PREDICTING URBAN SMOKE CONCENTRATIONS

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The national survey of smoke and sulphur dioxide has, since its inception in 1958, measured these general indicators of air quality in the cities and towns of South Africa. There are now 37 municipalities monitoring smoke at 147 sites (at 41 cities centres, 55 residential, 34 industrial, 14 non-white residential and 3 other sites), and 28 municipalities monitoring SO_2 at 114 sites. The data accumulated under the auspices of the survey represents a basis from which detailed statistical analysis can be undertaken.

The precision by which the Soiling Index is measured by the standard method[1] has been determined[2]. The data collected in 1985 indicated that 72% of the operational sites returned results within one Soiling Index unit, whilst 90% of the results were within two units. This assessment of the accuracy of both the sampling and subsequent analysis was repeated in June 1987. The data have yet to be fully analysed, but the interim results indicate very similar characteristics as the 1985 test.

The data collected from each of the operational monitoring stations are routinely reported in a biannual report[3]. Among other factors, the short and long-term trend tendencies of the measurements are included. As part of the analysis undertaken, the period over which each of the trend parameters are determined, was examined.

Whilst all the data from the measurement network have been computerised since October 1980, the data from two specific locations, Church Square, Pretoria and Mayor's Garden/City Hall, Cape Town, have been entered back to 1958. This specific data set was analysed to determine cyclic and global trends in the Soiling Index measurements[4].-

The data were initially reduced to weekly means because

(a) The method of sampling results in data were accumulated over unequally spaced periods (i.e. 2, 2, 3 days), and

(b) Periods over which no samples were collected being present within each data set (i.e. for holidays, Christmas and building operations).

The data were further reduced to monthly averages to enable the seasonal component to be modelled.

From preliminary analysis of the Pretoria data set, it was established that a major structural change in the data occurs between the winters of 1971 and 1972. This is attributed to a restriction on the free-flow and parking of vehicles in Church Square being imposed on 1 February 1972. This change in the local environment surrounding the sampling site required that the data set was treated as two different time series models.

Later analysis indicated another significant drop in recording concentrations from 1984. Site inspection and checks on the analysis technique revealed nothing wrong. Work on trace element concentrations[5] indicated a significant reduction in certain key elemental concentrations due to successful antipollution techniques being implemented by ISCOR iron and steel complex to the west of Pretoria. Although no direct evidence exists to link these antipollution measures to the observed reduction of smoke concentrations, the coincidence allows this to be a plausible explanation.

AUTO-REGRESSIVE MODELS

The preliminary analyses of the logarithms of the monthly data by means of spectral analysis and sample autocorrelation functions gave indication of a strong seasonal trend for a period of 12 months. By fitting a full autoregressive process of order 12 or 24 (or even 36), and examining the residuals from any fitted process to detect further cyclical trends, it is possible to build a model to fit the data series. The model that was found to fit both the Cape Town and Pretoria data between 1972 and 1984, is based on lag periods of 1, 2, 12, 13, 14, 24, 25 and 26 months. To forecast the logarithm of the Soiling Index for March 1984, the following would apply:

$$\begin{aligned}
&\psi_1 SI_{FEB84} + \psi_2 SI_{JAN84} + (1+\theta_1) SI_{MAR83} - \\
&\psi_1(1+\theta_1) SI_{FEB83} - \psi_2(1+\theta_1) SI_{JAN83} + \\
&(\theta_2-\theta_1) SI_{MAR82} + \psi_1(\theta_1-\theta_2) SI_{FEB82} + \\
&\psi_2(\theta_1-\theta_2) SI_{JAN82} - \theta_2 SI_{MAR81} \\
&+ \psi_1\theta_2 SI_{FEB81} + \psi_2\theta_2 SI_{JAN81}
\end{aligned}$$

where, for example, SI_{FEB84} is the (natural) logarithm of the measured Soiling Index for February 1984. The parameters for the autoregressive model being given in Tabel 1.

TABLE 1
Parameter for the autoregressive models

	ψ_1	ψ_2	θ_1	θ_2
Cape Town	-0,48501	-0,11759	0,59780	0,34204
Pretoria 1	–	–	0,67483	0,39295
Pretoria 2	-0,49903	-0,19271	0,36868	0,42361

The model for the Pretoria data prior to 1972 uses lags of only 12 and 24 on the difference data, implying that data from any month can be predicted adequately from the data for that month for the three previous years:

$$(1 - \theta_1 B^{12} - \theta_2 B^{24})(1 - B^{12})y_t = A_t$$

where y_t is the observation at time t. The value for θ is given in Table 1.

CONCLUSION

It is encouraging that the two selected sites, one situated on the coast and the other on the Highveld, yielded similar models and that the modelling exercise was successful. It is possible that, given sufficient data, other monitoring stations within the national survey could be successfully modelled.

Since the models for this analysis required data over a 36 to 38 month period, and assuming that such auto-regressive models are applicable to all the stations in the survey, in the future short-term trend analysis will take place on seven years of data and the long-term trend analysis on a minimum of ten years of data. The use of a ten-year minimum period will afford some degree of protection against models covering more than 38 months, owing to local circumstances, and to changes in the model over time.

If models such as those described here can be established for other sites in the national survey, they will provide a tool by which the data being collected can be checked against predicted values and any discrepancies can be investigated. This could be an integral part of the control programme.

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