PRECIPITATION AND OTHER ATMOSPHERIC PHENOMENA IN THE CENTRAL AND NORTH-EASTERN PARTS OF FORMER POLAND FROM 1658 TO 1667

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RESUMEN
En este articulo se presenta la reconstrucción de algunos fenómenos atmosféricos (precipitación, tormentas, nieblas) en la Comunidad Polaco-Lituana para el periodo 1658-1667 basada en el diario escrito de Jan Antoni Chrapowicki. Las anotaciones meteorologicas diarias realizadas durante este periodo permiten el calculo de las frecuencias para algunos de los fenómenos investigados. Para propósitos del análisis, las frecuencias mensuales, estacionales y anuales de la ocurrencia de días con precipitación, tormentas, granizadas y nieblas han sido calculadas. La evolución anual de la frecuencia de ocurrencia de estas variables revelan los mismos patrones que en el clima actual. Tampoco hay cambios significativos entre el periodo histórico y el actual en el numero de dias al año con precipitación y granizo. Por otro lado, los valores absolutos de días con tormentas y nieblas fueron apreciablemente más bajos en el período del estudio que en la actualidad. Parece que esta diferencia puede ser explicada, por lo menos parcialmente, por el hecho de que el clima de Polonia en el siglo XVII fue más frío y más continental.

Palabras clave: climatología histórica, precipitación, fenómenos atmosféricos, Polonia

ABSTRACT
The paper presents a reconstruction of some weather phenomena (precipitation, thunderstorms, hailstorms, fogs) in the Polish-Lithuanian Commonwealth for the period 1658-1667 based on a diary written by Jan Antoni Chrapowicki. Daily weather notes made by him during this period permitted the reliable calculation of frequencies for at least for some of the weather phenomena which were investigated. For purposes of analysis, the monthly, seasonal, and annual frequencies of occurrence of days with precipitation, thunderstorms, hailstorms and fogs have been counted. The annual courses of frequency of occurrence of these variables reveals the same pattern of changes as in today's climate. Also there are no significant changes between the annual number of days with precipitation and hailstorms in the historical and present-day periods. On the other hand, absolute values of days with thunderstorms and fogs were significantly lower in the study period than they are today. It seems that this difference can be explained, at least partially, by the fact that the climate of Poland in the 17th century was colder and more continental than .

Key words: historical climatology, precipitation, atmospheric phenomena, Poland

1. INTRODUCTION

In Poland in the last 10-20 years, significant research progress has been in the field of historical climatology. To reconstruct the history of the pre-instrumental climate in Poland, three types of proxy data have been used: documentary evidence, dendrochronological data and geophysical data (MAJOROWICZ *et al.*, 2004; PRZYBYLAK *et al.*,2005). As a result, our knowledge of the climate of Poland in the last millennium is markedly greater. For a review of the present state of knowledge see e.g. MAJOROWICZ *et al.* (2004), PRZYBYLAK *et al.* (2005) and PRZYBYLAK (2007).

The aim of the present paper is to reconstruct some weather phenomena (precipitation, thunderstorms, hailstorms and fogs) in the central and north-eastern parts of the Polish-Lithuanian Commonwealth (hereafter 'Poland') for the period 1658-1667 based on a diary written by Jan Antoni Chrapowicki, a nobleman who was a Vitebsk voivode (CHRAPOWICKI 1978, 1988).Chrapowicki began keeping his diary in 1656 and continued it up to his death on 3rd November 1685. For more details see BOKWA *et al.* (2001) or NOWOSAD *et al.* (2007). NOWOSAD *et al.* (2007) have shown that Chrapowicki's diary, as far as the weather phenomena noted in it are concerned, is reliable only for the period 1658-1667. Thus, in the present paper weather phenomena are described only for this 10-year period and are then compared with conditions in the modern period.

