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The Influence of Weather on Urban Air Quality in United Kingdom

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Abstract. This research focuses on the relationship between weather and air quality in UK cities. Three cities (Norwich, Swansea and Dover) have been chosen to contrast the roles of different topographic factors. Norwich suffers from the south-east England plume, has N02 and PM10 problems due to traffic volumes, and is influenced by the proximity of the North Sea. Swansea is the wettest city in the UK and has an N02 problem due to traffic. It benefits from an advanced air quality monitoring system. Mountains to the north of Swansea are associated with up and down wind (katabatic airflow), causing air containing pollutants to be spread horizontally, reducing the potential for dispersion. Dover is a major ferry port, has the highest urban S02 concentrations in England resulting from ship emissions and is influenced by a continental climate and sea breezes. This study analyses inter-annual and seasonal variability of the local and surrounding climate in relation to the topography and in conjunction with urban air quality, together with pollutant exceedences associated with specific short-term weather conditions.

Key words: Weather, Air pollution, Air Pressure, Air temperature, Inversion..

Introduction

Meteorological variability can confound air quality management attempts. There are a number of meteorological spatial and temporal scales which are important for understanding why and when air quality reaches levels that are deemed unacceptable by government authorities.

Ground-based temperature inversions, which occur most often during winter, trap pollutants and, exacerbated by low wind speeds, can cause pollutant concentrations to accumulate overnight, rather than to disperse. Temperature inversions tend to be a winter phenomenon because cold ground surfaces mean that the layer of air in which pollutant-mixing takes place is thinner than over warmer ground, leading to increased pollution mixing ratios. Additionally, during the winter when ambient air temperatures are lower, motor vehicles take longer to reach efficient operating temperatures and so emissions of pollutants are, on average, higher.

The summer of 2003 was characterized by sustained heatwave across much of Europe in the first two weeks of August and temperature peaked at a new record of 38.5°C in the UK (Stedman, 2004). The temperatures and durations, however, were not typical of European summers and so this summer can be described as abnormal. However, it is predicted to become normal by 2030 or 2040, the impacts of changes in the various input parameters make climate modelling very difficult but there is a consensus that Europe will be warmer (Burt, 2004; WHO, 2003). Extremes of temperature tend to be associated with air quality episodes; in this case, ozone was of particular concern but there was a commensurate rise in PM,0 (Stedman, 2004).

Wind promotes atmospheric turbulence and instability, and increases mixing and dilution (Colls, 2002), As the ground heats during the day, the air becomes more turbulent, especially in the middle of the day. Air turbulence causes polluted air to disperse as it moves away from its source.

Throughout Europe there is increasing activity to assess and improve air quality in urban areas by using a variety of models (Carruthers et al., 1999). The ESCOMPTE program produced a relevant set of data for testing and evaluating regional pollution models in Marseilles, south-eastern France (Cros et al., 2004; Dufour et al., 2005). In Berlin, the BERLIOZ model was used to study the effect of different meteorological conditions on pollution episodes (Volz-Thomas et al., 2000). The European wide project COST715 provided a framework in which the relationship between meteorology and urban air pollution problems was studied in 19 European countries (Fisher et al., 2005). CIVITAS is a part-EU funded project aimed at creating healthier cities through the reduction of Vehicle emissions (Stephenson, 2007). This has been adapted by many cities (more on this in Chapter 5) and promotes measures such as the establishment of Low Emission Zone (LEZ), and the promotion of eco-driving, Heavy Duty Vehicle (HDV) controls and fitting buses with engine cut-off switches for use at bus-stop, Human beings often pollute the air with waste that is bad for their health (Visconti, 2001), However, air pollution data alone does not reveal the whole story, and to obtain an understanding about why air quality varies from day to day, researchers must also measure and analyse meteorological conditions as well. Overall, meteorology plays a very important role on both the temporal and spatial scales as it significantly affects the concentration of air pollution as it builds in the air, whether over rural or urban regions. One of the influences on weather and urban air quality is local topography. There is a need to increase our understanding of the effects of complex local terrain and of land and sea breeze effects.

The forecasting of weather and air pollutant concentrations is especially significant over specified periods or seasons. This allows us to make predictions and to compare present data with possible future outcomes, i.e. we can use these data as inputs for our models. Nevertheless, to make accurate predictions of air quality, we must have reliable evidence to use in a model, and only then can the output from our models test the levels of air quality and assess the significance of city pollution sources. However, meteorological variation can confound attempts to improve air quality through emission control.

The study Area

The physical location of the UK plays a central role in its climate as it is influenced by prevailing westerly winds and by the North Atlantic Drift which comprises warm water of tropical origin producing lower summer and higher winter temperatures compared to other areas of comparable latitude (Hulme and Barrow, 1997). However, the UK is also renowned for great variability in day-to-day weather, leading to episodic periods, of varying length, which can strongly influence pollution emission, transformation and dispersion. The research presented in this study concentrates on documenting and analysing the relationship between weather and air quality in three case study UK urban areas located in Figure 1 (a); Norwich, Swansea and Dover. Figures 1 (b), (c) and (d) show hourly wind roses for these three places in the typical year 2005, highlighting important local differences in wind speed and direction.

