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Air pollution by ozone across Europe during summer 2007

Overview of exceedances of EC ozone threshold values for April–September 2007

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Executive summary

Ozone levels during the summer of 2007 were among the lowest in the past decade.

The number and spatial extent of exceedances was lower than in any of the last ten summers. In contrast to the summer of 2006, no exceedances of the information threshold value (180 μg/m^3, Directive 2002/3/EC) occurred in the northern part of Europe.

As in all previous years 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. The target value for human health protection was also exceeded in a significant part of Europe.

The highest, one-hour ozone concentration of 479 μg/m^3 was observed in Italy on the island of Sicily, while the second highest level of 363 μg/m^3 was observed in Romania. High hourly ozone concentrations of between 300 and 360 μg/m^3 were reported a total of six times in France, Greece, Italy and Romania.

Forty-five percent of the total number of exceedances of the information threshold, 39 % of exceedances of the alert threshold and 12 % of exceedances of the long-term objective were observed during a single episode from 14–21 July.

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 2007 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 (European Parliament and Council of the European, 2002) Union requires Member States to report exceedances of the information threshold and alert threshold values (see Table 1.1) 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 data on exceedances of the long-term objective for the protection of human health (daily maximum 8-hour average concentrations of 120 μg/m^3).

In order to provide as timely information as possible, the summaries of the monthly data provided by the countries were made 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), which shows the situation for ground level ozone across Europe based on near real-time data. The site was developed by the EEA as a joint European project and provides up-to-date information in the form of maps and graphs (see Annex 3).

Overview of ozone air pollution in the summer of 2007

All 27 EU Member States provided information to the European Commission on observed one-hour exceedances. All states also observed and reported long-term objective exceedances. In addition, eight other countries (Bosnia and Herzegovina, Croatia, Iceland, Liechtenstein, FYR of Macedonia, Norway, Serbia and Switzerland) supplied information to the EEA upon request.

Ozone levels during the summer of 2007 were among the lowest in the past decade. Ozone air pollution was the highest in July; the relatively low temperatures in June were associated with a much lower number of exceedances then in previous years.

Main findings

From a total of 2 062 ozone monitoring sites reporting data, 2 012 were located in EU Member States. The following preliminary conclusions can be drawn from the period of April–September 2007:

Exceedance of the information threshold

- The number of exceedances of the information threshold (180 µg/m³ of one-hour ozone concentration) expressed as a percentage of stations with recorded exceedances, was the lowest recorded in the last ten summers. Ozone concentrations higher than the information threshold were reported from monitoring sites in 17 EU Member States and 4 non-member countries. The information threshold was exceeded at approximately 27 % of all operational stations.

- The spatial extent of the observed exceedances was less extensive than in previous years. In contrast to the summer of 2006, no exceedances occurred in the northern part of Europe. The most frequent exceedances of the information threshold were observed in northern Italy and at several locations in Austria, Romania and around the Mediterranean (southern France, Greece, Italy, the FYR of Macedonia, Portugal and Slovenia).

Exceedance of the alert threshold

- Ozone concentrations higher than the alert threshold of 240 µg/m³ were reported on 96 occasions in 12 EU Member States (Austria, the Czech Republic, France, Germany, Greece, Hungary, Italy, Portugal, Romania, the Slovak Republic, Slovenia and Spain) and 3 non-member countries (the FYR of Macedonia, Serbia and Switzerland).

- Exceedances were observed in northern Italy and at other locations with the highest number of information threshold exceedances. In general, the alert threshold was exceeded on one or two days per station; only 20 % of stations with recorded alert threshold exceedances reported more than two days of exceedances within the maximum number of six days.

Maximum concentrations

- The highest one-hour ozone concentration of 479 µg/m³ was observed in Italy on the island of Sicily, with the second highest concentration, of 363 µg/m³, being observed in Romania. High, hourly ozone concentrations of between 300 and 360 µg/m³ were reported a total of six times in France, Greece, Italy and Romania.

