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VARIABILITY OF THE ICELANDIC LOW AND THE AZORES HIGH IN JANUARY AND THEIR INFLUENCE ON CLIMATIC CONDITIONS IN POLAND

Abstract: The study analysed long-term changes and the variability of the Icelandic Low and the Azores High in January and their influence on thermal, precipitation and nival conditions in Poland in the period 1901–2000. There were no statistically significant (0.05) trends of analysed centres of action in January in the 20th century. However, in the second half of the century the center of the Icelandic Low in January moved northwards and the sea-level pressure in the center of the Azores High increased significantly. The latter change was the reason for the significant increasing difference between the Azores High and the Icelandic Low. This change caused the intensification of western advection over Europe. Changes in sea-level pressure in the Icelandic Low and the longitude of the Azores High in January explain about 40% of temperature and snow cover variability in Poland. The variability of some features of the centres of action describes the changes of precipitation and snow cover in Poland better than the NAO index.

Key words: climate change, atmospheric circulation, Icelandic Low, Azores High, Poland, winter

Introduction

This study analysed long-term changes and the variability of the Icelandic Low (Ice) and the Azores High (Azo) in January and their influence on climatic conditions in Poland in the period 1901–2000 (1954–2000). The variability of the centres of action of the atmosphere (CAA) has been analysed by e.g. Sahsamanoglou (1990); Mächel et al. (1998) and Hasanean (2004). A strong correlation was found between the latitude of the Ice and sea-level pressure in the center of the Azo (Mächel et al. 1998). Higher than usual difference between the Azo and the Ice is accompanied by warming in northern and central Europe (Kapala et al. 1998). The Azo in winter is influenced by the sea surface temperature in tropical part of the Northern Atlantic (Hasanean 2004). The influence of the CAA on climatic conditions in different regions of the world has also been investigated (Zhang et al. 1995; Kapala et al. 1998; Katsoulis et al. 1998; Gong and Ho 2002). Katsoulis et al. (1998) found that the anticyclonicity of the western part of southern Europe and the Mediterranean is in relation to the intensity of Azo, while the eastern part of that area is under the influence of the Siberian High. In Poland such research are not fully displayed.

Data and method

The geographical longitude (x1 for Ice, x2 for Azo), latitude (y1 for Ice, y2 for Azo) and the atmospheric pressure value (z1 for Ice, z2 for Azo) in the centers of each CAA were read in maps of mean monthly sea level pressure: 1) by Lamb and Johnson (1966) for the period 1901–1960 and 2) based on the gridded 2.5° x 2.5° data of the Reanalysis Project of the National Centers for Atmospheric Research for the period 1951–2000. For the reading of CAA features in maps it was assumed that both CAA are oceanic and cannot be situated above a land area (except for Iceland). Moreover, if two or more baric centers were found in the area of the occurrence of the Ice or Azo, the one which was counted was that which was located closer to the mean multi-year location. The data for the period common to the two sources (1951–1960) turned out to be very similar in both bases. The homogeneity of all series was controlled by using the SNHT Single Series test in the AnClim program (Štepanek 2006), paying particular attention to the year of the data source change (1951). No series revealed an inhomogeneity in the period 1901–2000.

Also investigated was the dependence on individual features and on complex of features of centers of action of the mean air temperature (in 14 meteorological stations), precipitation and snow cover (in 41 stations) in Janu-

