

TRENDS IN UK VISIBILITY BETWEEN 1980 AND 1996

by

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EXECUTIVE SUMMARY

The time series of daily observations of visibility at Heathrow and Stansted between 1980 and 1996 has been studied in order to identify any possible trends and their correlation with industrial sulphur dioxide emissions. In general, the annual average visibility at each site improved between 1980 and 1993, and subsequently deteriorated between 1994 and 1996. These trends are significantly stronger when the analysis is limited to air received from the north west which improved by approximately 31% before deteriorating to its 1980 level. Air received from this direction is interpreted as being mainly influenced by sources of atmospheric aerosols from within the UK which directly contribute towards visibility reduction.

The trend of increasing visibility (between 1980 and 1993) was observed to correlate with a 34% decline in UK sulphur dioxide emissions. However, the subsequent deterioration in visibility does not correlate with sulphur dioxide emissions. Further study is required to identify the cause of reduced visibility between 1994 and 1996.

TRENDS IN UK VISIBILITY BETWEEN 1980 AND 1996

1 BACKGROUND

The UK has not experienced sustained smog events in urban areas since the Clean Air Acts came into force in the early 1950's. However, there has been some concern that visibility in rural areas has declined over the same time period. Various causes have been put forward to explain this apparent trend. The most plausible of these is that visibility is being reduced by the formation of aerosols resulting from the emission of sulphur dioxide into the atmosphere (largely as a result of fossil fuel combustion) [1].

1.1 Objective of the Project

The objective of this study is to determine whether there is a correlation between visibility measured at meteorological stations and airports in the UK and increased emissions of sulphur dioxide in the UK.

2 INTRODUCTION

2.1 Visibility

Visibility is a component of environmental quality that has received little attention in the UK. It is rigorously defined as "the distance, under daylight conditions, at which the apparent contrast between a specified type of target and its background becomes just equal to the threshold contrast of an observer". Values of visual range are estimated from the appearance of buildings and special targets at differing distances against the skyline. Visibility is limited by the presence of aerosols which scatter light and hence reduce the contrast of objects viewed from a distance. Since visibility is related to the optical scattering properties of the atmosphere, it can be related to the backscatter coefficient [2,3] of the atmosphere, β by

$$R = \frac{1}{\beta} \ln \frac{C}{\epsilon}$$

where C is the inherent contrast of the target against the background (at 550 nm), and ϵ is the threshold contrast of the observer. For a black target and an observer with a contrast threshold of 0.02

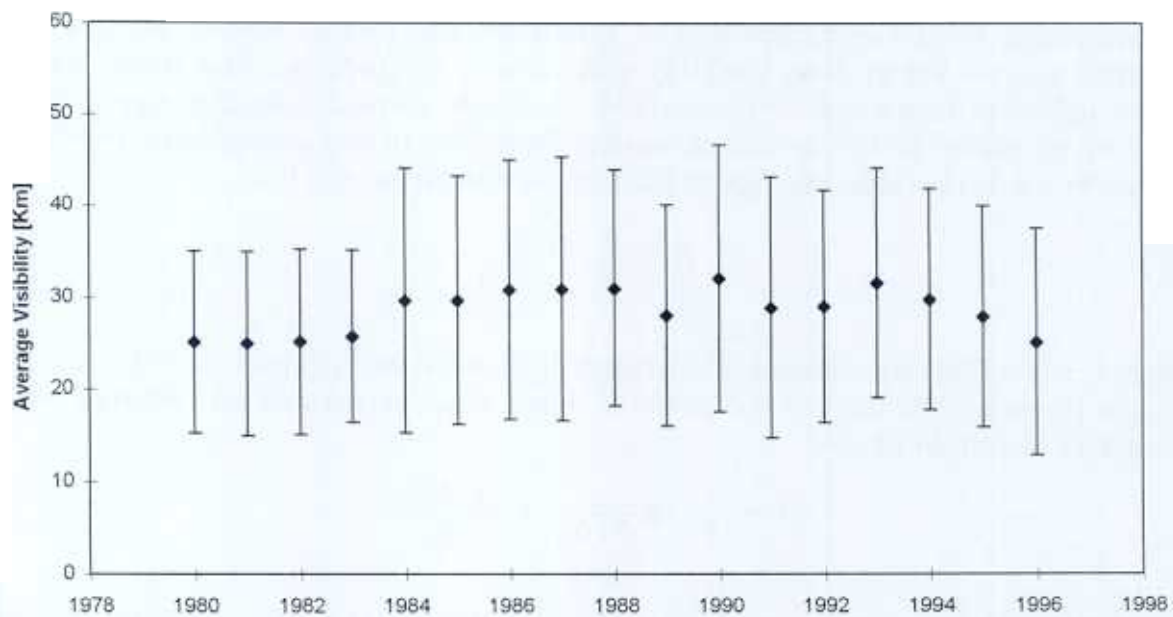
$$R = \frac{1}{\beta} \ln \frac{1}{0.02} = \frac{3.912}{\beta}$$

This simple relationship between the visibility and the backscatter coefficient of the atmosphere emphasises that visibility is limited by scattering processes in the atmosphere and hence is a measure of the presence of aerosols in the atmosphere.

Figure 1 - Average Annual Visibility at Heathrow



Figure 2 - Average Annual Visibility at Stansted



2.2 Aerosols in the Atmosphere

Aerosol particles are microscopic solid or liquid particles suspended in air. The chemical and physical properties as well as their size range can vary significantly. They can include wind-blown sand and dust as well as a wide variety of air pollutants. In urban air, soot and other primary particles are important contributors to visibility impairment, whereas in rural areas the visibility reduction is caused mainly by sulphates and nitrates. Both sulphates and nitrates take up water and transform to liquid droplets at relative humidities above 70 to 90%. However, for most values of the relative humidity, the optical attenuation is nearly proportional to the atmospheric content of sulphates and nitrates [6].

2.3 Visibility Studies in the United States

There has been considerable debate about the importance of visibility in the United States. This has largely been triggered by observations of reduced visibility in the National Parks and resulted in the imposition of a requirement in 1977 to remedy "any existing impairment in visibility" in some designated areas.

The most well known example concerns the influence on visibility in the Grand Canyon of a 2GW power station located 110 km upwind. Studies of this issue have shown that impaired visibility was primarily caused by sulphate aerosol from the power station, which was subsequently required to abate its emissions.

2.4 Data Selection and Screening

A search of possible sources of data on visibility and sulphur dioxide emissions for the UK has been carried out for this study. The most useful sources are listed in Annex A. The most important of these is the UK Meteorological Office which keeps records of visibility observations made at midday every day at Weather Stations throughout the UK. Since the Met Office make a charge for the use of this data, it was decided to limit the study to two stations and to study the period 1980 to 1996. Heathrow and Stansted were chosen because each has a long series of uninterrupted observations available. They are also conveniently located on opposite sides of London which enables analysis to be made of the influence of London on visibility. A more comprehensive study would require data from stations spread more widely around the UK and could cover a longer time series.

Observations of visibility are significantly influenced by fog, mist, rain and other similar meteorological phenomena. Since this study is intended to evaluate underlying trends in visibility caused by changes in aerosol density, it is important to screen these influences out of the data. The methodology used to do this is described in Annex B. In general, visibility observations are not strongly influenced by local factors since observations of local smoke or mist events will be screened out by the observer. The location of the sites and the paths used for the visibility observation will have been chosen to minimise this type of effect.

Figure 3 - Visibility Averaged Over Summer Months for Heathrow

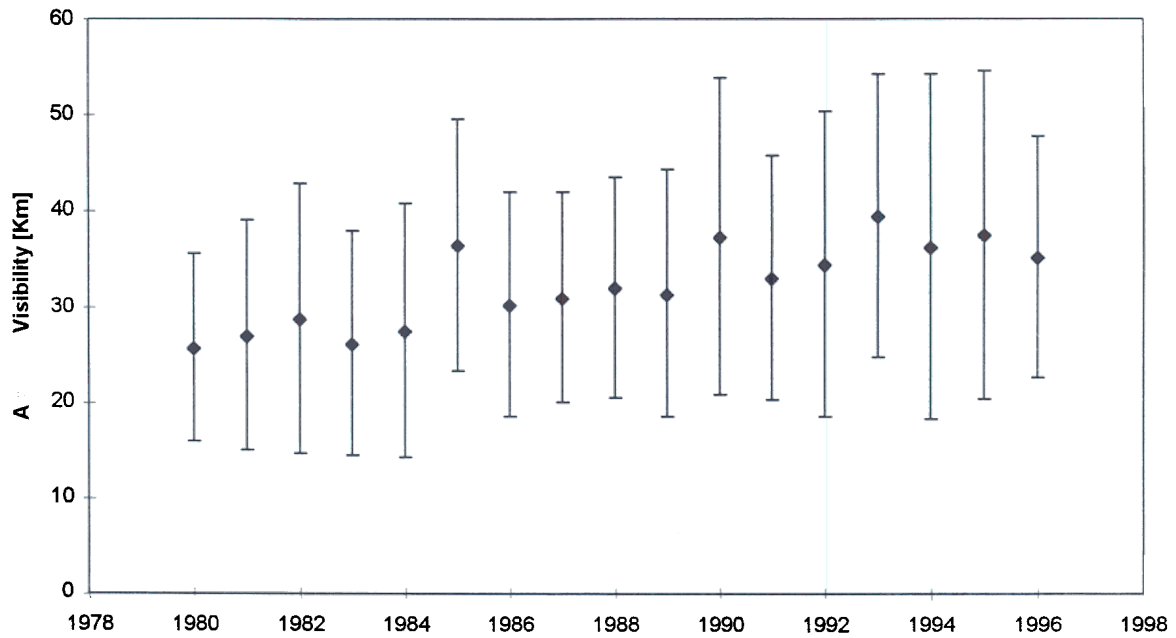
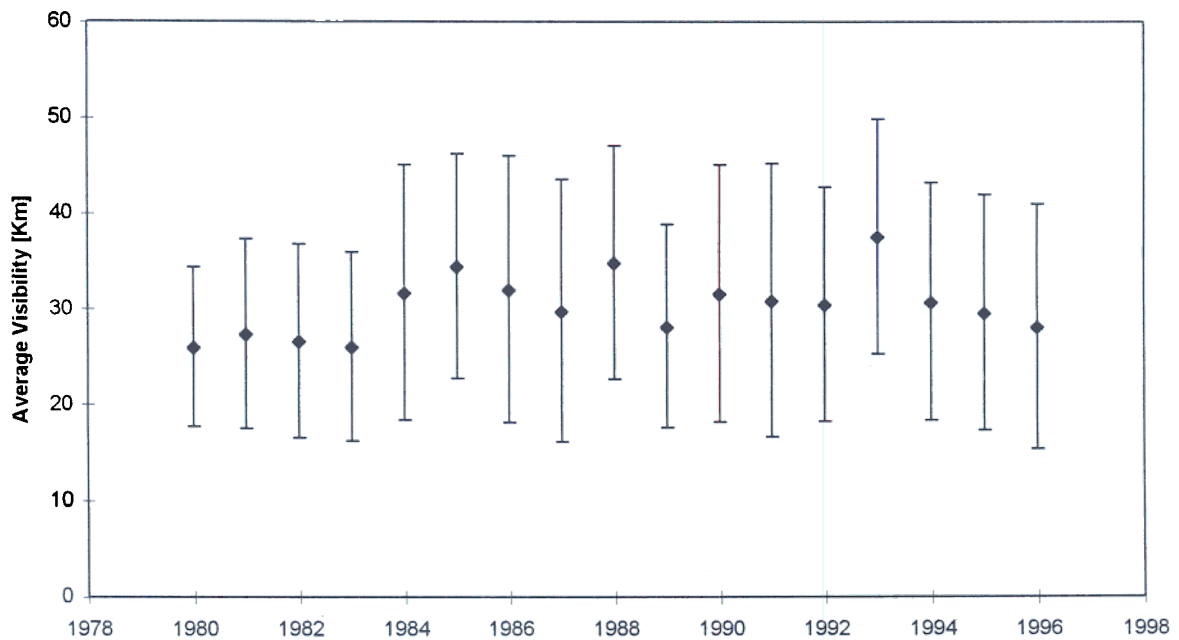


Figure 4 - Visibility Averaged Over Summer Months for Stansted



3 TRENDS IN ANNUAL AVERAGE VISIBILITY

3.1 Annual Average Visibility

The objectives of this study are associated with assessing trends in visibility data over a time scale of many years. Since these long-term trends are smaller than the variations in visibility from season to season, it is necessary to carry out some averaging of the data in order to reveal them. The most straightforward way to do this is by averaging the daily visibility data for each year. This has been done for Heathrow and Stansted in Figures 1 and 2. An indication of the spread of data during each year is given by the bars which represent the standard deviation of the midday values*. The maximum and minimum annual average values at each site are also given in Table 1. There appears to have been a steady increase in visibility at Heathrow between 1980 and 1996. The lowest visibility is 24.2 km in 1980, and the highest is 34.8 km in 1995. However, this trend is small compared with the standard deviation during any given year.

