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Chapter 5

Extreme Weather Events in Ukraine: Occurrence and Changes

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Additional information is available at the end of the chapter

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Abstract

Extreme weather is in the attention focus of many scientists and managers during the last decades. The leading aspect of these phenomena investigations in the recent years is the risk of material and human losses and damage mitigation. Especially, the interest is with regard to effects of weather extremities on natural systems and social processes such as land use practices, water resources management, emergency management, and planning. The main objectives of the investigations are clarifying of spectrum, space and time regularities of extreme weather events occurring in Ukraine as well as their intensity, duration, daily and seasonal variation, spreading, recurrence in the regions, and their changes analyzed. Applying statistical and geographical space–time analyses, the main regularities of the extreme weather events' occurrence have been described as well as the trends and intensity of the extreme weather regime changes in Ukraine have been calculated and assessed.

Keywords: Ukraine, extreme weather event, recurrence, changes trends

1. Introduction

Weather event can be defined as extreme when it reaches a certain boundary value. In Ukraine, about 20 weather phenomena can be called as the extreme weather event. They are observed by the State Hydrometeorology Committee. These phenomena occur on the whole territory of Ukraine with different recurrence and intensity (**Table 1**) [1].

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Phenomenon	Events amount	%	Amount of points	%
Heavy rain	1335	44.0	3712	52.9
Heavy snowfall	237	7.8	462	6.6
Hail	131	4.3	287	4.1
Strong wind	398	13.1	989	14.0
Squall	164	5.4	234	3.3
Spout	16	0.5	47	0.7
Sand storm	3	0.1	33	0.5
Snowstorm	249	8.2	427	6.1
Fog	292	9.6	536	7.6
Glazed frost	68	2.3	139	2.0
Soggy snow adhering	68	2.3	79	1.1
Compound ice deposits	70	2.4	78	1.1
Total	3031	100	7023	100

Table 1. Extreme weather phenomena and their occurrence in Ukraine and the amount of observation points where the phenomenon has been observed in 1986–2010 [1].

The duration, spreading, recurrence, and intensity of extreme weather events will increase during this century both globally and regionally [2], and many practical problems require relevant information on extreme event changes. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [3], the main effects of the regional climate changes due to the global warming are not only a significant increase in air temperature, in the heat waves, changes of thermal regime [4, 5], precipitation structure, and an increase in the number of heavy precipitation [4], but also an increase in the frequency and intensity of extreme weather events [2, 6, 7] and their effects like alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, human mortality, and negative consequences for human well-being [3]. Losses from weather-related disasters have increased substantially in recent decades.

The scientists are still debating the best methods to account climate change in extreme weather value analysis. The wide range of available and applicable methods is presented in [2]. In Ukraine, the main definitions of the extreme weather events as well as the methods and instructions on their analysis and prediction are presented in [8, 9].

The trends, scales, and intensity of climate and weather extremes changes are analyzed in global [4, 6], regional [10], and national [1, 7, 11] aspects. There are a few papers on the occurrence and spreading of the main weather extreme phenomena on different time periods [11–14]. But since extreme weather is very unstable and changeable in space and time, it is necessary to complete and actualize existing knowledge base.

The climatologic information has been presented in our research according to administrative division by the regions, groups of the regions, and for Ukraine as a whole (**Figure 1**).

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Figure 1. Study area.

To analyze the spectrum of the regularly observed extremely dangerous meteorological phenomena and to evaluate the long-term changes of their recurrence in Ukraine, two periods have been worked out. As the base, the period 1961 (1971)–1990 has been chosen, and as the recent one the period 1981–2010 has been worked out. The linear trends of the extreme weather events amount changes as well as tendencies of their intensity changes have been analyzed. The statistical significance of the linear trends has been assessed as well. Most of events recurrence was analyzed for a point of observations. Since extreme squalls, hails are characterized by poor recurrence in the observation point and spread on local areas; therefore, to evaluate the risk of these phenomena development and their space–time changes, the events amount was adjusted to 100 km^2 area (β-mesoscale).

2. Extreme weather events occurrence, characteristics, and changes

2.1. Heavy rain

In Ukraine, the rain becomes a dangerous weather event when it reaches 15–50 mm per 12 h (15–30 mm per 12 h for mud flow and erosion threat areas) and distress event when exceed 50 mm per 12 h (30 mm per 12 h for mud flow and erosion threat areas). Other extreme weather events are heavy rainfalls (>30 mm per hour) and long-continued rain (duration more than 1 day and precipitation is 100 mm and more) [8].

The recurrence of all types of heavy rains has a good marked seasonal course. All rainfalls, 94% of heavy rains and 88% of long-continued rains, are observed in the warm period. The

maximum of the extremes is observed in July. Rainfalls dominate and long-continued rains are seldom. The share of extreme rains in winter period is 6–12%. Long-continued rains dominate in winter, especially in the western region.

As usual, extreme rains start afternoon (most of distress rains start between 12 and 18 o'clock by maximal convection). Long-continued rains start in the night hours.

During distress rain (>50 mm per 12 h and less), most often (77%), precipitation sum is 50–70 mm. Rains with 100 mm are very rare (3.5%) and locate in the southern and central regions of Ukraine as usual. In the western region, extreme rains have the highest recurrence. The maximum of precipitation per 12 h in Ukraine has been fixed 9.05.1968 in Voznesens'k City in Mykolaiv region (151 mm). Mostly, the extreme rainfalls (86%) have intensity of 30–50 mm per hour and less. Sometime (probability <1%), rain intensity can reach 100 mm per hour. The intensity and recurrence of the rainfalls are highest in the South of Ukraine. The maximum (122 mm per hour) was observed 9.05.1968 in Voznesens'k City.

Most of long-continued rains (83%) are characterized by 100–150 mm precipitation sum. A share of rains with more than 200 mm sum in Ukraine is about 1%. In the South, it can reach 5%. The longest rains are observed in Western and Southern Ukraine. The absolute maximum was observed in Crimean Mountains (Ay-Petri) 5–6.09.1968 (207 mm).

In Ukraine, heavy rains and rainfalls are observed annually, long-continued rains—two times per 3 years. The rains of 50 mm and more per 12 h and less are observed annually in all regions. Heavy rainfalls are observed every year in the southern, western, and central regions. Long-continued rains are observed every 3–4 years in the southern and western regions. In central and northern regions, they are observed every 6–8 years and are very rare in the eastern region. Heavy rainfalls are very local (on the territory of one or two administrative districts), but heavy and long-continued rains can occupy a few administrative regions especially in the West and South.

The recurrence of extreme rains is very changeable in space and time, but it decreases from the North and North West to South and South East. The highest recurrence (about two events in a station) is in Ivano-Frankivs'k and Transcarpathian regions in mountains (extreme rain reaches about 40 mm per 12 h in average and 100 mm and more as maximum). Also, a high recurrence (5–8 per 10 years in a station) is observed in Lviv, Ternopil, Chernivtsi regions, and Crimea, especially in the mountains and highlands (intensity is from 50 mm (average) to >150 mm (maximum) per 12 h). Rarely (less than one event per 10 years), extreme rains are observed in the North and North East (from 60 to 70 mm (average) to 100–130 mm (maximum) per 12 h). The recurrence of extreme rains depends also on the altitude. Events amount, duration, and intensity increase with altitude. At that, the amount of dangerous rains increases faster than distress ones. The altitude 500–700 m is most optimal for all types of extreme rain occurrence. The maximum of distress rains recurrence is observed in the Carpathians and Crimean Mountains. Another factor of recurrence is water surface. Above waters and coasts, the recurrence of extreme rains in spring and the start of summer is less than over land. In April and June, along the Black and Azov Sea shore, 25–35% of the extreme rains are observed. At the same time, at the distance of 100–150 km, this parameter is 35–50%.