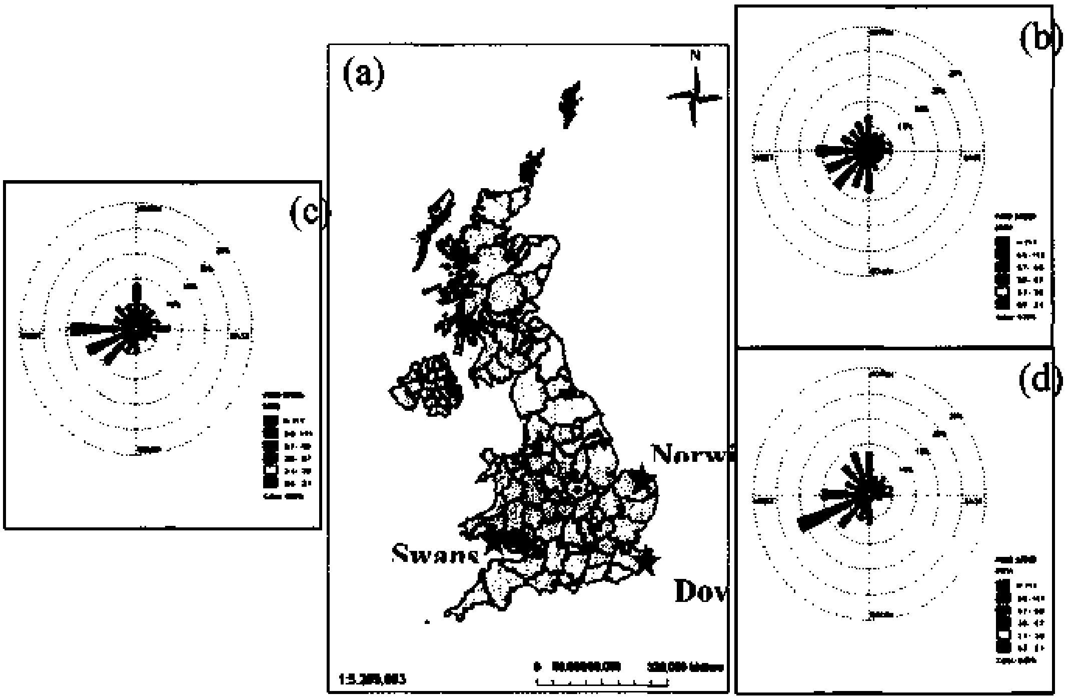

Figure (1). (a) Locations of the three UK urban areas. 2005 hourly wind roses for (b) Coltishall station near Norwich, (c) Mumbles Head near Swansea and (d) Langdon Bay near Dover.

Norwich is the most easterly city in the UK, in relatively simple terrain and is likely to be impacted by continental weather conditions (Chatterton et al., 2000). It is influenced by the proximity of the North Sea and, in late Spring and summer, by its sea breezes (Glenn, 1987). Being further inland than Dover and Swansea (and therefore less windy) and with the influence of the nearby continent, night-time temperature inversions are likely to be influential in controlling air pollution dispersion especially in winter. Located approximately 100 miles north east of London, Norwich does experience the "plume" from the capital under suitable meteorological conditions. Norwich has declared traffic-related Air Quality Management Areas (AQMA) due to exceedences of $N0_2$.

On the South Wales coast and with complex terrain to the north, Swansea is the wettest city in the UK and has a windier and more maritime climate than Norwich (Wheeler and Mayes, 1997). The local area experiences orographically enhanced precipitation. In a coastal area like Swansea, the differential heating between land and sea can lead to greater frequency of sea and land breeze systems when compared to Norwich. These, coupled with the presence of a windier climate in general, impact upon the dispersion of pollution in the city. On the other hand, cold air drainage from neighbouring high ground has the potential to stabilise the urban atmosphere, reducing the potential for dispersion. Also notable is that $N0_2$ was projected to fail the annual mean objectives at several locations in Swansea due to traffic problems. The City Council therefore declared Hafod, around the city centre, an AQMA.

Dover is located in the extreme south-east of England at the nearest point to mainland Europe and is sheltered by high cliffs. It is a major ferry port with the highest urban $S0_2$ concentration from ship emissions in England. It has a somewhat continental climate which is relatively dry but, being on the coast, is subject to sea breezes which spread pollution from the harbour area to the city centre. The City Council has declared the harbour area an AQMA due to the high levels of $S0_2$ there.

Methodology

The study approach here is to compare, over different timescales, the synoptic weather conditions and meteorological data of air temperature, air pressure, wind speed and direction with measurements in these three urban areas of the air pollutants, $N0_2$, PM_{10},0_3 and $S0_2$. The period addressed is 2000- 2006. Two profile stations (Sodar and Mast) will used in this study; the Sodar measures wind speed and direction at 19 intervals between 30m and 300m and the Mast measures wind at 10m and at 30m above ground level. Sodar and Mast data were available for the calendar year 2008, and it has therefore been possible to compare these data with the air quality station data for the same year in Swansea.

