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CHANGES IN THE ATMOSPHERIC CIRCULATION TYPES OVER WESTERN UKRAINE IN THE 20th-21st CENTURIES

Changes in regional atmospheric circulation can reflect or cause climate change over several decades and centuries. These changes are linked to both the anthropogenic factor and the cyclical fluctuations of the atmospheric circulation centers in the North Atlantic, which are distinctively manifested in different parts of the European continent.

The study aims to identify changes of the atmospheric circulation types in the years of 1881–2017 at different time spans in Western Ukraine, where the manifestation of regional atmospheric circulation is like the circulating patterns over Central Europe.

For statistical analysis of regional circulation changes, a calendar of types of atmospheric circulation according to the Niedźwiedz T. classification, who identified 21 types of atmospheric circulation, was applied. The peculiarities are detected at the three-time spans (1881–1940, 1940–1970, 1970–2017) and compared to the course of air temperatures and precipitation in the seasonal and annual context.

In the period of 1881–2017, there was no clear trend in changes of anticyclonic or cyclonic types, although anticyclonic types are predominant in the year (over 75 % of all the years). At shorter intervals, changes in the ratio of anticyclonic and anticyclonic types correspond to some long-term changes in air temperatures and precipitation amounts (periods of 1881–1940, 1970–2017). Some periods with several years of deviation, such as the years of 1940–1970 and 1971–2017, are consistent with certain types of fluctuations in the North Atlantic Oscillation. The most evidenced is the increase in anticyclonic types of atmospheric circulation at the turn of the XX–XXI centuries corresponding to warming. More features in the temporal distribution of types of atmospheric circulation are observed in the seasonal context. In April – November, in 78 % of annual cases, the prevalence of anticyclonic weather was detected, but the predominance is much smaller (up to 16 %) than in terms of years. The anticyclonic type of wedge or high-pressure ridge (Ka) and the cyclonic type of the low-pressure trough (Bc) is invariably frequent in April – November. However, since the 1970s, an increase in anticyclonic types of the western sector (SWa, Wa, NWA) has been observed. In December – March, the number of anticyclonic types from the western sector has also increased. Instead, a decrease in the number of days with typical for the region cyclonic situations from the west and northwest has been detected. In terms of months, since the 1970s, the biggest changes were observed in December and January. In December, the number of anticyclonic types has increased, and in January the number of days with the western cyclonic type has decreased.

The multidecadal course of air temperatures and precipitation is associated with the changes in the ratio between the cyclonic and anticyclonic circulation types and NAO phases in three periods within 1881–2017. The changes and the peculiarities detected imply that the types of atmospheric circulation are appropriate to detect decadal climate changes in terms of seasons and months.

Keywords: types of atmospheric circulation, climate change, Western Ukraine, North Atlantic Oscillation.

Introduction. Climate change is the result of multi-level natural cycles and fluctuations enhanced by anthropogenic influence (IPCC, 2021; Lüdecke et al., 2013; Mokhov et al., 2012; Myhre et al., 2013). The complexity of these changes is related to the interpretation of the climate system through the interaction of dynamic physical processes of the atmosphere with different surfaces (Seip et al., 2019; Solomon et al., 2011; Terray, 2012). Accordingly, areas with a variety of the deeply cut surfaces in the midcontinent, show complex distribution of climatic indicators over time. Regional climate models show that the territory of Ukraine, in particular the western part, looks less apparent or different in the context of climate change (Kovats et al., 2015). Here, atmospheric circulation is considered as a factor and indicator of long-term climate variability (Walanus et al., 2021). The variability of atmospheric circulation types over Western Ukraine is reflected in the ratio of cyclonic and anticyclonic types. They are reflected in changes of the solar radiation intensity across decades, years, seasons, and months (Kholiavchuk, 2019). Several decades of increasing solar radiation intensity trends since the early 1980s in Europe are associated with changes in cloudiness and anthropogenic emissions (Pfeifroth et al., 2018). Therefore, the relevance of the research is related to the identification of short-term cycles in the distribution of types of atmospheric circulation and their characteristic features as a natural basis for climatic changes in the area.

Cycles are characteristic features of natural changes. However, due to the overlapping of several multidirectional natural and anthropogenic cycles with different characteristic times, attribution of cycles in the studies of climate change is treated differently. Changes in atmospheric circulation during the 20th century are linked to three periods of changes in global surface air temperatures: two periods of warming from the beginning of the 20th century to the mid-1940s and from the mid-1970s to the

present, and a period of relatively stable air temperatures between these two periods (Bartoszek, 2017; Martazinova et al., 2009). 11-year cycles of solar activity, 7-, 20-, 30-, and 50-70-year fluctuations of the multi-decadal North Atlantic Oscillation (NAO) are the main natural background for multidecadal climate fluctuations in Europe (Mann et al., 2020; Pfeifroth et al., 2018; Terray, 2012). The last century is a clear evidence of the prominent changes in air temperatures, though significant trends have not been confirmed in the distribution of atmospheric precipitation. The latter is explained by terrain features and atmospheric circulation (Cheval et al., 2014; Kynal & Kholiavchuk, 2016; Mokhov et al., 2012).

