Analysis of spatial and temporal distribution of freezing rain events in Romania and Germany

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Abstract—**In order to perform the analysis of the spatial and temporal distribution of freezing rain and freezing drizzle, we have selected a number of 49 and 74 meteorological stations evenly distributed over the territory of Romania and Germany, respectively. 9 (5) of these stations are situated at altitudes higher than 1000 m and 37 (54) of them are situated at altitudes lower than 500 m in Romania (Germany).**

The study was made for 6 months (January, February, March, October, November and December) for the 1980-1999 period for the stations in Romania. It was carried out for all month of the year in the same analysis period (1980-1999) for the stations in Germany.

The analyzed meteorological data are the occurrence frequencies of freezing rain and freezing drizzle in the SYNOP messages. For each month under consideration and for each type of phenomenon (freezing rain and drizzle) the occurrence frequencies were computed as the ratio of the number of SYNOP messages, including the respective type of phenomenon for the particular month, by the total number of SYNOP messages for the month.

The general features of the spatial and temporal distribution of freezing rain and drizzle are strongly influenced by the topographical position of the meteorological station.

I. Introduction

THROUGH their presence and development, some meteorological phenomena can represent risk factors for the human life and activities. During the cold season freezing precipitation events constitute such a risk phenomenon. Freezing precipitation may have multiple economical implications. It can affect the safety and the fluidity of the road and air transportation; some exposed localities can be isolated until the phenomenon ends. It may damage power lines, affecting both the human comfort and economical activities. It can damage renewable energy systems (wind turbines or solar panels) or decrease their efficiency. It may have an impact on the functionability of scientific equipment (meteorological, astronomical, etc).

According to [1] freezing precipitation is a cloud physics process which primarily depends on in-cloud temperature. However, this paper was developed from the point of view of classical climatology, using the analysis of the rain and drizzle cases which lead to the formation of the glaze on the ground.

The International Meteorological Vocabulary of the World Meteorological Organization (WMO, 1992), which applies to the SYNOP reports used in this study, defines freezing precipitation as

- precipitation drops freezing on impact to form a coating of clear ice (glaze) on the ground and on exposed objects,
- a coating of ice, generally clear and smooth but usually containing some air pockets, formed on exposed objects by freezing of a film of super-cooled water deposited by rain, drizzle, fog, or possibly condensed from super-cooled water vapour.

Glaze, which is formed by freezing precipitation, is denser, harder and more transparent, than either rime or hoarfrost that are formed by other icing processes.

Following [2], two mechanisms can be considered for freezing rain and drizzle drops:

- Super-cooled rain and drizzle drops can form from the 'ice process', originating from ice or snow crystals melting when they fall through a layer of positive temperature (often called as 'warm nose' in the TEMP), and then fall through a sub-freezing layer near the surface. The characteristics of the thermodynamic sounding for the occurrence of the ice process must include an ice phase at the top, a layer at positive temperature beneath the ice cloud and a layer with negative temperature near the ground [3]. These features are often found in association with a warm front.
- Super-cooled drizzle drops can form from the 'coalescence process'. The drops then originate directly from liquid cloud drop coalescence and diffusional growth in super-cooled clouds, with accelerating factors such as vertical wind shear in the cloud or near the top, the presence of microscopic salt particles (near sea shores) or an upslope motion. The characteristics of the thermodynamic sounding for the occurrence of the coalescence process often include a cloud top temperature higher than about –15 °C (otherwise, low temperatures favour the apparition of the ice phase) and a surface temperature below 0°C. Without accelerating mechanisms, the coalescence process is much slower (in the order of one hour).

A necessary condition for the accretion of the ground glaze are surface temperatures slightly below or around 0°C (see [1]). Freezing precipitation events may occur at temperatures between 0°C and 5°C, too ([1]). In general they are observed the more seldom the higher the air temperatures are. They unlikely occur at air temperatures below -5 °C (see [1]).

Wet bulb temperature can be used to identify meteorological conditions for freezing precipitation (see [4], [5]). If the wet bulb temperature is at or below 0°C, the heat balance at the surface of rain or drizzle drops is negative – a necessary pre-condition for freezing at structures and the ground surface.

In the methodology which guides the activity of the national meteorological network of Romania the freezing precipitation is considered a phenomenon of major risk and everytime it occurs meteorological stations have to transmit warning messages of different sternness degrees according to the severity of the event.

From the methodological perspective at the manned meteorological stations in Romania the deposition of the glaze is observed on the ground and measured on a special designed device any time the meteorological phenomenon occurs, for the whole period it persists, in order to determine the following meteorological parameters: the type of ice deposit, the minimum and maximum diameter, the time (hour and minute) of the beginning and the end of ice accretion.

In Germany, the deposition of glaze was observed and measured at up to 35 stations in the east part of Germany during 1965-1990 [6]. At these stations the icing mass was determined and additional information (e.g. icing diameter and direction, ice vane dimension, icing type(s)) was compiled by the observer. Since 1991 the number of locations with direct icing measurements has been reduced to a total of six (see [6]). Ice load sensors are implemented at these six stations. They measure the weight of the ice accumulated on a vertical pole by the use of an electro-mechanical scale system.

At automatic meteorological stations in Romania and Germany the presence of the glaze formed by the freezing precipitation is detected using the Present Weather Detector PDW 12 and respectively the Present Weather Sensor PWS.

II. DATA

In this paper the analysis of the freezing precipitation events was not based on the warning messages or direct measurements of ice amounts at weather stations that are equipped with special instruments.

The goal of the study is to analyse both the spatial and the temporal distribution of freezing rain events in Romania and Germany from the point of view of classical climatology. That means, the frequencies of occurrence of freezing rain events are analysed in order to get a general picture of their spatial and temporal distribution, without analysing single events and their results (for instance ice loads).

