Experiences with hoar-frost and its monitoring in Western Bohemia, Czech Republic

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Introduction

Hoar-frost still plays important role in winter maintenance of roads. Its formation is gradual and it is sensitive to local conditions. Sometimes it forms only on car windows but if it is also on the road surface it can be hard to say when this thin sheet turns to danger form of slipperiness. Visual observation by drivers or maintenance personnel is rather complicated and results of detection by road sensors can be unambiguous in some cases, especially if sensors of different generation or technology are used in one region.

Regional forecasting office of Czech Hydrometeorological Institute in Pilsen has been equiped with IceCast software and has access to data from Vaisala sensors installed on highway D5 between Prague and border crossing Rozvadov – Waidhaus and on some other sites in Western Bohemia too. This part of Czech Republic has complex terrain with elevations between 300 and 900-1000 m above sea level (the highest point of highway D5 is 620 m asl), some road stretches are in forested areas and some are close to water reservoirs or lakes. Our border mountains are also natural frontiers for temperature inversions with frequent occurence of low cloudiness and fogs. Intensity of transit traffic in this region is very high in spite of the highway A6 to Amberg and Nűrnberg on German territory is not still finished. The second very frequent border crossing is on the road E48 near the town Cheb where Vaisala sensors are installed too.

Accident statistics shows that besides of black ice and snow cover the hoar-frost is often the cause of crashes. The danger comes to different dimension on highways, due to higher speed. So we utilize the opportunity to study data from relatively dense measuring network along the highway D5 and we prepared some basic statistics of conditions of hoar-frost formation.

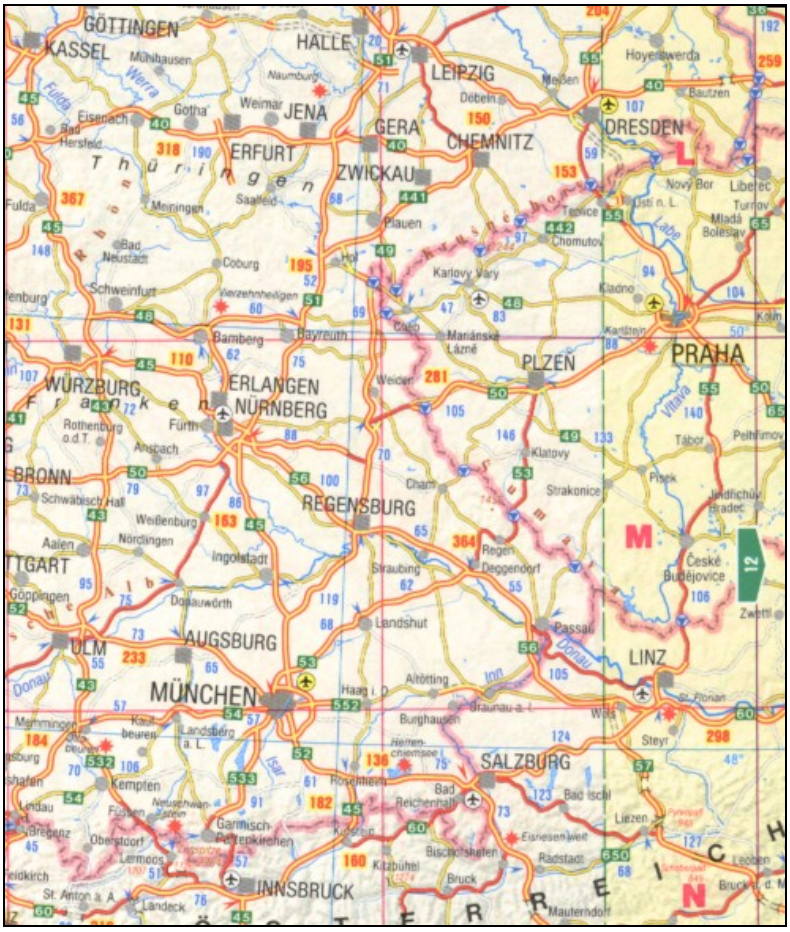

Figure. 1 Situation of connection Prague-Nürnberg, highway D5 on Czech territory

Measurements

Winter season 2002/2003 was chosen because of its numerous situations with influence of high pressure areas and cold spells followed by warm advection. The second reason is that new Vaisala station "As" in elevation 650 m asl has started its operation since 19th December 2002 (so this dataset is shorter then in other sites).

