Utilization of minimum temperature prediction

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Abstract: - Techniques for forecasting the minimum temperature are mostly empirically based, using collections of statistics over a long period of time for a range of weather situations. The very popular method is McKenzie's method, which uses the maximum temperature and the dew-point at the time of maximum temperature, together with a set of correction factors for cloud and wind. Main aim is to adjust the corrections to aerodromes currently used by Czech air force. Adjustment of McKenzie technique to the territory of Czech Republic could be very useful tool in particular forecast, especially in forecast of dangerous weather phenomena that are linked with minimal temperature prediction, e.g. forecasting of road surface conditions etc. "The Road meteorology" is a branch of an applied meteorology, which deals with the meteorological elements and phenomena in the light of their influence over running of communication, namely the major roads and motorways on a given territory inclusive of bridges and tunnels constructions. Road meteorology tries to solve the theoretic problems pair with the meteorological support of the road maintenance.

Key-Words: - Minimum temperature, forecasting technique, meteorological data, correction factor, verification, ice formation on roads

1 Introduction

Temperatures used to vary on a range of time scales. Most obviously, summers are warmer than winters, and days are generally warmer than nights. The diurnal range is a particular interest to the local forecaster: given today's maximum, how low will the temperature fall tonight; or given tonight's minimum, how warm will it be tomorrow? The degree of diurnal variability is by no means constant, depending on a range factors:

1. Cloudy weather tends to have low maximum temperatures, and high minimum temperatures; clear sky brings about generally warm by day but cold at night.
2. Windy weather tends to reduce daily temperature range, while calm weather increases it. On a cloudy, windy day in winter it is not unusual for temperatures to remain constant, within a degree or so, for 24 hours or more, as turbulent mixing, cloud, and advective effects are dominant and solar insolation has negligible influence.

Surface characteristics: We have already observed that surface characteristics such as soil type, vegetation, albedo, specific heat capacity and thermal conductivity have a significant effect on temperature rise and fall. It follows, therefore that the daily range of temperature will be much greater where these factors favour rapid heating and cooling.

It is, therefore, vitally important in any temperature forecast to consider the characteristics of the area, and modify the general forecast to allow for the local climatology.

2 Forecasting technique

Various techniques have been developed over the years to assist in temperature forecasting. The normal procedure is first to predict the day maximum and night minimum temperatures, then to interpolate between these two values to produce a realistic 24-hour temperature graph. The success of the technique depends not only on the correct application of the techniques, but also on the skills of the forecasters in knowing how temperatures will vary through the 24 hour-period. Factors to be considered include changes in the synoptic situation, fronts, variations in clouds and wind, advective effects, topography and other local climatological effects etc. Most techniques for forecasting the minimum temperature are empirically based, using collections of statistics over a long period of time for a range of weather situations.

One of the most popular method is McKenzie's method, which uses the maximum temperature and the dew-point at the time of maximum temperature, together with a set of correction factors for cloud and wind. Correction factors are available for many stations around the Great Britain and beyond. The technique is very simple to apply, and has the advantage that by using site-specific correction factors it is including local effects implicitly.

McKenzie's technique is based on solution of the regression equations on actual observations, which gives the technique the advantage of taking of local factors account. The night-time minimum air temperature (T_{min}) can be forecast as follows [2]:

$$T_{\min} = 0{,}5(T_{\max} + T_d) - K \quad (1)$$

where symbol T_{max} represents maximum temperature, T_d air-mass dew point at time of T_{max} and K is introducing local constant depending on forecast surface wind and low cloud amount). The value *K* is very significant value which amends the forecast number of T_{min} by correction on clouds effect and wind. As has been already said, cloudy weather tends to have high minimum temperatures; clear weather is generally colder at night. Windy weather tends to reduce daily temperature range, while calm weather increases it.

3 Adjustment of McKenzie's technique on territory of Czech Republic

McKenzie's method for forecasting of the minimal temperature has been adjusted on currently used Czech air bases, Praha-Kbely, Caslav, Pardubice, Namest and Prerov. The process consisted in calculation of the value *K*. For this reason were decrypted meteorological reports (SYNOP) from August 1997 till May 2006. SYNOP (surface synoptic observations) is a numerical code (called FM-12 by World Meteorological Organization) used for reporting weather observations made by manned and automated weather stations. A report consists of groups of numbers (and slashes where data is not available) describing general weather information, such as the temperature, barometric pressure and visibility at a weather station.

For processing were chosen maximal temperature (T_{max}) of day and the value of dew point temperature (T_d) on the time of T_{max}, all figures about wind speed and amount of cloudiness in period from midnight to 04.00 UTC of next day (day of forecasted T_{min}) and minimal temperature T_{min} measured in 06.00 UTC. The average values of constant *K* for separated groups given by values of mean surface winds and clouds amount overnight were calculated as differences between (T_{max} + T_d)/2 and measured T_{min}. Values of constant *K* were determined only in case, when number of the measurements exceeds more than 10. Otherwise values were interpolated from contiguous groups (marked by *) as it is shown in following tables.