2. AREA, DATA AND METHODS

Chrapowicki was a politician, a member of the Polish parliament, and an owner of many estates located in different areas of the Great Duchy of Lithuania. He traveled extensively, frequently staying away from home for months at a time, both in order to maintain his estates and to participate in parliamentary sessions, six of which took place during the study period (1658, 1659, 1661, 1664-65 and 1667). These sessions lasted, on average, over two months. Generally his stays were limited to the four regions shown in Figure 1: (1) Masovia (Warsaw), (2) Podlasie (Grodno) andsouthern Lithuania, (3) Minsk, and (4) Vitebsk and Mscislav. For the first region, the majority of his weather notes come from Warsaw. On the other hand, entries for the other Masovian areas were most often written during his short trips from Lithuania to Warsaw and back home, which tended to last a few days. His stays in Podlasie and southern Lithuania tended to be long, lasting for over half a year in the years 1656-1659, 1662 and 1665.The fewest entries are available for his stays in the region of Minsk. His first visit here is dated 1660. From 1666 onward his stays were more frequent but their duration was rather short, lasting from around two weeks to a couple of months. Finally Chrapowicki very often in the region of Vitebsk and Mscislav between 1664 and 1667. The duration of the visits here varied from more than 20 days to about 8 months in 1666. For more details see NOWOSAD *et al.* (2007).

Using Chrapowicki's notes, both rainfall and solid precipitation were stratified into three categories (slight, moderate and heavy or long-term). Monthly, seasonal and annual frequencies of occurrence of all these precipitation categories have been calculated. In the case of other atmospheric phenomena (thunderstorms, hailstorms and fogs) their monthly, seasonal and annual frequencies have been computed without any stratification.

For purposes of comparison, long-term average precipitation characteristics have been collected for the four meteorological stations located in the present areas of Poland (Warsaw and Biaystok) and Belarus (Minsk and Vitebsk), the first three for the period 1931-1960 and the Vitebsk station for the period 1971-2000. The number of thunderstorms, hailstorms and fogs for the period 1971-2000 ha been taken from the Atlas of Polish Climate (LORENC, 2005).

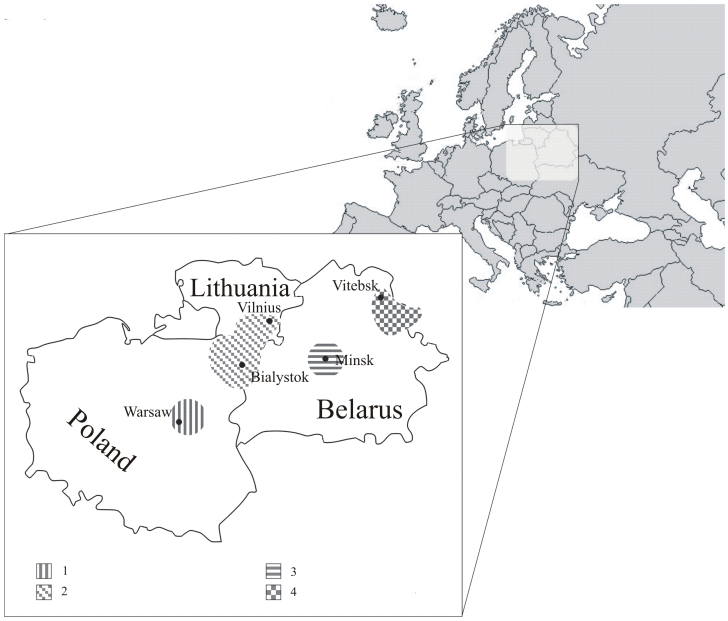

Fig. 1: Location of regions for which Chrapowicki's weather notes are available and the location of meteorological stations from which contemporary climate data were taken. 1-Masovia, 2 – Podlasie and southern Lithuania, 3 – Minsk, 4 – Vitebsk and Mscislav (after NOWOSAD *et al.*, 2007, modified)