The amount of extreme rain events in Ukraine changes every year. At that with the probability of 99% during the last 40 years (1971–2010), their recurrence increases. The amount of

precipitation and its maximal sum also increase. These trends are characteristic almost for the whole territory of Ukraine but most marked trends are ascertained in the western, northern, and southern regions, especially in Ivano-Frankivs'k, Chernivtsi, Lviv, Rivne, Kherson, and Kropyvnyts'kyi administrative regions (**Table 2**, **Figure 2**). In the East and the Centre low increasing of the rains amount and decreasing of their intensity are observed. And only in Donets'k,

Region	Administrative region	Recurrence				Average intensity				Maximal intensity			
		Distress rains		Dangerous rains		Distress rains		Dangerous rains		Distress rains		Dangerous rains	
		α	p	α	p	α	p	α	p	α	p	α	p
West	Volynian	0.002	0.93	0.594	0.00	0.051	0.90	0.140	0.01	−0.0001	0.99	0.292	0.02
	Transcarpathian	0.149	0.26	0.136	0.43	−0.021	0.62	0.014	0.15	0.160	0.34	0.052	0.06
	Ivano-Frankivs'k	0.224	0.01	0.324	0.06	0.026	0.82	0.008	0.44	0.684	0.02	0.010	0.62
	Lviv	0.086	0.23	0.394	0.09	0.150	0.17	0.035	0.01	0.387	0.09	0.127	0.09
	Rivne	0.018	0.15	0.186	0.02	0.758	0.11	0.109	0.06	0.780	0.10	0.235	0.07
	Ternopil	0.008	0.75	−0.023	0.81	0.029	0.91	0.031	0.13	0.172	0.63	0.169	0.08
	Khmelnyts'kyi	0.018	0.48	0.126	0.33	−0.175	0.51	0.047	0.02	−0.058	0.86	0.173	0.03
	Chernivtsi	0.085	0.03	0.055	0.43	0.207	0.30	0.041	0.03	0.319	0.34	0.022	0.48
South	Zaporizhzhia	0.030	0.21	0.155	0.30	0.185	0.67	0.133	0.02	0.289	0.52	0.267	0.04
	Crimea	0.127	0.46	0.385	0.27	−0.107	0.09	0.087	0.08	0.226	0.65	0.191	0.10
	Mykolaiv	0.002	0.87	0.036	0.77	0.579	0.21	0.102	0.06	0.521	0.29	0.150	0.21
	Odesa	−0.003	0.87	0.335	0.02	0.339	0.31	0.009	0.63	0.600	0.18	0.052	0.42
	Kherson	0.033	0.27	0.225	0.16	1.098	0.02	0.109	0.04	1.344	0.01	0.244	0.04
North	Zhytomyr	0.009	0.48	0.251	0.05	0.032	0.95	0.085	0.10	0.032	0.95	0.126	0.28
	Kyiv	0.004	0.87	0.324	0.13	−0.570	0.14	0.021	0.35	−0.354	0.43	0.120	0.19
	Sumy	0.0008	0.95	0.010	0.94	0.014	0.98	0.095	0.06	0.016	0.97	0.124	0.28
	Chernihiv	0.010	0.48	0.206	0.18	0.015	0.98	−0.016	0.45	0.042	0.94	0.060	0.46
East	Donets'k	−0.012	0.74	0.067	0.64	−0.299	0.33	0.005	0.84	−0.437	0.23	0.092	0.40
	Luhans'k	0.0003	0.98	0.148	0.20	−0.044	0.93	−0.020	0.47	−0.075	0.88	0.107	0.27
	Kharkiv	0.020	0.41	0.079	0.70	0.376	0.41	0.011	0.63	0.513	0.33	0.122	0.15
Centre	Vinnytsia	−0.033	0.13	−0.158	0.33	0.067	0.89	0.008	0.71	−0.244	0.67	0.027	0.67
	Dnipro	−0.002	0.91	0.105	0.54	−0.413	0.42	0.116	0.03	−0.463	0.39	0.201	0.08
	Kropyvnyts'kyi	0.042	0.02	0.543	0.00	0.136	0.72	0.028	0.31	0.271	0.56	0.060	0.48
	Poltava	−0.002	0.89	−0.153	0.23	0.421	0.34	0.137	0.01	0.471	0.34	0.184	0.16
	Cherkasy	0.008	0.65	0.420	0.02	−0.545	0.20	0.007	0.78	−0.541	0.24	0.108	0.23
Ukraine		0.948	0.02	4.992	0.05	−0.051	0.21	0.023	0.00	0.366	0.17	0.040	0.06

Table 2. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events) and the intensity (average and maximal) of the extreme rains in observation point in Ukraine and its regions.

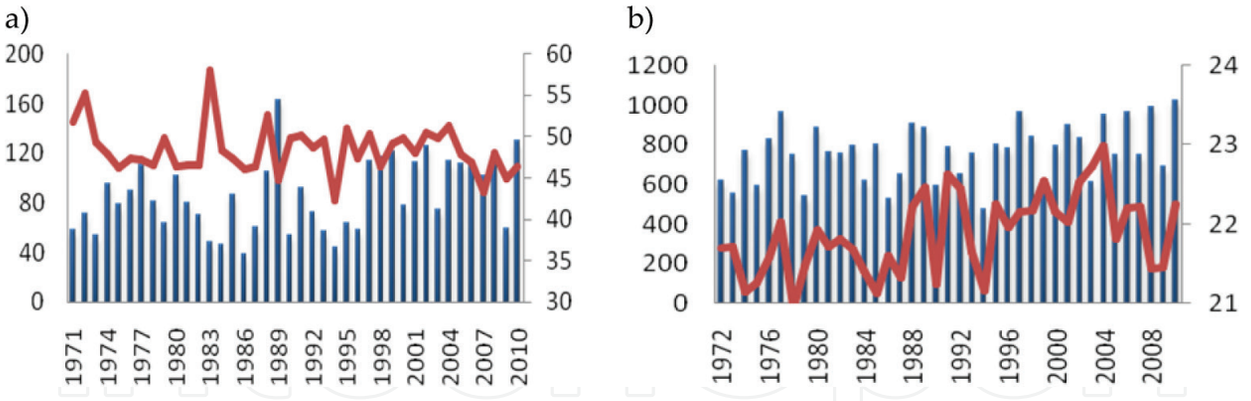


Figure 2. Changes of recurrence and intensity of the distress (a) and dangerous (b) rain events in Ukraine. Blue columns—amount of events. Red line—average precipitation, mm.

Dniptopetrovs'k and Vinnytsia regions, there is a weak tendency to decrease the recurrence and intensity. In the South and Center, the distress rains intensity has significantly increased.

The most noticeable changes of the recurrence and intensity of extreme rains in warm period are observed from the end of twentieth—the start of the twenty-first centuries (**Figure 2**). The changes are caused by an average troposphere temperature increase, humidity increase, and the intensification of convection and rain-forming processes [11]. Another significant cause of these changes is transformation of atmosphere circulation reflected in increasing of meridional processes in cyclones forming, changes of regions of cyclones forming, their moving trajectory and intensity.

2.2. Heavy snowfalls

In Ukraine, the snowfall becomes extreme weather event when precipitation sum reaches 20 mm per 12 h and less. Such snowfalls cause disturbance in the economy, transport, communications, and avalanches activization. The most dangerous is combining heavy snowfalls with freeze and strong wind.

