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Meteorological conditions of ice and snow accretion formation in the Ukraine

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ABSTRACT

Meteorological conditions of formation of icing events, including glaze, hard and soft rime, wet and frozen wet snow for 25 sites of the Ukraine are examined on the basis of surface observation in the 2002–2009 period. To provide the information about the maximum expected amount of accreted ice at a certain site, a site icing index is calculated by using icing frequency, duration and intensity. For all stations degree of severity of local icing conditions varies from 'occasional' to 'moderate'.

Keywords: ice accretion, site icing index, statistic analysis, probabilistic forecast

1 INTRODUCTION

Ice and snow on roads may cause severe damage to vehicular traffic. For example, these phenomena increase the risk of accidents and leads to road closures and hence economic losses. There are several effective strategies for road maintenance in winter (for example, anti-icing that is often used to keep the roadways free of ice), but all of these techniques hurt the environment. The physical process that produces ice on roads is complex and strongly depends on the weather and involves the interaction the weather with road surface conditions. Given the preventive nature of several strategies, accurate icing forecasts are needed. A good estimate of the probability of ice formation is needed and deterministic forecasts do not provide it. To provide the probabilistic forecast of ice accretion it is necessary to study the meteorological conditions of ice formation and saving [1,2].

2 METEOROLOGICAL CONDITIONS OF ICE AND SNOW ACCRETION IN THE UKRAINE

In this study the various ice accretions, namely glaze, soft and hard rime, wet and frozen wet snow, from 2002 to 2009 over the Ukraine, are examined on the basis of the hourly weather observations of 25 stations. Database contains 3100 icing 'simple' events, for which temperature, wind speed and direction in the beginning of icing accretion and at the moment that the icing accretion reached maximum in the size, are collected. 'Simple' event means that during icing formation only accretion type is observed.

The locations of stations, for which the ice formation conditions are studied, and number of the icing events for each site are shown in Fig. 1. We can see that spatial distribution of the icing events is strongly dependent on local geographic features. The most number of cases are observed in the landlocked mountainous terrain. The highest frequency of occurrence of atmospheric icing is obtained for the Vinnitsia, Khmelnitskyi, Kirovohrad and Kharkiv regions (table 1). These regions are located on the plateaus, average height of which reaches about 100-150 m above sea level there. For the mountainous terrain such as the Donetsk ridge, the Crimean Mountains and the Carpathians the average frequency of icing is reported. Such result can be explained by absence of the detailed information which describes the local terrain features more accurately. In order to provide better results it is necessary to involve the data of more number of stations in these regions.

Figure 2 displays the frequency disribution of atmospheric icing in the Ukraine. For all regions, not specified by kind, the glaze most frequently occurs (39,4%), frozen wet snow are the rarest events (about 0,3%). The frequency of the soft and hard rime is about equal (25,6 and 22,5 %, respectively).

