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Contribution to Prediction of Temperature

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Abstract:

Techniques for forecasting extreme temperature are mostly empirically based, using collections of statistics over a long period of time for a range of weather situations. In the article we have used the McKenzie's method for forecasting the minimum temperature and Callen and Prescott's method for forecasting the maximum temperature. Both of methods belong among the successfully and routinely used techniques. Main aim is to adjust these methods for routine application on aerodromes currently used by Czech Air Force.

Keywords:

Minimum and maximum temperature, forecasting techniques, meteorological data, correction factor, verification

1. Introduction

Temperatures 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 weather 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.

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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 therefore follows 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 to modify the general forecast to allow for the local climatology.

2. Forecasting Techniques for Extreme Temperature Prediction

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. [9]

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.

McKenzie's method, a very popular method for minimum temperature prediction, uses the maximum temperature and the dew-point at the time of maximum temperature, together with a set of correction factors for clouds and wind. Correction factors are available for many stations around the Great Britain and beyond. The technique is very simple to apply, and its advantage is 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 an advantage of taking local factors into account. The night-time minimum air temperature (Tmin) can be forecast as follows:

$$T_{\min} = 0.5(T_{\max} + T_d) - K \tag{1}$$

where symbol $T_{\max}$ represents maximum temperature, T_d is 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 a very significant value which amends the forecast number of $T_{\min}$ by correction on clouds effect and wind. As it 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. [6]

Callen and Prescott method developed for maximum temperature prediction is based on the thickness of the 1000–850 hPa layer. There is an obvious link between thickness and temperature, which is exploited by this method – the higher the thickness, the greater the maximum temperature. Adjustments are made for the time of the year and cloud amount. The advantage of this method is that it provides a very simple guide to maximum temperatures over a large area, based on a map showing 1000–850 hPa thicknesses. Such maps are available as NWP output for several days ahead, so the method may be applied to longer-range temperature forecasts.

3. Adjustment of Mckenzie's Technique on Territory of the Czech Republic

McKenzie's method for forecasting of the minimal temperature has been adjusted on currently used Czech Air Force bases Prague-Kbely, Caslav, Pardubice, Namest and Prerov. The process consists of 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 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} read from extreme thermometer at 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 the number of measurements exceeds more than 10. Otherwise values were interpolated from contiguous groups (marked by *) as it is shown in following tables.

Tab. 1: Values of local constant K for Prague 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	3.0
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	5.0	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*

Tab. 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*

Tab. 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*

Tab. 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*

Tab. 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 Technique

Verification of McKenzie's method was performed on minimum temperature measurement array on the above-mentioned air bases in the 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 the number of observations and attempts to forecasts. [2]

Tab. 6: Comparison of forecasted and recorded minimum temperature values statistics

Station	N	RMSE [°C]	BIAS [°C]	MED [°C]	MIN [°C]	MAX [°C]
11567	793	2.1	–0.2	–0.4	–6.4	8.5
11624	787	2.2	–0.2	–0.5	–7.2	12.6
11652	797	2.4	–0.4	–0.6	–8.5	12.5
11692	555	2.1	0.2	–0.1	–7.1	12.2
11748	805	2.2	–0.3	–0.5	–6.2	9.0

