ISSN 1849-0700
ISSN 1330-0083
CODEN HMCAE7

Hrvatsko meteorološko društvo
Croatian Meteorological Society

HRVATSKI METEOROLOŠKI ČASOPIS
CROATIAN METEOROLOGICAL JOURNAL

53

Hrv. meteor. časopis	Vol. 53	p. 1-82	ZAGREB	2018

HRVATSKI METEOROLOŠKI ČASOPIS
CROATIAN METEOROLOGICAL JOURNAL

Izdaje
Hrvatsko meteorološko društvo
Grič 3, 10000 Zagreb
Hrvatska

Published by
Croatian Meteorological Society
Grič 3, 10000 Zagreb
Croatia

Časopis se referira u / Abstracted in
Scopus
Geobase
Elsevier/Geoabstracts
Zugänge der Bibliotheke des Deutschen Wetterdienstes
Meteorological and Geoastrophysical Abstracts
Abstracts Journal VINITI

Časopis sufinancira / Journal is subsidized by:
Ministarstvo znanosti i obrazovanja

Adrese za slanje radova
hmc@meteohmd.hr
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Časopis izlazi jedanput godišnje
Web izdanje: *http://hrcak.srce.hr/hmc*
Prijelom i tisak: ABS 95

Naklada: 150 komada

Addresses for papers acceptance
hmc@meteohmd.hr
djuricic@cirus.dhz.hr

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Znanstveni časopis *Hrvatski meteorološki časopis* nastavak je znanstvenog časopisa *Rasprave* koji redovito izlazi od 1982. godine do kada je časopis bio stručni pod nazivom *Rasprave i prikazi* (osnovan 1957.). U časopisu se objavljuju znanstveni i stručni radovi iz područja meteorologije i srodnih znanosti. Objavom rada u Hrvatskom meteorološkom časopisu autori se slažu da se rad objavi na internetskim portalima znanstvenih časopisa, uz poštivanje autorskih prava.

Scientific journal *Croatian Meteorological Journal* succeeds the scientific journal *Rasprave,* which has been published regularly since 1982. Before the year 1982 journal had been published as professional one under the title *Rasprave i prikazi* (established in 1957). The *Croatian Meteorological Journal* publishes scientific and professional papers in the field of meteorology and related sciences.
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Hrvatski meteorološki časopis – Croatian Meteorological Journal, 53, 2018., 17–29

Izvorni znanstveni rad
Original scientific paper

DYNAMICS OF MACROCIRCULATION PROCESSES ACCOMPANYING BY THE DRY WINDS IN UKRAINE IN THE PRESENT CLIMATIC PERIOD

Dinamika makrocirkulacijskih procesa praćenih suhim vjetrom u Ukrajini u sadašnjem klimatskom razdoblju

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Received 16 October 2018, in final form 21 January 2019
Primljeno16. listopada 2018., u konačnom obliku 21. siječnja 2019.

Abstract: Dry wind in modern climate is an actual problem in Ukraine because it occurs almost every year during the vegetation period. We studied the spatial and temporal distribution of dry winds, their meteorological characteristics, dynamics of development and circulation processes leading to their formation in Ukraine. In this paper we described the features of temporal distribution of the hot dry winds over Ukraine from April to August, for the period of 1995–2015 as well as interannual variability of dry winds. The analysis of the atmospheric circulation conditions was carried out using the classification of elementary circulation mechanisms (ECM) of the Northern Hemisphere, which was developed by Dzerdzeevsky (1968). The most repetitive of ECMs in the period of dry wind were identified, which are characterized by a formation of anticyclone periphery processes over the territory of Ukraine.

Key words: dry wind, elementary circulation mechanisms, atmospheric circulation, macrocirculation processes

Sažetak: Suh vjetar u aktualnoj klimi stvarni je problem u Ukrajini jer se javlja gotovo svake godine u vegetacijskom razdoblju. Proučavali smo prostornu i vremensku raspodjelu suhog vjetra, njegova meteorološka svojstva, dinamiku razvoja te cirkulacijske procese koji dovode do njegovog formiranja nad Ukrajinom. U radu je prikazana vremenska raspodjela vrućeg, suhog vjetra i njegova međugodišnja varijabilnost u Ukrajini, od travnja do kolovoza, za razdoblje od 1995. do 2015. godine. Analiza uvjeta nastanka atmosferske cirkulacije provedena je klasifikacijom elementarnih cirkulacijskih mehanizama (ECM) sjeverne hemisfere koju je razvio Dzerdzeevsky (1968). Identificirani su najčešći ECM-ovi sa suhim vjetrom koji su karakteristični za rubno područje anticiklone iznad Ukrajine.

Ključne riječi: suhi vjetar, elementarni cirkulacijski mehanizmi, atmosferska cirkulacija, makrocirkulacijski procesi

1. INTRODUCTION

Dry wind is a widespread dangerous phenomenon, which reduces the yield of crops in Ukraine. The hot and dry winds inflict a special harm to spring grain crops, the active development of which falls during the spring–summer period. In a short period of time, the dry wind can significantly reduce or completely destroy the future harvest.

A study of the spatial and temporal distribution of dry winds, their meteorological characteristics, the dynamics of development, the circulation processes leading to their formation in Ukraine, in the conditions of the modern climate is an actual problem, because dry winds, like droughts, occur almost every year during the vegetation period (Climate of Ukraine, 2003; Semenova, 2014; Buchinskij, 1970; Buchinskij, 1976).

In Ukraine, at the present time the phenomenon of dry wind is defined, according to Climate of Ukraine (2003), as simultaneous combination at least in one observation, of such values of meteorological values: air temperature 25 °C and higher, wind speed at 10 m height 5 ms^{-1} and more and the relative air humidity 30% or lower.

Detailed analysis by Zuberbiller and Romushkevich showed that dry winds in Eurasia occur only under certain aerosynoptic conditions, which contribute to the movement of air masses from the northern regions with their subsequent transformation (Buchinskij, 1976). Further research has shown that, one way or another, the processes of dry wind formation are associated with the formation and evolution of anticyclones. Modern fluctuations of the global climate influence the dynamics of regional macrocirculation processes, and can be reflected in the trends of the running of the dry wind processes in Ukraine.

