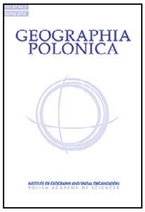

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THE IMPACT OF CLIMATE WARMING ON THE AIR HUMIDITY CHARACTERISTICS AND THEIR LONG-TERM PERSPECTIVE IN POLAND

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Abstract

Long-term changes in saturation, actual water vapour pressure, and saturation deficit in Poland were studied. For that purpose, data from 48 meteorological stations covering the 1966-2020 period were used. A significant trend was found in the saturation water vapour pressure, which influences other humidity conditions. In contrast, changes in actual water vapour pressure were generally negligible. Due to a notable change in saturation water vapour pressure that determines the saturation deficit, its trend was also significant. The most pronounced changes in humidity properties occurred mainly during spring and summer, particularly in Southern and Central Poland.

Keywords

air humidity • atmospheric water • water vapour pressure • saturation deficit • saturation state • Poland • climate change • climate warming

Introduction

Air humidity can be described using several characteristics. Some describe the real amount of water vapour or its impact on the atmosphere (actual water vapour pressure, absolute humidity, specific humidity, or mixing ratio). Others indicate the level of water vapour saturation (relative humidity, saturation deficit) and depend on the saturation water vapour pressure, and therefore on the air temperature, which generally increases (Wypych, 2010). The Clausius-Clapeyron equation states that a 1°C change in air temperature corresponds to a 7% change in the capacity of atmospheric water vapour (Trenberth, 2011).

Actual water vapour pressure describes the real pressure currently exerted by water vapour. Wei et al. (2021) compared air humidity characteristics, including actual water vapour pressure, in arid regions of northern China. They noted that actual water vapour pressure is a humidity measure less temperature-dependent than relative humidity.

Additionally, changes in actual water vapour pressure better show the impact of advection on air moisture conditions. The absolute humidity, specific humidity, and mixing ratio are the air humidity characteristics based on the amount of atmospheric water vapour or its ratio to the air volume mass. The trend in specific humidity is positive in most regions (Vincent et al., 2007; Wypych, 2021). Dai (2006) points to significant dependencies between increasing specific humidity and rising air temperature, as defined by the Clausius-Clapeyron equation. Due to this dependence, a warming climate will lead to an increase in the amount of atmospheric water vapour.

Relative humidity is the most widely used and versatile measure of atmospheric moisture, indicating the degree of saturation with water vapour. Trends in relative humidity are mostly decreasing, and climate warming plays a crucial role in these changes (Peixoto & Oort, 1996; Douville et al., 2021). Likewise, the saturation deficit shows an increasing trend globally (Li et al., 2023). Lapin et al. (2009) also presented projections of changes in saturation deficit in Slovakia to the end of this century, based on the A2 and B1 SRES emission scenarios. These air-humidity characteristics, based on water-vapour saturation levels, indicate atmospheric drying.

Most papers on air humidity in Poland describe local conditions (Kotońska, 1974; Bryś, 2003). Many studies have investigated long-term changes in humidity caused by climate change and have mostly relied on relative humidity, which shows a significant decreasing trend (Wypych & Piotrowicz, 2008; Sachindra & Nowosad, 2021; Wypych, 2021; Bartoszek et al., 2023; Krawczyk, 2025). The saturation deficit in Poland increased, indicating atmospheric drying, consistent with the trend in relative humidity (Wypych, 2008; Wibig & Krawczyk, 2023). However, there are increasing trends in actual water vapour and specific humidity (Limanówka et al., 2012; Wypych & Bochenek, 2018).

The main purpose of this paper is to detect long-term changes in air humidity conditions in Poland and to explain spatial and seasonal differences. This research extends the latest humidity observations in Poland and examines their relationships with climate change. A simultaneous comparison of different humidity characteristics shows their diversity and helps explain the origin of these changes.

Data and methods

Data

The air humidity properties described in this paper concern Poland. Most of its areas are lowland, with a temperate, transitional climate. Poland is located in the mid-latitudes of central Europe, south of the Baltic Sea, and bordered by mountains (the Sudetes and Carpathians) to the south. Due to this relief pattern, continental and oceanic air masses formed in different climate regions can affect weather conditions in Poland. Therefore, milder weather is observed in western Poland because of oceanic air masses. In contrast, the impact of continental air masses in eastern Poland makes the weather more austere and more differentiated throughout the year (winters are colder and summers are warmer). The transitional climate allows the impact of wet and dry air masses on weather to be observed, so this border location in Poland encourages the observation of long-term changes in regions differentiated by air humidity. This research allows for rating the range of continentality processes due to climate change.

The research described in this paper is based on meteorological data from 48 measurement stations across Poland at elevations below 500 m a.s.l. (Fig. 1). This altitude restriction excludes the mountainous region, where atmospheric properties and processes differ slightly. The network of measuring stations is operated by the Polish Institute of Meteorology and Water Management – National Research Institute, which maintains an archival database. The data used in the study cover the period from 1966 to 2020 and include air temperature (T), relative humidity (f), and air pressure at the station's level (p)

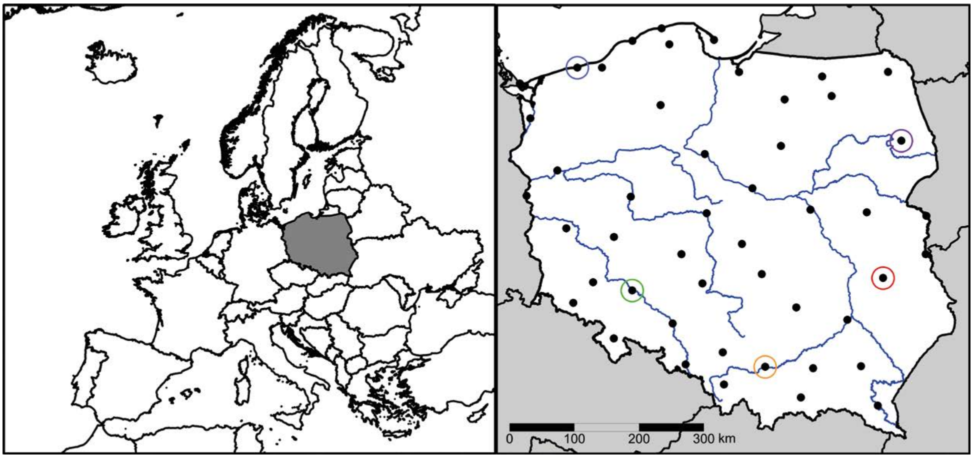

Figure 1. Location of Poland in relation to European countries (on the left) and the distribution of measurement stations of the Polish Institute of Meteorology and Water Management – National Research Institute (black dots) in Poland (on the right); colour circles show the location of stations used in Figs. 8 and 13

at 12 UTC in four selected months representing four seasons of the year (January, April, July, and October). The comparison of monthly mean humidity shows conditions appropriate to the seasons, while seasonal averages could equalise results, making the seasonal differences less pronounced. The choice of measurements at noon is influenced by the greatest differentiation in humidity during the diurnal cycle (Wibig & Krawczyk, 2023). Additionally, measurement frequency varied across stations in the last century; however, measurements were always collected at 12 UTC, so the database is almost complete. There are 42 measurement stations with complete data records. There are fewer than 4% gaps across 6 datasets; moreover, the gaps in 3 of them are no higher than 0.1%. The data gaps were not filled, and these data were excluded from the research. The homogeneity of the data was confirmed using the Alexandersson test (Alexandersson, 1986).

Methods

To analyse long-term changes in humidity characteristics, the current water vapour pressure (e), the saturation water vapour pressure (E), and the saturation deficit (Δe) were used. Relative humidity (f), air temperature (T), and air pressure at the station's level (p) enabled the calculation of the values of other humidity indices using appropriate formulas recommended by the World Meteorological Organisation (WMO) (JCOMM 2015):

$$e = Ef/100$$

$$E = 6.112 \exp \cdot \left(\frac{17.62T}{243.12 + T} \right) \cdot \left(1.0016 + + 3.15 \cdot 10^{-6} p - 0.074 p^{-1} \right)$$

$$\Delta e = E - e$$

where:
f – is the relative humidity (in %),
T – means air temperature (in °C), and
p – is the air pressure at the station's height (in hPa).

Changes in air humidity in Poland are described using the mean values and the coefficient of variation of the saturation and actual water vapour pressure and saturation deficit. The mean values were also calculated for three 15-year subperiods: 1966-1980 (P1), 1986-2000 (P2), and 2006-2020 (P3), allowing comparison of air humidity conditions across different stages of the long-term period.