Table 1 - Maximum and Minimum Annual Average Visibility

Location	Maximum Annual Average Visibility [km]	Year	Minimum Annual Average Visibility [km]	Year
Heathrow	34.8	1995	24.2	1980
Stansted	32.2	1990	25.0	1980

At Stansted (Figure 2), there is a smaller trend between 1980 and 1993. The lowest visibility is 25.0 km in 1980 and the highest is 32.2 km in 1990. However, from 1993 to 1996, there is some indication of a trend in the opposite direction resulting in a decline in visibility. This decrease from 1993 to 1996 is of similar magnitude to the increase between 1980 and 1993.

3.2 Visibility During Summer Months

Previous work [4] has studied trends in visibility over the summer months (June, July and August) in order to ensure that the raw data is free from the effects of fog and mist which occur predominantly in the winter. In this study, the data have been screened (Annex B) so we would expect this effect to be less pronounced. To confirm this, the average visibility for the two sites during the summer months is shown in Figures 3 and 4. A comparison with Figures 1 and 2 shows the same general trends as the full year data, although the data are spread more widely. The maximum and minimum values of summer month visibility are shown in Table 2.

*The use of the standard deviation is only strictly justified when the data are normally distributed. In this case, we use the standard deviation as a quantitative indicator even though the data are not normally distributed.

Figure 5 - Visibility Distribution for Heathrow

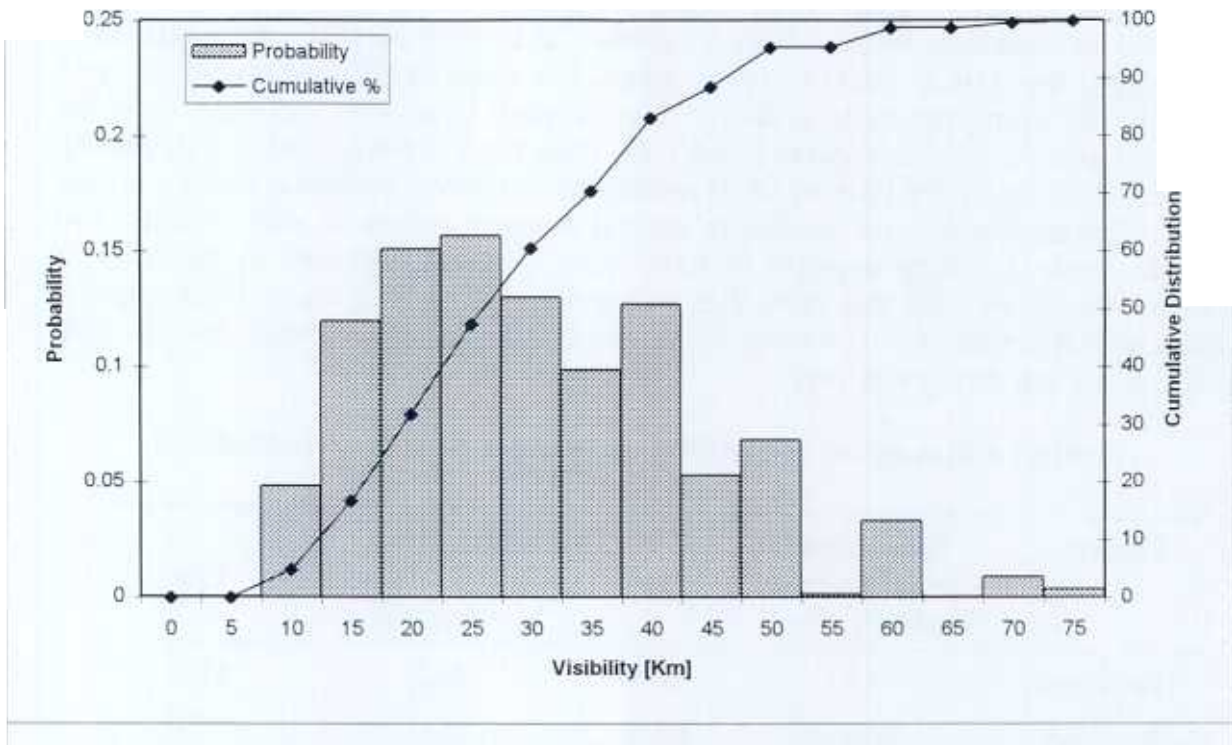
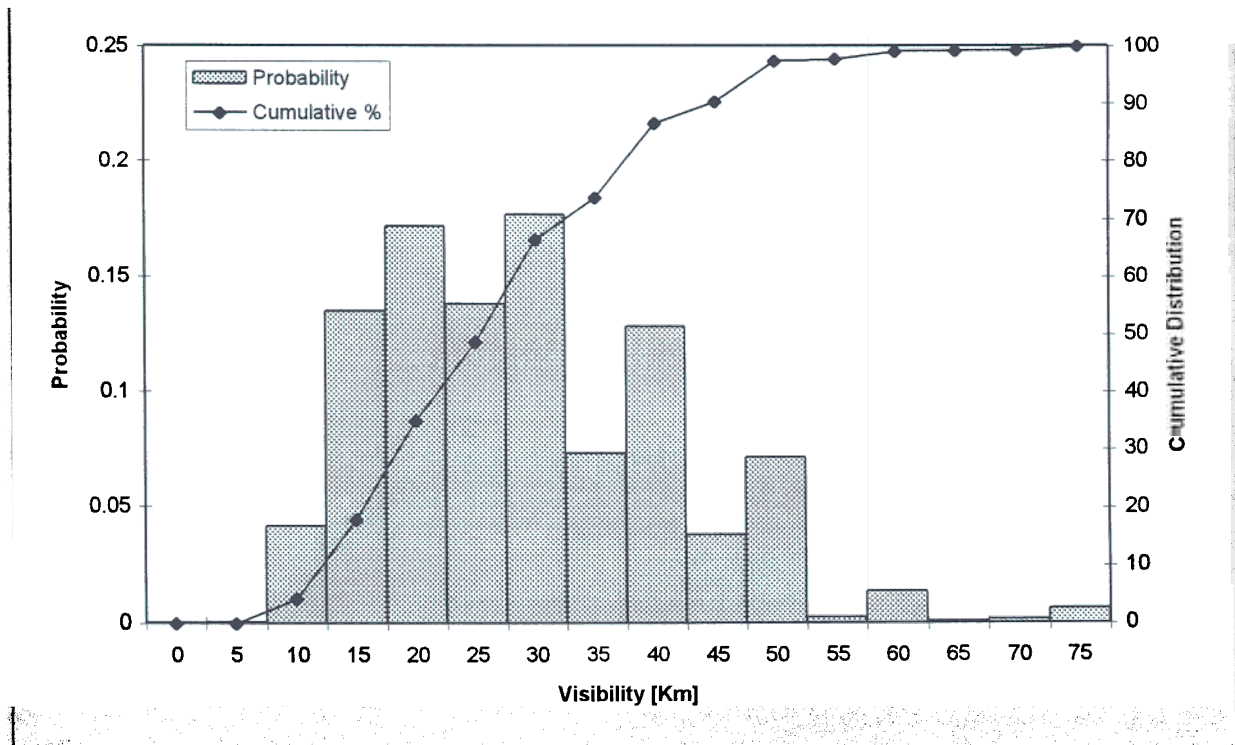


Figure 6 - Visibility Distribution for Stansted



At Heathrow, the highest summer month value is 39.5 km in 1993 (compared with the highest annual average value of 34.8 km in 1995). A similar effect is observed in the data from Stansted where the highest summer month value is 37.6 km in 1993, compared with the highest annual average of 32.2 km, also in 1993. Since the trends are less obvious in the averages for summer months, the remainder of the study uses the whole annual data set (after screening out the poor weather days as described in Annex B).

**Table 2 - Maximum and Minimum Average Visibility
During Summer Months**

Location	Maximum Summer Average Visibility [km]	Year	Minimum Summer Average Visibility [km]	Year
Heathrow	39.5	1993	25.8	1980
Stansted	37.6	1993	26.0	1983

3.3 Probability Distribution

The probability distributions of screened data (1980 to 1996) for the two sites are shown in Figures 5 and 6. There are no observations of visibility of less than 10 km at either site and the distribution has the same approximate form for each. The tenth and ninetieth percentile points fall at the same points in the distribution at the two sites.

The similarity of the distributions justifies the use of direct comparisons between the sites using the same statistical indicators.

4 CORRELATION OF VISIBILITY AND WIND DIRECTION

4.1 Visibility and Wind Direction

Presentations of the whole data set for each year do not enable any analysis of the origins of the particular air that was measured at the site at midday on any particular day. In order to facilitate this type of analysis, the data set also included the wind direction recorded at the time of the visibility observation. The combination of the wind direction and visibility enables the data to be presented in the form of "visibility roses" as shown in Figures 7 and 8. These polar plots are divided radially into 10 degree sectors. Two lines are plotted, one of which shows the mean visibility for all occasions when the wind was blowing from each sector, and the other shows the relative frequency with which the wind blew from that direction.

