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TRENDS IN SURFACE OZONE OVER EUROPE, 1978-1990

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ABSTRACT

It has been suggested that surface ozone concentrations in rural areas of Europe have been increasing at a rate of 1 to 3% per year over the past two to three decades, presumably due to human influences (Feister and Warmbt, 1987; Bojkov, 1988; Penkett, 1989). Recently, we have analyzed surface ozone data from 20 European stations of differing character (remote, rural, suburban and urban) for a common period of 1978-1988 (Low *et al.*, 1992). It was found that there were pronounced annual and seasonal variations in the linear trends in different areas, and there was no dominant region-wide trend. In spring and, most notably, summer, stations on the maritime fringe of the network generally exhibited negative trends whilst those located further into the continental interior exhibited positive trends. In winter, most of the stations in the network exhibited positive trends. Relatively few of these trends were statistically significant. This paper updates our earlier analysis by extending the data sets of the network up to the year 1990. The spatial variations in surface ozone trends over the extended period 1978-1990 are examined and discussed in comparison to the 1978-1988 patterns. The update confirms the overall conclusions of the earlier analysis, specifically that caution should be exercised in interpreting the results of trend analyses based on station data representative of a limited period of time and/or geographical area.

1. INTRODUCTION

During an investigation of the links between surface ozone concentrations and atmospheric circulation in Europe, time series of surface ozone data from over 130 stations have been collected (Davies *et al.*, 1990). Most stations had a time series of less than ten years. Of those with longer periods of data, 20 stations were selected and linear trends in surface ozone concentration were determined for the common period 1978-1988. The statistical significance of the trends was tested taking into account autocorrelation in the data. The results are detailed in Low *et al.* (1992).

Recently we have updated the network time series to the year 1990. The spatial variations in surface ozone trends over the extended period 1978-1990 are examined in this paper and comparison is made with the patterns for the period 1978-1988.

2. THE NETWORK OF STATIONS

The stations and their site characteristics are listed in Table 1 and their locations are shown in Figure 1a. Most stations are classified as "rural" with a few classified "suburban" and two "remote" (these latter stations are located over 1750m above sea level). London is the only station classified as "urban". Neuglobsow and Wank are WMO Background Air Pollution Monitoring Network (BAPMoN) stations.

3. SURFACE OZONE TRENDS

The linear trends in the annual and seasonal data for each station are given in Table 2 for the periods 1978-1988 and 1978-1990. The trends are expressed in terms of percentage change per year.

It is notable that the number of statistically significant trends is greater over the longer period. Moreover, most of the trends that are statistically significant in one or both periods remain of similar value, although others change markedly. This latter result is not surprising given that we are attempting to define trends over a short period of data. Sensitivity to the period of analysis has been well illustrated by Low *et al.* (1990, 1991).

The general conclusions reached in Low *et al.* (1992) are confirmed:

(1) Pronounced annual and seasonal variations are apparent in the trends in different areas.

(2) Relatively few of the trends are statistically significant.

(3) There is no dominant region-wide trend, although most of the stations in the network exhibit positive trends in the winter average data.

There are certain changes in the spatial character of the seasonal trends over the extended period (Figure 1b-f). We noted in Low *et al.* (1992) that over the period 1978-1988 there was evidence of a contrast between the trends over the continental interior and those over the maritime fringe of the network. Most marked in the summer data, stations on the maritime fringe of the network generally exhibited negative

Table 1 **Surface ozone monitoring stations used in this study.**

Country	Station	Location	Height (m asl)	Site class	Record	Meas. tech.	Comments
Former GDR	Arkona	54.68N 13.43E	42	rural	1956-90	I	BAPMoN; coastal; SO_2 filter from 1972; continuous since 1982
	Dresden	51.12N 13.68E	246	suburban	1972-90	I	SO_2 filter from 1972; continuous since 1981
	Fichtelberg	50.43N 12.95E	1213	rural	1970-90	I	Continuous recording since 1982
	Neuglobsow	53.15N 13.03E	62	rural	1978-90	I	BAPMoN; continuous since 1982
	Schmücke	50.65N 10.77E	937	rural	1978-90	I	Continuous since 1982
FRG	Hamburg	53.65N 10.12E	49	suburban	1976-90	I	
	Hohenpeissenberg	47.80N 11.02E	975	rural	1971-90	I/C	SO_2 filter from 1976
	Garmisch-Partenkirchen	47.48N 11.07E	740	rural	1978-90	C	Valley station
	Wank	47.52N 11.15E	1780	remote	1978-90	C	BAPMoN; mountain station
	Zugspitze	47.42N 10.98E	2964	remote	1978-90	C	Mountain station
United Kingdom	Bottesford	52.93N 0.82W	32	rural	1978-90	C	1 km south of motorway
	Central London	51.50N 0.08W	20	urban	1972-90	C	City centre (Victoria)
	Sibton	52.30N 1.47E	46	rural	1977-90	C	Open flat cereal farmland; woodland to the northwest
	Stevenage	51.88N 0.20W	90	suburban	1977-90	C	Edge of industrial estate; 100 m east of motorway
The Nether-lands	Balk	52.92N 5.57E	1	rural	1978-90	C	Data interruption in 1986
	Biddinghuizen	52.42N 5.59E	-5	rural	1978-90	C	Station moved about 200 m in 1986
	Brandwijk	51.89N 4.80E	-0.5	suburban	1978-88	C	Data interruption in 1985; record ended in 1988
	Cabauw	51.97N 4.93E	-0.5	suburban /rural	1978-90	C	
	Hellendoorn	52.38N 6.40E	20	rural	1978-90	C	Data interruption in 1985
	Kloosterburen	53.40N 6.41E	1	rural	1978-90	C	Coastal