Therefore, the study was elaborated using the hourly ground SYNOP messages as primary data in order to accomplish an accurate description of the phenomenon in time and space from (nearly) homogeneous data sets. However, using the SYNOP database for the analysis of freezing precipitation can introduce a disadvantage in comparison with the climatological database, which often includes more precise information like the exact time of the beginning / end of the icing event.

The convention regarding the hourly ground SYNOP messages used for the elaboration of this paper was the selection of those SYNOP messages (ww-codes from table 4677) which report freezing precipitation events.

For analysis of freezing precipitation in Romania the following codes were used[1]:

- freezing rain (ww= 66, 67) and
- freezing drizzle phenomena (ww =56, 57).

Observations with code ww=24 (freezing rain or drizzle) for the precipitation of the preceding hour were not included in the data analysis for Romania.

For analysis of freezing precipitation in Germany the following codes were used[1]:

- freezing rain or drizzle during the preceding hour before observation (ww=24),
- freezing rain (ww= 66, 67),
- freezing drizzle phenomena (ww =56, 57),
- ice spheres (ww=79).

In addition to those SYNOP messages which report freezing precipitation events directly, the following codes were used for analysis of freezing precipitation in Germany, if wet bulb temperature was lower or equal 0°C (see [4], [5]):

- drizzle of various intensity, with or without breaks during the observation interval (ww=50-55),
- drizzle of various intensity, mixed with rain (ww=58, 59)
- rain of various intensity, with or without breaks during the observation interval (ww=60-65).

The meteorological data used in order to elaborate this paper are from the 1980-1999 period. Data for six months (January, February, March, October, November and December) were examined for the stations in Romania. It was carried out for all month of the year for the stations in Germany.

For a detailed analysis using hourly SYNOP messages it was necessary to select those meteorological stations that fulfil the following criteria:

- during the period of 20 years from 1980 to 1999 the stations provided continuously SYNOP messages with information about the state of the weather (ww-codes from table 4677) which report freezing precipitation,
- the stations are representative from the point of view of the geographic position and
- the final number of stations and their spatial distribution allow a correct evaluation of the freezing precipitation characteristic over the two countries.

[1] Unfortunately, different criteria have been used for the analysis of freezing precipitation events in Romania and Germany. The reason for the inconsistency is that examinations had different specific goals and were carried out independently by working groups in both Meteorological Services. The results were discussed under the umbrella of COST Action 727 and are presented in this combined paper.

Fulfilling these criteria, 49 stations in Romania and 74 stations in Germany were selected for the evaluation of freezing precipitation. 9 (5) of these stations are situated at altitudes higher than 1000 m and 37 (54) of them are situated at altitudes lower than 500 m in Romania (Germany). The locations of the selected 49 stations in Romania and of the 74 stations in Germany are plotted in Figure 1 to Figure 5 and in Figure 6, respectively. The longitude, the latitude as well as the altitude of the 74 stations in Germany are given in Table 1.

For each month under consideration and for each type of phenomenon (freezing rain and drizzle) the occurrence frequencies were computed as the ratio of the number of SYNOP messages, including the respective type of phenomenon for the particular month, by the total number of SYNOP messages for the month during the period 1980-1999.

The processed data regarding the frequency of occurrence of freezing precipitation events were represented graphically on monthly maps (January, February, March, October, November and December) for Romania using a Geographical Information System (gstat R package, Arc Map 9.2). The results of yearly frequencies of occurrence of freezing precipitation events were plotted using a GIS (ESRI®, Arc Map 9.2®).

III. Spatial and Temporal Distribution of Freezing Rain Events in Romania and in Germany

A. Romania

As a first finding, from the analysis of the Romanian maps, it can be said that the figure (range) of the frequency is very small, leading to the idea that the conditions for the occurrence of this phenomenon are quite difficult to fulfil and mostly depend on local factors.

The order of measure for all these 6 months stretches from $0.69*10^{-4}$ (the lowest value in November) to $91.40*10^{-4}$ (the highest value in January).

In October the freezing precipitation occurrence is scarcely distributed in the analysed period, 1980-1999, over Romania's territory. The values of the air temperature are not low enough in order to produce the cooling of the falling drops and the surface soil temperature is not in the close vicinity of 0°C, but higher. However, the mountain stations with altitudes over 1500 m located in the Western and Southern Carpathians present favourable conditions for the formation of freezing precipitation: Balea Lac (2055 m) $2.65*10^{-4}$, Ceahlau Toaca (1897 m) $2.02*10^{-4}$, Sinaia 1500 (1510 m) $1.34*10^{-4}$, Tarcu (2180 m) $5.38*10^{-4}$, Vladeasa 1800 (1836 m) $6.05*10^{-4}$, Varfu Omu (2504 m) $6.05*10^{-4}$.

The following autumn month is characterized by lower air and surface soil temperature, but conditions for the formation of glaze are not evenly distributed over the territory of Romania. The extra-Carpathian region with a cooler regime due to the air masses circulation from the North is propitious for freezing precipitation, unlike the inner Carpathian region where the mountain chain acts like a barrier for the cold air diminishing the opportunity occurrence of the studied phenomenon. Thus, as shown in Figure 1 in the southern and eastern regions, the frequency is higher compared to the rest of the territory. The frequency values distributed in the interval $[30.1*10^{-4} - 40.0*10^{-4}]$ represents 22.4% from the total cases and occurred only in the southern and eastern part of the country. Also, the highest frequency values of November $[50.1*10^{-4} – 60.0*10^{-4}]$ are characteristic only to those regions.