Dozen of classifications of atmospheric circulation types have been developed for regional analysis of climate changes over the last decades. They are divided into three large groups: subjective, mixed, and objective classifications (Huth et al., 2008). The classifications of the last two groups are considered more accurate, as they are based on the application of mathematical and statistical modelling of atmospheric parameters. However, the selection of atmospheric circulation types and the degree of their similarity remains subjective in such classifications (Cahynová & Huth, 2016; Lüdecke et al., 2013; Łupikasza, 2010). Furthermore, the dataset for these classifications is available only from the second half of the 20th century. Therefore, the study focuses on subjective classifications that have a long history of application, more than a century of data series and several studies for the European region carried out in the field (Dziedziewski & Monin, 1954; Girs, 1974; Hess & Brezowski, 1977; Lamb, 1972; Niedźwiedz et al., 2009). Among them, the classification of H. Lamb (1972), based on daily observations of atmospheric processes over the British Isles and calculations of six indices of the geostrophic flow of air masses, is considered fundamental

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(Lamb, 1972). Lamb's classification became the basis for the modified classifications of synoptic situations for the whole of Europe. The authors of such classifications distinguished synoptic types according to the air flow directions and coded the data accordingly. Previous studies in similar regions show a variety of possible classifications for Central and Eastern Europe, without giving preference to any of them (Cahynová & Huth, 2016; Lüdecke et al., 2013; Łupikasza, 2010; Łupikasza, 2016; Niedźwiedz et al., 2009). Hence, in this study, climatic changes are interpreted using the subjective classification of T. Niedźwiedz (1981, 2019), tested in the author's previous studies, covering a period of more than a century and fitting to the Carpathian area (Kholiavchuk & Cebulka, 2019).

The study aims at identifying patterns and features of changes in atmospheric circulation as a factor and

indicator of climate changes during 1881–2017 at different time spans in Western Ukraine.

Materials and methods. The modified Lamb's classification developed by the Polish climatologist T. Niedźwiedz (Niedźwiedz, 1981) was used in the study. The classification represents the analysis of the 500 mb synoptic maps collected over a 137-year period of meteorological observations in Central and Eastern Europe. As a result, 20 circulation types and one with undefined direction are distinguished for Southern Poland (Table 1). The circulation patterns according to this classification are congruent to the prevailing types of circulation effecting Western Ukraine, with the exception of Transcarpathia, given the influence of the Carpathian Mountains (Kholiavchuk & Cebulka, 2019; Łupikasza et al., 2010; Twardosz et al., 2010).

Table 1. Types of atmospheric circulation according to T. Niedźwiedz (Niedźwiedz, 2019)

Anticyclonic types:		Cyclonic types:	
Na	North (direction of air masses advection, geostrophic wind)	Nc	North
NEa	North–East	NEc	North–East
Ea	East	Ec	East
SEa	South–East	SEc	South–East
Sa	South	Sc	South
SWa	South–West	SWc	South–West
Wa	West	Wc	West
NW	North–West	NWc	North–West
Ca	central anticyclone situation (high centre)	Cc	central cyclonic, centre of low
Ka	anticyclonic wedge or ridge of high pressure	Bc	trough of low pressure (different directions of air flow and frontal system in the axis of trough)
x	unclassified situations or pressure col		

To determine the temporal features and trends in the distribution of various circulation types over the region, the period from 1881 to 2017 was analysed. The year of 1881 was chosen as the starting point. The reason for this is the availability of data from several weather stations in Western Ukraine (Chernivtsi, Kolomyia, Lviv, Uzhhorod) since 1881 that enables to compare average annual air temperatures and annual precipitation amount with circulation types. The climatological analysis was carried out at different time spans according to the course of climate variables and the NAO phases.

Results. In general, during 1881–2017, the annual predominance of anticyclonic circulation types in the area is revealed. They prevailed in more than 75 % of the years (fig. 1). The predominance of cyclonic types was detected for the first time in 1915 and 1916, although it was 2% and 1%, respectively. On the contrary, in 1918 and 1919, the number of anticyclonic types per year exceeded 75%, which are the highest values during the whole period. These years coincide with the NAO negative phase and anomalous Arctic warming (Osborn, 2011). Years with a significant predominance of anticyclonic types were often accompanied by significant droughts (Kholiavchuk & Cebulka, 2019).