Results and Discussion

The Yearly Timescale

Table 1 shows that Dover winter mean figures for $S0_2$ remained below the annual mean objective of 20ugm"^{3} although in 2003, the recorded figure of 19ugm"^{3} came close to matching it. However, the 15-minute mean figures show the frequency with which this objective was exceeded; it was matched in 2005 but was considerably exceeded in 2002 and 2003, when the figures of 48 and 43 exceedences were higher than the objective of 35 times per year.

Table (1). Statistics for SQ2 levels exceeded at Dover (Langdon Cliff station). 2001-2006.

	2001	2002	2003	2004	2005	2006
Data Availability (%)	75.34	96.52	93.47	89.67	90.54	92.97
Annual mean (objective = 20μgm^{-3})	12.3	15.6	15.7	12.3	13.5	10.2
Maximum	309.0	301.0	322.0	333.0	567.0	383.0
Winter mean (objective = 20μgm^{-3}) from 1 October to 31 March	-	13	19	14	10	12
Number of exceedences of the 15 min mean objective (266μgm^{-3}), not to be exceeded more than 35 times per year	25	48	43	13	35	14
Number of exceedences of the one hour mean objective (350μgm^{-3}), not to be exceeded more than 24 times per year	0	0	0	0	2	1
Number of exceedences of the 24 hour mean objective (125μgm^{-3}), not to be exceeded more than 3 times per year	0	0	0	0	0	0

Figure (2) shows the number of $S0_2$ exceedences for 2001 to 2006. Of particular interest is the combined data (2001-2006), which shows that there are seasonal variations; June has the highest values when summer winds tends to be lower and December has the lowest values when winter winds tend to be stronger. The wind flow might be preferentially from the port (from the southwest) in summer,

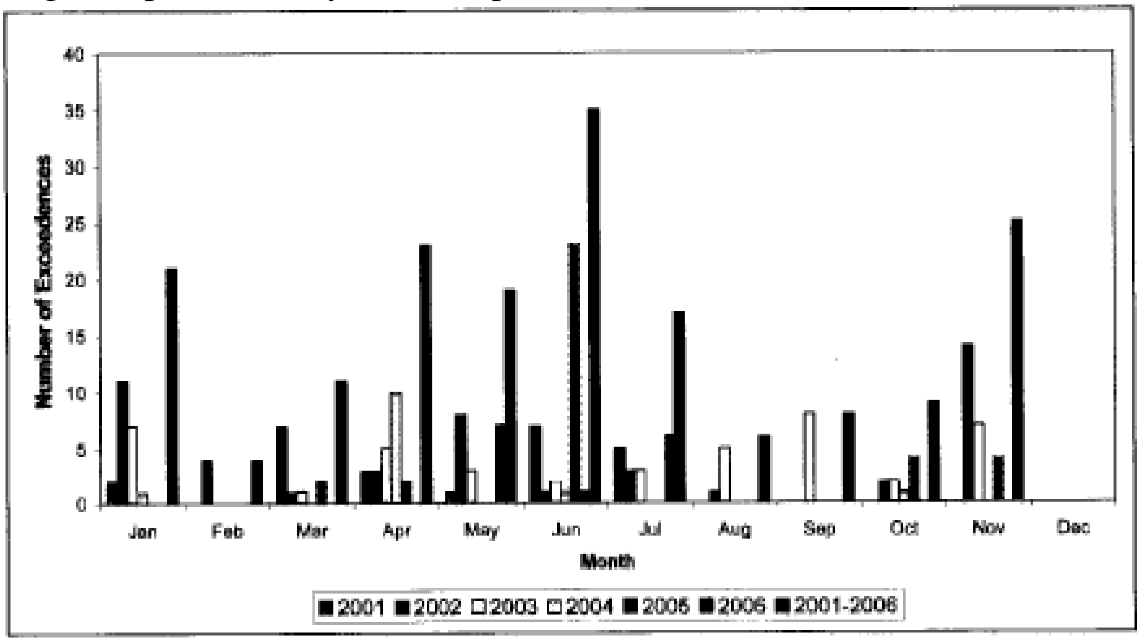

Figure (2). Number of S02 exceedences on a monthly basis, 2001-2006.

Figure 3 (b) (2002) shows high concentrations of $S0_2$ coming from due south in the harbour area towards the town. These as previously mentioned, are higher than the 15-minute mean objective of 266ugm-3 in that year (Table 1). In 2004, by contrast, the 15-minute mean objective dropped to 13 exceedences, due to less wind direction from the south. Moreover, wind speeds in 2002 were low reducing dilution and this is why concentration of pollutants increased.