In Ukraine, 85% of heavy snowfalls are characterized by an average precipitation of 20–30 mm per 12 h and are observed almost in all regions. The exclusion is mountain areas of the Carpathians and Crimea, Zaporizhzhia, Dnipro, Kyiv, and Sumy regions, where snowfalls are characterized by a higher intensity. The maximal precipitation on the plain territory of Ukraine can reach 40 mm, in the mountains—100 mm and more. The absolute maximum in the period of 1971–2010 has been observed 14–15.02.1997 on the Ay-Petri Mountain (132 mm).

Heavy snowfalls in Ukraine usually occur in the period October–April, but are possible in September and May as well (1966, 1989, 1991, 1992). Their recurrence has a good marked seasonal course. They are observed usually in winter (62%) and reach a maximum in January. In spring, about 22% and in autumn almost 14% of extreme snowfalls are observed. Heavy snowfalls are formed in night and morning hours as usual.

The average duration of extreme snowfalls varies from 9 to 12 h. The most long-continued snowfalls are observed in the West, the shortest duration in the South. The minimal duration is 1–2 h. The absolute minimum has been fixed 15.03.1998 on the Ay-Petri Mountain (0.9 h) with 21-mm precipitation. The longest duration snowfalls are observed in autumn and spring, the shortest duration in January.

In Ukraine, the extreme snowfalls are observed almost every year. Such a recurrence is typical for southern and western regions. In the North, they are observed once per 2 years, and in the East once per 4–5 years. Most often, heavy snowfalls in observation point are fixed in Ivano-Frankivs'k and Transcarpathian regions (two to four events per 10 years), a maximum in Carpathian (1–2 per decade) and Crimean Mountains. Noticeable recurrence (5–8 events per 100 years in meteostation) is observed also on the Volynian-Podolian Highland, in Ternopil, Khmelnyts'kyi, Zhytomyr, Vinnytsia, and Kropyvnyts'kyi regions. Less occurrence is characteristic for the Black Sea Lowland and Azov Highland, in Zaporizhzhia, Mykolaiv, Donets'k, and Dnipro regions. The least recurrence is observed on western and southern slopes of the Middle-Rus' Highland, in Sumy, Kharkiv, Luhans'k regions (two events per 100 years in meteostation).

Usually, the highest intensity of extreme snowfalls is characteristic for those regions which are characterized by a highest recurrence. In the Ukrainian Carpathians, during extreme snowfalls, the intensity is about 26–30 mm per 12 h in average and more than 100 mm per 12 h maximum. In the Crimean Mountains, the average intensity is 22–23 mm and maximal can reach 80 and more per 12 h. In the Black Sea Lowland and Azov Upland, in Zaporizhzhia, Mykolaiv, Donets'k, Dnipro, and Odesa regions, the average intensity of snowfalls is 24–25 mm and the maximal is 38 mm per 12 h. Less intensity is observed on the western and southern slopes of the Middle-Rus' Highland, in Sumy, Kharkiv, and Luhans'k regions, where heavy snowfalls occupy smaller areas. The least intensity is observed in the North-Western part of Ukraine, in Polissia.

In 1970s, a stable decrease of extreme snowfalls amount has been observed. The minimum has been reached in the middle of 1990s. Since the end of the twentieth century, recurrence and intensity started to increase and continue until now. The regional features of these changes are presented in **Table 3** and **Figure 3**.

With 99% of probability ($p \leq 0.01$), we can say about a significant increase of extreme snowfalls amount in Ukraine. The intensity of increase equals four events per 10 years in the observation point. At that, largest changes are observed in the South, East, and West, where recurrence and intensity (especially maximal one) during snowfall increased. The Biggest changes concern the Ukrainian Carpathians and Crimean Mountains.

In the central regions, the amount of snowfalls has not changed noticeably except Kropyvnyts'kyi and Cherkasy regions where the increase is 10–15%. Decreasing of recurrence is most noticeable in Lviv and Ternopil regions and a little less in the northern regions except Chernihiv. The intensity has been decreased significantly in the North, Lviv, and Ternopil regions as well during 1971–2010. These decreases reach 5–7 mm per decade with 99% probability (**Table 3**). During the last 40 years, the locality of extreme snowfalls is changed due to a decrease of recurrence and intensity within the Volynian-Podolian Highland and a noticeable increase of these parameters in Black Sea Lowland and Azov Highland.

2.3. Glazed frost

Glazed frost is a layer of suffused or transparent risen on the objects due to the freezing of rain drops frizzle or fog. The intensity of glazed frost is defined by the thickness of the ice layer, the velocity of the ice layer rising per time unit, and the duration of the phenomenon. In Ukraine, the glazed frost becomes a dangerous event when the ice layer thickness is

	Administrative region	Recurrence		Average intensity		Maximal intensity	
		α	p	α	p	α	p
West	Volynian	0.004	0.542	0.043	0.521	0.046	0.516
	Transcarpathian	0.082	0.077	0.232	0.171	0.368	0.120
	Ivano-Frankivs′k	0.095	0.001	0.392	0.037	0.635	0.006
	Lviv	−0.030	0.049	−0.195	0.177	−0.261	0.135
	Rivne	0.002	0.626	0.048	0.589	0.048	0.589
	Ternopil	−0.014	0.069	−0.204	0.136	−0.211	0.129
	Khmelnyts′kyi	−0.014	0.150	−0.111	0.445	−0.123	0.405
	Chernivtsi	−0.002	0.733	−0.021	0.844	−0.021	0.844
South	Zaporizhzhia	0.019	0.179	0.210	0.150	0.224	0.175
	Crimea	0.112	0.027	0.184	0.361	0.258	0.486
	Mykolaiv	0.008	0.315	0.313	0.041	0.308	0.047
	Odesa	0.022	0.224	0.295	0.074	0.306	0.077
	Kherson	0.005	0.411	0.126	0.214	0.126	0.218
North	Zhytomyr	−0.009	0.266	−0.187	0.146	−0.185	0.154
	Kyiv	−0.008	0.501	−0.183	0.179	−0.208	0.163
	Sumy	−0.005	0.522	−0.100	0.469	−0.099	0.493
	Chernihiv	0.010	0.428	−0.017	0.912	−0.010	0.951
East	Donets′k	0.026	0.069	0.164	0.182	0.214	0.125
	Luhans′k	0.016	0.160	0.228	0.032	0.234	0.041
	Kharkiv	0.014	0.295	0.197	0.153	0.206	0.153
Centre	Vinnytsia	−0.009	0.544	0.067	0.625	0.042	0.779
	Dnipro	0.022	0.116	0.174	0.258	0.199	0.223
	Kropyvnyts′kyi	0.026	0.095	0.264	0.049	0.281	0.045
	Poltava	−0.021	0.117	0.012	0.930	−0.015	0.913
	Cherkasy	0.007	0.575	0.227	0.122	0.221	0.143
Ukraine		0.389	0.012	0.051	0.560	0.116	0.696

Table 3. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events) and the intensity (average and maximal) of the extreme snowfalls in observation point in Ukraine and its regions in 1971–2010.

6–19 mm and distress when it exceeds 20 mm [2]. Such events cause damage and losses in the energy, transport, communications, domestic economy, and so on. Glazed frost with a thickness of more than 20 mm in Ukraine is observed from October to April with two maximums: November and February–March. Extreme-gazed frost occurs in morning (3–6) and evening hours (16–20) [8].