Zolotokrylin (2010) gives examples of hot dry winds in the Mediterranean basin: "Wind called sirocco occurs in the Mediterranean. It is a hot, strong southern or south-eastern wind blowing from the interior desert areas of North Africa and the Arabian Peninsula. It is either humid or dry depending on air masses. … In the eastern Mediterranean, sirocco is very dry and carries a lot of sand dust. … Hot sirocco blows in the northern Sahara early in summer. It comes from the central Sahara." Further, Zolotokrylin says that similar winds are also found in other parts of North Africa, where they have different names in different countries. For example, in Morocco the dry wind name is shergy, in Lybia – gebly, in Egypt – samum or khamsin. Last is accompanied by sharply increasing temperature and decreasing air humidity.

Modern climate conditions in Ukraine are characterized by rapid changes compared with the mid and late 20th century. As shown by Martazinova et al., (2016) the air temperature in all summer months in 2006–2015 was higher than in 1961–1990. During the period 1995–2005, in some months the air temperature was close to climatic norms or lower. Since 2008, an increase in summer monthly air temperature more than 3 °C and a strong precipitation deficit is observed in Ukraine.

The large-scale atmospheric circulation in the last two decades has changed towards colder winter and arid hot summer conditions. The most typical development of synoptic processes associated with positive temperature anomalies was the situation when in the first half of summer extensive warm anticyclonic formations spread from the south and southwest. The formation of cyclogenesis area in the Northern Europe leads to the invasion of cold air accompanying by heavy precipitation in Ukraine. In the second half of summer, a synoptic situation is often connected with an extended high-pressure strip, which passes through the Southern Europe and reach up the Urals. Such synoptic situation causes hot and dry conditions not only in Ukraine, but also in neighboring countries, and plays a leading role in their formation in all years starting from 2000.

The aim of this study is to define the conditions of the atmospheric circulation leading to the formation of dry winds in modern climatic conditions and to determine the effect of these conditions on the repeatability of dry winds in Ukraine.

2. DATA AND METHODS

For studying the spatial-temporal distribution of the dry winds, an analysis of the regime of the temperature and humidity at meteorological stations in Ukraine, located at the different agroclimatic zones (Fig. 1) was made. The initial data were daily observations at 24 meteorological stations for the period 1995–2015 from April to August, obtained from NOAA Satellite and Information Service (https://www7.ncdc.noaa.gov/CDO/cdo).

To determine the phenomenon of dry wind, according to the specified criteria, the data for 8 terms of daily observations of air temperature, relative humidity and wind speed were analyzed. The corresponding database of cases of the dry winds was compiled for each station. This database was the basis for determining the interannual dynamics of the frequency of dry winds in different regions of Ukraine.

Ukraine is situated in the south-west of the East European Plain. Its territory is 603.7 thousand km². In the south, Ukraine is washed by the waters of the Azov and Black Seas. The major part of its area is flat and only 5% is mountainous. Ukraine is located in zones of mixed forests, forest-steppe and steppe of the East European Plain and in two-mountain provinces the Ukrainian Carpathians and the Mountainous Crimea. Complex physico-geographical conditions cause a variety of climate, which changes from wetlands in the west of Polissya to arid southern steppe areas (Fig. 1). The climate of Ukraine can be described as moderately continental climate with hot, dry summer and a relatively warm winter, and only on the southern coast of Crimea the climate is of subtropical, Mediterranean type. The Climate of the Ukraine by Köppen-Geiger classification can be classified as *Dfb* climate (hot-summer humid continental climate), and only in the coastal Black Sea areas – *Cfa* (humid subtropical climate) and *Cfb* (temperate oceanic climate) climates (Kottek et al., 2006).

An analysis of the atmospheric circulation conditions was carried out using the classifica-

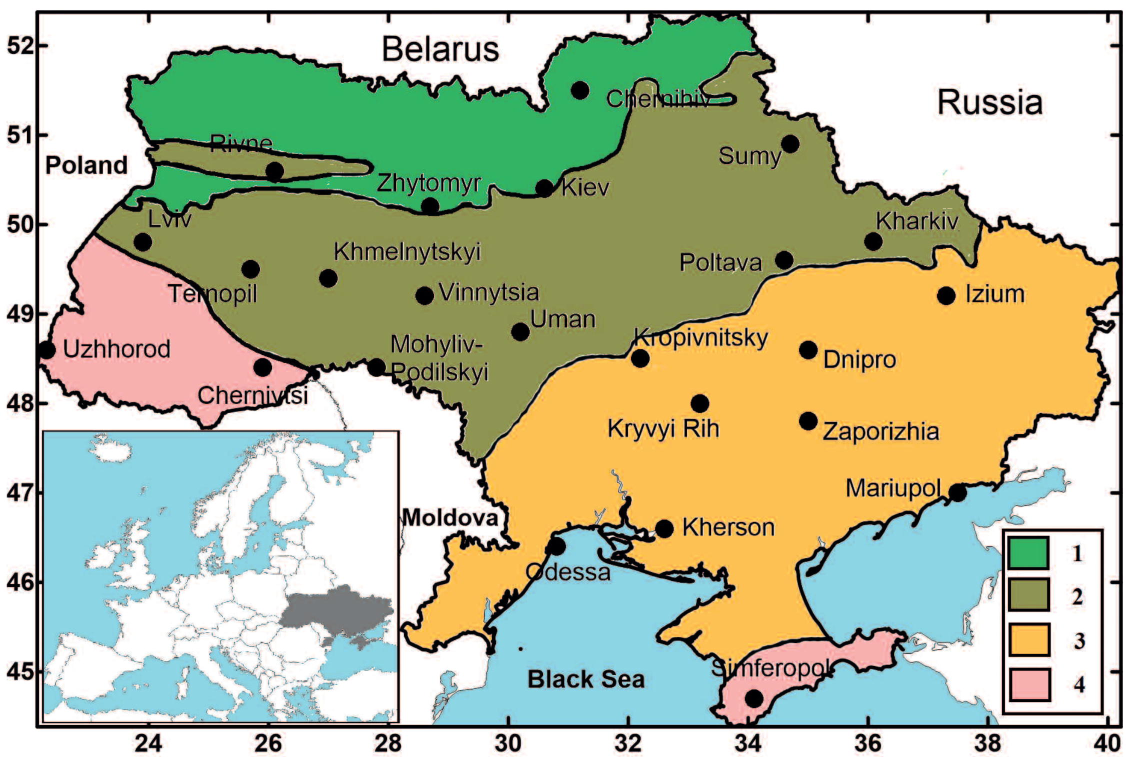

Figure 1. A map of Ukraine with the location of meteorological stations, schematic location of the territory of Ukraine on the map of Europe and schematic location the main agroclimatic zones of Ukraine: 1 – Polissya, 2 – Forest-steppe, 3 – Steppe, 4 – Mountains.

