AIR HUMIDITY AND EVAPORATION CONDITIONS IN POLAND IN RELATION TO ATMOSPHERIC CIRCULATION PATTERNS

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ABSTRACT. – Air humidity and evaporation conditions in Poland in relation to atmospheric circulation patterns. The issue describing the amount of water vapour in the atmosphere and its backgrounds seems to be very important because of water vapour role among meteorological processes which are taking place within the atmosphere. The principal aim of this study is to examine the atmospheric circulation conditionings of evaporation and air humidity differentiation in Poland. Research was based on data for the period 1981-2010. The temporal and spatial differentiation of evaporation and air humidity in relation to atmospheric circulation patterns were examined by analysis of evaporation, evapotranspiration as well as specific humidity and saturation deficit values. The circulation factor was determined by a local atmospheric circulation calendar by Niedzwiedz. The results showed that atmospheric circulation is an important factor for humidity and evaporation conditions with the most significant: water vapour content and air mass temperature. Both air humidity and evaporation report temporal and spatial differentiation modified by particular synoptic situations. It is proved mainly by the extremes.

Keywords: air humidity, evaporation, atmospheric circulation, Poland.

1. INTRODUCTION

Feedback system of the atmosphere is worth being recognized to explain some environmental processes. Air humidity describing the amount of water vapour in the air, is an important factor of many meteorological processes, e.g. energy transportation (Unger, 1993; Willet et al., 2008). Although the role of atmospheric circulation in modifying moisture conditions seems to be forceful it is rarely examining due to its methodological complexity. Getting knowledge about the role that water vapour plays in hydrological cycle together with evaporation and condensation seems to be crucial to evaluate and balance national water resources.

The study is a result of preliminary analyses conducted to describe the impact of atmospheric circulation on moisture conditions in Poland for economy, mainly agriculture, needs and is a contribution to further research.

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2. DATA

Basic research data come from evaporation stations and psychrometric measurements covering growing season from May to October when evaporation measurements are provided. Detailed data exploration produced the final database from the period 1981-2010 from 8 measuring points (Fig. 1). 20m^2 evaporometer daily measurements were used together with temperature (psychrometric measurements) and air pressure data from midday term (12 UTC). The latest were used to calculate air humidity parameters. Meteorological station in Radzyń (Fig. 1) due to its high measuring spectrum was used as reference point. The data was used to verify particular results and for further detailed methodological analyses.

Figure 1. Localisation of the stations used in the study

0Air humidity parameters were calculated: vapour pressure, relative humidity, saturation deficit, due point temperature and specific humidity. The calculations were done for the periods 1981-2003 and 2004-2010 separately because of their different measuring equipment. For detailed analyses two parameters: saturation deficit (d) and specific humidity (s) were chosen as they are widely used for moisture content and atmospheric circulation studies.

3. METHODOLOGY

To accomplish the main aim of the research, i.e. to analyse higric conditions and water vapour content in Poland within particular synoptic situations, it was necessary to complete the evaporation data because of irregular distribution of measuring points (Fig. 1). Therefore it was decided to implement – as necessary for further analyses – empirical data obtained from available formulas recommended to be used in Central Europe climatic conditions (Garnier, 1992; Jaworski, 2004; Jurak, 1976; Lange (ed.), 1993). Preliminary sixteen equations were chosen but finally the results of ten were thoroughly verified comparing with *in-situ* data.

Despite the relative accordance in seasonal evaporation and evapotranspiration totals significant differences in in-between months: May (spring), September and October (autumn) could be seen (Fig. 2). It is a result of heat capacity. After winter time water accumulated in reservoirs is cooled down and radiation energy supply warms it up successively however the temperature increase is slow whereas in the autumn the amount of heat stored during summer time is released gradually, not keeping up with incoming cooling air masses. It is clearly seen in the evaporation intensity higher in autumn what is not considered in empirical formulas based on weather conditions with the importance of atmospheric circulation and solar radiation.