The highway D5 between Prague and Rozvadov border crossing is 150 km long and at this distance 12 measuring stations has been installed since 1997 all with following basic equipment: temperature and humidity sensors and precipitation detectors at high of 2 m. Older type of road sensors are situated especially in part Prague – Pilsen, new sensors DRS511 are in some stations between Pilsen and Rozvadov and in western part of region. Positions and description of all stations are in Fig. 2 and its legend:

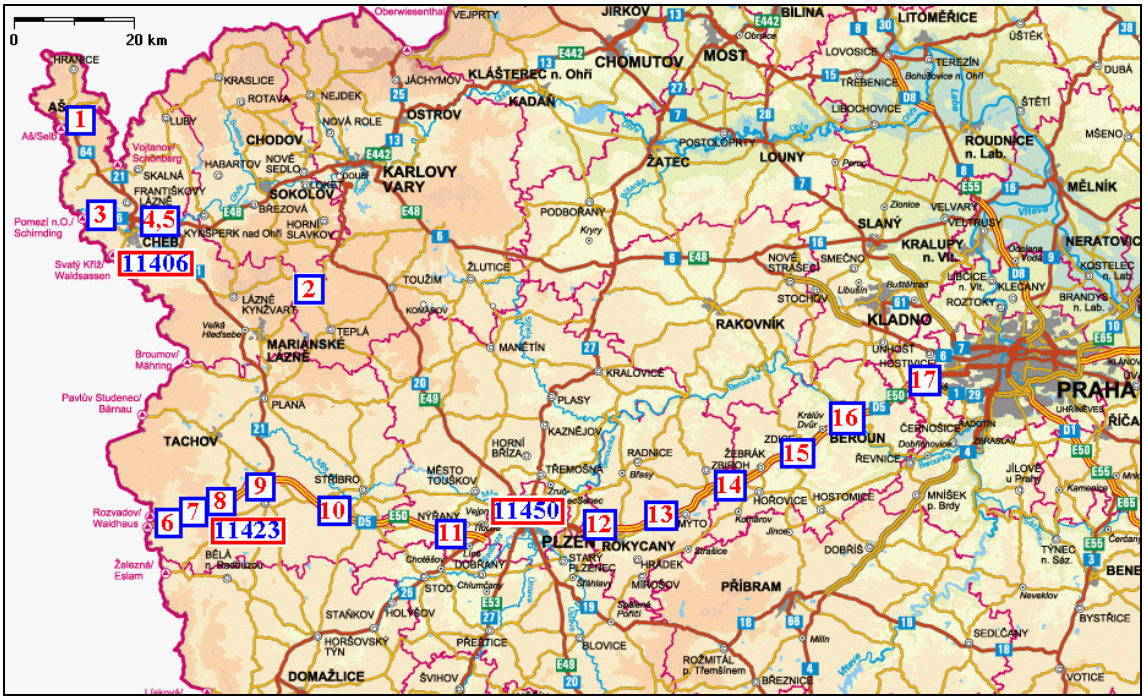

Figure.2 Vaisala stations on highway D5 and 1-st class road near the town Cheb, two instalations (1,2) are in elevation 650 resp. 730 m above sea level. Reference synoptic meteorological stations with indikatives 11406, 11423, 11450.

1 **As (650 m)** – western suburb of the town, screened by trees during late afternoon, exposed to W-SW winds
2 **Mnichov (730 m)** – open upland area
3 **Skalka (460 m)** – in shallow valley close to bridge and water recervoir
4 **Estakada (450 m)** – bridge over shallow valley with river, open area
5 **Jindrichov (450 m)** – in front of bridge Estakada
6 **145.km D5 (510 m)** – on the northern edge of forest in humid area close to small peat-bogs, not screened
7 **141.km D5 (550 m)** – in forest and cut of hill, in direction from northeast to southwest, screened, sheltered, western side of ridge of the hill
8 **136.km D5 (550 m)** – open station, exposed to E winds, eastern side of hill ridge
9 **128.km D5 (480 m)** – open station close to small forest, area of ponds (in circle 1-2 km)
10 **112.km D5 (410 m)** – open station, forest towards the south, not screened
11 **96.km D5 (340 m)** – open area, close to streams, small forest towards the southwest
12 **62. km D5 (360 m)** – shallow valley close to water and bridge, not screened
13 **53.km D5 (460 m)** – eastern edge of forest, station screened during late morning and afternoon
14 **41.km D5 (410 m)** – shallow valley between forested hills, next to bridge over local road
15 **35.km D5 (360 m)** – open and flat area
16 **23.km D5 (250 m)** – deep valley with river and next ponds, not screened
17 **12.km D5 (340 m)** – valley under forested hill, slope exposed to E winds, not screened