Table 1: Values of local constant *K* for Praha Kbely Airbase (World Meteorological Organization indicative (WMO) 11567, International Civil Aviation Organization indicative (ICAO) LKKB)

Wind (knots)	Average cloud amount overnight (octas)				
	0	2	4	6	8
0	6,4	6,3	5,1	4,8	3
3	6,3	5,7	5,3	4,4	2,4
6	6,0	5,5	4,6	3,9	2,3
10	5,6	5	3,3	2,9	2,2
16	5,2*	4,5*	1,9*	1,5	1,5
21	4,8*	4,1*	0,5*	0,1*	0,0*

Table 2: Values of local constant *K* for Caslav Airbase (WMO 11624, ICAO LKCV)

Wind (knots)	Average cloud amount overnight (octas)				
	0	2	4	6	8
0	7,8	7,4	6,7	5,3	3,3
3	7,0	6,4	5,8	5,0	2,4
6	5,4	4,8	4,6	4,1	2,6
10	4,5	3,9	3,5	3,1	2,4
16	3,5*	2,4*	2,2*	2,1*	1,5
21	2,5*	1,3*	0,5*	0,2*	0,0*

Table 3: Values of local constant *K* for Pardubice Airbase (WMO 11652, ICAO LKPD)

Wind (knots)	Average cloud amount overnight (octas)				
	0	2	4	6	8
0	8,5	7,5	7,2	5,7	3,3
3	8,0	6,9	6,5	5,0	2,9
6	6,3	5,4	4,8	4,3	2,6
10	4,3	4,1	4,0	3,8	2,4
16	2,8*	2,6*	2,5*	2,4*	1,6
21	2,5*	1,5*	1,4*	1,0*	0,9*

Table 4: Values of local constant *K* for Namest Airbase (WMO 11692, ICAO LKNA)

Wind (knots)	Average cloud amount overnight (octas)				
	0	2	4	6	8
0	6,3	5,6	5,5	4,4	2,7
3	5,7	5,5	5,1	4,3	2,6
6	4,9	5,0	4,4	3,7	2,4
10	4,7	4,2	3,6	2,5	2,3
16	4,5*	3,4*	2,8*	2,4*	1,3*
21	4,3*	2,7*	1,9*	1,0*	0,4*

Table 5: Values of local constant *K* for Prerov Airbase (WMO 11748, ICAO LKPO)

Wind (knots)	Average cloud amount overnight (octas) 0	2	4	6	8
0	8,9	8,3	7,4	6,6	3,5
3	8,1	7,7	6,5	5,7	3,2
6	6,8	6,7	5,4	4,6	2,5
10	6,3	4,4	3,3	2,9	2,4
16	5,8*	2,0*	1,5*	1,3*	1,2*
21	4,8*	1,0*	0,9*	0,4*	0,1*

4 Verification of McKenzie's method adjusted for Czech territory

Verification of McKenzie's method was performed on minimum temperature measurement array on mentioned air bases in period of years 2006 - 2009. For every air meteorological station was calculated root mean square error (RMSE), bias (BIAS), median (MED), minimal variation (MIN), maximal variation (MAX) according to number of observations and attempts to forecasts. [2]

Table 6: Comparison of forecasted and measured minimum temperature values statistics

	11iii	N	RMSE	BIAS	MED	MIN	MAX
Year	567	793	2.08	-0.18	-0.35	-6.35	8.50
	624	787	2.23	-0.17	-0.45	-7.20	12.60
	652	797	2.38	-0.42	-0.60	-8.45	12.50
	692	555	2.09	0.19	-0.05	-7.05	12.15
	748	805	2.22	-0.33	-0.50	-6.15	9.00
warm season	567	440	2.01	-0.02	-0.20	-5.25	7.65
	624	434	2.07	0.11	-0.13	-6.90	8.70
	652	444	2.08	-0.11	-0.30	-6.10	8.15
	692	343	2.10	0.48	0.25	-4.00	12.15
	748	446	2.04	-0.11	-0.33	-4.80	9.00
cold season	567	353	2.15	-0.39	-0.60	-6.35	8.50
	624	353	2.40	-0.51	-0.80	-7.20	12.60
	652	353	2.70	-0.81	-1.10	-8.45	12.50
	692	212	2.09	-0.28	-0.53	-7.05	7.50
	748	359	2.41	-0.61	-0.85	-6.15	8.35

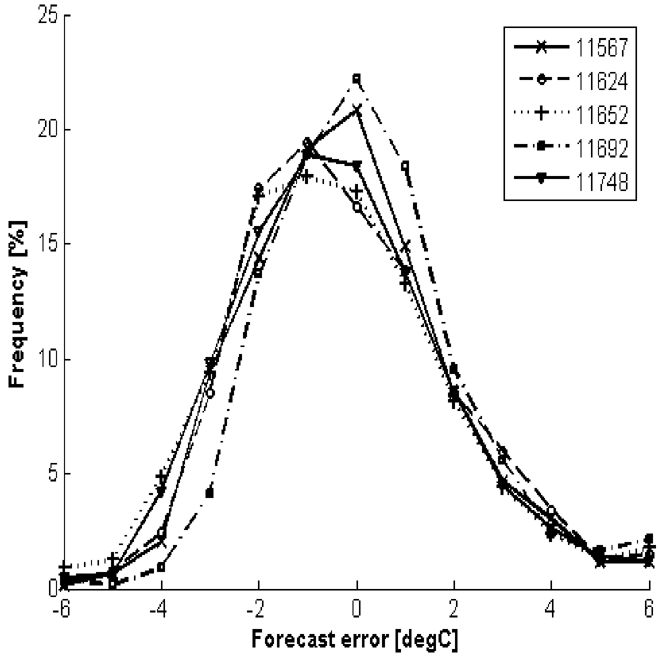


Fig.1 Differences between forecasted and measured values of minimum temperature during whole period