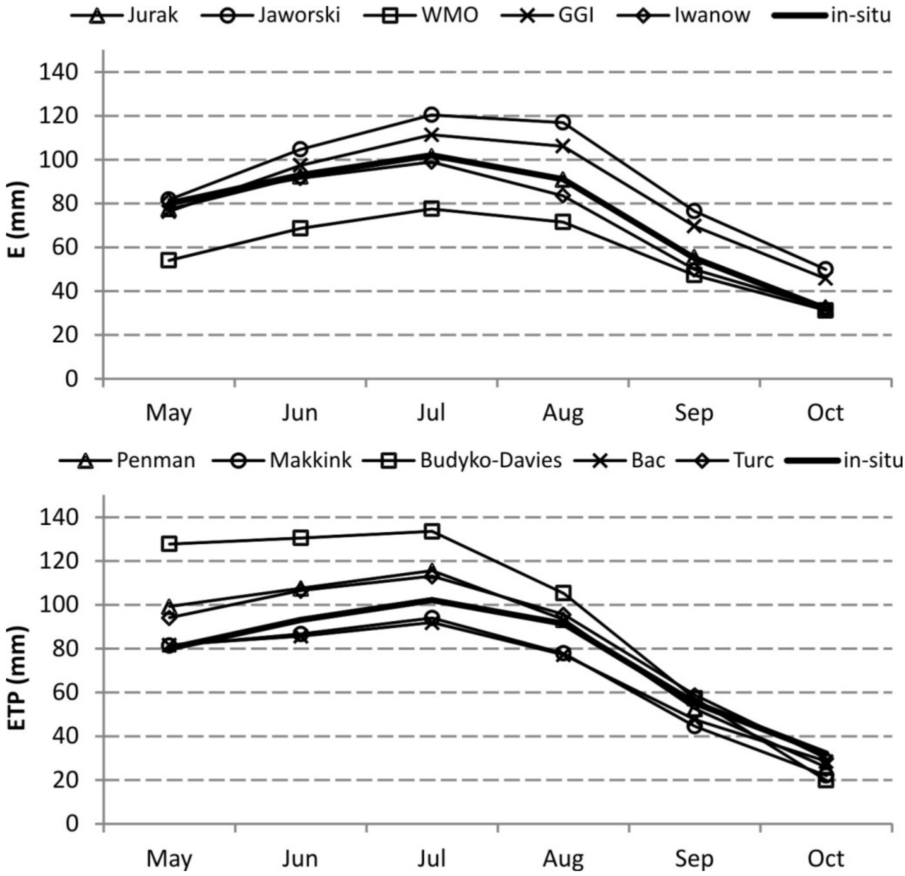

Figure 2. Monthly evaporation (E) and evapotranspiration (ETP) totals by different methods – Radzyń (1981-2010)

The achieved results indicate univocally implementing GGI and Jaworski formulas to count evaporation (E) and Turc, Penman or Budyko-Davies for potential evapotranspiration (ETP). Unfortunately due to data accessibility but also the main research goal Budyko-Davies equation (with WMO recommendation) was decided to be used for calculations (Garnier, 1992).

$$ETP\ (BD) = 0.9[0.405(0.617K\downarrow - 1.0)] \quad (1)$$

where:
ETP (BD) – potential evapotranspiration by Budyko-Davies [mm/day]
$K\downarrow$ – total solar radiation [$MJ \cdot m^{-2}$]

The last step was to estimate the impact of atmospheric circulation on moisture conditions spatial differentiation in Poland. Daily evaporation and evapotranspiration totals (E and ETP), saturation deficit (d) and specific humidity (s) values were taken into account. To describe circulation factors one used local classification by Niedzwiedz (2013) which is visually easy to be interpreted (see explanations to Figure 4).

Spatial differentiation of air humidity and evaporation intensity were analysed as well as the relationships between moisture content and evaporation within particular synoptic situations in each month. The probability of extreme conditions occurrence (<10% of days with intensive evaporation, low humidity or high amount of water vapour in the atmosphere) was also examined in relation to the most frequent air mass advection.