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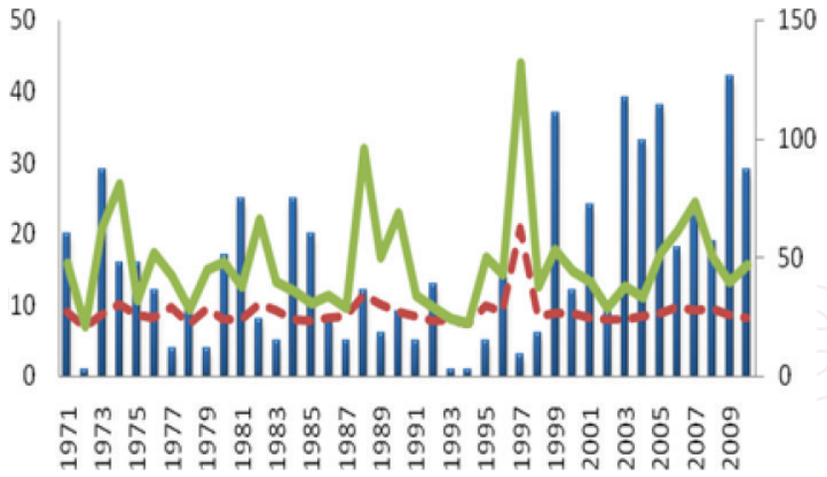


Figure 3. Changes of recurrence and intensity of the heavy snowfalls events in Ukraine. Blue columns—amount of events. Red line—average precipitation, mm. Green line—maximal precipitation, mm.

The average thickness of dangerous glazed frost ice layer varies between 9 and 17 mm, of the distress one—between 20 and 60 mm. This thickness dominates almost in all regions except north-western regions where it does not exceed 10 and 40 mm accordingly. Ice sediments of more than 100 mm are observed very rare, advantageously in the Crimea, and amount 1% of events. But there are events with the ice sediment thickness more than 200 mm. In November–December 2000, the ice sediments of 207 mm have been fixed in Zatyshshia village (Odesa region) and 307 mm in Karabi-Yayla (Crimea) in March 1977. Distress glazed frost is characterized by the high intensity. In 50% of the events, it amounts 1.1–2.0 mm per hour. In the Ay-Petri (Crimea), it reaches 5 mm per hour and more [11].

The overall duration of glazed frost in Ukraine fluctuates between a few hours and a few days and amounts about 60 h in average. The maximal duration can reach 100–200 h and even more. Usually, it is observed in the central and south-western regions. Most often (54%), ice deposits of more than 20 mm maintain less than 24 h. About 70% of the glazed frost events continue up to 2 days. Very rarely, extreme glazed frost can continue more than 1 week. For example, in November 2000, in Zhmerynka city (Vinnytsia region), the glazed frost has continued 250 h, in Vinnytsia city 282 h. The most long-continued extreme glazed frost maintains in November and February in the East and South-East.

The spatial occurrence of the extreme glazed frost is characterized by significant inequality. The highest recurrence (5–9 events per 10 years in observation point) of dangerous glazed frost with ice thickness more than 6 mm is observed in the East and South-East of Ukraine, especially within the Donets'k Range and the Azov Highland. The distress glazed frost with more than 20-mm ice layer in these regions is observed once per 3–5 years. The average ice layer thickness amounts to 10–12 mm, the maximum can reach 70 mm and more. A significant recurrence of extreme glazed frost (3–8 events per decade) is observed in the central part of the Black Sea Lowland and in the eastern part of the Dnipro Highland. These regions are characterized also by a highest intensity of extreme glazed frost. The average thickness changes between 10 and 17 mm, the maximal one can reach 200 mm and more. Such parameters are caused by the main course of the southern and south-western cyclones moving through these

	Administrative region	Recurrence		Average		Maximal	
		α	p	α	p	α	p
West	Volynian	0.02	0.09	0.07	0.31	0.09	0.23
	Transcarpathian	0.05	0.10	0.27	0.10	0.27	0.51
	Ivano-Frankivs′k	−0.02	0.42	−0.08	0.34	−0.18	0.13
	Lviv	−0.06	0.01	−0.12	0.07	−0.16	0.06
	Rivne	−0.02	0.08	−0.05	0.31	−0.11	0.15
	Ternopil	−0.06	0.002	−0.11	0.12	−0.15	0.14
	Khmelnyts′kyi	−0.06	0.01	−0.05	0.55	−0.04	0.76
	Chernivtsi	−0.004	0.73	−0.04	0.58	−0.05	0.56
South	Zaporizhzhia	−0.03	0.33	−0.02	0.81	−0.05	0.65
	Crimea	−0.11	0.05	−0.30	0.29	−1.17	0.08
	Mykolaiv	−0.004	0.89	−0.12	0.37	−0.15	0.47
	Odesa	−0.11	0.03	0.15	0.42	0.24	0.60
	Kherson	−0.11	0.20	−0.13	0.12	−0.25	0.23
North	Zhytomyr	0.01	0.55	0.01	0.81	0.06	0.44
	Kyiv	−0.002	0.93	−0.06	0.39	−0.09	0.34
	Sumy	−0.002	0.89	−0.12	0.07	−0.11	0.17
	Chernihiv	−0.02	0.26	−0.02	0.82	0.01	0.93
East	Donets′k	−0.12	0.13	0.03	0.84	−0.003	0.98
	Luhans′k	−0.02	0.59	−0.13	0.14	−0.41	0.07
	Kharkiv	0.01	0.77	−0.01	0.88	−0.02	0.93
Centre	Vinnytsia	−0.07	0.07	−0.06	0.42	−0.10	0.45
	Dnipro	−0.002	0.96	−0.04	0.56	0.01	0.93
	Kropyvnyts′kyi	−0.12	0.06	−0.10	0.17	−0.17	0.24
	Poltava	−0.12	0.001	−0.19	0.003	−0.30	0.01
	Cherkasy	−0.02	0.53	−0.04	0.58	−0.08	0.38
Ukraine		−0.67	0.14	0.08	0.12	−0.13	0.80

Table 4. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events) and the ice deposit thickness (average and maximal) of the extreme glazed frost in observation point in Ukraine and its regions in 1971–2010.

regions and the strong frontal glazed frost forming with high intensity. Distress glazed frost (more than 20 mm) in these regions is observed every 5–10 years and can occupy more than two administrative districts. A much less recurrence (2–3 times per decade in meteostation) is characteristic for the slopes of Volynian-Podolian Highland and Ukrainian Carpathians. The average ice layer amounts to 9–11 mm, the maximal value can reach 60 mm and more.

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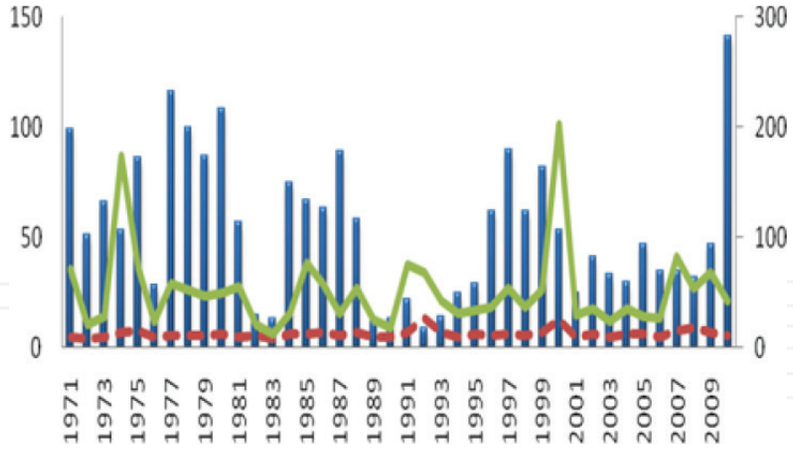


Figure 4. Changes of recurrence and ice deposit thickness of the extreme glazed frost events in Ukraine. Blue columns—amount of events. Red line—average thickness, mm. Green line—maximal thickness, mm.