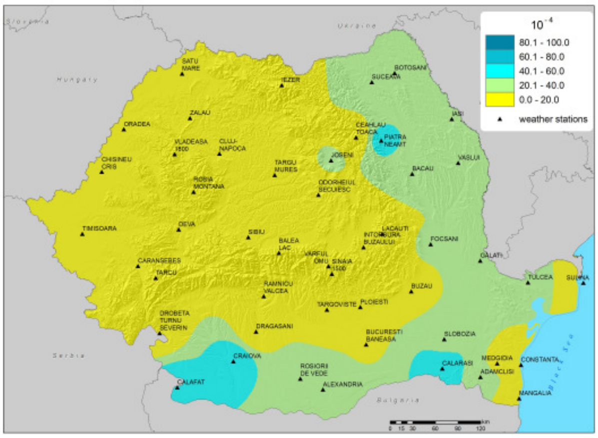

Figure 1. Spatial distribution of relative frequency of freezing precipitation events in Romania for November during observation period 1980-1999

In Romania, December is the first winter month and one of its characteristics is the decrease of the number of days with liquid precipitation, an important factor for the formation of the analysed phenomenon. Especially in the mountain region, Figure 2, the air and ground temperature go below the favouring values for the occurrence of freezing rain and drizzle. In some southern and south-eastern parts of the country the favourable conditions enhanced. The lower temperatures of December allow the formation of freezing precipitation in the intra-Carpathian region.

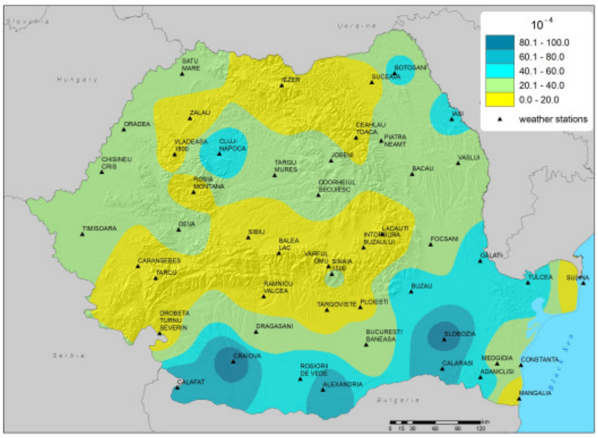

Figure 2. Spatial distribution of relative frequency of freezing precipitation events in Romania for December during observation period 1980-1999

In January, the freezing precipitation is present with different persistence at the majority of the analysed stations, with five exceptions (Figure 3): Four mountain stations and Intorsura Buzaului station with an altitude over 700 m, located in the vicinity of Lacauti mountain station (1776 m) which showed the particularity of a total lack of freezing precipitation during all the six analysed months. January is the only month which has frequency values distributed in all the intervals, from [$0.0*10^{-4}$–$10.0*10^{-4}$] to [$90.1*10^{-4}$–$100.0*10^{-4}$].

In February, Figure 4, the frequency values of the most of the cases is concentrated in the interval [$0.0*10^{-4}$ – $20.0*10^{-4}$] with a cumulated percentage of 73.5%. The stations with no freezing rain event are the same as in January. The phenomenon's intensity becomes weaker than in December and January, the highest frequency values belonging to the interval [$40.1*10^{-4}$-$50.0*10^{-4}$] with a distribution of 2.0%.

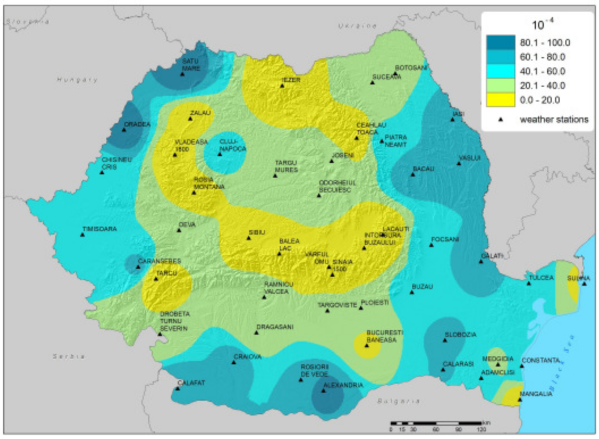

Figure 3. Spatial distribution of relative frequency of freezing precipitation events in Romania for January during observation period 1980-1999

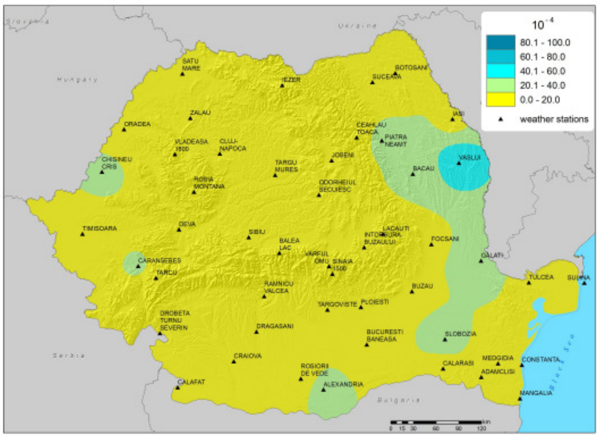

Figure 4. Spatial distribution of relative frequency of freezing precipitation events in Romania for February during observation period 1980-1999

In March, Figure 5, 65.31% of the analysed stations have frequency values different from 0.0 compared to 12.24% of the stations from October. The most representative region in this month is the eastern part of the country (except Dobrudja) with 70% of the frequency values distributed in the interval [10.1*10-4 – 20.0*10-4]. In the intra-Carpathian region only one station, Cluj Napoca, has a frequency value different from 0.0.

