet. Since 2007, both stations have shown a slight prevalence of dry and wet seasons and high variability of precipitation character of winters, especially in the years 2011-2018 in Wroclaw. In Toruń, the prevailing winter seasons were wet (10 out of 19), with six winter seasons having extremely wet character. At the same time, four normal and dry precipitation seasons were recorded in the discussed period. In Lodz, after the initial period (2001-2006) with the dominance of extremely wet winter seasons, a period of the interweaving of normal, dry and wet winter seasons occurred. In eastern Poland, the interweaving of the wet and extremely wet winter seasons dominated. In Suwalki two winter seasons (2001/2002 and 2006/2007) had an extremely wet character. Moreover, in the years 2001-20019 five winter seasons with normal precipitation and two dry winter seasons were recorded at this station. In Lublin, the period 2001-2006 was characterised by the dominance of wet winter seasons. In the years 2007-2013, there is a certain normalization of precipitation at this station. Starting from the winter season 20014/2015 all winter seasons were anomalous, with the dominance of extremely wet periods. The described variability of the precipitation character of winters refers to the trends of changes in the sums of precipitation of this season, described by [6], which indicate a decrease in the sums of precipitation in south-eastern Poland and their upward trends in the eastern part of the study area. Similar tendencies were shown by the studies [2], except for south-eastern Poland, where in the period 1960-2008 a decrease in precipitation of the winter season is observed. This discrepancy can be explained by the high variability of seasonal sums from year to year and different methods of examining trends of changes [2,6]. Both articles also indicate that the observed trends of changes are not statistically significant.

2.2. Spring precipitation

The normal rainfall for the spring season ranges from 81.8 mm in Torun and 108.8 mm in Wroclaw to 109.2 mm and 144.4 mm in Torun and Suwalki respectively (Table 4). The extremely dry season is characterized by sums of precipitation with values equal or lower to 60.8 mm - 88.0 mm depending on the station. The spring season with extremely high precipitation is the one in which the sums of rainfall are not lower than 141.9 - 166.1 mm.

Table 4. The values [mm] of the 10th, 30th, 70th, and 90th quantile of Spring (MAM) precipitation totals in selected meteorological stations in Poland, 1971-2000

| Station  | 10%  | 30%  | 70%  | 90%  |
|----------|------|------|------|------|
| Szczecin | 76.16| 92.69| 124.04| 155.56|
| Wroclaw | 88.08| 108.71| 124.36| 162.42|
| Torun    | 60.84| 81.78| 109.13| 141.87|
| Lodz     | 79.23| 101.88| 127.79| 149.08|
| Suwalki  | 81.67| 101.89| 144.45| 159.17|
| Lublin   | 79.76| 106.05| 138.85| 166.05|

In the course of the precipitation character of spring seasons in the 21st century in Szczecin, two sub-periods can be distinguished (Table 5). The first one, covering the years 2001-2008, was characterized by the anomalous nature of precipitation with the predominance of wet spring periods. Since 2009, the precipitation character of spring seasons at this station is variable, normal seasons interweave with dry and extremely dry and wet and extremely wet seasons. In Wroclaw, the spring seasons were definitely dominated by anomalous precipitation. The wet and extremely wet seasons were interspersed with dry and extremely dry seasons. Only spring precipitation in 2017 can be characterized as falling within the
norm. At the beginning of the 20th century at the station of Torun, the spring periods were alternating between normal and anomalous in terms of precipitation. Since 2009 wet and extremely wet spring season have dominated at this station. In Lodz, the spring seasons of wet and extreme characters prevail. The spring normal precipitation seasons were recorded more often in the years 2003-2007. In the years 2009-2012, there was a short period when the spring seasons were dry, while in 2010 the spring precipitation was extremely high. The Suwalki station was characterised by the lowest precipitation variability. The dominant spring seasons were normal in terms of precipitation, in the first decade of the 21st century there were two dry spring seasons and one wet and one extremely wet spring season recorded at this station. The second decade of 21st century was characterized by greater variability of spring precipitation. Apart from five normal seasons, three wet or extremely wet seasons and one dry season were recorded. In Lublin, spring seasons with normal precipitation dominated at the beginning of the 21st century (2001-2004) and the end of its second decade (2016-2018). In the period 2005-2015, spring seasons with high or extremely high precipitation prevailed. Spring 2007 was extremely dry and spring 2011-2012 was dry in terms of precipitation. Fluctuations in the precipitation character of spring seasons in northern and central Poland reflect small changes in the sum of seasonal precipitations, especially in Szczecin, Torun, Lodz, and Suwalki, described by [6]. The tendency of increasing sums of precipitation in Lublin, shown by [6], is confirmed by the high frequency of occurrence of wet spring periods at this station. In reference to south-western Poland, represented by Wroclaw station, the mentioned authors, similarly to [2], indicate a clear decrease in precipitation totals in the spring season, which is difficult to notice in the precipitation character of this season at this station. However, the observed high variability of the precipitation character of the spring seasons, not only at Wroclaw station, is an effect of the increase in precipitation variability described by [7] and [8], resulting in a large extent from the variability of atmospheric circulation.

