Air pollution by ozone in Europe in summer 2006

Overview of exceedances of EC ozone threshold values for April–September 2006

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Executive summary

In summer 2006, levels of ground-level ozone were high in southern Europe and north-western Europe, with widespread exceedances of the information threshold value (180 µg/m^3, Directive 2002/3/EC). The frequency of these exceedances was higher than those in previous years, though not as high as in the record year 2003. The highest one-hour ozone concentration in summer 2006 (370 µg/m^3) was observed in Italy. Other high hourly ozone concentrations of between 300 and 360 µg/m^3 were reported in Austria, France, Italy, Portugal, Romania and Spain.

The directive's long-term objective — to protect human health (maximum ozone concentration of 120 µg/m^3 over 8-hours) — was extensively exceeded in the EU and other European countries. In a significant part of Europe the target value to protect human health was also exceeded.

During a single episode with two pronounced peaks between 17–22 July and 25–28 July (with a total duration of nine days) 49 % of the total number of exceedances of the information threshold, 56 % of exceedances of the alert threshold and 20 % of exceedances of long-term objective were observed.

There has been a slight increase in the occurrence of exceedances during the summer period between the years 2004–2006. The occurrence of exceedances in summer 2006 was the second highest in the last decade in north-western, central and eastern Europe. A wide area of the United Kingdom was affected and several exceedances occurred in the Baltic countries.

Ground-level ozone is one of the air pollutants of most concern in Europe. Ozone pollution is produced by photochemical processes involving nitrogen oxides and volatile organic compounds in the lower atmosphere. Ozone levels become particularly high in regions close to high ozone precursor emissions during summer episodes with stagnant meteorological conditions when high insolation and temperatures persist. Levels continue to exceed both target values and the long-term objectives established in EU legislation to protect human health and prevent damage to ecosystems, agricultural crops and materials.

This report provides an evaluation of ground-level ozone pollution in Europe for April–September 2006 based on information submitted to the European Commission under Directive 2002/3/EC on ozone in ambient air. Since the submitted data have not yet received their final validation by Member States, the conclusions drawn in this report should be considered as preliminary.

Directive 2002/3/EC requires Member States to report exceedances of the information threshold and alert threshold values (see Table 1) to the Commission before the end of the month following an occurrence. Furthermore, by 31 October the Member States must provide additional information for the summer period. This information should include information on exceedances of the long-term objective for the protection of human health (daily maximum 8-hour average concentrations of 120 µg/m^3).

Table 1 Ozone threshold values, long-term objective and target value for the protection of human health

Objective	Level [µg/m^3]	Averaging time
Information threshold (IT)	180	One-hour
Alert threshold (AT)	240	One-hour
Long-term objective (LTO)	120	8-hour average, daily maximum
Target value (TV)	120, not to be exceeded more than 25 days per calendar year *	8-hour average, daily maximum

* Averaged over three years and to be achieved where possible by 2010.

In order to provide information as timely as possible, the summaries of the monthly data provided by the countries were made available as they became available on the European Topic Centre on Air and Climate Change website: (http://etc-acc.eionet.europa.eu/databases/o3excess).

In July 2006 EEA launched a pilot near real time ozone web site (http://www.eea.europa.eu/maps/ozone). The site shows the situation for ground level ozone across Europe based on near real-time data. It was developed by the EEA as a joint European project and provides up-to-date information in the form of maps and graphs. The information is based on near real-time data from over 700 stations provided by national and regional organisations in 20 countries on a voluntary basis.

Overview of ozone air pollution in summer 2006

All 25 EU Member States except Luxembourg provided information to the European Commission on observed one-hour exceedances by the deadline. All of them also observed and reported long-term objective exceedances. In addition, 10 other countries (Bosnia and Herzegovina, Bulgaria, Croatia, Iceland, Liechtenstein, FYR of Macedonia, Norway, Romania, Serbia and Switzerland) supplied information to the EEA on request.

Air pollution by ozone was exceptionally high in July due to the meteorological situation during this period of summer 2006. Colder weather in April–May and August–September meant that the occurrence of exceedances was much lower during these periods.

Specific meteorological conditions during ozone episodes in July 2006 meant that northern and north-western Europe was more affected by ozone pollution than in previous years.

Main findings

From a total of 2 069 ozone monitoring sites reporting data, 1 985 were located in EU Member States. The following preliminary conclusions can be drawn from the period April–September 2006:

Exceedance of the information threshold

- The number of exceedances of the information threshold (180 μg/m^3 of one-hour ozone concentration) was higher than in previous years, but not as high as those in the record year 2003 (EEA, 2003). Ozone concentrations higher than the information threshold were reported from monitoring sites in all 25 EU Member States, except for Cyprus and Latvia. High concentrations were also reported from six non-EU countries. The information threshold was exceeded at approximately 56 % of all operational stations (68 % in 2003, 35 % in 2004 and 42 % in 2005).

- The spatial extent of the observed exceedances was greater than the one observed in 2004 and 2005 (EEA, 2005; EEA, 2006) and is comparable with the spatial extent of the hot summer of 2003. The most frequent exceedances of the information threshold were observed in northern Italy, southern France, Germany and at several locations in Benelux, FYR of Macedonia, Greece, Portugal, Romania, Slovenia and Spain. A wide area of the United Kingdom was affected and several exceedances occurred in the Baltic States.

Exceedance of the alert threshold

- Ozone concentrations higher than the alert threshold of 240 μg/m^3 were reported on 190 occasions (on 127 occasions in 2004) in 12 EU Member States (Austria, Belgium, the Czech Republic, France, Germany, Greece, Italy, the Netherlands, Portugal, Slovenia, Spain and the United Kingdom) and two other countries (Romania and Switzerland). In comparison, 13 Member States and two other countries reported exceedances of the alert threshold in 2003, eight Member States and four countries in 2004 and nine Member States and two countries in 2005 respectively.

- The exceedances were found largely in northern Italy, southern France, Portugal and Germany. Generally, there were only one or two days with exceedances of the alert threshold per station, 15 % of stations with recorded alert threshold exceedances reported between 3 and 20 days of exceedances.

Maximum concentrations

- The highest one-hour ozone concentration in of 370 μg/m^3 was observed in northern Italy. High hourly ozone concentrations of between 300 and 360 μg/m^3 were reported in Austria, France, Italy, Portugal, Romania and Spain, ten times in total. An exceedance of an ozone level of 360 μg/m^3 was recorded once in summer 2005 with a maximum concentration of 361 µg/m^3, three times with a maximum of 419 µg/m^3 in summer 2004 and four times with a maximum ozone level of 417 µg/m^3 in summer 2003.

Exceedance of the long-term objective for the protection of human health

- Similar to previous years the exceedances of the long-term objective (LTO) for the protection of human health for ozone, i.e. daily maximum 8-hour average concentrations higher than 120 µg/m^3, were observed in every country, in almost every summer month and at most of the stations in summer 2006. Approximately 85 % of all stations reported one or more exceedances (86 % in 2005, 70 % in 2004).

- For those countries that reported exceedances, the number of exceedance days per country ranged from 2 (Malta) to 178 (Italy). There was no day without any exceedance in Europe in summer 2006. On average 27 days of exceedances were observed at stations that recorded at least one exceedance (23 days in 2005, 21 days in 2004).

Exceedance of the target value ([1]) for the protection of human health

- Exceedances of the target value were observed in 17 EU Member States (Austria, Belgium, the Czech Republic, France, Germany, Greece, Hungary, Italy, Lithuania, the Netherlands, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden and United Kingdom) and in four other countries (Bulgaria, Lichtenstein, Romania and Switzerland). Luxembourg did not deliver data but knowing by the situation in neighbouring countries and in previous years, it is most likely that the target value was also exceeded in this country.

- Exceedances of the target value occurred at 42 % of all monitoring stations providing reports (30 % in 2005, 19 % in 2004).

- The target value was exceeded in approximately 42 % of the area for which data was reported (42 % in 2005, 23 % in 2004) and affected approximately 47 % (34 % in 2005, 28 % in 2004) of the total population on the assessed territory ([2]).

Main ozone episodes

- The most important ozone episode occurred between 17–28 July. During this period, 52 % of the total number of exceedances of the information threshold, 59 % of exceedances of the alert threshold and 24 % of exceedances of the long-term objective were observed.

- The ozone episode was characterised by a stable, wide high-air-pressure area spread over the continent with the centre situated just over western, central and southern Europe. The highest ozone concentrations were measured here. The temporary high air pressure area attenuation led to a reduction of the area with ozone exceedances between 23–24 July.

Comparison with previous years

The occurrence of exceedances slightly increased during the period 2004–2006. The occurrence of exceedances in summer 2006 was the second highest over the last decade in north-western, central and eastern Europe. A wide area of the United Kingdom was affected and several exceedances occurred in the Baltic States.

Disclaimer

The report contains summary information based on data delivered before 1 January 2007 (i.e. two months after the deadline set by the directive).

The information describing the situation during summer 2006 is based on non-validated monitoring data and hence should be regarded as preliminary.

([1]) Daily maximum 8-hour average concentrations were compared with the legally set objectives solely for indicative purposes to assess the current situation and its distance from objectives, and not for checking compliance with Directive 2002/3/EC. As reporting of maximum daily 8-hour average concentration of ozone started in 2004, exceedances of TVs presented in this report are counted for indicative purposes if LTO has been exceeded more than 25 times during the assessed summer period.
([2]) The ORNL Global Population Dataset version 2002 has been used for the affected population estimate, http://www.ornl.gov/sci/landscan.

1 Introduction

Ozone is the main product of complex photochemical processes in the lower atmosphere involving oxides of nitrogen and volatile organic compounds as precursors. Ozone is a strong photochemical oxidant. In elevated concentrations it causes serious health problems and damage to ecosystems, agricultural crops and materials. The main sectors that emit ozone precursors are road transport, power and heat generation plants, household (heating), industry, and petrol storage and distribution.