3. RESULTS

The average number of days with precipitation in Poland in the study period amounted to 171.2 (46.9% of all the days in a year) and varied from 158 (in 1667) to 195 (in 1662) (Figure 2a). Rainfall was noted on 68.0% of all days with precipitation, while there was snowfall and snowfall with rainfall on 27.6% and 4.4% of days respectively. The annual frequency of days with rainfall generally exceeded 100 and was greatest in 1662 (141) and lowest in 1666 (95) (Figure 2b). The average annual number of days with snowfall amounted to 47.3; in particular years, however, it oscillated from 69 (1666) to 28 (1661) (Figure 2c). The simultaneous occurrence of rain and snow was noted very rarely by Chrapowicki (Figure 2d). The annual number of such days generally lies between four and eleven. Looking at Figure 2 it is clear that during the period 1658-1667 there is no trend in the frequency of occurrence in any of the described kinds of precipitation.

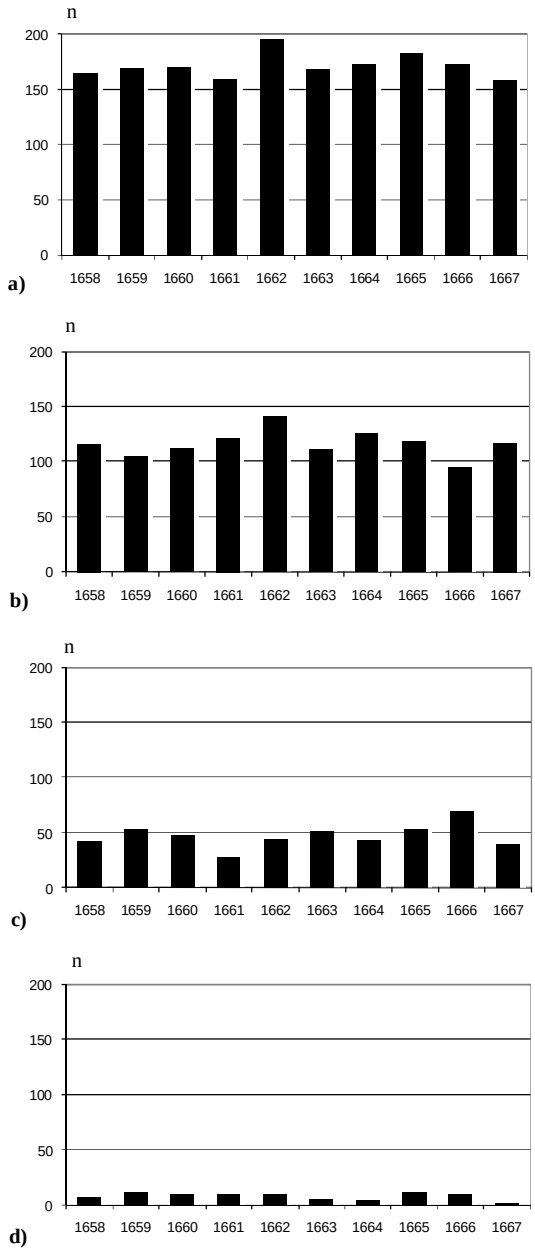

Fig. 2: Year-to-year courses of annual numbers of days (n) with all kinds of precipitation (a), rainfall (b), snowfall (c) and the simultaneous occurrence of rain with snow (d) in Poland from 1658 to 1667

In the annual course of number of days with precipitation, two maxima (in summer and winter) and two minima (in spring and autumn) can be distinguished (Figure 3a). The lowest number

of days with precipitation occurred in April (10.2) and the highest in July (17.6). Rainfall was noted in all months, with a markedly greater frequency from May to October (on average, more than 10 days) (Figure 3b). The maximum of days with rainfall was observed in July (17.5) and the minimum in January (2.5). Snowfall was noted by Chrapowicki mainly from October to May, with an average maximum of snowy days (11.8) occurring in January (Figure 3c). It should be noted that snowfall was also observed in July.

