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VARIABILITY OF THE ATMOSPHERIC CIRCULATION ABOVE CENTRAL EUROPE IN THE LIGHT OF SELECTED INDICES

Abstract: The study presents variability of different circulation indices above Central Europe for the long period 1873, September–2000, February. For that purpose some synthesis in the materials dealing with the frequencies of 21 different circulation types had to be done. The results have been obtained using the simple circulation indices P (progression or W – westerly zonal), S (southerly meridional), C (cyclonicity) as proposed by R. Murray and R. Lewis with further modifications. The author calculated these indices for the year and the particular seasons. The most important is the W index. For the investigated area its mean value reaches 119. The largest intensity of the westerly flow was observed during 3 periods: 1891-1904, 1924-1932 and from 1983 to 1994. The highest annual values were noticed in 1990 (245) and in 1899 (239). The negative values which point the prevalence of the easterly advection frequency have been notified only in: 1963 (-41), 1972 (-7) and 1996 (-18). That index is very well correlated with the winter temperature. The W index is very well correlated with the most important for Europe, North Atlantic Oscillation (NAO) index.

Key words: Central Europe, circulation indices, Westerly zonal index, North Atlantic Oscillation.

1. Introduction

The atmospheric circulation is the most important natural factor strongly influencing the weather and climate of the temperate zone. Its role in the change of the contemporary climate conditions seems to be much more significant than any other factor, including anthropogenic impact. The study presents variability of different circulation indices above Central Europe for the long period 1873, September-2000, February. For that purpose some synthesis in the materials dealing with the frequencies of 21 different circulation types had to be done. The results have been obtained using the simple circulation indices P (progression or W – zonal westerly), S (meridional southerly), C (cyclonicity) as proposed by R. Murray and R. Lewis (1966). The author

calculated these indices for the year and the particular seasons. Variations of the westerly zonal index (W) above Central Europe were compared with the North Atlantic Oscillation (NAO) index changes.

2. Data and Methods

Investigated area covers the part of Central Europe centred in surroundings of Cracow (grid point 50°N and 20°E) with radius ca 200 km. The study based on the mesoscale of original calendar of circulation types (Niedźwiedź 1981, 2000) has been prepared with the help of the available synoptic maps of Europe: Polish (1922-1938, 1952-1997), Austrian and German (*Europäischer Wetterbericht* 1976-2000; *Tägliche Wetterbericht* 1873-1995), and especially with published in 1945 US Weather Bureau historical map series of the Northern Hemisphere (Historical Weather Maps 1899-1950). Twenty circulation types have been distinguished. The advection directions are marked by the capital letters while the anticyclonic situations by the subscript a and the cyclonic ones by subscript c; for example, Wa and Wc denote the anticyclonic and cyclonic situations respectively, with the air advection from the West. Thus, there are 16 circulation types with definite directions of the air masses. The other 5 situations are non-advection: Ca - centre of anticyclone, Ka - anticyclonic wedge, Cc - centre of cyclone, Bc - cyclonic trough, and x – pressure colls and situations which cannot be classified. This classification is similar to H. Lamb types (1972) and based on methods described in the most important works in synoptic climatology (Barry, Perry 1974; Yarnal 1993).

The calendar of circulation types (1873-2000) was used to estimate the changes of atmospheric circulation over Central Europe. For that purpose some synthesis in the materials dealing with the frequencies of 21 different circulation types had to be done. The results have been obtained using the simple circulation indices: zonal westerly circulation W index, similar to P progression index, index of southerly meridional circulation - S, and index of cyclonicity - C, as proposed by R. Murray and R. Lewis (1966) with some modifications. The author calculated these indices for each year, season and month.

W index was calculated by summation of daily scores ascribed to selected directions of air flow: +2 for W, +1 for NW and SW, -2 for E, –1 for NE and SE, and 0 for other synoptic situations. Thus, the relatively high positive value of W index informs about strong westerly air flow above Central Europe, negative one – means the zonal, but easterly air flow. Other scores were used for calculation of the meridional southerly index (S): +2 for S, +1 for SE and SW, -2 for N, -1 for NE and SE, and 0 for other types. Relatively high value of S index means the strong air flow from the southern sector, while the negative one – prevailing advection of air masses from the northern part of the horizon. Cyclonicity index (C) was calculated by summation of the following numbers: +2 for cyclonic situations Cc and Bc, +1 for other cyclonic situations and –2 for anticyclonic patterns Ca and Ka and –1 for other anticyclonic types. Thus positive values means the domination of cyclonic types above the anticyclonic one during the particular period.