In view of the harmful effects of photochemical pollution in the lower levels of the atmosphere, the Council adopted Directive 92/72/EEC on air pollution by ozone (CEC, 1992). This directive was succeeded by Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air. Directive 2002/3/EC, also known as the third daughter directive to the Air Quality Framework Directive 96/62/EC, which sets long-term objectives, target values as well as an alert threshold and an information threshold (Table 1) for ozone for the purpose of avoiding, preventing or reducing the harmful effects on human health and environment. It provides common methods and criteria for the assessment of ozone concentrations in ambient air, and ensures that on the basis of this assessment adequate information is made available to the public. It also promotes cooperation between the Member States in reducing ozone levels.

The report gives an overview of the situation between April–September 2006, and provides a comparison with previous years over the last decade. The EEA has prepared similar overviews since 1994. Previous reports are available from EEA's website: http://www.eea.europa.eu.

Legal requirements on the reporting of provisional data on exceedances of the ozone long-term objectives, target and threshold values during summer period, which are the basis of this report, are summarised in Annex 1.

2 Ozone air pollution in summer 2006

Air pollution by ozone was exceptionally high in July 2006 in comparison with previous years. It was caused by a long-lasting, stagnant period of high-air-pressure air masses over the continent during the summer of 2006. Due to colder weather in April–May and August–September the occurrence of exceedances was much less frequent in the rest of summer 2006. Specific meteorological conditions during ozone episodes in July 2006 meant that northern and north-western Europe was more greatly affected by ozone pollution than in previous years.

Details on reported data and ozone monitoring networks are given in Annex 2.

This chapter gives detailed country-by-country, month-by-month and day-by-day tabular, graphic and geographical based information on threshold exceedances. Additionally, the largest episodes with threshold exceedances are described.

2.1 Summary of hourly exceedances reported

Ozone concentrations higher than the information threshold were reported from monitoring sites in all EU Member States except those of Cyprus and Latvia ([3]) and six other countries — Bulgaria, Liechtenstein, FYR of Macedonia, Norway, Romania and Switzerland (Table 2.1).

Although the occurrence of exceedances was higher than in the summers 2004 and 2005, they were not as high as in the record year 2003. A wide area of the United Kingdom was affected and several exceedances occurred in the Baltic States.

Table 2.2, Figure 2.1 and Figure 2.6 present the seasonal behaviour of hourly exceedances. The highest number of exceedances ([4]) occurred during July: 71 % of all observed exceedances of the information threshold and 75 % of all observed exceedances of the alert threshold. The percentage for July is exceptionally high in comparison with previous years (30 % of all observed exceedances of the information threshold and 25 % of the alert threshold in 2005, 44 % and 59 % in 2004) and relates to the meteorological situation as described in Section 2.4. Due to colder weather, the occurrence of exceedances was low in April–May and August–September. No exceedances of the alert threshold were observed in May, which is rather exceptional in comparison with previous years.

The frequency distribution of hourly ozone concentrations over information threshold (Figure 2.2) shows that at European level 25 % of the maximum hourly concentrations of all the observed exceedances were below 186 µg/m^3 (186 µg/m^3 in 2005, 185 µg/m^3 in 2004, 207 µg/m^3 in 2003). The highest values of the 75th percentile of all maximum concentrations in a country during exceedances were below 206 µg/m^3 (the same value in 2005, 203 µg/m3 in 2004, 305 µg/m^3 in 2003), which is also comparable with the maximum 75th percentile value during summers 2002 (219 µg/m^3) and 2001 (208 µg/m^3).

([3]) Luxembourg did not deliver data but a comparison with surrounding stations and with observations in previous years, exceedances most likely also occurred in Luxembourg.

([4]) In this report, one-hour exceedances are counted on a daily basis, i.e. a day on which an information/alert threshold is exceeded during which time at least one hour is counted as one exceedance.

Table 2.1 Overview of exceedances of the one-hour thresholds during summer 2006 on a country-by-country basis

Country	No. of stations (1)	Stations with exceedance (2)					No. of days with exceedance (3)		Maximum observed concentration (µg/m³)	Occurrence of exceedances (4)				Average duration of exceedances (hour)	
		(Number)		(%)											
Austria	118	67	2	57	2	3	21	2	336	1.9	3.4	0.0	1.5	2.9	1.3
Belgium	40	38	8	95	20	21	17	2	260	5.3	5.5	0.2	1.0	4.6	1.5
Cyprus	2	0	0	—	—	—	—	—	209	—	—	—	—	—	—
Czech Republic	69	51	1	74	1	2	28	1	227	2.3	3.1	0.0	1.0	3.3	8.0
Denmark	11	2	0	18	—	—	3	—	194	0.3	1.5	—	—	x	—
Estonia	7	1	0	14	—	—	1	—	186	0.1	1.0	—	—	4.0	—
Finland	14	1	0	7	—	—	1	—	195	0.1	1.0	—	—	5.0	—
France	496	306	17	62	3	6	54	12	327	2.8	4.5	0.1	2.2	3.1	1.2
Germany	297	253	21	85	7	8	32	5	272	3.7	4.3	0.1	1.0	3.7	1.6
Greece	20	10	1	50	5	10	16	1	263	2.0	3.9	0.1	1.0	2.1	1.0
Hungary	21	10	0	48	—	—	11	—	207	1.5	3.1	—	—	2.1	—
Ireland	9	4	0	44	—	—	2	—	208	0.6	1.3	—	—	4.8	—
Italy	218	139	25	64	11	18	82	28	370	6.5	10.2	0.4	3.1	3.9	6.3
Latvia	5	0	0	—	—	—	—	—	158	—	—	—	—	—	—
Lithuania	15	1	0	7	—	—	1	—	181	0.1	1.0	—	—	1.0	—
Luxembourg	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Malta	4	1	0	25	—	—	2	—	216	0.5	2.0	—	—	1.0	—
Netherlands	40	30	3	75	8	10	21	2	276	2.7	3.5	0.1	1.0	3.9	3.0
Poland	61	33	0	54	—	—	14	—	227	1.1	2.0	—	—	3.6	—
Portugal	54	41	11	76	20	27	44	13	323	5.3	6.9	0.4	1.8	2.5	1.5
Slovak Republic	20	10	0	50	—	—	11	—	236	1.2	2.4	—	—	2.2	—
Slovenia	12	9	1	75	8	11	24	1	243	4.5	6.0	0.1	1.0	3.4	8.0
Spain	344	66	5	19	1	8	60	6	324	0.5	2.6	0.0	1.2	2.7	1.3
Sweden	12	3	0	25	—	—	2	—	191	0.3	1.0	—	—	2.3	—
United Kingdom	96	55	3	57	3	5	17	1	278	1.9	3.3	0.0	1.0	3.6	3.7
EU area	**1 985**	**1 131**	**98**	**57**	**5**	**9**	**124**	**46**	**370**	**2.7**	**4.8**	**0.1**	**1.9**	**3.5**	**3.6**
Bosnia and Herzegovina	2	0	0	—	—	—	—	—	153	—	—	—	—	—	—
Bulgaria	12	4	0	33	—	—	7	—	202	0.6	1.8	—	—	2.3	—
Croatia	1	0	0	—	—	—	—	—	141	—	—	—	—	—	—
Iceland	4	0	0	—	—	—	—	—	171	—	—	—	—	—	—
Liechtenstein	1	1	0	100	—	—	4	—	186	4.0	4.0	—	—	1.5	—
Macedonia, FYR of	13	4	0	31	—	—	17	—	218	1.3	4.3	—	—	4.3	—
Norway	9	2	0	22	—	—	2	—	186	0.2	1.0	—	—	1.0	—
Romania	28	8	2	29	7	25	37	4	330	1.6	5.5	0.1	2.0	2.9	1.5
Serbia	1	0	0	—	—	—	—	—	169	—	—	—	—	—	—
Switzerland	13	11	2	85	15	18	38	3	273	8.6	10.2	0.3	2.0	3.3	2.5
Whole area	**2 069**	**1 161**	**102**	**56**	**5**	**9**	**135**	**48**	**370**	**2.7**	**4.9**	**0.1**	**1.9**	**3.4**	**3.6**
Whole area (Summer 2003)	1 805	1 220	326	68	18	27	137	x	417	5.4	9.3	8.0	x	3.4	*
Whole area (Summer 2004)	1 852	654	52	35	3	8	128	46	419	1.4	3.9	0.1	1.8	2.8	2.1
Whole area (Summer 2005)	1 931	815	64	42	3	8	157	54	361	1.6	3.6	0.1	2.0	3.2	2.4

White columns refer to information threshold, grey to alert threshold.

x No data delivered (no data from Luxembourg, no duration of exceedances from Denmark.

Turkey was not included in summer data processing due to incomplete information (only information of no exceedances for April and May on one station was delivered).

— Not applicable.

* Not evaluated in 2003.

(1) Total number of stations with ozone measurement.

(2) The number and percentage of stations at which at least one threshold exceedance was observed; fifth column: percentage of stations with information threshold exceedance at which alert threshold exceedance were also observed.

(3) The number of calendar days on which at least one exceedance of thresholds was observed.