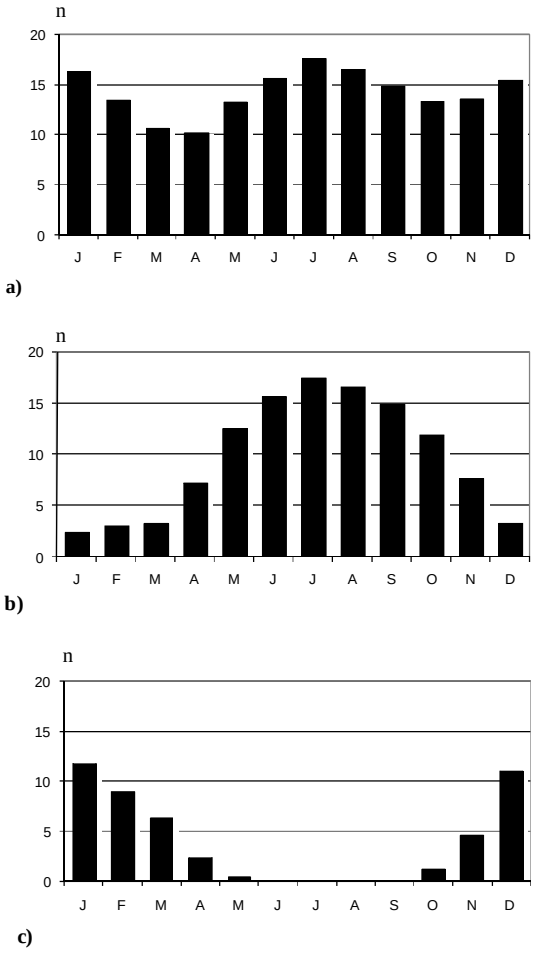

Fig. 3: Annual courses of number of days (n) with all kinds of precipitation (a), rainfall (b), and snowfall (c) in Poland from 1658 to 1667

Figure 4 presents annual courses of frequencies of occurrence of days with rainfall (a) and solid precipitation (b) stratified into three categories (slight, moderate and heavy or long-term). In the case of rainfall, the third category is dominant (about 39%), especially in autumn and winter. The reason for this at this time of the year is the intensive cyclonic activity, which

brings warm and humid air masses from the Atlantic. Slight and moderate rainfall were observed with almost the same average annual frequency (about 30%). On the other hand, monthly frequencies of these categories of rainfall differ significantly more (see Figure 4a). Moderate solid precipitation (snow, hail and other kinds) was markedly dominant in almost all months of the study period (Figure 4b) and years (not shown). On the other hand, heavy or long-term solid varieties of precipitation were observed by Chrapowicki with the lowest frequency.

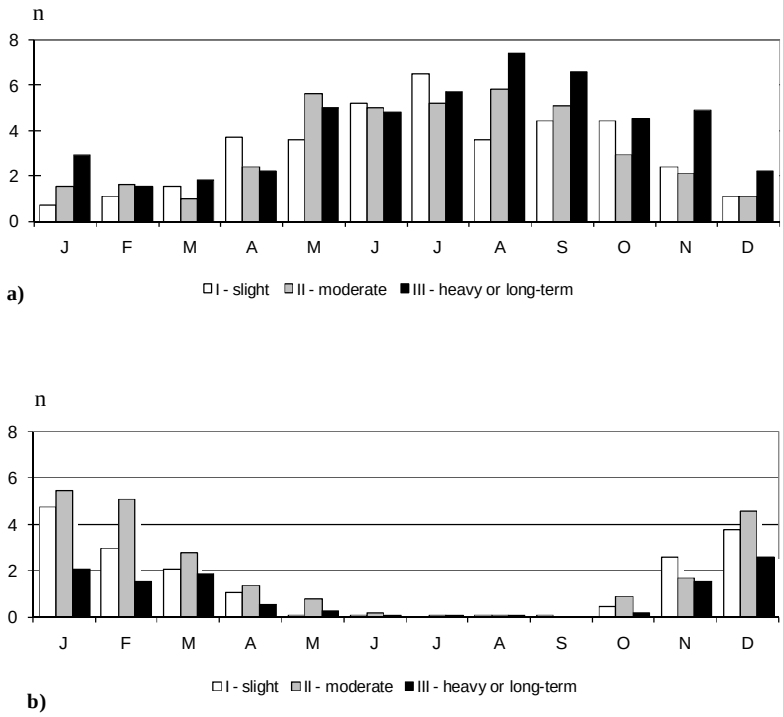

Fig. 4: Annual courses of the number of days (n) with rainfall (a) and snowfall (b) stratified into three categories (slight, moderate and heavy or long-term) in Poland from 1658 to 1667