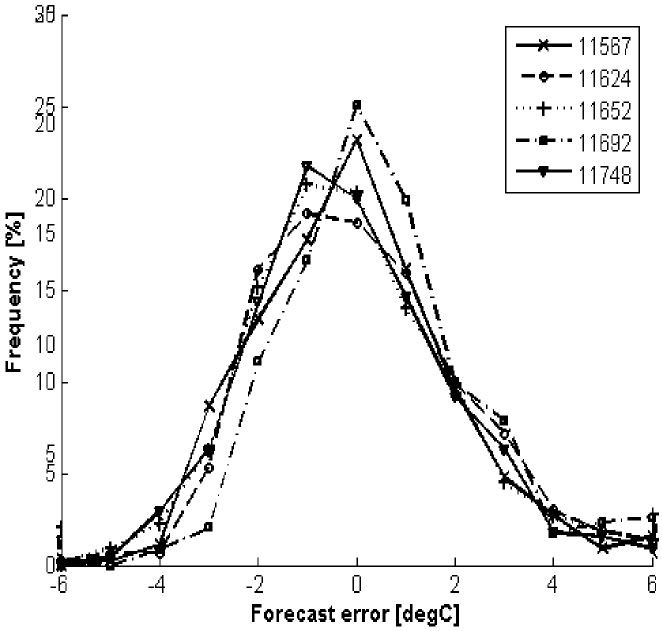


Fig.2 Differences between forecasted and measured values of minimum temperature during summer half-year

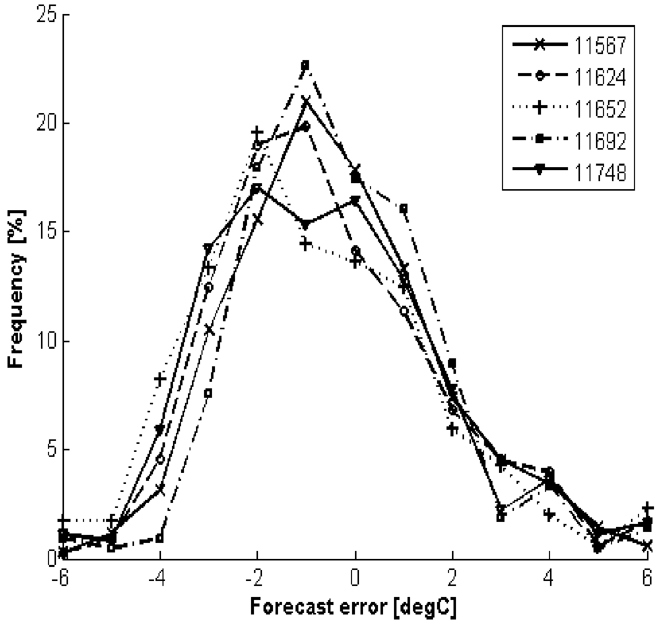


Fig.3 Differences between forecasted and measured values of minimum temperature during summer half-year

Comparison has been done not only for whole period, but also for seasons, separately for warm (i. e. from April till September incl.) and cold season (i. e. since October till March incl.). From table 6 alike from figures are apparent that the McKenzie's method is more precise for summer half-year. With regard to numerical value of root mean square error is possible to mention c. 70 percent of forecasted minimum temperature is with departure less than 2 degrees of Celsius which means that modified McKenzie's method could be sufficient. On the other hand method, according to statistics, has tendency slightly underestimate the nocturnal cooling, when the ground is covered by snow. Exceptionally low minima may also occur when there is a large catchment area for katabatic drainage and the lowest layers are very dry. So, generally speaking, the modified McKenzie's method is applicable for most ordinary events on territory of Czech Republic.

5 Conclusion

The temperature of the near-surface air is influenced primarily by the underlying surface temperature. This is also the main reason, why the values of constant K are so locally different from place to place. Although, temperature forecasts are produced routinely by the various numerical meteorological models, which take model variables at a particular grid point, adjustment of McKenzie technique to the territory of Czech Republic could be very useful tool in particular forecast, especially in forecast of dangerous weather phenomena that are linked with minimal temperature prediction, e.g. forecasting of road surface conditions etc.

6 Following steps

Precise forecasting of minimum temperature can be taken into account as first, but inevitable step, in forecasting of more complex meteorological values. Our main aim has been focused for last few years on prediction of ice formation on road surfaces. So, it obvious, of course, why there is a precise value of minimum temperature important. With acknowledge of minimum temperature value of another important meteorological value known as minimum road temperature can be derived. Due to many observations a and following calculations it was found that the difference between screen minimum, $T_{\min}$, and (concrete) road minimum temperatures varied with the length of night. The following regression equation was obtained[7]

$$T_{\min} - T_r = 0{,}28t - 2{,}9 \qquad (2)$$

where T_r is minimum temperature on the road, t is the length of night (in hours). Forecasting the temperature of road surfaces is especially important in winter when icy conditions may occur. It is not straightforward, because of the wide variations in meteorological conditions which are found over short distances on the same night as well as variations in the thermal capacity and conductivity of different types of road and the road state (wet, ice-covered, salted, dry). Evaporation from the surface into dry ambient air will cool the surface.