(4) Occurrence of exceedance is calculated as the average number of observed exceedances per country, i.e. the total number of exceedances for all stations divided by the total number of operational stations. Left column: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

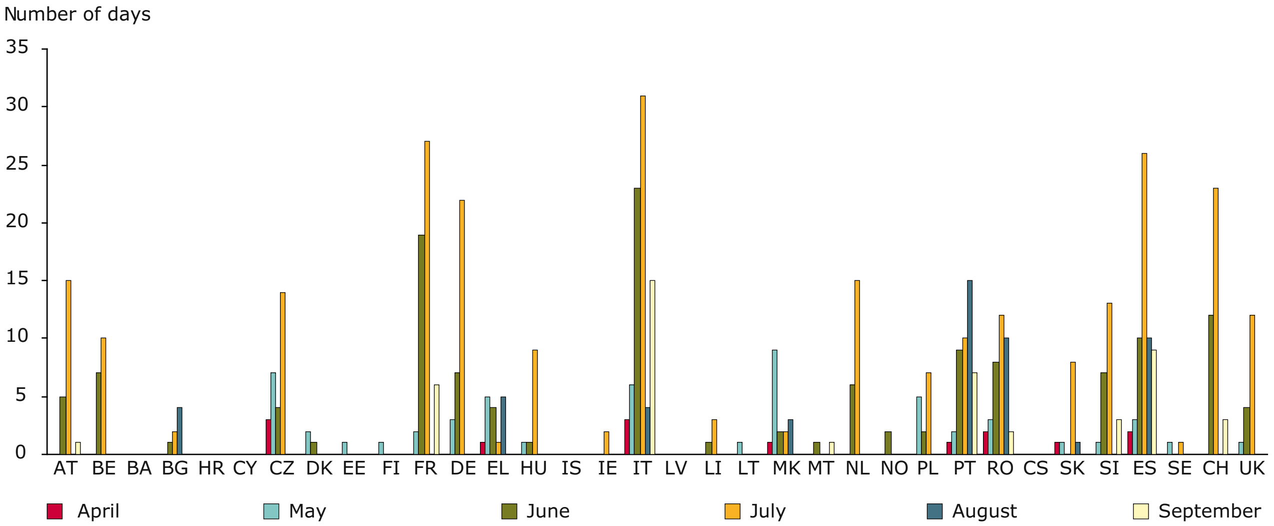
Table 2.2 Overview of exceedances of the one-hour thresholds during summer 2006 on a month-by-month basis

Month	Stations with exceedance [2] (Number)		(%)			Total no. of exceedances		No. of days with exceedance [3]		Maximum observed concen– tration (µg/m³)	Occurrence of exceedances [4]				Average duration of exceedances (hour)	
April	11	0	1	—	—	14	—	10	—	223	0.0	0.0	—	—	1.1	—
May	142	0	7	—	—	176	—	21	—	239	0.1	0.2	—	—	3.0	—
June	466	10	23	0	2	1065	18	28	9	275	0.5	0.9	0.0	0.2	3.2	2.4
July	1 046	82	51	4	8	3 983	142	31	22	370	1.9	3.4	0.1	1.4	3.6	4.1
August	83	11	4	1	13	233	15	26	11	295	0.1	0.2	0.0	0.1	2.8	1.6
September	88	12	4	1	14	168	15	19	6	330	0.1	0.1	0.0	0.1	2.7	1.5

[2],[3],[4] See notes on Table 2.1.

Figure 2.1 Number of days on which at least one exceedance of the one-hour threshold value was observed per country and per month during summer 2006 (only countries which delivered data are shown)

a) Information threshold exceedances



b) Alert threshold exceedances

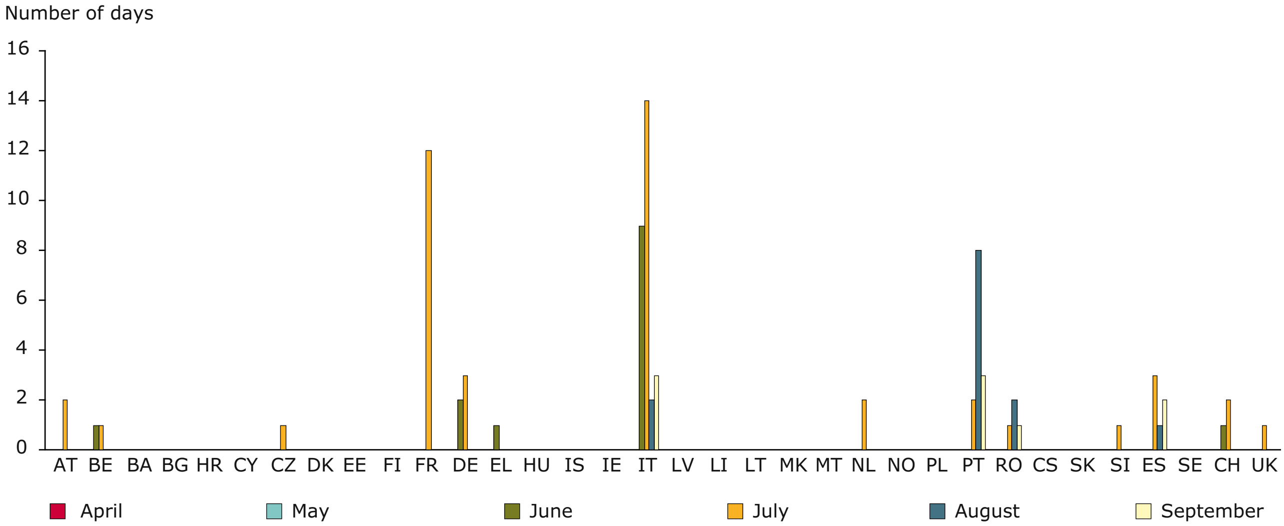
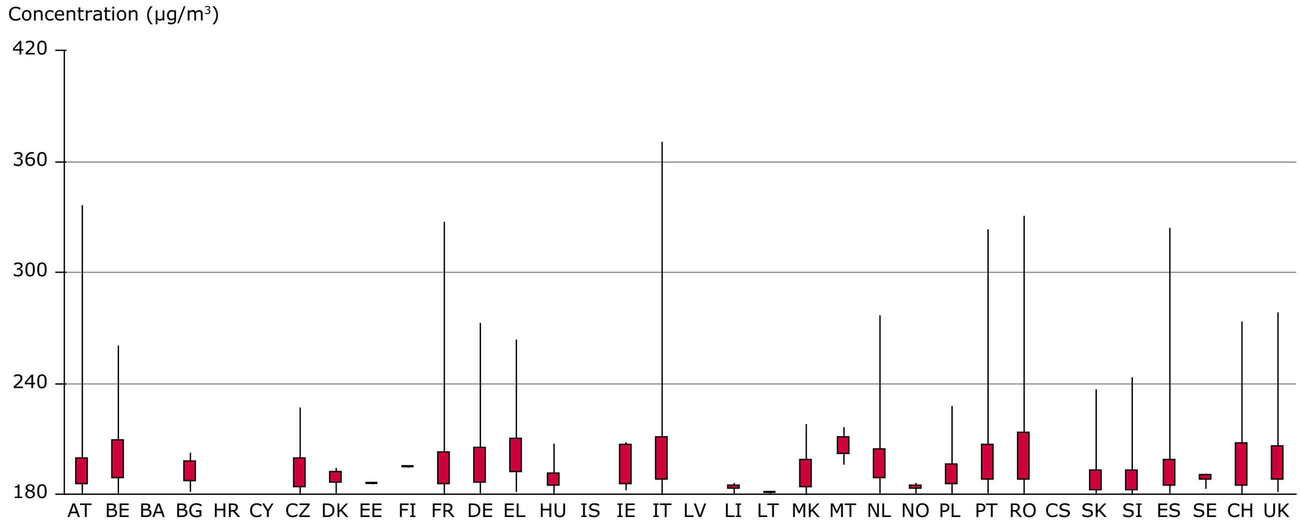


Figure 2.2 Frequency distribution of concentrations in excess of the one-hour information threshold during summer 2006 (only countries which delivered data are shown)



Note: Presented as box-jenkins, plots and indicates the minimum, the 25th percentile, the 75th percentile and the maximum value.

2.2 Overview of exceedances of the long-term objective and target value for the protection of human health

Exceedances of the long-term objective (LTO) during summer 2006 were observed in every country, in almost every summer month and at most stations (see Table 2.3) (LTO is exceeded when the daily maximum 8-hour average concentration of ozone is higher than 120 µg/m³. TV is exceeded when LTO has been exceeded at a particular station more than 25 times per calendar year averaged over three years). Approximately 85 % of all stations reported at least one exceedance (86 % of stations in 2005, 70 % in 2004). There was no day without any exceedance in Europe in summer 2006.

The occurrence of exceedances was higher than in summers 2004 and 2005. The more widely effected were areas of north-western and central Europe.

Table 2.4 summarises the exceedances on a monthly basis, Figure 2.6 on day-by-day per country basis.

The highest number ([5]) of exceedances occurred during July (46 % of all observed exceedances), June (26 %) and May (14 %). The quotient of July is exceptionally high in comparison with previous years (25 % in 2005 and 24 % in 2004) and pertains to the meteorological situation as described in chapter 2.4. Due to colder weather the occurrence of exceedances was lower in August and September (5 % and 4 %) in comparison with summer 2005 (10 % and 7 %) and summer 2004 (24 % and 12 %).

Figure 2.4 shows the frequency distribution of 8-hour ozone concentrations exceeding the long-term objective level. At European level, 25 % of maximum 8-hour concentrations of all the observed exceedances were below 127 µg/m³ (125 µg/m³ in 2005 and 2004). The highest values of the 75th percentile of all maximum concentrations in a country during exceedances were below 148 µg/m³ (144 µg/m³ in 2005, 143 µg/m³ in 2004).

2.3 Geographical distribution of ozone air pollution

Similar spatial distributions of ozone air pollution for the various exceedance parameters throughout Europe are found every year. In 2006 the highest ozone levels were found in southern Europe and also in north-western Europe. Widespread exceedances of the threshold as well as target values for the protection of human health occurred. Due to the specific meteorological conditions over the

([5]) The counting of 8-hour exceedances is carried out in the same way as the counting of one-hour exceedances, i.e. a day on which at least one 8-hour average exceeded the long-term objective level is one exceedance.