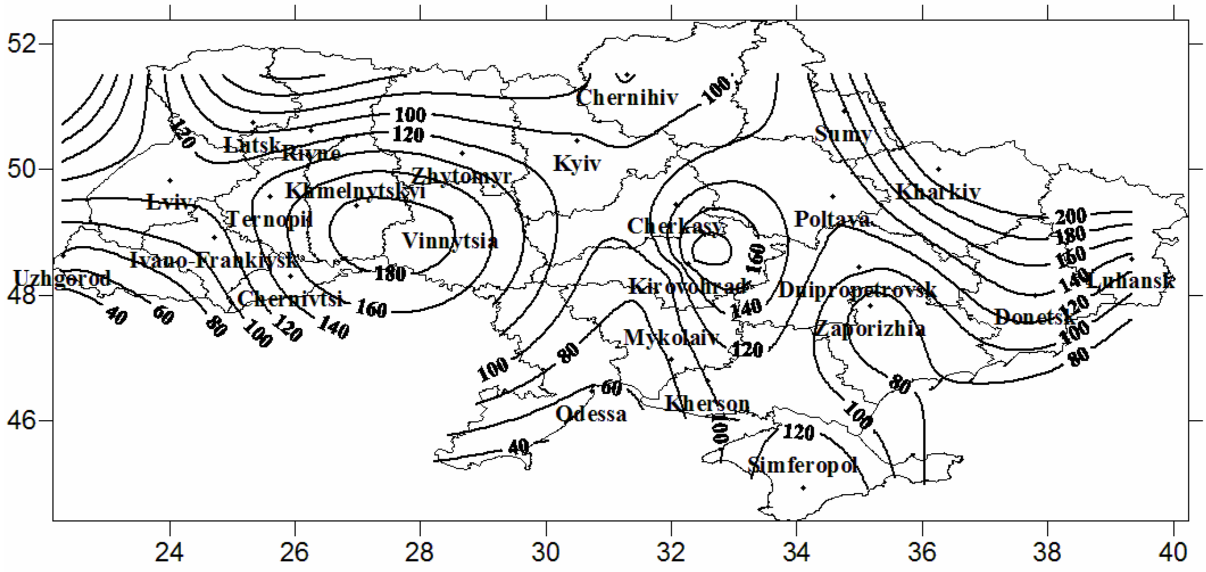

Figure 1. Location of the cites in the Ukraine, for which the ice formation conditions are studied in the paper, and number of the icing cases.

In the table 1 the distribution of the number of the cases depending on event type are given. Frequency of the glaze is highest in the Donetsk and Rivne provinces (from 59,2 to 69,5 %, respectively). Soft rime has the lowest frequency in the Mykolaiv and Odessa provinces (from 1,3 to 10,3 %, respectively). It can be connected with the presence of the high humidity in this seaside terrain.

	glaze	*soft rime*	*hard rime*	*wet snow*	*frozen wet snow*	
Cherkasy	42	44	12	19	0	117
Chernihiv	35	35	35	3	0	108
Chernivtsi	50	49	41	10	0	150
Dnipropetrovsk	47	15	29	11	0	102
Donetsk	84	32	23	3	0	142
Ivano-Frankivsk	29	46	36	1	0	112
Kharkiv	101	47	41	21	2	212
Kherson	39	22	23	18	0	102
Khmelnytskyi	81	25	37	40	0	183
Kirovohrad	72	38	48	16	0	174
Kyiv	33	26	22	21	0	102
Luhansk	33	57	26	18	0	134
Lutsk	27	34	20	5	0	86
Lviv	46	52	22	8	0	128
Mykolaiv	31	1	43	5	0	80
Odessa	22	6	15	15	0	58
Poltava	44	34	38	8	0	124
Rivne	64	21	14	5	0	104
Simferopol	45	29	16	36	0	126
Sumy	58	50	30	12	4	154
Ternopil	62	28	39	17	0	146
Uzhgorod	38	14	10	17	0	79
Vinnytsia	70	55	39	15	0	179
Zaporizhia	20	16	9	26	1	72
Zhytomyr	47	19	28	29	3	126
total	1220	795	696	379	10	3100

Table 1. Frequency distribution of the number of the cases depending on event type for each region