Slika 1. Karta Ukrajine s lokacijom meteoroloških postaja, shematski položaj područja Ukrajine na karti Europe i shematski položaj glavnih poljoprivrednih zona Ukrajine: 1 – Polissya, 2 – šumske stepe, 3 – stepe, 4 – planine.

tion of elementary circulation mechanisms (abbreviated as ECM) for the Northern Hemisphere, which was developed by Dzerdzeevsky (1968) and continued at the Laboratory of Climatology of the Institute of Geography at the Russian Academy of Sciences. The materials of the ECM classification used in the study, were obtained from the website (http://atmospheric-circulation.ru/).

A main feature of the ECM classification is that it characterizes the state of atmospheric circulation over the extratropical zone of the Northern Hemisphere and allows tracing the trajectories of cyclones and anticyclones over specific regions. In the ECM classification, 41 elementary circulation mechanisms are distinguished. ECMs differ in the direction and quantity of Arctic intrusions (blocking processes) and of southern cyclone passages. All ECMs were united in 13 types and 4 groups.

Group I – zonal, includes types of the ECM 1 and 2. This group is characterized by the presence of an anticyclone on the North Pole and the absence of blocking processes, with simultaneous exits of southern cyclones in two or three sectors of the hemisphere.

Group II – disturbance of zonal, includes the ECM types of 3–7. High pressure is on the Pole, one blocking process is formed connecting the Arctic and subtropical anticyclones, and 1–3 outlets of southern cyclones in different sectors of the hemisphere.

Group III – northern meridional circulation, types of the ECM 8–12. For this group high pressure is located in the Arctic, 2–4 blocking processes and 2–4 southern cyclones passages are observed.

Group IV – southern meridional circulation, the ECM type 13. A distinctive feature of this group is the development of cyclonic circulation over the Arctic on the Arctic front. Such processes are observed during the whole year, but in summer more often than in winter. For designations, the ECM types use numbers from 1 to 13.

The average duration of the ECMs is 2–4 days. The change of one ECM to another is recorded in the calendar of the consecutive change of the ECM.

In schemes of the classification, the dynamics of the annual cycle of atmospheric circulation, the restructuring of the pressure field of the hemisphere and the change of its signs over continents and oceans are well traced. As a result, a number of ECMs characteristic for certain seasons and ECMs for transitional types of the circulation had been identified.

The development of the anticyclones process over European Russia (ER) in the warm period often leads to the occurrence of summer droughts in this territory (Cherenkova and Kononova, 2012; Kononova, 2014). The summer ECMs, which is connected with a strong stationary anticyclone development over the ER, are the ECM 9a, 12a and 13s. The ECM 13s is characterized by the presence of a wide low-pressure depression formed above the Arctic (Fig. 2a) and four passages of southern cyclones (Dzerdzeevsky, 1968; Brencic, 2016). In the period of the ECM 13s, the territory of Ukraine is under the influence of a stationary anticyclone, located over the central, south and south-east parts of the ER. It leads to the formation of sunny anticyclonic weather. An anticyclone disturbs the advance of Mediterranean cyclones and, thus, the transfer of cooler and humid air to the east. At the same time, the dry hot continental air from the Ural regions is transported to the territory of the country.

Most often the ECM 13s is present from March to September. The maximum repeatability (about 20%) is recorded in July. Currently, there is a decrease in duration, but in recent years, the annual duration remains 2–3 times higher than the long-term average (Kononova, 2015).

The next characteristic spring-summer ECM is the ECM 12a. Its distinctive feature is the presence of four Arctic invasions and four passages of southern cyclones (Fig. 2b) (Brencic, 2016).

During the transitional seasons of the year, at days with the ECM 12a, a powerful blocking process over Siberia and the Volga region is developed. A belt of low pressure passes through the territory of Ukraine. The Mediterranean cyclones move through the northern coastline of the Black Sea to the western part of ER. The eastern parts of

Ukraine are under the influence of the warm subtropical air flows.
The ECM 12a is found round the year, with the maximum frequency (18%) at the beginning of May. In the last decade the annual duration was the highest (Kononova, 2015).

Another type of the ECM accompanied by anticyclonic processes in the territory of Ukraine is the ECM 9a. It is characterized by two blocking processes and three passages of southern cyclones (Fig. 2c). During the period of the ECM 9a, the territory of Ukraine is affected by an extensive anticyclone over Eastern Europe. This leads to the establishment of dry, warm weather with an air temperature exceeding 25°C (Cherenkova and Kononova, 2012). Southern cyclones, encountering a barrier in the form of an extensive anticyclone, circle it along the southern periphery and go to the territory of Kazakhstan.

The ECM 9a is present from March to October with the maximum frequency (15%) on the first decade of June. In the second half of the twentieth century, there was a growing trend in repeatability of this ECM type. The maximum duration (31 days) was recorded in 1993. Duration close to the maximum was also noted in 2002 (29 days) (Kononova, 2015).

