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I.A. Khomenko[1], assistant lecture, N.P. Chakina[2], prof.
[1]*Odessa State Environmental University, Odessa, Ukraine*
[2]*Hydrometeorological Center of Russia, Moscow, Russia*

FREEZING PRECIPITATION IN THE UKRAINE

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Introduction

Freezing precipitation (FP), which causes icing of the parked, taking-off or landing aircraft and subsequently produces glaze, represents one of the weather phenomena that is hazardous for aviation. Despite all the present-day anti-icing facilities, accidents caused by icing still happen. The largedrop FP caused several fatal accidents in the 1990's, which led to understanding that the existing means of the aircraft protection against icing should be improved. In particular, this implies improvement of the forecasting efficiency of icing on aircraft, both at the surface and airborne. For this purpose, in a number of countries and under the support of the World Meteorological Organization (WMO), studies have been carried out on weather conditions and climatic characteristics of freezing precipitation [1]. Studies and forecasting of icing phenomena are of interest for a number of fields of economic activity, including communications, power engineering, transportation and housing.

In this paper, conditions associated with FP at 8 Russian and 4 Ukrainian airports are studied. The study is based on surface observations in these airports along with radiosonde data. The results outline specific features of weather conditions, vertical stratification of the atmosphere and synoptic situations at these airports, under FP in different climatic and physical-geographic conditions.

Data

For fore airports of Odesa, Kyiv (Zhulyany), Lviv and Kharkiv, and also for five meteorological stations of Shepetivka, Dnipropetrovsk, Illichivsk, Krivyy Rih and Kolomak the surface observations for periods of 10 to 20 years are analyzed. The locations of these airports and stations are shown in Fig. 1.

The periods for which the data are available and the observation numbers for each station are shown in fig. 1. For the Kyiv, Odesa and Lviv airports the hourly data are available, and for other stations only 3-h observations are available during 1986–2001.

The cases of FP (including freezing rain, FR, freezing drizzle, FZ, and "FP during last hour") are selected from the surface observations. The radiosonde data for which FP is observed within 2-h vicinity of the launching time are also collected.