Although changes in instrumentation have occurred at some of the stations, the quality of these data is considered to be good over the period of record analysed. The site classification follows that of the original observers and may not be based on entirely comparable criteria. All available data are used. For further details, see *Low et al.* (1991).
Key: Meas. tech., Measurement technique; BAPMoN, WMO Background Air Pollution Monitoring Network station; GDR, German Democratic Republic; FRG, Federal Republic of Germany; I, Iodometric; C, Chemiluminescent.

trends whilst those located further into the continental interior exhibited positive trends. Over the period 1978-1990, this pattern becomes clearer in other seasons. Stations on the maritime fringe of the network generally exhibit negative trends in the annual, spring and autumn data. Those located further into the continental interior exhibit positive trends in the annual, spring and summer data. This clustering of trends with similar signs in regional groupings does suggest a common causal mechanism, lack of statistical significance notwithstanding.

The variations in the trends at different locations reflect the complexity and diversity of the processes that control ozone formation, transport and destruction. The factors which influence the nature of the trend at a particular station have been discussed by Low *et al.* (1992). They include:

(1) The specific geographical or topographical location of the station. This will determine, for example, the effectiveness of the surface destruction of ozone (Galbally and Roy, 1980).

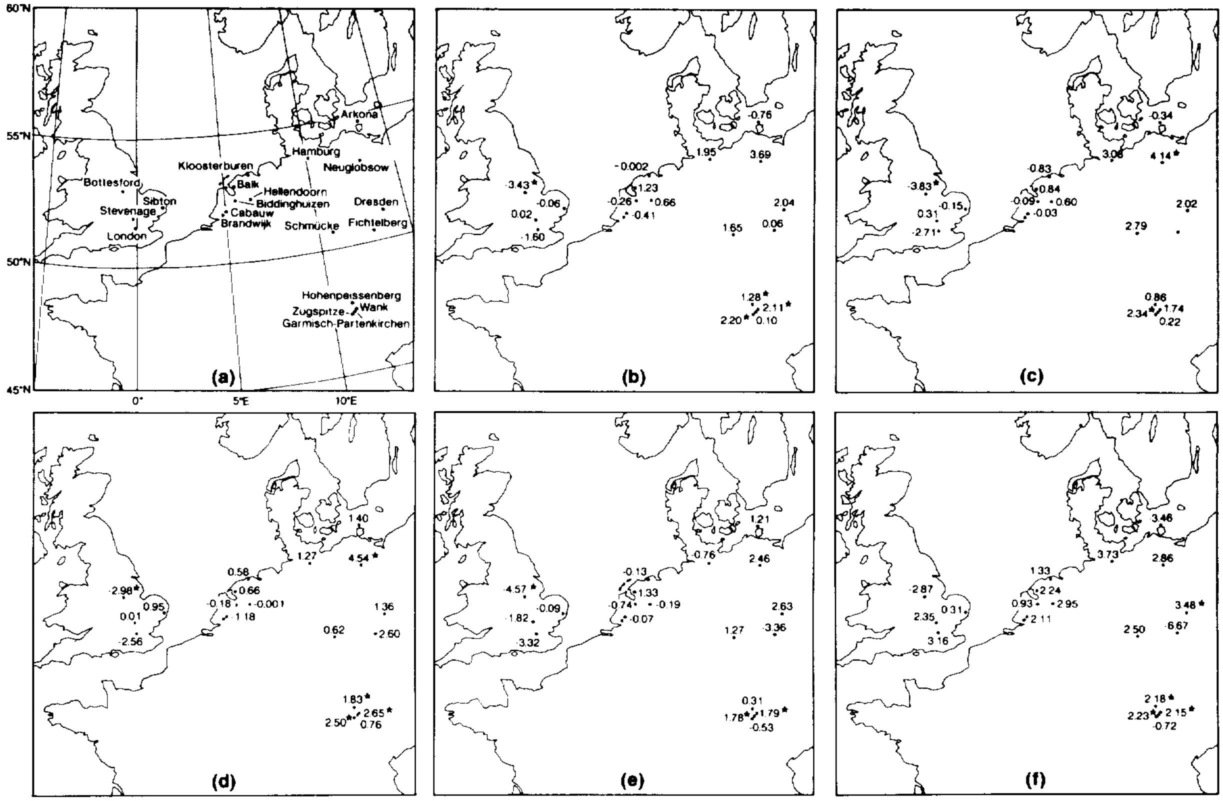

Figure 1 **Station locations *(a)* and linear trends in surface ozone concentration over the period 1978-90, expressed as percentage change per year, for the *(b)* annual, *(c)* spring, *(d)* summer), *(e)* autumn and *(f)* winter data. * indicates statistical significance at the 5% level, after allowing for autocorrelation.**

(2) Horizontal and vertical variability in the amount of solar radiation reaching the surface (Feister *et al.*, 1989; Schmidt, 1989). This is dependent on topography and fluctuations in cloudiness and, perhaps, the concentration of aerosols (Feister *et al.*, 1989).

(3) The influence of local emission sources as well as the medium- and long-range transport of pollutants from elsewhere. These determine the distribution of the concentrations of precursors, particularly NOx, and, hence, the photochemical production and destruction of ozone (Liu *et al.*, 1987).

(4) Natural climate variability, such as changes in the atmospheric circulation. This can affect ozone concentration on the interannual and longer time scales (Davies *et al.*, 1992).

