International Journal of Advanced Science and Technology
Vol. 29, No.02, (2020), pp. 279-286

Variability of meteorological parameters on the Uznam and Wolin islands (Baltic Sea)

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Abstract: *The aim of the work is to analyze the variability of temperature, precipitation and snow cover, as well as the number of days with wind over 10 ms-1 and storms occurring on the Uznam and Wolin – coastal islands of the Baltic Sea (Poland/Germany). The research material used in the paper were data collected in the years from 1960 to 2018 from the meteorological station Świnoujście belong to the Institute of Meteorology and Water Management – National Research Institute (IMWH-NRI). The non-parametric Mann–Kendalls test were used to detect trends in the changes in time series. Statistically significant trends of changes in the meteorological parameters analyzed were observed.*

Index Terms: *climate change, extreme weather, global warming, Mann–Kendall test.*

I. INTRODUCTION

Uznam (also called Usedom) and Wolin are coastal islands of the Baltic Sea [10] (Fig.1.). The greater part of the Uznam island is located within Germany, only a small, eastern part belongs to Poland, while the Wolin Island is located east of the island of Uznam and belongs entirely to Poland [3]. The island of Uznam has an area of 445 km^2 (of which about 72 km^2 in Poland), while the island of Wolin has an area of 265 km^2 and is the largest island of Poland.

Fig.1. Location of Uznam-Wolin islands

On the islands, there is a special birds protection area called Natura 2000 Delta Świna. There are about 200 species here. In order to protect unique forms of nature on Wolin Island, the Woliński National Park was created in 1960, the symbol of which is the white-tailed eagle. The park's task is to preserve the unique cliff coast and native flora and fauna. However the destructive activity of water and wind, makes cliffs on the seafront slip, going back an average of about

ISSN: 2005-4238 IJAST

0.80 m a year.

Due to global warming and the increasing incidence of extreme weather events, more and more attention is being paid to changes. The collaboration of Estonian, German, Lithuanian, and Polish geoscientists and coastal engineers research teams investigated that the glacio-isostatic subsidence enhances the effect of climate-induced sea-level rise and strong storm effects are causing a continuous retreat of the Baltic Sea coast in this area. In order to understand mentioned processes and propose a future projection of coastline morphology changes the regional climatic and meteorological conditions should to be described [2], [6], [7], [12].The aim of the work is to analyze the variability of temperature, precipitation and snow cover, as well as the number of days with wind over 10 ms^{-1}, hail, fog and occurring on the Uznam and Wolin islands in the long term period between 1960 and 2018.

II. MATERIALS AND METHODS

The research material used in this paper were data recorded at meteorological station of the Institute of Meteorology and Water Management – National Research Institute (IMWM-NRI) in Świnoujście from the years 1960 to 2018.Measuring station in Świnoujście (Fig. 2), as part of a national measurement and observation network at hydrological and meteorological service, is a synoptic station which is participating in the international weather monitoring program (Weather World Watch) as part of the World Meteorological Organization (WMO), of which Poland is a member. The location of the meteorological station, more or less in the middle of Uznam–Wolin islands, is appropriate for assessing the trends of changes in selected climatic elements based on a long measurements series (Fig. 1).

Fig. 2. Location of Świnoujście

In order to determine trends of changes in data time series non-parametric Mann–Kendalls test were used [5]. This test answers the question as to whether the values measured in the time series $\{x_1, x_2, \ldots, x_n\}$ have a tendency to gradually increase or decrease. The Mann–Kendalls test analysis the sign of the difference between successively measured measurement values. The newly measured value is compared to all previously measured values [4]. Statistic S of the test is calculated using the following formula [1], [8]:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i)$$

where

ISSN: 2005-4238 IJAST

$$\mathrm{sgn}(x_j - x_i) = \begin{cases} 1 \text{ if } (x_j - x_i) > 0 \\ 0 \text{ if } (x_j - x_i) = 0 \\ -1 \text{ if } (x_j - x_i) < 0 \end{cases}$$

The rate of the change of the analyzed trend in time can be described by the directional coefficient of the straight line expressed by Sen's slope estimator, calculated for every $i < j$ (where $i = 1, 2, \dots, n-1$ and $j = 2, 3, \dots, n$) [11]:

$$\beta = \mathrm{mediana}\left(\frac{x_j - x_i}{j - i}\right)$$

Changes (increases or decreases) at a significance level (α) above 95% were considered as statistically relevant. Moreover changes at the significance level from 90 to 95% were assumed to be close to statistical significance, while changes in the significance level from 75 to 90% were assumed to be a tendency to change. Changes at the level of significance below 75% were considered statistically insignificant and consequently without a specific direction of change [9].