The least recurrence (1–2 times per decade in the point) of extreme glazed frost is observed in Polissia Lowland. Here, the phenomena are with the least intensity and the average ice layer between 8 and 10 mm and the maximal value of 23–34 mm.

Since extreme glazed frost belongs to weather phenomena which are characterized by least recurrence, to evaluate the long-term changes, both kinds of glazed frost (dangerous and distress) were analyzed. With the 85% probability, we can say about a decrease in extreme glazed frost recurrence since 1971 in the whole territory of Ukraine. The most significant decrease in recurrence and ice layer thickness is observed in the West (**Table 4**, **Figure 4**), especially noticeably in Lviv region (probability >95%). Volynian and Transcarpathian regions are excluded, where noticeable increase in both parameters is observed (**Table 4**). A noticeable decrease of the analyzed parameters is the characteristic for the central and southern regions as well. The most significant changes in these regions are observed in Poltava region and Crimea. A feeble decrease in recurrence and ice layer thickness is observed also in the northern and eastern regions (**Table 4**).

2.4. Soggy snow adhering

In Ukraine, the soggy snow adhering becomes a dangerous weather event when the thickness of deposits amounts to 11–34 mm and distress one when the thickness exceeds 35 mm. At that only in 6% of soggy snowfalls, the adhering process is observed [8]. The main parameter of this phenomenon is its diameter in mm. About 80% of the events amount to 35–60 mm, about 2% of events have a diameter of >100 mm. The most intensive adhering is observed in the western and southern regions, where events of 80 mm amount to >5%, in the northern regions 3%. The level of danger depends on the phenomenon duration. The average duration in Ukraine fluctuates from 14 to 19 h. The maximum varies from 2 days to a week and more. The longest soggy snow adhering is observed in the West of Ukraine. But absolute maximum was fixed in Olevs'k City (Zhytomyr region) 12.02.1983 (304 h).

Extreme soggy snow adhering with distress diameter occurs in October–April usually. Most often (about 70%), it is in December–February. About 20% of events arise in evening hours, from 18 to 21 o'clock.

	Administrative region	Recurrence		Average diameter		Maximal diameter	
		α	p	α	p	α	p
West	Volynian	0.03	0.14	0.13	0.49	0.16	0.47
	Transcarpathian	0.06	0.09	−0.01	0.97	0.75	0.15
	Ivano-Frankivs'k	−0.04	0.01	−0.46	0.05	−1.07	0.007
	Lviv	−0.03	0.19	−0.08	0.67	−0.22	0.39
	Rivne	−0.01	0.55	−0.22	0.20	−0.23	0.25
	Ternopil	−0.003	0.82	−0.04	0.84	−0.05	0.82
	Khmelnyts'kyi	−0.002	0.94	−0.10	0.55	−0.10	0.69
	Chernivtsi	0.01	0.05	0.24	0.09	0.24	0.09
South	Zaporizhzhia	0.01	0.47	−0.22	0.30	−0.17	0.51
	Crimea	0.06	0.02	0.26	0.24	0.57	0.15
	Mykolaiv	−0.04	0.02	−0.26	0.15	−0.42	0.06
	Odesa	0.04	0.13	0.34	0.02	0.38	0.05
	Kherson	0.02	0.11	0.18	0.36	0.23	0.30
North	Zhytomyr	0.02	0.49	−0.05	0.80	−0.13	0.69
	Kyiv	0.06	0.08	0.03	0.88	0.10	0.69
	Sumy	0.10	0.001	0.31	0.05	0.54	0.01
	Chernihiv	0.08	0.004	0.44	0.002	0.57	0.001
East	Donets'k	0.02	0.47	0.13	0.52	0.20	0.40
	Luhans'k	0.04	0.07	−0.03	0.91	0.08	0.77
	Kharkiv	0.11	0.004	0.35	0.02	0.59	0.01
Centre	Vinnytsia	0.002	0.87	−0.14	0.44	−0.17	0.40
	Dnipro	0.02	0.22	0.10	0.56	0.12	0.51
	Kropyvnyts'kyi	0.06	0.02	0.20	0.35	0.30	0.20
	Poltava	0.03	0.27	0.22	0.15	0.30	0.17
	Cherkasy	0.06	0.05	0.04	0.82	0.17	0.41
Ukraine		0.76	0.002	−0.10	0.06	−0.09	0.85

Table 5. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events) and the snow deposit diameter (average and maximal) of the extreme soggy snow adhering in observation point in Ukraine and its regions in 1971–2010.

Soggy snow adhering in Ukraine is a very local phenomenon and occurs almost every year. The highest recurrence in observation point is characteristic for the West and South (2–3 times per year), especially on the south-west slopes of the Carpathians, in the Precarpathians and in the Crimea Mountains, where soggy snow adhering has a maximal average diameter of

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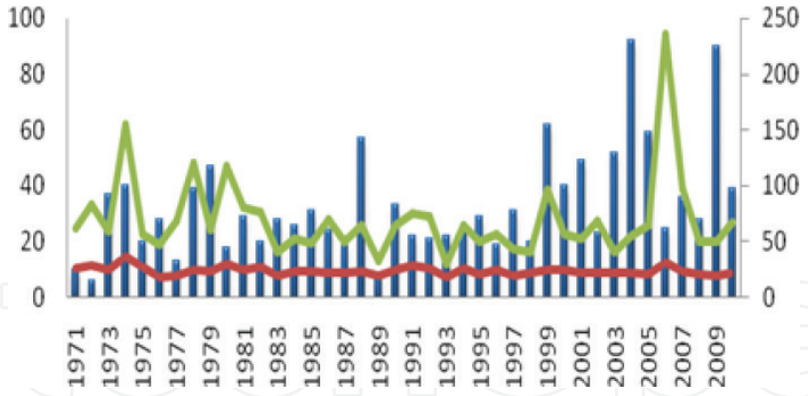


Figure 5. Changes of recurrence and snow deposits (diameter) of the extreme soggy snow-adhering events in Ukraine. Blue columns—amount of events. Red line—average diameter, mm. Green line—maximal diameter, mm.

25–30 mm and the maximal one can reach 200 mm and more. Eastern Polissia and north-western regions have the same recurrence but less diameter of 21–24 (average) and 120 mm (maximal). Recurrence in the central and south-eastern regions is once per year, the average diameter varies between 20 and 29 mm, and the maximal between 50 and 70 mm.

Because of low recurrence in one point of the phenomenon for the assessment of the long-term changes, both kinds of extreme soggy snow adhering (dangerous and distress) were analyzed. Analysis carried out has testified that in the period 1971–2010, the recurrence of soggy snow adhering and its diameter with 99% probability increased (**Table 5**, **Figure 5**) on 7–8 events in observation point for 10 years in average. The most significant increase of recurrence and diameter is observed in the North and East of Ukraine (Chernihiv, Sumy, Kharkiv regions). But increasing is characteristic not for the whole territory of Ukraine. A decrease is observed in the West, especially in Ivano-Frankivs'k region.