Long-term variability of the W index is the most important for Central Europe and was elaborated for the standard seasons and in annual periods, by using the smoothing of the curves with the 11-year moving averages. For comparison with the atmospheric processes above Western Europe, the North Atlantic Oscillation (NAO) index was used. The monthly data of this index was applied for the period 1821-1997 from P.D. Jones et al. (1997) and CRU (2000), extended up to March 2000 (Osborn et al. 1999; CRU 2000).

3. Zonal Westerly Index (W) and its Relation to North Atlantic Oscillation (NAO)

The most important for climatological investigations seems to be the W index (Niedźwiedź 1978, 1993a, b, 1996). For Central Europe its mean value reaches 119 (Tab. 1). The largest intensity of the westerly flow was observed during 3 periods (Fig. 1): 1891-1904, 1924-1932 and from 1983 to 1994. The highest annual values were noticed in 1990 (245) and in 1899 (239). The negative values which point the prevalence of the easterly air flow frequency have been notified only in: 1963 (-41), 1972 (-7) and 1996 (-18). That index is very well correlated with the winter temperature (Niedźwiedź 1993a; Niedźwiedź et al. 1994). The W index is very good correlated with the most important for Europe, North Atlantic Oscillation (NAO) index, defined as the function of the normalised pressure difference between the Azores High and the Icelandic Low (Hurrel 1995; Hurrel, van Loon 1997), or between the Gibraltar and Southwest Island pressure (Jones et al. 1997; Osborn et al. 1999). Its importance for creation of climate conditions for different parts of Europe is well documented (Chen et al. 1999; Hurrel 1995; Hurrel et al. 1996; Jönsson et al. 1994; Kożuchowski et al. 1988; Kożuchowski 1993; Makrogiannis et al. 1991; Malberg et al. 1997; Rodwell et al. 1999).

Tab. 1. Average and extreme values of the zonal westerly index – W for the selected normal periods.

Period	Annual	Winter	Spring	Summer	Autumn
1873-1900	130	40	6	43	43
1901-1930	122	43	5	43	32
1931-1960	121	40	11	33	36
1961-1990	105	37	5	22	41
1991-1999	118	53*	10	19	37
1874-1999	119	41**	7	34	38
Maximum	245	119	60	94	116
Year	1990	1988/1989	1945	1919	1899
Minimum	-41	-49	-47	-36	-19
Year	1963	1946/1947	1984	1972	1920

*- data for the period of 1991-2000
** - data for period of 1874-2000

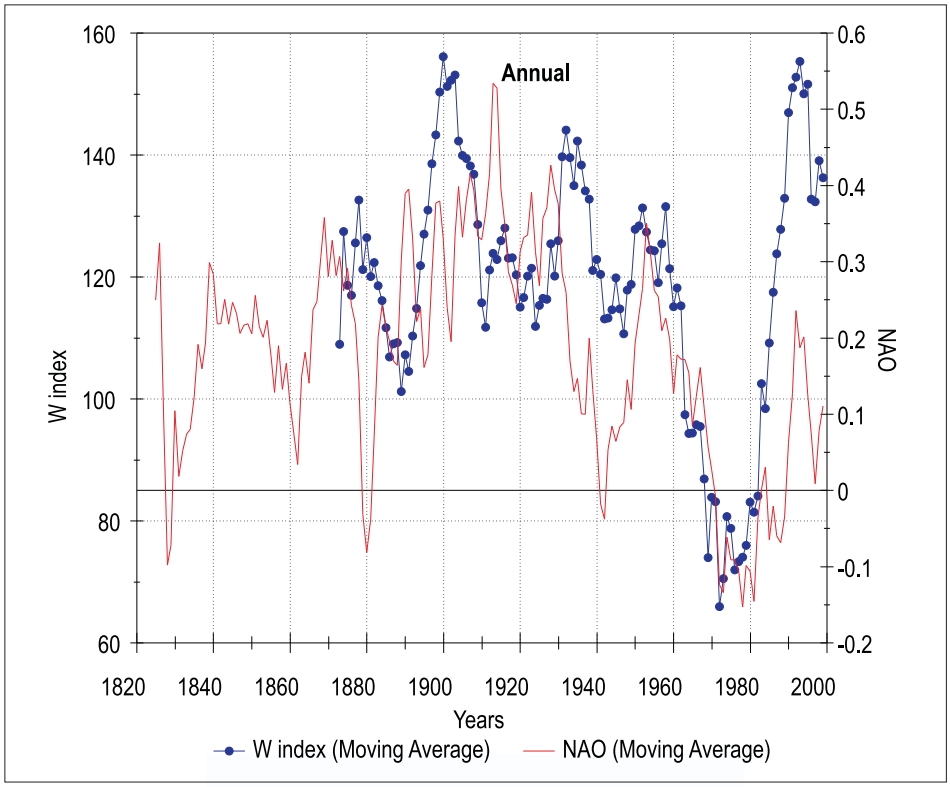

Fig. 1. Long-term variation of the annual zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1880-1999. The 11-year moving averages assigned to the end of the averaging period.

