Forecasting the formation of radiation fog

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Abstract: - Fog formation is complex; its occurrence is widely variable in space and time, forming under a wide range of meteorological circumstances. In all cases it forms as a result of air near the surface becoming saturated and being cooled below its dew point. The main goal is developed method for fog forecasting on different territory based on the real data observations routinely done in meteorological practice.

Key-Words: - radiation fog, Craddock and Pritchard's method, meteorological data, true skill statistic, verification

1 Introduction

The formation of fog is a complex phenomenon and depends upon a delicate balance of events; although it is easily recognisable on most occasions by about midday that the following night is likely to be a radiation night, the problem of forecasting the occurrence of fog is often a very difficult one. The factors favourable for the formation of radiation fog might be specified as following:

1. Clear sky or just thin, high cloud,
2. Moist air in the lowest 100 m or so,
3. Moist ground (e. g. after rain or over marshes),
4. Slack pressure gradient, allowing the surface wind (preferably measured at 2 m) to decrease to near calm,
5. Favourable local topography.

Although it may seem that the rehearsal of terms for fog formation is complete, it is still necessary to bear in mind the importance of local factors such as surface moisture and topography because there is no substitute for a good knowledge of the specific characteristics of your area.

Radiation fog forms when radiative cooling of the ground causes the air close to it to become saturated. Once the ground temperature has cooled to the dew point of the air (T_d), dew deposition begins, causing a gradual decrease in dew point. Water vapour will diffuse from higher levels to replace that condensed out, leading to a drying out of the air over a considerable depth. Hence the temperature will normally have to fall significantly below the air mass dew point before fog forms. The temperature at which fog eventually forms is known as the fog point (T_f).

One of the most difficult meteorological phenomenons to predict is formation of fog. The main goal of this work is developed methods for fog forecasting on different territory based on the currently used method in meteorological practise.

2 Fog occurrence observed on air meteorological station on territory of the Czech Republic

A number of techniques have been developed to enable T_f to be determined. The technique used for forecasting of fog in this article is described below. These new methods then will be evaluated on real data. In order to forecast of fog the value of air temperature, dew point temperature in 12 UTC and minimum temperature (observed during forecasted period) were chosen as predictors. In extensive form also the visibility and relative humidity in 12 UTC and mean cloud coverage (taken from 18, 0 and 6 UTC) were included.

Occurrence of fog has been forecasted on all military air meteorological stations located in Prague-Kbely (WMO indicative 11567), Caslav (11624), Pardubice (11652), Namest (11692) and Prerov (11748). All data with view to obtain predictors were decoded meteorological reports SYNOP of these stations during the August 1997 to the May 2010. Existence fog has been was identified according to code described present and past weather state at the station. Table 1 shows which present weather code were accepted and figure 1 record relative frequency of weather state from table 1 during given period divided by stations.

Table 1: Present weather code table with fog

code figure	weather description
11	Patches of shallow fog. It is not thicker than about 2 metres above ground level, and the visibility above the shallow fog is 1000 metres or more
12	More or less continuous shallow fog. It is not thicker than about 2 metres above
28	Fog cleared in the last hour. Visibility must be now 1000 metres or more

40	Fog visible at a distance, but the visibility at the station is 1000 metres or more. there must have been no fog at the station during the preceding hour
41	Visibility less than 1000 metres in some directions but not in others
42	Fog getting thinner during the last hour, sky or clouds visible
43	Fog getting thinner during the last hour, sky or clouds not visible
44	No change in the fog during the last hour, sky or clouds visible
45	No change in the fog during the last hour, sky or clouds not visible
46	Fog getting thicker during the last hour, sky or clouds visible
47	Fog getting thicker during the last hour, sky or clouds not visible
48	Fog depositing rime, sky or clouds visible
49	Fog depositing rime, sky or clouds not visible