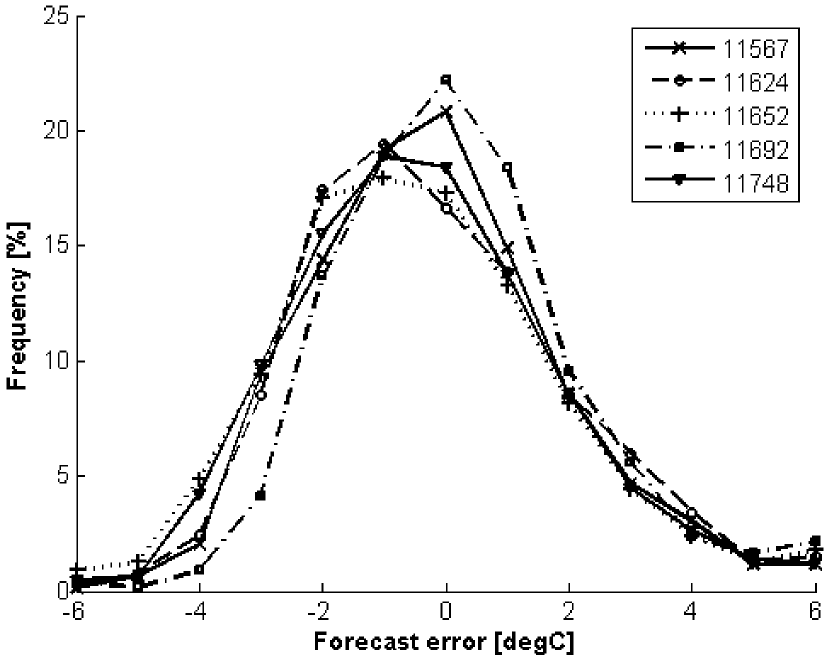

Fig.1 Differences between forecasted and recorded values of minimum temperature during whole period

With regard to numerical value of root mean square error, it is possible to mention c. 70 percent of forecasted minimum temperature is with departure less than 2 °C, which means that modified McKenzie's method could be sufficient. On the other hand, method, according to the statistics, has a tendency to 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. Adjustment of Callen and Prescott's Method on Territory of the Czech Republic

This is an empirical method based on the maximum temperatures observed at Gatwick and the 1000–850 hPa thickness values at midday at Crawley. To accomplish our main goal, i.e. to adjust the method for routine application on the territory of the Czech Republic, we have used the data of maximum temperature from Prague – Kbely, Caslav, Pardubice, Namest and Prerov, currently used Czech Air Force Bases and the 1000-850 hPa thickness, i.e. the difference in height between two atmospheric pressure levels.

There are three steps:

(1) Classify the cloud cover or presence of fog between dawn and 1200 UTC on a scale from 0 to 2 (see Tab. 7). Values for classes were chosen so that approximately coequal amount of observations was included in every class.

(2) Using Figs. 2-6, to obtain the temperature adjustment for the month for the appropriate cloud class.

Tab. 7: Delimitations of classes

Classes	Cloudiness (in octas) and other meteorological phenomena
0	CL + CM + CH ≤ 3/8
1	all other cases
2	CL + CM ≥ 6/8 predominately with precipitation or persistent fog

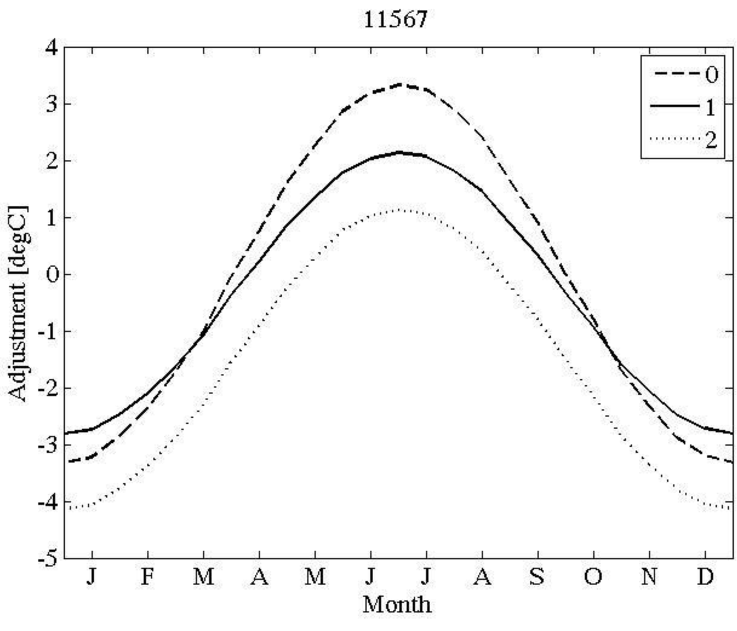

Fig. 2 Adjustment for Prague Kbely Airbase (indicative WMO 11567, ICAO LKKB)