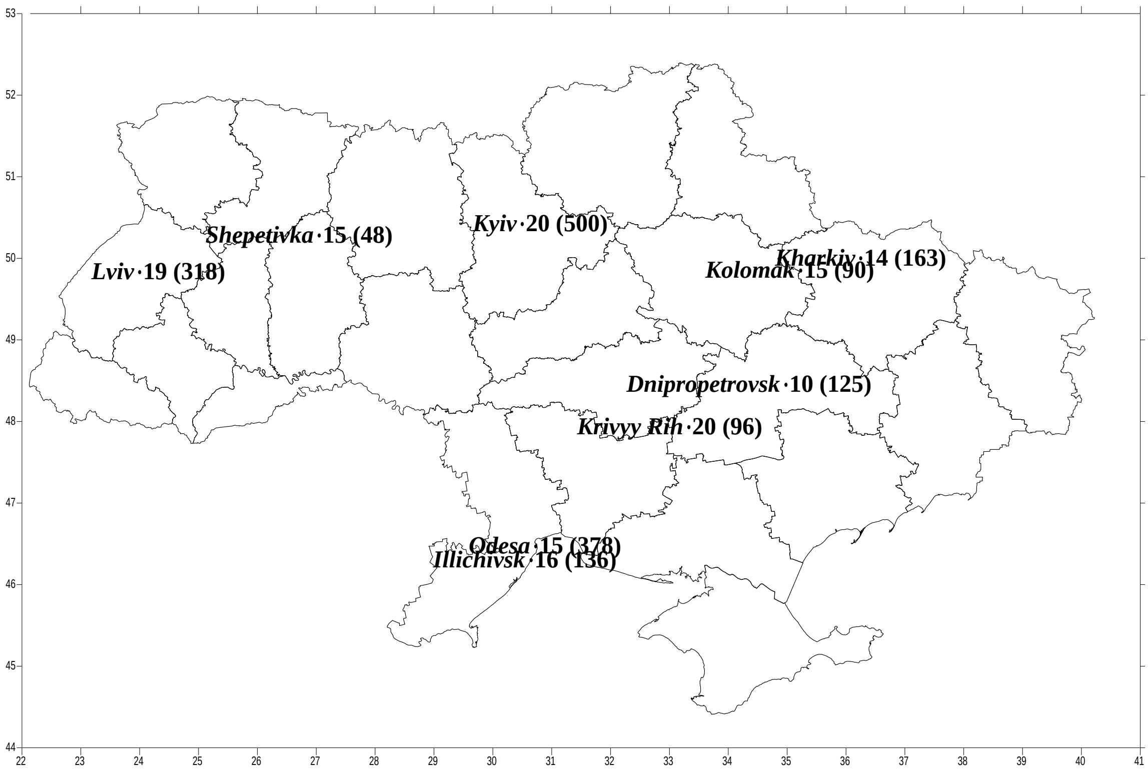

Fig. 1. – Locations of the airports and meteorological stations in Ukraine, for which the FP conditions are studied in the paper. The surface observation period (in years) is next to the station and number of the observation is in parenthesis.

Surface data

In the Ukraine the FP are observed from November to March with the exception of the Kyiv airport, where the FP may form also in October. The occurrence frequency of FP varies in a wide range: from 0.02 to 1.5 % and strongly depends on local circulations and climate conditions. A maximum monthly mean occurrence frequency corresponds to Kharkiv (1.5% in December). At the other stations FP monthly mean maxima 1.35 (Kyiv, December), 1.10% (Odesa, Illichivsk, January), 0.78 % (Lviv, December). For Kolomak and Dnipropetrovsk, the maximum monthly mean occurrence frequencies derived from the available data are about 1.0% (November to January) and 1.45% (December).

Both types of precipitation – freezing rain (FR) and freezing drizzle (FZ) – are geographically distributed: for Odesa, Illichivsk, Dnipripetrovsk a predominant type is the FR (56.6 and 59.4 % respectively), and for the other stations a predominant type is the FZ: from 66.7 (Shepetivka) to 85.0 % (Kyiv).

On the basis of the obtained results for the FP it may be supposed that maximum occurrence frequency of FR in the Odesa region was caused by two factors: by moist marine airmasses and by the Mediterranean storms. Weather in Dnipropetrovsk is also influenced by cyclonic activity, and therefore FR also frequently observed there. At the other sites the predominant type of FP is FZ that was induced by air-mass mechanism of FP formation.

The duration of the FP episodes, that is, the time period from the beginning to the end of the event, also varies largely: 55 to 83% of the episodes last less than 3 h at all airports.