4. RESULTS

The amount of water vapour in the atmosphere is dependent on both meteorological and environmental factors. Differentiate higric conditions come from the varied relief, land cover and surface waters. It also shows significant seasonality connected with different radiation amount provided within the year. Due to Clausius-Clapeyron formula temperature is the main factor influencing moisture conditions of the air mass. The amount of water vapour increases with the increase of temperature and higher absorption capabilities. Evaporation intensity increases simultaneously, but sometimes because of the moisture shortage also saturation deficit increases.

4.1. Hygric conditions and evaporation differentiation in Poland

Temporal differentiation of hygric conditions and evaporation process intensity is characterized by visible seasonality. Specific humidity (s) reaches the highest values during summer time whereas the amount of water vapour in May, September and October is similar (Fig. 3). Nevertheless, research done hitherto proves (Wypych, 2010) that spring is much drier than autumn what is confirmed also by saturation deficit values (Fig. 3) higher in May than in autumn months (Sept., Oct.). The most intensive evaporation is – as a matter of course – in summer and, dependent on absorption capabilities, much higher in May (when also high saturation deficit values are recorded) than in autumn.

Spatial differentiation (represented by particular stations) is not clearly marked. The most important factor responsible for the amount of water vapour in the atmosphere is elevation. Lower specific humidity values and, what is the result of lower temperatures, not such high saturation deficit and less intensive evaporation consequently are observed in the mountains. Pretty distinguished from the rest of the country are warmer regions of Carpathian foothills or Carpathian basin; however the differences are not significant (Fig. 3).

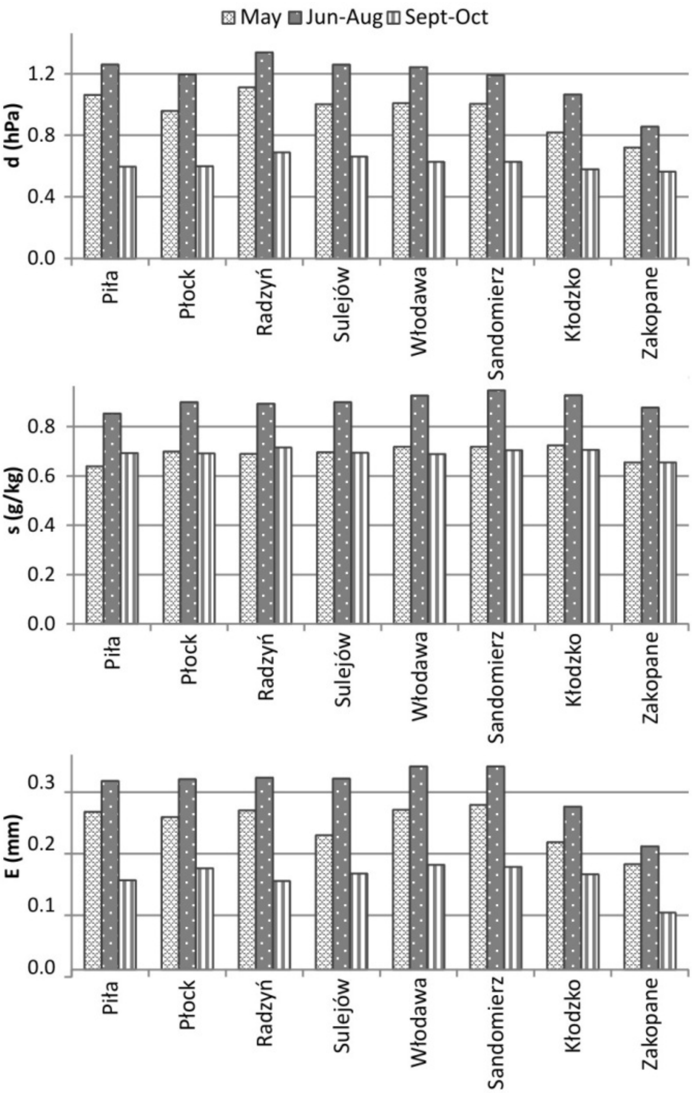

Figure 3. Seasonal differentiation of saturation deficit (d), specific humidity (s) and evaporation (E) at selected stations in Poland

4.2. Circulation background of moisture conditions differentiation in Poland

The study confirms univocally the seasonal importance of atmospheric circulation in forming hygric conditions and evaporation intensity in Poland and also its impact on their spatial differentiation.