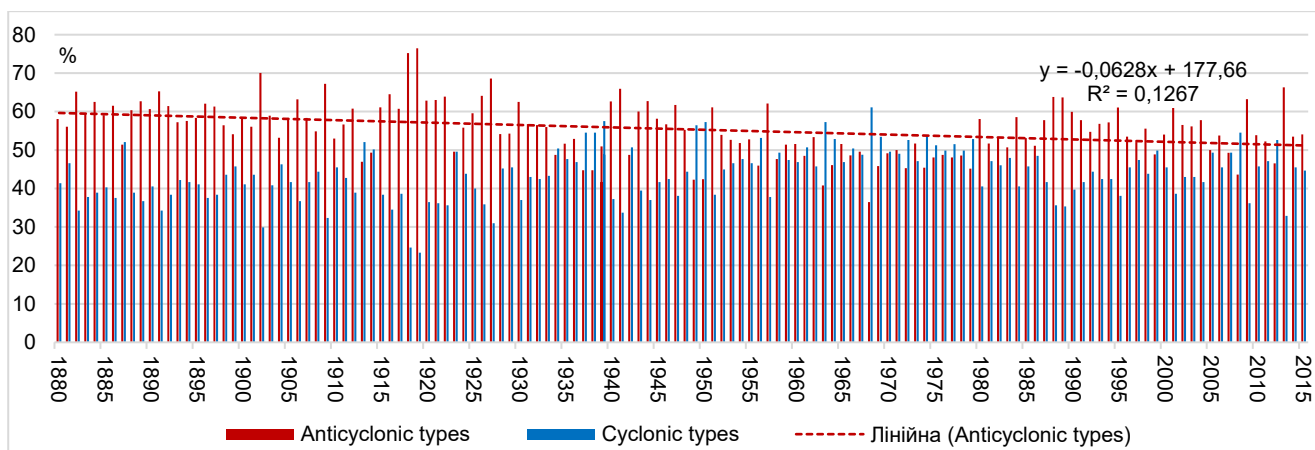


Fig. 1. The percentage of days with anticyclonic and cyclonic types of atmospheric circulation and the linear trend in the number of days with anticyclonic types during 1881–2017

Though the frequency of anticyclonic types tends to decrease over the entire study period, it is not statistically significant. This is indicated by the high percentage annual values of the anticyclonic days in 2009 (63 %) and in 2013 (65 %). No apparent cycles in the annual number of

anticyclonic or cyclonic days were also found. Therefore, for further analysis, the period of 1881–2017 is divided into smaller time spans according to precipitation or temperature trends that are detected in the author's previous study (Kynal & Kholiavchuk, 2016).

The first period from 1881 to 1940 corresponds to the increase in the annual precipitation. That is congruent to a decrease in the annual number of days with anticyclonic types, although this trend is significant at 95 % confidence level (fig. 2A). Apparent deviations from general course are detected in some years like in 1918 and 1919. These years also refer to the end of the 40-year NAO cycle. On the other hand, in the next period from 1941 to 1970, when a decrease in the annual amount of atmospheric precipitation was

detected, a statistically significant negative trend (99 % confidence) in the annual number of anticyclonic days is found (fig. 2B). Besides, this period is marked as a time of transition to a new North Atlantic Oscillation phase (1943–1975) (Seip et al., 2019). During the last period since 1971, when there is no apparent trend in the temporal distribution of the annual precipitation, there is a tendency towards an increase in the recurrence of anticyclonic types (95-percent confidence).