Table 2.3 Overview of exceedances of the long-term objective for the protection of human health during summer 2006 on a country-by-country basis

Country	No. of stations (1)	Stations with LTO exceedance (2) (Number)	Stations with LTO exceedance (2) (%)	Stations with TV exceedance (6) (Number)	Stations with TV exceedance (6) (%)	No. of days with LTO exceedance (3)	Maximum observed concentration. (μg/m³)	Occurrence of LTO exceedances (4)	
Austria	118	113	96	81	69	111	208	31.3	32.7
Belgium	40	38	95	24	60	52	229	28.0	29.4
Cyprus	2	2	100	—	—	12	131	7.5	7.5
Czech Republic	69	68	99	54	78	119	227	33.9	34.4
Denmark	11	7	64	—	—	33	178	9.7	15.3
Estonia	7	7	100	—	—	28	176	13.0	13.0
Finland	14	14	100	—	—	37	183	13.2	13.2
France	505	413	82	182	36	149	220	21.8	26.6
Germany	297	293	99	214	72	100	234	30.1	30.5
Greece	20	15	75	7	35	124	196	26.1	34.7
Hungary	21	17	81	10	48	92	188	23.5	29.1
Ireland	9	9	100	—	—	11	194	4.1	4.1
Italy	218	159	73	96	44	178	290	25.3	34.7
Latvia	5	2	40	—	—	8	144	1.8	4.5
Lithuania	15	14	93	1	7	34	174	11.9	12.7
Luxembourg	x	x	x	x	x	x	X	x	x
Malta	4	4	100	—	—	2	154	1.0	1.0
Netherlands	40	37	93	6	15	49	246	17.6	19.0
Poland	61	51	84	29	48	78	197	23.2	27.7
Portugal	54	46	85	14	26	127	222	20.9	24.5
Slovak Republic	20	18	90	13	65	77	207	29.7	32.9
Slovenia	12	12	100	10	83	107	221	48.1	48.1
Spain	344	272	79	100	29	177	308	17.8	22.5
Sweden	12	11	92	1	8	39	177	11.6	12.6
United Kingdom	96	79	82	1	1	42	223	6.9	8.4
EU area	**1 994**	**1 701**	**85**	**843**	**42**	**183**	**308**	**22.8**	**26.8**
Bosnia and Herzegovina	2	2	100	—	—	2	144	1.0	1.0
Bulgaria	12	9	75	1	8	51	183	7.6	10.1
Croatia	1	1	100	—	—	3	130	3.0	3.0
Iceland	4	1	25	—	—	5	161	1.3	5.0
Liechtenstein	1	1	100	1	100	40	174	40.0	40.0

x No data delivered from Luxembourg, FYR of Macedonia and Serbia.

— Not applicable.

(1) Total number of stations with ozone measurement.

(2) The number and percentage of stations at which at least one exceedance was observed.

(3) The number of calendar days on which at least one exceedance was observed.

(4) Left column: averaged over all implemented stations, right figure: averaged over all stations which reported at least one exceedance.

(6) See note 1.

Table 2.4 Overview of exceedances of the long-term objective for the protection of human health during summer 2006 on a month-by-month basis

Month	Stations with LTO exceedance (Number)	Stations with LTO exceedance (%)	Total no. of LTO exceedances	No. of days with LTO exceedance (3)	Maximum observed concentrations (µg/m³)	Occurrence of LTO exceedance (4)	
April	661	32	2 490	30	178	1.2	1.4
May	1 260	61	6 739	31	196	3.2	3.8
June	1 530	74	12 028	30	231	5.8	6.9
July	1 584	76	21 406	31	290	10.3	12.2
August	460	22	2 314	31	336	1.1	1.3
September	486	23	1 820	30	308	0.9	1.0

(2)–(4) See notes on Table 2.3.

Figure 2.3 Number of days on which at least one exceedance of the long-term objective for the protection of human health was observed per country and per month during summer 2006 (only countries which delivered data are shown)

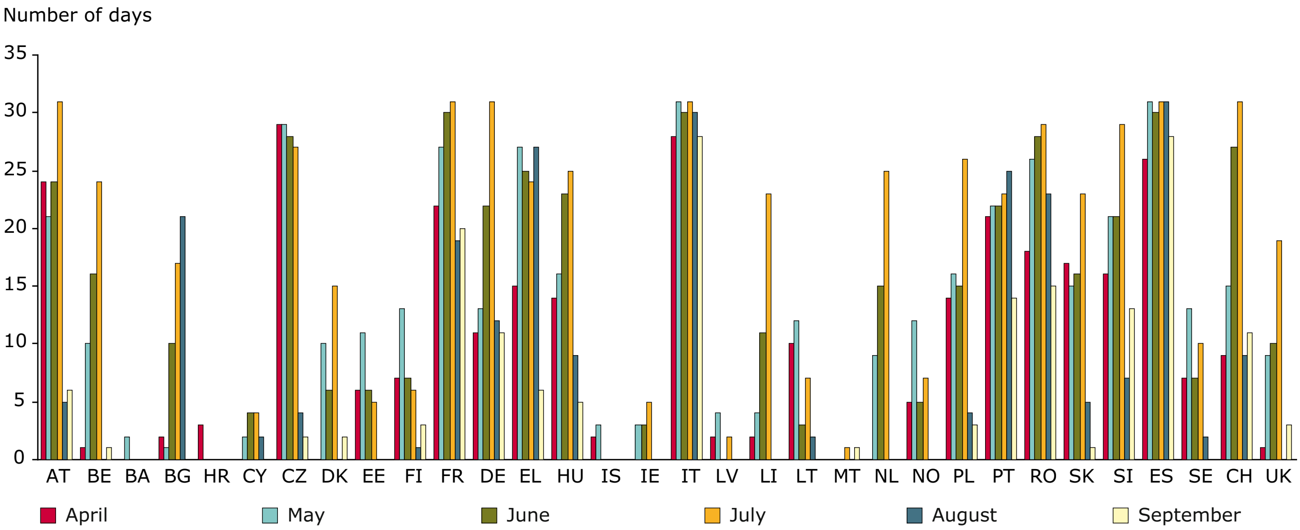
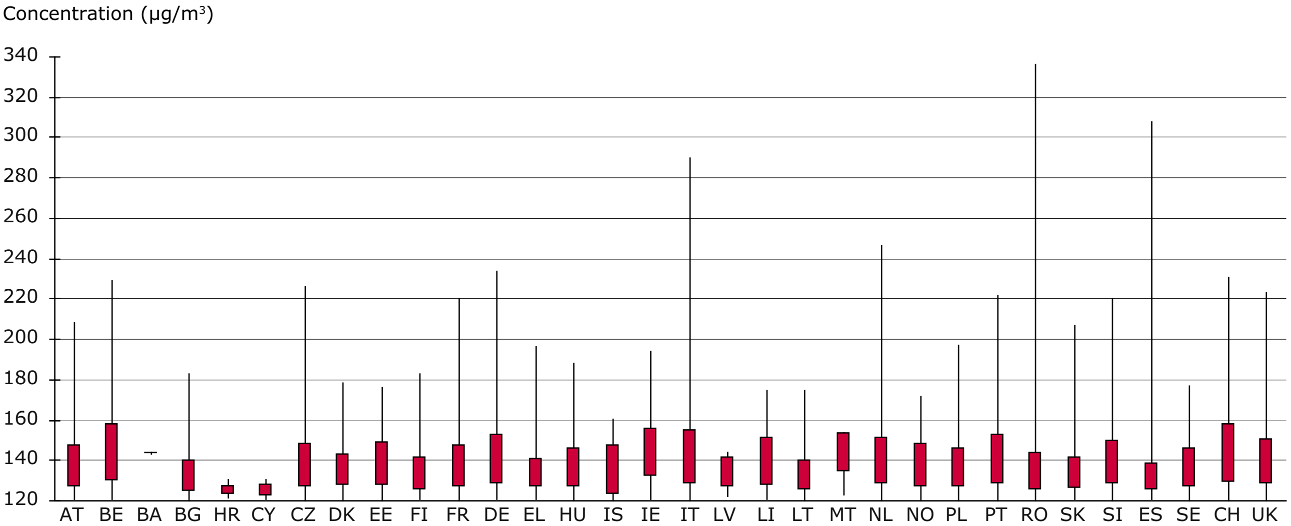


Figure 2.4 Frequency distribution of concentrations in excess of the long-term objective for the protection of human health during summer 2006 (only countries which delivered data are shown)



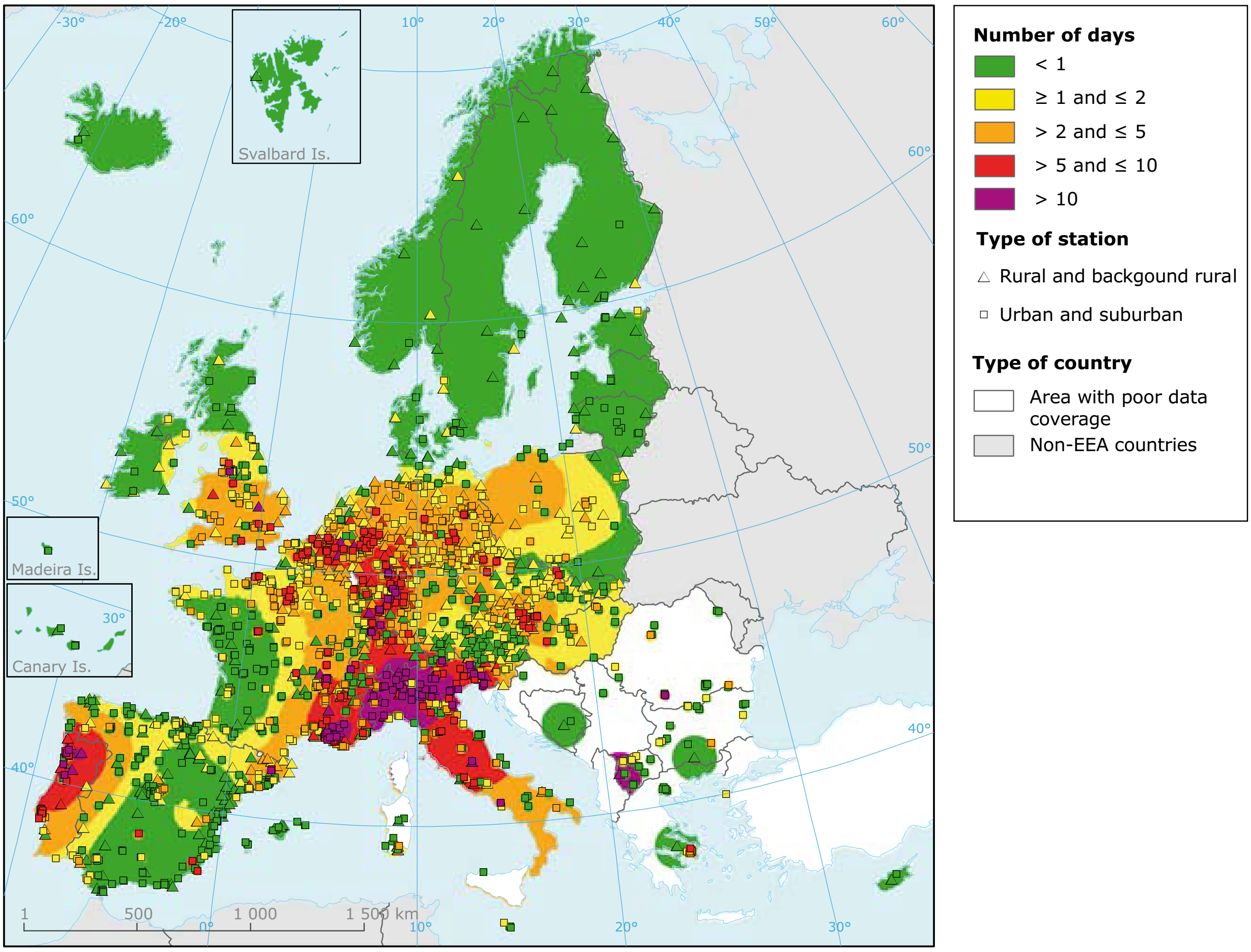
Note: Presented as Box-Jenkins, plots and indicates the minimum, the 25th percentile, the 75th percentile and the maximum value.

summer of 2006 northern and north-western Europe was more greatly affected than in the previous two years.