Simultaneously, the use of three equally distributed subperiods allows assessment of the magnitude of changes between subperiods and verification of the distribution of modifications in air humidity characteristics in the long-term perspective. This approach allows rating whether the changes in air humidity were greater in the first or second half of the 55-year period. The statistical significance of long-term changes was assessed using the Mann-Kendall test at the 95% confidence level, and the slope was estimated using the Theil-Sen estimator (Gocic & Trajkovic, 2013). The autocorrelation of the series was calculated to exclude serial correlation and confirm the independence of the data over time. The use of autocorrelation also validated the application of the Mann-Kendall test and the reliability of its results. Long-term changes in these characteristics were visualised on maps generated in Surfer 10 using the Ordinary Kriging interpolation method.

Results and analysis

The relation between climate warming and saturation water vapour pressure change

The saturation water vapour pressure is an atmospheric characteristic that describes the atmosphere's capacity for water vapour rather than the amount of atmospheric water, and it depends mostly on air temperature. Therefore, its annual variation is similar to the seasonality of air temperature. The lowest saturation water vapour pressure occurred in winter (Fig. 2); the mean *E* values ranged from 5 hPa in Northeastern Poland to slightly more than 7 hPa in Western and Southwestern Poland. In spring and autumn, the *E* conditions were similar (slightly higher in October (12.4-16.4 hPa) than in April (11-16 hPa)). The spatial distribution of *E* in October is similar to that in January: the lowest values were observed in Northeastern Poland, with values increasing to the southwest. In April, *E* values increased from the coastal regions of Northern Poland to the southern parts of the country. The highest *E* was observed in summer (Fig. 2), and its spatial distribution was similar to that of spring. The lowest values (<23 hPa) were observed in the coastal region, whereas the highest *E* (> 28 hPa) was observed in Southern and Central Poland (Fig. 3).

Climate warming increases the atmosphere's capacity to hold water vapour, so the amount of water vapour required to reach saturation increases. Low changes are visible in the colder half of the year. The Sen's slope of *E* ranged from 0.1 to 0.3 hPa/10 years in January and from below 0.1 to 0.4 hPa/10 years in October. The change in *E* was mainly over 0.2 hPa/10 years, with the lowest slope observed in Southern and Southeastern

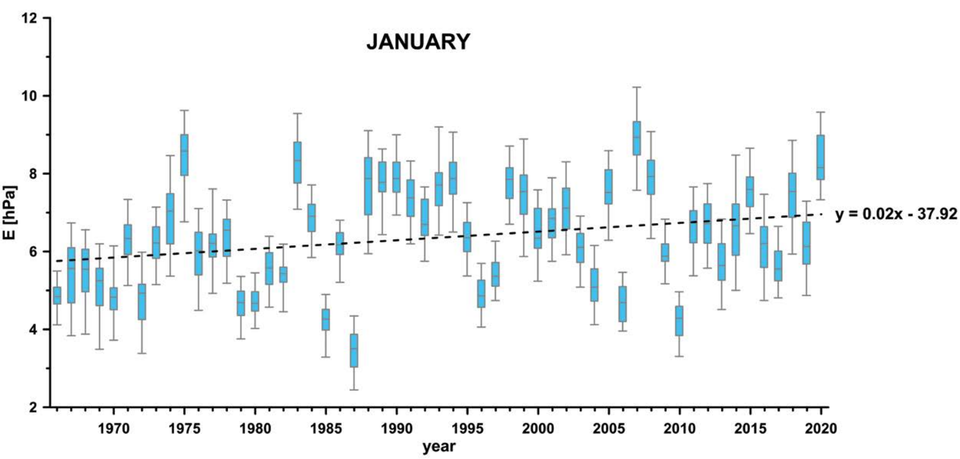

Figure 2A. The saturation water vapour pressure range in all stations in January (blue)

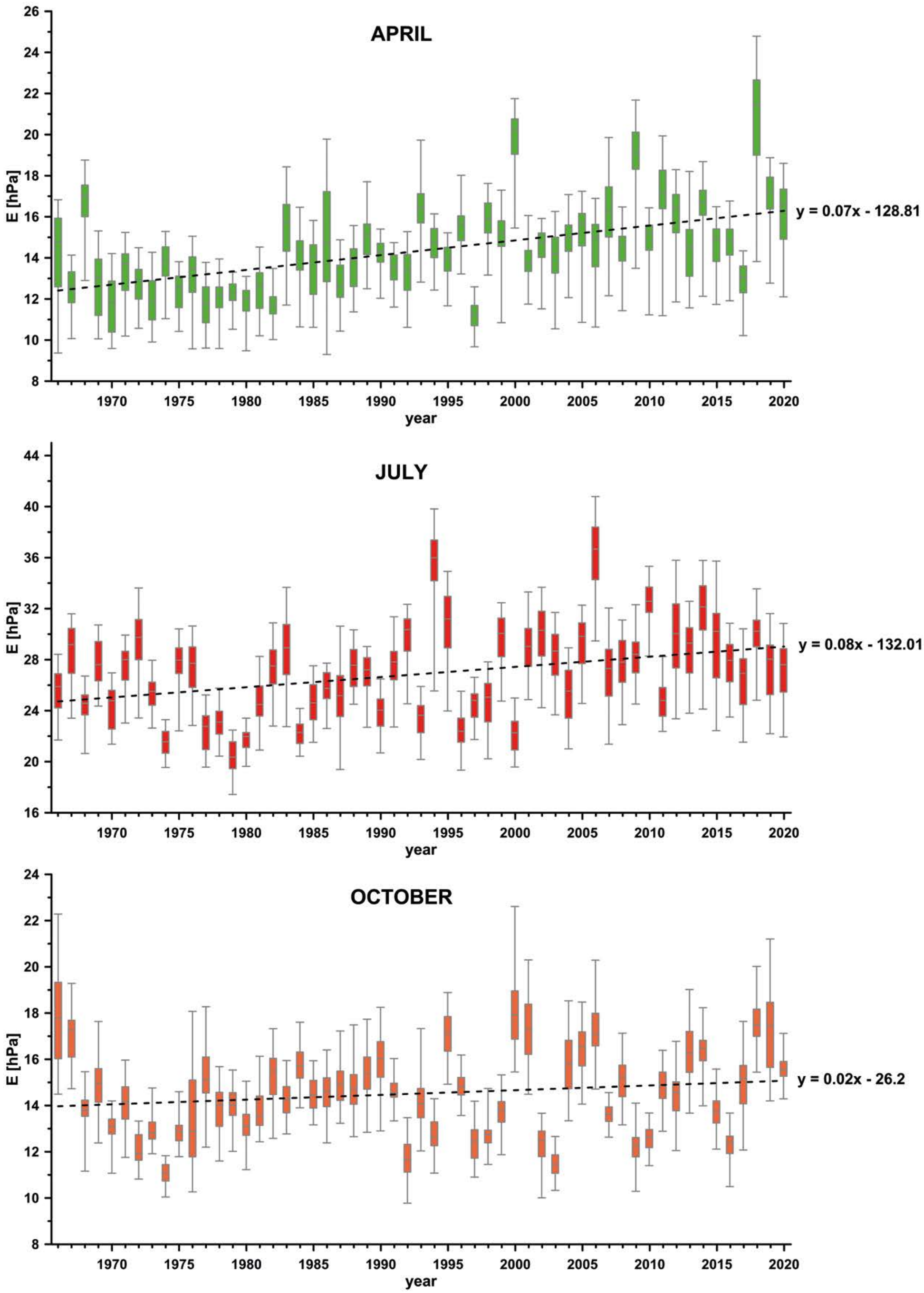

Figure 2B. The saturation water vapour pressure range in all stations in April (green), July (red), and October (orange) from 1966 to 2020 and the linear trend of mean values

