Imperial College London
Projects

Environmental Research Group

Sussex Air Pollution Monitoring Network Forecast Analysis 2020

Independent analysis provided by:

Hima Chouhan, Senior Air Quality Analyst
Dr Anna Font Font, Research Fellow
Erica Winn, Senior Air Quality Analyst

School of Public Health
Environmental Research Group, Imperial College London

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Sussex Forecast Analysis for 2020

Introduction

The Environmental Research Group at Imperial College London provides an air pollution forecasting and alert service for the Sussex Air Quality Partnership. The accuracy of the forecasts provided during 2020 has been analysed.

There are two main pollutants of interest; ozone (O_3) and particulate matter (PM_{10} and $PM_{2.5}$). O_3 is the pollutant that most commonly exceeds the 'moderate' threshold in Sussex as it is higher in rural and background locations and is influenced by long range transport from the nearby continent. Particulate matter exceeds the 'moderate' threshold less frequently and this tends to occur during still, settled weather conditions which lead to poor dispersal. It is also influenced by long range transport from the continent which adds to local emissions.

The other main pollutant measured in Sussex, nitrogen dioxide (NO_2) has generally been less problematic and the 'moderate' threshold for NO_2 was not exceeded during 2020 at the Sussex sites. It has not been included in this analysis.

The air pollution bands for O_3, PM_{10} and $PM_{2.5}$ are shown below in Table 1.

Banding	O_3 (µgm^{-3}) – Running 8 hourly mean	$PM_{2.5}$ (µgm^{-3}) - 24 hr mean	PM_{10} (µgm^{-3}) - 24 hr mean
'Low'	0-100	0-35	0-50
'Moderate'	101-160	36-53	51-75
'High'	161-240	54-70	76-100
'Very high'	≥241	≥71	≥101

Table 1 - air pollution bands µgm^{-3} as defined in the UK Daily Air Quality Index

Forecasts are issued before 1pm on each working day, covering the following day. On weekends, the forecast is issued on Friday and covers Saturday, Sunday and Monday. For longer periods, such as a bank holiday weekend, a forecast is issued to cover the non-working days and the first working day after. However, this type of forecast is challenging, and accuracy is reduced towards the end of the forecast period.

Method

There were two stages to the analysis:

1. Measurements from air quality monitoring sites in Sussex were interrogated to identify events of ‘moderate’ or above air pollution during 2020. These were compared to the forecasts issued by the Environmental Research Group to assess the proportion of pollution events which were predicted.

2. The forecasts issued by the Environmental Research Group during 2020 have been examined to identify the number of ‘moderate’ or above forecasts which were followed by ‘moderate’ or above pollution during that forecast period and the number of forecasts which were false alarms.

Where weekend forecasts have been issued, the alert has been assumed to cover the full three days (Saturday, Sunday and Monday) unless specified otherwise in the forecast text.

Results and discussion

1. Were pollution events predicted?

Figure 1 summarises the O_3 and PM episodes during the year. PM episodes occurred during February, March and April. O_3 episodes were during the spring through to early autumn: March to September. Alerts were issued during the same periods plus during November for particulates. The general meteorological conditions that give rise to episodes are matched well by the alerts though an exact day match was not always achieved. During springtime the conditions that lead to O_3 and PM episodes can be similar, as was the case during April and August when alerts were issued for both O_3 and PM.