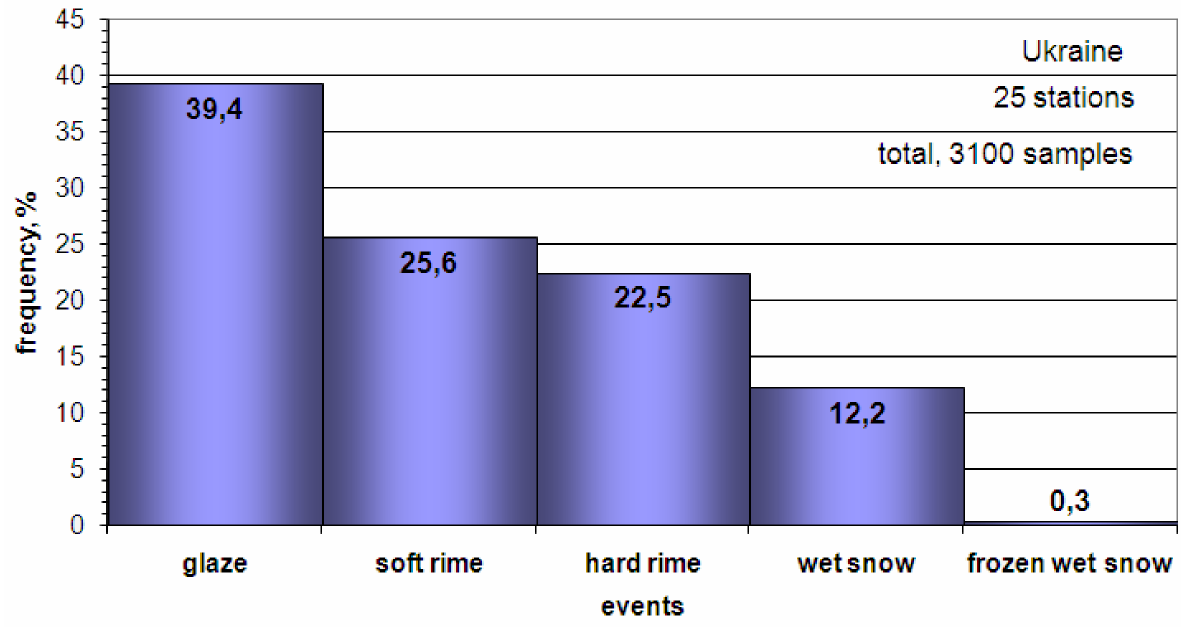

Figure 2. Frequency disribution of atmospheric icing in the Ukraine.

In order to provide the information about the maximum expected amount of accreted ice at a certain site, in according to 'COST 727: Atmospheric Icing on Structures Measurements and data collection on icing: State of the Art' a site icing index is introduced by using icing frequency, duration and intensity: this index is the parameter to be used by the meteorological community to determine how severe ice accretion is expected at a particular site.

Cite	*Days with meteorological icing/year*	*Duration of meteorological icing, %/year*	*Intensity of icing, g/100cm2/h*
Cherkasy	**14,8 (S3)**	**1,23 (S2)**	**2,75 (S1)**
Chernihiv	**13,9 (S3)**	**1,38 (S2)**	**2,84 (S1)**
Chernivtsi	**19,6 (S3)**	**2,92 (S2)**	**2,63 (S1)**
Dnipropetrovsk	**12,9 (S3)**	**1,30 (S2)**	**3,86 (S1)**
Donetsk	**18,6 (S3)**	**2,00 (S2)**	**4,34 (S1)**
Ivano-Frankivsk	**14,3 (S3)**	**2,44 (S2)**	**1,15 (S1)**
Kharkiv	**27,3 (S3)**	**2,31 (S2)**	**3,66 (S1)**
Kherson	**13,8 (S3)**	**1,46 (S2)**	**3,21 (S1)**
Khmelnytskyi	**26,1 (S3)**	**3,72 (S2)**	**4,16 (S1)**
Kirovohrad	**22,3 (S3)**	**1,94 (S2)**	**3,52 (S1)**
Kyiv	**13,6 (S3)**	**1,18 (S2)**	**2,64 (S1)**
Luhansk	**17,3 (S3)**	**1,69 (S2)**	**1,53 (S1)**
Lutsk	**10,8(S2)**	**0,93 (S2)**	**1,93 (S1)**
Lviv	**16,1 (S3)**	**1,94 (S2)**	**2,52 (S1)**
Mykolaiv	**10,6 (S2)**	**1,04 (S2)**	**2,46 (S1)**
Odessa	**7,5 (S2)**	**0,72 (S2)**	**3,89 (S1)**
Poltava	**15,6 (S3)**	**1,63 (S2)**	**2,84 (S1)**
Rivne	**13,6 (S3)**	**1,54 (S2)**	**3,79 (S1)**
Simferopol	**19,1 (S3)**	**1,71 (S2)**	**5,61 (S2)**
Sumy	**19,4 (S3)**	**2,02 (S2)**	**3,41 (S1)**
Ternopil	**19,0 (S3)**	**2,60 (S2)**	**3,64 (S1)**
Uzhgorod	**10,1 (S2)**	**1,00 (S2)**	**1,32 (S1)**
Vinnytsia	**23,8 (S3)**	**3,24 (S2)**	**3,77 (S1)**
Zaporizhia	**9,1 (S2)**	**0,84 (S2)**	**2,51 (S1)**
Zhytomyr	**17,1 (S3)**	**1,55 (S2)**	**2,11 (S1)**