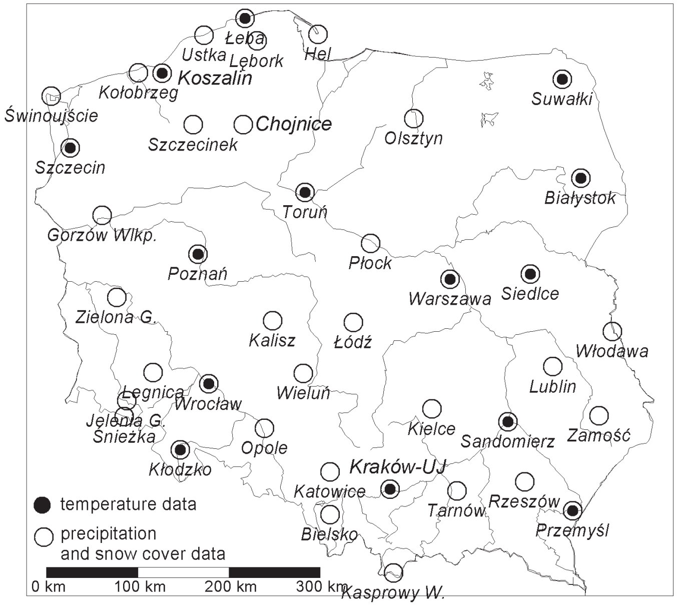

Fig. 1. Location of meteorological stations used in the study

ary in Poland for the period 1954–2000 (1901–2000 for Kraków) (Fig. 1). The main climatic data sources were Roczniki Meteorologiczne, Codzienny Biuletyn Meteorologiczny IMGW, Globalsod base, Global Daily Summary, Monthly Climatic Data for the World, World Weather Records. The inhomogeneities in 2 precipitation series (Sandomierz and Białystok) and in a few snow cover series were removed.

The following methods were used in the investigation:

– simple regression for detecting long-term trends of CAA,
– simple and multiple regression and correlation for the investigation of the influence of CAA on climatic conditions in Poland,
– time-lagged analysis to check the possibility of medium-time forecasting of the temperature and precipitation conditions,
– canonical analysis for the description of climatic conditions in Poland by the simultaneous action of the CAA features.

Results

Variability and changes of the centres of action of the atmosphere

The mean (1901–2000) locations of CAA in January are 31°W, 60°N for Ice and 27°W, 33°N for Azo (Table 1, Fig. 2). In particular years the locations were enclosed in fields: 57°W-20°E and 42°N-80°N for Ice and 70°W-13°E and 22°N-48°N for Azo. Year-to-year variability of the respective features of Ice and Azo are similar for both CAA: the standard deviation is 16–17° for the longitude, 6° for the latitude and 4–6 hPa for the sea-level pressure in the center of CAA. The distance between both centres is about 3000 km for the mean location and it varied from ca. 2000 km in 1918 to nearly 6000 km in 1979. The pressure gradient of Azo-Ice is about 1.1 hPa/100 km for the mean values and it varied from 0.2 hPa/100 km in 1979 to 1.5 hPa/100 km in 1974.

None of the investigated long series (1901–2000) of CAA revealed statistically significant trends. However, in the second half of the 20th century an increasing trend (statistically significant at the level of 0.05) of the latitude of the Ice and of the sea-level pressure in the center of the Azo was observed (Fig. 3). The center of Ice moved northwards by an average of 1.3° latitude every 10 years. Air pressure in the center of Azo increased by an average of 1 hPa every 10 years. The latter change was the reason for the significant (0.05) increasing tendency of the difference between the Azo and Ice (w1).

Table 1 Characteristics for Ice and Azo features in January (1901 – 2000). Denotations: std – standard deviation; other denotations – see in text

CAA	Icelandic Low			Azores High		
feature	x1	y1	z1	x2	y2	z2
average	-31	60	992	-27	33	1025
maximum	20	80	1007	13	48	1034
minimum	-57	42	975	-70	22	1017
std	16	6	6	17	6	4