11406 (470 m) – synoptic meteorological station Cheb
11423 (750 m) - synoptic meteorological station Primda
11450 (330 m)- synoptic meteorological station Plzen
10791 (1450 m) - synoptic meteorological station Grosser Arber, not in the picture

Data from four synoptic meteorological stations were used to have representative measurements of wind. The station Grosser Arber with index 10791 is the highest point of Sumava mountains (on German territory) and its wind observations can be considered as in free atmosphere. Wind direction and velocity were extracted from SYNOP reports with one hour frequency.

Data from D5 are collected every 12 minutes via optical cabel along highway. Data from other localities are collected every 20 minutes via GSM. Forecaster has access to measurement outputs in operatinal regime. Data are archived every 10 days on PC in forecasting office. There is no expert system used at this time.

Methodology

As other national meteorological services, the Czech Hydrometeorological Institute does not observe or monitor rime on road surface. There is only observation of these phenomena only on the grass, trees and other terrain forms around the climatological site. At this time we have no feed back from road maintenance dispatchings. To study conditions of hoar-frost deposition the simplier form of criterion used by J.Norrman (2000) was applied :

$$Tr < Td \qquad Tr < 0°C$$

For the purpose of this study the light hoar-frost formation was also accepted. All situations from archived data that fulfiled the criterion were registered with respect to the term of occurence, duration, wind conditions and type of meteorological situation. Cases of warm air advection and pooling of cold air were distinguished. Information about surface state from sensors was used only marginally because in many cases residual salt was present or maintenance operations were applied.

Results

During winter season November 2002 – March 2003 conditions for deposition of hoar-frost were positive at least at one location in 75 days from 148 ones recorded. Warm air advection was present in 39 cases and cold air pooling in 36 cases. Other conditions are in following table:

station	warm air advection			cold air pooling		
	predominant winds			predominant winds		
	SW-NW	SE-NE,calm	velocity m/s	SW-NW	SE-NE,calm	velocity m/s
11406	21	18	2-6	8	28	0-3
11423	30	9	2-10	10	26	2-8
11450	20	19	1-5	6	30	0-3
10791	34	5	5-17	16	16	2-15
conditions	warm or occlusion fronts pressure troughs or lows 15 days with pressure high			out of frontal zone or after front passage 30 days with pressure high		

It is not surprise, that cold air pooling is common for synoptic situations of high pressure area. Centres of them were over different parts of Europe but most often in northwest sector with prevailing SE-NE winds, in lowlands of speed below 3 m/s. In cases with warm air advection high pressure area was present in 15 days mostly as a consequence of previous meteorological situation. Predominant phenomena was passage or proximity of warm or occlusion front coming from southwest sector with SW-NW winds over 2 m/s.

From next table we can see that conditions needed for hoar-frost forming were more suitable with increasing altitude which correspond to higher probability of lower temperatures and proxinity of bottom base of inversion cloudiness with higher relative humidity:

Number	Station	Altitude	Tr<Td, Tr<0°C	
			Days	Hours
1	As	650	41*	384*
2	Mnichov	730	58	580
3	Skalka	460	25	163
4	Estakada	450	29	236
5	Jindrichov	450	11	71
6	145.km D5	510	27	277
7	141.km D5	550	58	758
8	136.km D5	550	13	106
9	128.km D5	480	24	237
10	112.km D5	410	10	62
11	96.km D5	340	8	49
12	62.km D5	360	4	17
13	53.km D5	460	44	339
14	41.km D5	410	9	30
15	35.km D5	360	8	37
16	23.km D5	250	5	19
17	12.km D5	340	0	0