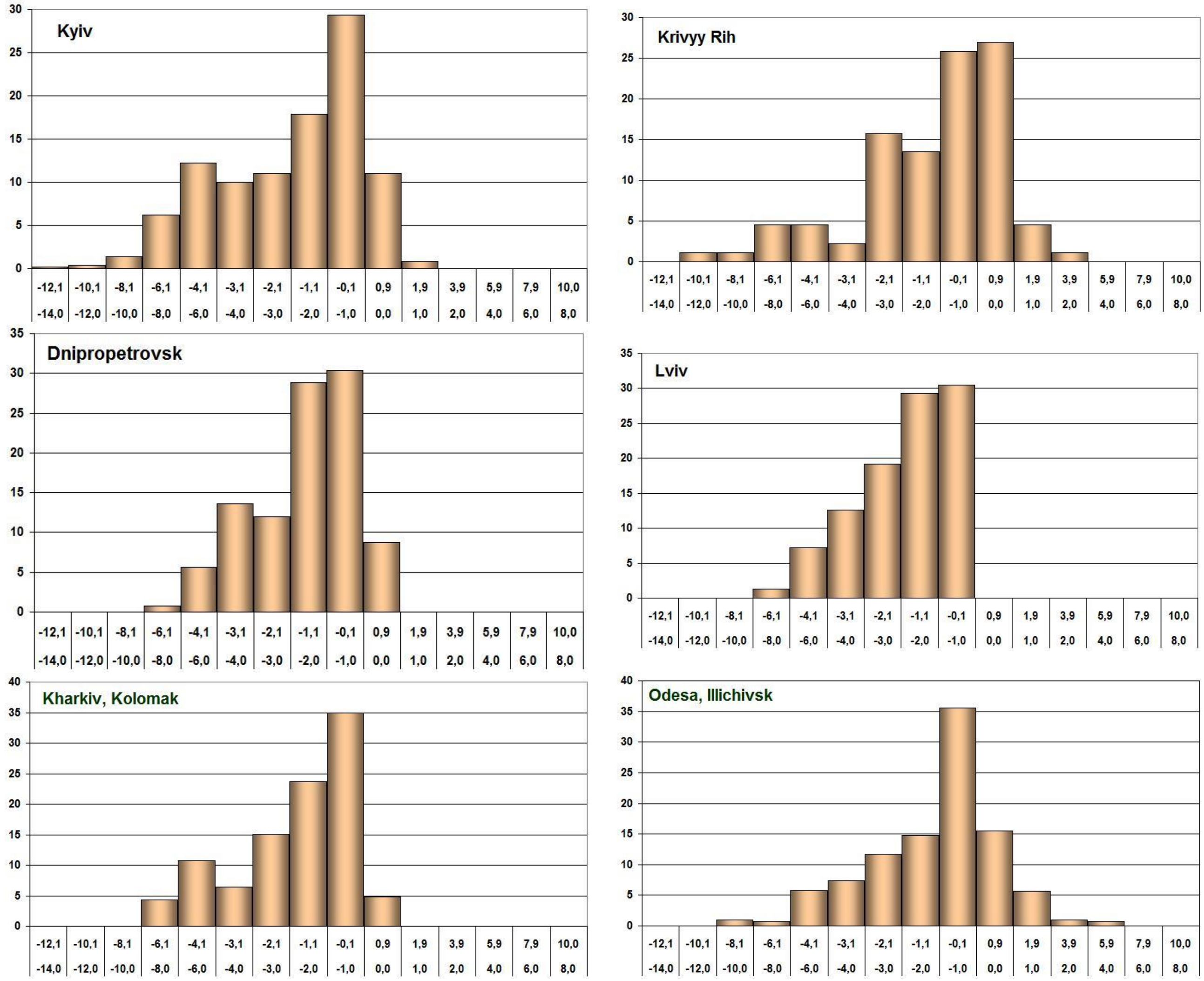

Fig. 2 – Frequency (%) of surface temperature (^{0}C) associated with FP. Vertical axis – case percentage (%). Horizontal axis – surface temperature (^{0}C). The FP cases for pairs of stations – Kharkiv–Kolomak and Odesa -Illichivsk – are analyzed together, as distances between the sites don't exceed 100 km.

The distributions of FP cases as dependent on surface air temperature, that is temperature at 2m above the surface, are shown in Fig. 2. Maximum number of the FP cases is observed under temperatures −2.0 to 0^{0}C. At all sites, FP is not observed below −14^{0}C. Everywhere, a certain, low number of the cases is observed under positive temperatures below 6^{0}C.

The measured cloud base height (ceiling) is usually below 300m and is, on average, higher in the cases of FR than of FZ. The distributions of wind direction at the airports reflect local features of circulation in the lower layers. As a result, the differences between different sites are large (Table 1).

The winds from N, NE, E dominate in Odessa. In Dnipropetrovsk the winds with eastern component (NE, E, SE) prevail. In the central Ukraine (Kiev), the wind direction distribution is more homogeneous, because the contribution of the east winds, typical for the southern Ukraine, decreases, while westerly flows become more frequent.