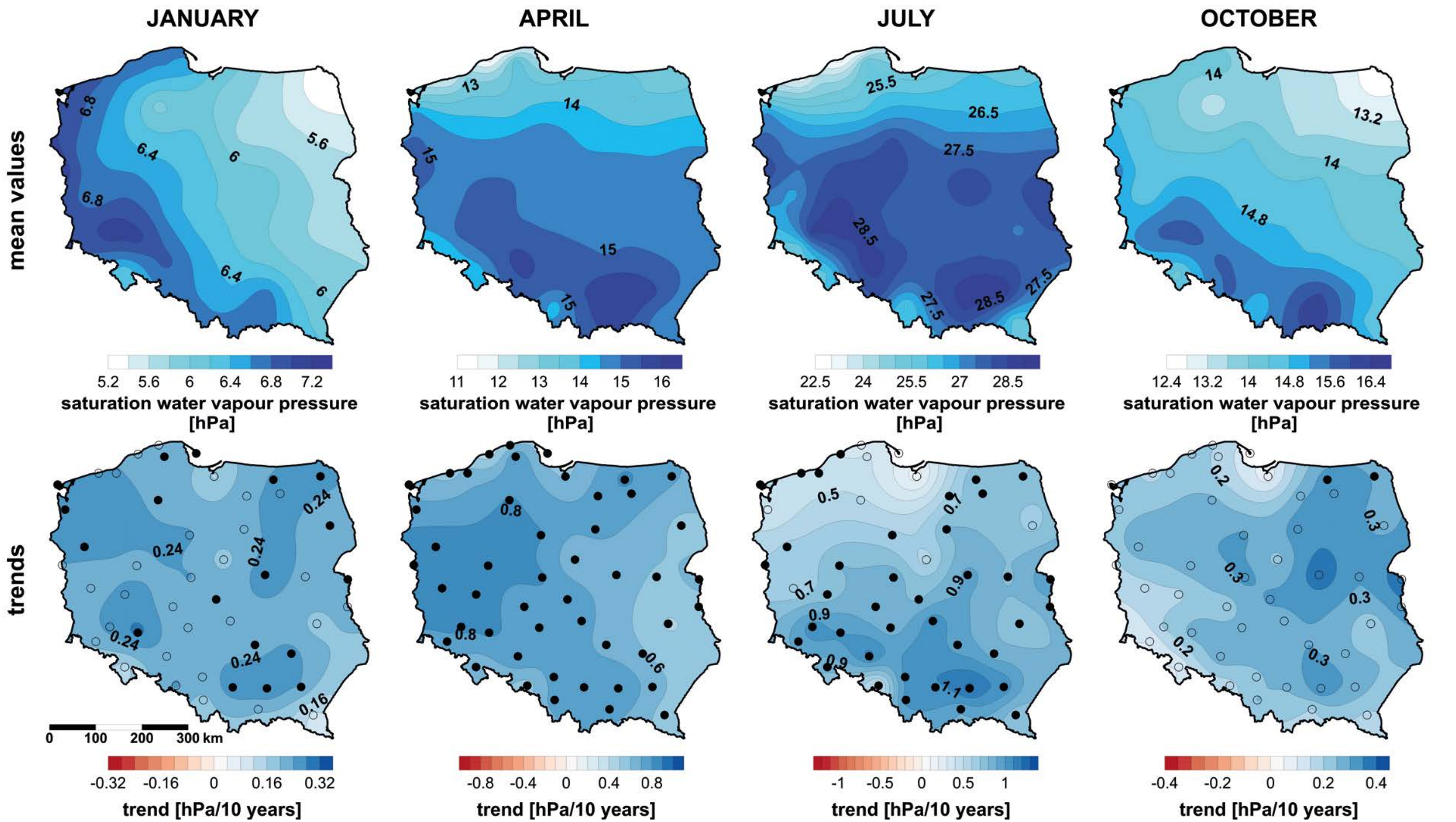

Figure 3. Spatial distribution of mean values and trends (described on the left-hand side) of saturation water vapour pressure in January, April, July and October (described on the top) in Poland (black dots indicate a statistically significant trend and the empty ones – a statistically insignificant trend)

Poland in January. In October, the higher slope was mostly in Northeastern Poland (> 0.3 hPa/10 years). These trends were statistically significant at 18 measurement stations across Poland in January. By contrast, the *E* trend was mostly insignificant in October (statistically significant at only 2 stations). The long-term changes in *E* were greater and more spatially variable in the warmer half of the year. The Sen's slope of *E* was from 0.4 to slightly over 0.9 hPa/10 years in April. Then, the lowest Sen's slope was observed in Eastern Poland and the coastal region (< 0.6 hPa/10 years), while a greater change in *E* was observed in Western Poland (> 0.8 hPa/10 years). These changes are statistically significant at all stations. In July, the slope was between 0.1 and 1.3 hPa/10 years, but exceeded 0.7 hPa/10 years in most of the country. The high increase in *E* (> 1 hPa/10 years) was observed in Southern Poland, whereas the lower change in *E* (< 0.5 hPa/10 years) was in the coastal region in July. The *E* trend was statistically significant at more than 80% of measurement locations (39 out of 48). Insignificant trends were mostly observed in the coastal region (Fig. 3).

Actual water vapour pressure changes

The lowest values of the actual water vapour pressure were observed in winter (3.9-6.2 hPa in January) (Fig. 4). It was slightly lower in P1 (3.9 to 5.4 hPa) than in other subperiods (from 4.7 to 6.2 hPa). In general, the lowest values were observed in the eastern parts of Poland and increased toward the west (Fig. 5). Simultaneously, lower *e* values were associated

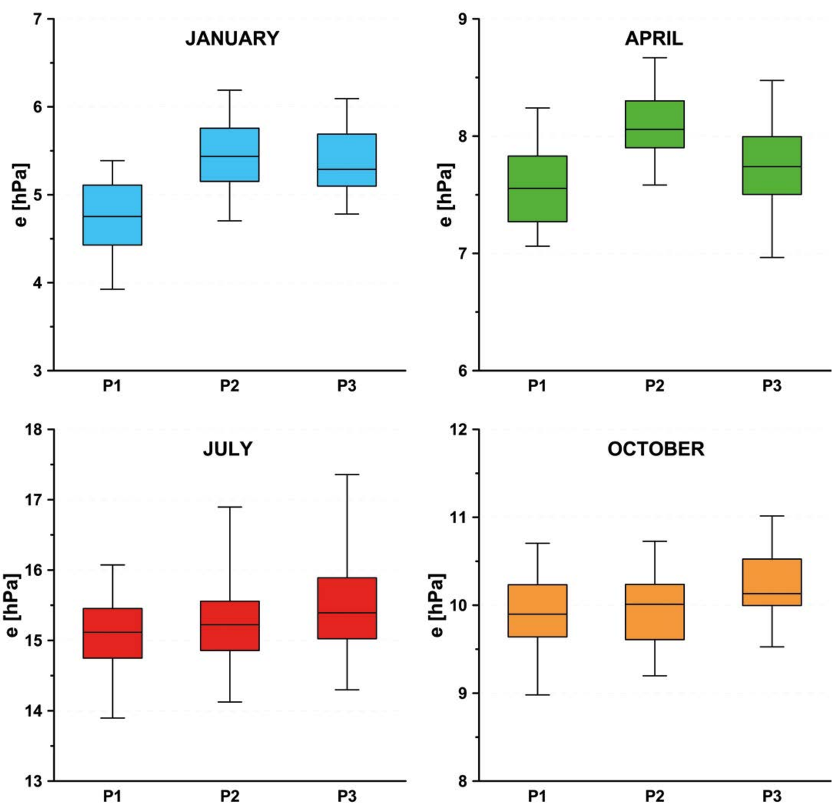

Figure 4. The actual water vapour pressure range of mean values in all stations in subperiods P1-P3 in January (blue), April (green), July (red) and October (orange) in Poland