Comparison with present-day data (1931-1960) shows that the difference between the average annual numbers of days with precipitation is small. Monthly differences do not exceed 3-5 days (see Figure 5). In the historical period in the warm half-year the average monthly number of days with precipitation was greater than present-day values, while in the cold half-year it was . Small, insignificant changes in the annual numbers of days were also found for rainfall and snowfall.

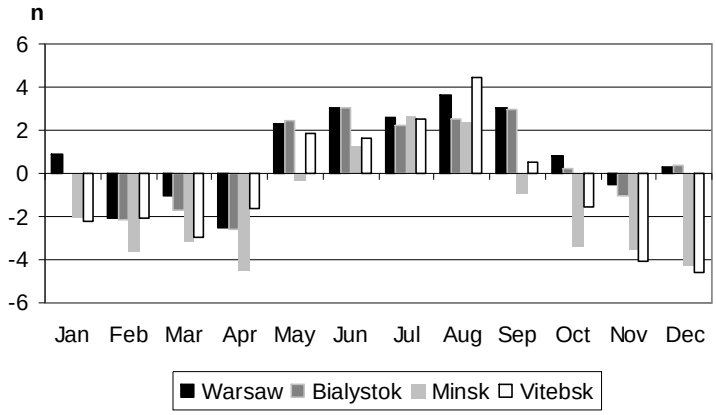

Fig. 5: Differences in the number of days (n) with precipitation in Poland between the historical period (1658-1667) and the modern period (1931-1960)

BRÁZDIL and KISS (2001) conducted a similarinvestigation for Košice (Slovakia) for the period 1677-1681 based on daily weather records available in the Latin *Diarium* of the Jesuit friary. In comparison with present-day data, the annual number of days with precipitation (including liquid and solid precipitation) in the study period was significantly lower (by about 25-30%). The cited authors assume that this difference may be connected with the fact that weak precipitation, mainly at night, was not recorded. NOWOSAD *et al*. (2007) came to the same conclusion in their analysis of data for the first two years of Chrapowicki's diary, i.e. 1656 and 1657, when the annual number of days with precipitation was evidently too low (about 100 days). Therefore, for the present analysis these two years were excluded. The fact that for the years 1658-1667 we obtained a similar number of days with precipitation to the figures for the present-day period means that Chrapowicki was very precise in recording his weather notes. Thus, we can assume that his diary is a reliable source, at least for the reconstruction of precipitation frequency.

Thunderstorms in Poland in the study period were observed from March to October, average monthly frequencies (above 2) from May to August (Figure 6a). Their average annual frequency amounted to only 12.4. This value is significantly lower than for the present-day climate (which is about 20 thunderstorms per month, according to LORENC, 2005). This difference, in part, can probably be attributed to the omission of some night-time thunderstorms, which Chrapowicki did not notice. Only in three years (1662-1664) was the number of noted thunderstorms comparable with present-day values (Figure 6b). On the other hand, in three other years (1658, 1660 and 1661) their number was very low and did not exceed 5 cases. BRÁZDIL and KISS (2001) found a similar ratio between the number of days with thunderstorms in historical and present-day periods for Košice.
The average annual numbers of hailstorms in the historical and present-day (1971-2000, LORENC, 2005) periods are almost similar, amounting to 1.8 and 2.0 days respectively. Hailstorms were noted by Chrapowicki from April to October with a maximum average frequency (4) both in May and June. Hailstorms were not observed in all years. They occurred in 6 years during the study period, with maximum frequencies in 1662 (7 cases) and 1664 (5).

