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TECHNIQUES FOR SMOOTHING HOURLY DATA FOR TIMELY SMOG ALERTS ANNOUNCEMENTS

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Abstract: The Czech Republic has implemented a smog alert and regulation system for PM_{10}, SO_2, NO_2, and tropospheric ozone O_3. During last years the concentrations of PM_{10} and O_3 have been playing the most important role during winter season and summer season respectively. Remaining pollutants reach mostly concentrations far below relevant thresholds.

With respect to PM_{10}, the area of the Czech Republic is divided into 15 zones. PM_{10} smog situation is announced when 24-hour moving average of hourly concentration in one representative station exceeds the informative threshold value 100 µg.m^{-3} over 25 consecutive hours and the trend of 12-hour moving average increases at the same time over the past 6 hours in at least half of the representative stations. Using 24-hour moving average for data smoothing and condition of exceedance over 25 consecutive hours in combination with trends brings some difficulties for decision making authorities. The main problem is, that smog situation is usually announced too late, when the threshold value has been already exceeded for up to two days or even more. On the other hand the smog situation often lasts even when PM_{10} concentrations have dropped under the threshold value.

In order to solve the problem, new rules were proposed (shortening required length of exceedance, inclusion of the forecast of dispersion conditions or air quality) and also new smoothing method were examined, namely exponential filters Exponential Moving Average (EMA), Kaufmann Adaptive Moving Average (KAMA) and Triple Exponential Moving Average (TEMA). None of the methods used additional information on trend behaviour. The results obtained with exponential filters and the results from the current system were compared with measured daily averages for the years 2010–2013.

KAMA shows the best response to hourly data behaviour, but smoothing is insufficient. KAMA filter also causes higher number of false smog alert announcements. The best results for our purpose were obtained with TEMA filter, which seems to be a good compromise among smoothing, quick response and a good applicability to the legislation.

Key words: *Czech Republic, smog alert system, PM_{10}, smoothing filters*

INTRODUCTION

Smog alert and regulatory system in the Czech Republic

Czech Hydrometeorological Institute (CHMI), authorized by the Ministry of the Environment, operates the Smog Alert and Regulatory System (SARS). Information provided through this system serve both for informing on the extraordinary level of ambient air pollution (smog situation) and for the regulation (reduction) of pollutants released from selected sources markedly influencing ambient air quality in the given territory. The monitored pollutants include PM_{10}, SO_2, NO_2 and ground-level ozone (O_3).

Starting from 1 September 2012 the operation of SARS is set down by the Air Protection Act and by the Decree No. 330/2012 Coll.[1] Smog situations and regulations (alert for ozone) are announced on the basis

1 Decree No. 330/2012 Coll. on the method of assessment and evaluation of ambient air pollution level, on the extent of informing the public on the level of ambient air pollution and during smog situations

of the threshold values exceedances. The rules laying down the operation of SARS are presented in Table 1. Figure 1 shows the SARS areas and representative stations for PM_{10} as valid in September 2012.

Table 1. The rules for the announcement and cancelling of smog situations and regulations (alerts)

	Threshold value			Exceedance duration	Number of stations	Supplementary condition
	Abbrev.	**µg.m^{-3}**	**Interval**			
Announcement of smog situation						
PM_{10}	**ITV**	100	24 h	2 days (i.e. 25 hours)	1 station	increasing trend of the running 12-hour averages of PM_{10} in at least half of the stations over the past six hours
NO_2		200	1 h	3 hours		---
SO_2		250				---
O_3		180		1 hour		---
Announcement of regulation (alert)						
PM_{10}	**RTV**	150	24 h	3 days (i.e. 49 hours)	50 %	increasing trend of the running 12-hour averages of PM_{10} in at least half of the stations over the past six hours
NO_2		400	1 h	3 hours		---
SO_2		500				---
O_3	**ATV**	240		1 hour	1 station	---
Cancellation						
A regulation (alert) or smog situation is cancelled if no respective threshold values are exceeded at any measuring station representative for the pollution level in the given area and this state continues without interruption for at least 12 hours (in the case of $PM_{10,}$ the moving 24-hour average concentration is lower than the respective threshold value for at least 12 consecutive hours) and the reappearance of the meteorological conditions which cause a smog situation is not anticipated based on meteorological forecasts over the course of the 48 hours following the pollution levels decline below the threshold values. The time **interval of 12 hours shall be reduced up to three hours** if the meteorological conditions are not considered to be capable of causing a smog situation and it is effectively ruled out that such conditions will reoccur over the next 48 hours based on the meteorological forecast.						