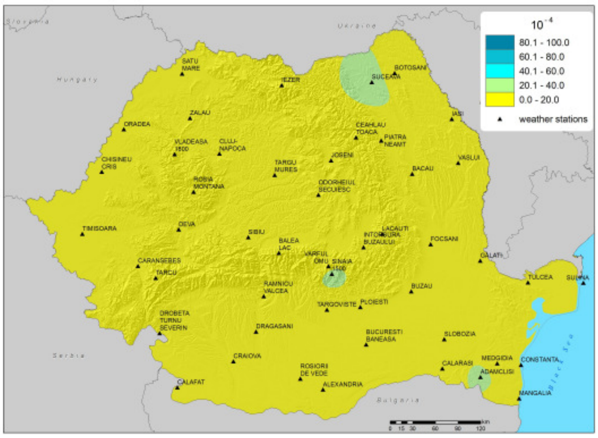

Figure 5. Spatial distribution of relative frequency of freezing precipitation events in Romania for March during observation period 1980-1999

B. Germany

The results of analysis of frequencies of freezing precipitation events for 74 stations in Germany are presented in Figure 6. Frequencies of occurrence of freezing precipitation events vary between 3 ‰ in lowlands and 16 ‰ in mountainous regions of Germany.

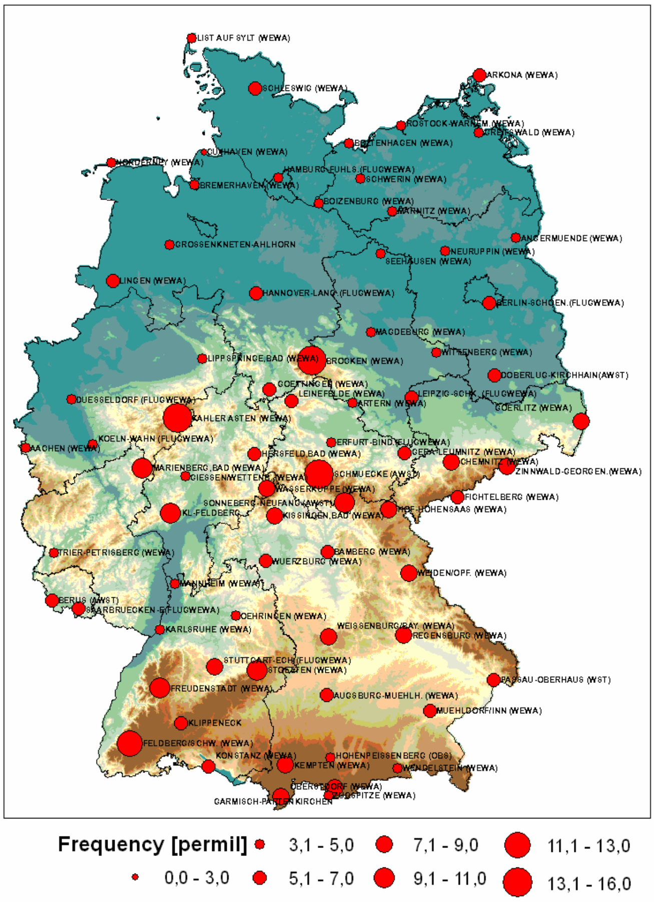

Figure 6. Spatial distribution of yearly relative frequency of freezing precipitation events in Germany during the observation period 1980-1999. Background colour varies with altitude from blue (lowlands) to brown (mountainous areas).

Figure 6 shows that freezing precipitation events most often occur in mountainous regions of Germany with altitudes between about 500 m and 1500 m above sea level, having frequencies higher than 8 ‰. In lowland regions, mainly in the northern part of Germany, freezing rain and freezing drizzle events occur more seldom, with frequencies between 3 ‰ and 8 ‰. In high altitude areas as in the Alps, mainly at exposed locations, the frequency of freezing precipitation decreases remarkable, as analysed for stations Hohenpeißenberg, Wendelstein and Zugspitze, for instance.

The absolute number of freezing precipitation events for every month of a year for 74 stations in Germany are summarised in Table 1.

Table 1: Absolute number of monthly freezing precipitation events in Germany during observation period 1980-1999. Months with maximum numbers of freezing rain events are highlighted in green. Stations with altitudes higher than 700 m and 1800 m are highlighted in grey and orange, respectively. Stations that have been used to analyse the dependency of freezing precipitation on air temperature are highlighted in light blue.