The geographical distribution of the number of days with exceedance of the one-hour information threshold (Map 2.1) shows that the spatial extent of the exceedances observed in summer 2006 was greater than in 2005 and 2004, and is comparable with the hot summer of 2003. The area with more than 10 exceedance days in summer 2006 covered northern Italy, south-eastern France, northern Portugal, western parts of Germany and several other more isolated locations. In the same area the highest numbers of exceedance days of the one-hour alert threshold were recorded.

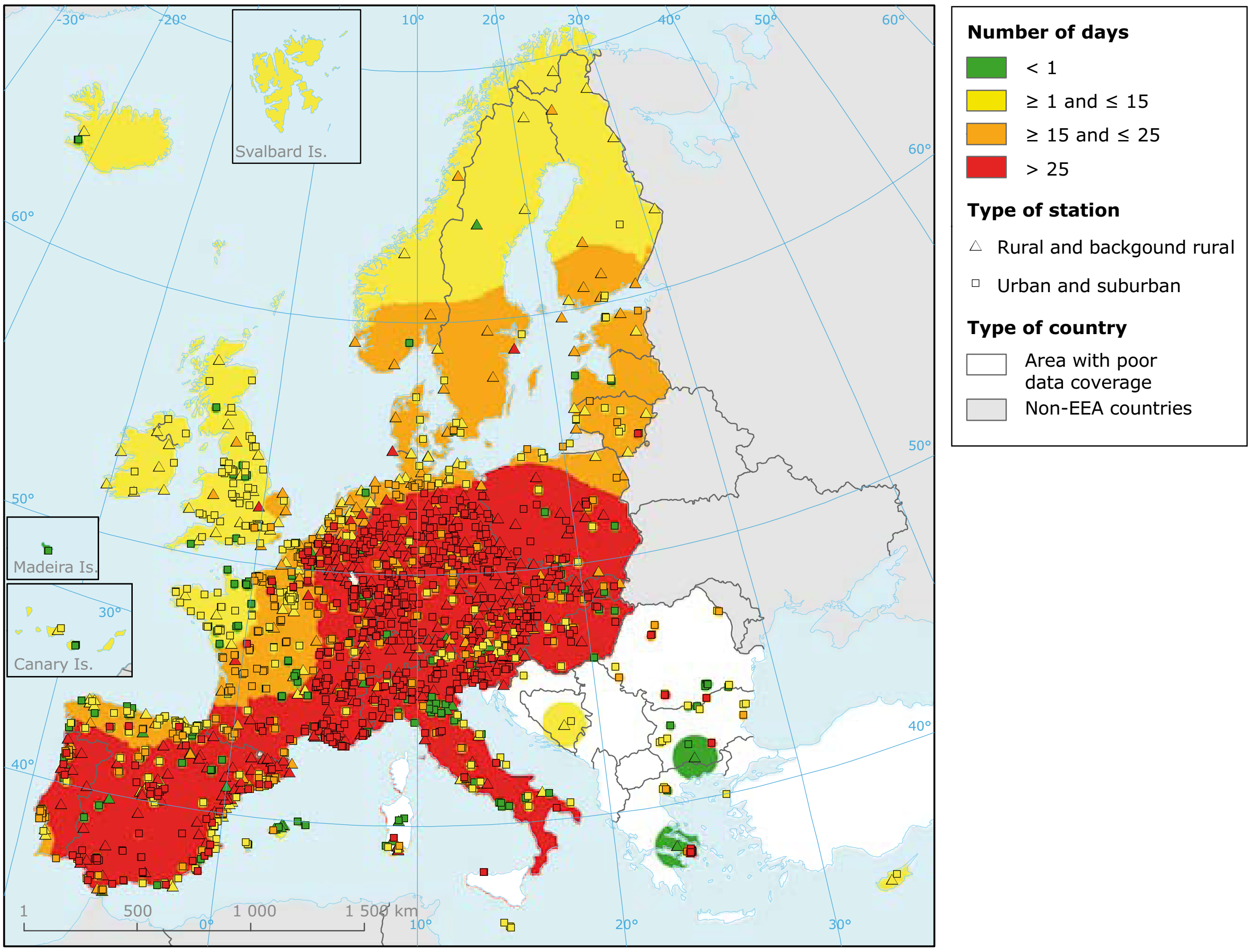
Map 2.2 shows the geographical distribution of the number of days on which the long-term objective for the protection of human health level (LTO) was exceeded. The area with the observed number of days with LTO exceedance higher than 25 (exceedance of TV) covered a larger area than in the previous two years and extended to the north-west of Europe. The lowest ozone levels occurred in the Baltic States and Scandinavia. Nevertheless, the long-term objective for the protection of human health was also often exceeded in these countries.

Map 2.1 Number of days with exceedance of the information threshold



The background of spatial distribution maps is the number of exceedance days from the rural stations interpolated by the ordinary kriging method (Cressie, 1993) i.e. a geostatistical method based on the knowledge of the air quality field spatial structure ([7]). The colour coding is common for station symbols as well as for interpolated maps.

Map 2.2 Number of days with exceedance of the long-term objective for the protection of human health



([7]) Ordinary kriging was used because it is a more appropriate method than the inverse distance weighting method (IDW) which was applied in previous years. The use of kriging is supported by the works dealing with the spatial mapping development (ETC/ACC Technical Paper 2005/7; possibility of using the kriging method in case of interpolating the number of exceedances — de Kassteele, 2005).
The density of ozone monitoring sites is too low to provide reliable estimates of the spatial distribution by interpolation for the south-eastern part of Europe and so the data are presented with an arbitrary IDW interpolated radius representing 100 km for rural stations. This radius has been chosen corresponding to the representative coverage of the ozone rural background stations given by the ozone directive.
The use of interpolation is questionable also for neighbouring parts of southern Italy and Hungary due to the small number of rural stations. No interpolation was made for the Mediterranean islands of Sicily, Sardinia and Corsica without measurements. Urban and suburban stations are represented by coloured symbols with an arbitrary IDW interpolated radius representing 20 km surrounding of stations.
The geographical coordinates were not known for approximately 5 % of stations and the type of station was not known for approximately 5 % of stations. This fact could affect the precision of mapping in some areas.

2.4 Main ozone episodes

Ozone formation in the atmosphere is a complicated, non-linear photochemical process. In the troposphere (the lower part of the atmosphere), ozone formation results from a chain mechanism involving photochemical reactions of nitrogen oxides chained with oxidative decomposition of VOCs, carbon monoxide (CO) and methane initiated by hydroxyl radicals (OH). The amount of ozone formed during the ozone episodes is dependent not only on the intensity of solar radiation and the concentration of precursors, but also on the ratio of VOC to NO_X concentrations. In urban areas, the NO_X concentrations are usually higher and the VOC/NO_X ratio is lower than the optimal VOC/NO_X ratio for maximum ozone formation. Consequently, zone concentrations in city centres are usually lower than the rural ('background') concentrations because of terminating reactions of NO_X with OH radicals which prevail in NO_X-rich city centre regions. During the night (reduced photochemical activity) ozone concentrations in city centres also decrease due to chemical scavenging by locally emitted nitrogen oxides.

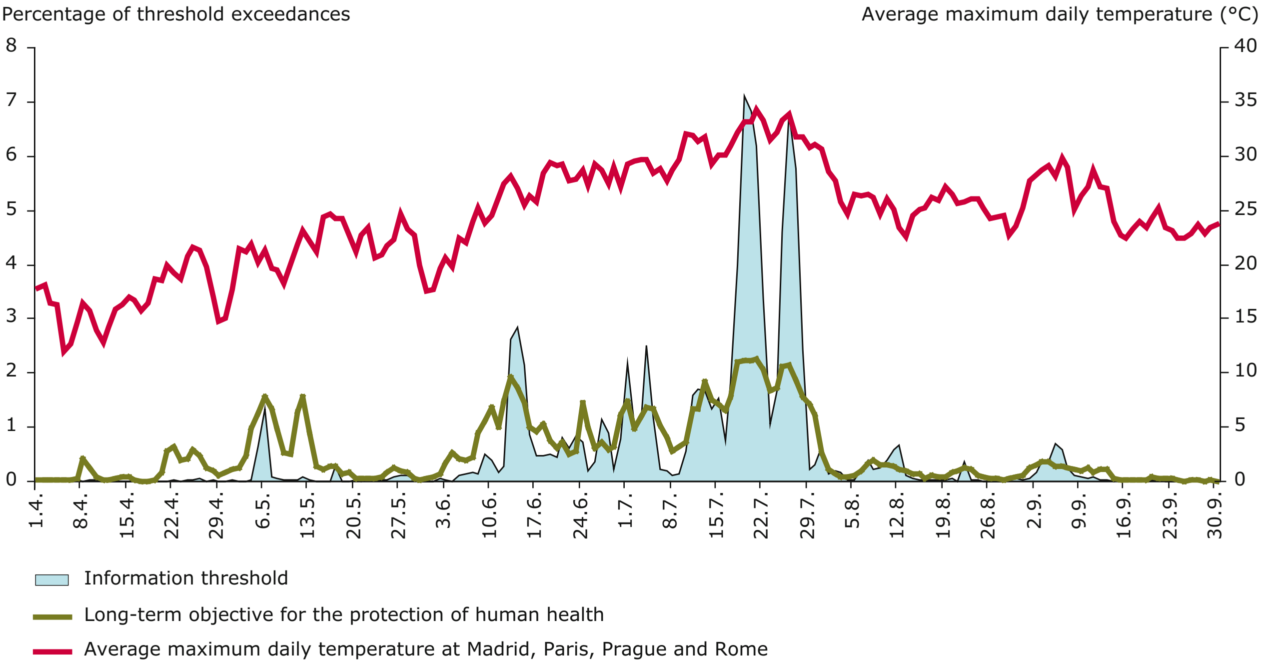
Episodes with elevated ozone levels occur during periods of warm sunny weather. The level of ozone concentration depends on the meteorological situation. The largest ozone episodes with highest ozone concentrations occur in areas of high air pressure (anticyclones). Within the high air pressure areas the formed stagnant conditions mean that emissions of ozone precursors are only slowly dispersed into the atmosphere and chemical reactions leading to ozone formation take place.