Note: ***ITV*** – informative threshold value, ***RTV*** – regulatory threshold value, ***ATV*** – alert threshold value. The requirements for the number of stations are related to the representative stations for the given SARS area.

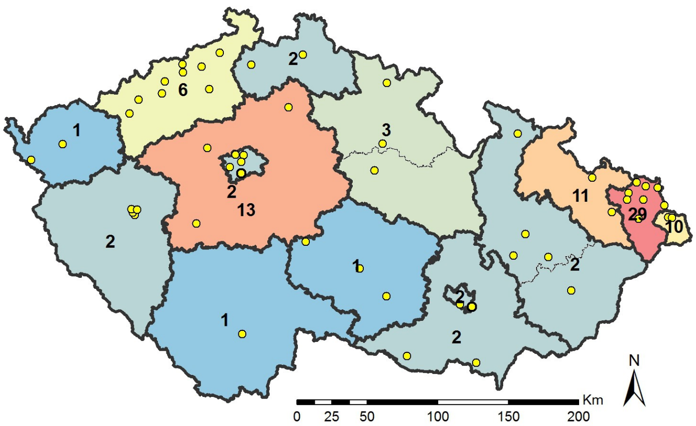

Figure 1. SARS areas and representative station for PM_{10} as valid in September 2012.
Numbers show average number of days with smog situation due to high concentration of PM_{10} in heating season (October–March) (backward analysis according current legislation period 2014/X – 2013/III; for Central Moravia zone only data for 2012/X – 2013/III were available).

Smog situations are often announced too late, sometimes even more than 2 days later after the threshold values were exceeded (Fig. 2). This is because of combination of several factors and one reason is that concentrations usually rise quickly above the threshold and then remain variable. This makes the condition of increasing trends quite hard to be fulfilled.

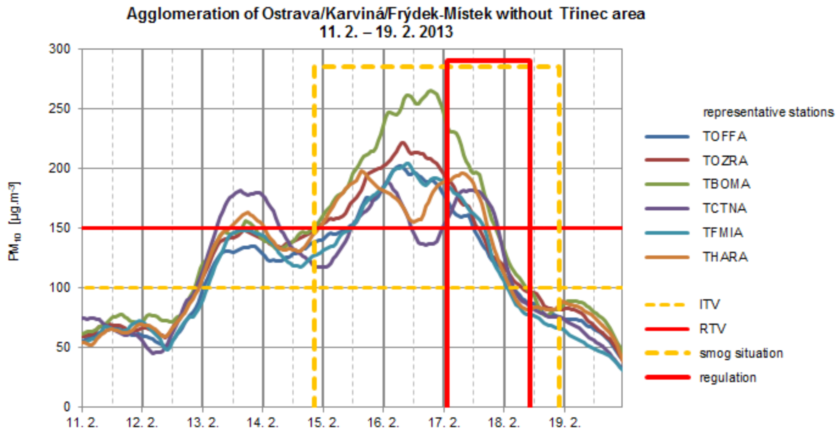

Figure 2. Delay in the announcement of smog situations and regulations under current legislation. 24-hour moving averages are shown.

METHODS

Change of SARS rules

Regarding SARS rules we tested two approaches:

1. keeping the current rules and using different smoothing. We also tried two slight modifications:
   - different tolerance for the trend of 12-hour moving averages (0, 1, and 2 $\mu g.m^{-3}$)
   - different interpretation of 2 (3) days of exceedance (i.e. interpreting 2 (3) days as exceedance of threshold value in 2 (3) non-overlapping consecutive windows od 24-hour averages)
   - for EMA, KAMA, and TEMA filters the trends were not taken into account
2. proposing new rules for PM_{10}:
   - removing trends assessment
   - announcing smog situation and regulation when threshold value is exceeded in at least half of representative stations (no condition of 2 or 3 days exceedance)
   - inclusion of air quality / dispersion condition forecast (i.e. assumption that concentrations will not drop below the threshold value within next 24 hours)

Smoothing filters

Apart from standard 24-hour and 12-hour moving average, the following smoothing filters were tested: Exponential Moving Average (EMA), Kaufmann Adaptive Moving Average (KAMA), both described by Kaufman (1995), and Triple Exponential Moving Average (TEMA, Mulloy, 1994). **EMA** is defined as follows:

$$F_t = C_t \cdot a_t + F_{t-1} \cdot (1 - a_t) \tag{1}$$

where F_t is smoothed value at time t, C_t is concentration at time t, and a_t is smoothing constant. According to Kaufman (1995), smoothing constant relates closely to the number of days n in a standard moving average by the relationship $2/(n+1)$. Thus $a_t = 0.08$ corresponds to the standard 24-hour moving average.