Problems of weather manifestation on the communications deal with in present time extant dynamically elaborative line of meteorology that has been named as the road meteorology. Among especially dangerous meteorological phenomena belongs to get frostbitten damp carriage way at crossing communication surface temperature below freezing point, which is for The Czech republic very frequent phenomenon in cool season of the year. Road meteorology as a line of applied meteorology isn't from the history point of view so extensive like e.g. aeronautical meteorology, which developed concurrently with development of air transport and demands on qualitatively higher safeguard of human lives. It is necessary indeed to remark, that separate mark road meteorology has been used already for longer period and is linked together with meteorological predictions related to land transportation.

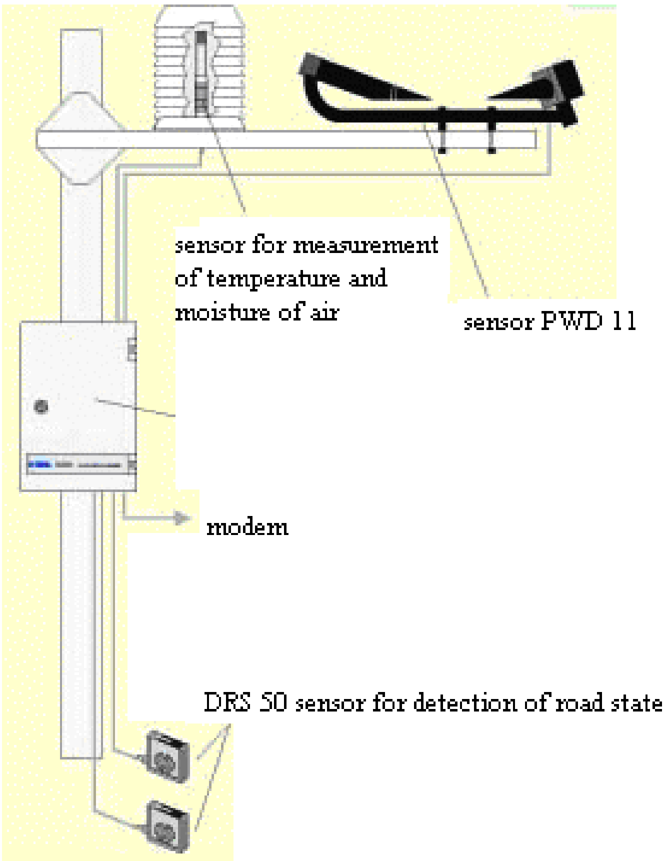
In order to allow some leeway in the difficult task of forecasting road condition for a particular site, the forecaster may have the option of issuing two forecast curves simultaneously. These are known as the "Realistic" and "Pessimistic" forecast. The Realistic Forecast is simply based on the expected meteorological conditions, and is thus relatively straight forward to produce. The Pessimistic forecast is used to indicate the effect on road should meteorological conditions be somewhat "worse" than expected.

7 Parameters measurement

The most significant element is the network of the specialized measurement which provides actual data along the main roads and it is possible this one to mark like a Road weather information system. Among the measurements belong values of the classical weather elements and also special temperatures measuring and measuring of road surface. It is evident that increasing attention is apply to dangerous sections, in the light of the production of black ice, frost, drifting snow etc. Most widespread station on territory of the Czech Republic is weather-station "Rosa" of Vaisala production (Figure 4 and 5). Specialized measurements are pursued by automatic station network, which it is possible simply named like road meteorological station. Z tenet things is however desirable, to this metering transaction how in representative locations, so in places with hi-risk occurrence dangerous phenomenon. However on principle is desirable to pursue the measurement both in representative locations and in places with high risk of dangerous phenomenon occurrence.

Smoothness of transportation on roads, railroad track or on airports depends upon economy. Weather affects transport and its safety really high. In many cases bad weather e.g. ice, snow and fog could be cause of accident and distance-velocity lags. Alert service in the operational range of applied road meteorology played inevitable role. Alert system is able to prevent from bad weather influence on the road transport, if need be on state of runways and road maintenance staff or airport technical support staff they may in time ensure safe and fast-moving traffic road, motorway and air transport above all in winter season.

Civil and military weather service in light of their instrumentation bet on offers of Finnish firm Vaisala. For branch of road meteorology offers Vaisala modular and additional series of products and services designed to grant to operators of maintenance of highway, railway and airport substantial information, which are necessary to create fast and accurate decision leading to upkeep to minimize unfavourable effects weather.