				Month											
Station	Lat [°]	Long [°]	Alt [m]	1	2	3	4	5	6	7	8	9	10	11	12
Aachen	50.8	6.1	202	229	227	21	5	0	0	0	0	0	4	96	115
Angermünde	53.0	14.0	54	174	139	76	12	4	0	1	0	0	9	63	252
Arkona	54.7	13.4	42	243	160	131	53	0	0	0	0	0	3	64	155
Artern	51.4	11.3	164	187	115	53	26	0	1	0	1	0	2	122	238
Augsburg	48.4	10.9	462	202	143	75	63	4	1	1	1	0	19	129	249
Bamberg	49.9	10.9	239	150	93	41	20	0	0	0	0	0	0	54	132
Berlin_Schönefeld	52.4	13.5	45	213	198	70	32	0	0	0	0	0	7	143	319
Berus	49.3	6.7	363	169	117	46	41	3	1	0	0	1	1	22	165
Boizenburg	53.4	10.7	45	73	68	43	6	0	0	0	0	0	0	27	143
Boltenhagen	54.0	11.2	15	136	64	77	30	0	1	0	1	0	0	39	166
Bremerhaven	53.5	8.6	7	144	122	98	24	1	0	0	0	0	2	58	233
Brocken	51.8	10.6	1142	455	329	312	189	106	33	0	2	4	148	379	499
Chemnitz	50.8	12.9	418	329	208	91	84	10	0	0	1	0	15	200	305
Cuxhaven	53.9	8.7	5	108	86	74	16	4	1	1	0	0	1	33	177
Doberlug_Kirchhain	51.7	13.6	97	76	92	43	15	0	1	0	0	0	1	44	120
Düsseldorf	51.3	6.8	37	171	109	84	33	0	1	0	0	0	0	98	163
Erfurt	51.0	11.0	316	169	108	51	41	1	0	0	0	0	5	171	178
Feldberg	47.9	8.0	1486	313	208	272	183	158	80	4	1	61	157	179	325
Fichtelberg	50.4	13.0	1213	161	115	88	117	53	14	1	1	4	89	187	200
Freudenstadt	48.5	8.4	796.5	190	156	162	104	21	0	0	0	0	57	110	226
Garmisch-Patenkirchen	47.5	11.1	708	146	70	134	145	36	2	0	0	1	14	88	127
Gera	50.9	12.1	311	261	187	99	56	14	0	0	0	0	11	163	170
Giessen	50.6	8.7	186	218	137	100	38	0	0	1	0	0	0	70	248
Görlitz	51.2	15.0	238	311	184	81	70	0	0	2	0	2	7	181	309
Göttingen	51.5	10.0	167	143	92	86	35	0	0	0	0	0	4	62	130
Greifswald	54.1	13.4	2	196	157	41	16	1	0	0	0	1	4	93	224
Großenkneten	52.9	8.2	42	41	26	16	2	1	0	0	0	0	1	6	58
Hamburg	53.6	10.0	11	212	145	100	25	0	1	0	0	0	2	60	270
Hannover	52.5	9.7	55	204	190	126	32	0	0	0	0	0	3	121	356
Hersfeld	50.9	9.7	272.2	158	111	80	31	0	0	0	0	0	0	66	141
Hof	50.3	11.9	567	299	241	134	122	13	0	0	0	0	16	198	390
Hohenpeißenberg	47.8	11.0	977	116	111	103	105	39	3	1	0	0	64	87	136
Kahler_Asten	51.2	8.5	839	488	307	294	186	55	0	0	0	2	74	307	569
Karlsruhe	49.0	8.4	111.6	168	94	28	10	0	0	1	0	0	2	61	99
Kempten	47.7	10.3	705	215	122	138	139	35	0	0	0	1	10	114	178
Kissingen	50.2	10.1	282	251	147	90	35	0	0	0	0	0	4	99	216
Kl.-Feldberg	50.2	8.5	826	287	183	172	88	22	0	1	0	0	30	167	307
Klippeneck	48.1	8.8	980	107	126	90	75	15	0	0	0	0	39	92	121
Köln	50.9	7.2	92	214	108	85	45	0	1	0	0	0	2	109	237
Konstanz	47.7	9.2	442.5	245	178	140	139	1	1	0	0	2	9	125	184
Leinefeld	51.4	10.3	356	155	100	71	50	8	0	0	1	0	2	96	216
Leipzig	51.4	12.2	131	258	130	72	41	5	0	0	1	0	5	137	236
Lingen	52.5	7.3	22	149	128	53	22	0	0	1	0	0	0	50	220
Lippspringe	51.8	8.8	157	142	116	72	28	0	0	0	1	0	0	63	132
List	55.0	8.4	26	158	169	129	26	2	0	0	0	0	0	48	153
Magdeburg	52.1	11.6	76	148	123	56	22	0	0	0	1	1	1	88	220
Mannheim	49.5	8.6	96.1	180	110	42	21	0	0	0	1	0	0	61	147
Marienberg	50.7	8.0	547	292	174	117	57	13	0	0	0	0	6	133	329
Marnitz	53.3	11.9	81	38	28	22	6	0	0	0	0	0	1	14	76
Mühldorf	48.3	12.5	405	136	82	50	50	0	0	0	0	1	6	78	175
Neuruppin	52.9	12.8	38	181	124	44	17	0	0	0	1	0	5	73	213
Norderney	53.7	7.2	11	147	92	68	12	1	0	0	0	0	0	46	163
Oberstdorf	47.4	10.3	806	157	120	150	124	70	2	0	0	1	43	80	91
Öhringen	49.2	9.5	275.9	218	97	64	32	0	0	0	0	1	1	62	136
Passau	48.6	13.5	409	246	129	70	58	8	0	1	0	0	4	99	295
Regensburg	49.0	12.1	366	450	187	87	52	2	0	0	0	0	8	144	532
Rostock	54.2	12.1	4	159	116	106	33	0	0	1	1	1	3	54	182
Saarbrücken	49.2	7.1	320	294	194	118	66	7	2	0	0	0	0	57	269
Schleswig	54.5	9.6	43	219	231	166	53	0	1	0	0	0	2	61	275
Schmücke	50.7	10.8	937	382	301	251	128	62	3	2	0	8	87	320	513
Schwerin	53.6	11.4	59	169	84	62	18	0	0	0	0	0	0	48	215
Seehausen	52.9	11.7	21	178	122	47	19	0	2	0	0	0	0	57	199
Sonneberg	50.4	11.2	626	32	9	7	10	2	0	0	0	0	1	7	24
Stotten	48.7	9.9	734	316	229	219	138	30	0	2	0	0	59	302	469
Stuttgart	48.7	9.2	371	305	197	134	111	5	0	0	0	0	19	133	315
Trier	49.8	6.7	265	240	166	66	40	1	0	1	0	0	1	69	230
Wasserkuppe	50.5	9.9	921	380	244	200	135	41	3	0	0	2	84	213	418
Weiden	49.7	12.2	439.6	318	216	111	75	8	0	0	0	0	10	145	381
Weissenburg	49.0	11.0	422	291	139	79	86	8	0	0	0	0	10	140	274
Wendelstein	47.7	12.0	1832	20	19	70	57	76	73	29	15	58	64	67	39
Wittenberg	51.9	12.7	105	217	150	75	37	1	0	0	1	0	2	83	200
Würzburg	49.8	10.0	268	326	147	80	43	0	0	0	0	0	0	117	233
Zinnwald	50.7	13.8	877	102	79	72	55	24	1	0	0	0	31	135	132
Zugspitze	47.4	11.0	2960	0	0	8	0	30	196	177	169	147	44	16	1

Table 1 shows in general that freezing precipitation may occur throughout the whole year, depending on the topographic location of the site under consideration. As expected, most freezing precipitation events occur during the winter season in months December and January. Freezing rain and freezing drizzle episodes may be observed during months from October until April at most locations in Germany. At places in higher altitudes they are likely to occur in months May and September, too. At exposed locations higher than about 700 m above sea level freezing precipitation events may occur throughout the whole year.

