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A comparison of the annual courses of the index of variability of circulation types: the example of the Hess-Brezowsky classification

Porównanie rocznych przebiegów wskaźnika zmienności typów cyrkulacji na przykładzie klasyfikacji Hessa-Brezowsky'ego

Key words: atmospheric circulation, Grosswetterlagen, Central Europe, low-pass filter, 30-dimension space, Manhattan metric

Słowa kluczowe: cyrkulacja atmosferyczna, Grosswetterlagen, Europa Środkowa, filtr dolnoprzepustowy, przestrzeń 30-wymiarowa, metryka Manhattan

INTRODUCTION

Research on the variability of weather conditions over the year has been carried out for many decades. Barry and Chorley (1992, p. 193) wrote that "many calendars of singularities have been compiled, [...] but the early ones [...] did not prove very reliable". These authors emphasized that investigations by Lamb for the British Isles and by Flohn and Hess for Central Europe were very successful.

Lamb (1950) spoke appreciatively about investigations made by "a number of German workers" in the field of the concept of singularities. He quoted publications by Schmauss, Flohn, Baur and Hess.

The Grosswetterlagen (GWL) conception was raised for several decades of the 20th century by Baur and afterwards was modified by Hess and Brezowsky (1952). Descriptions of this classification can be found both in articles (e.g. Gerstengarbe, Werner 1993, 1999, 2005) and in books (e.g. Barry, Perry 1973,

p. 122–131; a primer written by Yarnal 1993, p. 30–31). Some scientists claimed that the GWL catalogue is valid for the area between 30°W–45°E and 24°–70°N (see Barry, Perry 1973, p. 126). Yarnal (1993) emphasized that this classification focused on central Europe and may relate to all surface areas adjacent the Baltic and North Seas. GWL is classified like a subjective approach on a continental scale (Barry, Perry 2001, p. 549).

The features of the atmospheric circulation over central Europe were characterized on the basis of the GWL classification (e.g. Hess and Brezowsky 1952; van Dijk and Jonker 1985; Vysoudil 1987; Bardossi and Caspary 1990; Gerstengarbe and Werner 1993; 1999; 2005; Kaszewski and Filipiuk 2003). The GWL classification was even applied to analyses of climatic conditions concerning separate countries of the eastern part of Central Europe – Poland (Ustrnul and Czekierda 2001; Ustrnul 2006) and Estonia (Keevallik et al. 1999; Keevallik and Rajasalu 2000; Keevallik and Russak 2001), as well as e. g. the capital city of the Czech Republic (Kyselý 2002).

OBJECTIVE, MATERIAL AND METHODS

The aims of this paper are:

– to define the index of variability of circulation types (as the tool for the analysis of the day-to-day changes of the structure of circulation types),

– to compare the annual courses of this index calculated for the 1st and 2nd half of the 20th century.

The calendar of the GWL types from 1901 to 2000 was the input data for this paper. The Internet-accessible version of the calendar published in 2005 was used (Gerstengarbe and Werner 2005)[1].

In the present paper the following method was used to create the index of variability of circulation types. First, the frequency of occurrence of every type was counted for each of the 365 days.

The input data are prepared in the form of a 366×30 matrix (GWL classification consists of 30 types). There is the frequency of each type on each day of the annual cycle (e.g. the frequency sum for Jan 1st is 100%, for Jan 2nd also 100%, and so on). The frequency of the occurrence on Feb 29th is moved to Feb 28th and

[1] One can find some differences between the two versions of the published calendar data (Gerstengarbe, Werner 1999; 2005). They are the following: 2–7 April 1995 (publication 1999 type NWZ, publication 2005 – NWA), 23–26 April 1997 (publication 1999 – WZ, 2005 – WA), 11–17 February 1998 (1999 – WA, 2005 – NWA) and 5–7 May 1998 (1999 – WZ, publication 2005 – TM (5 May), U (6 May) and SWA (7 May)).

Mar 1st (50%/50%). The sum of the frequency of these 2 days is larger than 100%. The quasi-standardization for Feb 28th and Mar 1st was realized. The annual courses of the daily frequency of each type were smoothed by the filter. The low-pass filter for daily data proposed by von Storch and Zwiers (1999, p. 388) was applied. The 30-dimension space was then created (the dimension of space is equal to the number of circulation types in the Hess-Brezowsky classification). Then, the distances between every pair of days were counted in this space (the Manhattan metric was used), creating the distance matrix 365 × 365. The Manhattan metric does not provide such a large weight to the dimension in which the largest difference occurred between compared objects (days). An example and comparison of the use of the Manhattan and Euclidean metrics was published by Nowosad (1998, p. 21).