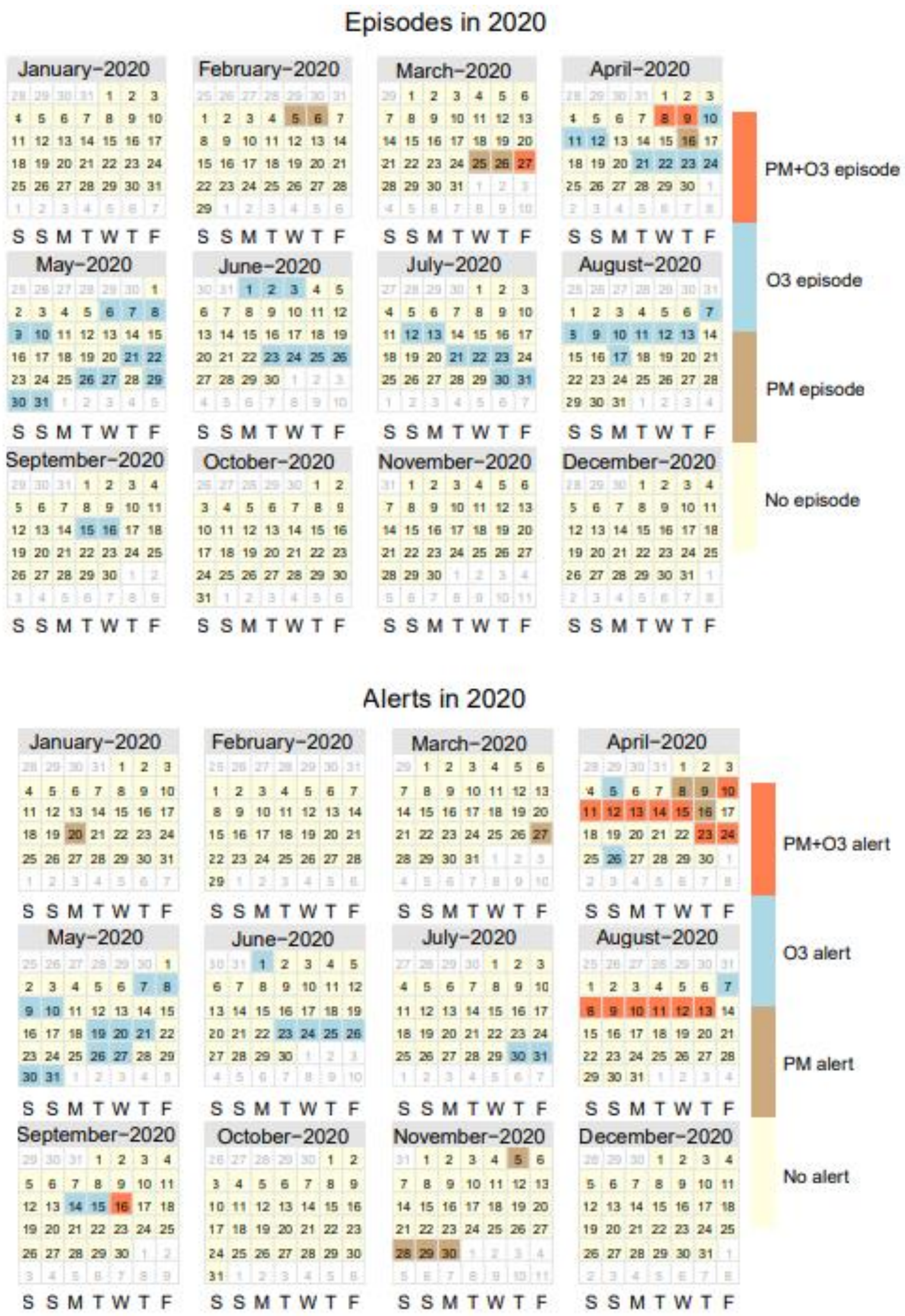

Figure 1 – calendar plot of episodes and alerts in 2020 produced using the R OpenAir package.

O_3

Episodes	Total Measured	Predicted %	Number predicted	Not predicted %	Number not predicted
‘high' roadside	0	n/a	0	n/a	0
‘high' urban background	4	100%	4	n/a	0
‘high' rural	3	100%	3	n/a	0
‘Moderate’ roadside	17	94%	16	6%	1
‘Moderate’ urban	26	77%	20	23%	6
‘Moderate’ rural	41	63%	26	37%	15

Table 2 - Table showing the proportion of the total number of O_3 pollution events which were predicted

Ozone episodes occurred from April through to September. ‘High’ O_3 events are rare and were recorded and predicted on five days in Sussex during 2020 resulting in a 100% prediction rate.

There were forty-one days when ‘moderate’ O_3 was measured at rural locations in Sussex during 2020, 63% of these were predicted. ‘Moderate’ O_3 was also measured at background locations on twenty-six days, 72% of which were predicted and at roadside locations on seventeen days during 2020, 94% of which were predicted.

Three of the days when ‘moderate’ O_3 was measured, but not predicted were weekend days. Forecasts covering weekends include several days and are more challenging to forecast due to uncertainty in the forecast weather patterns.

There were also four days of ‘moderate’ O_3 recorded at a single site only, isolated occurrences, difficult to predict.

A further five days resulted in levels at less than $3µm^{-3}$ above the ‘low’ banding – a very small margin, again difficult to predict.

In all there were sixteen days where O_3 episodes were not predicted, thirteen of those days, as described above, occurred in circumstances almost always difficult to foresee. Furthermore, alerts are often issued around the time of actual episodes; as can be seen in the calendar plot in figure 1, six of the missed episode days were missed by one day only.