Table 5. Quantile classification of spring (MAM) precipitation totals in selected stations in Poland, 2001-2019

| Year | Station          | Szczecin | Wroclaw | Torun | Lodz | Suwalki | Lublin |
|------|------------------|----------|---------|-------|------|---------|--------|
| 2001 | +1               | +1       | +2      | +2    | +1   |         |        |
| 2002 | +1               | -2       | +2      | +2    | +1   | -1      |        |
| 2003 | -2               | +1       | -1      | -1    |      |         |        |
| 2004 | -1               | -2       | +1      |       |      |         |        |
| 2005 | +1               | +1       | +2      | +1    |      |         | +1     |
| 2006 | +1               | -1       | -2      | -2    | +2   |         |         |
| 2007 | +1               | -2       | +1      |       |      | -2      |         |
| 2008 | +1               | +1       | -1      |       | +2   |         |         |
| 2009 | +1               | +1       | +1      | +1    |      |         | +2     |
| 2010 | +2               | +2       | +2      | +2    | +2   |         |         |
| 2011 | -2               | +1       | -2      | +1    |      | -1      |         |
| 2012 | -2               | -2       | -2      | -2    |      | -1      | -1     |
| 2013 | +1               | +1       | +2      | +2    | +1   | +2      |         |
| 2014 | +2               | +1       | +2      | +2    | +2   |         |         |
| 2015 | +1               | +1       | +1      |       | +1   | +1      |         |
| 2016 | +2               | +1       | +1      | +1    |      |         |         |
| 2017 | +2               | +1       | +2      | +2    | +2   |         |         |
| 2018 | +1               | +1       | +1      |       | -1   |         | +1     |
| 2019 | +1               | +1       | -1      |       | -1   |         | +1     |
2.3. Summer precipitation

Normal precipitation ranges in summer from 150.6 - 186.7 mm to 191.9- 258.3 mm at Szczecin and Suwalki stations respectively (table 6). The extremely dry summer season is characterized by rainfall no higher than 95.6 mm in Szczecin to 147.3 mm in Wroclaw. Precipitation described as extremely high in the summer season exceeds 250.8 - 320.2 mm at the stations in Szczecin and Wroclaw respectively.

| Station     | 10%  | 30%  | 70%  | 90%  |
|-------------|------|------|------|------|
| Szczecin    | 95.66| 150.60| 191.90| 250.84|
| Wroclaw     | 147.36| 172.80| 225.57| 320.62|
| Torun       | 105.05| 165.50| 215.30| 272.32|
| Lodz        | 130.24| 169.37| 230.83| 276.55|
| Suwalki     | 132.13| 186.73| 258.38| 299.38|
| Lublin      | 118.37| 181.66| 231.91| 269.47|

Table 6. The values [mm] of the 10th, 30th, 70th and 90th quantile of summer (JJA) precipitation totals in selected meteorological stations in Poland, 1971-2000

Table 7. Quantile classification of summer (JJA) precipitation totals in selected stations in Poland, 2001-2019

| Year | Station     | Szczecin | Wroclaw | Torun | Lodz | Suwalki | Lublin |
|------|-------------|----------|---------|-------|------|---------|--------|
| 2001 | -1          | +1       | +2      | +1    | +2   |         |        |
| 2002 | -1          | +1       | -1      | -1    | -1   |         |        |
| 2003 | -1          | -2       | -1      | -1    | -1   |         |        |
| 2004 | +1          | -1       | -1      | -1    | +2   |         |        |
| 2005 | -1          | -2       | -2      | -1    | +2   |         |        |
| 2006 | +1          | +1       | +1      | +1    | -1   |         |        |
| 2007 | +2          | +2       | +1      | +1    | +2   |         |        |
| 2008 | -1          | -2       | -1      | -1    | +1   |         |        |
| 2009 | +1          | +2       | +2      | +1    | +1   |         |        |
| 2010 | +1          | +1       | +2      | +1    | +1   |         |        |
| 2011 | +2          | +1       | +1      | +2    | +1   |         |        |
| 2012 | +1          | +1       | +1      | +1    | -1   |         |        |
| 2013 | +1          | +1       | +1      | +1    | -1   |         |        |
| 2014 | -1          | -1       | -1      | -2    | -2   | -2      | +1     |
| 2015 | -1          | -2       | -1      | -2    | -2   | -2      | -2     |
| 2016 | +2          | -2       | -1      | -2    | -2   | -2      | -2     |
| 2017 | +2          | +1       | +2      | +1    | +1   | +1      | -1     |
| 2018 | -1          | -1       | -1      | -2    | -1   | -1      | -1     |
| 2019 | -1          | -2       | -1      | -2    | -1   | -1      | -1     |