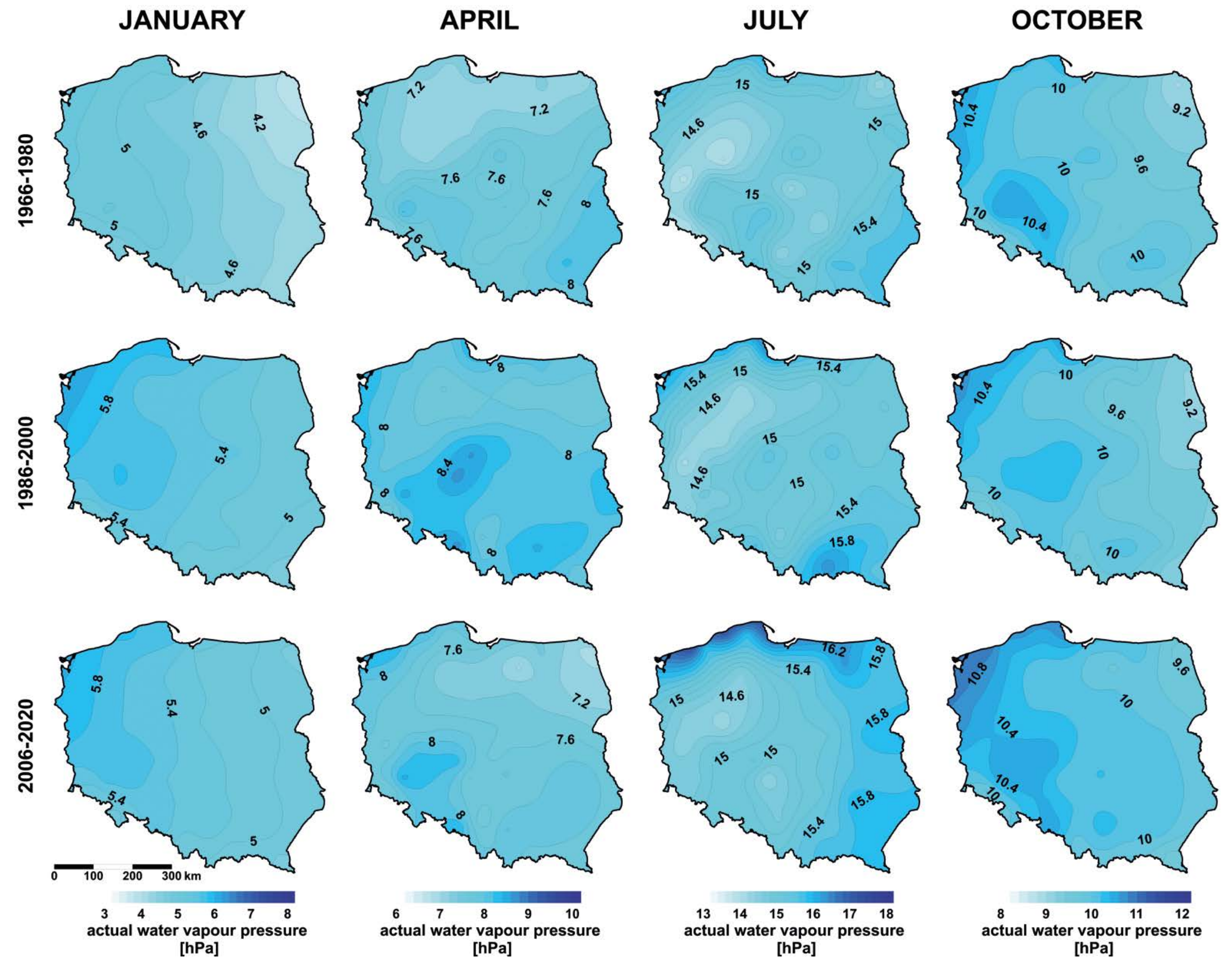

Figure 5. Spatial distribution of mean values of actual water vapour pressure in January, April, July and October (described on the top) in three 15-year subperiods (1966-1980, 1986-2000, 2006-2020; described on the left-hand side) in Poland

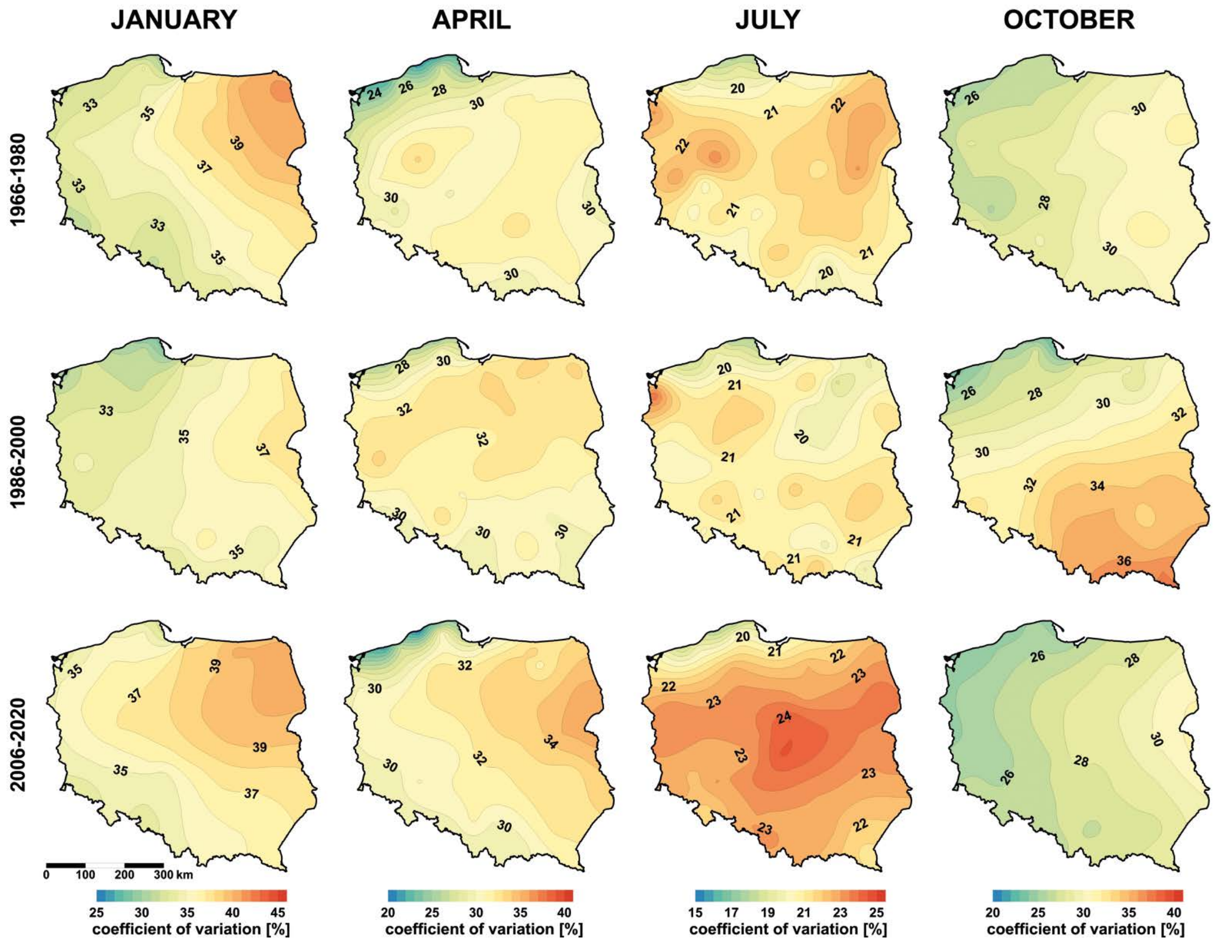

Figure 6. Spatial distribution of the coefficient of variation of actual water vapour pressure in January, April, July and October (described on the top) in three 15-year subperiods (1966-1980, 1986-2000, 2006-2020; described on the left-hand side) in Poland

with higher coefficient of variation in Eastern Poland than in other regions in winter (>35%). The long-term change in *e* in January is ambiguous, as the highest *e* value and the highest mean across all stations' measurements were observed in P2.

The spatial distribution of *e* in autumn was similar to that in winter: it increased from east to west. In October, *e* values were the lowest in P1 (9-10.5 hPa) and increased slightly in the next subperiods (9.5-11 hPa in P3). Significant changes in *e* were observed in autumn, with differences in its distribution between P2 and P3. In P3, the lowest *e* values in Eastern Poland were not less than 9.5 hPa, and mean values in most of the country area were over 10 hPa (Fig. 5). The *e* was the least varied in the coastal region (coefficient of variation below 26%). The highest diversity of the *e* was in Eastern Poland (coefficient of variation over 30%) (Fig. 6).

In spring, the *e* conditions were distinctly different from those in the autumn and winter months. The temporal and spatial differentiation was irregular, and the values were quite similar across country areas. The *e* in April was between 6.9 and 8.7 hPa in 1966-2020, while the values were a little higher only in P2 (7.5-8.7 hPa) (Fig. 5). The *e* values are more diverse in April than in October. The coefficient of variation was greater than 30% in most of the country areas in spring. The *e* was least variable in the coastal region (below 26%), whereas the highest coefficient of variation was in Central and Eastern Poland (over 32%), especially in P3 (Fig. 6).

The highest values of actual water vapour pressure were observed in summer (Fig. 4). In July, the *e* values gradually increased throughout the long-term period. The highest values were in Northern Poland, especially in the coastal region (more than 16 hPa in P1 and increasing to over 17 hPa locally in P3), whereas the lowest *e* was observed in Western Poland (< 14 hPa in P1, increasing to 14-14.5 hPa in P2 and P3). A comparison of *e* values across the country area in all subperiods suggests that the amount of water vapour in atmospheric air increased gradually (Fig. 5). The coefficient of variation in *e* was up to 25%. The lowest coefficient was observed mostly in Northern Poland, where air moisture conditions were least varied. The most variable conditions were observed mostly in the lowland belt in Central Poland (Fig. 6).