III. RESULTS

The calculations results of trends in changes of selected meteorological elements such as: average annual temperature (T), annual precipitation sum (P), maximum snow cover (H), number of days with snow cover (DH), number of days with precipitation (DP), number of days with snowfall (DS), number of days with wind above 10 m/s (W10), and number of days with thunderstorms (S) as well, were presented in Table 1. The table summarises the measurement period, S statistics, slope β, and the statistical significance (α) which were relevant for each of the analyzed meteorological parameters in the context of assessing the islands climate condition trends of and the impact of these conditions on coastal erosion processes.

Table 1. Calculations results

Parameter	period	S	β	α
T	1960–2018	681	0.030	100%
P	1960–2018	191	1.063	78.6%
H	1961–2018	–246	–0.125	90.0%
DH	1961–2018	–391	–0.520	99.1%
DP	1960–2018	408	0.364	99.2%
DS	1960–2018	–316	–0.206	96.1%
W10	1966–2018	–207	–0.232	88.6%
S	1966–2018	115	0.042	62.0%

The visualization of the long-term variability of individual indicators has been presented in plots from 3 to 10, indicating the red line trend described by the calculated statistics. With the exception of the S parameter(thunderstorms), P parameter (annual precipitation), W10 parameter (days with wind above 10 m/s) changes in all other parameters were found to be statistically significant with clear change trends and the α statistic value obtained more than 90 %.Thus, in the case of the average annual temperature (T), statistically significant increasing trends were obtained ($\alpha = 100\%$) at the level of 0.20°C/decade, with a maximum amount of 10.03°C recorded in 2014 and the lowest amount of 6.87°C in 1996 (Fig. 3).

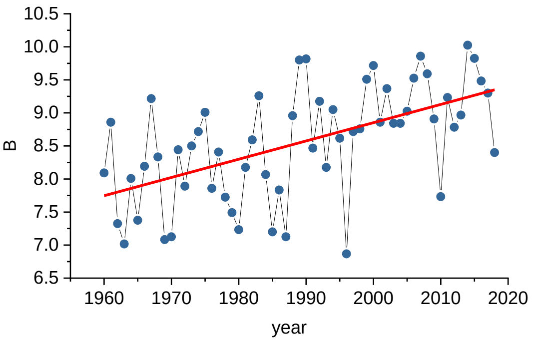

Fig. 3. Changes in the average annual temperature (T) in 1966–2018

In the case of average annual precipitation amount (P), there was a tendency to change ($\alpha = 78.6\%$) at the level of 10.6 mm/decade, with the maximum value of 783.4 mm recorded in 2017 and minimum of 386.1 mm in 1982 (Fig. 4).

In the case of the maximum height of snow cover (H), changes close to statistical significance ($\alpha = 90.0\%$) were found at the level of –1.25 cm/decade, with the maximum amount of 52 cm recorded in 2005 and minimum of 2 cm in 1975 and 1990 (Fig. 5).

In the case of the number of days with snow cover (DH), a statistically significant ($\alpha = 99.1\%$) decreasing trend was noted at the level of –5.20 days/decade, with the maximum value of 106 days recorded in 2010 and minimum of 3 days in 1990 (Fig. 6).