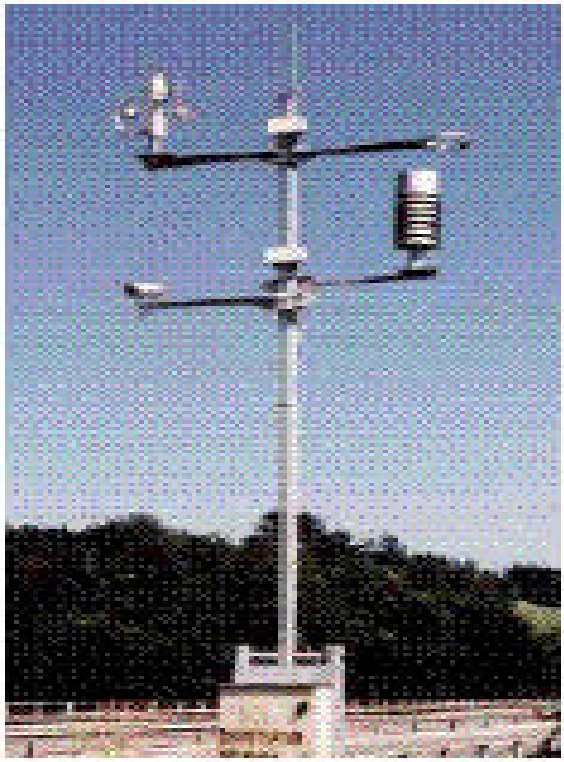


Fig.4 and 5 Meteorological station ROSA

8 Road surface conditions forecasting

The main idea is possible to express by following. „If it is possible enough exactly forecast the future development of weather in short-term period, is as well possible forecast behaviour of chosen carriage way stage or runway". For forecast of ice formation on road surfaces have been used methods for prediction of ice formation in free atmospheres in air meteorology, though it isn't quite ideal. In contradistinction to free atmosphere surface temperature and road condition are affected by various factors, which these methods are not able to cover. Various factors affect the road surface temperature; in the discussion below these have been separated into dynamic and static groups. The dynamic factors are those that change with time.

Hence they are largely governed by the prevailing weather conditions:

1. Short wave (solar) radiation, is responsible for the warming of the surface during daylight hours. Though during mid/winters this is a relatively small heat flux, from early March through to mid-October, continuous sunshine during afternoon can produce high surface temperatures. Depending on local conditions, maximum surface temperature can reach 55 to 60°C.
2. The long wave radiation is also continuously emitted from road surface. The amount of energy lost by this process is a function of surface temperature that also absorbs long wave radiation emitted by surrounding, warmer objects or clouds, representing a gain in heat energy. A portion of the radiation emitted by the surface may also be reflected from surrounding, warmer objects or clouds, so reducing the net heat loss.
3. The presence of moisture on the road surface may also result in heat exchanges affecting the surface temperature. Through evaporation of standing water or moisture, the road surface loses heat energy. The rate of evaporation determines the response, in terms of the change in surface temperature. Condensation, the deposition of moisture on the road surface, takes place when the surface temperature is lower than the dew point temperature of the air in contact with the surface. This air, cooled by the underlying surface, saturates, and the excess moisture accumulates on the surface. A small amount of heat energy is added to the road surface by this process. Evaporation can take place at any time during the 24-hours, the only provision being that the road is wet. Condensation though usually occurs only overnight: due to the input of solar radiation, the roads will normally be warmer than air during daylight hours.
4. Sensible heat or convection are the primary process by which the roads and the air directly above exchange heat energy, through the movement of air over the surface. The direction of heat flow depends on relative temperatures of the two. Overnight, when the air is usually the warmer of the two, the road will gain energy by convection. Thus higher wind speed, e.g., which might be thought to promote cooling through a "wind-chill" effect, actually result in the opposite in this case. During daylight hours, the road is normally the warmer and so will lose heat through convection.

In addition to the factors considered above, there are a number of static factors which influence surface temperature. A brief summary will follows.

1. Latitude. The latitude directly affects the duration of sunlight, and the angle with which the radiation is incident upon the road surface. Both factors obviously influence the short wave radiation budget.
2. Sky-View factor. The long wave radiation budget is heavily dependent on the exposure of the roads. Nearby objects reduce the "sky-view factor"; the proportion of sky visible from the surface. An area overshadowed by building, for instance, will how a lower net radiative heat loss than will an exposed site, on open ground. Depending on the location of such objects relative to the road, the flux of short wave radiation may also be affected.
3. albedo. This is a measure of the amount of reflected radiation compared with that which is incident upon the surface. Black surfaces will generally have a relative low albedo, and so reach higher daytime temperatures than, e.g., a neighbouring concrete surface.
4. Sub-surface thermal properties. In addition to the heat exchanges outlined above, the surface also exchanges heat with the sub-surface, and that in turn exchanges heat with the sub-soil. The dominant method of heat flow is conduction, and so, in general, the rate of flow is small compared to the heat fluxes mentioned above. A number of properties influence the sub-surface heat flows such as the depth on construction of the road, the materials used in construction, and the nature of the soil.