KAMA is defined the same way as in equation (1), but smoothing constant is adopted according to the data variability:

$$a_t = \left[ER \cdot \left(a_{fast} - a_{slow} \right) + a_{slow} \right]^p \tag{2}$$

where efficiency ratio ER is calculated as follows:

$$ER = |C_t - C_{t-m+1}| / \sum_{i=0}^{m-2} |C_{t-i} - C_{t-i-1}| \quad (3)$$

Here again C_i are 1-hour concentrations and m is the width of window used for calculation of efficiency ratio. I our calculations we used 24-hour and 72-hour window for efficiency ratio calculations. We used a_{fast} = 0.667, which corresponds to the 2-hour window (n = 2), and a_{slow} = 0.08, which corresponds to 24-hour window (n = 24). We tested two values of p: p = 2, as used in Kaufman (1995), leads in fact to the widths of windows 3.5 for quick response (ER = 1) and 311 for slow response (ER = 0); p = 1, preserves 2-hour and 24-hour windows for quick and slow response respectively.

TEMA was proposed by Mulloy (1994) and we used the following definition:

$$TEMA = 3 \cdot EMA - 3 \cdot EMA(EMA) + EMA[EMA(EMA)] \quad (4)$$

TEMA can lead to negative values in some cases. This can be solved by applying TEMA to the logarithm of concentrations or simply by putting in the restriction that TEMA must be greater or equal to 1. First approach can sometimes lead to slight overshoots (compared to “standard” TEMA). Therefore we applied the second approach, which is sufficient for our purposes since we are not interested in concentrations close to zero.

Behaviour of different filters is shown in Figure 3. For the sake of the clarity we do not show KAMA for p = 1, but it follows very closely 1-hour data. It can be seen that EMA behaves very similarly to 24-hour averages. The lag between TEMA and 12-hour averages exceeding threshold value can be up to 6 hours.

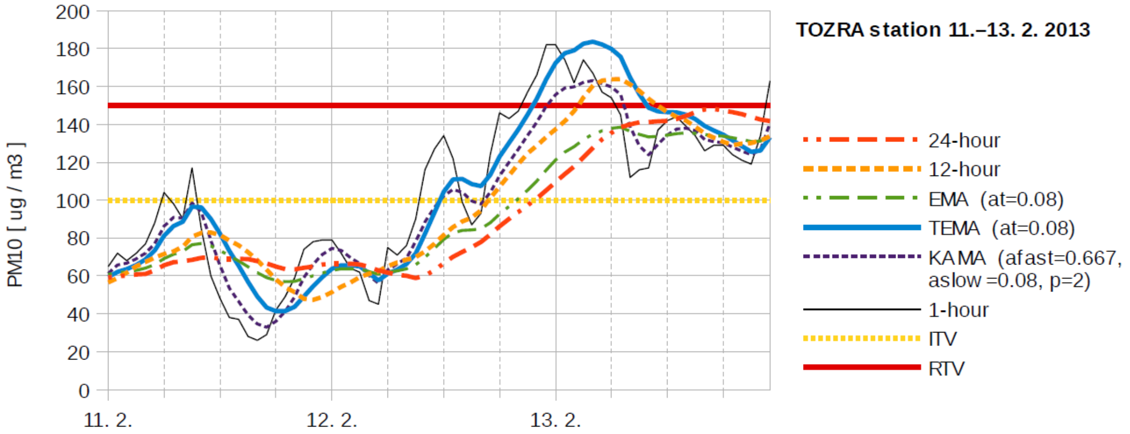

Figure 3. Comparison of different smoothing methods.

RESULTS

Figure 4 shows results of application of different smoothing under current legislation rules. In the top average daily concentrations for representative stations are shown. ***current*** denotes smog situations and regulations announced according the current rules. ***24-h T12 > thresh*** shows the same situation except that the trend od 12-h moving averages is taken as increasing if it is greater then *thresh*. In ***24-h NO T12 > thresh*** two (three) nonoverlaping consecutive 24-h averages are evaluated instead of 25 (49) 24-h moving averages. ***EMA***, ***TEMA***, and ***KAMA*** shows results when different exponential filters were used. In these cases the trends were not evaluated.