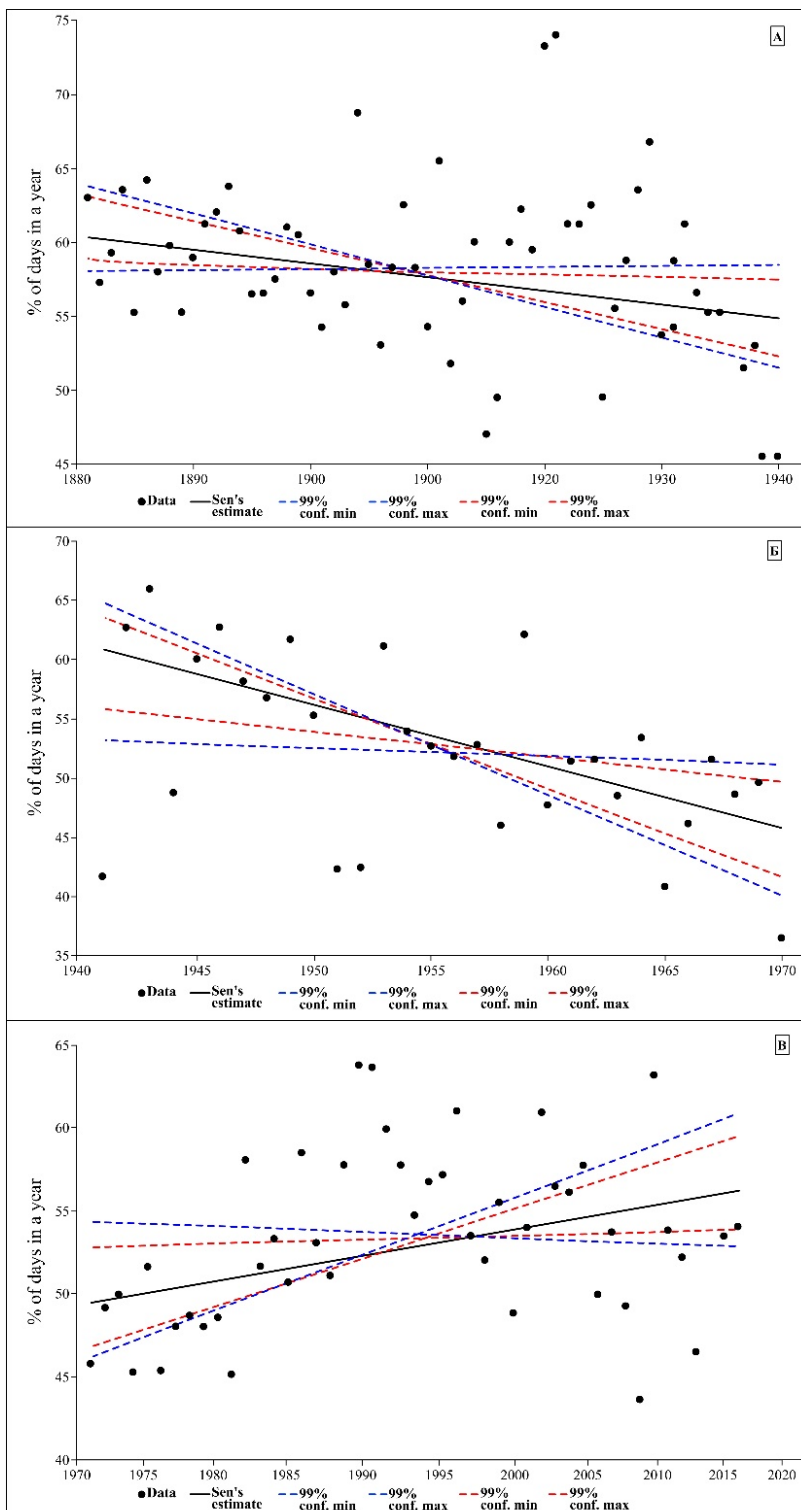


Fig. 2. Trends (according to the Mann-Kendall method) of annual number of days with anticyclonic circulation types at different time spans (in % of days in a year): A – 1881–1940, B – 1941–1970, C – 1971–2017

Finally, the longer period associated with the annual air temperature decrease in Western Ukraine (1881–1987) corresponds to the most significant decrease in the annual number anticyclonic days (99.9-percent confidence). Accordingly, temporal changes in the predominance of anticyclonic or cyclonic circulation types mainly reflect multi-decadal temperature changes in the area. Therefore, the next step in the research, given the strong seasonality

in the region, involves the analysis of seasonal changes in circulation types.

In the seasonal context, specific features for the months of the warm and cold period were revealed. Given the typical set of synoptic patterns, their temporal distribution, and the warming trend in the last decades in the area, two periods in a year are distinguished: December – March, April – November (*Kynal & Kholiavchuk, 2016; Niedźwiedz et al., 2009; Spinoni et al., 2015; Walanus et al., 2021*).