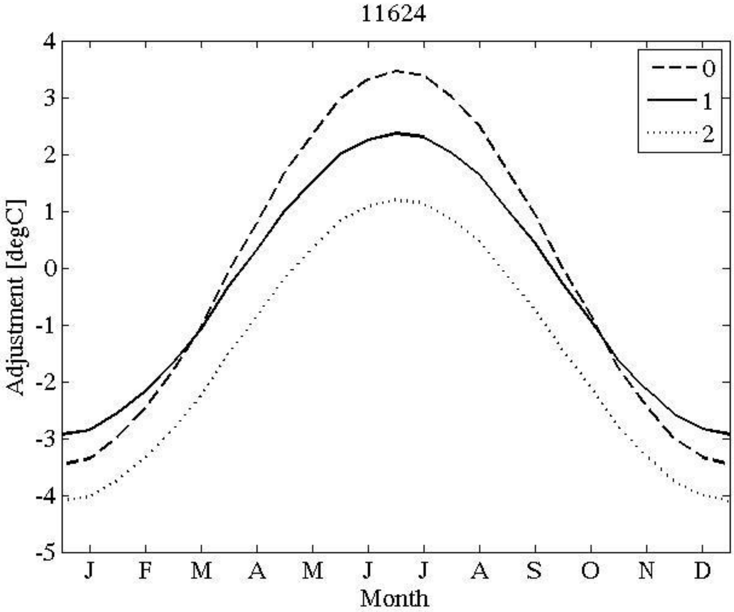

Fig. 3 Adjustment for Caslav Airbase (indicative WMO 11624, ICAO LKCV)

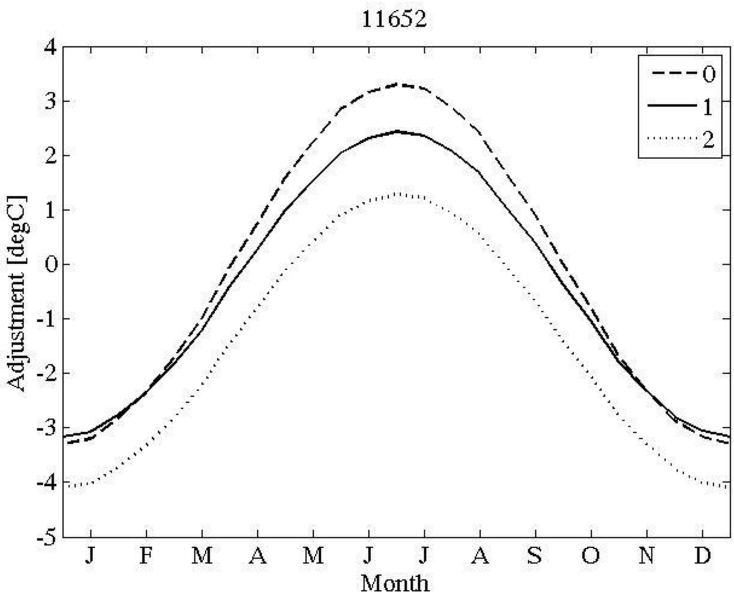

Fig.4 Adjustment for Pardubice Airbase (indicative WMO 11652, ICAO LKPD)