9 Method used for prediction

For evaluation ice formation from database inclusive temperature and atmospheric moisture it is possible use relatively wide spectrum of different methods, which are based either on comparison of temperature, dew point temperature, let us say deficit of dew point temperature, and sometimes pressure also. At exceeding default setting criteria is then specific kind of icing evaluated. Analysis of ice formation trough the use of below circumscribed methods was fulfilment on data series from winter season from years 2002 – 2005 with measured period of 12 minutes from road meteorological stations Bystřice nad Olší, Cheb Estakáda, Cheb Jindřichov, Chrlice, Kocourovec, Mirošovice, Nová Ves, Ostrov u Stříbra, Poříčany, Rozvadov, Rudná, Rudná Okruh, Velký Beranov. For statistical processing were used measured values of following quantities:

1. Air temperature in 2 m above ground level [°C];

2. Dew point temperature [°C];
3. Temperature in 5 cm above road surface [°C];
4. Relative humidity [%];
5. Road surface temperature [°C];
6. Freezing point [°C];
7. Road state.

The method producing a forecast do not distinguish the kind of icing but generally is possible to identify four states.

1. The first condition where some treatment might be thought necessary is known as a “dry frost”. Such a frost occurs when the surface falls to 0°C, or bellow, but remains dry. With no moisture on the roads therefore, ice will not form, no matter how cold the road becomes. The forecast will expect temperature curve falling below zero, but no indigent amount of moisture. Though such a frost may require no treatment, the forecast should be treated with care. The moisture forecast is heavily dependent on the relationship between surface and dew-point temperatures. A good example of this relationship may be seen through the development of frost on grass surface whilst adjacent, warmer, pavement remains dry. So, though the site-specific forecast may indicate dry conditions, a different section of the region road may experience lower temperatures, possibly leading to condensation and hence frost formation. As well as temperature variations, there may well be slight changes in relative humidity across the region. Sources of additional moisture, such as lakes, or heating outlets, may raise the relative humidity locally, producing icy patches. In addition, section of the roads subject to seepage may also be affected by ice.

The susceptibility of bridge decks to frost illustrates the problem rather nicely. Bridge decks are particularly frost prone largely because they are generally cooler than adjacent road surfaces. The temperature at the base of the road construction will generally be higher, in winter, than temperature at the base of the bridge deck, which is typically close to the ambient air temperature. By their very nature, many bridges are located close to lakes or rivers, in areas where the humidity may be locally raised by additional evaporation. Hence a combination of lower surface temperatures and higher humidity greatly increases the incidence, and severity, of frost formation of bridge decks.

2. Hoar frost, the formation of ice on the surface through condensation of the overlying air, can prove to be very hazardous. The conditions required for its formation are initially the same as for a dry frost; dry road surface and temperature falling below zero. However, in this case, the temperature falls to a point where air reaches saturation, resulting in the deposition of moisture on the surface. The extent of the deposition depends on a number of factors, the relative humidity of the air, the temperature of road surface relative to the dew-point temperature and the wind speed. For example, whilst light winds can lead to a substantial build-up of hoar frost, it has been observed that under calm conditions, accumulation is limited.

3. Black ice is a term used to describe freezing of standing water on the road surfaces. This may occur through one two scenarios, either the road is initially wet and then falls below freezing, or rain falls on to the sub-zero road, and freezes as a result. The former is the more common.

4. Snow. Snowfall may result in one of two potentially hazardous conditions; either accumulation of snow on the roads, or thawing of lying snow at a temperature close to freezing. As regards the accumulation of snow on the road, experience suggests that soon after the snowfall starts, the road will fall to a value a little bellow the ambient air temperature, leading to build-up of snow under most circumstances. If the snowfall occurs under very marginal conditions, with air temperatures close to or just above zero, once the snowfall stops, the surface temperature will generally rise, leading to gradual thawing of lying snow. Where the snowfall temperature is below freezing prior the start of the snowfall, then obviously snow will readily accumulate on the surface, and remain once the fall has ceased. In the case of the thawing of lying snow, either on or alongside the road, leading to the presence of melt water on the surface, it is clearly up to the forecaster to assess the risk of ice. Roads are generally vulnerable to wetting from melting snow for longer than might be expected if the original snowfall was cleared by ploughing. This action tends to lead to the formation of hardened banks of snow either side if the road which can be long lasting, more so in those localities where grit or sand is spread rather than salt.

Occurrence of ice formation was evaluated by the Robitsch’s method (calculation according to Řezáčová and calculation according to Červený [6] and Luers design method of estimation of water-vapour content (LUR) [1]. These methods were chosen pursuant to requirements leading to maximal objectification, i.e. eliminate human factor.

In Robitsch’s method; calculation by Řezáčová (abbreviation REZ), the procedure is based on calculation and comparison water-vapour pressure with respect to the water droplets for given dew point temperature and maximum water-vapour pressure with respect to the ice for given air temperature in standard level.

$$E_w(t).RH \cong E_w(t_d) > E_i(t) \quad (3)$$

where E_w presents maximum water-vapour pressure with respect to the water for given temperature, E_i presents maximum water-vapour pressure with respect to the water for given temperature and *RH* is relative humidity. If the equation (4) comes true, then in such given conditions the ice formation is predicted on Earth's surface.