Рік	Na	NEa	Ea	SEa	Sa	SWa	Wa	NWa	Ca	Ka	Nc	NEc	Ec	SEc	Sc	SWc	Wc	NWc	Cc	Bc	x
1970	10	8	12	3	11	2	13	8	9	22	8	5	4	5	10	9	36	28	8	18	11
1971	15	9	11	8	12	7	15	7	16	22	8	3	12	7	9	8	19	15	6	35	0
1972	9	5	22	10	10	1	12	6	17	13	21	6	10	2	7	7	21	18	5	32	8
1973	5	15	5	4	7	8	17	10	17	33	9	6	12	6	4	5	24	19	3	31	2
1974	7	3	10	9	7	9	8	4	13	25	14	8	9	6	5	15	16	22	17	24	12
1975	13	12	17	8	13	4	4	4	11	37	9	11	22	6	4	9	11	13	3	27	5
1976	9	6	4	6	11	6	10	6	4	48	13	9	14	11	8	10	15	14	1	32	3
1977	7	4	7	7	12	6	18	6	7	44	9	7	9	2	5	8	30	14	8	31	1
1978	5	7	7	2	3	3	26	12	16	49	8	4	7	5	4	3	23	25	4	23	5
1979	4	6	22	10	4	8	14	11	9	42	2	3	8	10	5	7	28	12	1	34	1
1980	1	11	9	2	2	5	19	6	10	37	7	15	10	3	4	9	31	16	1	34	8
1981	4	11	12	8	5	8	16	6	4	39	11	6	4	5	7	13	33	13	2	27	10
1982	8	11	10	7	5	11	15	5	11	49	5	7	5	3	7	15	28	7	1	29	11
1983	6	14	9	5	7	7	25	11	5	37	9	6	1	4	6	19	18	21	2	25	6
1984	5	9	9	7	10	9	20	19	1	30	6	3	7	9	12	14	28	14	0	29	4
1985	7	8	4	11	2	13	23	17	4	37	7	3	1	6	5	8	38	19	0	29	2
1986	14	8	10	7	6	14	27	10	5	42	7	8	3	1	6	15	13	7	2	33	4
1987	7	10	4	11	3	14	22	14	5	29	4	4	3	8	8	13	32	5	1	41	6
1988	5	13	10	13	10	11	27	20	6	31	7	1	0	4	2	8	18	17	0	39	2
1989	17	10	10	11	8	11	16	11	2	31	13	5	3	5	6	9	18	15	3	36	4
1990	15	4	1	3	4	11	20	27	7	52	3	3	3	5	4	7	31	13	1	24	5
1991	8	14	7	14	3	9	27	20	4	36	6	7	4	4	6	16	15	10	1	24	7
1992	7	12	9	7	7	14	19	11	5	40	3	4	9	6	3	17	27	7	1	34	2
1993	6	3	19	21	14	7	16	20	4	27	2	2	5	4	7	17	20	8	0	38	2
1994	6	16	11	9	3	10	14	16	5	44	5	1	5	6	6	16	22	10	1	33	4
1995	9	20	9	9	1	22	8	11	8	45	4	4	1	5	4	11	12	21	4	31	4
1996	7	13	12	7	3	13	13	16	4	32	9	13	4	14	8	18	10	10	1	35	2
1997	12	13	11	12	7	6	8	22	4	36	15	4	2	4	8	12	11	18	4	27	7
1998	2	11	5	16	4	8	17	9	1	31	6	5	1	9	8	14	31	20	5	33	7
1999	12	20	13	13	7	8	21	9	6	25	8	5	0	7	10	17	18	12	1	28	4
2000	4	4	11	13	9	10	18	13	3	39	3	2	5	5	21	18	8	12	2	39	5
2001	5	12	5	4	6	9	22	12	4	38	11	10	2	4	7	15	20	16	0	37	2
2002	6	9	14	17	6	3	14	4	5	39	7	3	11	13	17	17	12	6	2	35	3
2003	16	8	19	7	9	17	11	15	7	30	7	1	4	5	9	6	22	11	3	33	3
2004	10	11	12	9	5	15	18	17	5	36	2	2	4	7	8	8	26	13	1	32	3
2005	14	8	16	12	13	13	6	14	6	40	4	3	7	4	2	11	22	7	1	33	6
2006	9	6	10	9	13	10	19	8	5	45	4	1	2	2	5	19	26	12	0	32	4
2007	9	4	13	5	1	12	20	21	3	35	2	3	5	7	8	9	28	21	0	37	3
2008	6	10	9	8	3	14	25	4	4	37	5	12	8	5	6	15	19	8	1	35	6
2009	4	7	9	13	15	9	22	10	5	33	4	8	11	8	6	8	20	10	1	37	3
2010	7	9	10	13	5	12	10	5	4	28	15	9	4	11	12	9	20	15	0	38	7
2011	10	9	6	16	18	11	28	18	11	30	8	6	2	5	8	3	13	13	1	25	3
2012	4	7	8	11	11	22	16	15	10	16	6	3	8	10	7	10	24	10	1	42	3
2013	11	15	7	17	7	14	11	23	9	20	9	10	9	5	9	16	16	16	2	28	3
2014	4	7	3	21	12	16	7	9	5	18	5	9	14	22	12	11	11	11	0	34	4
2015	8	12	18	19	9	15	20	13	9	31	4	2	5	10	5	12	15	10	0	20	6
2016	7	10	12	7	8	9	16	22	6	34	4	8	9	11	5	14	5	10	3	37	7
2017	7	6	5	11	10	13	24	24	5	22	7	4	1	2	4	16	18	18	3	40	8

Fig. 3. The number of days with certain types of atmospheric circulation in April – November during 1970–2017

In April – November, in the period of 1881–2017, the predominance of the anticyclonic types in 78% of cases was found. Still, the prevalence is much smaller (up to 16 %) than in the annual context. The highest recurrence of cyclonic types was observed in 1974 and accounted for 56 % of all the types in the warm half of the year (fig. 3). Cyclonic types prevailed in the catastrophically rainy year of 2010. In contrast, in 2015, when extreme drought was observed over most of Europe (*Ionita et al., 2017*), anticyclonic types were predominant (63 % of all cases). The most recurrent circulation type refers to high-pressure ridges (Ka) and low-pressure troughs (Bc). However, since the 1970s, which are highlighted in a separate diagram (Fig. 3), an increase in the frequency of western anticyclonic types (SWa, Wa, NWa) has been observed. The combination of these types causes the development of blocking anticyclones and is the main reason for the onset of meteorological droughts (*Semenova,*

2017). Such periods were repeatedly recorded both in the last century and in the current one, not only in the steppe regions of Ukraine, but also in the west of Ukraine, like in Central and Eastern Europe in general.