Table 2. Site icing index for the Ukraine provinces

On according to the proposed classification (table 2) we got that by the first two parameters the icing intensity varies from "light" (S2) to "moderate" (S3). As a rule the most northern sites and sites, which situated at the elevated terrain (Vinnytsia, Khmelnitskiy, Kharkiv, Kirovohrad) have maximum values of the index, and the most southern or seaside (Odessa, Mykolaiv) ones have minimum values. For all the sites in accordance with the third parameter icing intensity is "occasional" (S1), except of Simferopol. The reason for such result may be wind regime in this site (as a rule wind speed is higher in the seaside territory than in the landlocked one). Similar results were obtained for seaside stations such as Ochakiv, Khorly, Illichivsk in the works [3,5].
It is well known that the density and type of ice strongly depend on the air temperature and wind. Therefore for all stations the frequency distribution of icing events as dependent on surface air temperature and wind direction are obtained.
The frequency distribution of air temperature at the beginning of the atmospheric icing near the surface is displayed in the fig. 3.

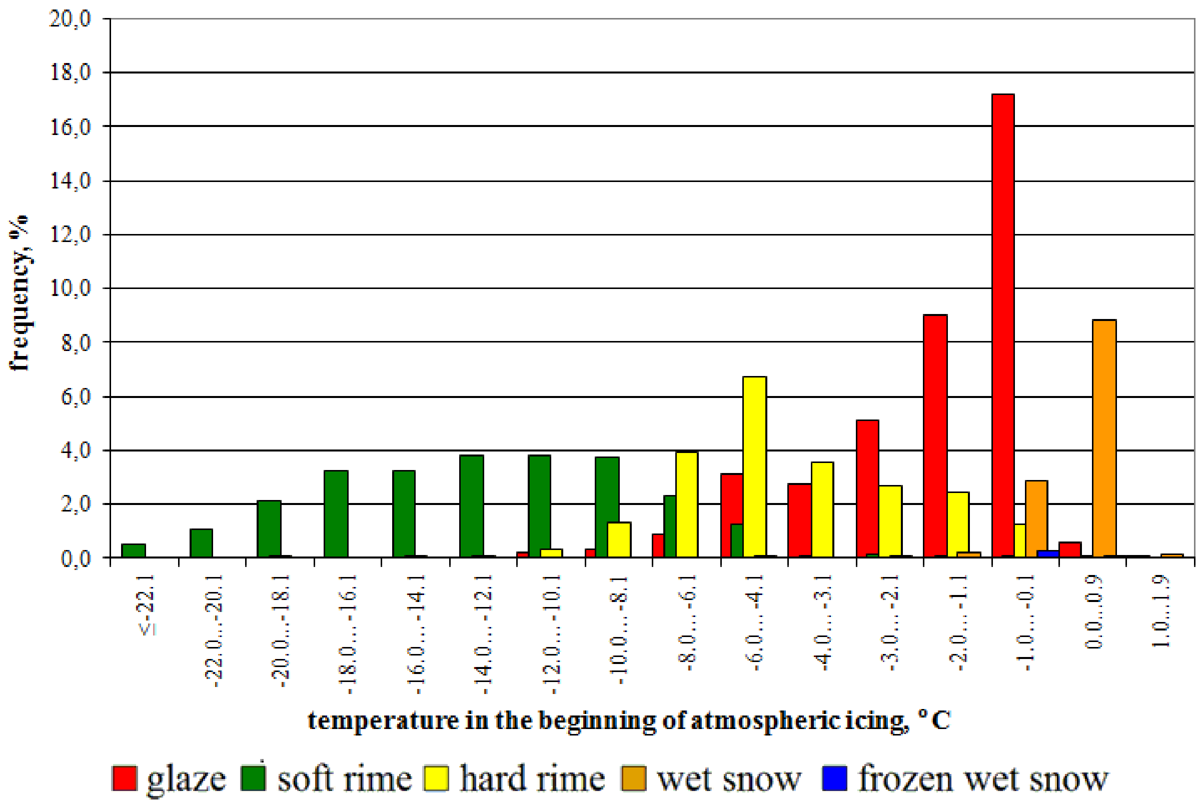

Figure 3. Frequency distribution of air temperature at the beginning of the atmospheric icing near the surface.

The most glaze events (about 86,8 %) are connected with the slightly negative temperature up to -4.0°C. In a half of these cases the slightly negative temperatures are observed from -1 to 0. This result is conformed to the recent results obtained for the glaze and freezing precipitation for Ukraine [3–5]. For the hard rime the more wide temperature interval is typical (-8…-1, 86,3 % of the cases). 34,7 % from these cases are associated with temperatures from -6 to -4.
The soft rime events are distributed almost evenly in the interval -20…-6, in which 87,3% of all the soft rime cases occur. 80,0% of the cases take place under -18…-8 temperature.
Approximately 90% of the wet snow cases are related with the -1.0…+1.0 °C interval.
The figure 4 shows the frequency distribution of the wind direction in the beginning of the event. The most number of hard and soft rime cases (24,0 and 43,4%) are reported under calm. It is very expectable result as usually these hydrometeors are related with low wind speed that confirms air-mass mechanism of rime generation. For the hard rime the remaining cases are distributed evenly in the other graduations. And for the soft rime the north-west and west direction with the highest frequency (20,0%) is selected.