The highest value of NAO index was observed in winter, and negative one – in autumn (Tab. 2). Long-term variation of annual values is from –1.13 in 1996 to 1.70 in 1868. The smoothed curves are very similar to variability of W index in Central Europe (Fig. 1). The great changes can be noticed after 1960, with very low indices in 1968-1970, and sudden jump to very high values in 1990.

The best coincidence of the both indices was observed in winter (Fig. 2). During this season the influence of the strong zonal air flow is the most important for Europe, especially in 1910-1935 and nowadays after 1989. Period of very weak influence of Atlantic Ocean for the climate of Central Europe occurred near 1971. During the spring (Fig. 3) the large fluctuations were typical. The greatest difference between the W index and NAO took place between 1930 and 1945. In summer (Fig. 4) the decreasing trend of the both indices was typical. But after 1985 W index in Central Europe increased again, while the NAO stabilised on a relatively low level. In autumn (Fig. 5) the courses of the both indices were quite different. W index was relatively

Tab. 2. Average and extreme values of the North Atlantic Oscillation (NAO) index for the selected normal periods; calculated after the data of P.D. Jones et al. (1997) and CRU (2000).

Period	Annual	Winter	Spring	Summer	Autumn
1871-1900	0.22	0.41	-0.11	0.85	-0.37
1901-1930	0.34	0.98	0.29	0.54	-0.42
1931-1960	0.13	0.30	0.02	0.28	-0.09
1961-1990	0.01	0.26	0.02	-0.17	-0.05
1991-1999	-0.04	1.12	-0.00	-0.52	-0.67
1874-1999	0.17	0.53	0.07	0.30	-0.23
1821-1999	0.17	0.52	0.06	0.40	-0.30
Maximum	1.70	3.21	2.36	3.81	2.05
Year	1868	1924/1925	1868	1836	1830
Minimum	-1.13	-2.33	-1.87	-2.35	-3.42
Year	1996	1916/1917	1971	1995	1842

