Comment: Are Ozone Exceedance Rates Decreasing?

Adrian E. Raftery

In this excellent paper, Professor Smith has synthesized a range of powerful methods for the analysis of extreme values. The point process of cluster peaks over a high threshold provides a remarkable condensation of the massive data set that he analyzes. It involves little loss of relevant information and permits fairly simple analyses. The methodology is sure to find wide application.

Nevertheless, I find it hard to think of physical explanations for the conclusion that there has been a downward trend in the extreme values without any accompanying decrease in the overall levels of the ozone series. Here I try to reassess the evidence in terms of a comparison between competing models for the intensity of a Poisson process. The analysis suggests that there is some evidence for a decreasing trend in exceedance rates but that it is rather weak. If there is a trend, it seems more likely to consist of a fairly abrupt change than a gradual decrease. The possibility that such a change is due to an improvement in measurement technology is discussed. I also consider the possibility of long-memory dependence and discuss the clustering method used.

1. ARE OZONE EXCEEDANCE RATES DECREASING?

The evidence in the paper for decreasing exceedance rates consists mainly of the fact that the estimated trend was downward in all the models that incorporated a trend. However, these models did not appear to fit better than models that did not incorporate a trend. For example, the likelihood ratio test statistic for splitting the data was 16.6 with 18 degrees of freedom.

This may be due more to the large number of degrees of freedom than to the absence of an effect. It might be worth, for example, fitting a model of the form (4.1), but with $\mu_{ij} = \alpha_j + \beta\delta_i$, where $\delta_i = 0$ for 1973–80 and $\delta_i = 1$ for 1981–86. One could then test the hypothesis that $\beta = 0$, which involves only one degree of freedom rather than 18. There are many other parsimonious possibilities.

The computer programs used to carry out the analyses may be obtained from the author by sending electronic mail to raftery@entropy.ms.washington.edu.

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Nonhomogeneous Poisson Process Models for Exceedances

Professor Smith's conclusion corresponds to a decreasing rate of occurrence in the point processes of exceedances above high thresholds. This process was not fully observed, and the proportion of time monitored varied over the period, increasing gradually but significantly. I therefore expressed times of occurrence in terms of monitored time since the start of the data, rather than calendar time. Also, ozone levels are highly seasonal. I estimated the seasonal effect as piecewise constant within each of the six 61-day periods and deseasonalized the data by transforming the time axis (Cox and Lewis, 1966). The resulting series of events are shown in Tables 1 and 2. I denote by T the period of observation and by $t = (t_1, \cdots, t_n)$ the event times.

If there is no trend, the data in Tables 1 and 2 are very nearly from a homogeneous Poisson process; we denote this model by M_0. This assumes that any short-term correlation has been removed by considering only cluster peaks. An alternative hypothesis is that the exceedance rate has been decreasing smoothly and gradually. This may conveniently be represented by the log-linear Poisson process, M_1: $\lambda(s) = \rho e^{-\beta s}$, where $\lambda(s)$ is the rate of occurrence at time s. Another possibility, suggested by the splitting of the data in the paper, is that the exceedance rate decreased fairly abruptly within a short time period. This may be represented by the change-point Poisson process, M_2: $\lambda(s) = \lambda_1$ if $0 \le s \le \tau$ and $\lambda(s) = \lambda_2$ if $\tau < s \le T$.

Model Comparison

The three competing models, M_0, M_1 and M_2, may be compared using the Bayes factor, or ratio of posterior to prior odds for M_i against M_j, B_{ij}, for each pairwise comparison. It has been argued that Bayes factors are better measures of evidence than P values (Berger and Sellke, 1987), and they are also more readily applicable to the comparison of nonnested models.