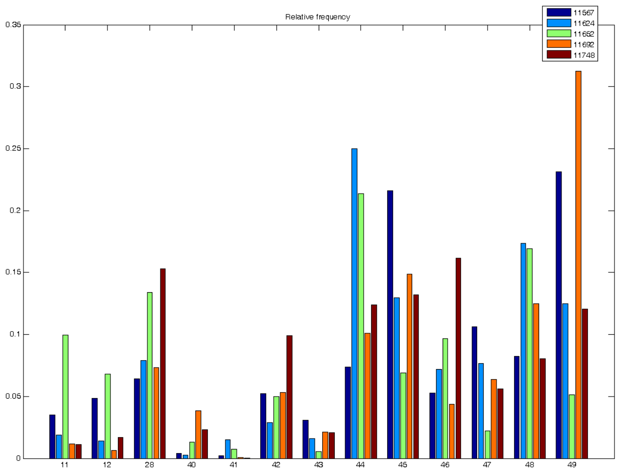

Fig. 1 Relative frequency of fog occurrence

The most frequent occurrence of fog has been observed at the station Namest (11692) and the opposite view has been on station Caslav as it is depicted on figure 2. The legend is described accordingly. Symbol 0 means fog has not been observed and visibility in all directions must be more than 1000 metres, symbol 1 means fog occurred and start up during night (18 – 06 UTC), symbol 2 means fog occurred, but had arisen before 18 UTC, symbol 3 means visibility has been less than 1000 metres. If the column on figure 1 is split, then the upper part belongs to cases when patches or shallow fog occurred (the same rule applies on following figures).

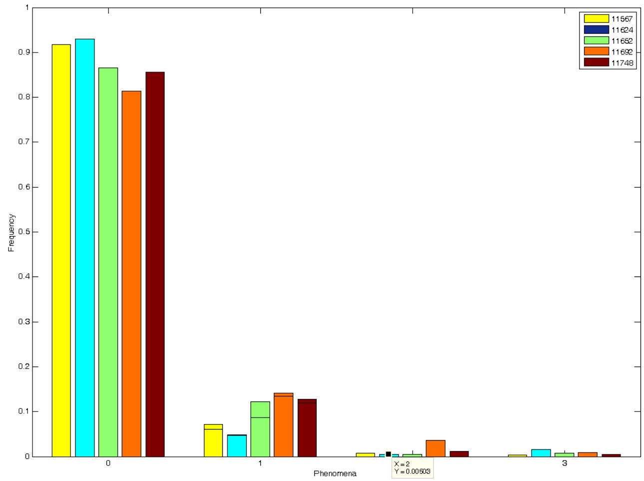

Fig. 2 Frequency of fog during period 18 – 06 UTC

On figure 3 there is depicted frequency of fog during the years in period 1997 - 2010, maximum in October and November, and minimum for June and July. Patches or shallow fog occurred mostly in Pardubice (11652); during in summer period forged almost 50% of whole cases of fog. These could be explained by presence of river Labe in vicinity of meteorological station. Here is also necessary to say all results are crucially dependent on quality of observations because visibility is temporarily and also spatially highly variable.

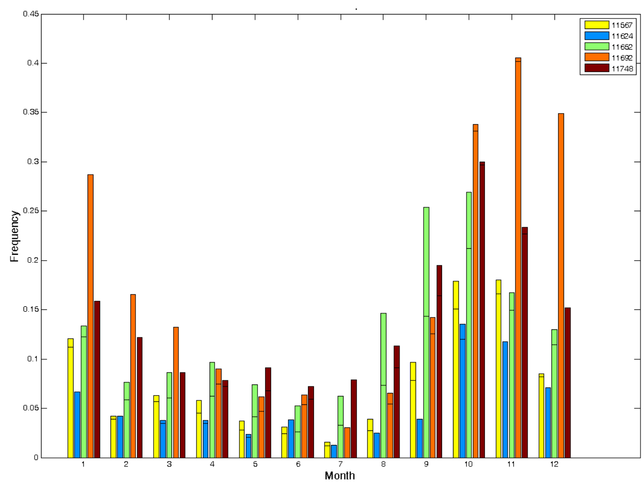

Fig. 3 Frequency of fog during years

On figure 4 is depicted ratio of cases when the precipitation (rain, snow etc.) has not been observed in period from 12 (18) UTC to 06 UTC on station. Those are exactly the cases of radiation fog we focused in.