(5) Station elevation. The higher-elevation stations at Wank and Zugspitze, for example, which exhibit positive trends annually and in all seasons (all bar one statistically significant), may be reflecting free tropospheric conditions to a much greater extent than the other stations at lower elevations.

(6) Local climatological factors, such as the frequency of nocturnal inversions and local circulations (Janach, 1989).

For certain stations which exhibit a negative trend in ozone concentration (such as Arkona), it should be noted that the trend is, to a large extent, the result of the marked and rapid decline in ozone concentration that occurred during the early 1980s. At other stations showing a negative trend (such London and stations in the Netherlands), the observed increase in the concentration of NO_x (particularly NO) may be pertinent as it is an important ozone sink (Low *et al.* 1992).

The positive trends observed in winter at most stations are consistent with the prediction of a gradual increase of background ozone in that season because of the longer photochemical lifetime of ozone and the more efficient accumulation process of newly-produced ozone (Liu *et al.*, 1987).

4. CONCLUSIONS

Given the diversity of the trends reported here and the complex influences on surface ozone concentrations, we

Table 2 **Linear trends in the seasonal and annual average data over the periods 1978-88 and 1978-90, expressed as percentage change per year. * indicates statistical significance at the 5% level.**

	Spring		Summer		Autumn		Winter		Annual	
Station	78-88	78-90	78-88	78-90	78-88	78-90	78-88	78-90	78-88	78-90
Arkona	-2.85	-0.34	-2.07	1.40	-4.52	-1.21	-6.30	-3.46	-3.19	-0.76
Dresden	1.57	2.02	0.45	1.36	1.89	2.63	1.57	3.48*	1.28	2.04
Fichtelberg	-4.17	0.76	0.02	2.60	-5.87	-3.36	-12.02*	-6.67	-4.12	0.06
Neuglobsow	4.55*	4.14*	3.76	4.54*	2.58	2.46	3.37	2.86	3.86*	3.69
Schmücke	1.02	2.79	1.03	0.62	-0.41	1.27	-1.36	2.50	-0.32	1.65
Hamburg	3.16	3.08	1.42	1.27	-0.06	-0.76	5.86	3.73	2.46	1.95
Hohenpeissenberg	0.43	0.86	1.13	1.83*	-0.44	0.31	0.91	2.18*	0.56	1.28*
Garmisch-Partenkirchen	0.93	0.22	0.62	0.76	-0.46	-0.53	0.68	-0.72	0.48	0.10
Wank	2.53	1.74	2.68	2.65*	2.12	1.79*	2.22*	2.15*	2.41	2.11*
Zugspitze	2.76*	2.34*	2.59*	2.50*	2.00	1.78*	2.45	2.23*	2.40	2.20*
Bottesford	-3.16	-3.83*	-3.20	-2.98*	-5.05*	-4.57*	-3.30	-2.87	-3.38*	-3.43*
Central London	-5.59	-2.71	-2.30	-2.56	-3.87	-3.32	4.32	3.16	-2.75	-1.60
Sibton	-0.33	-0.15	-0.08	0.95	-1.54	-0.09	-1.19	0.31	-1.26	-0.06
Stevenage	0.65	0.31	-0.12	0.01	-2.89	-1.82	2.64	2.35	-0.17	0.02
Balk	0.66	0.84	0.04	0.66	0.44	1.33	3.84	2.24	0.86	1.23
Biddinghuizen	-1.07	-0.09	-1.36	-0.18	-2.02	-0.74	1.95	0.93	-1.12	-0.26
Brandwijk	-2.86		-4.61*		-1.02		5.08		-2.34*	
Cabauw	-1.10	-0.03	-2.21	-1.18	-1.90	-0.07	0.56	2.11	-1.67	-0.41
Hellendoorn	-0.39	0.60	-0.86	0.00	-1.45	-0.19	4.24	2.95	0.11	0.66
Kloosterburen	-1.50	-0.83	0.59	0.58	-1.83	-0.13	0.91	1.33	-0.59	0.00