2.5. Compound (bedded) ice deposits

Compound ice deposits are ice layers formed on the object surface due to the sequential overlaying of different types of the ice which is caused by changeable weather conditions. The deposits consisted of glazed frost and dense snow-like friable atmospheric ice that are most dangerous. In Ukraine, such an event is dangerous when the compound ice deposits diameter is 11–34 mm and distress one when the diameter is >35 mm [8]. Such phenomena cause accident situations on the power engineering and communication lines, damage and losses in the transport, forestry, domestic economies, and so on. Compound ice deposits in Ukraine occur in the period from November to April (30% in December and 23% in January) in 6–9 o'clock in the morning and 18–20 o'clock in the evening. The diameter of the compound ice deposits is almost two times larger than the glazed frost. The average diameter fluctuates from 17 to 50 mm, the maximal one from 20 to 200 mm and more; 83% of the events have a diameter of <100 mm. In the West and South, this phenomenon is much more intensive. The share of >200 mm deposits is 2–7%. The total duration varies from a few hours to a few days and amounts to 40 h on average. The most long-continued compound ice deposits are in the western and southern regions. The maximal duration has been observed 27.11–5.12 2000 in

	Administrative region	Recurrence		Average diameter		Maximal diameter	
		α	p	α	p	α	p
West	Volynian	−0.067	0.067	−0.365	0.056	−0.355	0.085
	Transcarpathian	−0.037	0.016	−0.290	0.119	−0.315	0.107
	Ivano-Frankivs′k	−0.196	0.00002	−0.169	0.202	−0.333	0.026
	Lviv	−0.423	0.0006	−0.227	0.103	−0.393	0.023
	Rivne	−0.027	0.136	−0.235	0.186	−0.277	0.145
	Ternopil	−0.051	0.089	−0.142	0.452	−0.171	0.394
	Khmelnyts′kyi	−0.095	0.025	−0.526	0.002	−0.625	0.001
	Chernivtsi	−0.009	0.539	−0.300	0.108	−0.309	0.104
South	Zaporizhzhia	−0.124	0.004	−0.448	0.004	−0.494	0.004
	Crimea	−0.265	0.069	−0.034	0.066	−0.111	0.01
	Mykolaiv	−0.004	0.834	−0.048	0.792	−0.062	0.740
	Odesa	−0.014	0.726	0.019	0.922	0.019	0.923
	Kherson	0.237	0.002	0.259	0.010	0.399	0.002
North	Zhytomyr	−0.062	0.047	−0.497	0.006	−0.541	0.006
	Kyiv	−0.063	0.028	−0.217	0.253	−0.253	0.207
	Sumy	−0.026	0.024	−0.186	0.261	−0.200	0.237
	Chernihiv	−0.061	0.001	−0.639	0.0004	−0.684	0.0003
East	Donets′k	−0.093	0.054	−0.157	0.363	−0.217	0.269
	Luhans′k	−0.279	0.0002	−0.238	0.136	−0.359	0.043
	Kharkiv	−0.090	0.025	−0.271	0.127	−0.319	0.086
Centre	Vinnytsia	−0.094	0.042	−0.283	0.137	−0.344	0.089
	Dnipro	−0.080	0.032	−0.565	0.0003	−0.620	0.0004
	Kropyvnyts′kyi	−0.057	0.100	−0.223	0.238	−0.251	0.197
	Poltava	−0.043	0.008	−0.332	0.065	−0.355	0.054
	Cherkasy	−0.080	0.025	−0.569	0.002	−0.593	0.002
Ukraine		−2.082	0.001	−0.013	0.231	−0.106	0.028

Table 6. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events) and the diameter (average and maximal) of the extreme compound ice deposits in observation point in Ukraine and its regions in 1971–2010.

Khmelnyts′kyi region (199 h) and 29.11–6.12 2000 in Chernivtsi region (Nova Ushytsia, 155 h). The highest recurrence (82%) is characteristic for the events continued less than 3 days, 56%—less than 24 h. The phenomena continued more than a week are very rare.

The highest amount of the events in one observation point is in the Transcarpathian, Donets′k, and Luhans′k regions——4–5 per 10 years (maximum on the south-west slopes of the Carpathians

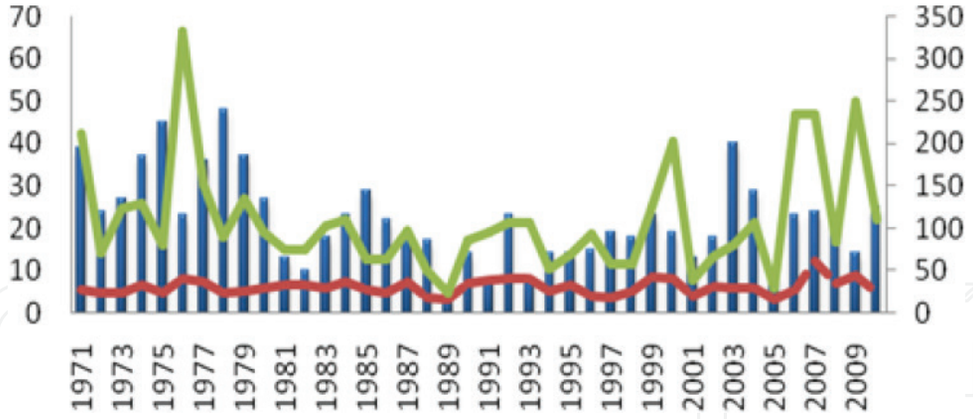


Figure 6. Changes of recurrence and the deposits (diameter) of the extreme compound ice deposits in Ukraine. Blue columns—amount of events. Red line—average diameter, mm. Green line—maximal diameter, mm.

and Donets'k Range). Significant recurrence (1–2 per 10 years) is observed in the Crimean Mountains, Ivano-Frankivs'k, Ternopil, and Kropyvnyts'kyi regions. In the northern regions, the compound ice deposits have not been observed in the analyzed period.

Compound ice deposits of the distress diameter are observed almost every year in the Crimea (Karabi-Yayla) and the Carpathians (Play) and occupy usually (99%) one district. There, the events are characterized by maximal diameter and duration. The maximal amount of days with the event (17) has been observed in 1970 in the South of Ukraine.

Because of low recurrence, the compound ice deposits of >11 mm were analyzed to assess their changes. The recurrence and diameter of compound ice deposits of distress diameter has been noticeably decreased with 99% probability (**Table 6** and **Figure 6**). Such trends are observed almost everywhere in Ukraine except the Kherson region. The most significant changes are observed in the northern and central regions, especially in the Chernihiv and Dnipro regions (**Table 6** and **Figure 6**).

2.6. Hail

In Ukraine, the hail belongs to a dangerous weather event, when its diameter is 6–20 mm and distress event, when its diameter exceeds 20 mm [8]. Most often (90%), the hail has a diameter of 20–50 mm. The hail of >50 mm diameter is observed very rare (6%) and in the southern regions usually. About 50% of events have a duration of 6–20 min. Hail continued more than an hour is observed very rarely. For example, on 22 July, 1987, in Sarat district of Odesa region, the hail has continued for 2 h 40 min and was a walnut size. Long-continued hail is observed in summer period usually and its duration in the mountain regions is higher than on the plains. The hail has a good marked daily variation with the maximum at 15–18 o'clock. In Ukraine, the extreme hail is observed in warm period usually. The recurrence of the extreme hail has also a good marked seasonal regime: maximum (70% occurrence) is observed in June and July. In spring and autumn, the extreme hail is rare. Mountain areas are characterized by a higher recurrence than plain.