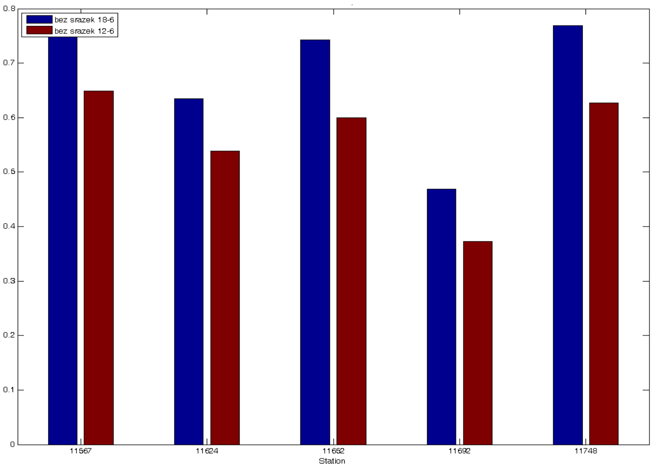

Fig. 4 Ratio of cases with fog but without precipitation

3 Equations for fog temperature calculation

Process to obtain the equation to set down temperature for formation of fog T_f has been prepossessed with Craddock and Pritchard's method for forecasting of fog. This method of assessment of T_f is based on measured values of air temperature T and dew point temperature T_d in 12 UTC. If the forecasting value of minimum temperature T_{min} will be lower than T_f then the fog could be presupposed, if it be to the contrary no.

For obtaining of prognostic equation only the nights in which the fog occurred have been involved. The exact value of T_f has been derived as temperature of air in term when fog occurred for the first time. Dependence on predictors was figured out by means of linear regression. The best results have been found in following expressions:

$$T_f = a_0 + a_1.T + a_2.T_d \quad (1)$$

$$T_f = a_0 + a_1.T_d \quad (2)$$

$$T_f = a_0 + T_d \quad (3)$$

$$T_f = -0{,}55 + 0{,}044.T + 0{,}844T_d \quad (4)$$

From introduced equations imply follows that fog will set in if applies to

$$T_f + A > T_{min} \quad (5)$$

Parameter A has been defined by maximum value of EQS (Hanssen and Kuipers discriminant) in given set of data for every station separately. To obtain these equations for forecasting T_f, but especially of radiation fog, only days satisfactory next terms were accepted, therefore, no precipitations after 12 UTC together with no difference more than 5 °C between dew point temperature T_d in 6 UTC (at the end prediction interval) and T_d of prior day, i.e. no change of air masses.

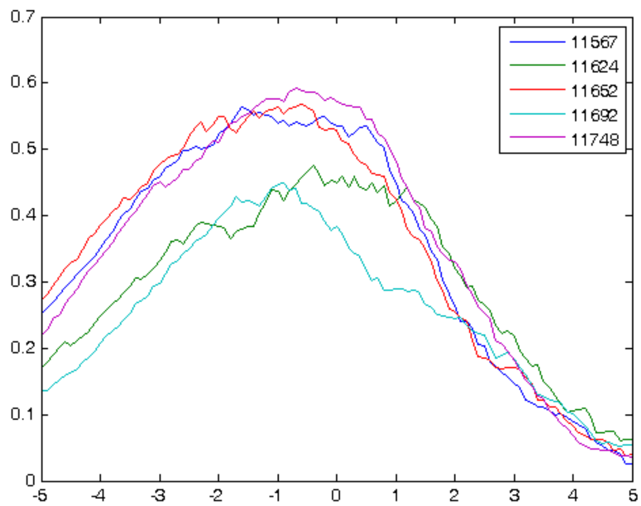

Fig. 5 Assessment of parameter A according to EQS

Other tested possibility consists in utilization of classes selected meteorological elements (table 2). Also for these selected elements were founded independent equations for T_f assessment. Consequential parameter A has been added on to the value of T_f.

Table 2: Classes of selected meteorological elements

meteorological element	chosen classes			
visibility at 12 UTC	< 1 km	1–2,5 km	2,5–10 km	> 10 km
relative humidity at 12 UTC	< 70 %	70 –90 %	90 –95 %	> 95 %
mean cloudiness (18-06 UTC)	< 2/8	3/8 – 4/8	5/8 – 6/8	> 6/8

4 Results

For evaluation of successfulness given methods with calculated parameter A were chosen statistical criteria EQS (true skill statistic), POD (probability of detection) and FAR (false alarm ratio).

These section will illustrated by the help of enclosed graphs. On graphs are depicted acquired values of EQS, FAR and POD for particular stations and every method. Crosses in graphs signify values without correction for relative humidity and visibility (further in text DOD). Values of EQS belong to interval from 0,4 to 0,6. Expressive improvement with DOD is only on stations where fog is observed only rarely (improvement for 11624 about 0,15), on the contrary on stations where fog is frequent phenomenon (11692 and 116520 there is none progressive improvement noticeable.