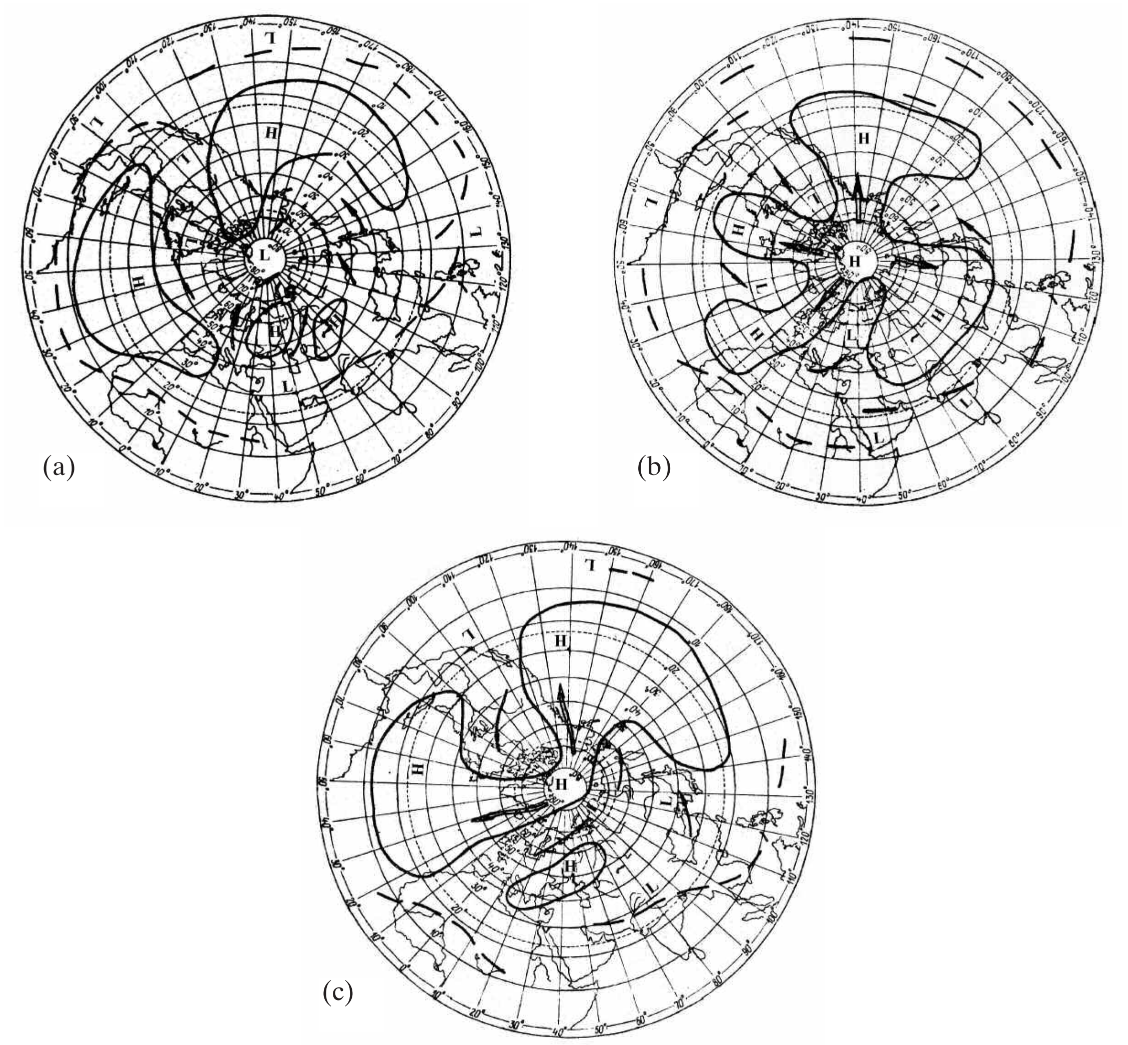

Figure 2. Dynamic schemes of the ECM in the Northern Hemisphere (according to Dzerdzeevsky, (http://atmospheric-circulation.ru/)): (a) ECM 13s, (b) ECM 12a, (c) ECM 9a.

Slika 2. Dinamičke sheme tipova vremena (ECM) na sjevernoj hemisferi (prema Dzerdzeevskom, (http://atmospheric-circulation.ru/)): (a) ECM 13s, (b) ECM 12a, (c) ECM 9a.

It should be noted that the processes corresponding to the ECM 13s, 12a and 9a, create significant pressure gradients in the study region, which lead to the formation of high wind speeds (Ivus et al., 2016).

Perennial fluctuations in the atmospheric circulation in the Northern Hemisphere show a change in the circulation epochs as the periods with positive or negative deviations of the zonal circulation from its average total annual duration. For the period 1899–2006 there was a change of three circulation epochs: two meridional (from 1899 to 1915 and from 1957 to the present) and one zonal (1916–1956). In the period 1981–2004 the predominance of meridional southern processes was observed with a substantial decrease in the duration of zonal and meridional northern processes.

3. RESULTS AND DISCUSSION

The analysis of the repeatability the dry winds (Fig. 3) showed that at selected stations, the largest number of days with the dry wind during the growing season was observed in 2007 (341 days), 2010 (300 days), 2013 (337 days) with the maximum in 2012 (418 days).

In these years, over the East European Plain during the vegetation period, the anticyclonic pressure field was dominated and accompanied by the blocking processes, which led to the formation of extensive droughts (Cherenkova et al., 2015). Since 1998, during

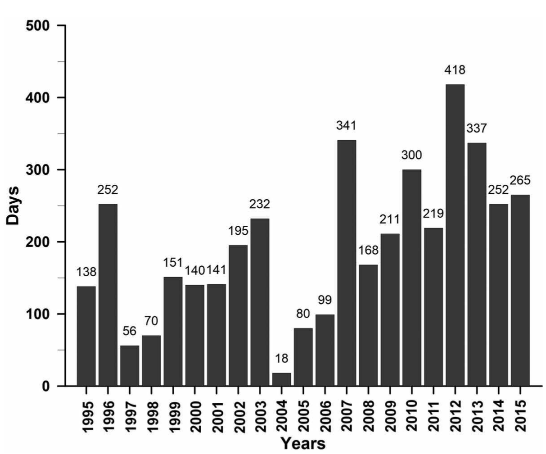

Figure 3. Distribution of number of days with the dry wind, in vegetation period.