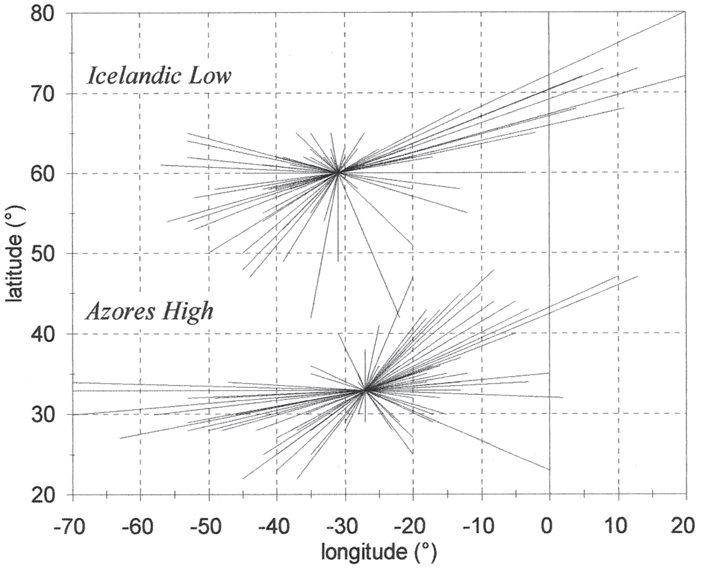

Fig. 2. Deviations of the location of CAA in particular years from the mean location in 1900–2000 (January)

CAA and the mean air temperature in January

The variability of mean air temperature in January in the second half of the 20th century is best described by multiple correlation coefficient including two independent variables: z1 and y2 (Fig. 4). The coefficient is above 0.6 throughout the whole area of Poland (except for the mountains). In northern Poland the changes in temperature are explained in above 40% by z1 and y2 variability. There are also strong correlations between air temperature and w1 and z2 (strongest in north-western Poland).

The mean air temperature averaged for the whole of Poland could be described by the following multiple regression model (all components of the equation are statistically significant):

$$\textbf{Temp Poland} = -0.1887 \cdot z1 + 0.2376 \cdot y2 + 176.882$$

R^2 adjusted for the number of degrees of freedom = 0.39

Statistically significant correlations are observed in all stations between z1, w1 in January and the temperature in February, March and mean for Dec-Feb.