Finally, Table 1 shows that at very high altitudes most of the freezing rain and freezing drizzle episodes take place in months from May until August. The reason for this result is that the meteorological conditions (air temperature, wet bulb temperature) at these locations are appropriate for freezing precipitation only during those months. Temperatures are often lower than -5°C during other times of the year. Therefore they are too small to allow freezing precipitation during other months of the year at those locations.

IV. Supplementary Examination of Freezing Precipitation in Romania and Germany

A. *Case Study for Romania: Dobrudja*

A closer look at the frequency values from January, February and March reveal a certain particularity of the stations located in Dobrudja and the Black Sea shore (Mangalia, Tulcea, Sulina, Adamclisi, Medgidia and Constanta), detailed in Figure 7: During this interval the first three stations present constantly decreasing values of the freezing rain frequency; unlike the first group, in the case of the last three stations the March values of the frequency show an increase of the phenomenon's occurrence compared to February. In order to analyse this situation, monthly values of the air and surface soil temperature, the relative humidity, the number of days with liquid / solid precipitation, rain and drizzle were processed for the analysed period 1980-1999 and the trends of the data rows were computed using the least square method.

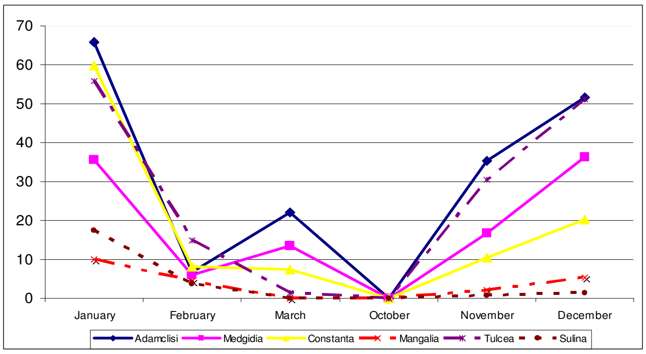

Figure 7. Frequencies of the SYNOP messages at the stations located in Dobrudja and the Black Sea shore during the 1980-1999 period

The decreasing frequency in February is an expected behavior because February is a winter month with air temperatures most of the time below -5°C and the number of days with solid precipitation is higher than the liquid ones. At the same time, during the winter, the air circulation is from land toward the sea, due to the colder temperature of the land compared to the sea. This kind of circulation does not favour precipitation occurrence.

Also, in the case of Adamclisi station, in February the temperature trend (over the 1980-1999 period) shows an increase by 3.8°C and both the trend of relative humidity and the number of days with liquid precipitation present a decreasing trend. Similar trend behaviour of these meteorological parameters was found for the Medgidia station. Unlike these two stations, in the case of Constanta the number of days with liquid precipitation is increasing. However, during these 20 years, the favouring conditions for the occurrence of the freezing precipitation show some changes leading to a decrease of the occurrence frequency.

B. Analysis of the rain and drizzle percentages from the total number of hourly SYNOP messages including freezing precipitation for Romania

Mountain stations

From the point of view of the percent values of the number of the SYNOP messages including freezing precipitation in January, February, March and December (Figure 8, Figure 10), it can be concluded that the values are quite similar. The main differences regarding the distribution of the values are found in October and November.

In the second autumn month, the most frequent precipitation type which leads to the glaze formation is rain. In November the situation is reversed, as drizzle becomes the main type of freezing precipitation.

If the study is focused on the prevalent type of precipitation during the 20-year period at the mountain stations in these six selected months at each station, results show that in case of four stations it is possible to establish a major type:

- drizzle for Balea Lac, Sinaia 1500 and Iezer (with 100% drizzle) and
- rain for Vladeasa 1800.

Moldavia region

For Moldavia region there were chosen the following stations: Botosani, Suceava, Iasi, Piatra Neamt, Bacau, Vaslui, Focsani and Galati.

Analysing the percentage values for October and November, it is possible to establish that the prevalent type of precipitation for the whole region is drizzle. During December the highest values of the occurrence frequencies show that rain becomes the main factor of the glaze formation for the entire region, except for Iasi and Botosani stations (30.2% and respectively 31.7% of rain). In January, February and March drizzle is the predominant type of precipitation. However, as an exception, in January at Iasi station 52.8% are represented by rain and at Galati station 50.0%.

