THE EVOLUTION OF THE WIND PATTERNS OVER REGIONS WITH COMPLEX TOPOGRAPHY IN THE LAST 50 YEARS (ON THE EXAMPLE OF THE DNIESTER CANYON, UKRAINE)

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ABSTRACT. – The Evolution of the Wind Patterns over Regions with Complex Topography in the Last 50 Years (on the Example of the Dniester Canyon, Ukraine). In the last 50 years the wind characteristics in Western Ukraine have been noticed to undergo changes in addition to temperature and precipitation regimes. Regions with complex topography are considered to be the territories that are the most susceptible to the global climate dynamics. The Middle Dniester Valley region as an area with the most complicated field of wind patterns is researched in this article. It identifies a number of spatial and temporal peculiarities of the wind regime within the valley. The intensification of thermal valley circulation is detected. Some degradation of eastern winds in the annual roses is detected that is well correlated with the evolution of barometric systems over the North Atlantic European sector.

Keywords: wind patterns, atmospheric circulation, canyon valley, heterogeneity of topography, SLP etalons.

1. INTRODUCTION

First of all, the issue of global climate changes is represented by temperature dynamics and precipitation, which are recognized to be the most apparent signals. Still, local climate regimes over complex topography reveal a much more complicated field of wind that is changeable in the long-term period. The amplitudes of values and variability of wind directions contribute to the importance of research of the backgrounds in reaction to global dynamics of macro-scale circulation patterns.

The mechanism of interaction between the changes of global thermal regimen and large-scale circulation patterns in the Northern hemisphere in the last decades is well recognized. The mountain regions are identified as the ones with the most significant variability in the climate reports. Meanwhile, as our previous research showed, the flat territory of Western Ukraine can also be distinguished by significant fluctuations of fields of the main meteorological elements (Kynal and Kholiavchuk, 2014). Here, wind patterns are considered to be the features that rather depend on the change of the climate system as a whole and the surface heterogeneity.

Among the hilly territories of Ukraine, valley regions show the most apparent transformation of air flows in time and space and dynamics in response to

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macroclimatic trends. Hence, the article aims at assessing the variability of wind regimes over the territory of the Middle Dniester region and searching for changes in the development and manifestation of regional wind patterns.

Unfortunately, the region is not provided with a dense network of weather stations, which would allow to reveal a detailed picture of wind distribution. Consequently, some additional field microclimate observations have been obtained in the last five years. They made it possible to discover the peculiarities of local circulations. The meteorological information of 3 representative weather stations was used for the statistical analysis of the wind characteristics. They are Kamianets-Podilskyy (217 m), located at the Smotrych, the canyon tributary of the Dniester in the surroundings of the Podolian Height; Novodnistrovsk (233 m) located on the upper terraces of the Dniester in the region of the water reservoir; and the most eastern site of Mogyliv-Podilskyy (77 m) located at the canyon bottom of the valley.

2. TOPOGRAPHY OF THE DNIESTER CANYON

The specific valley of the Dniester with its tributaries in Western Ukraine was formed on the inversial relief where endogeneous tectonic processes and exogeneous geomorphological forces made up the sculpture of the canyon. As a result, the river in its middle part forms a gorge that cuts the surface 150-200 m deep, has steep or even vertical walls and a narrow bottom. Besides, the valley is surrounded by the hills of the Hotyn and the Podolian Heights dissected by the Dniester's tributaries with average altitudes of 250-300 m (Fig. 1). Consequently, they intensify the local climate transformations, making it similar to the ones typical of the mountain regions.

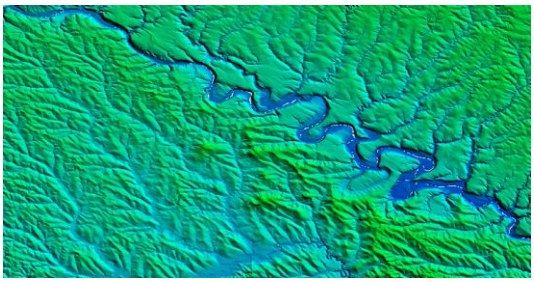

Fig. 1. ***The basin of the Middle Dniester River Valley.***

The canyon part refers to the lower part of the valley which turns into broad high terraces on its top. The canyon valley is distinguished by the geomorphological asymmetry related to a big number of meanders or meander groups stretching for 25-35 km each. These parts of the valley are remarkable for the topography heterogeneity. In addition, the geomorphological processes contribute to the genesis of all the diversity of slopes with different types of cover and directions.