Slika 3. Razdioba broja dana sa suhim vjetrom tijekom vegetacije.

all seasons in Ukraine, positive anomalies of the mean annual, mean minimum and mean maximum air temperature were recorded (Balabukh et al., 2015). In Ukraine during 1995–2012 in each growing season, 7–8 agrometeorological droughts were recorded (Semenova, 2016). In the southern regions droughts were observed during June–August in 1998, 2001, 2002, and from April to June in 2003. In the North of the country, main drought events were observed in April–June of 2000. A negative anomaly of precipitation was observed all over Ukraine, in the summer of 2000 and in the spring and summer of 2003 (Semenova, 2016).

In 2007, intensive drought (the drought index of the HTC and Palmer ranged from strong to extreme) was recorded all over Ukraine (Cherenkova et al., 2015). In 2010, an unusually hot summer was observed throughout Eastern Europe and intense heat waves were recorded in the south-eastern regions of Ukraine (Shevchenko, 2012). In 2012, a strong seasonal drought was recorded in the countries of southeast Europe and the Balkan Peninsula. This process was caused by the intrusions of Arctic air into the territory of Western Europe and Western Siberia, which contributed to the formation of a stationary anticyclone in the south of the East European Plain (Cherenkova et al., 2015).

Dzerdzeevsky (1953) determined the main process that leads to the formation of droughts and dry winds as some type of general circulation of the atmosphere, which provides to development and a sufficiently long existence of a stationary anticyclone in region. He noted that dry winds are often formed at the end of the dry period, and that they are the final stage of drought.

At the present time there are no qualitative and quantitative indicators that established a connection between dry winds and heat waves. However, the results of studies of these phenomena show that they are generated by similar circulation conditions. Numerous studies of heat waves (Black et al., 2004; Della-Marta et al., 2007; Fink et al., 2004; Meehl and Tebaldi, 2004) showed that they are associated with the occurrence of anticyclonic circulation anomalies, which lead to enhanced heat advection, adiabatic heating by subsidence and solar radiation heating due to a decrease in cloudiness. The study of heat waves in Georgia during 1961–2010 (Keggenho et al., 2015) showed that they arise when surface and mid-tropospheric anticyclonic patterns in the region were formed, together with westerly blocking, the advection of warm air masses from the southwest, enhance subsidence and surface heating in the anticyclone system and northward shift of the descending branch of the Hadley cell and the subtropical jet. This processes leads to a decrease of cloudiness, maximum insolation, the positive air temperature anomalies in the lower troposphere, negative precipitation anomalies and relative humidity in the middle troposphere, as well as increased wind speed in some parts of the region.

Concerning our study, some of the dry wind periods were connected with the extremely high air temperature, which reached up 40 °C at the Odessa station on 23 July, 2007 (ECM 9a), at the Zaporizhia station on 8 August, 2010 (ECM 4c) and on 10 August, 2010 (ECM 9a).

The minimum of the relative air humidity was 4% and was observed at the Odessa station on: 20 August, 1998 (ECM 8b), 15 August, 2001 (ECM 13s), 24 June, 2002 (ECM 13s), 15 May, 2003 and 15 August, 2003 (ECM 13s)

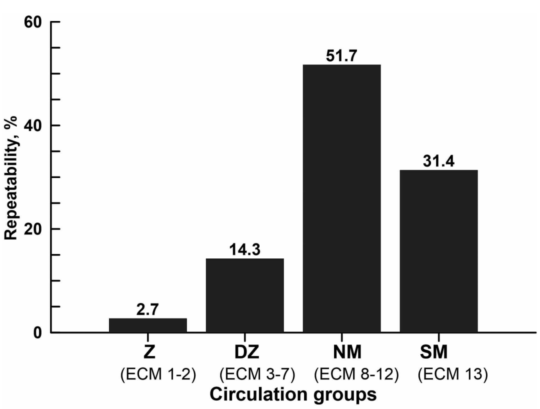

Figure 4. The repeatability (%) of circulation groups at days with dry wind: Z –zonal circulation, DZ – zonal disturbance, NM – meridional northern circulation, SM – meridional southern circulation.

Slika 4. Ponovljivost (%) cirkulacijskih skupina u danima sa suhim vjetrom: Z – zonalna cirkulacija, DZ – zonalni poremećaj, NM – meridionalna cirkulacija sa sjevera, SM – meridionalna cirkulacija s juga.

and at the Chernihiv station on 8 July, 1997 (ECM 10b) and 29 May, 2000 (ECM 12a).

For selected cases of dry wind a catalog was compiled, in which ECM type for this day was indicated. The counting of the repeatability of different ECM types and subtypes in the dry wind period has made it possible to identify synoptic processes accompanied by the formation of dry conditions.

The analysis of the repeatability of circulation groups (Fig. 4) showed that the meridional northern circulation (51.7%) has the greatest repeatability; on the second place is the meridional southern group (31.4%). The zonal disturbance and zonal circulation have repeatability of 14.3% and 2.7%, respectively.

A more detailed analysis of the circulation processes is shown in Figure 5. As it seems, the highest repeatability during the dry wind has the ECM 13s (31.1%), which belong to the meridional southern circulation group. A significant number of cases occur for the ECM 12a (15.1%) and ECM 9a (13.7%), which belong to the meridional northern circulation group.

As an example, for days with dry wind in which the three most frequently repeated types of the ECM were observed, the mean field of sea level pressure (SLP) (Fig. 6a, c, e) and geopotential height of isobaric surface of 500 hPa (Fig. 6b, d, f) were constructed for territory of the European sector from the

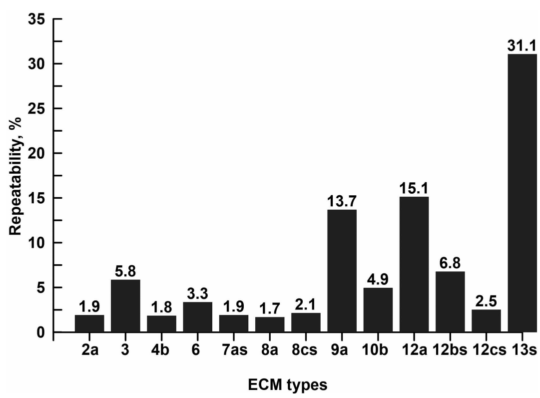

Figure 5. The repeatability (%) of ECM types at days with dry wind.