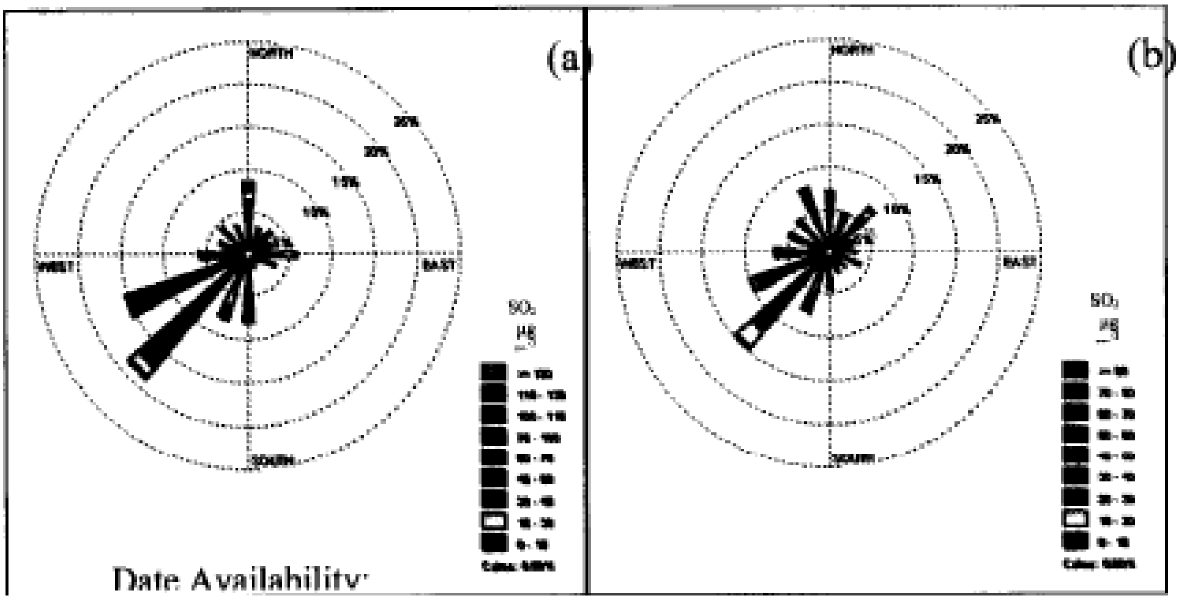

Figure (3), Hourly S02 pollution roses for Langdon Cliff station (by using the wind directions for Langdon Cliff), 2001 (a) and 2002 (b).

For different study area, the annual mean objective in Norwich diffusion tubes for $N0_2$ is 40(igm'3 but Table 2 shows that a large number of exceedences (highlighted in bold font) were recorded by diffusion tubes in the city. The highest concentration of $N0_2$ was recorded in St Augustines Street, which is in an AQMA, where northbound traffic queues as it leaves the roundabout at the bottom, and traffic going southwards slows down at the bend in the road shortly before traffic lights usually causing it to stop before joining the roundabout. It is the queuing at the traffic lights at the junction with Magpie Road which is the problem, especially where the vehicles trying to turn right are queuing uphill. There are buildings on both sides of the street, which help to block winds and increase pollutants, typical of a canyon. Table 2 shows most (but not all because some had missing data), of the diffusion tubes in the city. The year 2003 records the highest level of $N0_2$ (not for all stations), but as the data for the previous years have not been included in this study (due to missing data), it is not known whether this was an increase or a decrease.

Table (2). Annual mean of N02 diffusion tubes correçted by applying factors. Bold figures indicate readings above 40ugn-3 (the Annual Average Objective level).

Location	2003	2004	2005	2006	2007
Upper King Street	-	37,8	**40.5**	33,0	35,2
St Stephens	**43.9**	**40.7**	**42.3**	37.7	-
St Stephens (mid)	-	**48.7**	-	**47.5**	**47.2**
Johnson Place	$4.4	**46.0**	**45.9**	**41.3**	30,2
Earlham Road	**41.5**	**41.8**	**42.2**	39.4	27,3
Grapes Hill (lower)	-	-	30,8	29,7	28.9
Grapes Hill (upper)	-	-	28,9	26.1	25.0
Exchange St	**42.2**	39,6	**43.6**	**43.4**	**42,3**
St Augustines	**62.2**	**57.3**	**55.7**	**51.3**	**52.4**
Tombland	**49.0**	**45.7**	**46.9**	**42.9**	**45.4**
Cattlemarket Street	**56.6**	**49.1**	**49.1**	**43.5**	**48.7**
Castle Meadow	**50.3**	**53.7**	**53.4**	**47.1**	**49.6**
Castle Meadow 2	-	**49.3**	**51,4**	**46,9**	**47.3**
St Georges St	32.3	26,7	25,7	21,2	20,4
Riverside Road	**60,3**	**52,6**	**55.2**	**48,2**	**45.3**