The least significant role of the synoptic situation is noticeable while analysing specific humidity, mainly because of its inconsiderable diversity which balance depending on the weather type between 2.4 g·kg^{-1} in May to 2.9 g·kg^{-1} in summer (about 30% of the average value). The higher amount of water vapour in the atmosphere is connected with the southern advection. Since warm air is characterized by higher capacity and absorption capabilities, those situations are also responsible for high saturation deficit and the most intensive evaporation. It is worth seeing that cyclonic situations return more humid conditions so the worst moisture conditions (high saturation deficit and more intensive evaporation leading to meteorological drought) are accompanied by high pressure system often without any advection.

Saturation deficit differentiation reaches up to 125% of average value in summer depending on synoptic conditions. The highest moisture deficit (d>20.0 hPa) appears in anticyclones with southern advection. The air masses are dry so the situation introduces also intensive evaporation. Due to its modest absolute values (from 0.9 mm in autumn up to 1.5 mm in summer), the impact of synoptic conditions seems to be more significant while referring to evaporation intensity. 0.9 mm cited gives more than 56% of average autumn values.

Spatial differentiation of atmospheric circulation impact on moisture conditions is mostly seen during the summer. The range of saturation deficit values reaches over the area of the whole country (represented by selected stations) up to 10.8 hPa accompanying by cyclonic situations with northern or north-east advection. For the regions of southern and south-eastern Poland (from Sulejów, Włodawa, Sandomierz and down to south) these are humid air masses (high specific humidity – s) with less saturation deficit (d) and low evaporation intensity (E) whereas in Plock, Piła and Radzyń the conditions are slightly different. Mentioned synoptic situations (Nc, NEc) are those responsible for intensive precipitation and floods in southern Poland.

The role of atmospheric situation is significant also while analysing the frequency of extremes and their spatial differentiation (Fig. 4). The extremes were distinguished using probability method (10% of the highest values of humidity and evaporation were selected). It must be remembered that number of extremes follows the frequency of particular types within each season. To get to know the adequate conditions conditional probability was examined. For saturation deficit the most important, apart from the season, seems to be the sothern advection. Differences between western part of the country (Radzyń) and eastern border (Włodawa) could be seen – anticyclonic and cyclonic situations adequately (Fig. 4). As for specific humidity cyclones are the uppermost. The most complicated situation shows when examining evaporation intensity. In spring (May) the most important are anticyclonic types with north-east and south-east advection (NEa, SEa), also north-east advection (NWa) or centre of high pressure (Ca). In the autumn (September, October) also north-east advection seems to be essential with the other types on the margin. In the summer time it is difficult to distinguish any dominating situation (Fig. 4).