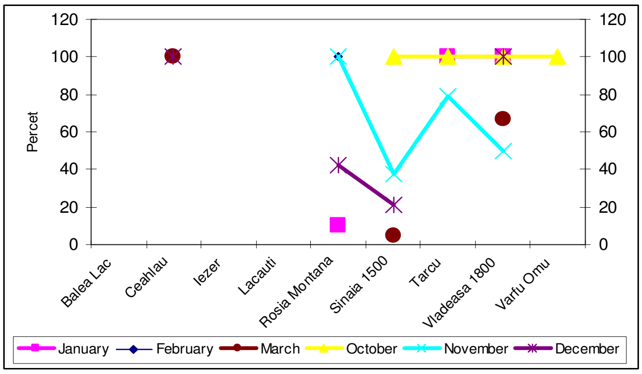

Figure 8. Rain percentages at the mountain stations from the total SYNOP messages, including freezing precipitation, during the 1980-1999 period

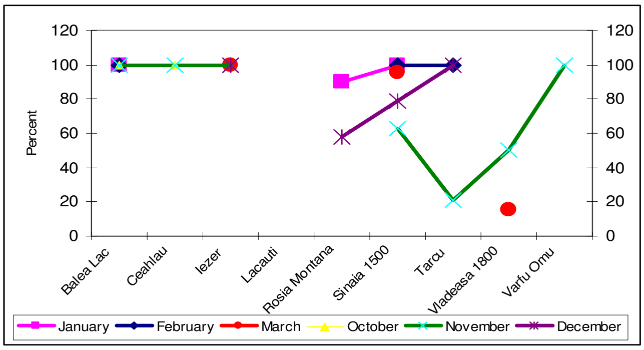

Figure 9. Drizzle percentages at the mountain stations from the total SYNOP messages, including freezing precipitation, during the 1980-1999 period

The inner part of the Carpathians

The inner part of the Carpathians is represented by: Satu Mare, Zalau, Cluj, Targu Mures, Odorheiul Secuiesc, Joseni, Intorsura Buzaului, Sibiu, Deva, Oradea, Chisineu Cris, Timisoara and Caransebes stations.

In November, December, January and February the study shows that rain is the main type of freezing precipitation. In March, rain and drizzle have the same representativity for the whole region. As an exception, Timisoara has 100.0% drizzle, Joseni has 100.0% rain and at Satu Mare this month brought no freezing precipitation during the 1980-1999 period.

Southern part of the country

For the southern part of the country the following stations were selected: Turnu Severin, Calafat, Ramnicu Valcea, Dragasani, Craiova, Rosiorii de Vede, Alexandria, Targoviste, Ploiesti, Bucharest-Baneasa, Buzau, Slobozia, Calarasi, Medgidia, Adamclisi, Constanta, Mangalia, Tulcea and Sulina.

For December and January it is possible to establish a division by zones. In January, in the western part rain is the prevalent precipitation and in reverse, drizzle in the eastern part. The zoning in December is slightly different because: the cases with drizzle as the main precipitation are limited to the three stations (Targoviste 61.1%, Sulina 100.0%, Alexandria 55.8%); in the case of Calarasi, Mangalia and Tulcea the percentage is very close to 50% in favour of rain (54.0%, 50.0% and 53.5%); at the rest of the stations, rain is the prevalent phenomenon with percentages between 69.6% and 96.0%.

In February rain has the highest percentage values for the majority of the stations located in the south region. However, three stations from the extreme south – Calafat, Alexandria and Mangalia present drizzle as the predominant phenomenon. In March and November, with small exceptions, glaze is a result of freezing drizzle.

C. Analysis of the years with the maximum number of SYNOP messages including a freezing precipitation case for Romania

In this part of the paper the data were processed in order to establish the years with the main and secondary maximum of the number of SYNOP messages including freezing precipitation. The shape of the graph (Figure 11) highlights the multi-annual variability of this phenomenon.

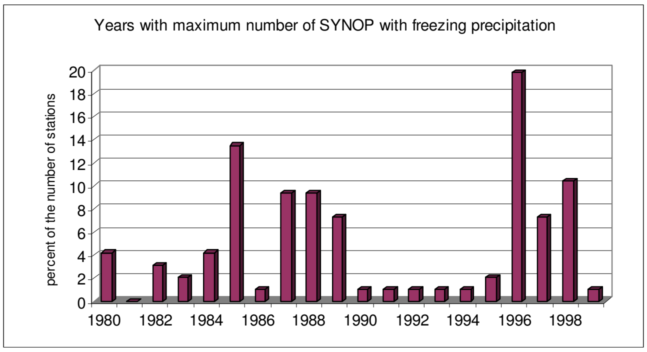

Figure 10. Years with maximum number of SYNOP including freezing precipitation

During the periods 1984-1985, 1987-1989, 1996-1998 a high number of freezing precipitation events occurred at many stations. This means that during these periods the main conditions necessary for the formation of the glaze were fulfilled. The most significant year is 1996, when 28.6% of the stations had a main maximum and 19.8% had both the main and the secondary maximum. However, the stations with this characteristic are spread in all the regions of the country, making a zoning attempt impossible. It is obvious that the periodic oscillations of the meteorological parameters (air and surface soil temperature, air humidity, wind, etc) affect the freezing precipitation formation.

D. Overview of the maximum duration of the continuous freezing precipitation cases for Romania

The last insight into the freezing precipitation characteristics studied in this paper is referring to the maximum duration of the continuous freezing precipitation events.

From the data rows the cases with the maximum number of SYNOP messages were extracted. In order to allow a facile analyse, values were arranged in intervals of six hours. Thus, it could be determined that the predominant maximum duration of the freezing precipitation in Romania is situated with a 34.7% percent between 13 and 18 hours (Figure 11). The other representative intervals are 7 to 12 hours with 24.5% percent and 0 to 6 hours with 18.4% percent. In the analysed period, 1980-1999, only one station (Rosiorii de Vede) presented an extremely long case of 35 hours.

Even if most of the stations are characterized by the intervals mentioned above, it is possible to highlight 3 zones that showed a duration of the cases of over 19 hours: the extreme south of the Romania's territory (Craiova, Rosiorii de Vede, Alexandria, Slobozia and Calarasi), the sub-Carpathian zone of Moldavia (Piatra Neamt, Bacau and Focsani) and from the western part Chisineu Cris and Caransebes.