The highest value of EQS we got for station 11748, the worst for 11692. Among methods the best results are provided mostly by method (2) and (3), the worst by method (1). Influence of utilization of classes selected meteorological elements is rather negligible crosswise all stations. POD achieving mostly about 0,8, i.e. 80% of all fog occurrence cases have been detected. On the other had high values of FAR are main insufficiency of all methods. Average values of FAR vacillate among 0,85 (11652) to best 0,6 for Prerov (11748).

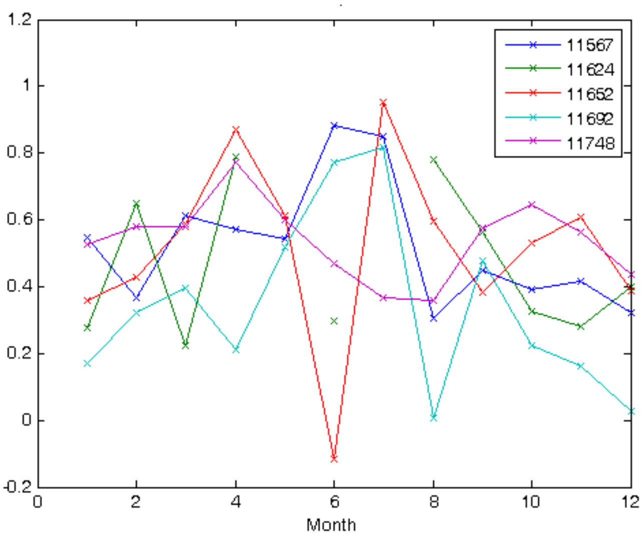

Fig. 6 Values of EQS

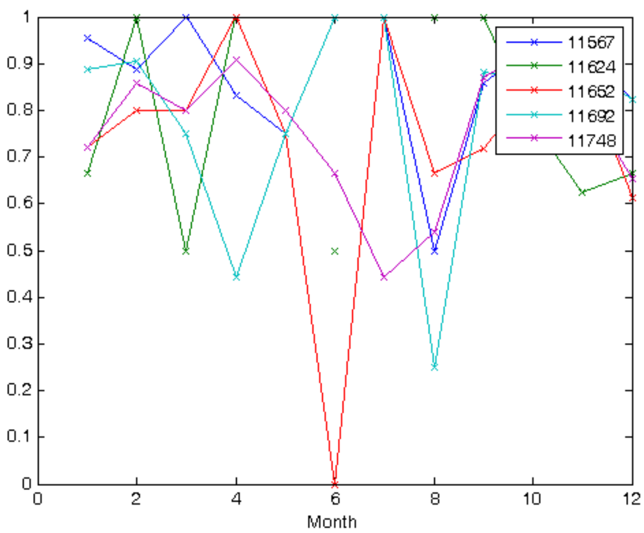

Fig. 7 Values of POD

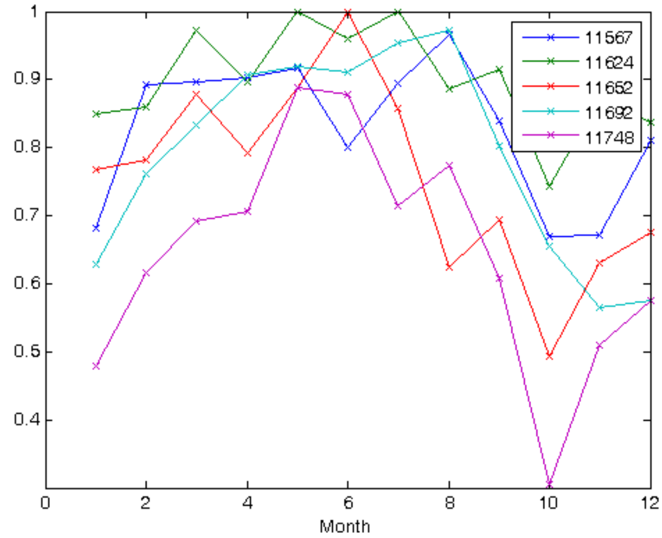

Fig. 8 Values of FAR

5 Conclusion

In this paper is shown how could be quite old Craddock and Pritchard's method for forecasting of fog adjusted for utilization on territory of the Czech Republic. Generally speaking we supposed much better results. But it is obvious that fog formation is complex; its occurrence is widely variable in space and time, forming under a wide range of meteorological circumstances. In all cases it forms as a result of air near the surface becoming saturated and being cooled below its dew point. Unfortunately only this is easy to say regarding occurrence of fog.

6 Acknowledgement

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