Consequently, the existence of a deep river valley of the Dniester with tributaries and numerous slope surfaces contributes to local climatogenesis. Different parameters of topoclimates are noticed within the variety of surfaces (Hotyn and Tovtry hilly adjusting territories and canyon river valleys). Wind

features are considered to be perhaps the most susceptible to topography characteristics such as elevation, exposition, steepness and landforms.

3. TEMPORAL AND SPATIAL ANALYSIS OF WIND CHARACTERISTICS

The special climate position of the Middle Dniester Region was already known in the scientific works of Vysotskyy G. (Vysotskyy, 1922), Voyeykov O. (Voyeykov, 1949) and Alisov B. (Alisov, 1947) in the early 20th century. They stressed upon the climatic differences within the basin of the dominant influence of the axis of extratropical maximum. The most important thing about it is that the average annual location of the axis in respect to the surface corresponds with the direction of the Middle Dniester Valley and is related to the specific orography. Accordingly, humid westerlies and southern airflows are dominant to the north of the main wind axis of the Northern Hemisphere. Northern and eastern continental air masses advect to the south of the axis bringing quite little of water vapour.

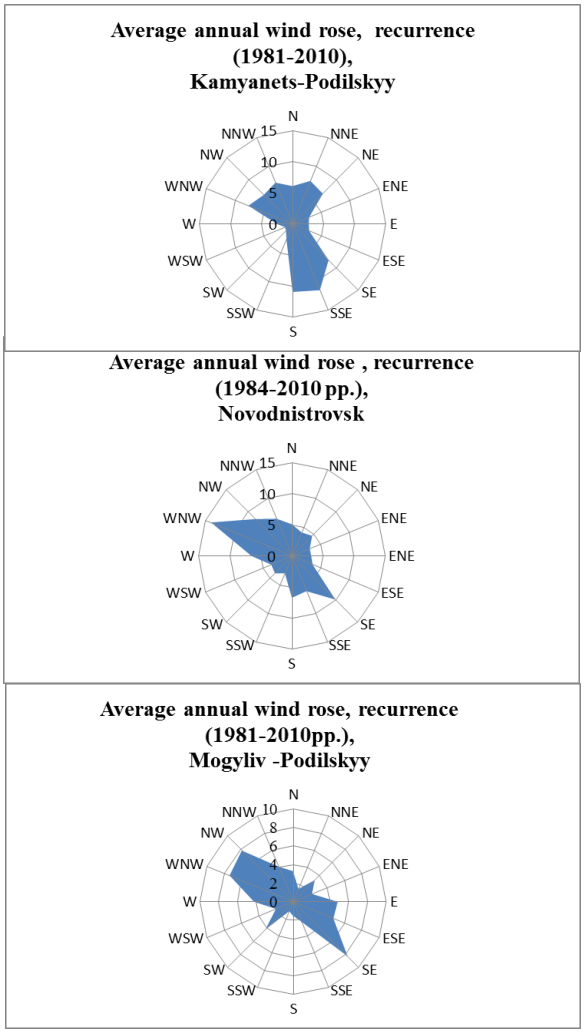

Fig. 2. ***The wind roses for the region of the Middle Dniester River Valley***

In general, having analysed the average annual distribution of macro-scale air atmospheric circulations over the region, one can state that Atlantic air masses make up 32 % of all the circulation processes. South-eastern dry continental masses contribute to 12% of synoptic situations. Just 8% of climate conditions relate to the northern arctic air masses. The warm period of the year is also determined by the penetration of dry tropical anticyclones, that can constitute up to 12% of all the occasions.

The principal characteristic of the wind regime in the Middle Dniester River Valley refers to the dominance of north-western and south-eastern circulations that coincide with the main direction of the valley (Fig. 2).

Accordingly, during cyclonic periods advective wind regimes are channelled by the orography. Hence, it contributes to the increase of the wind speed up to 6-7 m/s, especially characteristic of the warm period of the year.

Westerlies make up the majority of wind patterns over the Western part of Ukraine and, consequently, in the valley of the Middle Dniester River. Intensified by the topography, the amplitude and the significance of winds, and the influence on the regimes of temperatures, humidity and even precipitation increase.