The Sen's slope of *e* ranged from -0.4 to 0.5 hPa/10 years, indicating both increasing and decreasing trends. The increasing trend was observed only in January across the whole country. Decreasing trends were observed at 6 stations in July and October, and at 16 stations in April. The strongest trends of *e* (increasing and decreasing) were observed in July, when the slope reached up to 0.5 hPa over 10 years, whereas the trends in October were mostly weak and statistically insignificant. In the colder half of the year, the slope range was lower, but the trend was slightly higher in Northeastern Poland. The spatial differentiation of the trends was more visible in April and July. The strongest decreasing trend was observed in Eastern Poland in April and in the southwestern parts of the country in July. Moreover, the *e* growth was observed in Northern Poland in warmer months. The statistical significance of changes in *e* was observed mostly in Northern Poland and was more often noticed in January than in other analysed months (16 of 48 stations) (Fig. 7-8).

Saturation deficit changes

In winter, the saturation deficit was the lowest throughout the year (0.5-2.1 hPa in January) (Fig. 9). Low Δe values were observed in P1 (mostly $\Delta e < 1$ hPa), but increased slightly over the long-term period. The lowest values were in Northeastern Poland (below 1 hPa throughout the long-term period). By contrast, the highest Δe was in Southern and Southwestern Poland (over 1.5 hPa in P1, increasing locally to 2 hPa in P2 and P3) (Fig. 10). The area with $\Delta e > 1.2$ hPa expanded compared to P1 and other subperiods, so the increase in the saturation deficit is visible in winter in the long-term perspective. In winter, Δe varies from the mean; the coefficient of variation

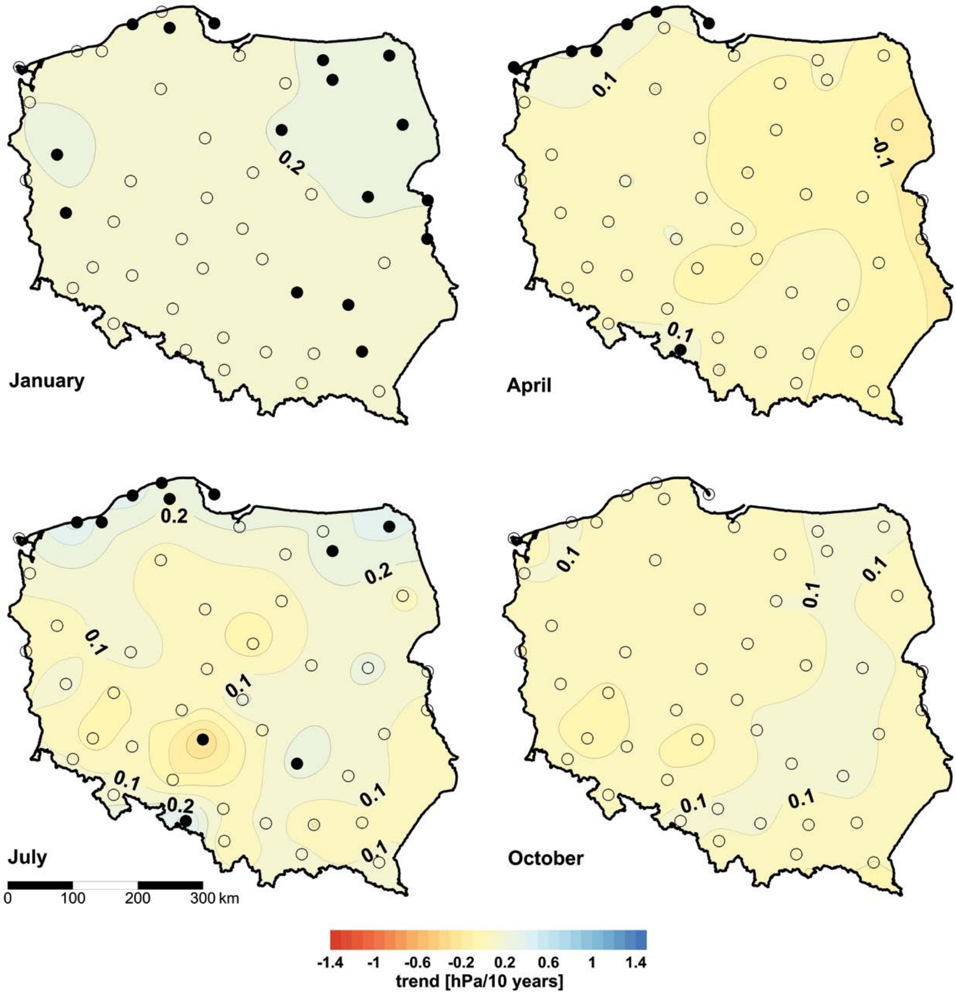

Figure 7. The actual water vapour pressure trends and its statistical significance in Poland in 1966-2020 (black/empty dots indicate a statistically significant/insignificant trend; colour scale – a trend in hPa/10 years)

is > 80% in most of Poland. Lower variation is mostly in the coastal area and locally in the mountain region and eastern parts of Poland, where it did not exceed 70% (Fig. 11).

Δ*e* was higher in autumn than in winter (Fig. 9); it ranged from 2.8 to 6.8 hPa in October and increased gradually in the subsequent subperiods. The lowest Δ*e* values were in Northeastern and Northern Poland (< 3 hPa in P1 and < 4 hPa in P2 and P3). In P1, Δ*e* < 4 hPa covered almost half the country's area, but this area shrank to a thin belt in Northern Poland in P2 and P3. The highest Δ*e* was in Southern Poland, where it increased from about 6 hPa in P1 to almost 6.8 hPa in P3 (Fig. 10). Δ*e* was more variable in P1; the coefficient of variation exceeded 80% over a large area in Central and Southern Poland (Fig. 11).

The growing Δ*e* contrasts in a year are visible in spring and summer. In April, Δ*e* ranged from 2.9 to 10.1 hPa and increased significantly from P1 to P3 (Fig. 9). The lowest values were found in the coastal areas and increased

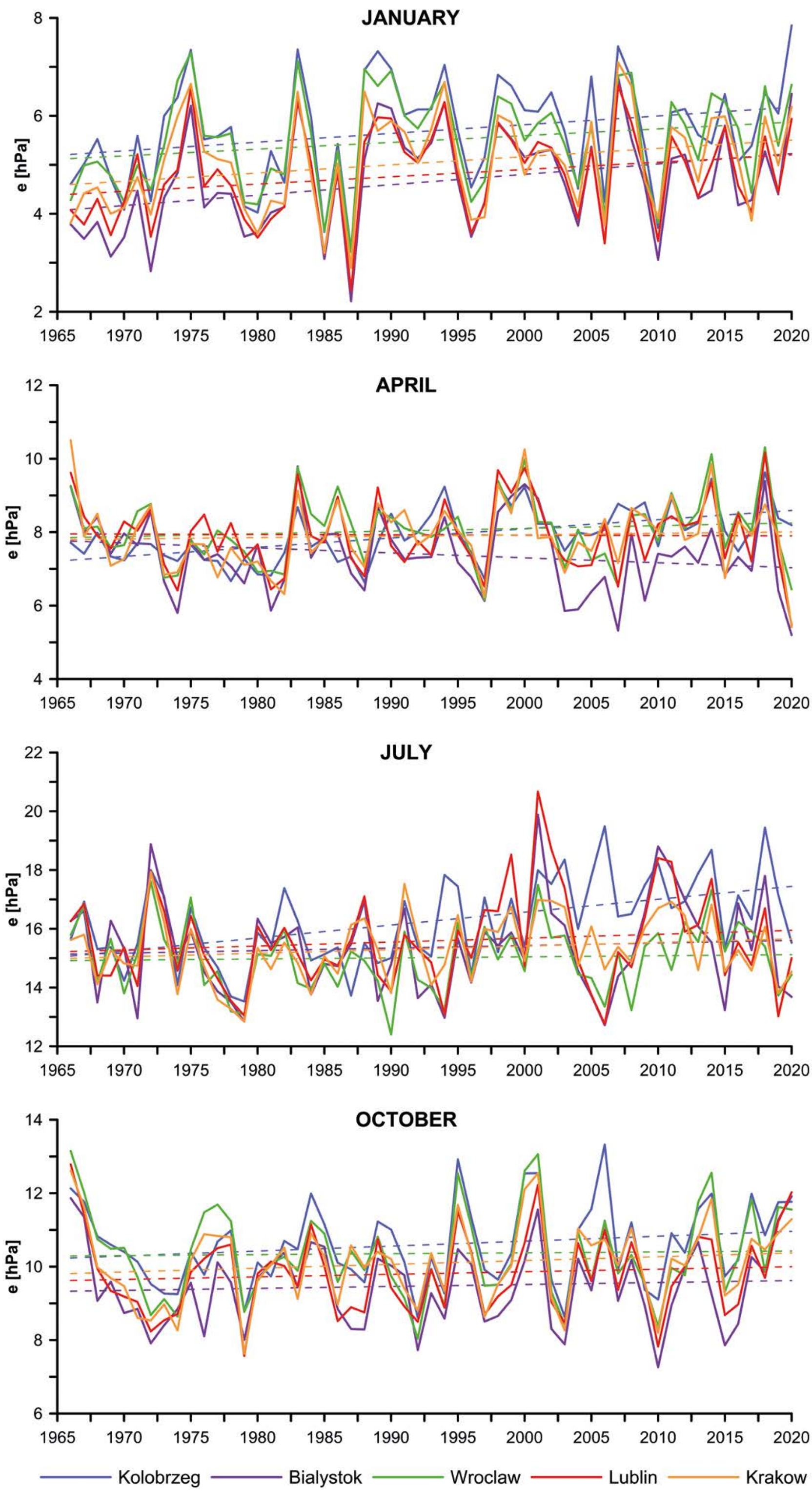

Figure 8. Changes in the monthly mean of actual water vapour pressure in the chosen stations representing other regions of Poland from 1966 to 2020