A summary of monthly-based exceedances was shown in Tables 2.2 and 2.4. Figure 2.5 shows the distribution of daily-based exceedances for the whole of Europe. Figure 2.6 shows the distribution of exceedances per day and per country during summer 2006. To demonstrate the correspondence of ozone levels with air temperature, the average daily maximum temperatures observed in four European capital cities (Madrid, Paris, Prague and Rome) are shown in Figure 2.5 (source of the temperature data: http://www.wunderground.com).

In summer 2006 the strongest ozone episode occurred between 17–28 July with two days of lower concentration on 23 and 24 July. During this period, 52 % of the total number of exceedances of the information threshold, 59 % of exceedances of the alert threshold and 24 % of exceedances of the long-term objective were observed.

Areas with elevated ozone concentrations during this episode covered a large area of Europe, mainly western, central and southern Europe. The situation

Figure 2.5 Distribution of exceedances during summer 2006 on a day-by-day basis

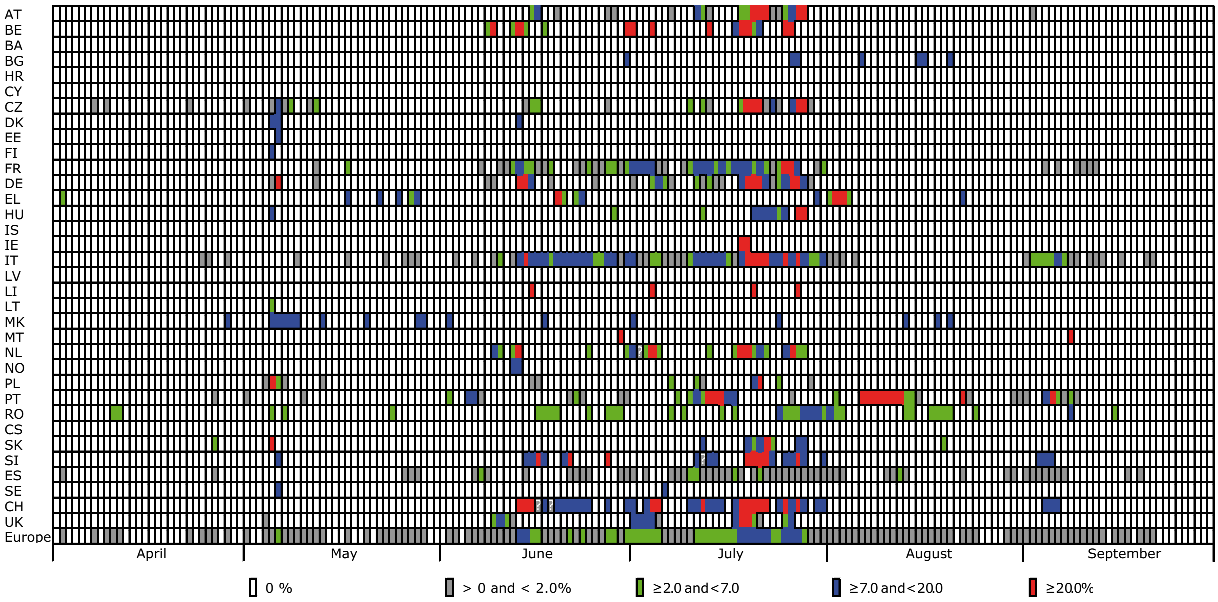


Note: The left y-axis represents the percentage of exceedances observed during a particular day. The total number of exceedances of the information threshold and the long-term objective for protection of human health is 100 % respectively.

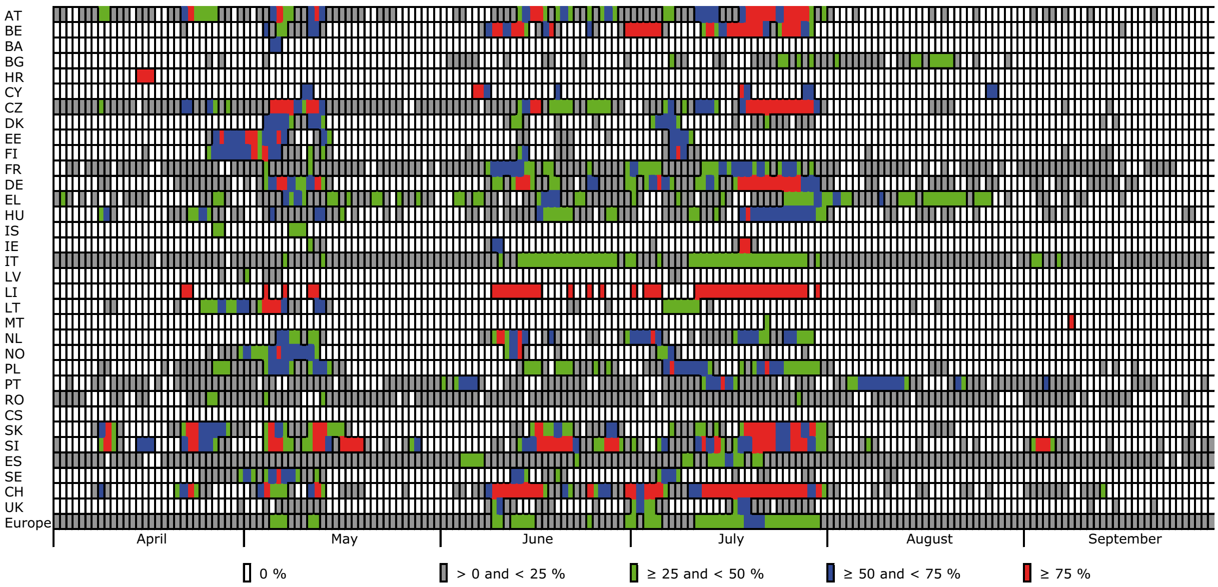
was characterised by stable, long-lasting wide areas of high–air–pressure spread over the continent. The highest pressure was situated just over western, central and southern Europe where the highest ozone concentrations were measured. On 23 and 24 July the high air pressure area was temporarily replaced by low pressure air masses which led to a reduction in ozone exceedances. The evolution of ozone concentrations and meteorological situation on selected days during the ozone episode in July 2006 are depicted on Map 3.3 (source of fields of ground level pressure, temperature and horizontal wind: http://www.eurad.uni-koeln.de/index_e.html). The maps clearly show the coincidence of areas with ozone exceedances with the areas of the highest temperatures in the high air pressure areas.

Figure 2.6 Distribution of exceedances during summer 2006 on a day-by-day basis per country in percentage of stations with exceedances of:

a) Information threshold exceedances

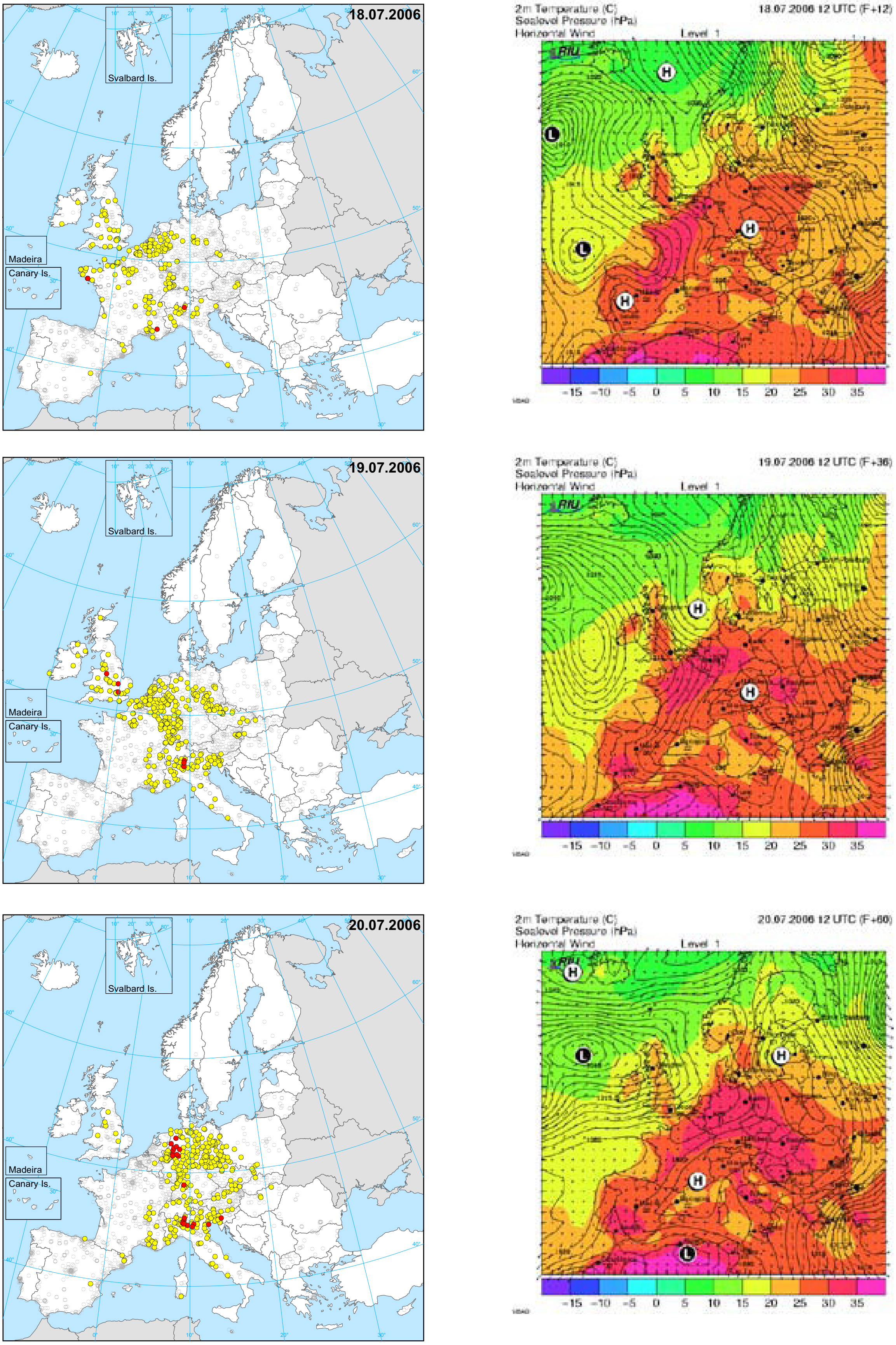


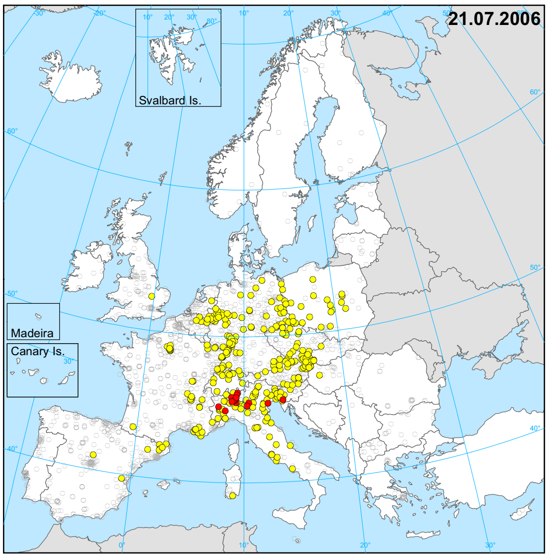
b) Long-term objective for the protection of human health exceedances

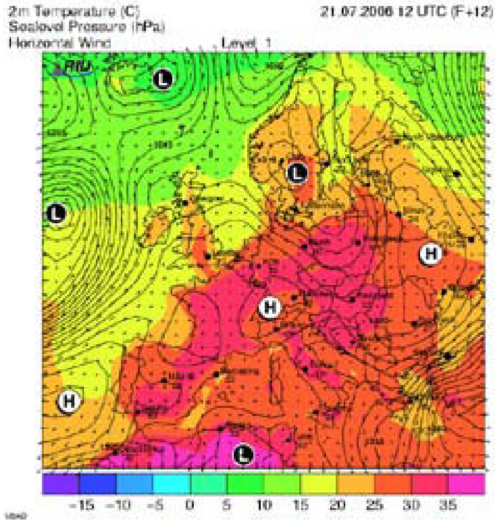


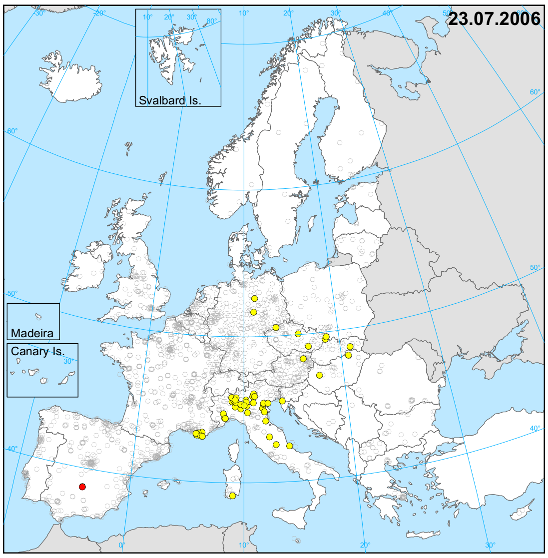
Note: Colours represent the percentage of stations with observed exceedances during a particular day. The total number of stations (see Table 2.1) for any particular country is 100 %.

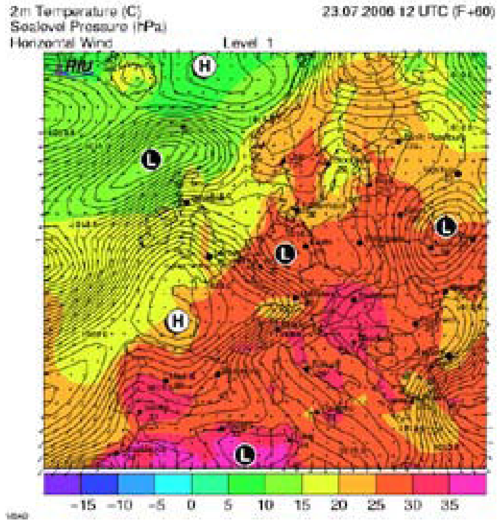
Map 3.3 **Selected days of the ozone episode in July 2006; maximum hourly concentrations (µg/m³), all station types;
white points: < = 180 µg/m3; yellow: >180-< = 240 µg/m³; red: >240 µg/m³**

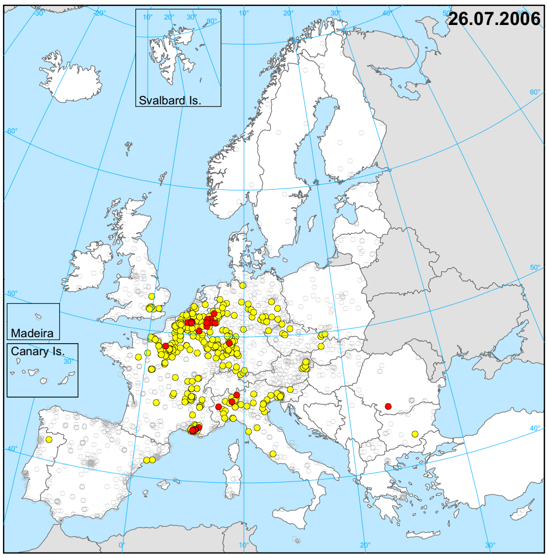


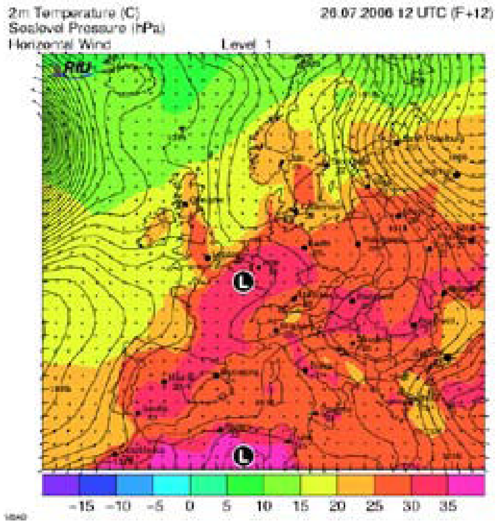

21.07.2006
Svalbard Is.
Madeira
Canary Is.


2m Temperature (C)
Sealevel Pressure (hPa)
Horizontal Wind
21.07.2006 12 UTC (F+12)
Level 1
-15 -10 -5 0 5 10 15 20 25 30 35


23.07.2006
Svalbard Is.
Madeira
Canary Is.


2m Temperature (C)
Sealevel Pressure (hPa)
Horizontal Wind
23.07.2006 12 UTC (F+60)
Level 1
-15 -10 -5 0 5 10 15 20 25 30 35


26.07.2006
Svalbard Is.
Madeira
Canary Is.


2m Temperature (C)
Sealevel Pressure (hPa)
Horizontal Wind
26.07.2006 12 UTC (F+12)
Level 1
-15 -10 -5 0 5 10 15 20 25 30 35

3 Comparison with previous years

Ozone levels in the summer of 2006 have been compared to ozone concentrations since 1995. However, the results should be interpreted with caution for following reasons:

- data over the period 1995–2002 refer to a full calendar year;
- 2003–2006 data were submitted under the Ozone Directive and refer to the summer months only. They are only partly validated.

Over the years the networks in Europe have changed. Some of the observed changes might be caused by the changes in location or density of the networks.

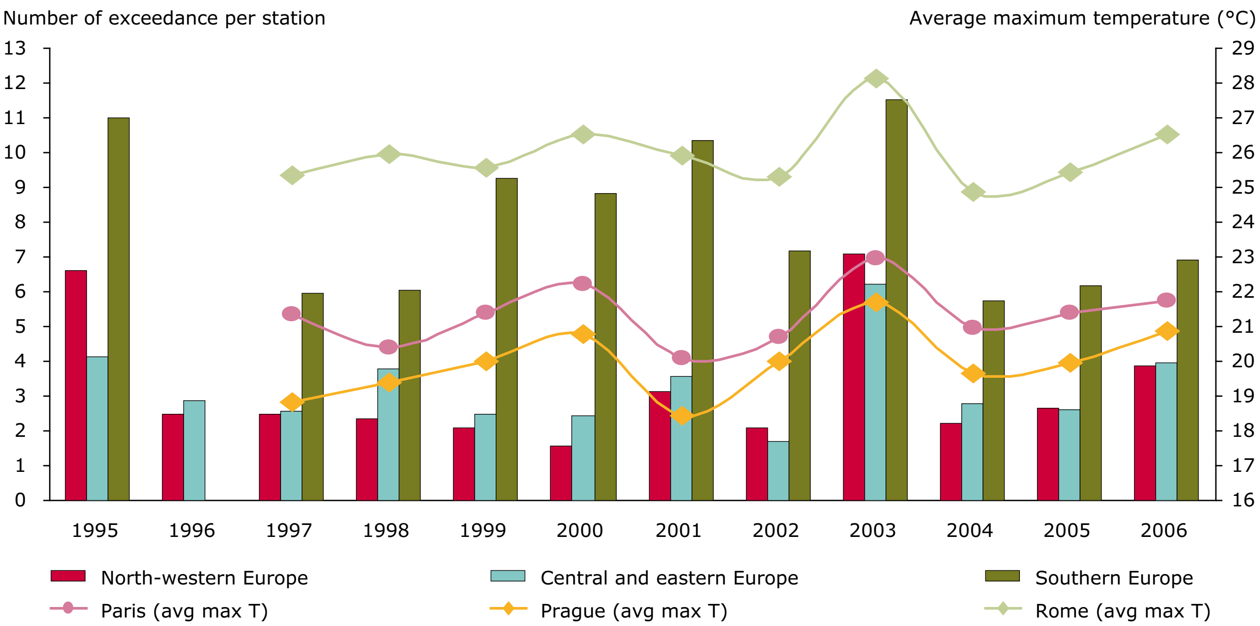
As described in previous chapters, the ozone concentrations over Europe vary widely, partly as a result of the large variations in climate over the continent. To examine a possible variation in the trend of ozone levels due to climatic differences over Europe, countries were divided into four regions (see key for Figure 3.1), based on last year's experience and this summer's data