The largest deviations in the number of anticyclonic days were observed in December – March during 1881–2017. In some years, like 1970, there were very few of them – 25 % of all the types in the cold season. In the other years, like 1918 or 1998, they were dominant – more than 72 % of all the types. The year of 1918, as mentioned earlier, was a year with a significant predominance of anticyclonic types. At the same time, considering the seasonal context, it is obvious that it was in the months of 1918 that the dominance of these types was decisive for the entire year, as evidenced by the pronounced negative phase of the NAO in the period from December to March (fig. 4).

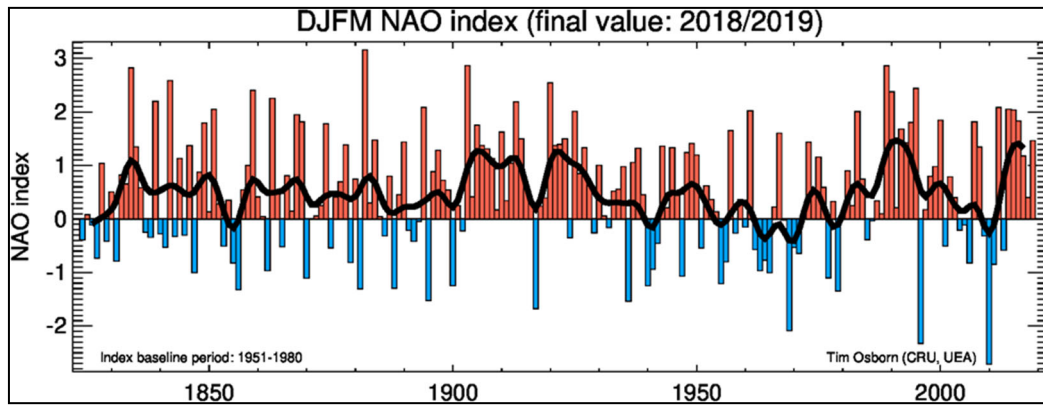


Fig. 4. Seasonal (December-March) values of the North Atlantic Oscillation index (updated from Osborn (2011))

The frequency of western anticyclonic circulation types (SWa, NWa) in December-March has increased since the 1970s (fig. 5). On the other hand, the number of days with cyclonic situations from the west and northwest (Wc, NWc) that are characteristic of the area has decreased. The most pronounced decrease (99 % confidence) in the number of cyclonic days in these months since 1970 refers to the

western cyclonic type, which often brings heavy snowfall in Western Ukraine. In addition, this trend is most apparent in January, which is usually a wet month. December has become drier in the flat and low-mountainous part of the northeastern Carpathian macroslope (Cebulska & Kholiavchuk, 2022). The latter is associated with the increase in the frequency of blocking western anticyclones.