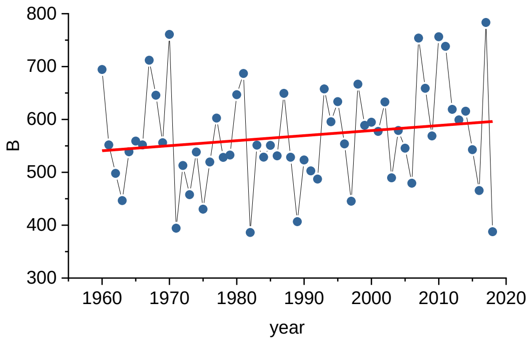

Fig. 4. Changes in average annual precipitation amount (P) in 1966–2018

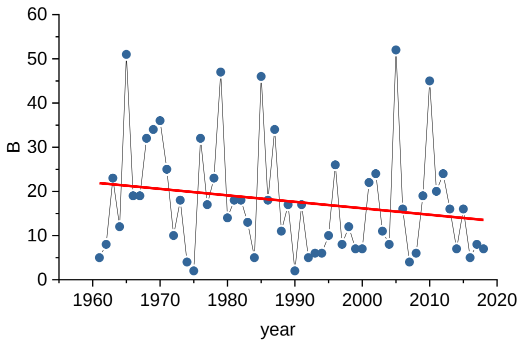

Fig. 5. Maximum height of snow cover (H) in 1966–2018

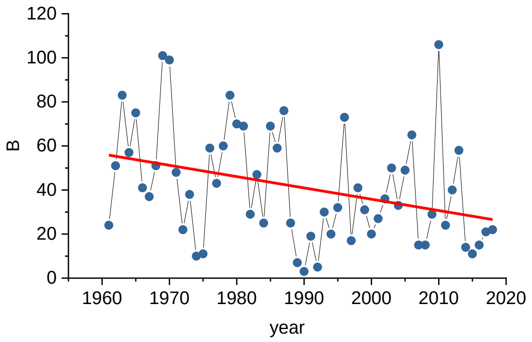

Fig. 6. Number of days with snow cover (DH) in 1966–2018

In the case of the number of days with precipitation (DP), a statistically significant growing trend (α = 99.2%) was observed at the level of 3.64 days/decade, with the maximum value of 165 days recorded in 2017 and minimum of 92 days in 1976 (Fig. 7).

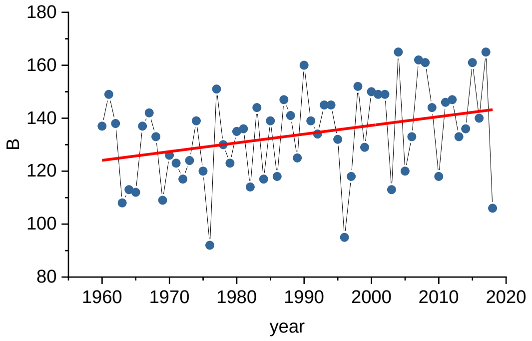

Fig. 7. Number of days with precipitation (DP) in 1966–2018

In the case of the number of days with snowfall (DS), a statistically significant decreasing trend (α = 96.1%) was noted at the level of –2.06 days/decade, with the maximum value of 63 days recorded in 2010 and minimum of 10 days in 2014 (Fig. 8).

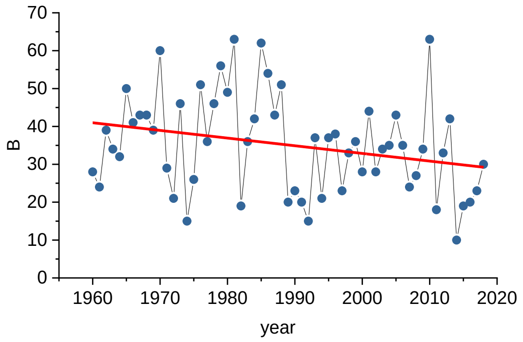

Fig. 8. Number of days with snowfall (DS) in 1966–2018

In the case of the number of days with wind above 10 m/s (W10), there was a tendency to change (α = 88.6%) at the level of –2.32 days/decade, with maximum value of 71 days observed in 1976 and the lowest of 6 days in 2010 (Fig. 9).

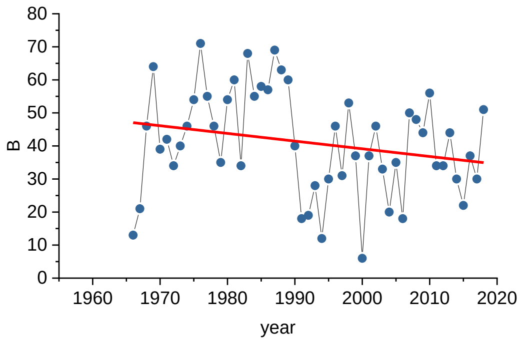

Fig. 9. Number of days with wind above 10 m/s (W10)
in 1966–2018

In the case of the number of days with thunderstorms (S), there were no change trends (α = 62.0%), with the maximum value of 23 days recorded in 1968, 1972 and 2011, and the minimum of 7 days in 1989 i 1994 (Fig. 10).