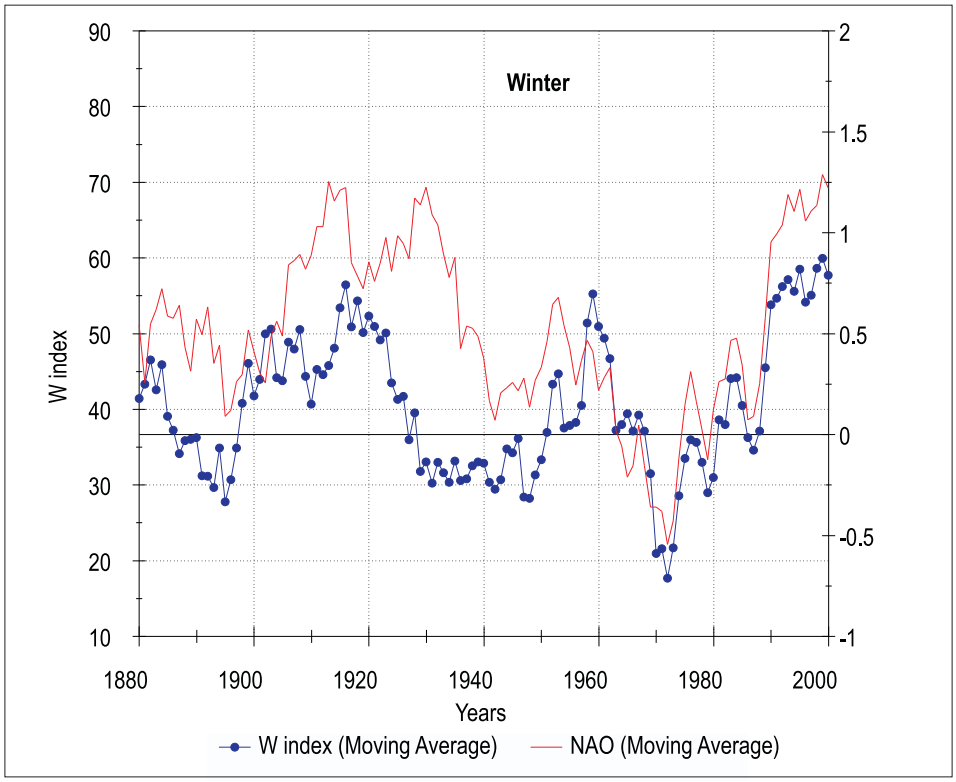

Fig. 2. Long-term variation of the winter zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1880-2000. The 11-year moving averages assigned to the end of the averaging period.

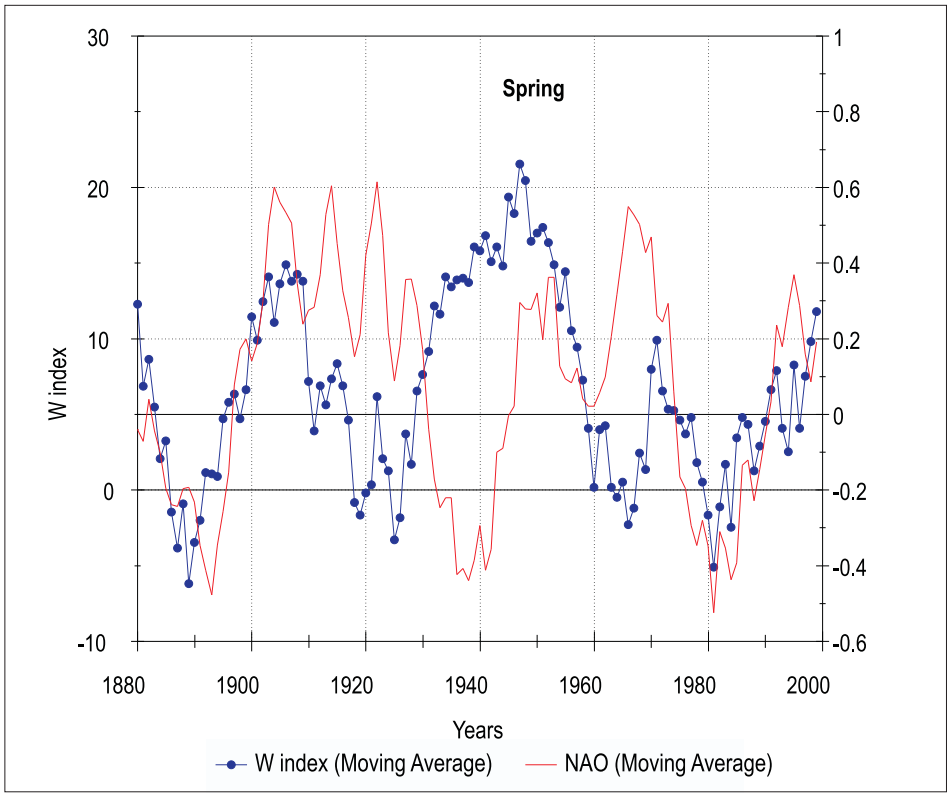

Fig. 3. Long-term variation of the spring zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1880-1999.
The 11-year moving averages assigned to the end of the averaging period.

high, while NAO was negative with irregular fluctuations. Only winter values of the both indices are well correlated (r=0.60) with significance level less than 0.1% (Fig. 6).

4. Other Indices: Meridional Southerly (S) and Cyclonicity (C)

Variability of the S index oscillated a little less than the previous one. Generally the highest intensity of the southerly advection was observed during the 1920-1940 but highest values of the index reached 100 in 1960 and 99 in 1951. Before 1920 the negative values of this index (prevailing of the northern advection), with minimum -99 in 1899, appeared. The second such period occurred in 1940-1949 (-57 in 1945) and the third one after 1980. Especially the year 1997, with the catastrophic flood