It turns out that (after using the low-pass filter) neighbouring days are the most similar to one another for all 365 days. The distance between neighbouring days received by means of this method after standardization was named the index of variability of circulation types.

A similar method was used for the analysis of the differentiation of circulation seasons (Nowosad 2007).

Test t was used for calculation of the significance of differences between the monthly and seasonal mean indices (derived for the first and second half of the 20th century).

RESULTS

The annual courses of the indices in the first as well as the second half of the 20th century were compared (Fig. 1).

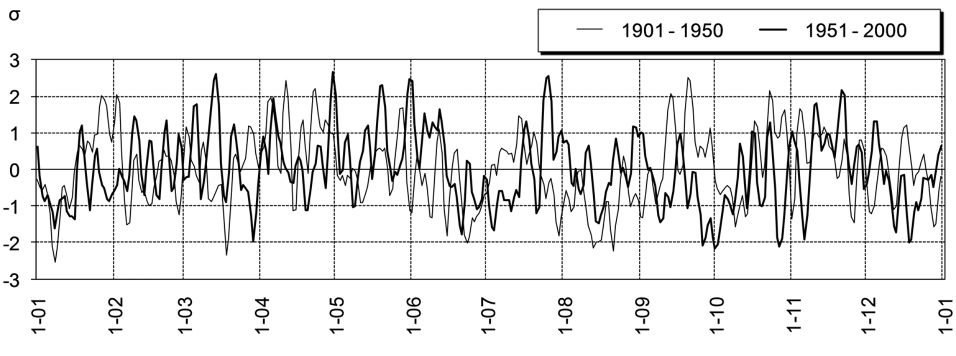

Fig. 1. The annual course of the Hess-Brezowsky Grosswetterlagen index of variability (ó – standard deviation)
Roczny przebieg wskaźnika zmienności typów Grosswetterlagen (σ – odchylenie standardowe)

The highest values of the index during the period 1901–1950 were reached on 20/21 Sept (2.5 σ), 11/12 Apr and 21/22 Sept (2.4 σ), and in the period 1951–2000 on 30 Apr/1 May (2.7 σ), 14/15 March (2.6 σ) and 26/27 July (2.5 σ).

The differences between the indices of 1951–2000 and 1901–1950 for individual days of the year were calculated. The highest values of the difference is at the turn of May to June (on 30/31 May and on 31 May/1 June they are above 3.5 σ). Some periods with high values of the difference are: from 10/11 to 22/23 of March (1.5 σ) and longer ones – 22/23 July to 6/7 Sept (1.2 σ), 28/29 Apr to 30 June/1 July (0.7 σ) and 8/9 Nov to 5/6 Dec (0.6 σ).

The lowest value[2] of the differences was for 19/20 Sept (–3.6 σ). Some periods with negative values of the difference were e. g. from 11/12 Jan to 4/5 Feb and from 7/8 Sept to 29/30 Oct (means –1.1 σ), from 1/2 to 21/22 July (–1.0 σ), from 23/24 Mar to 27/28 Apr and from 6 to 24 Dec (–0.9 σ).

The highest mean monthly value of this index for the period 1901–1950 was equal to 0,99 σ in April and the lowest one was –1,02 σ in August. The highest and lowest values for the period 1951–2000 were 0,57 σ in May and –0,61 σ in October (Fig. 2). The values for April, May and November were positive for both the 50-year periods.

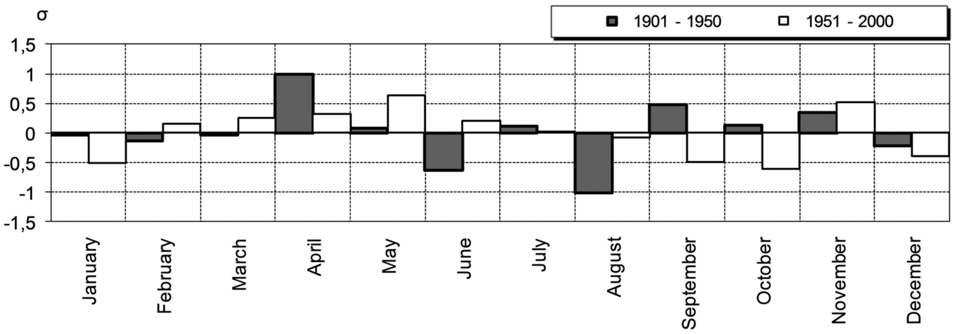

Fig. 2. The mean monthly values of the Hess-Brezowsky Grosswetterlagen index of variability (σ – standard deviation)
Średnie miesięczne wartości wskaźnika zmienności typów Grosswetterlagen (σ – odchylenie standardowe)