A comparison of Figures 7 and 8 shows that the angular distributions of the mean visibility and the wind direction frequency at the two sites do not show the same form. The difference between these angular distributions provides some information about the different sources of visibility reduction at the two sites. An approximate indication of the different behaviour of visibility at the two sites can be formed by

Figure 7 - Visibility Rose at Heathrow

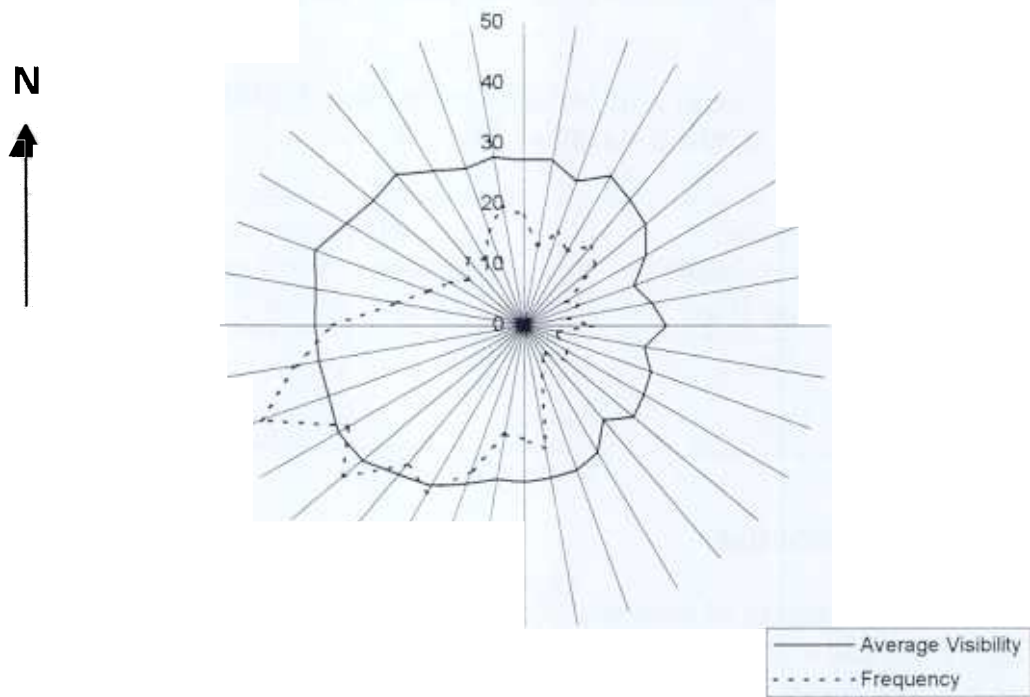
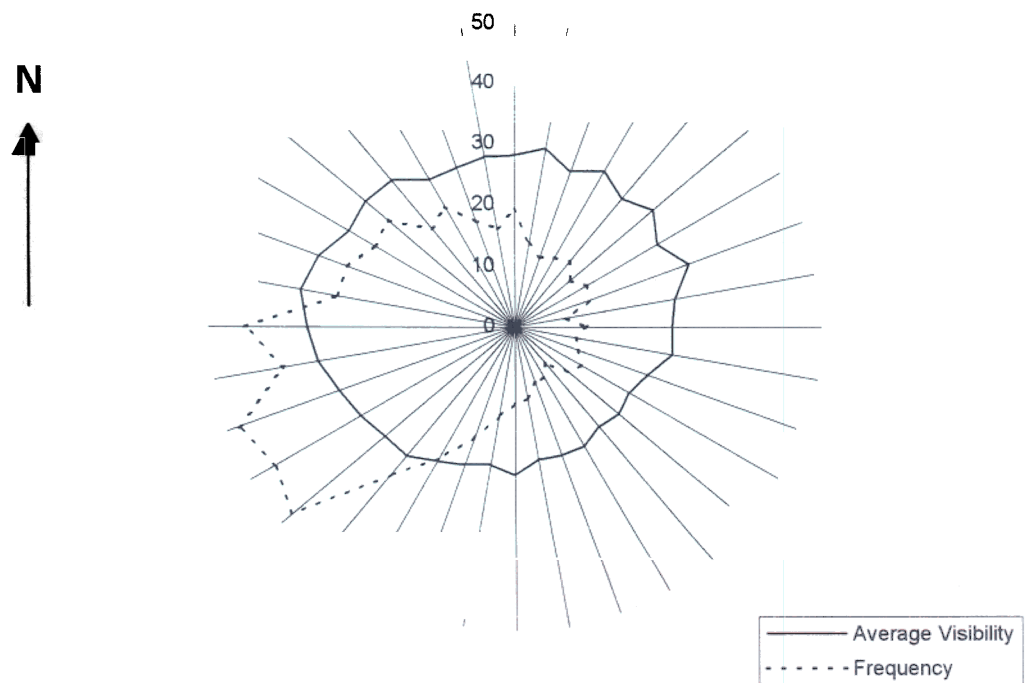


Figure 8 - Visibility Rose at Stansted



subtracting the two visibility roses (Figures 7 and 8). This can be done by using equation (2) to convert the visibility rose into a backscatter rose representing average values of β as a function of wind direction. The backscatter roses for each site can then be subtracted to produce Figure 10 which represents the difference in average backscatter at the two sites. It shows the directions in which the visibility at Heathrow is better than at Stansted and *vice versa*. A comparison of Figure 10 with a map of the locations of the two sites (Figure 9) enables some of the wind directions to be associated with particular sources of air.

4.2 Origin of UK Visibility

It is known that the meteorological systems that occur over continental Europe often sweep air into the UK from continental Europe. This effect is most often observed in packets of air that arrive in the UK from directions between the south east and south west. Air that arrives at Heathrow from the south east has passed over parts of London. However, air originating from the south west arrives at Heathrow without passing over any extended developed areas, hence, we can use this wind direction as an indicator of the influence of continental Europe on the UK. Figure 7 shows that the air with the highest average visibility arriving at Heathrow comes from the south west. When air arrives at Stansted from the same direction, the visibility has been reduced as a result of passing over London. Figure 10 confirms that, the south west is the only direction from which Stansted has worse visibility than Heathrow.

Similar reasoning can be applied to air arriving at Stansted from the north east. This air arrives from continental Europe with limited influence from UK sources. Figure 10 shows that the east and north east are the only directions for which visibility at Stansted is better than at Heathrow.

**Table 3 - Definitions of Wind Direction
Quadrants Used for Analysis**

Definition of Sector	Approximate Direction	Major Source of Air at	
		Heathrow	Stansted
[degrees]			
	NE	London	continental Europe
80 to 160	SE		
170 to 250	SW	continental Europe	London
260 to 340	NW	UK	UK
* SE direction has many sources and cannot be interpreted simply.			

The most interesting sector of wind direction for analyzing trends in visibility from the UK (but not from London) is the north west. Figure 10 shows that the average visibility of air arriving from the north west was very similar at the two sites. This is consistent with it being air from the same source. The fact that the direction of arrival of this air is the north west suggests that it might be representative of the UK together with a "background" contribution from the Atlantic Ocean.

Figure 9 - Map Showing Visibility Quadrants Used to Analyse Visibility Data

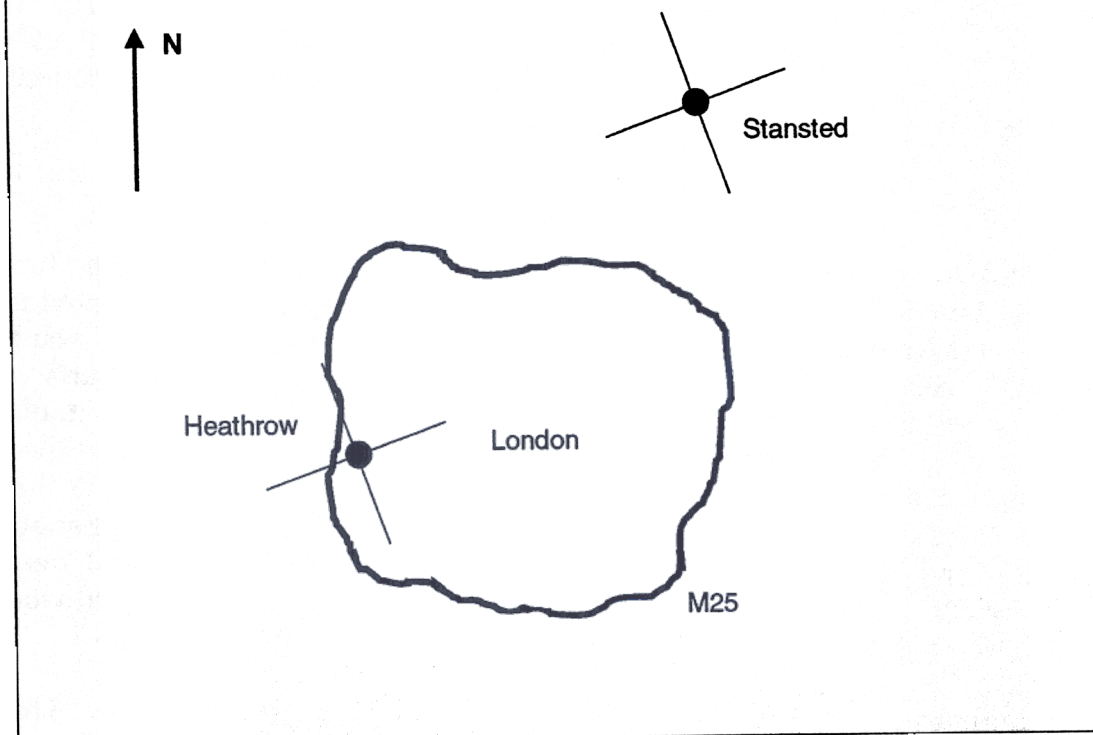
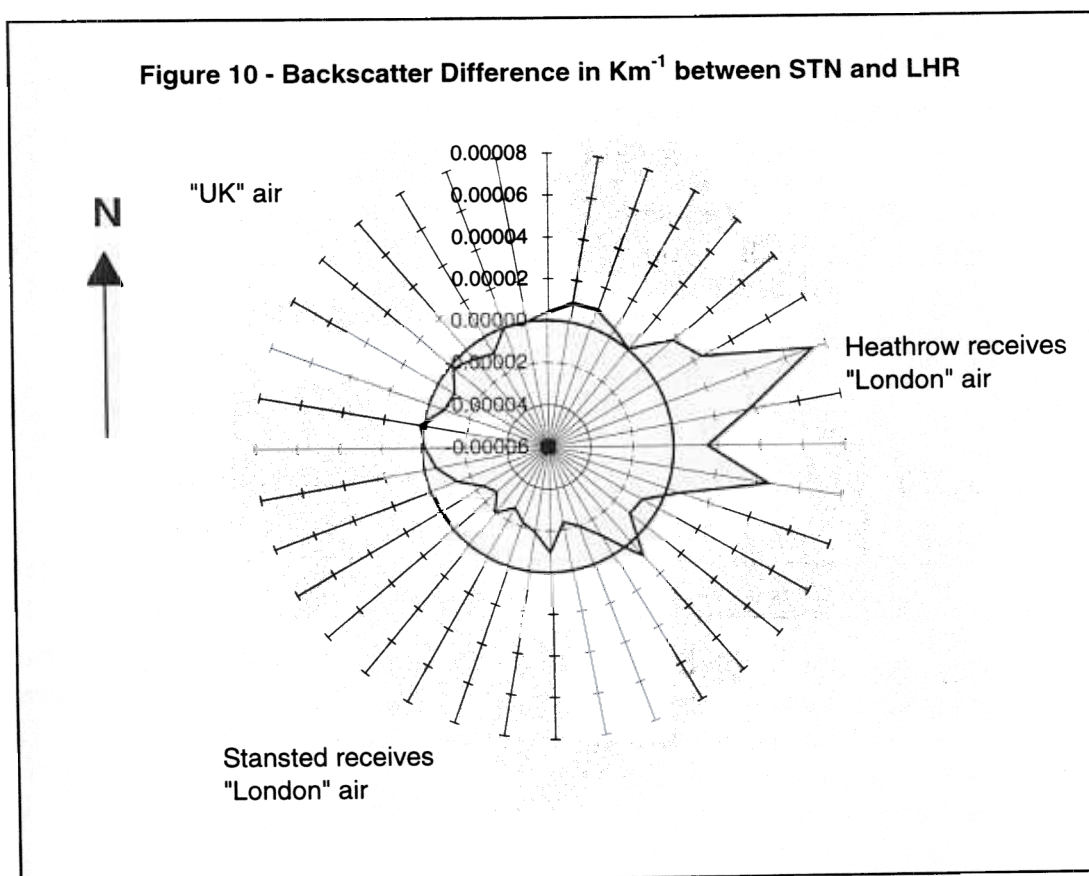


Figure 10 - Backscatter Difference in Km^{-1} between STN and LHR



4.3 Division of Data into Quadrants of Wind Direction

In order to extend this analysis, it is useful to divide the data into quadrants according to the wind direction [5]. In making such a division, it is important to orientate the quadrants so that they are most likely to encompass any directional biases in the data. Taking account of the shape of Figures 7 and 8, and the limit of 10 degrees to the resolution of the direction data, we have chosen the quadrants shown in Table 3.