The time variability of the character of summer season precipitation at all analysed stations is quite similar. In 2001, the summer season was generally wet or extremely wet (Table 7). Stations located in northern Poland were characterised by a certain deviation from this rule. In Szczecin, the 2001 summer season was dry, and in Suwalki it was normal. In the period 2002-2008 summer seasons were alternately
normal or extremely wet. Only the summer season of 2007 was marked as generally wet or extremely wet. The 2009-2012 summer seasons were generally wet or extremely wet. The precipitation of the summer season 2013 was normal at almost all analysed stations. From 2014 onwards, the dominance of dry or extremely dry summer seasons is observed. The exception is the summer season of 2016 - generally normal in terms of precipitation and the summer season of 2017 - wet or extremely wet at all stations except for Lublin.

A similar course of precipitation character of summer seasons at the analysed stations is probably a result of the variability of atmospheric circulation [7,8], which, shaping the direction of air masses' advection, determines the amount of humidity in the atmosphere and the development of processes favoring the formation of precipitation or its absence.

2.4. Autumn precipitation

The 30% quantile, which determines the lower limit of normal rainfall in the autumn season, ranges from 85.9 mm in Torun to 110.5 mm in Suwalki. The upper limit of precipitation classified as normal was from 126.3 mm in Szczecin to 161.9 mm in Suwalki (table 8). In extremely dry seasons the sum of precipitation does not exceed 72.0 - 98.7 mm in Torun and Suwalki respectively. Extremely wet seasons are characterized by the sum of precipitation higher than 157.8 mm in Szczecin and 230.4 mm in Suwalki.

Table 8. The values [mm] of the 10th, 30th, 70th and 90th quantile of autumn (SON) precipitation totals in selected meteorological stations in Poland, 1971-2000

| Station  | 10% | 30% | 70%  | 90%  |
|----------|-----|-----|------|------|
| Szczecin | 75.35 | 95.33 | 126.30 | 157.75 |
| Wroclaw  | 73.59 | 93.56 | 137.78 | 168.26 |
| Torun    | 72.08 | 85.85 | 133.64 | 185.33 |
| Lodz     | 87.67 | 102.90 | 146.59 | 160.99 |
| Suwalki  | 98.69 | 110.42 | 161.96 | 230.34 |
| Lublin   | 69.89 | 101.43 | 146.68 | 194.13 |

In the 21st century, the autumn precipitation was characterized by the lowest dynamics of changes compared to the rainfall in the remaining seasons (table 9), especially at stations located in western and central Poland. In Szczecin, extremely wet and wet periods prevailed. There was also a six-year period (2011-2016) when autumn precipitation was classified as normal. In Wroclaw, wet periods intertwined with normal and dry periods. A longer period with normal rainfall of the autumn season fell on the years 2012-2015. In Torun, the autumn season was generally characterized by rainfall of normal sums according to the quantile classification, especially in the years 2003-2009 and 2012-2015. At the end of the analyzed period, autumn seasons at this station were characterized by rainfall of anomalous heights. In Lodz in the 21st century, normal autumn periods interweaved with periods of high or extremely high precipitation. There were also three autumn seasons with extremely low precipitation (2005, 2011 and 2014). The course of the precipitation character of autumn seasons at stations located in eastern Poland (Suwalki and Lublin) differs from that observed at stations located in western and central Poland. In Suwalki, normal rainfall in the autumn season dominated in the first decade of the 21st century. In the second decade, a predominance of wet and extremely wet seasons was observed. In Lublin in the 21st century, only four normal autumn seasons were recorded, nine seasons were classified as wet or extremely wet and six as dry or extremely dry.
Table 9. Quantile classification of autumn (SON) precipitation totals in selected stations in Poland, 2001-2019