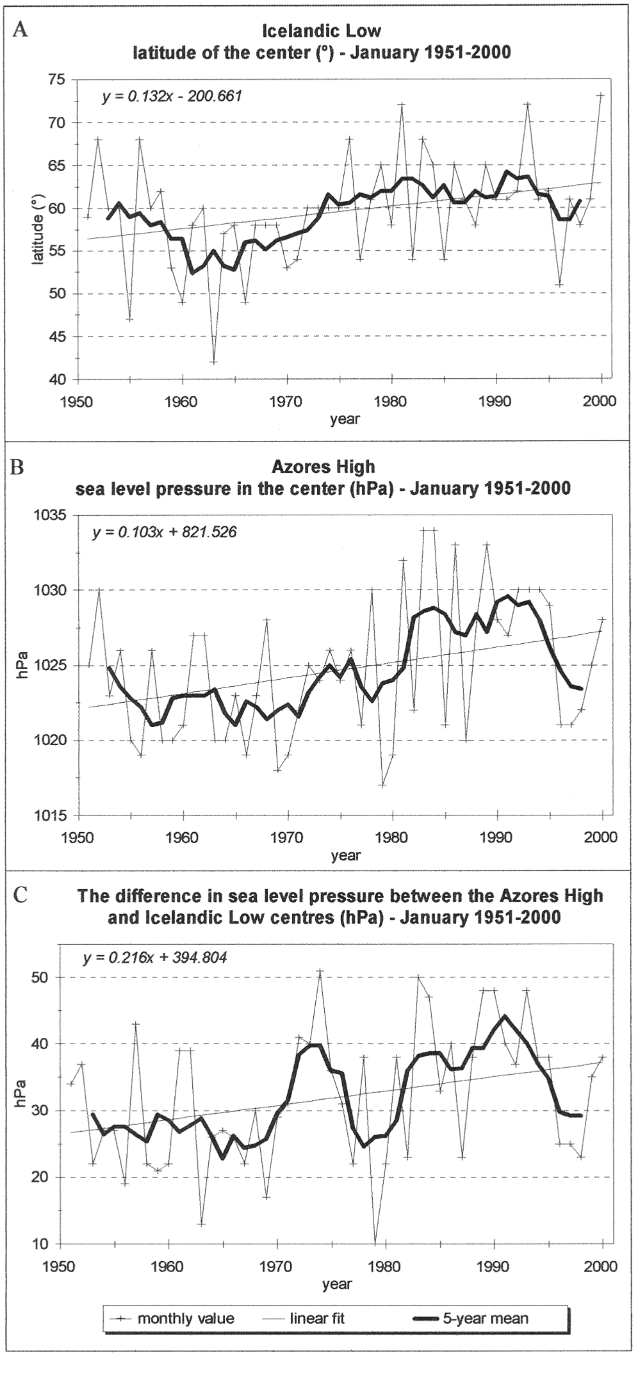

Fig. 3.
Long-term changes of different features of CAA (1951–2000). All of the shown tendencies are statistically significant at the 0.05 level

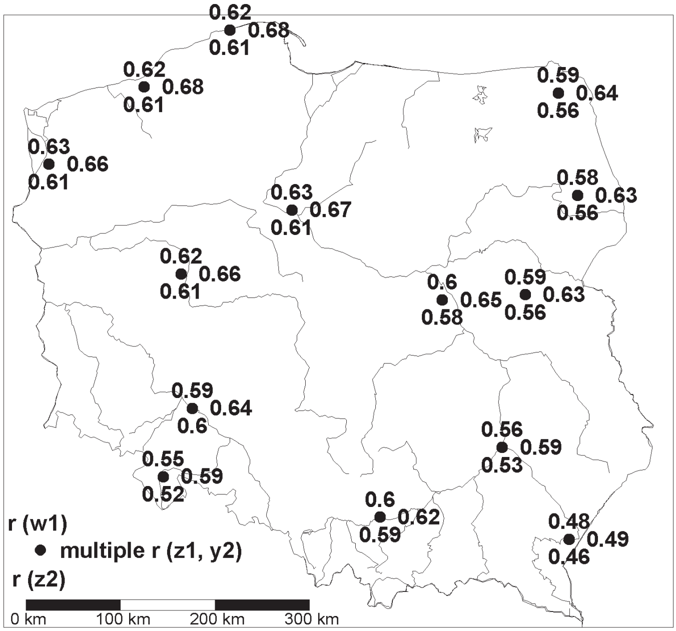

Fig. 4. Correlation coefficients (r) for the dependence of mean air temperature in January on selected features of the Ice and Azo. All coefficients are statistically significant at the 0.05 level

CAA and precipitation in January

Precipitation in January indicate the strongest relationship with z2 in the northern Poland, with x1 in the central and western Poland and with the x1 and z1 in the southern Poland (Fig. 5). Only in 2 stations (Koszalin and Suwałki), does the North Atlantic Oscillation index in Dec-Feb (NAO) better describe the variability of precipitation than one of the CAA features. In eastern and south-western Poland the correlations of precipitation with the NAO and CAA features are not significant. The correlation coefficient between precipitation and z2 exceeds 0.4 in some areas in Pomerania and Masuria and is not significant in the rest of Poland (Fig. 6). In northern Poland the z2 is also significantly correlated with the total precipitation in Dec-Feb.

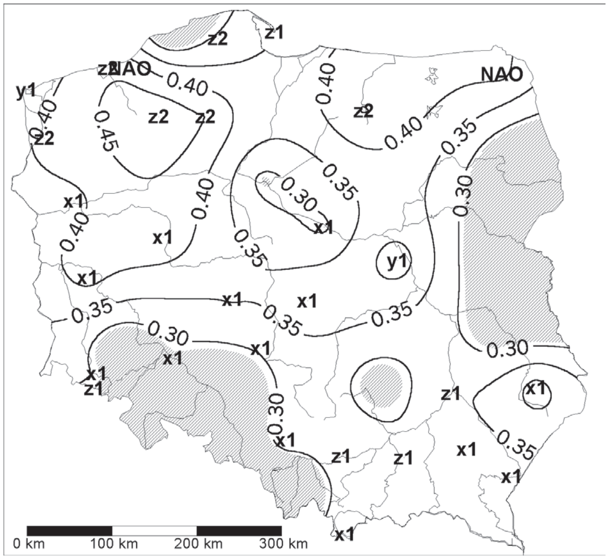

Fig. 5. The dependence of precipitation on Ice, Azo, NAO features: the strongest relationship from amongst all features and the sign of it for each station was shown. Areas of statistically insignificant dependences are diagonally hachured