4.4 Trends in Visibility in Each Direction Quadrant

Before developing the interpretation of the data in terms of the origin of the air, it is useful to look at the long-term trends in average annual visibility in each quadrant. Figure 11 and 12 show the average annual visibility in each quadrant between 1980 and 1996 at both sites. The spread of the data makes these Figures difficult to interpret, however, there is a tendency for the visibility at both sites to be best in the quadrant 260 to 340 degrees (north west), and worst in the quadrant 80 to 160 degrees (south east).

A more detailed analysis of Figures 11 and 12 should take account of the trends identified in the aggregated data (Figures 1 and 2). These aggregated trends indicated a possible change in behaviour in 1994, 1995 and 1996, so it is appropriate to analyze the quadrant time series in each quadrant over the shorter period 1980 to 1993. This reduced series of data, together with a straight-line regression fit to each set is shown in Figures 13 and 14. The gradients and intercepts of the regression model are listed in Table 4.

Table 4 - Gradient and Intercepts of Regression Fits to Data

Quadrant	Heathrow		Stansted	
	Intercept [m]	Gradient [m y ⁻¹]	Intercept [m]	Gradient [m y ⁻¹]
260 to 340	2751	72	2841	62
170 to 250	2573	70	2444	40
350 to 70	2107	57	2506	50
80 to 160	1954	45	2291	12

The intercept can be interpreted as the average visibility in 1980. At both sites, the gradients and intercepts of the regression fits are highest in the 260 to 340 degree quadrant and lowest in the 80 to 160 degree quadrant. The small differences between the data in this Table indicate that there are significant similarities between the long-term behaviour of the two sites.

Figure 11 - Quadrant Visibilities at Heathrow

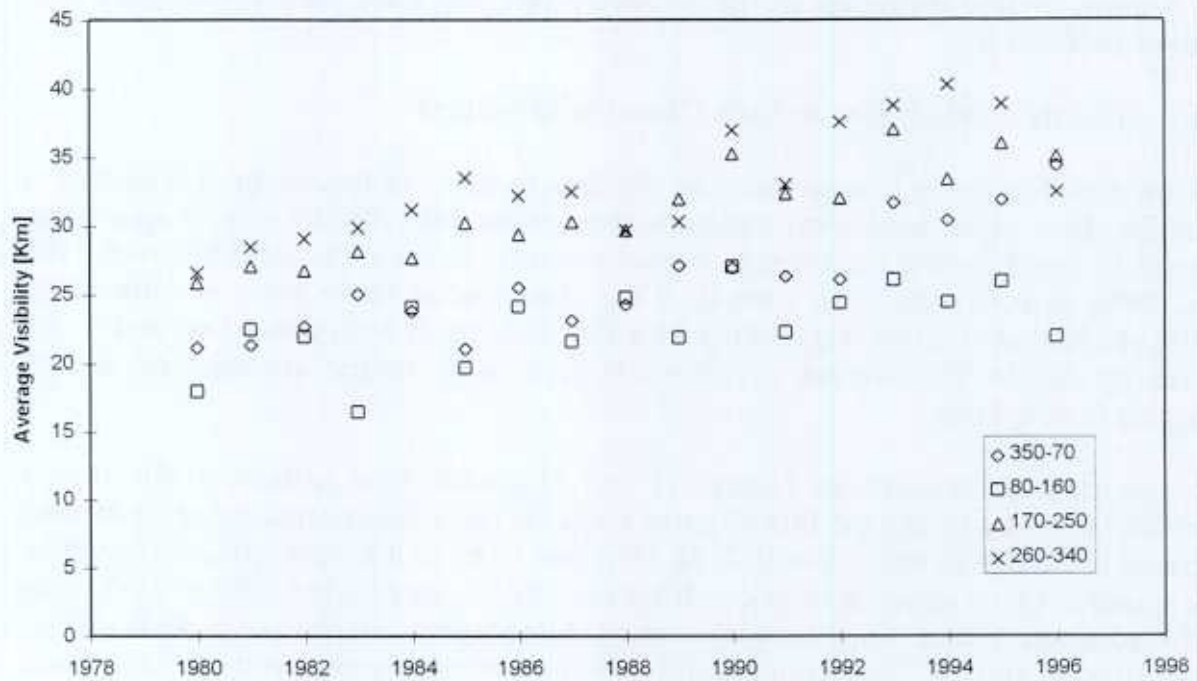
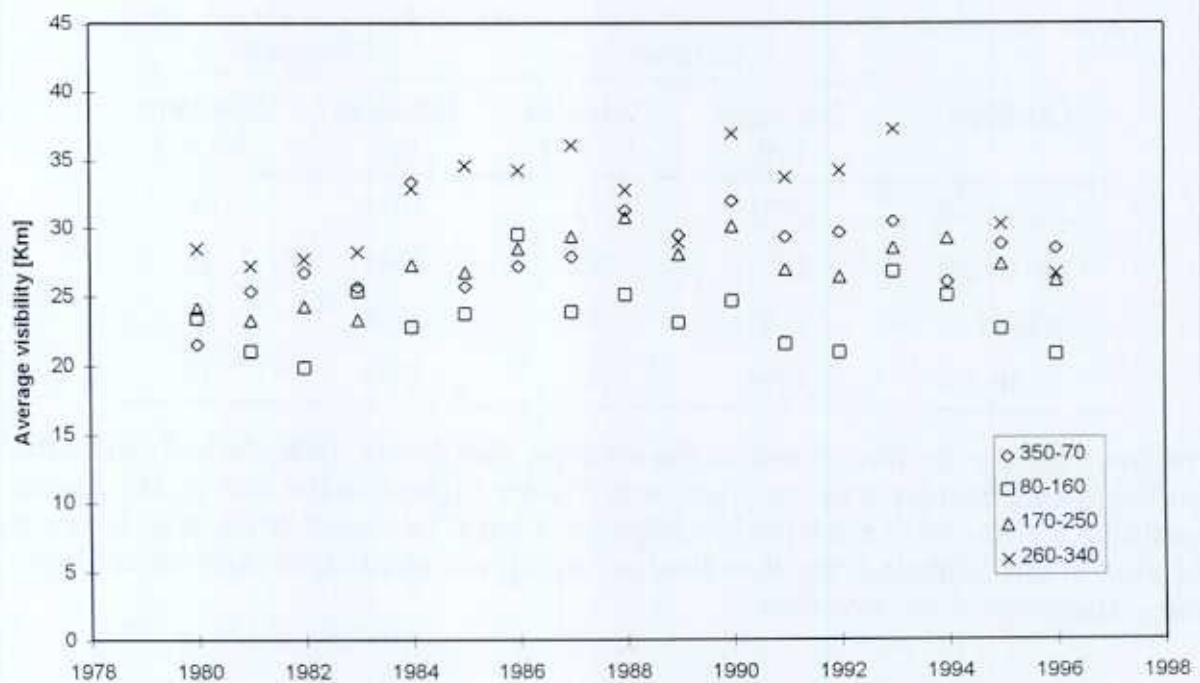


Figure 12 - Quadrant Visibilities at Stansted



5 INTERPRETATION OF QUADRANT DATA

Now that an association has been made between the wind direction quadrants and different sources of air, it is possible to discuss the influence of these sources on visibility.

5.1 "UK Representative" Air

The division of the data into quadrants enables the range of wind directions that are associated with air from particular sources to be grouped together. As discussed above, both sites receive air from the north west which is representative of the UK. In this analysis, this is represented by the quadrant between 260 and 340 degrees. The full series of annual average visibility is shown in Figure 15 together with the regression fits to the period from 1980 to 1993. The gradient of the regression fit and the direction of excursions away from the straight line at each site are similar. The mean gradient corresponds to a 31% improvement in visibility between 1980 and 1993. The data for 1994 to 1996 also show an almost equal reduction in visibility. The similarity in the data supports the hypothesis that the air measured in this quadrant at the two sites is from the same source. Additionally, Figures 11 and 12 show that when compared with air from other directions, this air generally has the best visibility at both sites.

5.2 "Non-UK Representative" Air

The two sites also receive air from directions that would appear not to be of predominantly UK origin. The quadrants that are most representative of this source of air are the south west (170 to 250 degrees) at Heathrow and the north east (350 to 70 degrees) at Stansted. The complete time series of annual means together with a regression fit for the data in these quadrants is shown in Figure 16. The similarity between the two sets of data is not as well developed as in Figure 15. This is probably because this air does not come along the same trajectories from continental Europe, so would not be expected to show exactly the same trends.

5.3 "London" Air

The third possible source of air and consequent influence on visibility that can be identified is London. A thorough analysis of the influence of London would require a very careful choice of sectors at each site since it subtends an angle of greater than 90 degrees at Heathrow and less than 90 degrees at Stansted. However, in this analysis, we use air from the south west at Stansted and the north east at Heathrow to illustrate possible trends. This has been done in Figure 17. Although there are no common features in the spread of the data at the two sites, the rate at which visibility is improving in this type of air is significantly smaller than for the "UK" or "non-UK" air.

Both sites receive air with low average visibility from the south east. This direction