| Year | Station       | Szczecin | Wroclaw | Torun | Lodz | Suwalki | Lublin |
|------|---------------|----------|---------|-------|------|---------|--------|
| 2001 |               | +2       | +1      | +1    | +1   | +1      | +1     |
| 2002 |               | +2       | +1      | +1    | +1   | +1      | +1     |
| 2003 |               |         | -1      |       |      |         |        |
| 2004 |               | -2       | -2      | -2    | -2   | -2      |        |
| 2005 |               | +1       | -2      | -2    | -2   | -2      |        |
| 2006 |               |         |         |       | +1   | -2      |        |
| 2007 |               |         |         |       |      |         |        |
| 2008 |               | +1       | -1      | -1    | +1   |         |        |
| 2009 |               | +2       | +1      | +2    | +2   | +1      |        |
| 2010 |               | +2       |         | -2    | -2   | -2      |        |
| 2011 |               |         | -2      | -2    | -2   | -2      |        |
| 2012 |               | +1       | +1      |       |      |         |        |
| 2013 |               |         |         | +1    | -1   |         |        |
| 2014 |               |         |         | -2    | -2   | -2      | -1     |
| 2015 |               | +1       |         |       | +1   |         |        |
| 2016 |               | +1       | +1      | +2    | +1   | +1      |        |
| 2017 |               | +2       | +1      | +2    | +2   | +2      | +2     |
| 2018 |               | -2       | -1      | -2    | -2   | -1      |        |
| 2019 |               | +1       | +1      |       | -1   |         |        |

The observed high frequency of autumn seasons with normal precipitation, especially in western and central Poland, indicates precipitation conditions in the 21st century similar to those prevailing in the years 1971-2000. According to [2], in all analysed stations, except Lublin, a statistically insignificant decrease in the sum of autumn precipitation in the years 1961-2008 was observed. Therefore, it is not strong enough to manifest itself in the increase in the frequency of dry or extremely dry autumn seasons in the 21st century. On the other hand, a high frequency of wet and extremely wet seasons in Lublin in the analysed period may be a confirmation of the increase in total precipitation in the autumn season indicated by [2] and [6] at this station.

2.5. Annual precipitation

The lower limit of annual rainfall totals classified as normal is 480.2 - 554.6 mm at Szczecin and Suwalki stations respectively, the upper limit ranges from 556.4 to 643.0 mm at the same stations (Table 10). The value of a 10% quartile of annual rainfall, which determines extremely dry years, ranges from 390.0 mm in Torun to 481.7 mm in Suwalki. Years with extremely high precipitation are those in which the annual sum of rainfall exceeds the value of 597.6 mm in Szczecin and 668.6 mm in Lublin.

In the first two decades of the 21st century, the prevalence of years with anomalous precipitation can be indicated (Table 11). In the years 2001-2002, normal or anomalously high precipitation prevailed, depending on the station. The period 2003-2006 was characterized by annual normal or below normal precipitation, especially in Wroclaw. In the years 2007-2013, an increased frequency of precipitation with anomalously high annual sums was recorded. In this period, the year 2010 was marked by extremely high precipitation at all analysed stations. From 2014 onwards, two-year periods alternating with shortage or excess of precipitation were observed. Therefore, it would be difficult to indicate the general direction of the trends in the changes in the precipitation character of the years at the analysed
stations. Therefore, the precipitation character of the years was determined more by the character of atmospheric circulation with a predominance of advection favouring excess or shortage of precipitation.

Table 10. The values [mm] of the 10th, 30th, 70th and 90th quantile of annual precipitation totals in selected meteorological stations in Poland, 1971-2000

| Station  | Quantile | 10%  | 30%  | 70%  | 90%  |
|----------|----------|------|------|------|------|
| Szczecin |          | 401.84 | 480.11 | 556.43 | 597.69 |
| Wroclaw  |          | 421.99 | 492.66 | 583.45 | 625.82 |
| Torun    |          | 390.01 | 449.00 | 574.91 | 613.13 |
| Lodz     |          | 426.74 | 502.73 | 581.76 | 650.61 |
| Suwałki  |          | 481.71 | 554.55 | 643.05 | 668.35 |
| Lublin   |          | 430.54 | 502.33 | 591.93 | 668.69 |