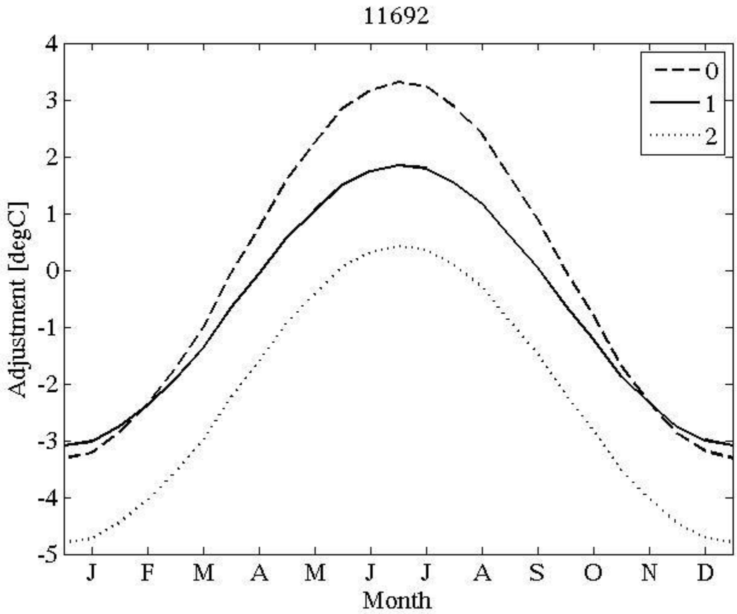

Fig. 5 Adjustment for Namest Airbase (indicative WMO 11692, ICAO LKNA)

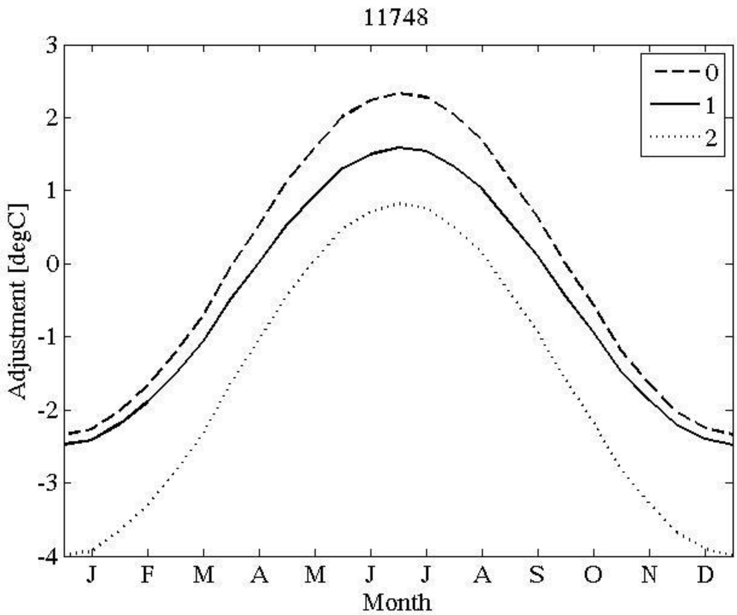

Fig.6 Adjustment for Prerov Airbase (indicative WMO 11748, ICAO LKPO)

(3) Apply this adjustment to the values given by equations (2-6) to calculate the predicted maximum temperature. The relationship between 1000-850 thickness (*h*) in

geopotential meters (gpm) and the unadjusted maximum temperature (T_u) is given by the following equations for Airbase Prague-Kbely (11567), Caslav (11624), Pardubice (11652), Namest (11692) and for Airbase Prerov (11748)

$$T_u = -237.23 + 0.1877h \tag{2}$$

$$T_u = -236.95 + 0.1879h \tag{3}$$

$$T_u = -239.37 + 0.1897h \tag{4}$$

$$T_u = -229.39 + 0.1814h \tag{5}$$

$$T_u = -252.09 + 0.1991h \tag{6}$$

The process consisted in derivation of those equations. For this reason aerological reports (TEMP) from 1997 till 2010 coming from aerological station Prague-Libus and Prostejov in order to find 1000-850 hPa thickness were decrypted. For processing, maximal temperature (T_{max}) of day from mentioned airbases were chosen. It could be easily obtained from meteorological reports SYNOP in given years.