Figure 13 - Quadrant Visibilities at Heathrow
Linear Fit to 1980 - 1993 Data

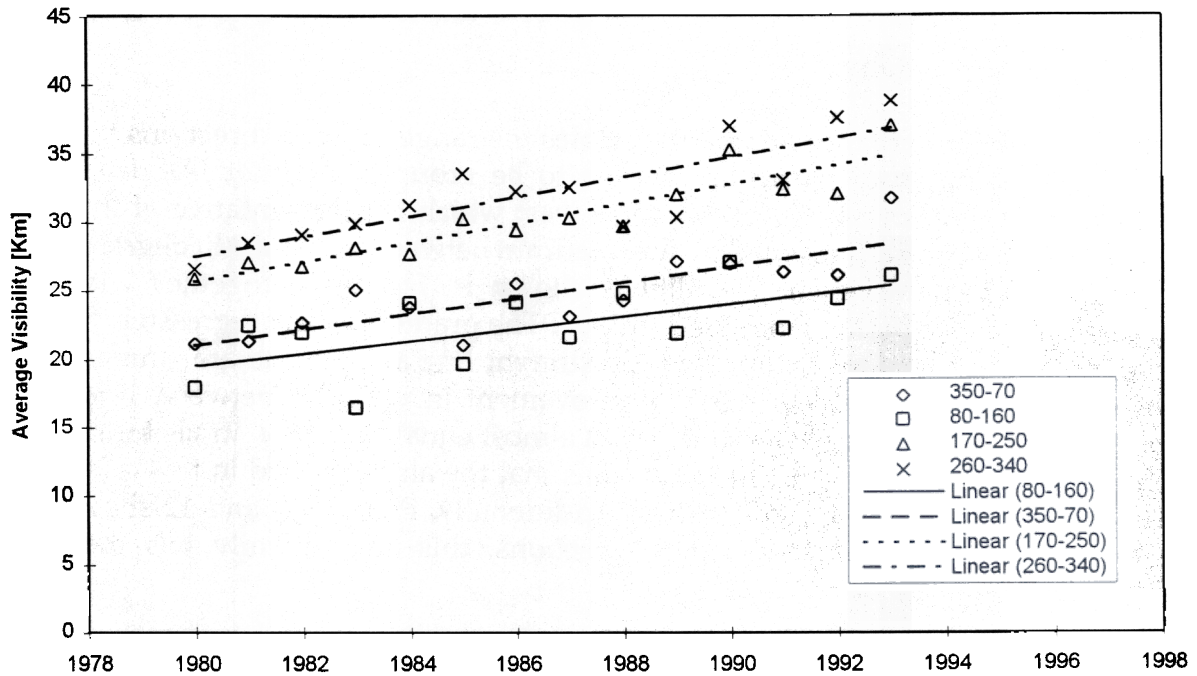


Figure 14 - Quadrant Visibilities at Stansted
Linear Fit to 1980 - 1993 Data

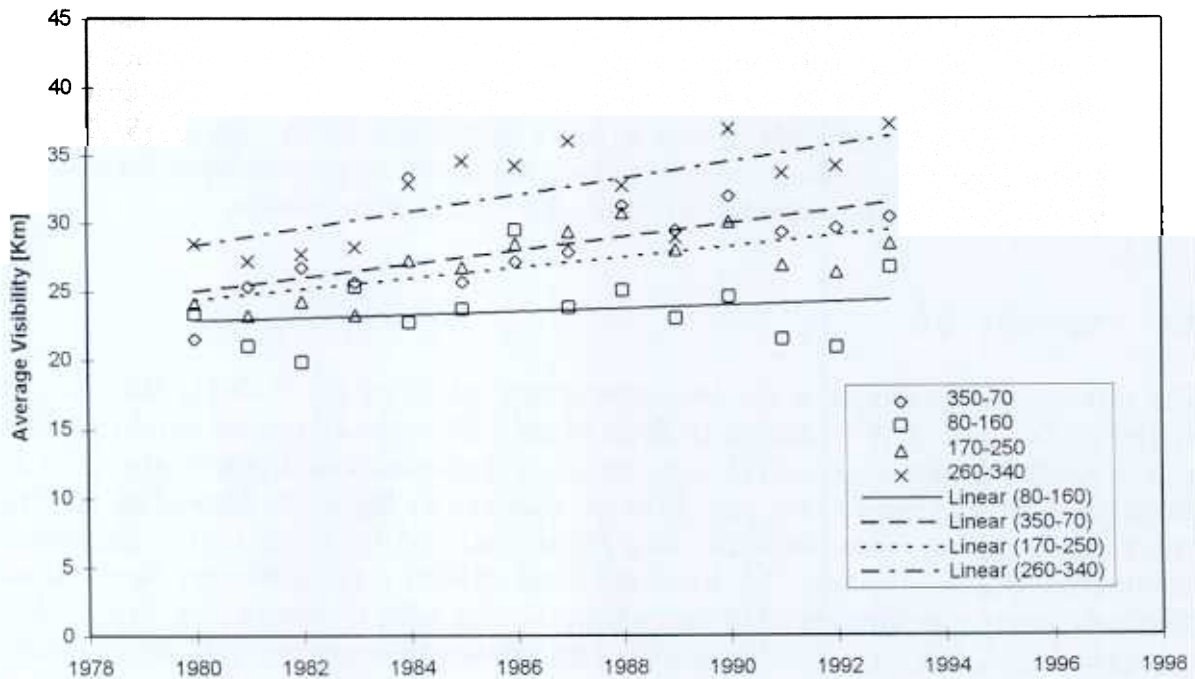


Figure 15 - UK Representative Air

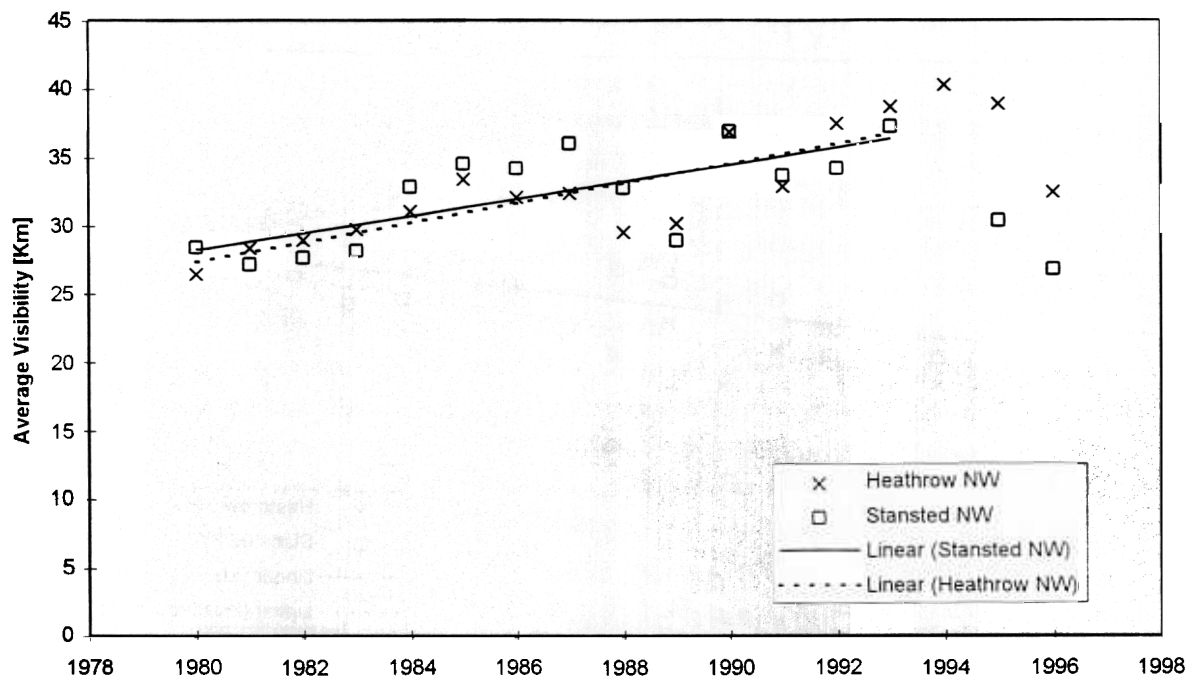


Figure 16 - Non-UK Representative Air

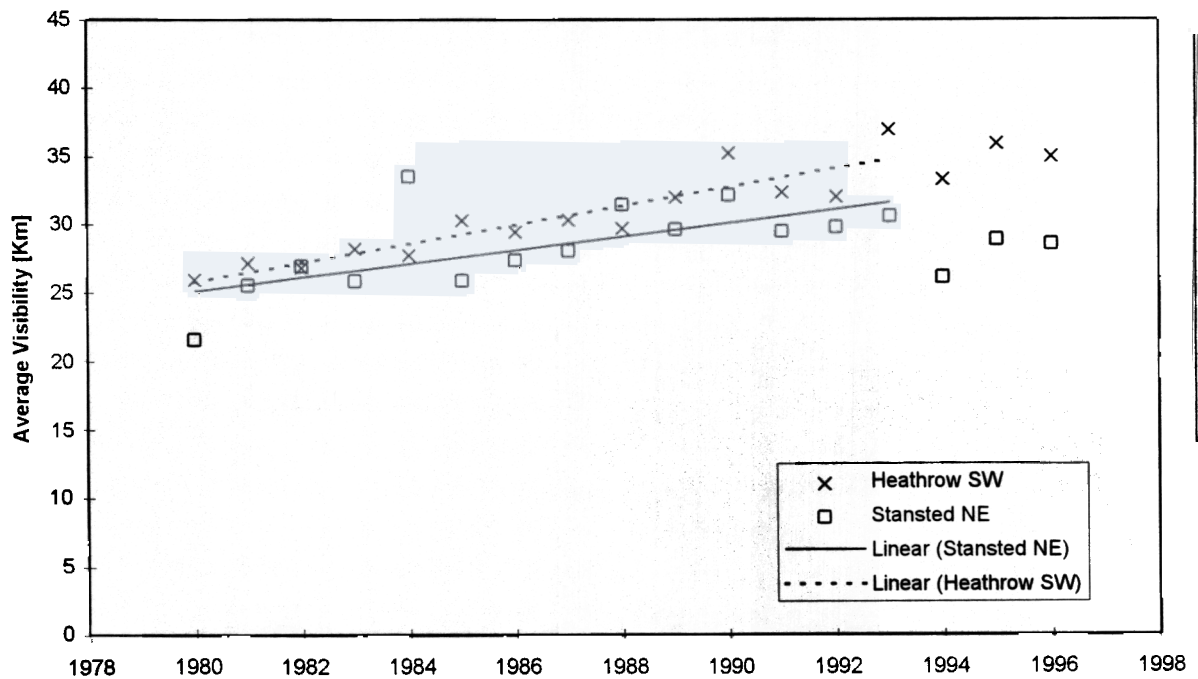
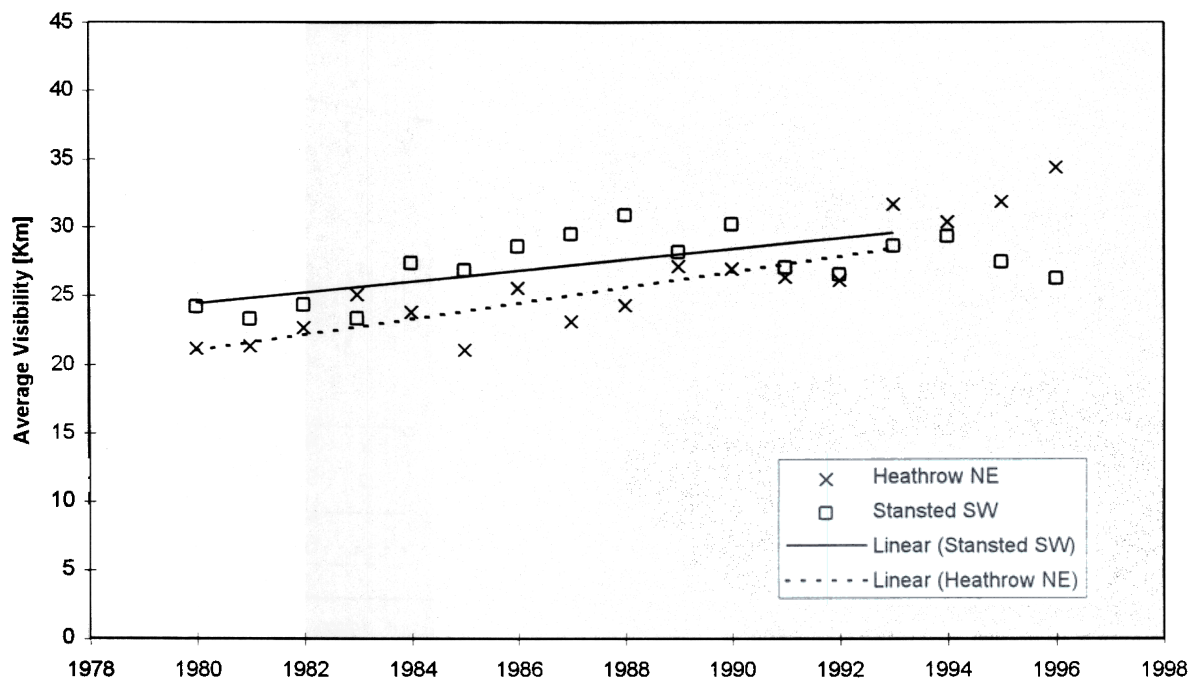


Figure 17 - London Representative Air



is difficult to analyze because it is close to London at both sites. Consequently, we have not interpreted data from this direction.

6 HIGH AND MODERATE VISIBILITY DAYS

The analysis described above uses the annual average visibility as a measure of visibility throughout the year. A more sensitive way to quantify visibility is to calculate the number of days on which visibility was either "high" or "moderate". This corresponds to quantifying the behaviour of the extreme points in the distribution shown in Figures 5 and 6. Since the behaviour of points at the extremes of a distribution (for example the 99th or 1st per centile points) can be extremely sensitive to changes in the distribution, we have chosen to use points closer to the median. Consequently, we define "moderate visibility" as being 20 km or worse, which corresponds to the 40th per centile point of the cumulative distribution. "High visibility" has been defined as being 40 km or better, which corresponds to the 85th per centile point.