For the glaze surface wind is characterized by high occurrence frequency of north, north-east, east, south-east and south directions. These five octants are associated with 70,9 % of the icing cases with maximum for north-east and south-east directions (56,5%). Such high frequency may be caused with cyclonic activity. Frequency of the glaze cases under the calm is significant (7,8%).
Wet snow is more often observed under north and north-west direction (13,8 and 17,5%, respectively), the remaining cases are distributed evenly by other directions.

Figure 4. Frequency distribution of wind direction at the beginning of the atmospheric icing near the surface.

3 CONCLUSIONS

Atmospheric icing in the Ukraine represents a rare event, whose monthly maximum averaged occurrence frequency does not exceed a few percent. Intensity of icing estimated by a site icing index varies from "occasional" to "moderate". In the most cases the duration and intensity of icing are determined by local terrain features. For example, the most northern sites and sites, which situated at the elevated terrain have maximum values of the index, and the most southern or seaside ones have minimum values of the index.
The density and type of ice strongly depend on the air temperature and wind. Therefore for all stations the frequency distribution of icing events as dependent on surface air temperature and wind are obtained. The most glaze events are connected with the slightly negative temperature up to -4.0^{o}C. For the hard and soft rime the more low temperatures are typical (-8…-1 ^{o}C and -18…-8^{o}C, respectively). And the wet snow formed during a very narrow surface air temperature interval (from -1 to +1 ^{o}C).
Glaze forms most frequently under east and south-east directions. The most number of hard and soft rime cases are reported under calm. Wet snow is more often observed under north and north-west direction, the remaining cases are distributed evenly by other directions.
These results can be used for a better understanding of the spatial and temporal evolution of icing events and developing of probabilistic forecast.

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