toward the south. More pronounced changes in the subperiods were associated with higher saturation deficit. Lower Δ*e* in Northern Poland increased slightly, while higher Δ*e* in Central and Southern Poland changed significantly. The Δ*e* was 2.9-6.7 hPa in P1, then grew to 3.9-7.7 hPa in P2 and 3.7-10.2 hPa in P3 (Fig. 10). The Δ*e* was more variable in the coastal region, whereas the coefficient of variation was below 80% in P1 and decreased to below 70% in P3 across most of Poland (Fig. 11).

The highest saturation deficit was observed in summer (Fig. 9). In July, it ranged from 6.1 to 16.8 hPa and increased significantly over the long-term period. Higher Δ*e* values were observed in Central Poland, and lower values in the coastal and mountain regions (Fig. 10). Increases in the saturation deficit across subperiods were concentrated mainly in areas with higher Δ*e*. The range of Δ*e* widened from 6.1-12.4 hPa in P1 to 6.9-16.7 hPa in P3. The July variation in Δ*e* was similar to that in April. The coefficient of variation was higher in the coastal region, whereas in other regions it did not exceed 70% in P1 and 60% in P3 (Fig. 11).

The trends of saturation and actual water vapour pressure impact long-term changes in the saturation deficit. Due to the significant growth of *E*, the trend of Δ*e* was mostly increasing. The Sen's slope was between -0.1 and 0.2 hPa/10 years in January and between -0.1 and 0.3 hPa/10 years in October; the trends were mostly increasing in both months (in 45 stations in January and 47 in October). In January, the 10-year change in Δ*e* was mostly below 0.1 hPa. In Southern Poland, the slope was slightly higher than

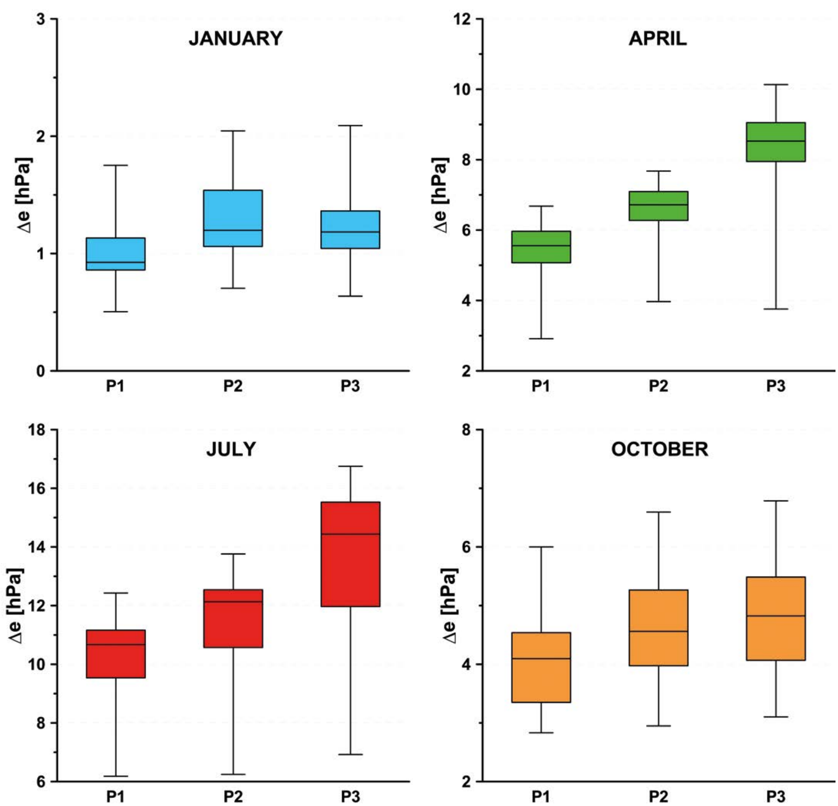

Figure 9. The saturation deficit range of mean values in all stations in subperiods P1-P3 in January (blue), April (green), July (red) and October (orange) in Poland

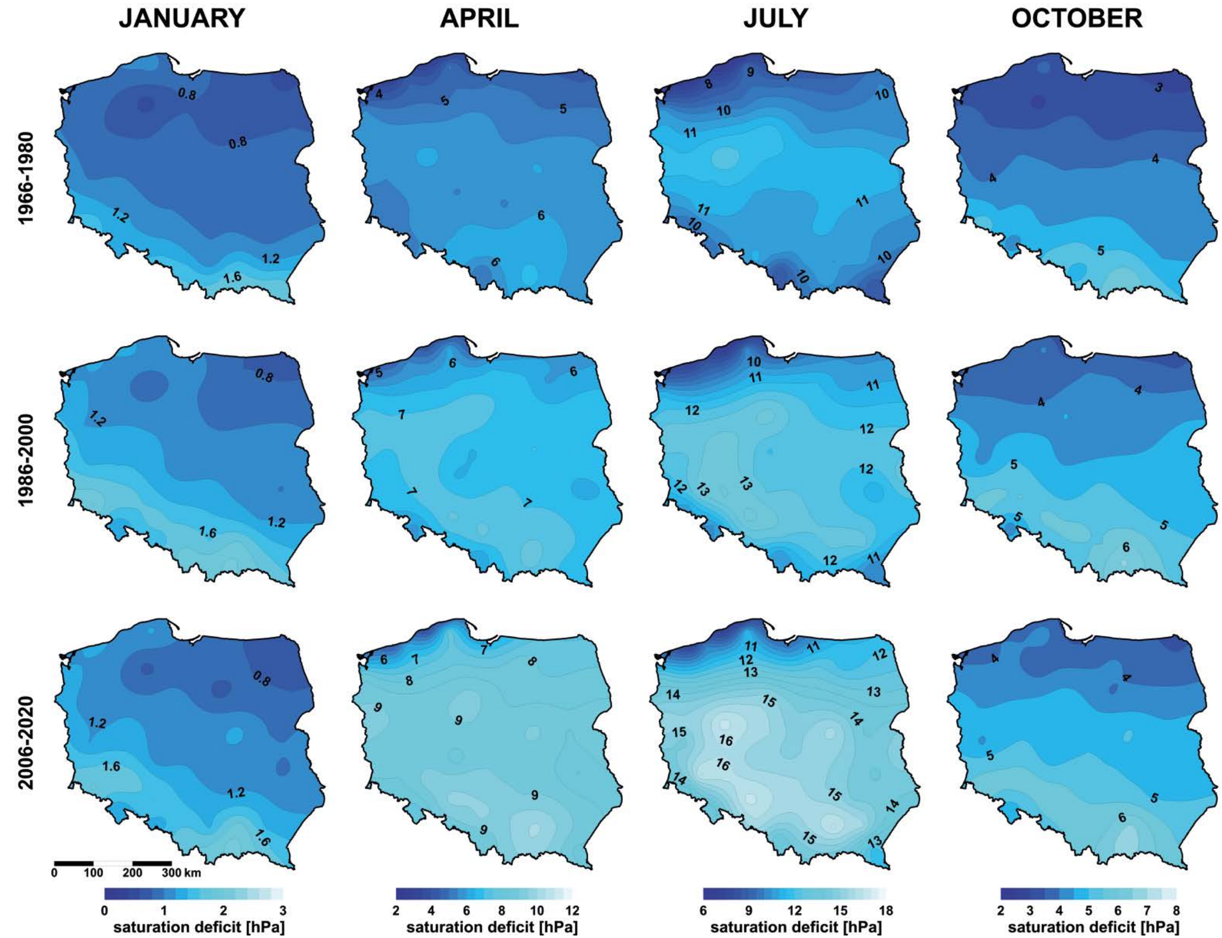

Figure 10. Spatial distribution of mean values of saturation deficit in January, April, July and October (described on the top) in three 15-year subperiods (1966-1980, 1986-2000, 2006-2020; described on the left-hand side) in Poland

