Air Quality Trends in Southern Hungary

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1. Introduction

Air pollution is one of the most important environmental problems, especially for cities.

The aim of the present study is to determine temporal characteristics and statistical interrelationships of air pollutants as well as to model the univariate and the joint tail behaviour of them. The air pollution load, including its human biometeorological assessment, is also estimated.

Concentrations of CO, NO, NO_2, SO_2, O_3 and particulates from the air quality monitoring station, at Szeged downtown, for the period 1997-1999, were used in this study.

2. Methodology

2.1. Extreme value analysis

The joint occurrences of extreme high values for CO-NO pairs are studied, using a step-by-step analysis, in order to model the univariate and the joint tail behaviour of the pollutants.

As most of the extreme value analysis methodology is suitable for independent and identically distributed observations, the basis of our study was formed by weekly maxima of the detrended and deperiodised data. This procedure made it possible to avoid that the high number of usually small values outweigh the most important larger ones.

2.2. A Special Case of the Two-Sample t-Test

A new statistical test was developed by Makra for counting if there was significant difference between expected values of non-independent data sets (Makra, et al., 2000; Tar, et al., 2000).

The developed expression $\dfrac{\overline{M}-\overline{m}}{\sqrt{\dfrac{N-n}{N\cdot n}}\cdot\sigma}$ is a probability variable with N(0;1) distribution. (1)

From the table of the distribution function of the standard normal distribution, it can be determined that x_p to a given $0 < p < 1$ number, for which:

$$P\left(\left|\frac{\overline{M}-\overline{m}}{\sqrt{\frac{N-n}{N\cdot n}}\cdot\sigma}\right| > x_p\right) = p \ . \quad (2)$$

If the absolute value of the above probability variable with N(0;1) distribution is higher than x_p then it is said that $\overline{M}$ and $\overline{m}$ differ significantly. The 0-hypothesis, according to which there is no difference between $\overline{M}$ and $\overline{m}$, is realised not more than at the critical p probability. Significance-tests are carried out at p = 0.01 probability level.

2.3. Numerical Expression of Air Pollution Load

The air quality stress index (AQSI) can be determined for mean and short term air pollution loads. It considers only the following components: sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and total suspended dust (TSD) (Mayer, 1995).

The air quality stress index (further:AQSI) for mean air pollution ($AQSI_1$) is given as follows:

$$AQSI_1 = 1/3 \cdot [I1(SO_2)/50 + I1(NO_2)/50 + I1(TSD)/50] \quad (3)$$

The AQSI for short-term air pollution ($AQSI_2$) is given below (after Mayer, 1995):

$$AQSI_2 = 1/3 \cdot [I2(SO_2)/125 + I2(NO_2)/150 + I2(TSD)/150] \quad (4)$$

3. Results and Discussions

3.1. Modelling extreme values of CO and NO

Daily maxima of CO and NO are shown in Fig. 1.

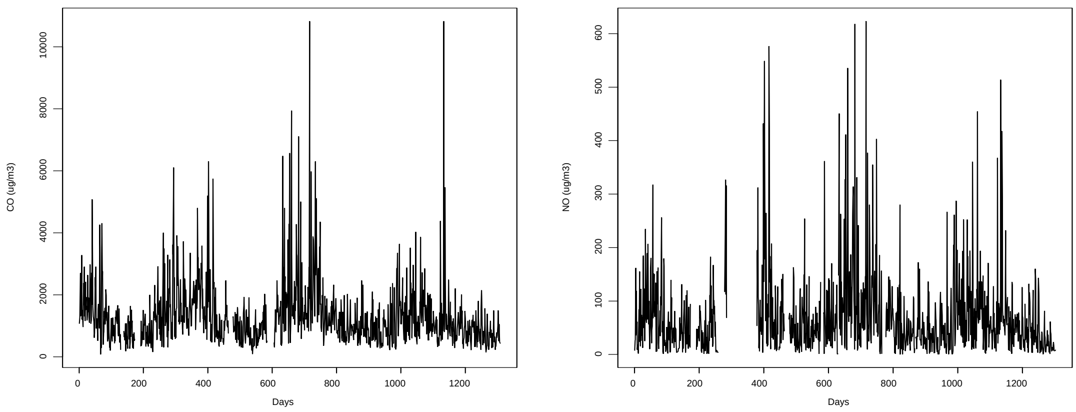

Fig. 1. Daily maxima of CO and NO at the air quality monitoring station, Szeged downtown, for the period 1997-1999.

We concentrate on the dependence of high values for both pollutants. The joint distribution can be modelled by the logistic bivariate extreme value distribution, for which the probability of exceeding high values in both coordinates can be given as:

$$P(X > x, Y > y) = \exp\{-(x^{1/r} + y^{1/r})^r\} \quad (5)$$

($0 < r < 1$ is the parameter, estimated by different methods). We estimated the so-called tail dependence coefficient χ, which corresponds to the parameter r in (5) as $\chi = 2 - 2^{1/r}$ (Coles, et al., 1999). Before estimating these quantities, we transformed the marginals of the weekly maxima into uniform distributions (first plot of Fig. 2).