Distributions of wind speeds are homogeneous enough: FP occurs under surface wind speeds below 7 m/s, in about 90% of the cases.

Table 1. Distributions of FP cases as a function of surface wind directions: number of cases and % in parenthesis are given.

	Kyiv	Odesa Illichivsk	Lviv	Kharkiv Kolomak	Dnipropetrovsk
N	19 (3.8)	141 (29.3)	23 (7.2)	1 (0.5)	4 (3.2)
NE	53 (10.6)	164 (34.0)	3 (0.9)	13 (7.0)	13 (10.4)
E	102 (20.4)	84 (17.5)	11 (3.4)	40 (21.5)	38 (30.4)
SE	77 (15.4)	7 (1.5)	80 (25.1)	54 (29.0)	30 (24.0)
S	61 (12.2)	7 (1.5)	7 (2.2)	23 (12.4)	3 (2.4)
SW	37 (7.4)	6 (1.2)	10 (3.1)	20 (10.8)	11 (8.8)
W	69 (13.8)	22 (4.6)	106 (33.3)	18 (10.0)	6 (4.8)
NW	46 (9.2)	48 (10.0)	63 (19.8)	5 (2.7)	4 (3.2)
Calm	36 (7.2)	2 (0.4)	15 (47.2)	12 (6.4)	16 (12.8)
Total	500	481	318	186	125

Radiosonde data

The radiosonde data are used to study the stratification of temperature and wind for the FP occurrence. The main purpose of the analysis is to reveal warm layers in the clouds, below and above them (stratification of "warm nose" type), and thus determine conditions in which the so called classical mechanism of FP formation can act. The classical mechanism suggests that the snow and ice particles, which precipitate from the cold upper part of the cloud, melt in the warm layer (inside or below the cloud) and then, in a form of droplets, fall into the lower cold layer, become supercooled droplets and finally freeze up at the surface.

The cloud top is estimated from the temperature and humidity profiles, as the level at which relative humidity decreases down to 95 or 90%. In the cases where these threshold values are not reached, statistical criteria are applied [2,3,4]. The soundings associated with FP are classified with respect to warm layer positions (Table 3).

Table 1. – Classification of radiosonde derived temperature profiles in the cases of FP: number of cases and corresponding % (in parentheses) are given for each class

Class of temperature profile	Kyiv	Odesa
Warm nose	16 (23.2)	6 (26.1)
Warm top of the cloud	3 (4.3)	2 (8.7)
Warm layer above the cloud	6 (8.7)	3 (13.1)
Warm surface layer	7 (10.1)	5 (21.7)
Warm cloud	–	1 (4.4)
All cold	37 (53.7)	6 (26.0)
Total	69	23

It is found that the warm layers, in or below the clouds, are not frequent (23% of the cases in Kyiv and 26% – in Odessa). On the contrary, stratification of “all cold” type dominates. That is, FP from cold clouds is typical for Ukraine. Almost all (90 to 100%) soundings under FP reveal the temperature inversion layers within the lower 3 km.

Conclusions

1. Freezing precipitation in the Ukraine represents a rare event, whose monthly maximum averaged occurrence frequency does not exceed a few percent.

2. The low clouds, which produce FP, are mainly cold. The classical stratification of “warm nose” type, with warm layer within the cloud, occurs, on average, in about 24% of FP cases, while “all cold” stratification – in about 40% of the cases. This result is important from a practical point of view. The existing schemes for FP forecasting are based on revealing the warm layers in or below the lower clouds [5,6,7]. It is evident now that this notion cannot be efficient in the situations typical for the Ukraine. Other approaches, in particular, probabilistic ones should be found. Investigations of FP conditions, using all of the available data, can provide useful indications for detection of areas with increased probability of FP.

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