Table 11. Quantile classification of annual precipitation totals in selected stations in Poland, 2001-2019

| Year | Station | Szczecin | Wroclaw | Torun | Lodz | Suwałki | Lublin |
|------|---------|----------|---------|-------|------|---------|--------|
| 2001 | +1      | +2       | +1      | +1    | +1   |         |        |
| 2002 | +2      | -1       | -1      | +1    | -1   | -1      | -1     |
| 2003 | -2      | -2       | -1      | -1    | -1   | -1      | -1     |
| 2004 | -2      | -1       | -1      | -1    | +2   | +1      | +1     |
| 2005 | +2      | -1       | -1      | -1    | -1   |         | -1     |
| 2006 | +1      | +2       | -1      | -1    | -1   | -1      | -1     |
| 2007 | +2      | -1       | +2      | +1    | +2   | -1      | -1     |
| 2008 | +2      | -1       | +2      | +2    | +2   | +1      | +1     |
| 2009 | +2      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2010 | +1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2011 | -1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2012 | -1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2013 | +2      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2014 | +1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2015 | -1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2016 | -1      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2017 | +2      | +2       | +2      | +2    | +2   | +1      | +1     |
| 2018 | -2      | -2       | -1      | +1    | -1   | -1      | -1     |
| 2019 | -1      | -2       | -1      | -1    | -1   | -1      | -1     |

3. Conclusions

Precipitation is characterized by high variability from season to season and from year to year. In the winter season until 2007, a similar precipitation character is observed at all analysed stations with above-normal precipitation dominance. Since 2007, the spatial diversity of the precipitation character of winter seasons with increased dry season frequency in western Poland, the high variability of precipitation in particular years in central Poland, and prevalence of seasonal sums above the norm in eastern Poland are observed. The precipitation character of spring seasons in the 21st century was characterised by high
variability, especially at stations located in southern Poland. The most stable precipitation conditions were observed in this season in Suwalki. The precipitation character of summer seasons in the discussed stations is distinguished by their similar time variability. There are two sub-periods (2002-2006 and 2014-2018) with normal or dry conditions and the period 2007-2013 in with the frequency of summer wet seasons was higher. The spatial variation of the precipitation character of these seasons is much smaller. Autumn precipitation was characterized by the lowest dynamics of changes compared to precipitation in other seasons, especially at stations located in western and central Poland. Seasons with anomalous amounts of precipitation prevailed at stations located in eastern Poland, especially in the second decade of the 20th century. On an annual basis, there are no visible trends in the character of precipitation in the years. The periods of lower and higher precipitation, observed alternately in relation to the norm, refer to the changes observed in the summer season. This is probably due to the fact that in Poland the highest amount of precipitation is falling in the summer, reaching 34-40% of the annual total [2.6], hence it has the greatest impact on annual sums. The increase in annual precipitation totals in the years 1961-2008 in the northern and north-western parts of Poland, described by [2], and their decrease in the central and southern parts are not reflected in an increase in the frequency of wet and very wet years at stations in Szczecin and Suwalki and an increase in the frequency of dry and very dry years at other stations. The observed changes in annual precipitation totals from about -0.1mm⋅year^{-1} in Wroclaw to about +1.0mm⋅year^{-1} in Szczecin [2] do not affect the change in precipitation character of the year at individual stations.

References
[1] "IPCC Climate Change 2013. The Physical Science Basis", WMO, UNEP, Cambridge University Press, p. 1535, 2013.
[2] M. Marosz, R. Wójcik, D. Biernacik, E. Jakusik, M. Pilarski, M. Owczarek, M. Miętus, “Poland’s climate variability 1951–2008. KLIAMAT project’s results”, Prace i Studia Geograficzne, vol. 47, pp. 51-66, 2011, (in Polish).
[3] M. Miętus, J. Filipiak, M. Owczarek, E. Jakusik, “Rainfall variability on the Polish Baltic Sea coast in the light of quantitative rainfall classification,” IMWM Research Materials, Series: Meteorology, vol. 37, p. 59, 2005, (in Polish).
[4] Z. Kaczorowska, “Rainfall in Poland over a long-term cross-section,” IG PAS Geographic Works, vol. 33, p. 117, 1962, (in Polish).
[5] Sz. Mrugała, “Precipitation at normal and anomalous heights in Poland (1951-1990)”, UMCS Publisher, p. 194, Lublin, Poland, 2001, (in Polish).
[6] M. Czarnecka, J. Nidzgrodzka-Lencewicz, “Long-term variation of seasonal rainfall in Poland”, Water-Environment-Rural Areas, vol. 12 (2), p. 45-60, 2012, (in Polish).
[7] K. Kożuchowski, “Changeability of precipitation in Poland in the 20th and 21st century”, [in:] K. Kożuchowski (ed.): Scale, conditions and perspectives of contemporary climate change in Poland, Biblioteka Publishing House, p. 47–58, Lodz, 2004, (in Polish)
[8] A. Ziernicka-Wojtaszek, “Changeability of precipitation in Poland in the years 1971–2000”, [in:] J. Trepinska, Z. Olecki (ed.): Climatic aspects of geographical environment, Inst. Geogr. and Sp. Man. UJ, p. 139–148. Krakow, 2006, (in Polish).