Slika 5. Ponovljivost (%) tipova vremena (ECM) u danima sa suhim vjetrom.

NCEP/NCAR Reanalysis dataset. Only days with dry wind were chosen for plotting for defined types of the ECM. Thus, mean field of SLP and geopotential height with the ECM 13s were plotted for the dry wind period of 13–31 July 2001, with the ECM 12a for the period of 7–12 May 2013, with the ECM 9a for the period of the 30 July–2 August 2014.

So, at days with a dry wind with the ECM 13s (Fig. 6a) the territory of Ukraine was in zone between a high pressure system located over the center of ER and a low pressure system located over the Black Sea. A near-surface flow over Ukraine has eastern and northeastern direction. During this period dry winds were spread over Ukraine in different agroclimatic

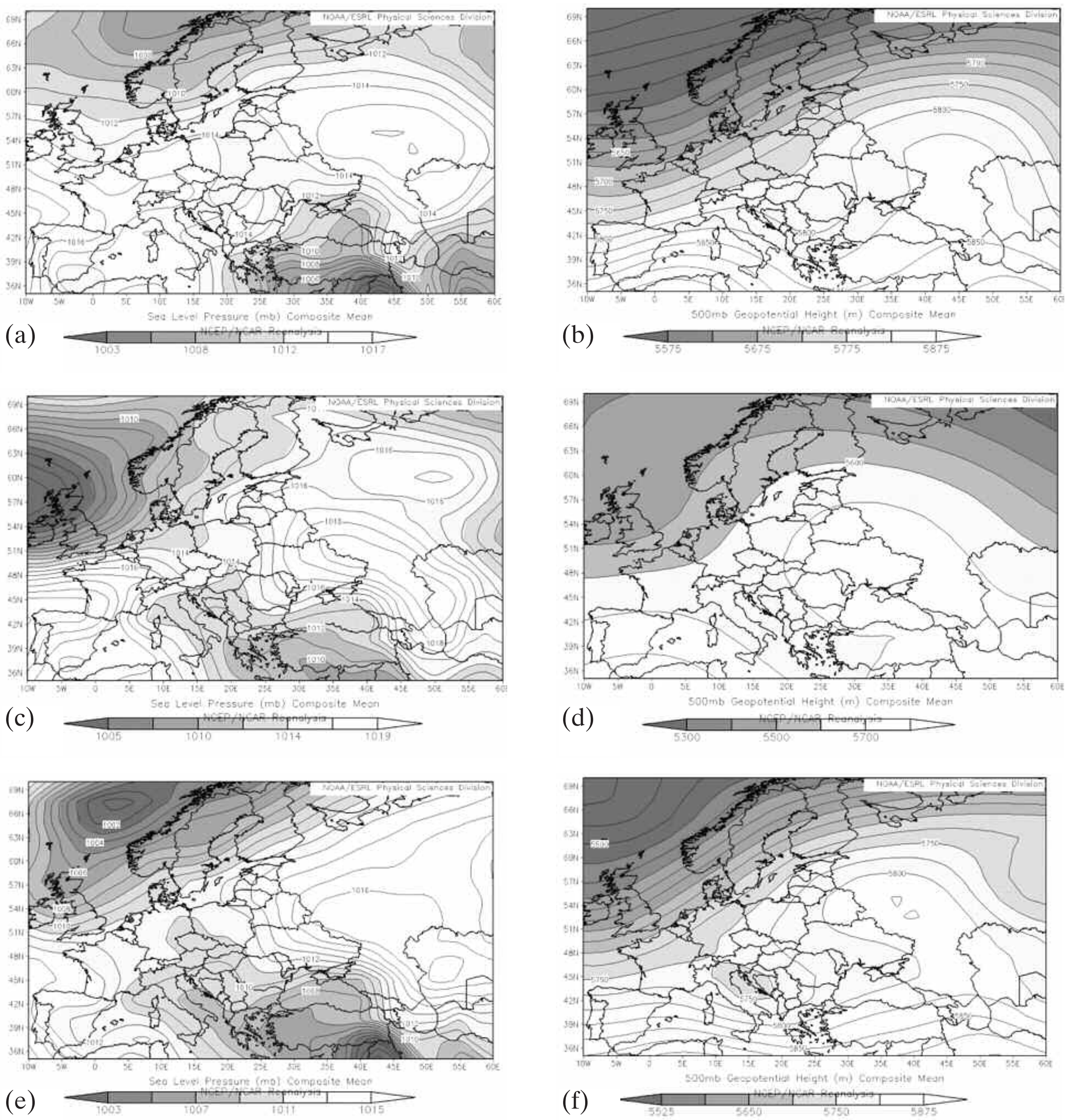

Figure 6. Mean SLP fields (hPa) on days with dry wind with the ECM 13s (a), 12a (c), 9a (e) and mean geopotential height of isobaric surface of 500 hPa on days with dry wind with the ECM 13s (b), 12a (d), 9a (f) (https://www.esrl.noaa.gov/psd/data/composites/day/).

Slika 6. Srednja polja tlaka zraka na razini mora (hPa) u danima sa suhim vjetrom i tipovima vremena 13s (a), 12a (c), 9a (e) i srednja geopotencijalna visina izobarne plohe od 500 hPa (m) u danima sa suhim vjetrom i tipovima vremena 13s (b), 12a (d), 9a (f) (https://www.esrl.noaa.gov/psd/data/composites/day/).

zones and some days were observed at 6 stations simultaneously.

The mean SLP field plotting for the dry wind period with the ECM 12a (Fig. 6c) demonstrates that Central and Southern Europe were under low pressure system. The south of ER was over an extensive anticyclone, the ridge of which extended to the entire territory of Ukraine. The Southern, Eastern and Central regions of country were under the influence of eastern air flows, the Western and Northern regions were in southern and southeastern air flows. All over Ukraine high SLP gradients were observed, which led to an increase of wind speeds. During this period, the multi-days dry winds spread all over Ukraine. There were days in which the dry winds were recorded at the same time at 11–15 stations located in different parts of Ukraine.