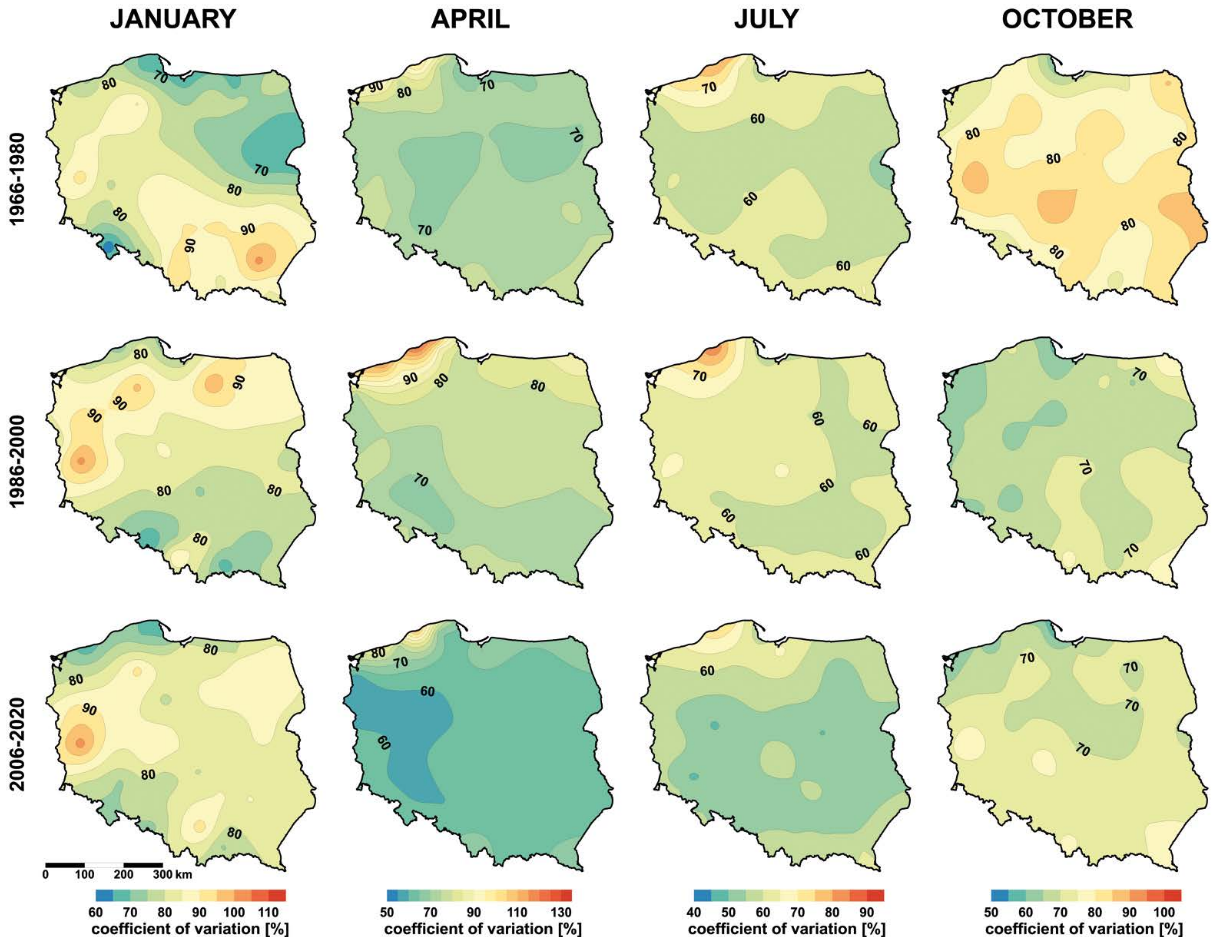

Figure 11. Spatial distribution of the coefficient of variation of saturation deficit in January, April, July and October (described on the top) in three 15-year subperiods (1966-1980, 1986-2000, 2006-2020; described on the left-hand side) in Poland

in the other regions in winter. Despite the low trend of Δ*e* in January, it was significant at 20 of 48 stations (mostly in Central and Western Poland). The trends were quite higher in October than in January (> 0.1 hPa/10 years at most stations), but they were mostly insignificant. In April and July, the changes in Δ*e* were much greater. The change in Δ*e* was mostly > 0.6 hPa/10 years in both months (0.2-0.9 hPa/10 years in April, while in July ranged from -0.1 to 1.3 hPa/10 years). The weakest changes were noticed in the coastal region (trends are close to zero), while a higher trend (over 1 hPa/10 years in July) was observed in Southern Poland. In the warmer half of the year, many more changes are statistically significant: at all measurement stations in April and at 29 out of 48 stations (over 60%) in Central and Southern Poland in July (Fig. 12-13).

Discussion and conclusions

Differences in humidity trend characteristics are partly related to progressive climate warming, driven by rising air temperature,

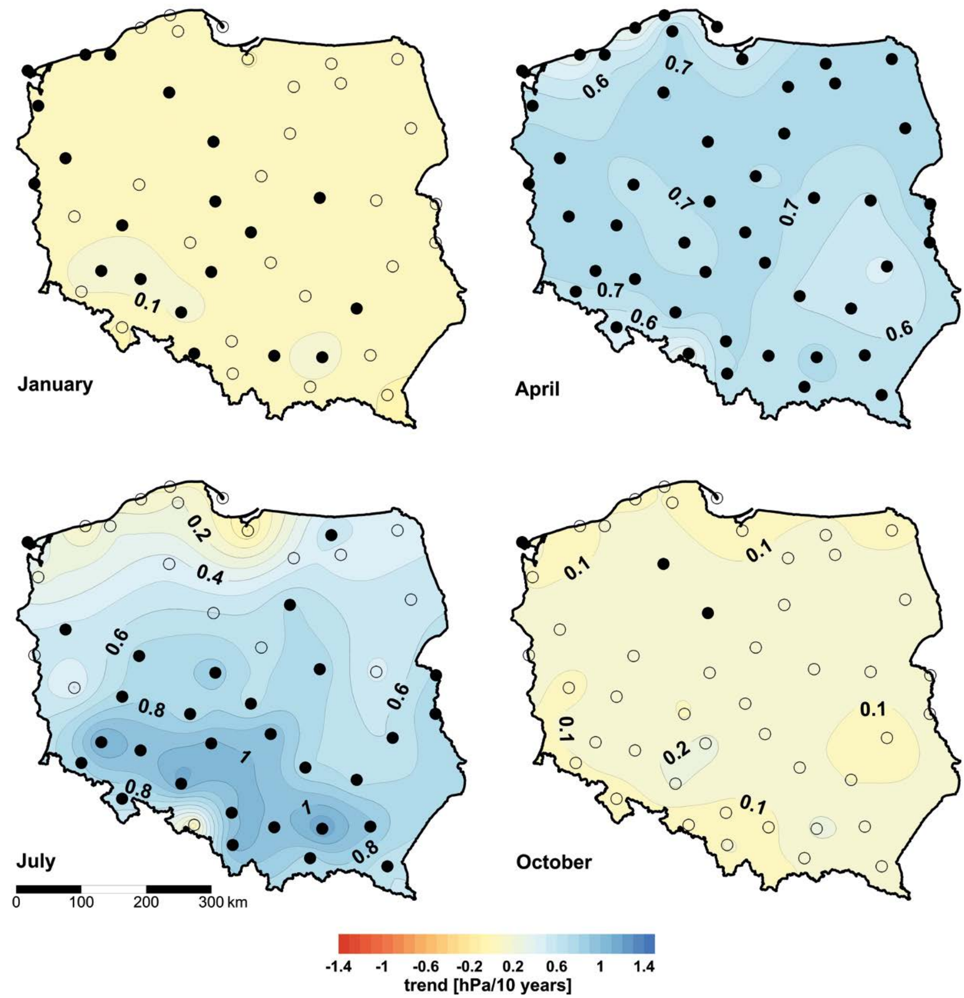

Figure 12. The saturation deficit trends and its statistical significance in Poland in 1966-2020 (black/empty dots indicate a statistically significant/insignificant trend; colour scale – a trend in hPa/10 years)