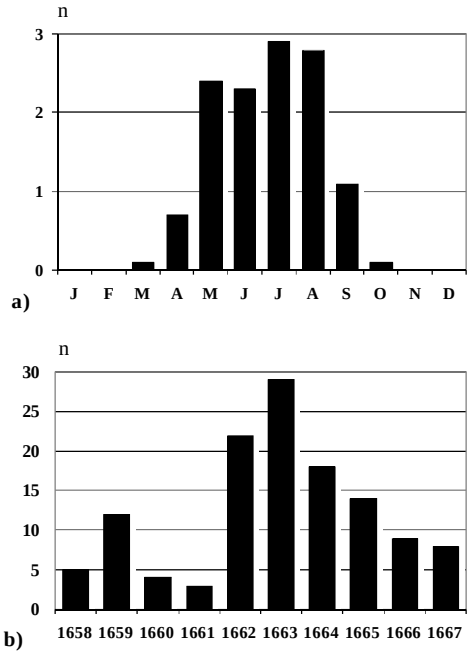

Figure 6. Number of days (n) with thunderstorms in Poland, 1658-1667. a) annual course, and b) year-to-year course

Days with fog in Poland from 1658 to 1667 were observed by Chrapowicki mainly in the cold half-year, with maximum occurrence in autumn (about 2.5 in each month). The lowest numbers of days with fog were clearly noted from April to June (Figure 7a). Their average annual number is only 15.1, but there exist significant year-to-year changes (see Figure 7b). The highest frequency of days with fog (28) occurred in 1663 when half of them were observed in October and November (7 days in each month). On the other hand, very few such phenomena were noted in 1659 (only 8 cases).

In the study period the number of days with fog was significantly lower than in the present-day climate, when about 40-60 such days are noted (LORENC, 2005). For Košice, BRÁZDIL and KISS (2001) also found similar results, i.e. in 1678-1680, the annual number of days with fog was only a third of the present-day figure. Partly, these differences in both areas can be explained by the fact that the climate in the historical period was significantly more continental than today (see BRÁZDIL, 1994; PRZYBYLAK *et al*., 2005). For example, in Poland in the 17th century, air temperature in the cold half-year (when fogs are most common) was colder by 2-3^{o}C than today. This means that advections of warm and humid air masses from the Atlantic were less frequent than today, and thus the fogs, being the result of these advections, had to be less frequent. Of course, it is also quite probable that some fogs occurring especially at night were not recorded both by Chrapowicki for Poland and by the authors of the *Diarium* for Košice. It should, however, been added that in both areas there is general similarity in the average annual courses of fog frequencies in the historical and present-day periods.

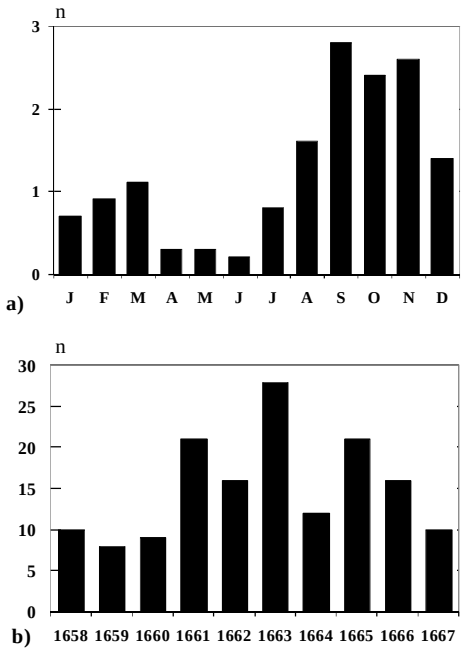

Figure 7. Number of days (n) with fog in Poland, 1658-1667. a) annual course, and b) year-to-year course

4. CONCLUSIONS

Simple statistical analysis of the data allows us to draw the following main conclusions:

1. The annual courses of frequency of occurrence of all the analysed weather phenomena (precipitation, thunderstorms, hailstorms and fogs) did not show any significant changes in comparison with present-day data.