During the dry wind period with the ECM 9a (Fig. 6e), the mean SLP field was characterized by the development of cyclonic activity over Central and Southern Europe as well as over the Black Sea. All of the ER and Western Kazakhstan were under a vast anticyclone with a center over Kazakhstan. The territory of Ukraine was located in the zone with high baric gradients between low and high pressure systems. The North-Eastern regions of country were under the influence of the southwestern periphery of anticyclone over ER. All of Ukraine was in the eastern air flows, which transported dry, hot continental air masses from Central Asia. This led to formation of the hot and dry weather conditions. During this period dry winds were observed all over Ukraine at 7–15 stations simultaneously.

The AT-500 maps (Fig. 6b, 6f) show that for the ECM 13s and 9a upper-level baric trough was located over the territory of Ukraine, the axis of which was oriented from north-west to southeast. Above the territory of ER upper-level baric ridge existed.

For the ECM 12a (Fig. 6d) upper-level baric field characterized by a trough passing through Western Europe and upper-level ridge with the axis oriented from the southeast to the northwest through Ukraine. All three upper-level baric fields show that during these periods over Central and Eastern Europe the meridional type of circulation with blocking processes was developed, which lead to the movement of air masses from the northern and southern regions and to intensive heating and drying of the air masses in anticyclonic system.

Previous studies shown that the frequency of blocking events in summer increased significantly over Eastern Europe and Asia at the beginning of the 21st century as compared with the mid of the 20th century (Barriopedro et al., 2006).

As follows from the results of Nedostrelova and Khokhlov (2010) the blocking episodes over Eastern Europe in 1998–2008 are more often observed over the north of ER, the Barents Sea and the Kola Peninsula. The smallest number of cases was noted over the southwest of ER, Ukraine and Belarus. Another maximum of the repeatability of blocking events are located over the territory of the Ural Mountains. The maximum number of blocking cases was observed in 2003 and 2006. The greatest number of blocking episodes was occurred in summer, and had average duration about 6–7 days. Also, a series of blocking events were observed in summer 2007, 2009, 2010 and 2012, which led to the emergence of intense droughts in the south of ER (Cherenkova, et al., 2015). Comparing with the results of repeatability of dry winds in Ukraine (see Figure 3) shows that at least in three specified years (2007, 2010 and 2012) an increase in the frequency of days with dry winds was observed. Thus, the relationship between the dry winds and blocking process needs further investigation.

To determine the dynamics of atmospheric circulation during the period of dry wind repeatability of the ECM types for the periods 1995–2000, 2001–2005, 2006–2010 and 2011–2015 was analyzed (Tab. 1).

The analysis showed that in 1995–2000 during the dry wind days the highest repeatability of meridional circulation group was observed in 46.2% cases of the meridional southern circulation and in 41.6% cases of the meridional northern circulation. In 2001–2015 the meridional northern circulation group prevailed, with a maximum repeatability in 2006–2010 (59.0%). In 2006–2010 the repeatability of the meridional southern circulation group reduced to 19.9%.

It should be noted that the zonal circulation group has the lowest repeatability at dry wind, because under zonal circulation the westerly flow transport the humid cool air from the oceans to the continents that decrease a value of radiation balance due to increasing of cloudiness and precipitation (Dzerdzeevsky, 1968).

Temporal changes in the circulation types repeatability may be accompanied by a change

Table 1. Repeatability (%) of atmospheric circulation groups on dry wind days.

Tablica 1. Ponovljivost (%) atmosferskih cirkulacijskih skupina u dane sa suhim vjetrom.

Years	Circulation groups			
	I	II	III	IV
	Zonal	Zonal disturbance	Northern meridional	Southern meridional
1995–2000	0.7	11.6	41.6	46.2
2001–2005	1.2	13.2	46.1	39.5
2006–2010	4.2	16.9	59.0	19.9
2011–2015	3.6	14.7	56.1	25.5