In Robitsch's method by Červený (CER), the technique is based on calculation of relative humidity of air for given temperature, when is air in respect to the ice saturated. If real relative humidity (acquired from measurement) is greater than one calculated is analysed ice. Calculated relative humidity F_i is possible to obtain from followed formula:

$$F_i = \frac{E_i}{E_w} \cdot 100\% \tag{4}$$

In Luers's method we directly work with characteristic of moistures. [4] In method is counted entire amount of all stages of water which could be deposited as a icing in layer above surface and comparison of results with value 0,11 g.m^{-3}. Estimation of value is based on calculation of humidity mixing ratio

$$vl = (1/2{,}87).(w_0 - w_1).\frac{p}{T} \tag{5}$$

where *e* presents vapour pressure with respect to the water for given temperature of air, *p* is constant atmospheric pressure on sea level, p = 1013,25 hPa, $w_{0/1}$ presents humidity mixing ratio in 2 m and in layer adjacent to ground accordingly, *T* is constant temperature of air on sea level [K]. [3]
For calculations of meteorological characteristic needed for exploitation of method are described below [5]

Maximum water-vapour pressure with respect to the water for given road temperature:

$$E_w = 6{,}11213\exp\{(7{,}602.T_r)/(241{,}2+T_r)\} \tag{6}$$

Maximum water-vapour pressure with respect to the ice for given road temperature:

$$E_i = 6{,}11213\exp\{(9{,}747 * T_r)/(272{,}186+T_r)\} \tag{7}$$

Maximum water-vapour pressure with respect to the ice for given dew point temperature:

$$E_i = 6{,}11213\exp\{(9{,}747 * T_d)/(272{,}186+T_d)\} \tag{8}$$

Maximum water-vapour pressure with respect to the water for given:

$$E_w = 6{,}11213\exp\{(7{,}602.T)/(241{,}2+T)\} \tag{9}$$

Water-vapour pressure with respect to the water for given temperature

$$\begin{aligned} e_w = {} & 6{,}111767 + (0{,}501948 * T) \\ & + (0{,}0143053 * T^2) \\ & + (2.6503.10^{-4} * T^3) \\ & + (3{,}0225.10^{-6} T^4) \\ & + (2{,}039.10^{-8} * T^5) \end{aligned} \tag{10}$$

Water-vapour pressure with respect to the ice for given temperature:

$$\begin{aligned} e_i = {} & 6{,}109527 + (0{,}501948 * T) \\ & + (0{,}018629 * T^2) + (4.0349.10^{-4} * T^3) \\ & + (5{,}398.10^{-6} * T^4) + (4{,}207.10^{-8} * T^5) \end{aligned} \tag{11}$$

To assess ability of single methods to forecast ice formation on roads were used criteria CSI (threat score – critical success index), POD (probability of detection), FAR (false alarm ratio), BIAS (systematic errors), HSS (Heidke skill score), EQS (Hansen and Kuipers discriminant) and own characteristic meaning percentage of successful forecasts (NGOOD) based on use of contingent tables. Value 0 and 1 accordingly represent, that event fail, or occurred, whereas first figure features reality, i.e. detection of ice formation by sensor, and second figure prediction of ice formation. Supporting narrative used in all graphs; d00…correct negatives, d01…false alarms, d10…misses, d11…hits.

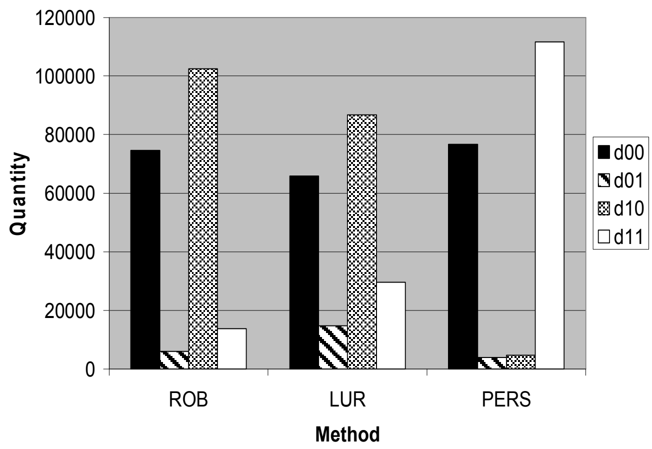


Fig 6: Quantity of all possible occurrences (forecast vs. observation)

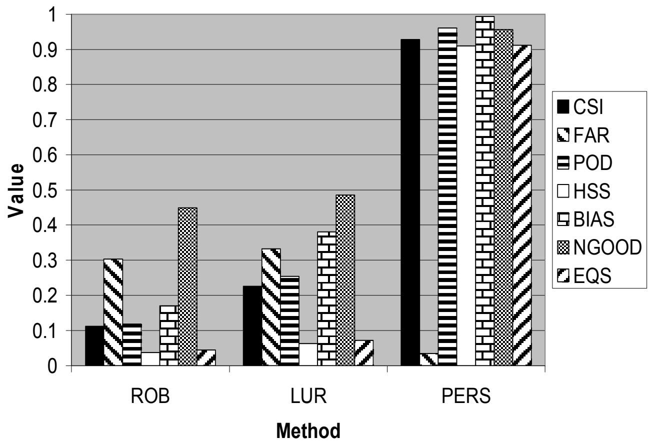


Fig 7: Methods evaluation with reference to criteria of successfulness of single methods

From figure 6 and 7 is obvious that the best forecast is attained by simple repetition of prognoses, i.e. persistent prediction (PERS), which is misguided, because if icing occurs and sensor detects icing e.g. for six hours, whereas interval following is about twelve minutes, will be successfulness of such prognoses by simple repetition thirty times successful and only twice poor. Using single methods according to the graphs and criteria will not provide in sufficient quality forecast. Nevertheless different values of statistical criteria achieved by evaluation based on different quantity describing state in ground layer atmospheres directly urge to their mutual combination. Those methods therefore might be combining at prognoses of ice formation, so it is possible forecast ice formation with higher accuracy. For this purpose was used method of linear regression.