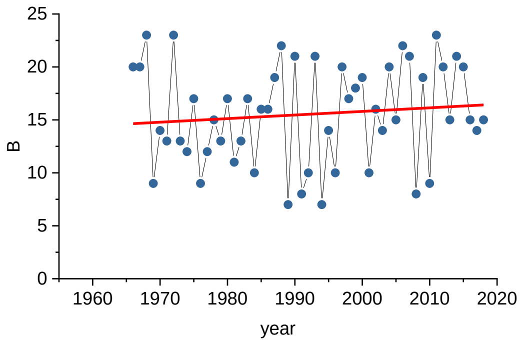

Fig. 10. Number of days with thunderstorms (S) in 1966–2018

IV. DISCUSSION AND CONLUSIONS

In this paper variability of certain meteorological elements, denoted at the Uznam–Wolin islands, has been examined using multi-year trends approach. The climate changes observed in recent years could be clearly observed also in the Polish-German part of the Baltic Sea coast. Also, the influence of the sea on the climate of the island was not insignificant and required to be mentioned [6], [7], [12]. Apparently, perceptible changes in the studied period values have been the average daily air temperature – observed increase by less than 1.5°C through the 59 years. Strongly correlated with the increase in average air temperature, there were trends of changes in other meteorological elements such as: a decrease in the snow cover height (Fig. 5); a decrease in the number of days with snow cover (Fig. 6) or a decrease in snowfall days appearance (Fig. 8), even with a simultaneous increase in the number of days with atmospheric precipitation (Fig. 7) – in this case mostly with rainfall. At the same time analysis of long-term period changes indicated a increasing trend of number with thunderstorms days (Fig. 10). Increasing trend of number with rainy days (Fig. 7) influences on annul precipitation trend – which was alsoincreasing (Fig. 4). Koźmiński and Świątek in of their researches [7] examined climatic parameters changes along Polish part of Baltic sea in the multi-year period from 1961–1990 as well as from 1986–2010 and discovered that the average duration of the Baltic warming effects which influences the air temperature at the coast excess in 215 days a year. The authors of this study (based on data from 1960-2018) indicated compliance with Koźminski's and Światek's [7] and Tylkowski [12] results. Harf et al. pointed that more frequent occurrence of the heavy rainfall and thunderstorms mixed with more and more frequent (at least in the last decade) occurrence of days with high air temperature supports costal erosive processes [2]. For this reason, the observed increasing trend in air temperature in the years 1960–2018 indicates the possibility of deepening mentioned processes, which becomes a negative phenomenon both for the landscape conditions of islands but also in the aspect of tourism and safety of inhabitants of towns located on the islands.Nearly the same conclusions Kostrzewski and team [6] formulated in the research conducted on Wolin island coast in the years from 1984 to 2016.Although thunderstorms occurrence change trend was close to be insignificant and the relationship between number of thunderstorm days and heavy rainfall occurrence is unknown, the decreasing trend of snow conditions on islands should be take into account and be considered as negative phenomenon, especially due to costal erosion process. Shorter duration of snow cover deposition makes possible to experience longer periods of the top soil layer freezing causing its destabilization and increasing erosion processes during spring and summer periods. Moreover constantly rising levels of the Baltic Sea occurring for completely different reasons, as well as the more and more intense storms in the autumn and winter, are consequently conducive to the acceleration of coastal erosion.However simple trend change analysis presented in this paper would not indicate real threats of islands functionality nonetheless it clearly shows how climatological conditions in long term period changes. It seems to be obvious that more detailed analyzes of individual meteorological elements should be made in order to present a full picture of observed changes, which on the one hand may be a proof or consequence of climate change observed across the whole globe and on the other an individual case, characteristic only for the examined islands.

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