Different trend tolerance did not bring significant improvement. Using 24-hour averages in non-overlapping windows advanced a bit announcement of smog situation and regulation. Using exponential filters led to higher flexibility in announcing regulation, but they often lasted when the concentrations had dropped under threshold.

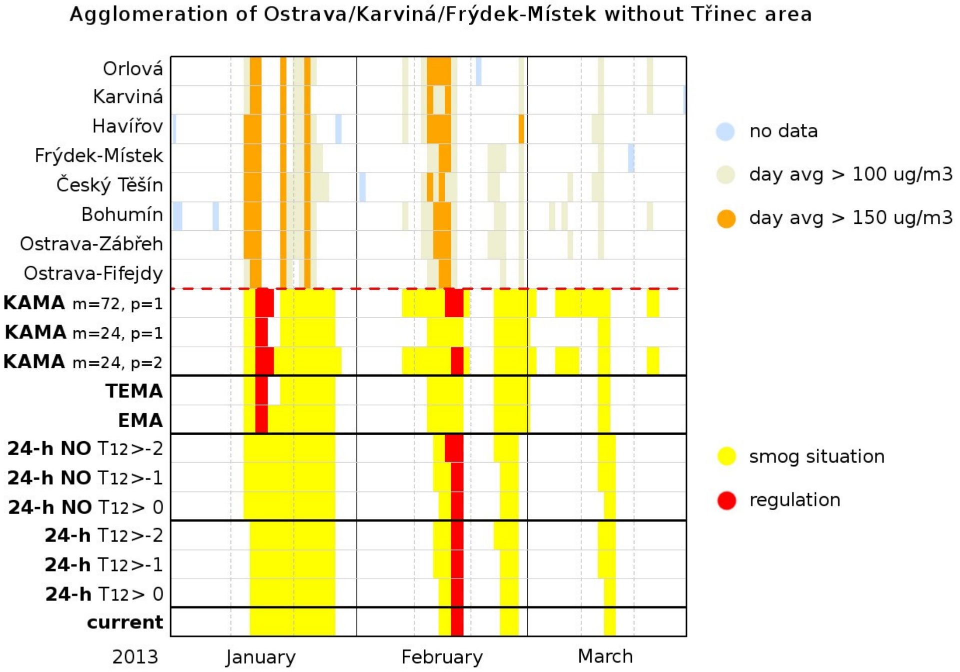

Figure 4. Comparison of different smoothing methods under the current SARS rules.

Figure 5 shows results for the new rules. Both 24-hour moving averages and TEMA are now more flexible especially in regulation announcement. Usage of TEMA leads to timelier announcement smog situation and regulation announcement. We hope that new legislation will adopt these rules and use of the TEMA smoothing.

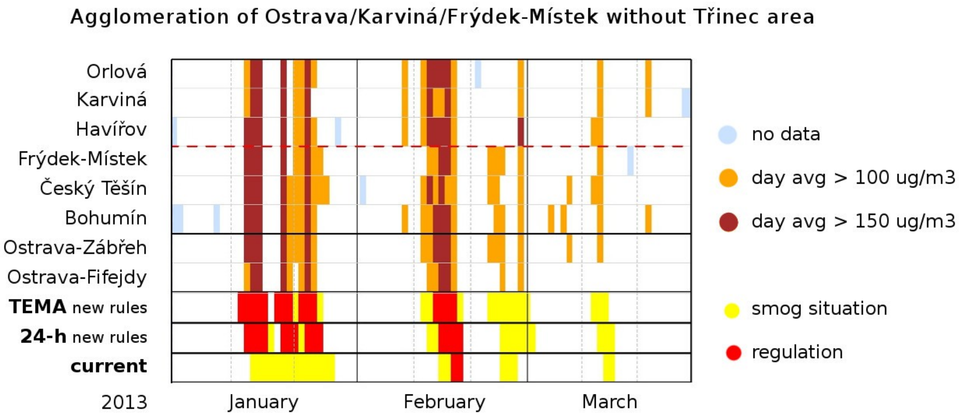

Figure 5. Comparison of the current and newly proposed SARS rules.

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