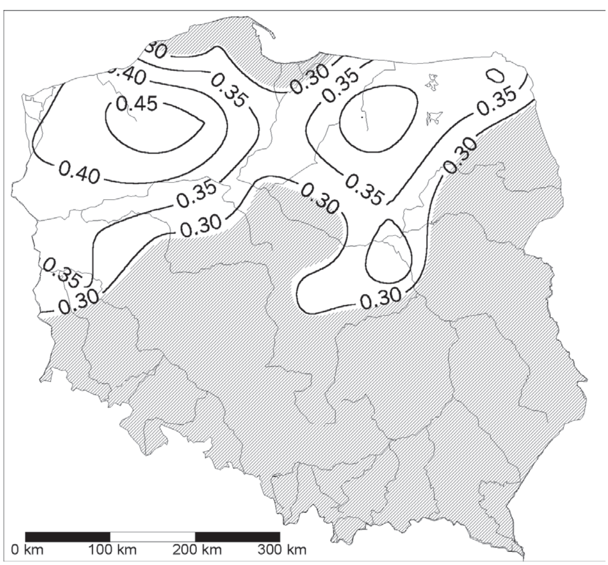

Fig. 6. The dependence of precipitation on the sea level pressure in the center of the Azo: correlation coefficient (January, 1954–2000). Areas of statistically insignificant dependences are diagonally hachured

CAA in January and seasonal snow cover

In all non-mountainous areas of Poland the seasonal snow cover duration depends significantly on z1 (Fig. 7). The relation is stronger and stronger towards northern and north-eastern Poland. However, the NAO describes better the snow cover duration than does z1. Maximum seasonal snow-cover depth indicates the strongest relationship with y2 in central Poland (Figs. 8, 9). In the rest of Poland with the exception of the south east, the variability of the maximum depth of snow cover is described best of all by NAO in Dec-Feb, NAO in January (NAO(I)) or w1.

The changes of snow cover duration averaged for the whole Poland are explained in 40% by the simultaneous variability of independent variables: z1 and the y2 and is expressed by the following equation:

Snow cover duration = 1.4919*z1 – 1.4332*y2 – 1370.924

The same CAA features describe the variability of maximum snow cover depth averaged for the whole area of Poland:

Maximum depth of snow cover = 0.5280*z1 – 0.6575*y2 – 479.894

adjusted $R^2 = 0.38$

CAA and the climate in the 20th century in Kraków (January)

In the period 1901(1921) – 2000 mean air temperature in Kraków was most dependent on z2, while precipitation was most dependent on z1, and snow cover on w1 (Table 2). Z1 is the only CAA feature (including the NAO) influencing significantly precipitation totals in Kraków in the 20^{th} century.

Multiple regression is better than the simple one for the describing the dependence of climatic conditions in Kraków on CAA features. However, for the precipitation the creation of a multiple equation was not possible. The long-term variability of air temperature in January 1901–2000 depends simultaneously on x1 and z2:

Temp Kraków = 0.0567*x1 + 0.3070*z2 – 315.085

R^2 adjusted for the number of degrees of freedom = 0.23

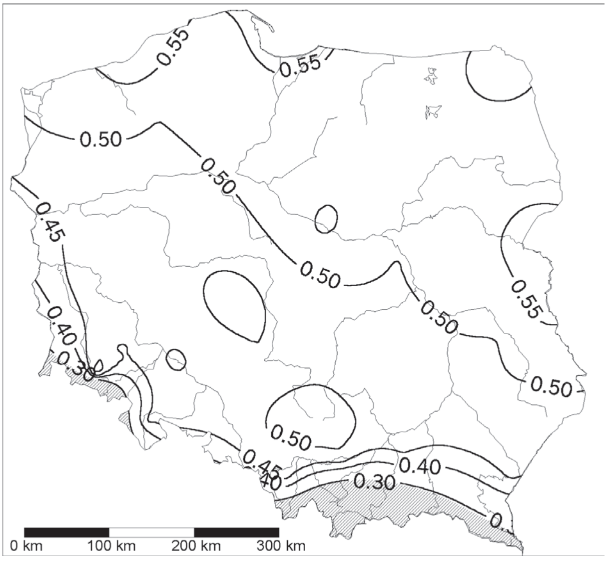

Fig. 7. The dependence of the seasonal snow cover duration on z1 in January: correlation coefficient (1954/55–1999/2000). Areas of statistically insignificant dependences are diagonally hachured

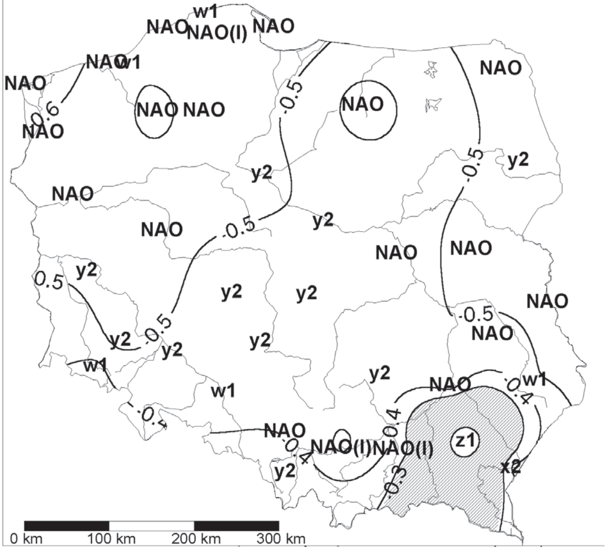

Fig. 8. The dependence of the seasonal maximum depth of snow cover on Ice, Azo, NAO features: the strongest relationship from amongst all features and the sign of it for each station was shown. Areas of statistically insignificant dependences are hachured

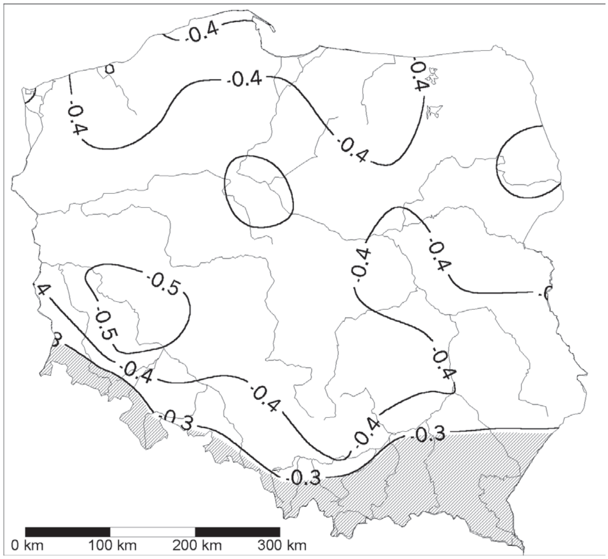

Fig. 9. The dependence of the seasonal maximum depth of snow cover on y2 in January: correlation coefficient (1954/55–1999/2000). Areas of statistically insignificant dependences are hachured

The snow cover duration (January 1921–2000) and the seasonal maximum of the snow cover depth (1901–2000) depend simultaneously on z1 and y2:

snow cover duration (J) = 0.6677*z1 – 0.5007*y2 – 625.324

adjusted $R^2 = 0.31$;

maximum snow-cover depth (season) = 0.4817*z1 – 0.3991*y2 – 443.188

adjusted $R^2 = 0.13$

All components of the above equations are statistically significant.