The north-western airflows dominate in the period from December to September. South-western winds occur from October to December and from January to April. They receive the same occurrence as the north-western ones. Less typical are the north-eastern, eastern and south-eastern winds. Northern, western and southern winds occur almost in the same temporal way. Besides, in comparison with the observations during the last century, significant deviations from typical wind patterns occurred in certain years (e.g. 2007, 2008, 2009, 2014). In particular, in the summers of those years an atypically big number of days with northern winds was observed.

The May circulation appears to differ from other months, with a rapid increase of eastern and north-eastern airflows. In particular, such winds are 2 times more frequent in May. They contribute to rapid heating of dry and continental air in the valley surrounding.

The summer season is highly associated with the prevalence of north-western winds. In particular, they predispose the main part of summer precipitation. Meanwhile, south-eastern and western winds are detected to occur 2 times less often during the season. Less likely in the period from May to September are southern and south-eastern winds. But during other months the occurrence of southern winds increases up to 40%. Consequently, northern winds are almost not typical for October-November. Less significant south-western and western winds occur during the whole year.

Due to sheltered topography places, the region is known to have quite a big amount of calm conditions that constitute up to 15 % of all the wind situations. Among the observed weather stations, the place of Mogyliv-Podilskyy located in the lower part of the canyon (77 m) is found to have the biggest number of calm days within the valley. In some years it can reach 36% of all the cases. They are related to anticyclonic types of weather in the period from August to October. During such occasions, discomfort bioclimatic conditions can develop. The most windy month is March with average speeds around 3 - 4 m/s.

On the whole, the region of the Middle Dniester River is distinguished by moderate wind speeds (2 - 3 m/s). The lightest winds are observed in August with an average speed of 2 m/s. Here, the landscape sites (Mogyliv-Podilskyy) at the bottom of the valley show a minimum speed of 1 m/s. Afterwards, the winds tend to become stronger, especially in November, February, and March. Strong winter

winds refer to snowstorm weather conditions. Strong summer winds with a duration of no more than 5 - 7 days, develop under the influence of thermal circulations and are followed by thunderstorms and heavy showers.

4. VALLEY AIR CIRCULATIONS AND WIND PECULIARITIES

The sculpture and the curvy line of the valley complicate the distribution of wind patterns typical for Western Ukraine, predisposing to the heterogeneity of topoclimates in terms of wind regimes. Hence, the straightened parts of the valley directed to the south-east have been observed to be the areas where strong north-western airflows develop with a speed of 6-7 m/s. Meander parts have shown the lightest winds. However, topography conditions in the meander valley serve as a good background for the formation of valley circulations similar to the mountain types.

Accordingly, thermal circulation is the most specific feature that distinguishes the topoclimates of valley landscapes from the adjusting territories. The deep cut of the hilly flat surface by the canyon and the great diversity of slopes in terms of exposition and steepness lead to spatial differences in the heat and radiation balance of slopes. Consequently, the valley climate system of thermal origin has energetic background to build up. In summation, the circulation is followed by anticyclonic conditions and is characteristic of the warm period of the year. The strength of such winds will increase up to midnight and gradually decrease by noon. Similar processes were observed in the Koropets and Zalishchyky meanders during the hot anticyclonic weathers in 2007-2009 (Kholiavchuk, 2009).

Local wind circulations are also reinforced by a large water reservoir in the eastern part of the Dniester Canyon created in 1981, where the amplitudes of wind speeds and the diurnal changes of wind directions have been the most apparent. Moreover, the dimensions of the water basin (with a width of up to 1.5 km, an average depth of 25-50 m and a length of 220 km) make it possible for breeze circulation to come. It often diminishes the effects of wind transformations described in the beginning. It can also be noticed from the cloud formation along the edges of the valley walls.

The transformation of regional air masses is also influenced by the functioning of the hydrotechnical system of the Dnister Reservoir in the eastern part of the region. In case of warm surrounding conditions, intensive evaporation leads to the accumulation of energy of the unstable surface air layer. In such a case advective movement toward the top of the valley and convective vertical flows within the valley develop. Conversely, the advected cold air is heated by the warm water reservoir in addition to active condensation.