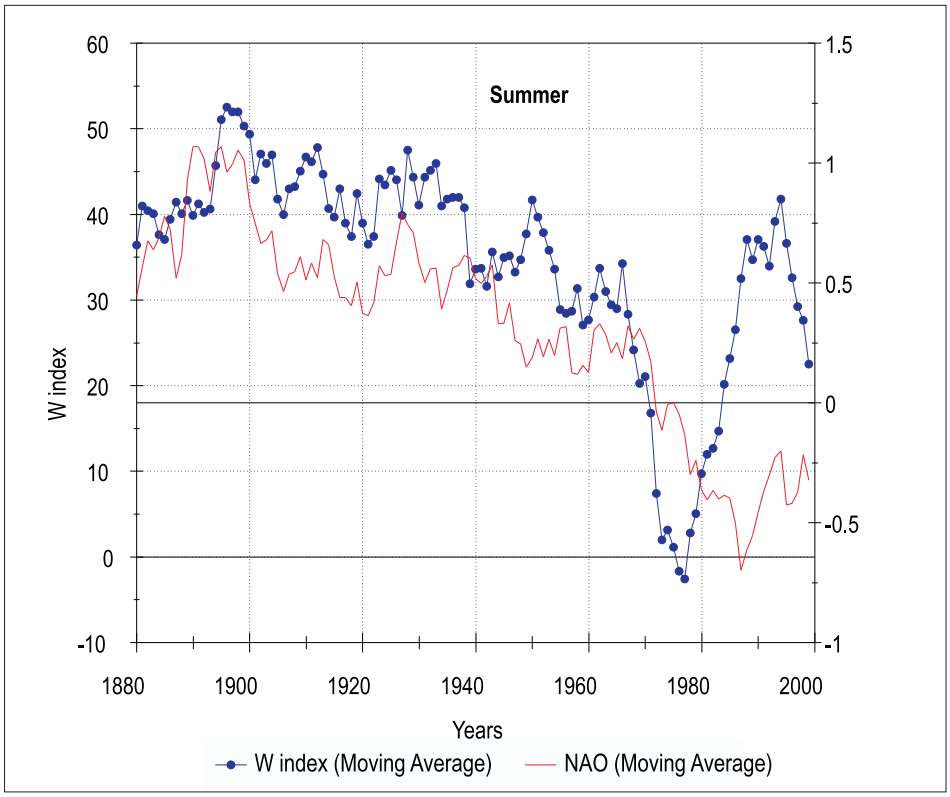

Fig. 4. Long-term variation of the summer zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1880-1999. The 11-year moving averages assigned to the end of the averaging period.

conditions in Central Europe, was distinguished by the low S index value (-63). The further reconstruction of the S index is also possible by using the pressure data for the stations on longitudinal profile between Prague and Lvov.

Central Europe area is under more frequent anticyclonic influences than cyclonic. It can be seen in the negative average value of the C index (-60). Its minimum occurred in 1921 (-228) when the highest frequency of the anticyclones has been observed over Central Europe. However in the period 1965-1975 the analysed index was positive with the relatively large maximum in 1970 (102). After 1975 the distinct decreasing trend was observed (e.g. -142 in 1990 and -101 in 1997). Cyclonicity index together with the S index play the important role in the origin of the orographic precipitation causing the flood situation over the Alps, Carpathians and Sudety Mountains (Niedźwiedź 1993b).