The Monthly Timescale

During winter, high levels of $N0_2$ are expected because when air temperature decreases, vehicle engines take longer to reach maximum operating efficiency, leading to higher $NQ/N0_2$ emissions. Figure 4 (a) shows data from 3 stations in Swansea for December 2004, confirming this pattern. The only exceedence in Swansea of the one hour $N0_2$ objective for the year occurred during this month, $N0_2$ measurements are made at a height of 3 m at the three stations. There is an exceedence of the one hour mean $N0_2$ objective of 200ugm"3 at the Morfa station on the 20th December, which may partly be due to the lower air temperature that day resulting in increased vehicles emissions. This is significant because if cars need more time to heat up on starting, they emit more pollutants. Further evidence is provided by the pollution rose in

Figure 4 (b). This shows the winds coming from the west and west-by-northwest where the residential area is located, are polluted. The more exposed Mumbles Head station on the coast exhibits substantially stronger wind speeds than would be expected in Swansea city itself.

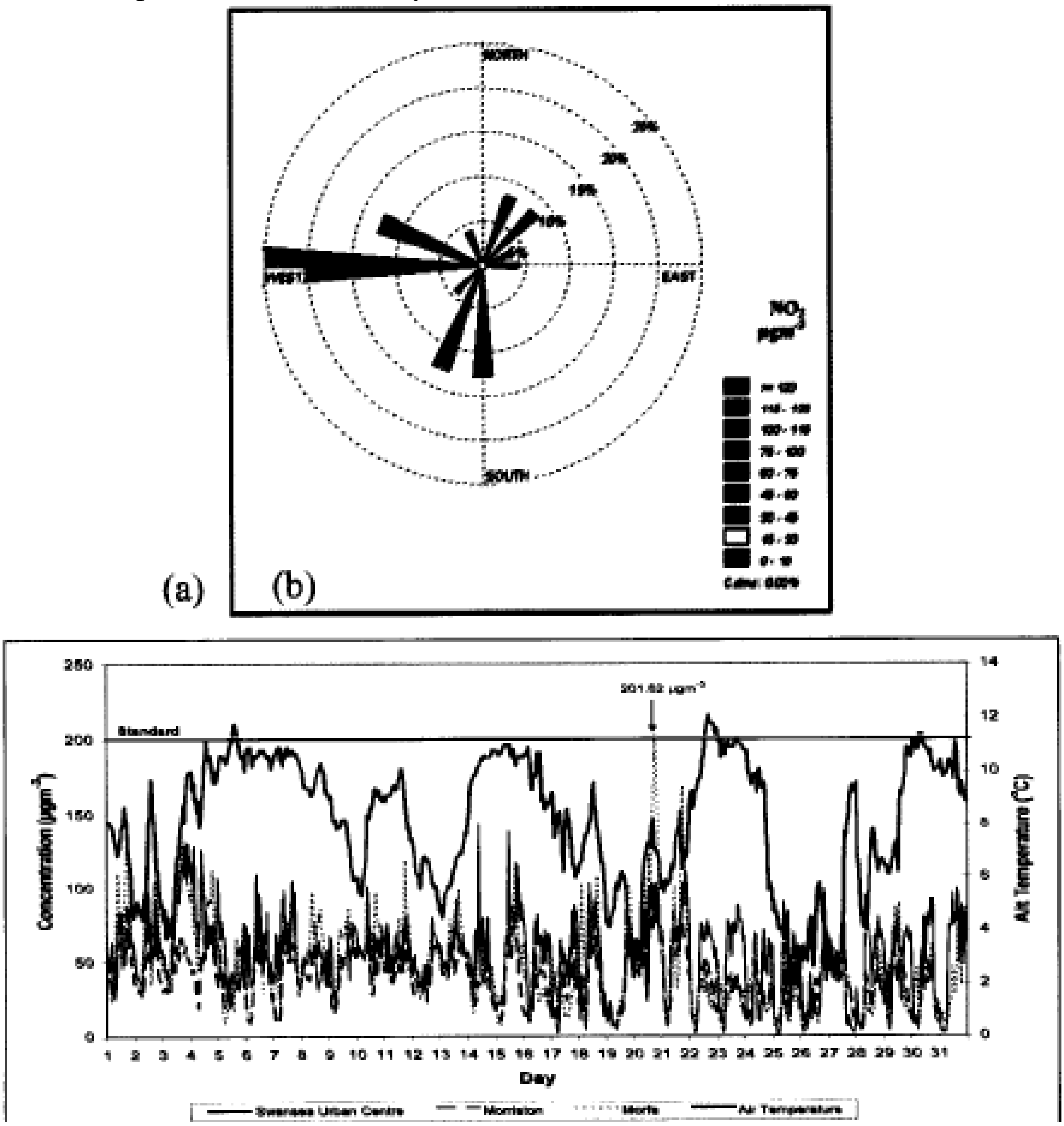

Figure (4). (a) Comparison for the Swansea Urban Centre, Morriston and Morfa station between N02 and air temperature, December 2004. Air temperature data from Mumbles Head station and (b) Hourly N02 pollution rose for Morfa station (by using the direction for Mumbles Head station), 20th December 2004.