think it would be inappropriate to use surface ozone data directly to infer any large-scale tropospheric ozone increase or decrease, unless it is certain that the air sampled at the surface ozone station is representative of that in the free troposphere. The mountain stations such as Wank and Zugspitze may be the most representative of all, although even at these stations the possibility of local anthropogenic influence cannot be excluded.

This analysis of the extended data set confirms the general conclusions reached by Low *et al.* (1992). First, it would be unwise to assume that the trends derived from a limited number of longer surface ozone records are necessarily representative of a wider area. Second, the occurrence of marked short-term variability means that conclusions concerning long-term trends drawn from records of limited duration may well be misleading.

REFERENCES

Bojkov, R.D., 1988: Ozone changes at the surface and in the free troposphere. In *Tropospheric Ozone* (edited by I.S.A. Isaksen), pp. 83-96, D. Reidel, Hingham, Mass., USA.

Davies, T. D., P. M. Kelly, P.S. Low, and C. E. Pierce, 1990: *Surface Ozone in Europe: Trends and Links to Atmospheric Circulation*, Report No. RK 4244, Climatic Research Unit, University of East Anglia, Norwich, pp.284.

Davies, T. D., P. M. Kelly, P. S. Low, and C. E. Pierce, 1992: Surface ozone concentrations in Europe: Links with the regional-scale atmospheric circulation, *J. Geophys. Res.*, *97(D9)*, 9819-9832.

Feister, U. and Warmbt, W., 1987: Long-term measurements of surface ozone in the German Democratic Republic *J. Atmos. Chem.* 5, 1-21.

Galbally, I. E. and C. R. Roy, 1980: Destruction of ozone at the earth's surface, *Quart. J. Royal Met. Soc.*, *106*, 599-620.

Janach, W. E., 1989: Trend details, seasonal variations, and interpretation, *J. Geophys. Res.*, *94(D15)*, 18289-18295.

Liu, S. C., M. Trainer, F. C. Fehsenfeld, D. D. Parrish, E. J. Williams, D. W. Fahey, G. Hübler, and P. C. Murphy, 1987: Ozone production in the rural troposphere and the implications for regional and global ozone distributions, *J.Geophys.Res.*, *92(D4)*, 4191-4207.

Low, P. S., T. D. Davies, P. M. Kelly, and G. Farmer, 1990: Trends in surface ozone at Hohenpeissenberg and Arkona, *J. Geophys. Res.*, *95(D13)*, 22441-22453.

Low, P. S., T. D. Davies, P. M. Kelly, and R. Reiter, 1991: Uncertainties in surface ozone trend at Hohenpeissenberg, *Atmos. Environ.*, *25A(2)*, 511-515.

Low, P. S., T. D. Davies, and P. M. Kelly, 1991: *European Surface Ozone Data Manual (First Edition)*, National Power Contract No. LC/3/0020, Climatic Research Unit, University of East Anglia, Norwich NR4 7TJ, pp. 131.

Low, P.S., P.M. Kelly and T.D. Davies, 1992: Variations in surface ozone trends over Europe. *Geophys. Res. Lett.*, *19*, 1117-1120.

Schmidt, M, 1989: Relationships between tropospheric ozone and global solar radiation in Germany. In *Ozone in the Atmosphere - Proceedings of the Quadrennial Ozone Symposium 1988 and Tropspheric Ozone Workshop* (edited by R. D. Bojkov and P. Fabian), pp.447-450), A. Deepak, Hampton, Va.

Penkett, S.A., 1989: Trends in atmospheric trace gases. In *Atmospheric Ozone Research and its Policy Implications* (edited by T. Schneider *et al.*), pp.159-166, Elsevier Science, Amsterdam.