2. Annual numbers of days with precipitation and hailstorms are close to today's values. Monthly differences in the number of days with precipitation do not exceed 3-5 days. In the historical period in the warm half-year, the average monthly number of days with precipitation was greater than present-day values, while in the cold half-year it was lower. These changes of differences in the annual course are in line with changes which are expected with a more continental climate occurring in the study period.

3. Annual numbers of days with thunderstorms and fog were significantly lower than today. As far as thunderstorms are concerned, their average 10-year frequency was 12.4 (now about 20), while the frequency of instances of fog in the historical period (about 15) was a third of the present-day figure. Partly, this difference can be explained by the change of climate between comparable periods. In the 17th century the climate of Poland was significantly colder and more continental (see PRZYBYLAK *et al.*, 2005). These conditions should result a reduced occurrence of thunderstorms, especially in the cold half-year. Moreover, it is at this time thatthey should reduce the frequency of advections of warm and moist air masses from the Atlantic, which favor the occurrence of fogs. It is also quite probable that some thunderstorms and fogs occurring especially at night were not recorded by Chrapowicki.

5. ACKNOWLEDGMENTS

The research in the present paper was funded by a grant obtained from the State Committee for Scientific Research (grant no. N306 018 32/1027). We would like to thank John Kearns for assistance with the English.

6. REFERENCES

BOKWA, A., LIMANÓWKA, D., WIBIG, J. (2001). *Pre-instrumental weather observations in Poland in the 16th and 17th centuries.* [In:] P.D. JONES *et al.* (Eds.) History and Climate. Memories of the Future?, Kluwer Academic/Plenum Publishers, Dordrecht-Boston-London, pp. 9-27.

BRÁZDIL, R. (1994). "Climatic fluctuations in the Czech Lands during the Last Millennium". *GeoJournal* 32.3, pp. 199-205.

BRÁZDIL, R. and KISS, A. (2001). "Daily weather observations at Košice, Slovakia, in the period 1677-1681". *Meteorologický ćasopis* 4, pp. 3-14.

CHRAPOWICKI, J.A. (1978). *Diariusz, part 1: years 1656-1664.* Elaboration and introduction: T. Wasilewski. Instytut Wydawniczy Pax, Warsaw, in Polish.

CHRAPOWICKI, J.A. (1988). *Diariusz, part 2: years 1665-1669.* Elaboration and introduction: A. Rachuba and T. Wasilewski, Instytut Wydawniczy Pax, Warszawa, in Polish.

LORENC, H. (Ed.) (2005). *Atlas of Polish climate,* Instytut Meteorologii i Gospodarki Wodnej. Warsaw, in Polish.

MAJOROWICZ, J.A., ŠAFANDA, J., PRZYBYLAK, R., WÓJCIK, G. (2004). "Ground surface temperature history in Poland in the 16th-20th century derived from the inversion of geothermal profiles". *Pure and Applied Geophysics* 161, pp. 351-363.

NOWOSAD, W., PRZYBYLAK, R., MARCINIAK, K., SYTA, K. (2007). "The diary of Jan Antoni Chrapowicki as a source for climate research in the Polish-Lithuanian Commonwealth in the second half of the seventeenth century". *Klio*, 9, pp. 21-60, in Polish.

PRZYBYLAK, R. (2007). "The change in the Polish climate in recent centuries". *Papers on Global Change IGBP*, 14 , pp. 19-37.

PRZYBYLAK, R., MAJOROWICZ, J., WÓJCIK, G., ZIELSKI, A., CHORĄŻYCZEWSKI, W., MARCINIAK, K. NOWOSAD, W., OLIŃSKI, P., SYTA, K. (2005). "Temperature changes in Poland from the 16th to the 20th centuries". *Int. J. of Climatology*, 25, pp. 773-791.