The Daily Timescale

Normally $N0_2$ concentrations are expected to peak during the day due to the diurnal cycle in emissions and atmospheric chemistry (Defra, 2008), but in Figure 5 the situation is different in Norwich. Partial cloud cover occurs at 22:00 hours on 3rd March coinciding with a peak of $N0_2$ concentration. At that time of night, there were limited traffic emissions. Further evidence in Figure 6 shows that the wind speed at that time was very light and switched direction to the west and southwest. As a ridge of high pressure extended across southern England (Figure 7 (b)), air temperature started dropping at noon on the 3 rd, increasingly so after sunset, reaching -2°C at 22:00, helping to stabilise the atmosphere with the presence of a ground-based temperature inversion under clearer skies (Figure 7 (a)), allowing $N0_2$ to accumulate as ozone was titrated away (Jacobson, 2002). With the approach of the frontal system shown in Figure 7 (b), wind speed, cloud cover and air temperature rose once again later in the night, leading to a reduction in $N0_2$.

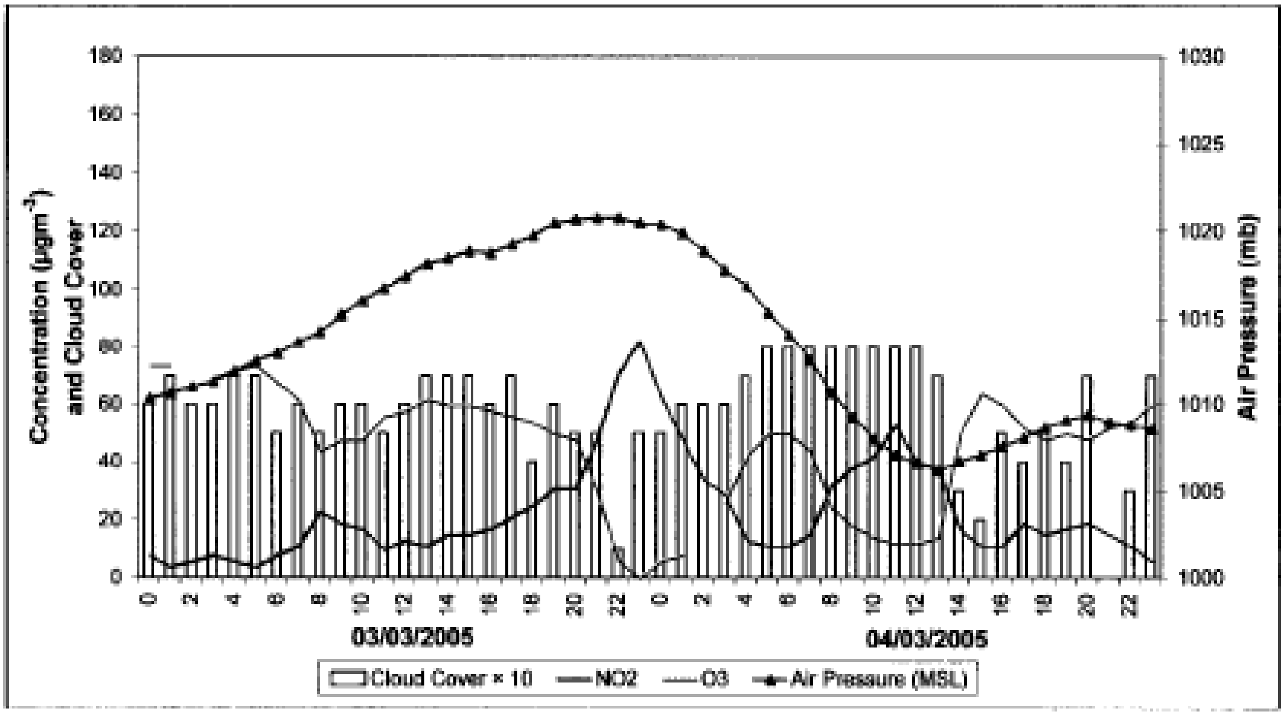

Figure (5). Comparison for the Norwich Urban Centre station (N02 and 03) with meteorological measurements from Coltishall (air pressure, cloud cover (oktas) (multiply by 10)), 3rd to 4th March 2005.