Pk	Na	NEa	Ea	SEa	Sa	SWa	Wa	NWa	Ca	Ka	Nc	NEc	Ec	SEc	Sc	SWc	Wc	NWc	Cc	Bc	x
1970	1	2	4	6	3	2	5	3	2	2	4	3	8	2	5	11	29	10	6	10	3
1971	3	1	7	3	2	3	11	5	3	5	6	6	6	5	8	11	13	14	1	3	5
1972	1	2	2	22	20	7	3	2	11	0	0	1	6	10	16	5	6	3	1	2	2
1973	3	0	5	4	13	0	11	9	3	10	6	4	0	2	6	5	14	13	2	6	5
1974	1	0	5	15	18	9	5	1	2	8	1	0	3	3	7	4	19	10	1	7	2
1975	2	4	2	2	1	9	17	8	5	11	3	1	5	5	4	5	15	8	0	10	4
1976	2	2	2	11	10	3	9	1	0	13	4	2	3	4	3	4	17	12	3	13	4
1977	1	2	2	6	11	1	9	3	3	17	1	2	1	3	7	10	14	11	8	5	4
1978	2	0	4	2	5	3	9	2	3	13	4	4	7	6	10	7	21	6	0	8	5
1979	1	1	5	6	5	3	11	1	3	8	5	1	0	10	9	14	19	10	0	7	2
1980	1	4	11	12	5	2	10	3	1	21	0	2	6	0	4	4	19	6	1	6	4
1981	0	5	2	7	4	5	6	4	0	13	3	3	6	4	0	12	27	5	2	10	3
1982	4	3	7	9	1	5	2	4	8	23	2	5	1	3	2	4	21	2	1	6	1
1983	5	5	2	0	2	3	21	8	3	8	3	2	5	1	2	6	26	10	0	6	3
1984	4	3	25	12	8	4	7	3	0	7	2	3	1	4	3	10	12	1	0	11	2
1985	4	2	2	8	5	1	8	4	4	16	4	1	2	3	6	8	18	5	1	11	8
1986	2	3	10	19	4	5	10	3	0	10	1	0	3	2	0	8	18	8	0	11	4
1987	2	6	14	0	4	2	11	8	3	20	0	4	3	4	4	9	9	8	1	6	3
1988	2	2	1	2	5	2	10	5	1	9	1	0	2	4	4	14	24	8	0	24	2
1989	0	0	2	6	1	4	41	12	8	7	1	0	0	0	0	14	16	1	1	6	1
1990	5	0	5	3	5	8	36	10	2	11	1	1	1	0	4	9	11	4	0	4	1
1991	5	5	5	5	3	6	17	10	7	21	1	0	0	3	3	3	10	3	0	11	3
1992	4	4	1	7	0	9	19	16	8	18	1	1	0	1	1	6	8	6	1	9	2
1993	2	3	5	6	1	6	23	3	7	13	2	3	3	1	0	6	20	7	2	5	3
1994	0	0	7	10	1	8	18	3	4	11	1	0	2	1	1	10	23	5	0	13	3
1995	4	0	11	10	4	5	8	1	2	17	0	1	1	2	0	15	17	6	1	14	2
1996	4	2	11	32	8	5	3	4	4	14	2	2	5	1	4	5	3	1	1	9	2
1997	7	0	5	5	2	7	24	14	6	17	4	2	2	5	1	2	8	2	0	7	1
1998	5	5	3	3	3	10	30	10	3	15	3	1	0	0	1	4	17	4	0	3	1
1999	2	6	7	0	0	10	18	6	2	3	0	4	0	2	2	16	22	8	0	13	0
2000	4	2	0	1	1	13	21	13	5	15	3	0	0	3	1	4	15	6	0	14	1
2001	3	5	8	6	4	3	5	9	4	10	3	2	2	3	5	18	7	9	0	8	7
2002	3	5	6	5	3	10	21	6	3	16	1	1	0	2	0	4	25	5	0	4	1
2003	9	3	10	2	4	7	16	2	4	24	5	3	2	2	2	8	9	1	0	7	1
2004	7	4	4	3	5	5	14	5	5	14	7	1	3	1	3	10	15	4	1	9	2
2005	6	0	3	6	2	4	21	6	2	9	5	4	8	3	3	2	11	12	2	11	1
2006	4	3	7	3	0	6	10	15	6	20	1	3	0	2	2	16	6	1	2	13	1
2007	2	4	5	5	2	5	8	8	0	18	1	1	0	3	1	5	23	9	2	17	2
2008	5	0	3	7	4	10	21	10	1	10	0	0	2	0	4	9	13	11	1	10	1
2009	3	5	3	3	0	1	6	9	0	18	7	2	7	5	7	11	2	7	0	18	7
2010	1	1	7	10	6	3	8	9	0	6	4	5	4	7	8	9	9	5	0	14	5
2011	5	0	8	7	0	8	19	10	3	10	1	1	1	5	1	13	11	4	0	11	3
2012	7	1	12	10	3	2	17	9	3	11	5	1	0	2	1	6	9	12	0	10	1
2013	2	5	6	6	1	7	14	6	3	3	2	20	9	11	3	6	9	8	1	6	2
2014	0	4	11	10	8	5	8	2	3	6	2	0	2	9	3	16	10	9	0	8	2
2015	2	2	4	9	2	9	28	4	5	7	2	3	5	2	4	5	6	5	0	11	3
2016	4	4	3	6	0	3	20	6	5	9	3	2	3	5	5	9	12	7	0	12	2
2017	2	7	5	6	1	4	11	14	2	10	0	1	1	0	1	8	11	5	0	21	2

Fig. 5. The number of days with certain types of atmospheric circulation (Niedzwiedz (2019) in December – March during 1970–2017

Conclusions. Regional atmospheric circulation is one of the defining markers of climate changes, reflecting both changes in the heat balance of different surfaces and NAO

fluctuations. The area of Western Ukraine with a deeply cut terrain, being the most strongly influenced by the global western atmospheric circulation in Ukraine, is an interesting

example to investigate the atmospheric circulation variability impact on climate change. To distinguish temporal changes in the distribution of atmospheric circulation types over Western Ukraine, a calendar of atmospheric circulation types according to the T. Niedźwiedz classification, which has been tested and is suitable for the studied region, was used. During 1881–2017, smaller time spans (1881–1940, 1940–1970, 1970–2017) were studied, which are characterized by differences in the course of annual air temperatures and precipitation. Periods with several years of deviation, such as 1940–1970, 1971–2017, correspond to the NAO phase. However, in the annual context, trends in the percentage ratio of days with anticyclonic or cyclonic types are hardly noticeable. On the other hand, the increase in anticyclonic types at the turn of the XX–XXI centuries is in good agreement with temperature changes.