This approach can now be used to analyze the trend in visibility during north-west wind directions, since this has shown the most interesting behaviour. The trend in "high" and "moderate" visibility days is shown in Figures 18 and 19. The abscissa refers to the fraction of days for which the wind direction is from the north west. The points are extremely widely spread which is typical of trends in statistics associated with points within a distribution. Although the spread appears to encompass any possible magnitude of trend, it is noticeable that in both Figures, the years 1994, 1995 and 1996 have experienced declining visibility. This confirms the conclusion drawn in Section 5.1.

7 CORRELATION WITH SULPHUR DIOXIDE EMISSIONS

7.1 Sulphur Dioxide Emissions

The primary objective of this study is to investigate the extent of any correlation between visibility and UK sulphur dioxide emissions [7,8]. The previous sections have provided a detailed review of the changes in visibility at two stations in the UK and their possible association with UK and non-UK sources. It is now possible to investigate whether these trends in visibility are correlated with trends in sulphur dioxide emission. Since the process of converting gaseous sulphur dioxide emissions to sulphate aerosol is slow and since we do not expect there to be any significant local emissions of sulphur dioxide at the two stations we will compare the local visibility observations with figures for UK sulphur dioxide emissions.

Annex A lists a number of possible sources of data about UK sulphur dioxide emissions. The best source of sulphur dioxide emission data is the UK National Atmospheric Emissions Inventory (UK NAEI). However, the most recent data only applies to 1994. Therefore, we have used data for UK inland coal consumption from the UK Digest of Energy Statistics as a reasonable indicator of subsequent sulphur dioxide emission trends.

Figure 18 - "High Visibility" (>40 Km) Occurring in NW Direction as a Proportion of the Total.

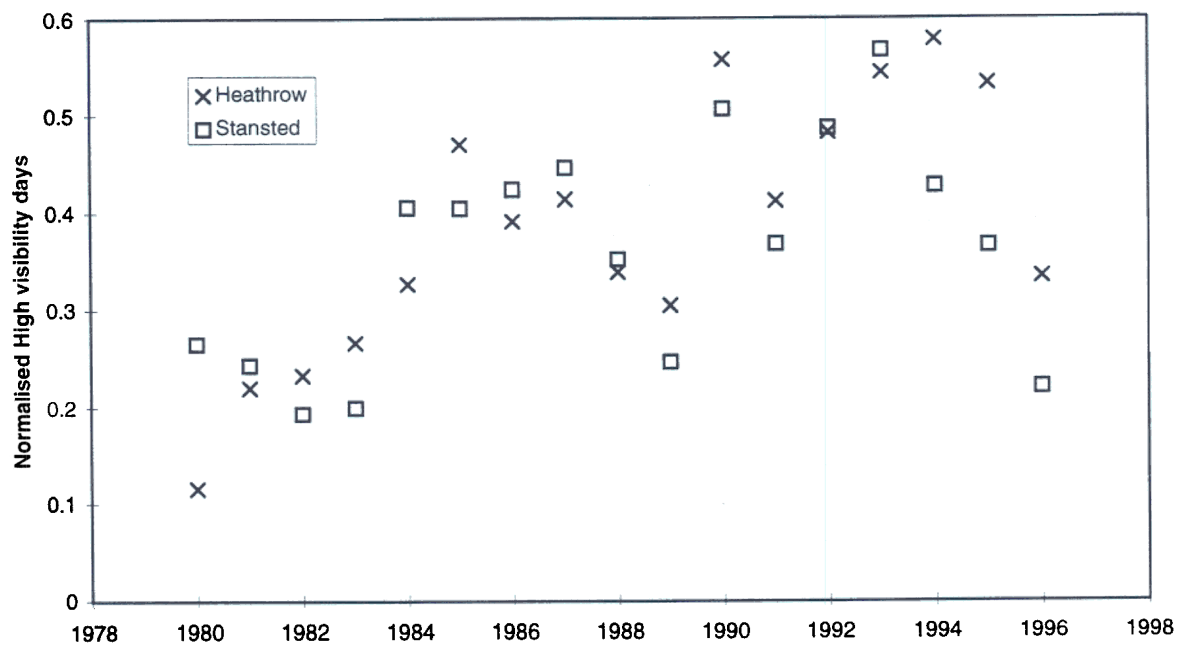


Figure 19 - "Moderate" Visibility (<20 Km) Occurring in NW Direction as a Proportion of the Total.

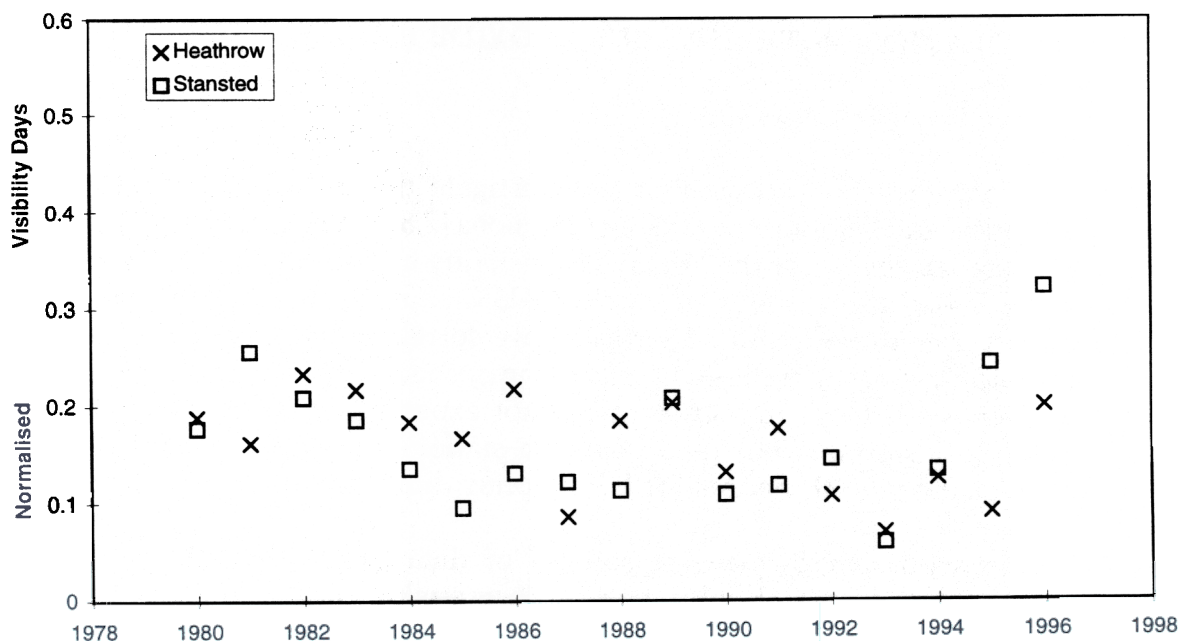


Figure 20 shows that UK sulphur dioxide emissions declined from 4.9 Mt in 1980 to 3.2 Mt in 1993. This Figure shows total sulphur dioxide emissions, as well as emissions from power stations. For comparison, UK inland coal consumption up to 1996 is shown in Figure 21. Since coal burning is the largest source of UK sulphur dioxide emissions, the two Figures show the same general behaviour. We can now judge the extent to which the trends in visibility (Figure 15) correspond with trends in industrial sulphur dioxide emissions (Figure 20).

Since, the transformation of gaseous sulphur dioxide into sulphate aerosol involves a series of complex chemical reactions, we do not expect the relationship between sulphur dioxide emissions and atmospheric scattering by aerosols to be linear. However, we would expect declining sulphur dioxide emissions to give rise to improving visibility. This is the case between 1980 and 1994, when sulphur dioxide emissions declined by 35% and visibility increased by 31%. However, this trend did not occur after 1994 when visibility deteriorated while sulphur dioxide emissions continued to fall. We believe that this indicates the presence of another source of atmospheric particles that has become more significant than sulphur dioxide over this period.

7.2 Other Causes of Visibility Reduction

In Section 2.2, various types of aerosol that could contribute to visibility reduction were discussed. This study has concentrated on the widely demonstrated hypothesis that links visibility reduction to the presence of sulphate aerosol.

However, the results of this study indicate that visibility reduction over recent years in the UK may not be dominantly caused by sulphate aerosol and may be influenced by other types of aerosol. These could include nitrate aerosol, organic carbon, elemental carbon and soil compounds, all of which can be involved in reducing visibility.

Since the size range is one of the parameters that determines how efficiently particles scatter light, it has been suggested that visibility reduction could be linked to the concentration of PM_{10} or $PM_{2.5}$ particulate matter. Such an approach would effectively link visibility to an aggregate measure of particle concentration, including particles of many possible chemical composition. If a trend could be established with PM_{10} or $PM_{2.5}$ particulate matter, subsequent work could focus on changes in the chemical composition of this parameter.

Figure 20 - UK Sulphur Dioxide Emissions

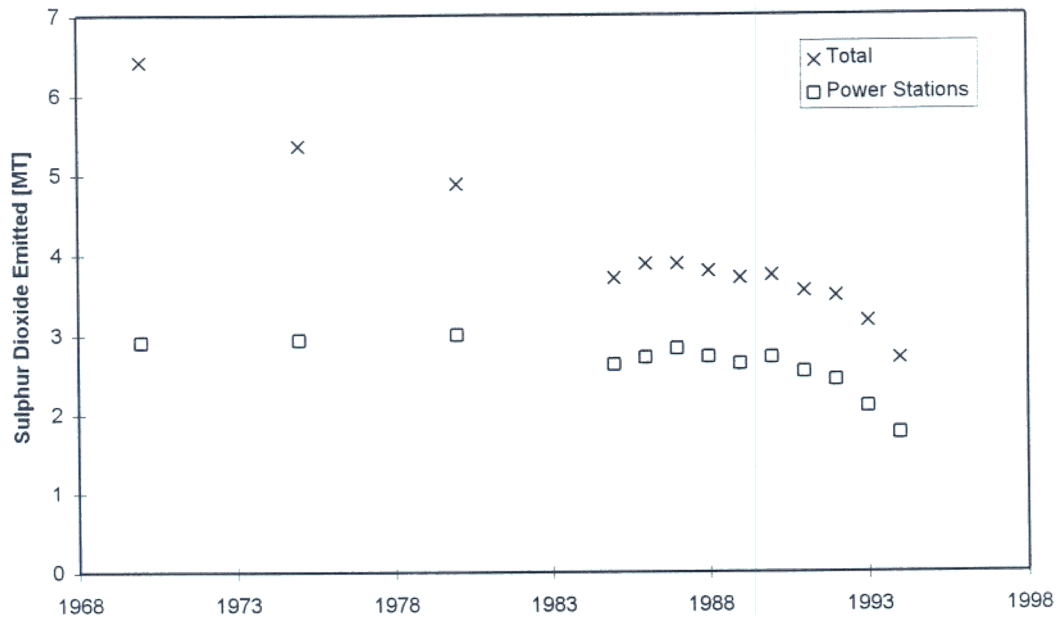
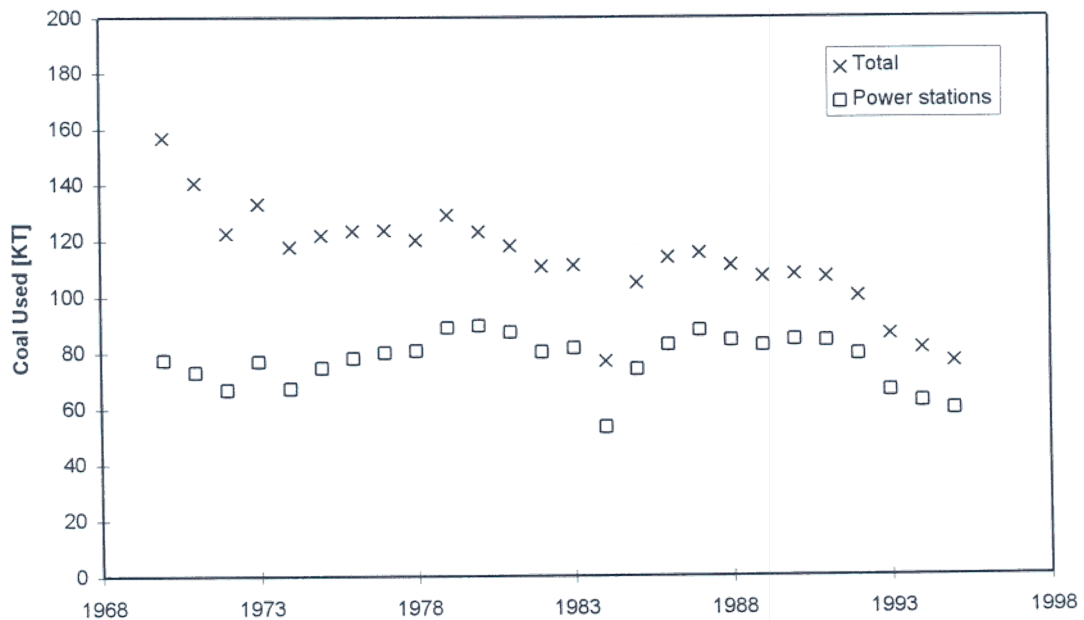