The analysis clearly shows (Figure 3.1) that the frequent occurrence of exceedances was quite common in southern Europe. Between 1999 and 2001, the number of occurrences in southern Europe was only slightly lower than in the extreme summer of 2003 which saw a very large number of occurrences. This was also the case in other parts of Europe. While the situation during the summer of 2004 returned to 'normal', a continuing increase of exceedance occurrence was observed between 2004 and the summer of 2006; especially in north-western, and central and eastern Europe. the daily maximum temperatures averaged for the period April to September of a particular year observed in four capital cities in regions (Paris (France), Prague (Czech Republic), Rome (Italy)) are drawn in Figure 3.1. This shows correspondence between temperature and the occurrence of exceedances (source of the temperature data: http://www.wunderground.com).

Although emissions of ozone precursors have been reduced over the last decade, ozone pollution has not changed consistently. In some cases a decrease of ozone pollution has been observed, such as for the peak values of ozone. This decrease levelled off during recent years. In other cases, the data show an increase in ozone air pollution (at approximately one third of the urban and street monitoring stations). Average concentrations of ozone show an increasing trend for all station types (EEA, 2005).

At the current level of precursor emissions, the year-to-year variation of occurrence of ozone threshold exceedances is substantially induced by climatic variability from one year to another (CCC, 2005). Hot, dry summers with long-lasting periods of high air pressure over large parts of the European continent lead to elevated ozone concentrations and the increased occurrence of exceedances of ozone threshold values; the hotter the summer, the higher the number of exceedances.

Figure 3.1 Average occurrence (the number of exceedances per station) per region for stations, which reported at least one exceedance, observed during the year, and the summer average maximum daily temperature in selected cities



North-western Europe: United Kingdom, Ireland, the Netherlands, Belgium, Luxembourg and France north of 45 ° latitude

Central and eastern Europe: Germany, Poland, the Czech Republic, Slovakia, Hungary, Austria and Switzerland;

Southern Europe: France south of 45 ° latitude, Portugal, Spain, Italy, Slovenia, Greece, Cyprus and Malta;

Northern Europe (Norway, Sweden, Finland, Estonia, Lithuania, Latvia, Denmark and Iceland) has not been included in this figure because of the low number of exceedances.

Note: No station in region southern Europe has reported ozone data in 1996, only a few stations in Greece and Spain in 1995. No temperature data available for 1995 and 1996.

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Annex 1 Legal requirements on data provision

Directive 2002/3/EC requires the following data to be provided to the European Commission (and to the EEA):

Monthly data (Article 10(2)(a)(i))

Before the end of the following month, data collected on exceedances of the information and/or the alert thresholds (one-hour ozone concentration higher than 180 $\mu g/m^3$ and 240 $\mu g/m^3$) must be reported. Data submitted in the monthly reports are considered provisional and are updated, if necessary, in subsequent submissions.

Summer data (Article 10(2)(a)(ii))

Additional provisional data for the foregoing summer period (from April to September), as defined in Annex III to the Directive (i.e. information on exceedances of alert and information thresholds, on exceedances of the health protection long-term objective, the daily maximum of 8-hour average ozone concentration higher than 120 $\mu g/m^3$, related NO_2 values when required and for each month one-hour maximum ozone concentrations) must be reported by 31 October.

Annual data (Article 10(2)(b))

Validated annual data for ozone and precursors (as defined in Annexes III and VI to the directive) of the previous year must be submitted by 30 September as well. The annual data flow is included in the questionnaire to be used for annual reporting on air quality assessment in the scheme of the Air Quality Framework Directive (96/62/EC) and its daughter directives — see Commission Decision 2004/461/EC for details (Commission of the European Communities, 2004).

Annex 2 Data reporting over summer 2006

To manage the monthly and summer data flows, the Member States are required to use a set of reporting forms as described in the Commission guideline 'Directive 2002/3/EC relating to ozone in ambient air: procedures and formats for the exchange' (ETC/ACC, 2004).

Ozone monitoring stations are operated mostly throughout the whole period April– September 2006. However, it is possible that some exceedances were not reported due to monitoring station being temporarily out of operation as a result of maintenance work or breakdown. Nevertheless, general experience with current, continuously operated ozone monitors shows that such situations occur rarely.

A summary of monthly reported data is presented and regularly updated on the ETC/ACC web page http://etc-acc.eionet.eu.int/databases/o3excess.

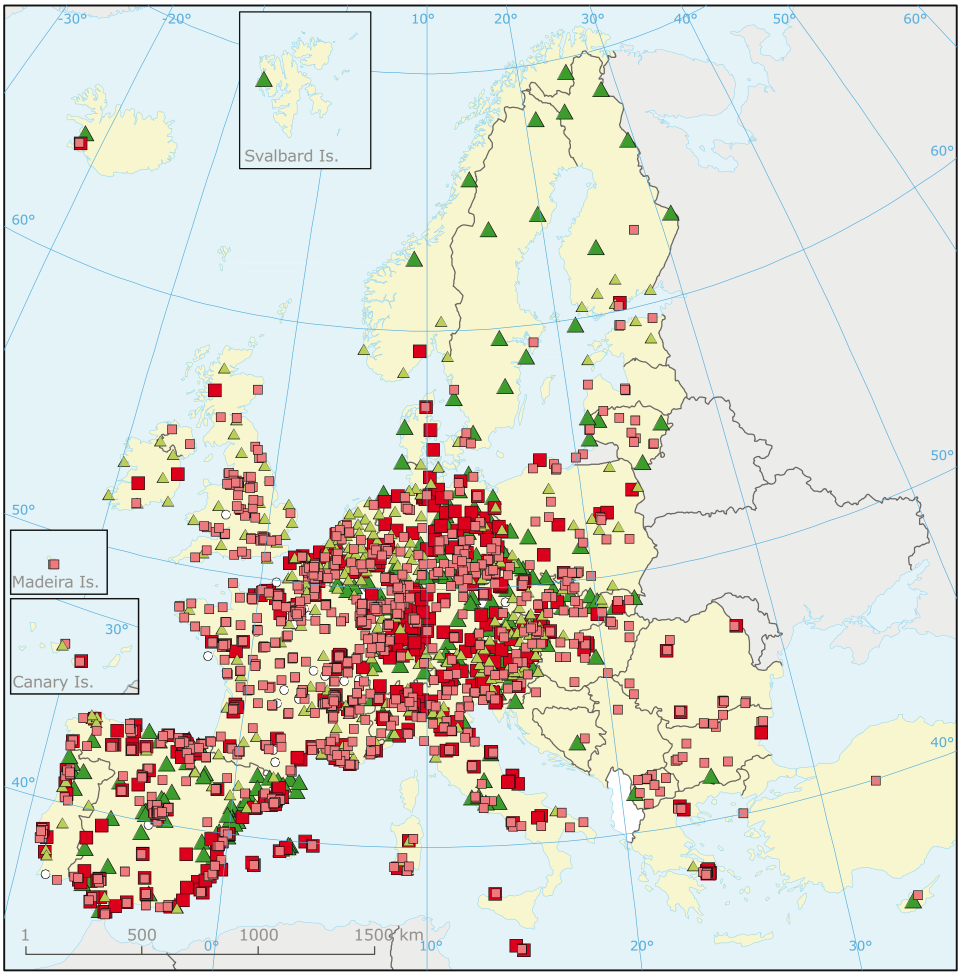
The ozone monitoring network in 2006

Map A.1 presents the location of all ozone-monitoring stations assumed to be operational in the reporting countries during the 2006 summer season. In total, 2 069 ozone-monitoring sites were operational in summer 2006; out of which 1 985 are located within the EU area. The number of stations reporting during summer has gradually increased in recent years (1 842 stations in 2001, 1 718 stations in 2002, 1 805 stations in 2003, 1 852 in 2004, 1 931 in 2005). There has been a significant increase in the number of stations in France (496 stations in 2006 in comparison with 455 in 2004), Italy (218/177), Romania (28/17) and Spain (344/313). For the first time, data were delivered from a few stations located in Bosnia and Herzegovina, Croatia and Serbia in 2006.

According to the requirements of the Ozone Directive, stations should be situated away from the influence of local emissions. When looking at the delivered station meta-information, 450, i.e. approximately 22 % are traffic or industrial stations (thereby not fulfilling the requirements), and were included in 2006 summer reporting.

The problem with missing or unclear meta-information on monitoring stations was not as large as in previous years. Most of the countries transmitted complete information about all operational stations. To fill the gaps in station meta-information, i.e. geographical coordinates, information was extracted from Airbase. Nevertheless, for approximately 5 % of stations, the type of station was not known.

Map A.1 Location of ozone monitoring stations as reported by Member States and other European countries in the framework of the Ozone Directive for summer



Type of station

- Rural
- Background rural
- urban
- Suburban
- Undefined and other

Type of country

- EEA countries reporting data
- EEA countries with no data reported
- Non-EEA countries

European Environment Agency

Air pollution by ozone in Europe in summer 2006
Overview of exceedances of EC ozone threshold values for April–September 2006

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