From two to four events of distress, hail can be observed on 100 km^2 area for a 40-year period in Ukraine. Such hail can damage about 1–2% of agricultural areas. Within the whole

	Administrative region	Recurrence		Average diameter		Maximal diameter	
		α	p	α	p	α	p
West	Volynian	0.000	0.894	−0.054	0.750	−0.054	0.750
	Transcarpathian	−0.006	0.148	−0.207	0.124	−0.207	0.124
	Ivano-Frankivs'k	−0.010	0.060	−0.240	0.103	−0.265	0.085
	Lviv	−0.002	0.617	−0.022	0.878	−0.114	0.534
	Rivne	−0.001	0.285	−0.106	0.285	−0.106	0.285
	Ternopil	0.000	0.967	−0.020	0.907	−0.020	0.907
	Khmelnyts'kyi	−0.002	0.481	−0.083	0.463	−0.083	0.463
	Chernivtsi	−0.004	0.183	−0.058	0.183	−0.058	0.183
South	Zaporizhzhia	−0.002	0.510	0.052	0.764	0.036	0.836
	Crimea	−0.001	0.904	0.301	0.132	0.268	0.224
	Mykolaiv	0.007	0.020	0.296	0.056	0.329	0.044
	Odesa	−0.002	0.340	−0.430	0.090	−0.430	0.090
	Kherson	0.002	0.261	0.158	0.518	0.158	0.518
North	Zhytomyr	0.001	0.560	0.047	0.680	0.055	0.657
	Kyiv	0.002	0.464	0.221	0.341	0.222	0.341
	Sumy	0.003	0.161	0.206	0.092	0.206	0.092
	Chernihiv	−0.001	0.606	−0.054	0.617	−0.057	0.607
East	Donets'k	−0.002	0.132	−0.169	0.084	−0.169	0.084
	Luhans'k	0.001	0.451	0.107	0.388	0.107	0.388
	Kharkiv	0.001	0.662	−0.088	0.551	−0.072	0.639
Centre	Vinnytsia	−0.003	0.219	−0.144	0.279	−0.147	0.273
	Dnipro	0.001	0.764	0.042	0.812	0.051	0.779
	Kropyvnyts'kyi	0.003	0.402	0.101	0.385	0.135	0.363
	Poltava	−0.004	0.107	−0.207	0.126	−0.246	0.174
	Cherkasy	−0.002	0.568	0.011	0.940	0.011	0.940
Ukraine		0.000	0.545	0.092	0.445	0.065	0.830

Table 7. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events per 100 km² per year) and the diameter (average and maximal) of the dangerous and distress hail in Ukraine and its regions in 1971–2010.

territory of Ukraine, these processes occur every year. The highest recurrence of distress hail is observed in the western regions (Transcarpathian, Ivano-Frankivs'k, and Ternopil) and the Crimea, where 6–7 distress hail events are observed on the 100 km² area for 40 years. The average diameter of the distress hail here varies from 23 to 29 mm, the maximum reaches 400 mm. Such hail can damage up to 20% of agricultural areas [11]. Southern slopes of the Volynian-Podolian, Dnipro, and Donets'k Highlands, which are opened for southern and

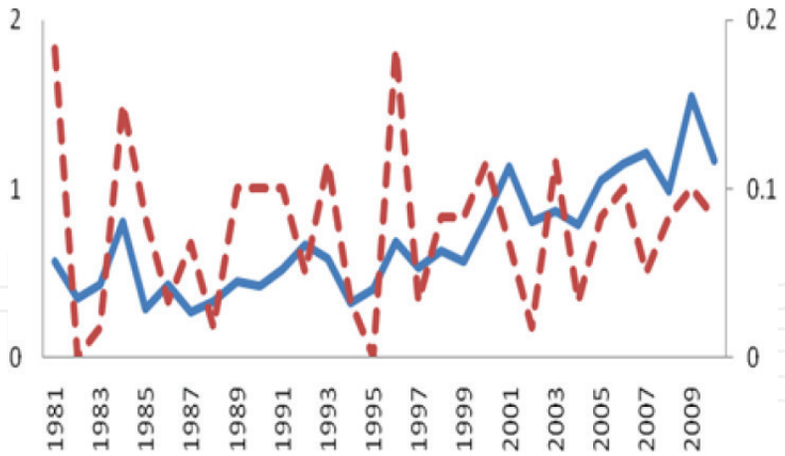


Figure 7. Changes of recurrence (event amount per 100 km^2 per year) of the dangerous and distress hail in Ukraine. Blue line—dangerous hail events. Red line—distress hail event.

south-western wet air masses, also are characterized by a significant distress hail recurrence (3–4 events per 100 km^2 per 40 years). But the hail intensity there is highest than in the West: the average diameter is 29–39 mm, and the maximum reaches 97 mm. The most dangerous in this aspect is the Bashtan district of Mykolaiv region, where not only the hail is very intensive but also other convective phenomena: squalls, storms, and spouts.

During the last decades, the tendency of the extreme hail recurrence increasing is observed in Ukraine. At that, the amount of hail with >6 mm diameter increases significantly, but with >20 mm it is not changed (**Table 7**, **Figure 7**). These changes were noticeably intensified since the end of the twentieth century because of convection processes intensity increase [11].

Some intensifying of the hail processes is observed in the Kropyvnyts'kyi, Dnipro, Kherson, and Mykolaiv regions where both recurrence and diameters of the hail have been increased. The average and maximal diameter has been increased also in the Crimea and Zaporizhzhia and Sumy region (**Table 7**).

2.7. Squalls

Among the dangerous weather phenomena of warm period, the share of squalls is not significant but the largest damages are caused by extreme squalls. In Ukraine, the squall with a wind velocity of 15–25 m/s is dangerous, with >25 m/s is distress. The average wind velocity of the extreme squalls changes from 18 to 22 m/s. Distress squalls have a wind velocity of 25–30 in 82.8% of events. A wind velocity of >40 m/s is very rare (1%). The most intensive squalls are observed in the south-western regions, where the average wind velocity amounts to 20–22 m/s, maximal—32–40 m/s. The share of squalls with 35 m/s velocity in these regions amounts to 20%, in the northern and southern regions—about 7%, in the central—4%.

The extreme squalls in Ukraine have a good marked seasonal recurrence. Most often (60%), they rise in June and July, 14% of events are observed in spring, about 7% in autumn, and about 3% in winter. Squalls have beaded daily variation with the maximum in the afternoon and evening hours (60% of events).

	Administrative region	Recurrence		Average velocity		Maximal velocity	
		α	p	α	p	α	p
West	Volynian	0.016	0.354	0.039	0.737	0.090	0.483
	Transcarpathian	0.032	0.002	0.286	0.013	0.317	0.011
	Ivano-Frankivs'k	0.006	0.462	0.143	0.297	0.153	0.291
	Lviv	0.061	0.003	−0.103	0.065	−0.079	0.386
	Rivne	0.021	0.017	0.157	0.224	0.194	0.149
	Ternopil	0.024	0.049	0.137	0.333	0.155	0.305
	Khmelnyts'kyi	0.057	0.009	0.221	0.093	0.284	0.050
	Chernivtsi	0.016	0.008	0.224	0.043	0.224	0.043
South	Zaporizhzhia	0.019	0.109	0.042	0.691	0.093	0.440
	Crimea	0.112	0.000	0.063	0.446	0.231	0.025
	Mykolaiv	0.030	0.003	0.301	0.012	0.375	0.005
	Odesa	0.046	0.013	−0.098	0.275	0.005	0.966
	Kherson	0.002	0.842	0.112	0.213	0.161	0.155
North	Zhytomyr	0.061	0.000	0.232	0.024	0.360	0.004
	Kyiv	0.058	0.000	0.219	0.029	0.336	0.009
	Sumy	0.047	0.000	0.316	0.014	0.370	0.009
	Chernihiv	0.005	0.560	−0.141	0.224	−0.213	0.117
East	Donets'k	0.010	0.201	0.083	0.492	0.121	0.380
	Luhans'k	0.053	0.000	0.352	0.003	0.438	0.001
	Kharkiv	0.058	0.000	0.233	0.039	0.383	0.003
Centre	Vinnytsia	−0.003	0.287	−0.152	0.293	−0.160	0.297
	Dnipro	0.039	0.000	0.276	0.045	0.414	0.008
	Kropyvnyts'kyi	0.014	0.120	−0.065	0.594	−0.065	0.634
	Poltava	−0.004	0.239	−0.178	0.172	−0.189	0.169
	Cherkasy	0.057	0.004	0.163	0.151	0.213	0.111
Ukraine		0.035	0.000	−0.041	0.005	0.032	0.563

Table 8. Linear trend coefficient (α) and its significance (p) of recurrence (amount of events per 100 km^2 per year) and the wind velocity (average and maximal) of the dangerous and distress squalls in Ukraine and its regions in 1971–2010.