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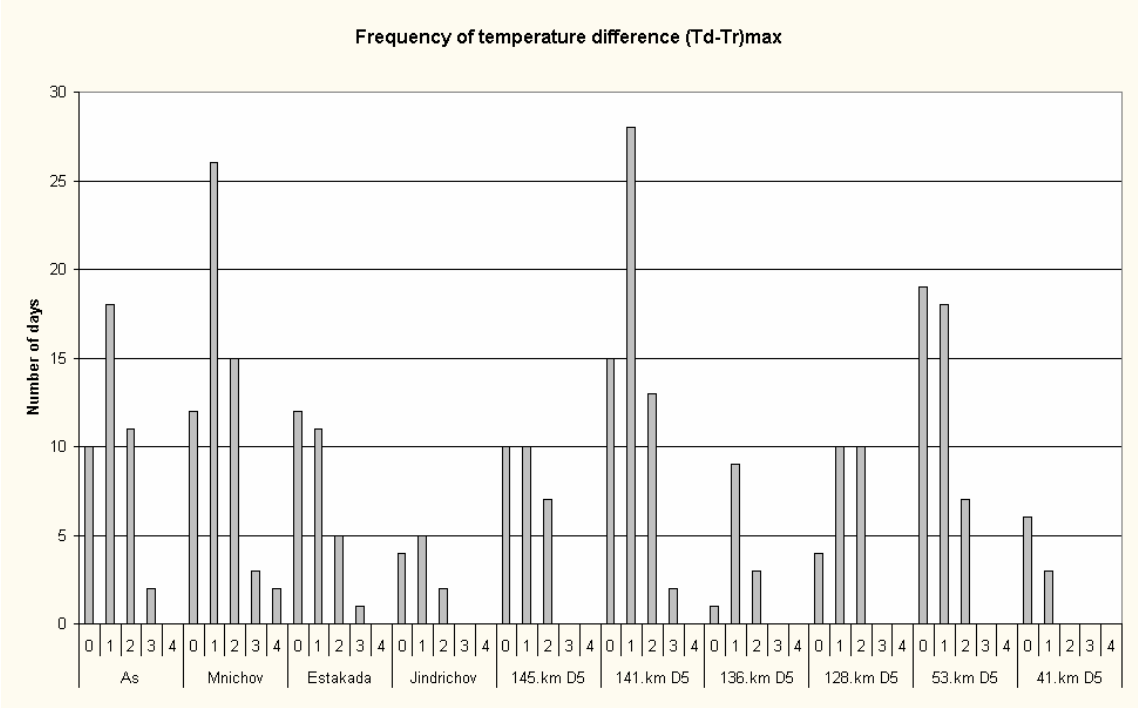
15	35.km D5	360	8	37
11	96.km D5	340	8	49
17	12.km D5	340	0	0
16	23.km D5	250	5	19

Station As started to measure in 19th December 2002, so the dataset is shorter.

But there are some exceptions apparent after ordering the table according to altitude:

1. maximum time of positive criterion values was found in location 141.km D5 at altitude 550 m asl, which is screened, sheltered and exposed to SW-W winds during warm air advection situations
2. at the same altitude but on the opposite side of crest a hill is location 136.km D5 with extremely reduced „positive time“ – it is open site exposed to east winds with lower humidity
3. only 8 km away in location 128.km D5 we can find more than twice longer „positive time“ – this is lower situated site in area of ponds
4. screened and sheltered site 53.km D5 surrounded by forest has several times longer „positive time“ than any other station between Prague and Pilsen
5. site 23.km D5 in deep valley in elevation 250 m has some „positive time“, but open station in 340 m only 11 km away has none
6. there is also interesting difference between Estakada site on the bridge and Jindrichov site only 500 m away in front of bridge

Besides of „positive time“ (criterion Tr<Td, Tr<0°C fulfiled), where also light hoar-frost is acceptable, we can compare occurence of different values of (Td-Tr)max:



This graph confirms results assigned before. Sheltering and sreening efect plays more comperable or maybe more important role than altitude.

Conclusion

At this study data from winter season 2002/2003 were used to find basic statistics about conditions suitable for hoar-frost deposition. Simple criterion according to Norrman (2002) was applied and important role of screening and sheltering effect was confirmed. The most critical place with the longest time of suitable conditions was found on sheltered and screened site in elevation 550 m above sea level on highway D5 near the border crossing Rozvadov – Waidhause. This result confirms the judgment from thermal mapping according to which this stretch is one of the most critical places of Czech highway network at all.

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