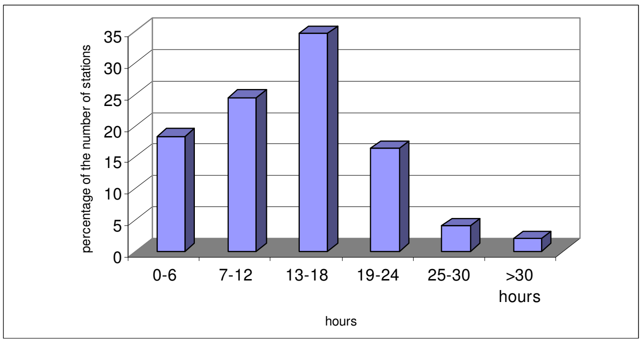

Figure 11. Maximum duration of freezing precipitation during 1980-1999 in Romania

Regarding the type of precipitation that generated the longest duration, the situation is as follows: in 52.8% of the cases it was drizzle, 35.8% it was rain and the rest of 11.4% it was an alternation between rain and drizzle. 65.5% of the longest duration with continuous drizzle is produced in the years with maximum number of SYNOP messages with a freezing precipitation case. The coincidence for the rain is only 27.6%.

E. Analysis of dependency of freezing precipitation on temperature and wind for Germany

In order to examine the dependency of observed freezing precipitation events (from SYNOP messages) on air temperatures, the SYNOP messages with indications for freezing precipitation and the corresponding air temperature data for 9 of the 74 stations in Germany (see Table 1) were analysed. Results of the examination are presented in Figure 12. They confirm the basic knowledge, that a necessary condition for the accretion of glaze near the ground is an air temperature slightly below or around 0°C, as reported in [1].

Figure 12 verifies that freezing precipitation events may occur at temperatures between 0°C and 5°C, too (see [1]). They should unlikely take place at air temperatures below -5 °C (see [1]). In contradiction to the general findings of [1], the present results show a remarkable number of freezing precipitation events at air temperatures below -5 °C. Reasons for these results are unclear so far.

Furthermore, Figure 12 confirms the usage of wet bulb temperatures for the identification of meteorological conditions for freezing precipitation (see [4], [5]). If the wet bulb temperature is at or below 0°C, the heat balance at the surface of rain or drizzle drops is negative – a necessary pre-condition for freezing at structures and the ground surface.

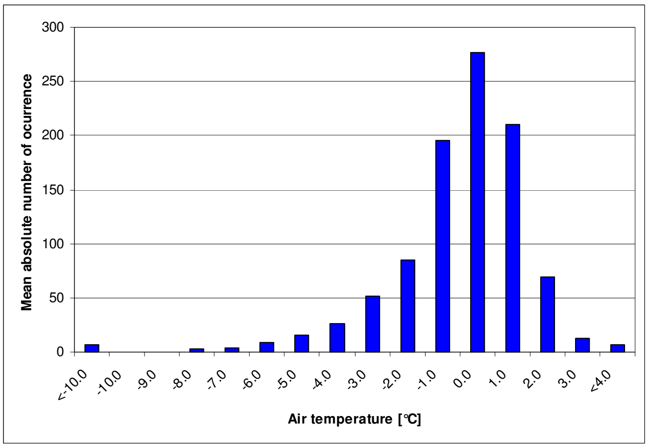

Figure 12. Mean absolute number of occurrence of observed freezing precipitation events in dependence on air temperature. Freezing precipitation and temperature data for 9 of the 74 stations in Germany (see Table 1) were analysed.

Depending on air humidity, wet bulb temperatures may be at or below 0°C, even if air temperature is greater than 0°C (see right part of Figure 12).

In order to examine the dependency of freezing precipitation events on wind direction and wind velocity, the SYNOP messages with indications for freezing precipitation and the corresponding wind data (wind velocity, wind direction) for 74 stations in Germany (see Table 1) were analysed. Results of the examination are presented in Figure 13.

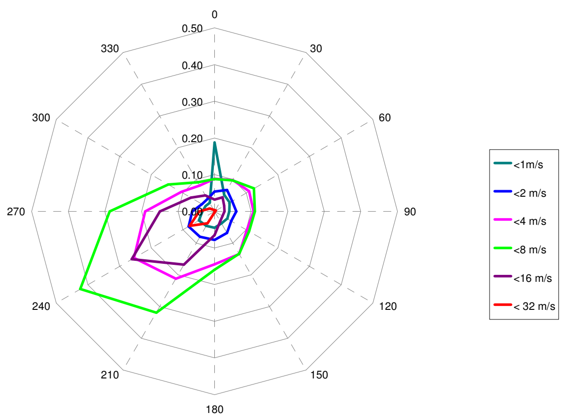

Figure 13. Mean relative frequencies of freezing precipitation events in dependence on wind direction and wind velocity. Freezing precipitation and wind data for 74 stations in Germany (see Table 1) were analysed.

Figure 13 shows that freezing precipitation most often occurs when winds blow from Southwest direction. Further examinations showed different results for locations near the cost line of the sea: At those locations freezing precipitation events are most often connected with wind directions from land to sea. Furthermore, examinations showed a turn of the prevailing wind direction with altitude: They higher the altitude of the location the more the prevailing wind direction turns to winds from West and Northwest.

Results in Figure 13 depict wind velocity ranges during freezing precipitation events. Most often freezing precipitation is combined with wind velocities greater than 4 ms^{-1} and lower or equal to 8 ms^{-1}. Freezing precipitation occurs more seldom in combination with wind velocities greater than 2 ms^{-1} and lower or equal to 4 ms^{-1} and in combination with wind velocities greater than 8 ms^{-1} and lower or equal to 16 ms^{-1}. Very seldom freezing precipitation is combined with very low (<2 ms^{-1}) or with high (>16 ms^{-1}) wind velocities.

V. Acknowledgement

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VI. References

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