Most of squalls (75% of events) continue less than 20 min, about 90% of them continue <30 min. Rarely, there are squalls of a 1-h duration. In the Odesa region 22.07.1987, the squall has continued more than 2 h with the wind velocity of 25 m/s and was accompanied by the hail of a walnut size. The largest amount of dangerous and distress squalls on the area of 100 km^2 per 40 years (1971–2010) has been observed in West and South, especially Lviv, Volynian, Odesa,

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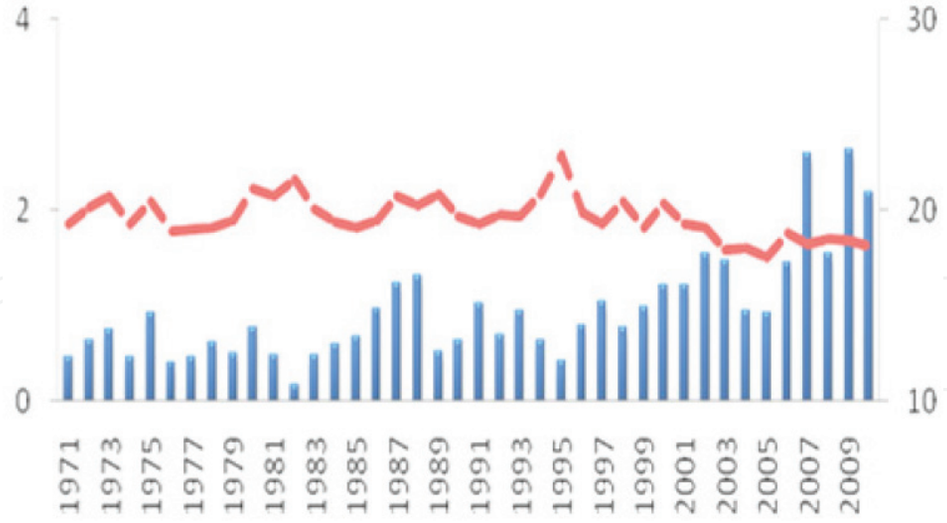


Figure 8. Changes of recurrence (event amount per 100 km^2 per year) and intensity of the dangerous and distress squalls in Ukraine. Blue columns—amount of events. Red line—average wind velocity, m/s.

Kherson, and Cherkasy regions (21–32 events) with an average wind velocity of 19–20 m/s, maximal—40 m/s. Significant recurrence and intensity are representative for the Polissia Lowland (except Rivne region), Khmelnyts'kyi, Zaporizhzhia, and Crimea (14–16 events). Extreme squalls are very rare in the eastern regions, where recurrence amounts to 3–7, an average wind velocity is 16–18 m/s, maximal—26–34 m/s.

The amount of the extreme squalls in Ukraine during the last decades has been increased. In the western and eastern regions, an increasing recurrence is accompanied by a significant increase in the squall intensity (average and maximal wind velocity). The same tendencies are representative for the Transcarpathian, Chernivtsi, Khmelnyts'kyi, Dnipro, Mykolaiv, and Crimea regions (**Table 8**, **Figure 8**).

2.8. Snowstorms

The snowstorms with a wind velocity of >15 m/s and a duration of >12 h are classified as distress in Ukraine [8]. For struggle with snow drifting on the roads, every year, millions of EURO are spent in Ukraine. Most of the snowstorms (70%) have a wind velocity of 15–30 m/s. This intensity events most often (95%) in the northern and central regions are observed. The more intensive snowstorms are representative in the western and southern regions, where the average velocity fluctuates from 25 to 29 m/s, the maximal one can reach 40 m/s and more. For instance, in the Ivano-Frankivs'k region, the share of snowstorms of 40 m/s amounts almost 25%. The least intensity snowstorms are representative for the North and North-East, where the average velocity is 17–21 m/s, maximal—24 m/s. Most of events (about 95%) last up to 2 days. The average duration is 15–30 h. The highest duration is observed in the Carpathian and Crimean Mountains, Donets'k Range. A maximal duration can reach 100 h. The absolute maximum has been fixed 10–20.02 1969 in the Luhans'k region (Daryivka)—242 h.

Snowstorm recurrence has a good marked yearly variation. The most intensive and long-continued snow-storms are observed from October to April with a maximum in February

(40.4%) and January (26.7%). About 12% of the events are observed in spring and 6% in autumn. Strong snowstorms can be observed any time of a day. Usually, they occupy a few administrative districts, but sometimes, they can occupy the area of a few regions. The snowstorms in Ukraine are observed almost every year. The highest recurrence is representative in the West, especially in the Ivano-Frankivs'k and Transcarpathian regions (2–9 events per 10 years), where the snowstorms have the highest wind velocity and duration. A significant recurrence is observed also in the southern and south-eastern regions. In the northern and central regions, the recurrence amounts 1–3 events per 10 years.

The snowstorm recurrence intensity decreases in Ukraine. The most significant changes are observed in the southern and northern regions, where recurrence and wind velocity have been decreased with 95% probability. At the same time, in the Ivano-Frankivs'k and Transcarpathian regions, especially in the mountains, the recurrence and wind velocity noticeably increase.

3. Conclusions

During 1971–2010, in Ukraine, the significant changes of the extreme weather phenomena recurrence and intensity have been observed which are caused by the meteorological preconditions of their forming, atmosphere circulation, and thermal regime changes.

In many regions of Ukraine, there is a trend of the rains and soggy snow recurrence increasing which has caused an increase of extreme soggy snow-adhering events amount. At the same time, the recurrence of the dangerous and distress glazed frost and compound ice deposits decreased. But since the start of the twenty-first century, an increase of these phenomena is observed.

During the last 40 years, also recurrence and intensity of the heavy snowfalls has been significantly increased. Also, the spatial occurrence of this phenomenon changed. In 1971–1990, the heaviest snowfalls occurred in the western and north-western regions, but during the last decades, the recurrence and intensity in these regions has decreased, simultaneously in the southern and south-eastern regions, they have been noticeably increased.

The air temperature, especially the maximal one in the warm period and air humidity increase, has caused convection intensification in Ukraine and unstability of the atmosphere. Due to such changes, the amount and intensity of the dangerous and distress rains, squalls and hail have increased.

Changes of macro- and mesoscale circulation in the second half of the twentieth century in the northern hemisphere have caused a decrease in strong baric gradient events which conditioned strong and long-continued winds. As a result, the recurrence of not only strong winds but also strong snowstorms and sand storms has been decreased.

The ascertained tendencies have regional specialties caused by the changes of their forming preconditions in these regions.

The next research consists in the assessment of the possible regional changes of extreme weather events for different scenario of the climate change, society development, and green gas emissions as well as social-ecological and socioeconomical effects of these changes.

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