10 Exploitation of Linear Regression

Linear regression was extract of pursuant to two years of teaching. Then third year was used for testing of prognoses. As an autonomous variables were considered values 0 or 1 given by measurement of sensor, i.e. 0, when sensor did not detect an icing, 1, when icing was detect by sensor. Coefficients of linear regression equation were derived through the use of the least squares method. Results of prognoses then will be value 0 or 1 in cases, when icing will be occurred or not. In linear regressions were used following combinations of predictors:

1. $R(vl,\ vc = RH - F_i,\ vr = E(t_d) - E_i(t))$ – equation of linear regression based on quantities used in methods ROB (REZ, CER) and LUR.
2. $R(vr)$, resp. R(vc), resp. R(vl) – independent equations of linear regression based on singling methods.
3. $R(t,\ t_d)$, resp. $R(t,\ t_d,\ t_f)$ – equation of linear regressions derived on combination of following parameters, e.g. combination of air temperature and dew point temperature, respectively on both of these parameters and temperature of road with the condition, that temperature surface would be smaller or equal to temperature of freezing (endeavour to filter off the influence of salting).

In graph are the regression method termed by $R(xxx)$, whereas the contemplated regresses are state in brackets.

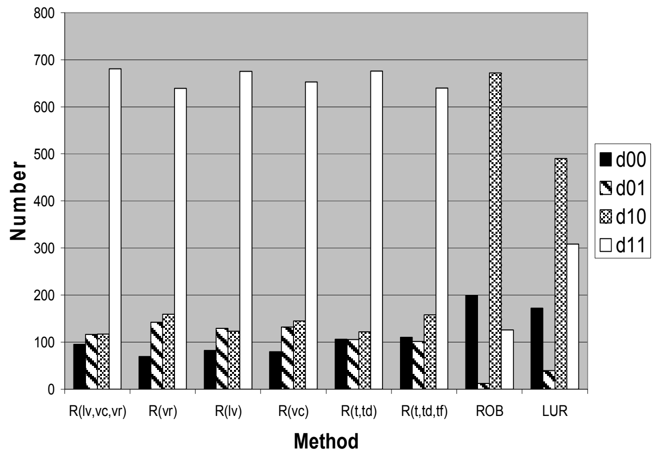


Fig 8: Absolute frequency of ice formation prediction according to single method and their combinations

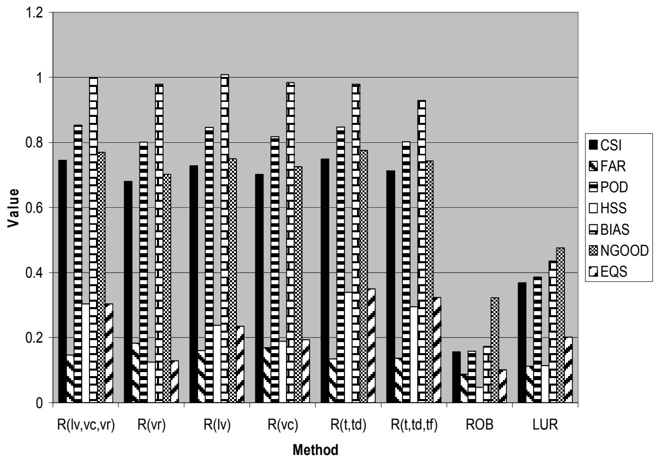


Fig 9: Criteria of successfulness of ice formation prediction according to single methods and their combinations

For the comparison there are in fig 8 and 9 state also results of regression analyses coming from measured values in terms, when icing occurred. In spite of fact, that we take absolute accuracy values of temperature, dew point temperature and road surface temperature, not their prediction, the results of regression analyse of combination singling methods are sufficiently good. It can be manifested by combination of single methods we achieved higher successfulness at prognoses of ice formation than by single methods.

11 Conclusion 2

The main outcome is simple forecast model of prognoses of ice formation based on comparison single empirical methods for the ice formation forecast in the free atmosphere and methods based on regression model. Results of prognoses is value 1, which means an icing will occur, or 0, when appropriate method will ice formation reject. Method are ordered according to their long-term successfulness assessed by single criteria (CSI, POD, FAR, BIAS, HSS, EQS), that is as well possible before calculation determined. This procedure leads to a prognosis that is not dependent upon subjective guesswork of meteorologist, because to users isn't given any possibility to influence prediction work. The issue has been also theoretically described and partly solved in doctoral thesis. Problems reaching without doubts behind limits of this work due to improve the quality of prognoses of ice formation are quality of input data. Accuracy of prognoses of thermal and moisture characteristics coming into the calculation then will have a direct influence on prediction of ice formation thereby will presage limits of quality of prediction.

For this purpose can be used method of logistic regression but best idea is linked with genetic algorithms. Hopefully we will see in future.

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