6. Verification of Callen and Prescott's Technique

Verification of Callen and Prescott's method was performed on maximum temperature measurement array on the above-mentioned air bases in the period of years 2006-2009. For every air meteorological station, the following values were calculated: root mean square error (RMSE), bias (BIAS), median (MED), minimal variation (MIN), maximal variation (MAX) according to the number of observations and attempts to forecasts. [1]

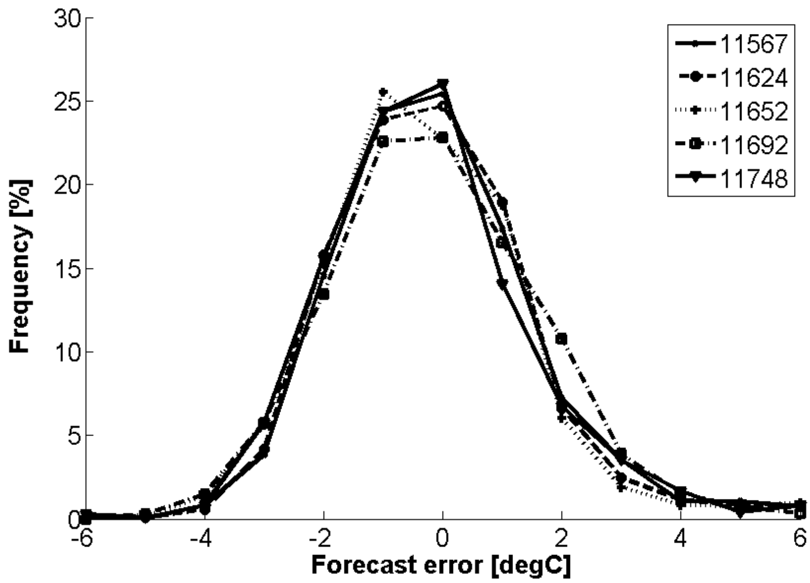

Fig.7 Differences between forecasted and recorded values of maximum temperature during whole period

Tab. 8: Comparison of forecasted and recorded maximum temperature values statistics

station	N	RMSE [°C]	BIAS [°C]	MED [°C]	MIN [°C]	MAX [°C]
11567	1223	1.7	–0.1	–0.3	–6.1	9.9
11624	1223	1.7	–0.2	–0.3	–6.7	10.1
11652	1214	1.7	–0.3	–0.4	–6.5	10.4
11692	1219	1.8	–0.1	–0.3	–4.8	7.6
11748	1219	1.8	–0.3	–0.4	–6.6	8.9

7. Conclusion

The temperature of the near-surface air is influenced primarily by the underlying surface temperature. This is also the main reason why tested relations are so locally different from place to place. The problem of methods consists in the incapability to take into account the advective changes. Temperature forecasts are produced routinely by various numerical meteorological models, describing advective changes on more realistic base. The raw numerical model outputs provide comparable values of statistics criteria of verification. The statistical post-processing could be used for the improvement of the results coming from the models.

Adjustment of McKenzie and Callen and Prescott's techniques for the territory of the Czech Republic could become a very useful tool in particular forecast, especially for dangerous weather phenomena. This would be utilized to link the phenomena to minimal temperature prediction, e.g. forecasting of road surface conditions. The main advantage of the aforementioned techniques is the usage of recorded values or values being often relatively well estimable, and therefore can be used in situations where other data sources are unavailable.

Precise forecasting of minimum temperature can be taken into account as the first but inevitable step in forecasting of more complex meteorological values. For the last few years, our main effort has been focused on the prediction of ice formation on road surfaces. So, it is obvious, of course, why the precise value of minimum temperature is important. With knowledge of minimum temperature value another important meteorological value known as minimum road temperature can be derived. On the other hand, the precise forecast of maximum temperature can aid road maintenance service with good timing of ground ice accretions removal. Therefore, the radiation model for ice creation prediction can be based on routinely used reliable method for forecasting extreme temperature. This will hopefully be realized in the near future.

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