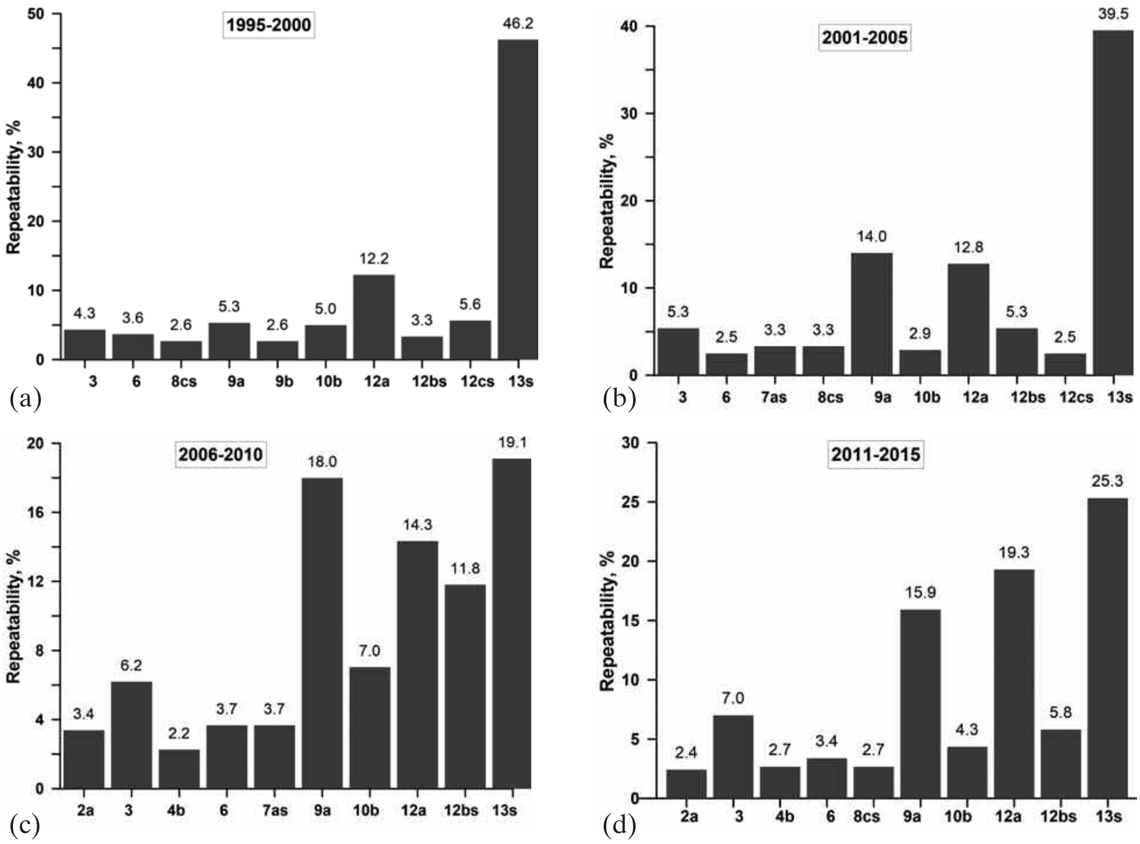

Figure 7. The repeatability (%) of ECM types on dry wind days for the periods: (a) 1995–2000, (b) 2001–2005, (c) 2006–2010, (d) 2011–2015.

Slika 7. Ponovljivost (%) ECM tipova vremena u danima sa suhim vjetrom za razdoblja: (a) 1995.–2000., (b) 2001.–2005., (c) 2006.–2010., (d) 2011.–2015.

in the number of cases of dry winds. Thus, during the period 1995–2000 the total number of the dry wind days on all selected stations was 807 days, in 2001–2005 was 666 days, in 2006–2010 was 119 days, and the maximum of 1491 days was recorded in 2011–2015.

In addition, in 1995–2000 the meridional northern and meridional southern circulation groups have similar durations (Kononova, 2014; Kononova, 2016). During that period the maximum of the repeatability of the meridional southern circulation group was observed in the days with dry wind. Now the number of days with meridional northern circulation predominates, with a decrease in duration of the meridional southern circulation. During these years, during dry wind days, the greatest repeatability of the meridional northern circulation group was observed, with a maximum of 59.0% in 2006–2010.

It can be concluded that the most favorable conditions for the forming of dry winds in Ukraine are formed under meridional northern processes, which are characterized by Arctic intrusions into middle latitudes.

The repeatability of the ECM types during dry wind for selected periods is shown in more details in Figure 7. In all periods, the greatest repeatability was observed for the ECM 13s (in 1995–2000 and 2001–2005 its percentage differed sharply from the number of other ECM types).

In 1995–2000, its amount is 46.2% of all cases, in 2001–2005, its repeatability decreased to 39.5%, but there is an increase in the number of the ECM 9a cases (14%). In 2006–2010, the number of the ECM 13s decreased to 19.1% and the ECM 9a increased to 18%. In 2011–2015, the repeatability of the ECM 13s is 25.3%, on the second place is ECM 12a with 19.3% and ECM 9a has also high repeatability (15.9%).

Using the regional classification of the atmospheric processes Ivus et al. (2016) showed that in summer the weather conditions in Ukraine are determined by the development of peripheral atmospheric processes without fronts. As he showed, there was a decrease in the repeatability of peripheral atmospheric

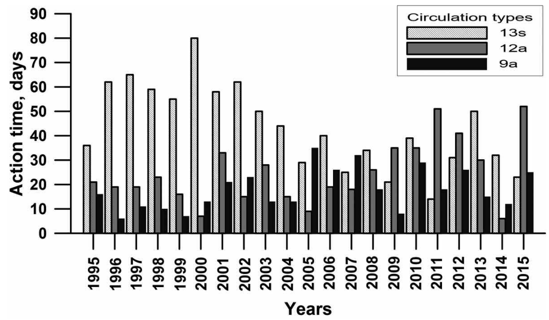

Figure 8. Number of days with ECM 13s, 12a and 9a types during the vegetation period.

Slika 8. Broj dana s tipovima vremena ECM 13s, 12a i 9a tijekom vegetacijskog razdoblja.

processes from 41.6% in 1993–1997 to 21.3% in 2008–2012. These changes were accompanied by four times growth of the cases with peripheral atmospheric processes with the passage of atmospheric fronts and by seven times growth of the cyclonic circulation processes with high pressure gradients.

The repeatability of the ECM 13s, 12a and 9a was calculated from year to year for the period from April to August (Fig. 8). It can be seen that in 1995–2004 the predominance of type 13s was observed. After 2004, the repeatability was equalized, especially between types 13s and 12a. Since 2009, a tendency of prevailing of the ECM 12a was observed, especially in 2011–2015. The repeatability of the ECM 9a in some years of the period 2005–2011 is higher than in other years and, in general, there is a slight increase in the number of days with this type of circulation.

Comparing this information with the dynamics of number of days with dry wind for the studying period, we can see that an increase in the number of dry wind days in 2007–2015 can be connected with the period of the increase in the number of ECM 12a.

4. CONCLUSION

The analysis of the spatio-temporal distribution and dynamics of dry winds as well as the circulation atmospheric processes leading to their formation in Ukraine, were performed in this study.

An increased number of days with dry wind were observed in 2007, 2010, 2012 and 2013. In separate years, intensification of droughts and heat waves in the ER and Ukraine were noted, which were caused by prevalence of the anticyclonic pressure field with a blocking of zonal flow during the vegetation period.

The formation of dry winds in Ukraine is associated with the establishment of the meridional type of atmospheric circulation in the Northern Hemisphere, mainly of the meridional northern circulation group. The lowest repeatability on days with dry wind has the zonal circulation group. The predominance of meridional northern processes duration may be associated with an increase in the number of cases of dry wind in Ukraine.

The greatest repeatability on days with dry wind has the ECM 13s, 12a and 9a types, but number of days during the vegetation season changes from year to year. In most cases, dry winds existed when the anticyclone was located over ER and Ukraine (ECM 13a, 9a), which led to rapid warming up and drying of air in a cloudless sky, as well as to advection of warm subtropical air mass in the fore part of southern cyclones (ECM 12a) coming out to the Northern Black Sea coast. An observed increase in the number of dry wind days in 2007–2015 can be connected with period of increase in the number of ECM 12a.

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