The significance of differences between the monthly mean indices (derived for the two periods) is important on the level α (equal at least to 0.02) for April, May, June, as well as for August, September and October. The significance of

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[2] If the difference is negative, the variability of structure of the types of circulation was greater in the first part of the 20th century than in the second one.

this difference for January is important on the level α equal to 0.065 and for other months the differences are not significant.

The mean season index values are positive for Spring (0.35 and 0.37 σ for 1st and 2nd part of the 20th century) and negative for Winter (–0.13 and –0.25 σ). The index of variability of circulation types achieves larger values for Spring and Autumn than for Summer and Winter. The mean values for Autumn were 0.32 σ (1901–1950) and –0.18 σ (1951–2000), as well as for Summer –0.51 σ and 0.02 σ. The significance of differences between the seasonal mean indices (derived for the two periods) is important on the level α equal to 0.00015 for Summer and 0.00101 for Autumn. In both cases the significance is on a very high level. Kalnicky (1987), while analysing circulation over the USA, found the most significant discontinuities in the annual regime of atmospheric circulation at the turn of August variability (the highest value between 31st August and 1st September).

The variability of structure of the GWL circulation types decreased in Autumn and grew up in Summer during the second half of the 20th century in comparison to the first half.

CONCLUSIONS

The analysis carried out by using the low pass filter for daily data and the Manhattan metric suggested that the variability of structure of the circulation types is greater in Spring and Autumn than in Summer and Winter. One can find a decrease of the index of variability of circulation types in Autumn, as well as an increase of it in Summer during the 20th century. The first conclusion is the confirmation of well known facts. On the other hand, the second conclusion (the differences of the index variability in Autumn and Summer) is the main result of this paper.

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STRESZCZENIE

Celem pracy jest zdefiniowanie wskaźnika zmienności typów cyrkulacji (jako narzędzia do analizy zmian z dnia na dzień wieloletniej ich struktury) oraz porównanie rocznych przebiegów tego wskaźnika w pierwszej i drugiej połowie XX wielu. Jako materiał wejściowy wykorzystano kalendarz typów cyrkulacji według typologii Hessa-Brezowsky'ego, dostępny w Internecie (Gerstengarbe, Werner 2005). Częstość występowania poszczególnych typów w poszczególnych dniach roku zestawiono w postaci macierzy 365×30. Następnie zastosowano filtr dolnoprzepustowy zaproponowany dla danych dziennych przez von Storcha i Zwiersa (1999, s. 388). Utworzono przestrzeń 30-wymiarową (bo tyle wynosi liczba typów w analizowanej klasyfikacji) i w niej obliczono odległości między poszczególnymi dniami cyklu rocznego za pomocą metryki Manhattan. Odległość w tej przestrzeni między sąsiednimi dniami (po standaryzacji) nazwano wskaźnikiem zmienności typów cyrkulacji. Przebiegi wskaźnika przestawiono na ryc. 1. Następnie dla każdego z 365 dni obliczono różnicę między wskaźnikami dla okresów 1951–2000 i 1901–1950. Największe wartości różnicy wystąpiły na przełomie maja i czerwca (ponad 3,5 σ), najmniejsze na przełomie II i III dekady września (–3,6 σ). Wartości wskaźnika są większe wiosną i jesienią w porównaniu do analogicznych wartości latem i zimą w czasie obu okresów pięćdziesięcioletnich. Sugeruje to większe zmiany struktury typów cyrkulacji z dnia na dzień w przejściowych porach roku. Zauważa się znaczny wzrost wskaźnika w XX wieku latem oraz jego spadek jesienią. Istotność statystyczna tych zmian średnich sezonowych wartości wskaźnika, określona za pomocą testu t, jest b. wysoka ($\alpha = 0{,}00015$ dla lata i $\alpha = 0{,}00101$ dla jesieni). O ile większe wartości wskaźnika potwierdzają znane ogólnie większe zróżnicowanie zmienności cyrkulacji atmosferycznej w przejściowych porach roku, to wskazanie sezonowych zmian wskaźnika latem i jesienią jest podstawowym wynikiem niniejszej pracy.