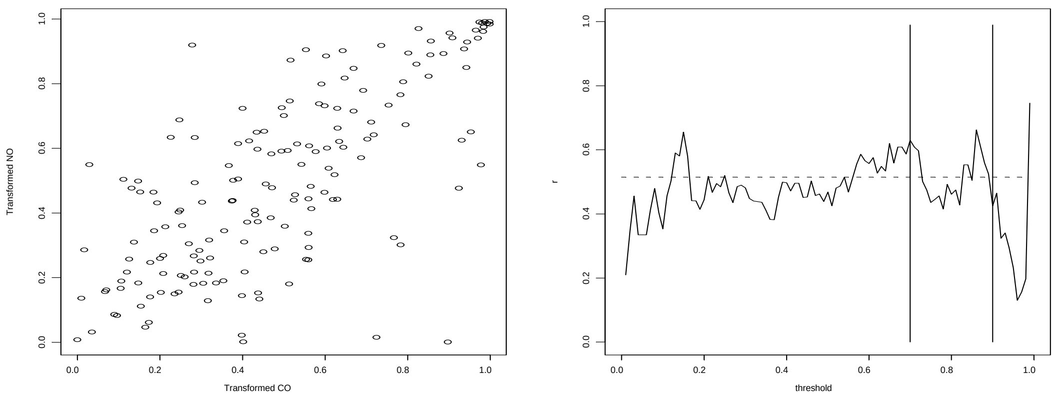

Fig. 2. Scatterplot of transformed (to uniform in both variables) data (first graph); the dependence of the estimated value of r on the threshold (the values between the vertical lines provided the actual value, shown by the dotted line, second graph)

One can see the strong dependence between the coordinates. To estimate the parameter r or χ, one has to define thresholds, where only the observations higher than the given threshold play a role in the estimator. The curve shown in the second part of Fig. 2. shows the different estimators for r, depending on the threshold. As we are interested in the dependence for the extremes, we decided to take thresholds between 0.7 and 0.9 into consideration (see the vertical lines; we excluded the thresholds higher than 0.9 because the high variation, which is due to the limited number of observations here). We accepted the average of the values in this area as our first estimator (r=0.5155;

see the dotted horizontal line).We used two other methods for estimating r, too: maximum likelihood and a moment-type estimator. The results are given in Table 1.

Table 1. Comparison of different estimators for the logistic model

(CO, NO) in μg/m^3	Estimator based on χ	Maximum likelihood	Moment-type
r	0.5155	0.4608	0.4951
	return period in years	return period in years	return period in years
(6000,500)	3.934	3.603	3.802
(8000,600)	9.333	9.809	10.128
(14000,900)	105.0613	99.46	102.74

One can summarise the results as follows: the difference among the estimated periods is less than 10%, with the largest value given by the estimator based on χ, which is probably due to the fact that here only the higher values were taken into consideration, which seems to be appropriate in our case, where one cannot hope for perfect fit of the extreme value model (supposed for the ML method).

3.2. Temporal Variability of Air Pollutants

Fig. 3. shows the annual cycles of NO, NO_2, O_3 and O_x at the air quality monitoring station, Szeged for the period between 1997-1999. O_x is a measure of the O_3 concentration, contained in an air mass. It is defined as the sum of NO_2 and O_3 and is more suitable for the assessment of the photochemical O_3 budget than O_3 alone, because it takes account of reversible chemical processes (Mayer, 1999).

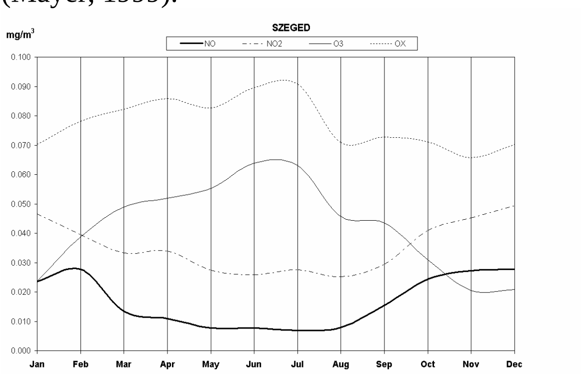

Fig. 3. Average annual cycles of NO, NO_2, O_3 and O_x at the air quality monitoring station, Szeged downtown, for the period 1997-1999.