The success rate was further improved at rural and urban sites by allowing for a 10.1µgm^{-3} (10%) margin above the 101µgm^{-3} 'moderate' threshold. At urban sites, twelve out of the fifteen days where O_3 reached 110.1µgm^{-3} or above were predicted. This means that on 80% of occasions where O_3 reached 110.1µgm^{-3} or above in urban locations, the public were warned in advance by the Imperial pollution forecasting and airAlert text service.

O_3 with 10% Margin

Episodes	Total measured	Predicted %	Number predicted	Not predicted %	Number not predicted
O_3 'moderate' rural	31	77%	24	23%	7
O_3'moderate' urban background	15	80%	12	20%	3

Table 3 - The proportion of rural and urban background O_3 events which were predicted, when 10% margin for uncertainty has been included.

There are several reasons for considering a 10% margin on the 'moderate' threshold. Firstly, there is an uncertainty on all measurements which should be considered although this would not necessarily result in a positive bias. Secondly, near real-time measurements form a large input to the forecasting process. This near real-time input is based on unratified measurements whereas post hoc analysis of forecast accuracy is based on ratified measurements and changes of concentrations of 10% can be common place in the ratification process, often sourced from audits, which are carried out on the Sussex network.

Air quality forecasts are not intended to predict pollution levels to such a high degree of accuracy but to give an indication to sensitive individuals of whether or not pollution is likely to affect them. Although the banding thresholds are based on likely health effects of air pollution, in reality these health effects do not have clear cut-off points. The difference that someone would experience when exposed to an 8-hourly mean O_3 concentration of 96µgm^{-3} compared to 104µgm^{-3} could be negligible.

Particulates (PM_{10} and $PM_{2.5}$)

Episodes	Total measured	Predicted %	Number predicted	Not predicted %	Number not predicted
Particulate 'moderate' roadside	3	100%	3	n/a	0
Particulate 'moderate' urban background	8	50%	4	50%	4

Table 4 - Table showing the proportion of particulate events which were predicted

'Very high' and 'high' levels of particulates were not measured during 2020

'Moderate' particulates were measured on eight days only during 2020 and were predicted on 100% and 50% of occasions at roadside and background locations respectively. The four unpredicted episodes occurred at a single site only, three of which were well below 10% of the moderate margin. Forecasting for individual hotspots is difficult and as described above, does not meet the requirements of providing a general indication of pollution levels affecting individuals.

Furthermore, with so few episodes recorded during 2020 missing just a few in this way will greatly bias the percentage correctly predicted.

2. Which forecasts were correct and which were false alarms?

Thirty-nine forecasts were issued for ‘moderate’ or above O_3 or particulate pollution in Sussex during 2020. These include days when ‘moderate’ days were the airAlert forecast was classified as ‘possible’, i.e. with a less than 50% chance of reaching ‘moderate’. Ten of these covered weekends. In total, there were forty-seven days where an alert was active. Three days have been counted for each weekend forecast unless specifically stated otherwise in the forecast text.

During Guy Fawkes bonfire and firework events, elevated particulate levels can occur very locally, so the public are frequently warned as a precaution, even if meteorological conditions do not suggest that prolonged or widespread pollution is likely.

Forecast category	**Days with active ‘moderate’ forecasts**	**Days with no ‘moderate’ or above pollution forecast**	**Days when ‘moderate’ or above pollution occurred as forecast**	**Days when ‘moderate’ or above pollution did not occur but was forecast**
O_3 ‘moderate’ rural	39	327	29	10
O_3 ‘moderate’ urban background	40	326	24	16
O_3 ‘moderate’ roadside	31	335	16	15
Particulate (PM_{10} and $PM_{2.5}$) ‘moderate’ roadside	27	339	3	24
Particulate (PM_{10} and $PM_{2.5}$) ‘moderate’ urban background	26	340	4	22

Table 5 - Table showing the number of ‘moderate’ forecasts issued and whether 'moderate' pollution occurred

These results have been further analysed according to the methods proposed by Stephenson (1999) to give the hit rate and the false alarm rate which are calculated as shown in Table 7.

		Episode Observed		
		yes	*no*	***total***
Forecast	*yes*	a	b	**a+b**
	no	c	d	**c+d**
	total	**a + c**	**b + d**	**a + b + c + d**
		Hit rate = a/a+c	**False alarm rate =b/b+d**	

Table 6 – Table illustrating Stephenson (1999) analysis method

So, the hit rate can be defined as the number of days when 'moderate' pollution was forecast and did occur divided by the total number of days when 'moderate' pollution occurred. The false alarm rate is the number of days when 'moderate' pollution was forecast but did not occur divided by the total number of days when there was no 'moderate' pollution. Tables with calculations for each prediction are shown in the Appendix.