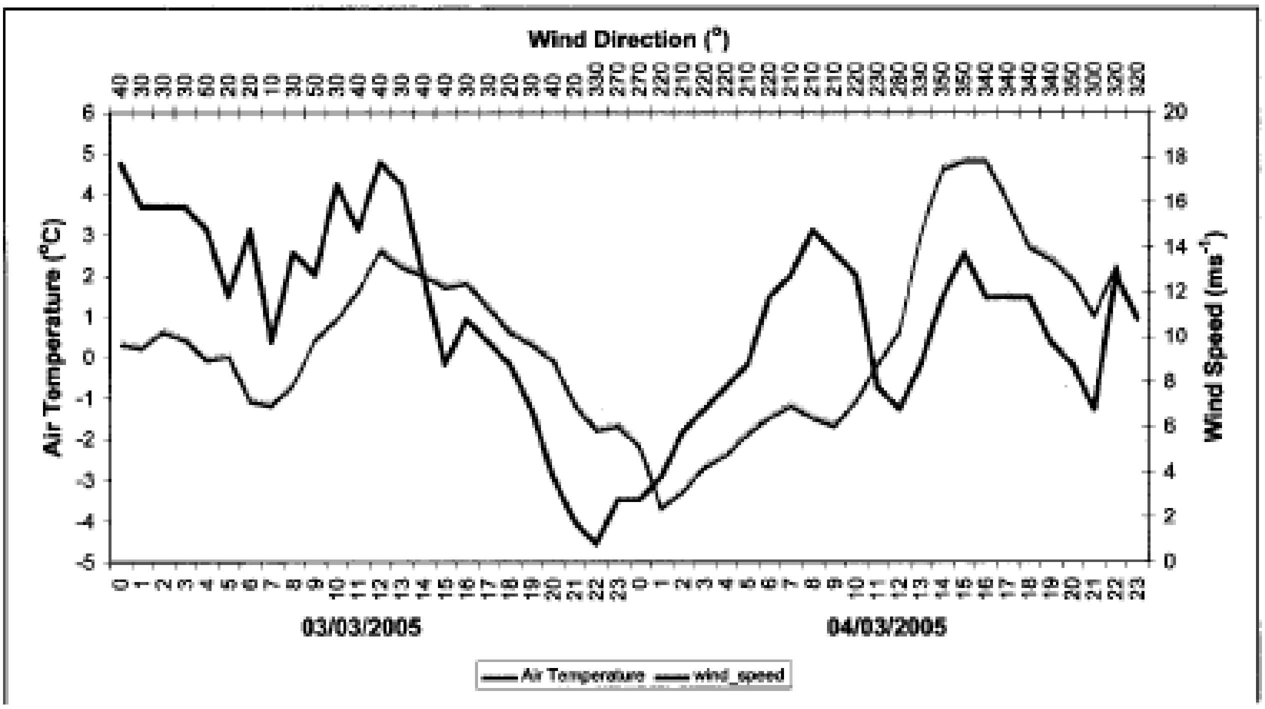

Figure (6). Coltishall air temperature, wind speed and direction, 3rd to 4th March 2005.

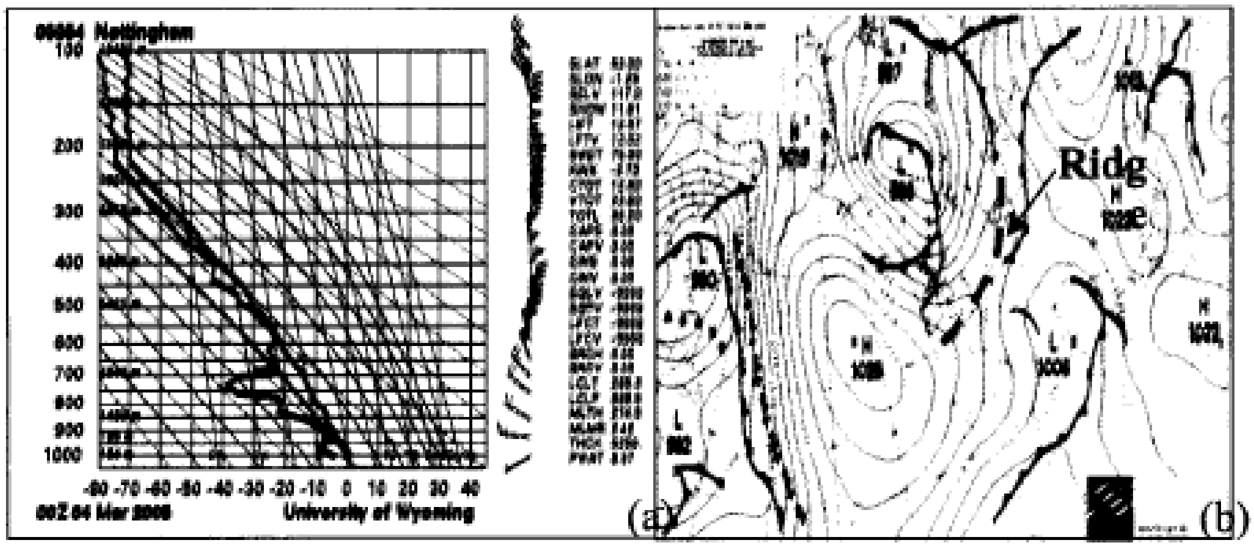

Figure (7). 00:00 4th March 2005 (a) Radiosonde ascent chart for Nottingham upper air station, (b) Sea-ievel Pressure analysis chart for the United Kingdom.