The temporal distribution of atmospheric circulation types in warm and cold periods indicates regional features in a better way. The periods of April – November from 1881 to 2017 are characterized by a higher frequency of days (78 % of all years) with anticyclonic circulation than the ones of December – March. Still, such a predominance in December – March is significantly lower (up to 16 %) than in the annual context. During these months, in some years, a significant predominance of cyclonic types (up to 73 %) is observed. However, there is less of such days in most years than anticyclonic days. In the warm period of the year, there is a predominance of the recurrence of days with the dominance of high-pressure ridges (Ka) and low-pressure troughs (Bc). An increase in the frequency of days with western anticyclonic circulation types (SWa, Wa, NWA) has been observed since the 1970s, which is consistent with changes in the NAO cycles. This feature is also characteristic of the warm period. In the cold season, a decrease in the number of days with cyclonic situations from the west and northwest typical for the area was also found. Starting from the 1970s, the most apparent changes in the monthly distribution of atmospheric circulation types were found in December and January.

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ЗМІНИ ТИПІВ АТМОСФЕРНОЇ ЦИРКУЛЯЦІЇ НАД ЗАХІДНОЮ УКРАЇНОЮ У ХХ–ХХІ СТ.

Зміни регіональної атмосферної циркуляції відображають і спричиняють кліматичні зміни кількадесятилітніх та столітніх періодів. Ці трансформації пов'язують як із антропогенним чинником, так і з циклічними коливаннями центрів дії атмосфери у Північній Атлантиці, що специфічно виявляють себе у різних частинах європейського континенту.

Дослідження спрямоване на виявлення таких змін упродовж 1881–2017 рр. у різних часових зрізах на теренах Західної України, де виявляється регіональної атмосферної циркуляції схожий до циркуляційних патернів над Центральною Європою.

Для статистичного аналізу часових змін регіональної атмосферної циркуляції використано календар типів атмосферної циркуляції за класифікацією Т. Niedźwiedz, яким виділено 21 тип атмосферної циркуляції. Особливості визначені у трьох часових проміжках (1881–1940, 1940–1970, 1970–2017) у розрізі сезонів і місяців та здійснене порівняння з ходом температур повітря та атмосферних опадів.

Упродовж усього періоду 1881–2017 рр. не виявлено чіткої тенденції у змінах кількості антициклоніальних чи циклоніальних типів, хоча переважаючими у році (понад 75 % від усіх років) є антициклоніальні типи. На менших часових проміжках трансформації у співвідношенні циклоніальних й антициклоніальних типів відповідають багаторічним змінам температур повітря й кількості атмосферних опадів (1881–1940, 1970–2017). Періоди з кількالیтнім відхиленням (1940–1970, 1971–2017) узгоджуються з певними фазами Північноатлантичного коливання (NAO). Найвиразнішим є збільшення днів з антициклоніальними типами атмосферної циркуляції на межі ХХ–ХХІ ст. Більше особливостей у часовому розподілі типів атмосферної циркуляції помічено у сезонному контексті. Упродовж квітня – листопада у 78 % випадків виявлено переважання антициклоніальної циркуляції, проте перевага значно нижча (до 16 %), ніж у розрізі років. Частими у квітні – листопаді є дні із синоптичними ситуаціями домінування баричного гребеня (Ka) та баричної улоговини (Bc). Однак із 1970-х років зросла кількість днів із західними антициклоніальними типами (SWa, Wa, NWA), особливо у холодний період. Натомість виявлено зниження кількості днів з типовими для регіону циклоніальними ситуаціями із заходу й північного заходу. У розрізі місяців із 1970-х років найбільші зміни помічені у грудні та січні. У грудні збільшилось антициклоніальних типів, а у січні зменшилась кількість днів із західним циклоніальним типом.

Зміни співвідношення циклонічних та антициклонічних типів атмосферної циркуляції вказують на зв'язок з ходом температур повітря та атмосферних опадів і з фазами Північноатлантичного коливання у виділені періоди. Означені зміни свідчать про придатність використання типів атмосферної циркуляції для виявлення кількадесятилітніх кліматичних змін у розрізі сезонів і місяців.

Ключові слова: типи атмосферної циркуляції, кліматичні зміни, Західна Україна, Північноатлантичне коливання.