Forecast category	**Hit Rate**	**False Alarm Rate**	**Total number of episode days**	**Total Number of non-episode days**
O_3 'moderate' rural	66%	3%	44	322
O_3 'moderate' urban background	80%	5%	30	336
O_3 'moderate' roadside	94%	4%	17	349
Particulate (PM_{10} and $PM_{2.5}$) 'moderate' roadside	100%	7%	3	363
Particulate (PM_{10} and $PM_{2.5}$) 'moderate' urban background	50%	6%	8	358

Table 7 - Stephenson analysis for all 'moderate' pollution forecasts in 2020

In general, the false alarm rates were rare, so the public were not often alerted unnecessarily.

In all cases, where a forecast has been issued, the probability of 'moderate' pollution has been approximated to 100% for simplicity of analysis. However, on the majority of occasions, a lower probability of 'moderate' pollution was expected. Therefore, even if the forecaster expects a low probability of 'moderate' pollution, and 'moderate' pollution does not occur, this will still contribute to the false alarm rate. Conversely, if the forecaster has expected a low probability of 'moderate' pollution and it does occur, this will contribute to the hit rate.

Conclusions, recommendations and future considerations

Measuring moderate levels of ozone at roadside locations is unusual due to the scavenging properties of NOx, however during 2020 there were a number of episodes for which the forecast hit rates were particularly good at 94%. For rural locations the ozone forecast hit rate was affected by a number of marginal and single site incidents that occurred.

The hit rates for particulates were also very good at 100% at roadside locations, however as so few episodes occurred during 2020 the hit rate for urban background locations was greatly biased by missing just four single site and marginal incidents.

The best hit rate was for roadside particulates at 100%.

False alarm rates were once again low, not exceeding 7% for any site type or pollutant, although a more precautionary approach has been adopted - alerts are now more readily issued when predictions for 'moderate' pollution are borderline. The highest false alarm rate was for roadside particulates.

Near real-time measurements form a large input to the forecasting process. This near real-time input is based on unratified measurements whereas post hoc analysis of forecast accuracy is based on ratified measurements and changes of concentrations can be commonplace in the ratification process.

The results of the forecast analysis are fed back to the forecasting team. This highlights any strong or weak points and raises awareness of areas for improvement. As a result of this analysis the issue of over caution in issuing forecasts will continue to be addressed, for all pollutants.

Reference

Stephenson, D. B., 2000. Use of the ''odds ratio'' for diagnosing forecast skill. Weather and Forecasting 15:2, 221-232.

Appendix

		Rural Ozone		
		Episode Observed		
		Yes	*No*	***total***
Forecast	*yes*	29	10	**39**
	no	15	312	**327**
	total	**44**	**322**	**366**
		Hit rate = 66%	**False alarm rate = 3%**	

Table 8 - Stephenson analysis for rural O_3

		Urban Background Ozone		
		Episode Observed		
		yes	*No*	***total***
Forecast	*yes*	24	16	**27**
	no	6	320	**326**
	total	**30**	**336**	**366**
		Hit rate =80%	**False alarm rate = 5%**	

Table 9 - Stephenson analysis for urban background O_3

		Roadside Ozone		
		Episode Observed		
		yes	*No*	***total***
Forecast	*yes*	16	15	**31**
	no	1	334	**335**
	total	**0**	**349**	**366**
		Hit rate = 94%	**False alarm rate = 4%**	

Table 10 - Stephenson analysis for roadside O_3

		Roadside Particulates (PM_{10} and $PM_{2.5}$)		
		Episode Observed		
		yes	*No*	***total***
Forecast	*yes*	3	24	**27**
	no	0	339	**339**
	total	**3**	**363**	**366**
		Hit rate = 100%	**False alarm rate =7%**	

Table 11 - Stephenson analysis for roadside PM_{10} and $PM_{2.5}$

		Urban background Particulates (PM_{10} and $PM_{2.5}$)		
		Episode Observed		
		yes	*No*	***total***
Forecast	*yes*	4	22	**26**
	no	4	336	**340**
	total	**8**	**358**	**366**
		Hit rate = 50%	**False alarm rate = 6%**	

Table 12 - Stephenson analysis for urban background PM_{10} and $PM_{2.5}$

Imperial College London
Projects

Environmental Research Group

Environmental Research Group
School of Public Health
Imperial College
Michael Uren Biomedical Engineering Hub
White City Campus
Wood Lane
London W12 0BZ

Telephone:	+44 (0) 20 75931515
E-mail:	erg-enquiries@imperial.ac.uk
	hima.chouhan@imperial.ac.uk
Internet:	www.imperial.ac.uk