CONCLUSION

The evidence presented here shows that there is a strong relationship between weather and air quality in urban areas. In Dover, short-term $S0_2$ peaks are associated with airflow from the port area. In Swansea, hourly NO2 exceedences can be observed when the generally windy coastal climate is temporarily replaced by light winds. In Norwich, temperature inversions can lead to short-term notable increases in $N0_2$, even overnight.

References

Burt, S. The August 2003 heatwave in the United Kingdom: Part 1-Maximum temperatures and historical precedents. 59, 199, 2004.

Carruthers, D., Edmunds, H., Lester, A., McHugh, C, and Singles, R. Use and Validation of ADMS-Urban in Contrasting Urban and Industrial Locations, Cambridge, UK, 1999.

Chatterton, T., Dorling, S., **Lovett,** A., **and Stephenson,** M. Air quality in Norwich, UK multi-scale modelling to assess the significance of city, county and regional pollution sources. *Environmental Monitoring and Assessment* **65,** 425-433, 2000.

Colls, J. Air Pollution, Spon Press, London, United Kingdom, 2002.

Cros, B., Durand, P., Cachier, H., Drobinski, P., Frejafon, E., Kottmeier, C, Perros, P. E., Peuch, V.-H., Ponche, J.-L., Robin, D., Said, F., Toupance, G., and Wortham, H. The ESCOMPTE program: an overview. *Atmospheric Research* 69, 241-279,2004.

Department for Environment, Food and Rural Affairs (Defra). Air pollution in the UK: 2007, United Kingdom., 2008.

Dufour, A., Amodei, M., Ancellet, G., and Peuch, V.-H. Observed and modelled "chemical weather" during ESCOMPTE. *Atmospheric Research* 74, 161-189, 2005.

Fisher, B., Kukkonen, J., and Schatzmann, M. Meteorology applied to urban air pollution problems COST 715. *Atmospheric Chemistry Physic Discuss* 5, 7903-7927, 2005.

Glenn, A. "Weather patterns of East Anglia," Terence Dalton Limited, Lavenham, United Kingdom, 1987.

Hulme, M., and Barrow, E. "Climates of the British Isles," Routldge, London, 1997.

Jacobson, M. Z. Atmospheric pollution: history, science, and regulation, Cambridge University Press, Cambridge, England, 2002.

Stedman, J. R. The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. *Atmospheric Environment* 38, 1087-1090, 2004.

Stephenson, M. Air Quality Review and Assessment - Annual Progress Report. Norwich. United Kingdom, 2007.

Visconti, G. Fundamentals of physics and chemistry of the atmosphere, 2001.

Volz-Thomas, D., Mihelic, S., Konrad, H., Houben, U., and Piatt, D. Perner Local Ozone Production Rates from Photostationary State of 03/NOx and from EGS Conference, Nice, France, 2000.

Wheeler, D., and Mayes, J. "Regional climate of the British Isles," Routledge, London, 1997.

World Health Organization (WHO). The health impacts of 2003 summer heat-waves Briefing note for the Delegations of the fifty-third session of the WHO Regional Committee for Europe, Vienna, Austria, 2003.

تأثير الطقس على جودة الهواء للمدن الحضرية في المملكة المتحدة

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ملخص البحث. تهتم هذه الدراسة بعلاقة الطقس مع جودة الهواء بالمدن البريطانية. حيث تم اختيار ثلاث مدن وهي نورج وسوانزي ودوفر لمعرفة الطبوغرافية التي تربطها ببعض وتأثيرها على الموقع العام. تقع مدينة نورج في شرق إنجلترا وتتأثر بالملوثات الهوائية القادمة من الجنوب الشرقي للمدينة وذلك بسبب تأثير الإنبعاثات الخارجة من المركبات وأيضاً إنتقال بعض الملوثات مثل ثاني أكسيد النتروجين والأتربة من المدن أو الدول القريبة. كما تقع المدينة الثانية وهي سوانزي في الجهة الغربية من إنجلترا وتتأثر بالتقلبات الهوائية بين اليابسة والبحرمما يظهر تأثر نسيم البر والبحر عليها جلياً في المقارنات المناخية مع جودة الهواء. كذلك تتأثر هذه المدينة من التقلبات الهوائية من جهة الجبال المحيطة بها من جهة الشرق وتأثيرها على هواء المدينة مما يزيد في تراكيز الملوثات الهوائية. وأخيراً تقع مدينة دوفر في الجنوب الشرقي لبريطانيا ويوجد بها الميناء الذي يربطها بفرسنا. حيث تتأثر هذه المدينة بالملوثات الهوائية المنبعثة من السفن وأهمها ثاني أكسيد الكبريت وأيضاً بعض الملوثات المنبعثة من المركبات. لذلك تطرقت هذه الدراسة إلي متابعة تأثيرات الطقس على جودة الهواء بالمدن مع مقارنة الزيادات في الملوثات مع الحدود المسموح بها من قبل منظمة الصحة العالمية والإدارة البيئية لجودة الهواء ببريطانيا.

الكلمات المفتاحية: الطقس، تلوث الهواء، الضغط الجوي، درجة الحرارة، الانقلاب الحراري.