All the above mentioned processes contribute to the existence of breeze circulation. The local cross-cut circulation of the surface air layer manifests itself the most evidently in the summer days with anticyclonic types of weather. Breeze effects are observed near the Dniester river bed and on the slope banks of the Dniester Reservoir. However, its influence can also be found over the surrounding

surfaces of the upper terraces. In particular, the local breeze circulation can predispose to the formation of a cloudless zone above the banks at a distance of 0.5 km from the river as a result of airflow transformation. Hence, these valley parts can be areas with decreased amount of precipitation (Kynal, 2006).

The climate of the upper terraces in the region of the Dniester Reservoir (represented by the weather station of Novodnistrovsk) is the most similar in terms of regimes of meteorological elements to the adjusting regions of transversal tributaries (represented by Kamianets-Podilskyy). However, the values of monthly temperatures, especially in August, January and March, differ by up to 1.5°C in the two parts. The differences are mainly caused by the essential influence of northern winds and the influence of active flat surfaces (Fig. 2). The years of 2006 and 2007 were characterized by the lowest extremes in January with average values of -30–35°C. At the same time, December and January of 1990 was characterized by atypically high temperatures (+15.5ºC and +14.2ºC) related to rapid advection of warm air masses from the Mediterranean sector.

The vertical climate zone of the bottom valley is considered to be the most representative example of local peculiarities. In particular, the location of Mogyliv-Podilskyy reflects in the best way the climate of the Middle Dniester Valley, being situated in the trench part of the valley sheltered from northern and southern winds. The area can be distinguished by the longest warm period with the highest average temperatures and extremes and the highest probability of thermal circulations as well as by a big number of comfort calm weathers. The late autumn and winter season in the region is characterized by the coldest events. They are often related to calm wind situations during which stagnation of cold air occurs.

5. DYNAMICS OF WIND PATTERNS

In the last three decades the wind roses have had a specific look and varied from year to year, which has to deal with the fluctuations of regional atmospheric circulation patterns as well as local features of climate genesis. The records of paleogeographical reconstructions and the data of instrumental observations in Ukraine reveal apparent regional climatic changes in the regimes of all the meteorological elements and, in particular, wind features. Modern climatic changes are first of all influenced by the macro-scale atmospheric circulation during the 20th century, contributing to regional circulation patterns and weather fluctuations. Within the centennial series of observations, wind patterns changes can be combined into three periods: 1) the phase of the first warming (the beginning of the 20th century – the end of the 40s), known for the increase of occurrence of westerlies; 2) the phase of thermal stabilisation (the end of the 40s – the beginning of the 70s), with the almost equal occurrence of north-western and south-eastern wind patterns; 3) the phase of the second warming of the 20th century and the beginning of the 21st century (the end of the 70s up to the present), during which the increase of north-western winds is followed by an intensive temperature increase in the Northern Hemisphere.

The changes are closely related to the changes of manifestation and intensity of atmospheric circulations during the last century. In the last 35-40 years the atmospheric circulation can be characterized by an intense activity of synoptic processes, diversification of seasonal circulation and weakening/intensification of cyclonic/anticyclonic activity (Kynal, 2006). The latter provokes the temperature increase.

Besides, the connection of the North Atlantic Oscillation with the dynamics of the above mentioned processes is noticed. In addition, thermal circulation, that is characteristic of the canyon valley, is one of the most vulnerable features of the climate change. Observations in the Middle Dniester Canyon imply an increase of strength of such winds and their recurrence. In summation, the occurrence of valley slope winds (south-western and north-eastern) perpendicular to the valley direction is observed to have increased in the late 90s of the 20th century up to 2013. In particular, in 2006 and 2007 the number of summer anticyclonic weathers increased twice, especially in the eastern part of the valley. Those were also the driest years of the decade.

Meanwhile, some disappearance of eastern components in local circulation patterns has been observed in the last decades. Such situations are well correlated with etalons of SLP fields for the Nortern Atlantic European sector, where over the decade of 1996-2005 stabilization of high pressure cells and the contraction of the Siberian maximum are distinguished (Martazinova et al, 2009).

6. CONCLUSIONS

The valley relief forms of the Middle Dniester and its tributaries appear to be the essential indicators of topoclimatic heterogeneity. Wind features are considered to be the most susceptible to topography characteristics such as elevation, exposition, steepness and landforms. The region is characterized by local wind dominance reinforced by valley direction, several types of southern and northern wind transformations as well thermal circulation which is mostly active in the warm period of the year and experiences the effects of climate changes. The Middle Dnister Valley can be suggested as a representative region for the research of wind transformations over valley terrains.

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