Figure 21 - UK Inland Consumption of Coal



8 CONCLUSIONS

8.1 Trends in UK Visibility

There has been a general improvement in annual average visibility measured at Heathrow and Stansted. However, this improvement is less than the standard deviation of the midday values during any single year. The trend of improving annual average visibility was consistent between 1980 and 1993, but appears to have broken down since then. At Stansted, it was followed by three consecutive years of declining annual average visibility in 1994, 1995 and 1996. The same behaviour is observed in visibility during the summer (June to August).

These trends can be analyzed in more detail by reference to the most likely origin of the air observed. This type of "source" analysis suggests that:

the visibility during wind directions originating from the UK (at both sites) increased by 31% between 1980 and 1993 (Figure 15). However, between 1994 and 1996, it deteriorated to close to its 1980 level. This air generally had better visibility than air from other directions.

the visibility of air originating from continental Europe (Figure 16) is not as good as that from the UK. It improved slowly from 1980 to 1993, but does not show the same pronounced deterioration between 1994 and 1996 as UK air does.

air influenced by London has improved more slowly than from the other sources. It does not show the same pronounced change in 1994 as air from the UK.

8.2 Correlation with Sulphur Dioxide Emissions

The most important conclusion from this study is based on the data in Figure 15. This shows that visibility observed during north-west wind directions improved by 31% from 1980 to 1993, but subsequently deteriorated between 1994 and 1996. There is significant justification for the hypothesis that air from this direction is representative of the impact of UK sources on visibility.

The 31% increase in visibility between 1980 and 1993 occurred over a period during which UK sulphur dioxide emissions declined by 34%. However, since then, visibility has deteriorated while sulphur dioxide emissions have continued to decrease. This suggests that other sources of atmospheric particulate may now be more significant than sulphate aerosols. This is the main observation of this work, which clearly merits further study.

8.3 Issues for Further Study

There are a number of areas in which the analysis presented in this report could be extended:

the number of sites and the length of the time series included in this study could be extended. This could further substantiate the conclusions developed here.

the method used to make the visibility observations could be reviewed to ensure there is no significant bias [9] and that local sources do not interfere.

changes in the distribution of visibility measurements (eg Figures 5 and 6) could be studied in more detail. This has been shown [10] to be a powerful method of revealing changes in visibility data.

in this report, the trend in the annual average visibility has been determined in the most straightforward way. More robust methods for carrying out this type of analysis have been developed [11] which would provide a better estimate of the trend together with a robust estimate of the uncertainty.

Any of these improvements would amplify the results and possibly indicate trends that have not been revealed here.

Of greater importance to the interpretation of the work is further work on the cause of visibility degradation. It would be valuable to extend the work to evaluate any possible correlation between trends in UK visibility and background (rural) PM_{10} concentrations. These could provide an indication of the presence of the types of aerosol and particulate that give rise to visibility reduction. A limited amount of data on rural PM_{10} concentration is available which could be used for such a study. This extension would give confidence in the conclusions of this work and possibly facilitate extrapolation to estimate future trends.

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ANNEX A - DATA SOURCES

The following data sources were searched as part of the study:

Source	Data
UK Met Office	"Dry day" visibility at various airports in the UK
UK National Airborne Emissions Inventory	Sulphur Dioxide Emission values 1970 - 1994
UK Air Quality Archive (WWW)	Ambient Sulphur Dioxide concentrations. Max of 10 years at some sites
UK Digest of Energy Statistics	Coal consumption each year 1970 - 1995
Eurotrac (GENEMIS)	Sulphur Dioxide emissions during 8 episodes of one/two weeks between 1985 and 1992
Corinair	Spatially segregated values of Sulphur Dioxide emissions for 1990
EMEP (NILU)	Similar to Corinair

ANNEX B - DATA SCREENING

In order to facilitate screening out those visibility observations that are adversely influenced by weather conditions, the Met Office codes categorising present weather conditions were used. These codes are recorded at the same time as the visibility observation at the same station. Each observation is recorded as a single code number on a scale from 0 to 99. For the purpose of determining whether there is any influence on visibility, the following division was used.

Codes 00 to 04 are defined:

- 00 Cloud development not observed or not observable.
- 01 Clouds dissolving or becoming less dense.
- 02 State of sky on the whole unchanged.
- 03 Clouds forming or developing.

Higher codes progressively refer to weather conditions that have a greater influence on visibility. For example:

- 04 - 09 Haze, dust, sand or smoke.
- 10 - 12 Shallow fog or mist.
- 13 - 16 Lightning, precipitation in sight.
- 17 - etc

Screening the data series from Heathrow shows that 59% of visibility observation (between 1980 and 1996) were made during weather codes 00 to 04. Similarly, 58% of visibility observations at Stansted were made during the same range of codes. It is these screened series that have been used for the analysis presented in this report.

ANNEX C - DATA SERIES PRESENTED AS RUNNING AVERAGES

The following Figures show some of the data presented in the main part of the report re-plotted as running averages over 5 preceding years.