The total redundance describing the explanation of both temperature and precipitation in Kraków (1901–2000) by the all 6 CAA features (x1, ..., z2) is 21%, while the canonical correlation for this relation is 0.54. The results

Table 2. Correlation coefficients between CAA features and climatic elements in Kraków (1901(1921) – 2000). There are only the statistically significant coefficients shown. Denotations – see in text

<table>
<tr><th colspan="2">element</th><th>feature/ period</th><th>x1</th><th>y1</th><th>z1</th><th>x2</th><th>y2</th><th>z2</th><th>w1</th></tr>
<tr><td colspan="2">mean air temperature</td><td rowspan="2">1901–2000</td><td>0.34</td><td>0.35</td><td>-0.24</td><td>0.32</td><td>0.34</td><td>0.42</td><td>0.37</td></tr>
<tr><td colspan="2">precipitation</td><td>-</td><td>-</td><td>0.24</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">snow cover</td><td>duration</td><td rowspan="2">1921–2000</td><td>-0.25</td><td>-0.34</td><td>0.50</td><td>-0.23</td><td>-0.34</td><td>-0.48</td><td>-0.58</td></tr>
<tr><td>maximum depth</td><td>-</td><td>-0.45</td><td>0.39</td><td>-0.23</td><td>-0.41</td><td>-0.39</td><td>-0.46</td></tr>
</table>

of canonical analysis are far better for the second half of the 20th century (1951–2000): the total redundance for CAA features and temperature, precipitation and snow cover duration is 38%, and the canonical correlation is 0.73.

Conclusion

The study is a contribution to describing changes of climate in Poland by using circulation features. The main investigation results are as follows:

– there were no statistically significant (0.05) trends of analysed centres of action of the atmosphere in January in the 20th century;
– in the second half of the 20th century the center of the Icelandic Low in January moved northwards and the sea-level pressure in the center of the Azores High increased significantly; the latter change was probably the reason for the significant increasing tendency of the difference between the Azores High and the Icelandic Low. The trend caused the intensification of the western advection over Europe;
– the variability of features of the CAA over the North Atlantic has the strongest influence on the climatic conditions in NW, N and NE Poland;
– changes of sea level pressure in the Icelandic Low and the longitude of the Azores High in January (taken into account as a complex of features) explain about 40% of the temperature and snow cover variability in Poland;

- the mean air temperature is also directly proportionally correlated with the sea level pressure in the Azores High and with the difference between the atmospheric pressure of the Azores High and the Icelandic Low. The significant upward trends of these two features of CAA seem to be a good explanation for the increasing tendency of the winter air temperature in Poland; the warming in periods with higher than average Azo-Ice is also observed in northern Europe (Kapala et al. 1998);
- the variability of some features of the centres of action of the atmosphere (x1, z1, y2, z2) describe the changes of precipitation and snow cover in Poland better than does the NAO index;
- the correlation of the air temperature in February and March with the pressure in the Icelandic Low and Azo-Ice in January are statistically significant but not so strong as to forecast thermal conditions;
- the total redundance describing the explanation of temperature, precipitation and snow cover in Kraków (1951–2000) by all 6 CAA features is 38%.

The results of other investigations concerning trends of the Azores High and the Icelandic Low obtained by using different databases and methods are partly similar to those presented here. Hilmer and Jung (2000) proved the shift of the Icelandic Low to the NE. The pronounced strengthening of the Azores High during approximately the last 20 years has been noticed by Hasanean (2004). Mächel et al. (1998) indicated the statistically significant trend (95%) of the pressure in this High in both 1950–1989 (5.7 hPa per 100 years) and in 1970–1989 (12 hPa per 100 years). Moreover, they also noticed a significant positive trend of the Azores High longitude in the 100-year period 1881–1989 which is not observed here.

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