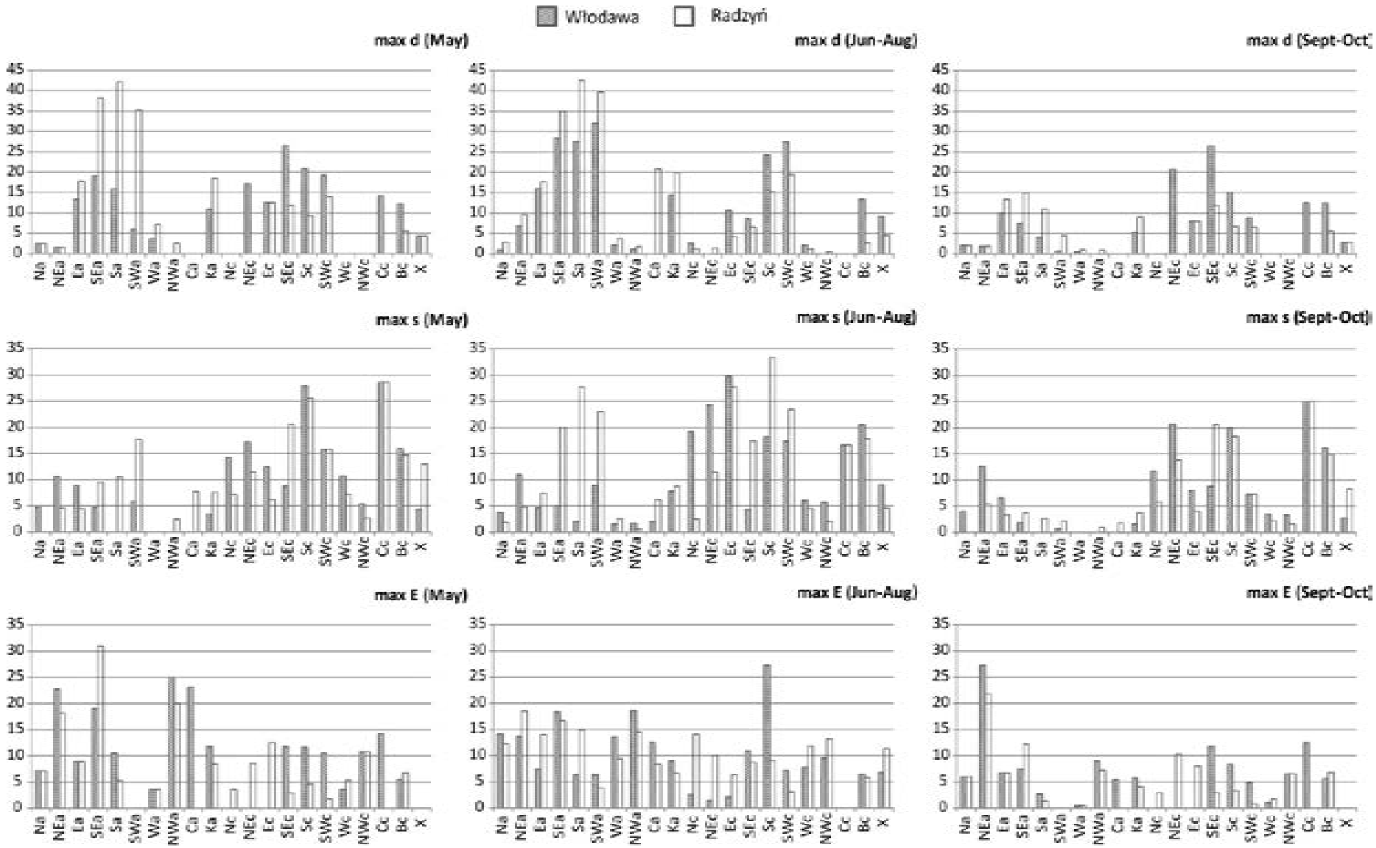

Figure 4. Conditional probability (%) of specific humidity (s), saturation deficit (d) and evaporation (E) extremes (<10%) at selected stations in particular synoptic situation types

Explanations: a – anticyclonic, c – cyclonic, capital letters – air flow direction, Ca – centre of high pressure system, Cc – centre of low pressure system, Ka – anticyclonic wedge, Bc- cyclonic through, X – unclassified

5. CONCLUSIONS

Atmospheric circulation plays an important role in modifying air humidity conditions and evaporation process likewise. A significant impact of both, moisture content and air mass temperature have been proved. Although specific humidity demonstrates inconsiderable spatial and temporal differentiation while accompanying by particular synoptic situations, the hot air mass advection with high evaporation capabilities is often – despite its high specific humidity – characterized by huge saturation deficit what has an important impact on evaporation intensity.

The diversity in circulation background of different weather elements in different regions of Poland (transitional location of the country) proved so far suggest the necessity of detailed spatial analysis for both evaporation processes and – further on – its contribution to climatic water balance modification.

It is necessary to include to the analysis also other predictors, especially the wind speed since the estimation of radiation and anemological factors importance in evaporation due to synoptic situation seems to be crucial and indicate the direction of further studies.

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