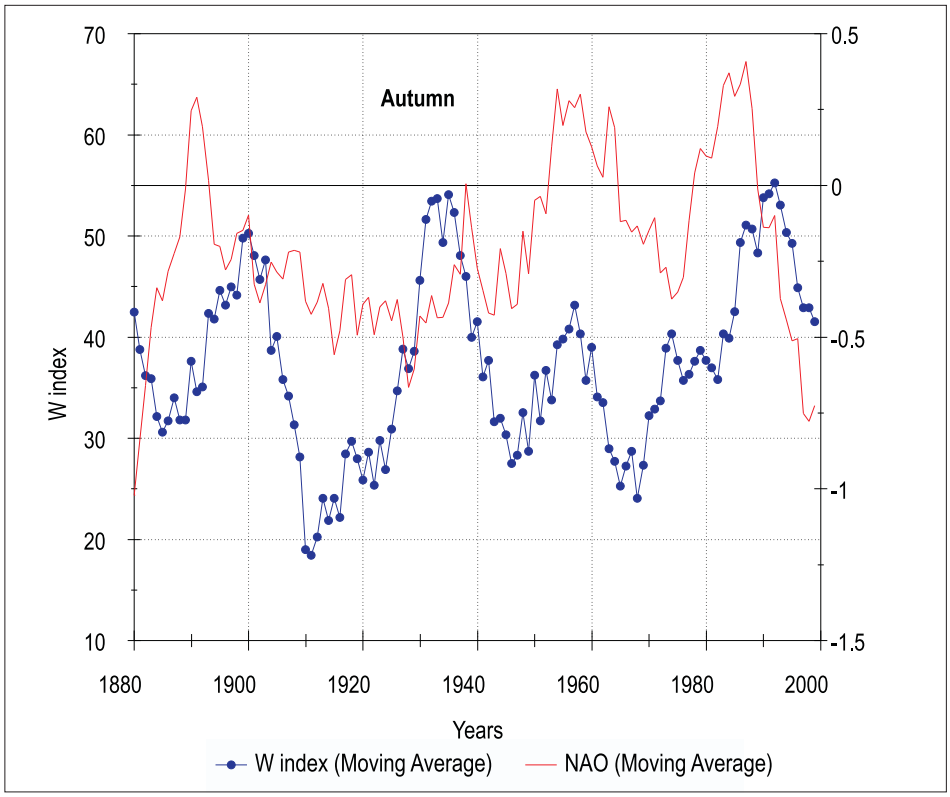

Fig. 5. Long-term variation of the autumn zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1880-1999. The 11-year moving averages assigned to the end of the averaging period.

5. Results

The results are comparable with those for the whole latitudinal zone of Atlantic and European sector of the Northern Hemisphere, between 35-55°N (Makrogiannis et al. 1991), as well as for the zone of 35 – 65°N (Kożuchowski 1993; Ustrnul 1997). The highest contrasts in the annual course can be observed between winter and spring seasons. During this first season the westerly zonal circulation is the most intense. During the late spring there is a rapid change and the westerly flow is the weakest, and very often in May it changes to the opposite - easterly flow. Also in the mentioned month the meridional indices of circulation reach the highest values. The further reconstruction of the new zonal W index for Central Europe is also possible by using the pressure data for the stations on latitudinal profile between Stockholm and Cracow.

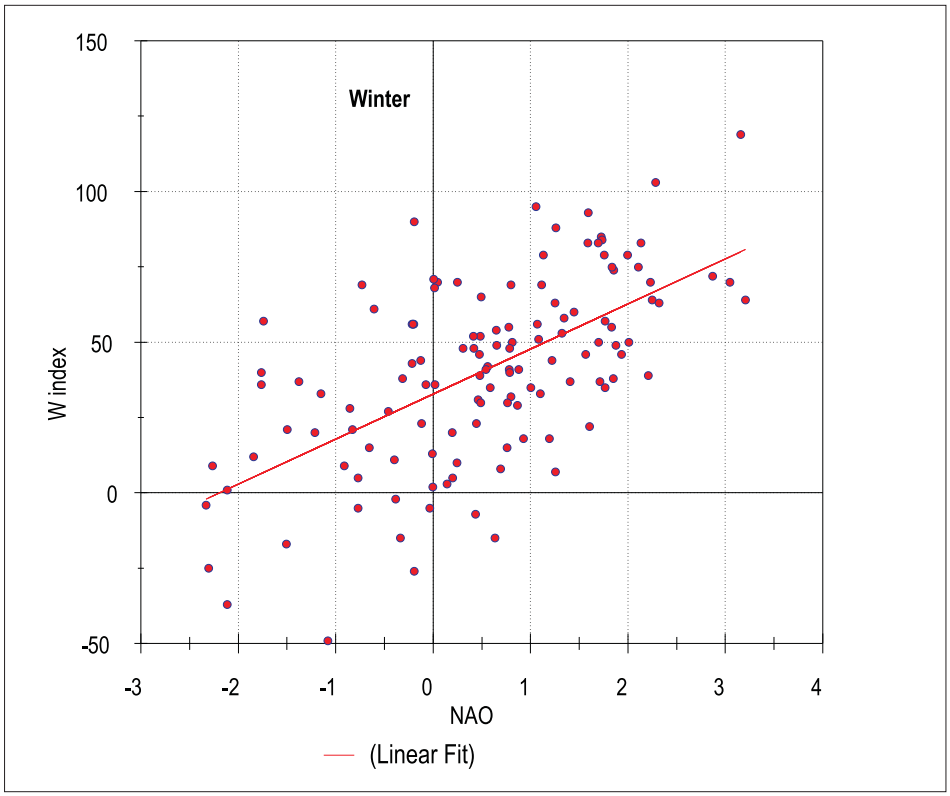

Fig. 6. Correlation between the winter zonal westerly index (W) above Central Europe and North Atlantic Oscillation (NAO) index for the period of 1874-2000. The regression line calculated by using the least square method of estimation:

W = 33 + 14.95*NAO; standard error of estimation = +-24; r^2 + 0.36 (significant on 0.1% level).

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