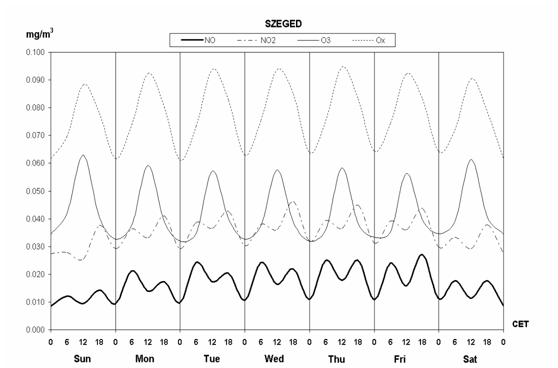

Fig. 4. Average weekly and diurnal cycles of NO, NO_2, O_3 and O_x at the air quality monitoring station, Szeged downtown, between 1997-1999.

The diurnal cycles of O_3 and that of O_x show a clear daily course with one wave, while those of NO and NO_2 have the shape of a double wave, with bigger amplitudes for NO than for NO_2 (Fig. 4.).

Average weekly and diurnal cycles of the pollutants at Szeged show lower values and extremes with less amplitudes, compared to those of Stuttgart. O_3 peak values show a maximum during weekend (Fig. 5.). Highest peak values of NO occur most frequently in the evening, while its local maxima are in the morning (Figs. 6.) (Mayer, 1999).

3.3. Significance between Averages in Non-Independent Data Sets

By applying the Makra-test, the most long-term periods (91-133 months) (data are from RIE stations), which are significant, are negative. The amount of deposited dust decreased considerably. Significant subperiods in the data sets of NO_2 and SO_2 concentrations do not show a clear difference.

3.4. Human Biometeorological Assessment of Air Pollution Load

Air quality, as for the human biometeorological assessment of the mean air pollution ($AQSI_1$), considerably improved at Szeged. Its values in 1998 and in 1999 were 0.606 and 0.448, respectively. Hence, the city answers the air pollution load of level I (Mayer, 1995).

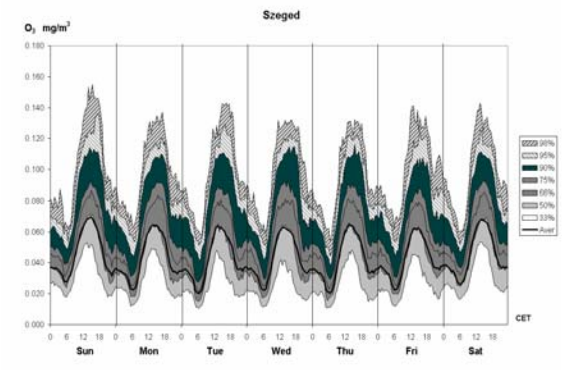

Fig. 5. Average weekly and diurnal cycle of percentile values of O_3 at the air quality monitoring station, Szeged downtown, for the period 1997-1999.

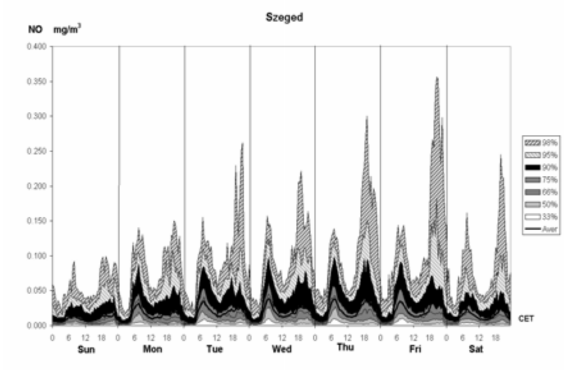

Fig. 6. Average weekly and diurnal cycle of percentile values of NO at the air quality monitoring station, Szeged downtown, for the period 1997-1999.

Difference in daily air pollution load ($AQSI_2$) between weekday and non-weekday (including Saturday, Sunday and holiday) was also studied. The results indicated that $AQSI_2$ increased in weekdays and decreased during the weekends. The air quality improves definitely on Saturdays in the summer half-year as well as on holidays in the winter half-year.

In order to get an overview of the air pollution load at Szeged, the number of days were selected in 1998 and 1999, on which daily air pollution load ($AQSI_2$) exceded the given levels (Matzarakis and Mayer, 1995). As regards the results, winter half-year is more characteristic in occurrences of days with heavier pollution load, than summer half-year. The air quality for short term air pollution substantially improved from 1998 until 1999.

CONCLUSIONS

- The extreme value analysis showed strong dependence between the components of the pair (CO,NO) (we have got similar patterns for most of the other pairs as well) for the whole range of observations. Thus the bivariate modelling allowed us to give much more exact return periods for given joint threshold than it would have been possible, based on univariate analysis only.
- Average annual cycle of O_3 is opposite to that of NO.
- Concentrations of O_3 and NO in a middle-sized Central-European city (Szeged) are lower and have extremes with less amplitudes, compared to those in a big one (Stuttgart) in a developed country (Germany).
- According to the Makra-test, long-term subperiods of deposited dust present important decrease, while those for NO_2 and SO_2 do not show a clear difference.
- The air quality stress index for mean air pollution ($AQSI_1$) has definitely decreased at Szeged. Short-term (daily) air pollution ($AQSI_2$) increased in weekdays and decreased at weekends.

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