Figure C1 - Five Year Moving Average Quadrant Visibilities at Heathrow

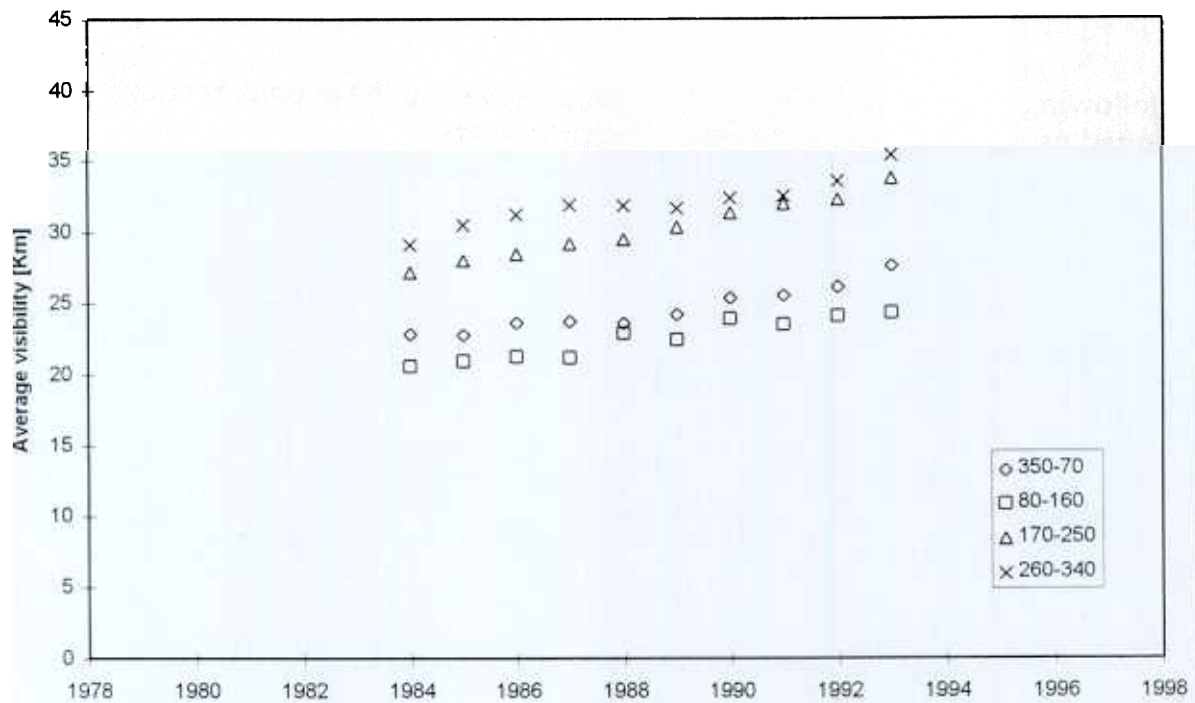


Figure C2 - Five Year Moving Average Quadrant Visibilities at Stansted

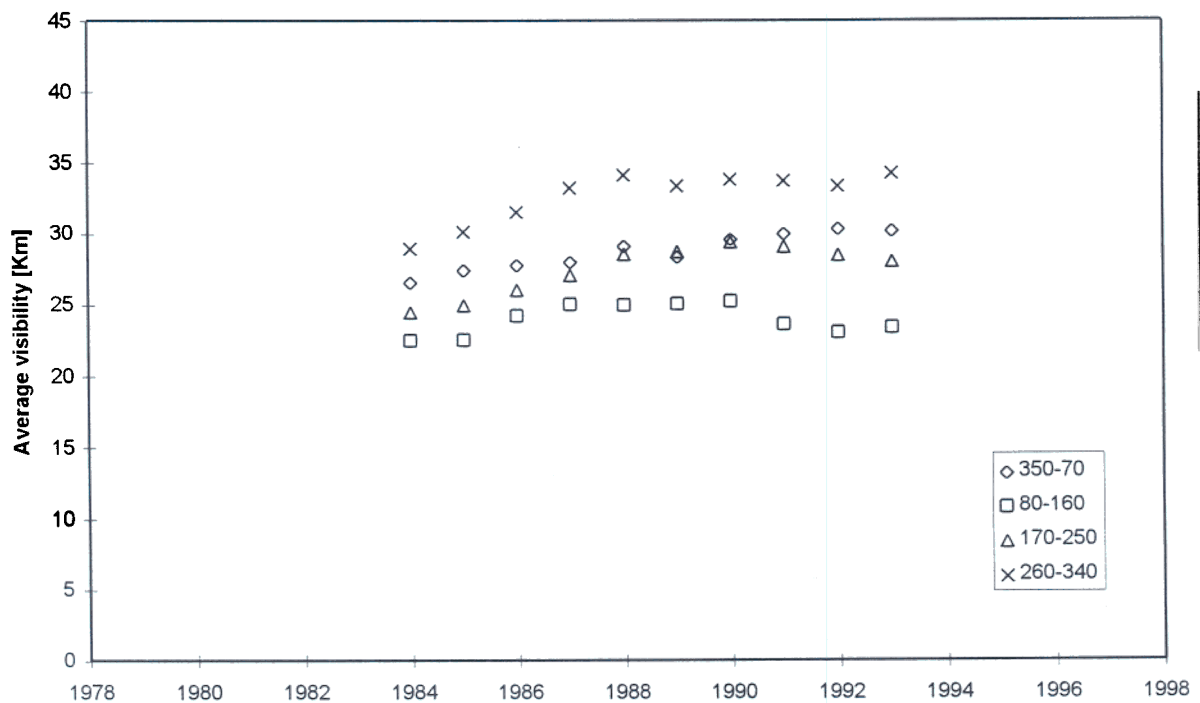


Figure C3 - Five Year Moving Average UK Representative Air

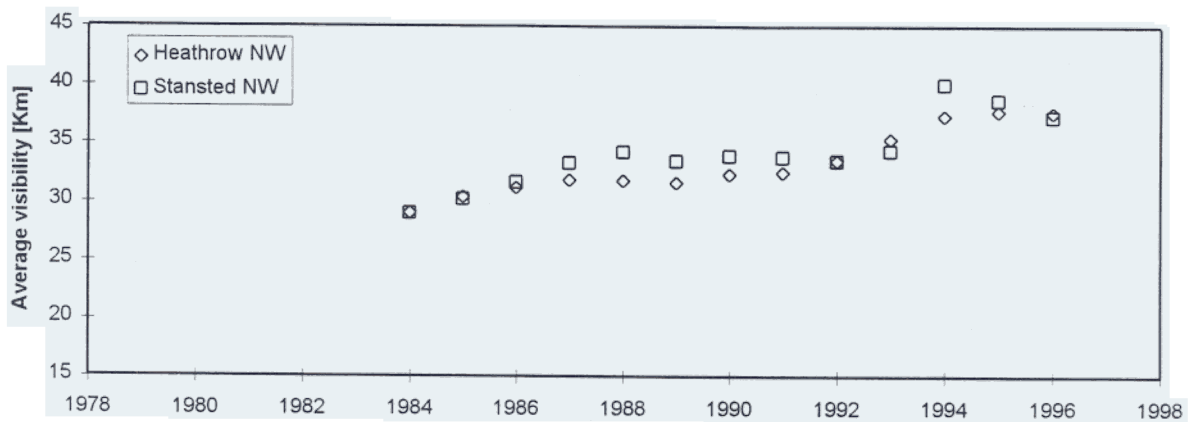


Figure C4 - Five Year Moving Average Non-UK Representative Air

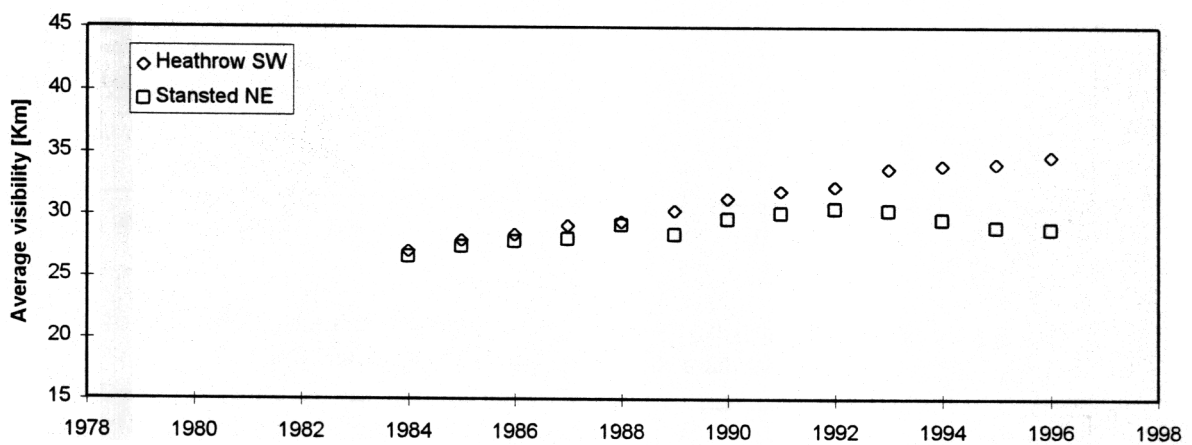


Figure C5 - Five Year Moving Average London Representative Air

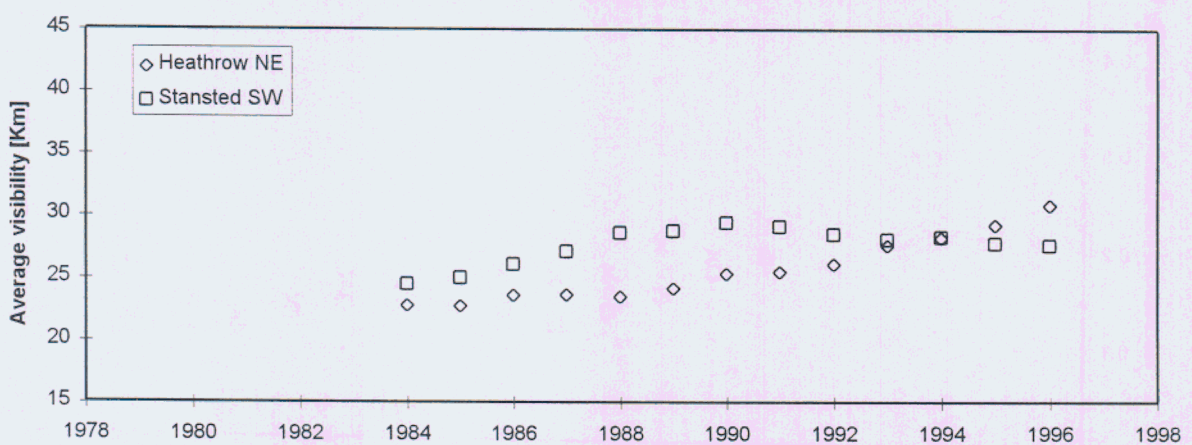


**Figure C6 - Five Year Moving Average of "High" Visibility (>40 Km)
Occurring in NW Direction as a proportion of the total**

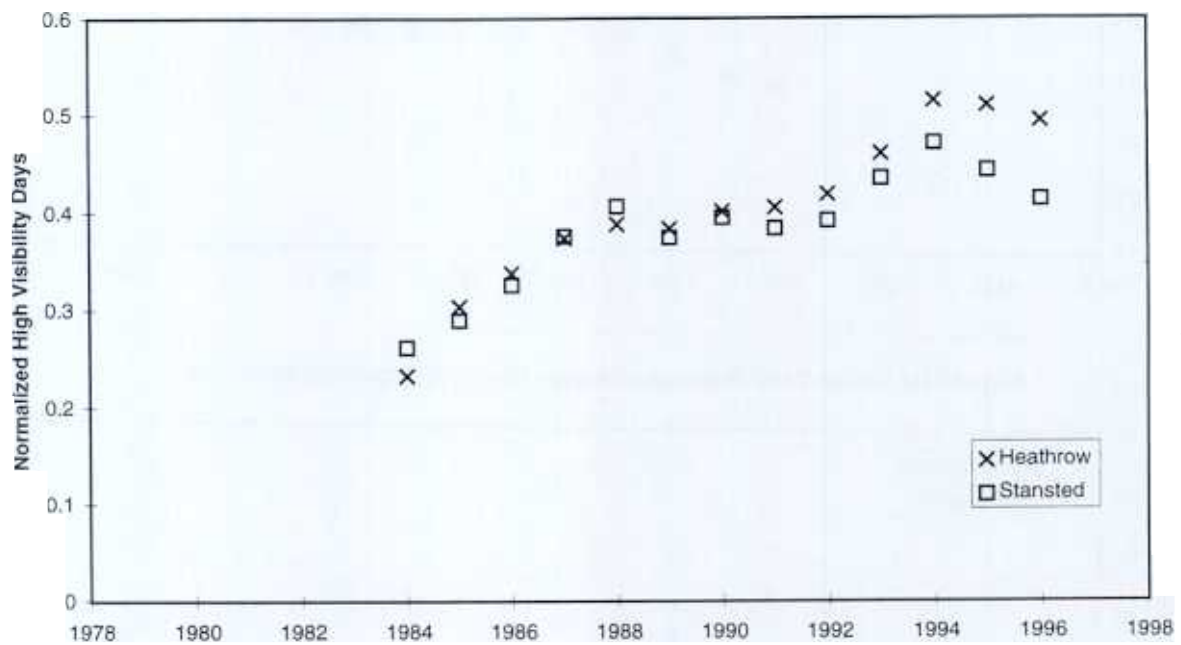


**Figure C7 - Five Year Moving Average of "Moderate" Visibility (<20 Km)
Occurring in NW Direction as a Proportion of the Total**

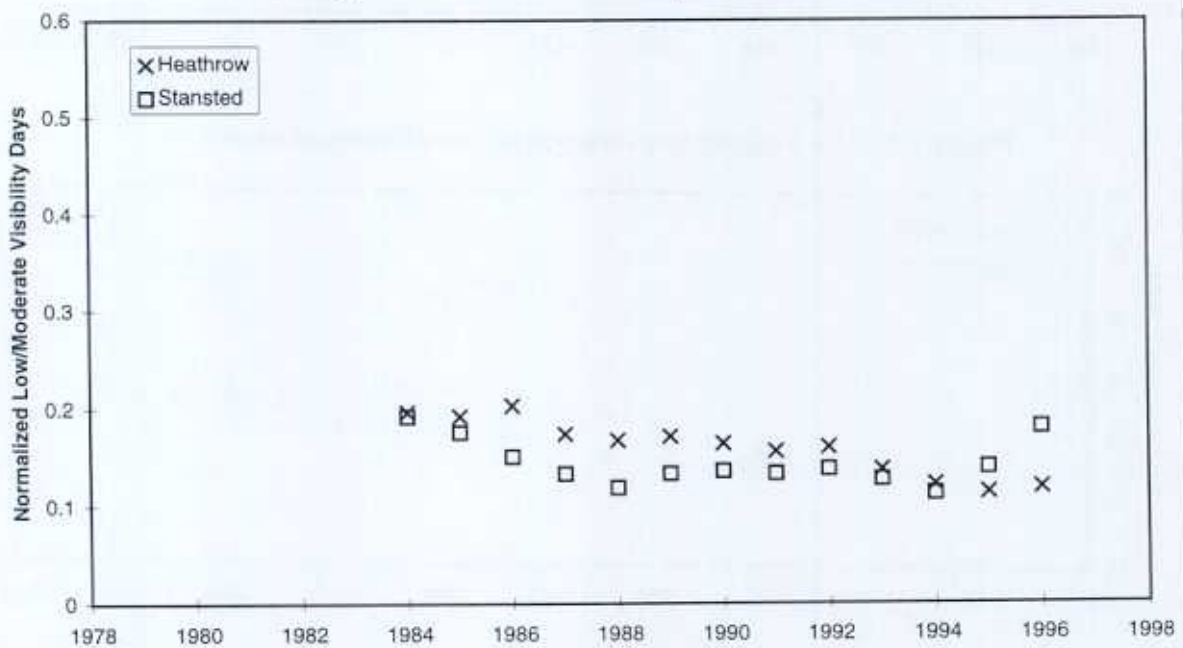


Figure No.	Filename
1	FILTD.XLS
2	FILTD.XLS
3	FILTD.XLS
4	FILTD.XLS
5	FILTOD.XLS
6	FILTOD.XLS
7	FILTOD.XLS
8	FILTOD.XLS
9	LONDON.CDR
10	FILTOD.XLS
11	FILTD.XLS
12	FILTD.XLS
13	FILTD.XLS
14	FILTD.XLS
15	FILTD.XLS
16	FILTD.XLS
17	FILTD.XLS
18	FILTVIS.XLS
19	FILTVIS.XLS
20	SO2DATA.XLS
21	SO2DATA.XLS
C1	FILTD.XLS
C2	FILTD.XLS
C3	FILTD.XLS
C4	FILTD.XLS
C5	FILTD.XLS
C6	FILTVIS.XLS
C7	FILTVIS.XLS

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