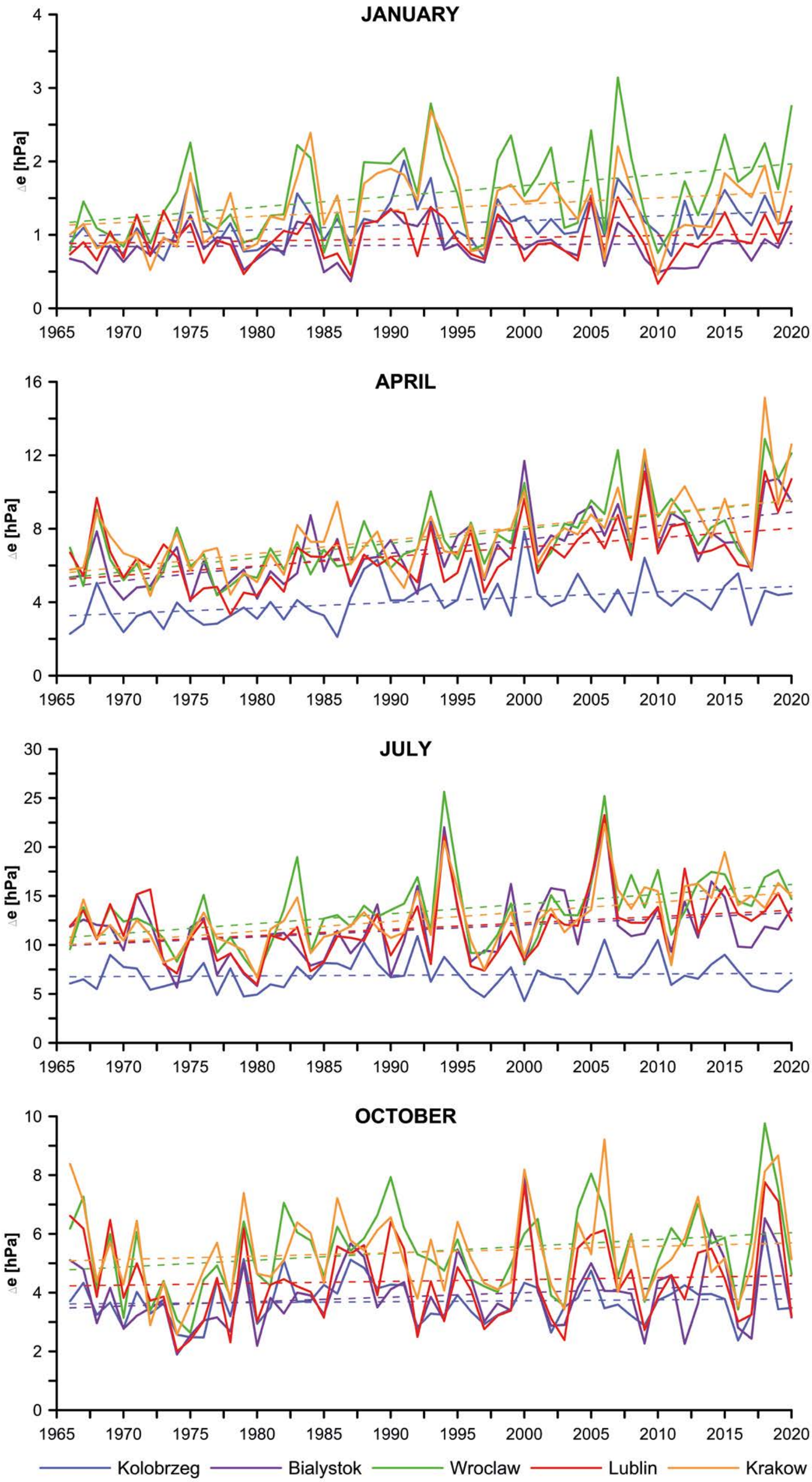

Figure 13. Changes in the monthly mean of saturation deficit in the chosen stations representing other regions of Poland from 1966 to 2020

which increases the saturation water vapour pressure (Limanówka et al., 2012; Lee et al., 2021). All humidity characteristics exhibit annual variability, with maximums in summer and minimums in winter (Wibig & Krawczyk, 2023; Figs. 3, 5, 10). The trends in actual water vapour pressure are weaker and mostly statistically insignificant, unlike those of the saturation deficit. Only in the coastal areas of Northern Poland did the amount of atmospheric water vapour increase slightly (Fig. 7), which is influenced by the marine climate and nearby sources of water vapour (advected from the Baltic Sea). Additionally, lower temperatures in coastal areas hinder soil and atmospheric drying, resulting in lower saturation deficit and drought risk. In Central and Southern Poland, the relevant rise in the saturation water vapour pressure and weak actual water vapour pressure trends (Figs. 2 & 4) contribute to an increasing trend of saturation deficit, which is particularly severe in spring and summer (Fig. 12). Dai (2006) also pointed to the dependencies of the growth in the amount of atmospheric water vapour and a decrease in the relative humidity on increasing temperature. On this basis, the growth of saturation deficit was conditioned by an increase in temperature, not by a change in the amount of atmospheric water vapour.

As Wei et al. (2021) stated, the actual water vapour pressure is related to precipitation occurrence and intensity. In Poland, the observed changes in precipitation totals were mostly insignificant, also in the growing season (Tomczyk & Szyga-Pluta, 2018a), which is consistent with trends of actual water vapour pressure (Fig. 7). Precipitation totals in summer decreased as opposed to winter precipitation totals, as Szwed (2019) showed. The difficulties in precipitation formation in summer are related to increasing saturation deficit, so the amount of water vapour is insufficient to reach saturation and further growth of cloud drops despite a non-decreasing trend in actual water vapour pressure. Increasing saturation water vapour pressure indicates a larger water vapour capacity of the atmosphere; therefore, more atmospheric water is available in a saturated state, and more water is released during precipitation. These dependencies might lead to stronger, more prolonged droughts or extreme precipitation (Ziernicka-Wojtaszek & Kopcińska, 2020). Łupikasza (2010) highlighted a decrease in the frequency of extreme precipitation occurring, especially in summer and winter. On the other hand, Pińskwar et al. (2018) also showed that the periods of consecutive dry days lasted longer in the warmer season in Poland, which might be attributed to an increase in air temperature and the strengthening of the water vapour deficit.

The changes in thermal and humidity conditions in Poland are relevant during the growing season. In a warmer climate, it starts earlier and ends later than a few years ago (Tomczyk & Szyga-Pluta, 2018a,b). Meteorological conditions in spring have a significant impact on plant growth (Chia & Lim, 2022; Liu et al., 2022). The humidity conditions in April were especially worth considering due to the highest increase in air temperature and the most pronounced changes in humidity properties (Krawczyk, 2025). The longer growing season and varying weather conditions pose adaptation challenges for previously cultivated plants, prompting the cultivation of new crop varieties in Poland (Wypych et al., 2017). Simultaneously, hot and dry weather conditions may impede plants' growth, so the growing trend in saturation deficit (Fig. 12, 13) and more frequent droughts might affect environmental and agricultural development.

In winter, the most visible manifestation of a changing climate is related to the thickness and duration of the snow cover. The melted snow is an important part of the water resources that reach the ground and surface water. Tomczyk et al. (2021) highlighted a decrease in cold waves and an increase in the prevalence of mild winters, accompanied by the increasing frequency of warm waves. Wibig and Jędruszkiewicz (2023) also highlighted the scale of this problem in Western Poland, where air temperatures have risen above 0°C in recent years. In winter, the increase in air temperature and saturation deficit also hinders snowfall and snow cover formation. A lack of snow cover reduces albedo, so the ground absorbs more solar energy. Simultaneously, less energy is used for snow melting and evaporation. Therefore, greater energy leads to stronger heating of the lower atmosphere, and so the saturation water vapour pressure increases (Figs. 2, 3). The faster disappearance of snow cover and warmer winters affect spring weather conditions, including humidity. In Central Poland, climate change is apparent in shorter snow cover duration and fewer days with snow cover (Szyga-Pluta, 2022). The impact of changes in snow cover on thermal properties is strongly related to the significant increase in the saturation deficit in spring (Fig. 12). Additionally, decreases in snow cover duration and its thickness affect the water cycle and water management. As a result, water deficits and droughts in spring and summer are more likely, negatively affecting many sectors of the national economy, especially agriculture (Szwed et al., 2017).

In conclusion, based on the previously mentioned results and other research, Earth's atmospheric processes are complex and interconnected. Climate warming has become more noticeable and is related to other weather phenomena and characteristics. The changes in the humidity conditions in Poland are mostly caused by the increase in air temperature, especially in spring and summer. The actual water vapour pressure slowly increased, while the saturation water vapour pressure and saturation deficit increased significantly. Therefore, the increasing trends in humidity characteristics in Poland are more strongly affected by rising temperatures than by changes in the amount of atmospheric water vapour.

Data Availability Statement:

The data used in this research are openly available at https://danepubliczne.imgw.pl/data/dane_pomiarowo_obserwacyjne/dane_meteorologiczne/

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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