Exceedance of the long-term objective for the protection of human health (LTO)

- As in previous years, ozone exceedance of the long-term objective for the protection of human health, i.e. a daily maximum 8-hour average concentrations higher than 120 µg/m³, were observed in every country, in almost every summer month and at most stations during the summer of 2007. Approximately 83 % of all stations reported one or more exceedance.

- For those countries that reported exceedances, the number of exceedance days per country ranged from 2 (Bosnia-Herzegovina and Latvia) to 174 (Italy). On every single day during the summer of 2007 at least one of the 2 062 operational stations in Europe reported an exceedance of the health related target value (TV). On average, 22 days of exceedance were observed at stations that recorded at least one exceedance.

Exceedance of the target value (1) **(TV)** *for the protection of human health*

- Target value exceedances were observed in 17 EU Member States (Austria, Bulgaria, Cyprus, the Czech Republic, France, Germany,

(1) Daily, maximum, 8-hour, average concentrations were compared with legal objectives set solely for indicative purposes for assessing the current situation and its distance from objectives, and not for checking compliance with Directive 2002/3/EC. As reports of maximum, daily, 8-hour, average concentrations of ozone started in 2004, exceedances of TVs presented in this report are counted for indicative purposes in cases where LTO limits have been exceeded more than 25 times during the assessed summer period.

Greece, Hungary, Italy, Luxembourg, Malta, Poland, Portugal, Romania, the Slovak Republic, Slovenia and Spain) and in 2 non-member countries (Croatia and Switzerland).

- Target value exceedances occurred at 27 % of all monitoring stations providing reports.
- The target value was exceeded in approximately 28 % of the area for which data was reported and affected approximately 28 % of the total population in the assessed territory ([2]).

Main ozone episodes

- The most significant ozone episode occurred on the dates of 14–21 July. During this period, 45 % of the total number of exceedances of the information threshold, 39 % of exceedances of the alert threshold and 12 % of LTO exceedances were observed.
- The meteorological situation during this episode was characterised by long-lasting wide areas of high air pressure spread over continental Europe.
- A period of frequent exceedance of the LTO was also observed in the second part of April.

Comparison with previous years

The ozone level during the summer of 2007 ranks as the lowest in the past decade and the spatial extent of the observed exceedances was less extensive than in previous years.

Disclaimer

This report contains summary information based on data delivered before 4 December 2007 (33 days after the deadline set by the directive).

The information describing the situation during the summer of 2007 is based on provisional monitoring data and, hence, should be regarded as preliminary.

([2]) See Section 2.2 for calculation details. The percentage of affected area and population is not comparable with those in summer reports for 2004, 2005 and 2006 because of different spatial distribution maps preparation — see Section 2.3.

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 of 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, sets long-term objectives and target values, as well as an alert threshold and an information threshold (Table 1.1) 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 adequate information is made available to the public on the basis of this assessment. It also promotes cooperation between the Member States in reducing ozone levels.

This report gives an overview of the situation between April–September 2007, and provides a comparison with the last ten years. The EEA has prepared similar overviews since 1994. Previous reports are available from EEA's website: http://www.eea.europa.eu.

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

Table 1.1 Ozone threshold values, long-term objective and target value for the protection of human health

Objective	Level (μg/m³)	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

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

2 Ozone air pollution in the summer of 2007

Ozone levels were lower during the summer of 2007 compared with those of previous summers. Details on reported data and ozone monitoring networks are provided in Annex 2.

This chapter provides detailed country-by-country, month-by-month and day-by-day tabular, graphic and geographical based information on threshold exceedances. The largest threshold exceedance episode is also described.

The frequency distribution of hourly ozone concentrations in excess of the information threshold (Figure 2.2) shows that European levels of 25 % of the maximum hourly concentrations of all observed exceedances were below 186 μg/m^3 (207 μg/m^3 in 2003, 185 μg/m^3 in 2004, 186 μg/m^3 in 2005 and 2006). The highest values of the 75th percentile of all maximum concentrations in a country during exceedances were below 206 μg/m^3 (305 μg/m^3 in 2003, 203 μg/m^3 in 2004, 206 μg/m^3 in 2005 and 2006).

2.1 Summary of reported hourly exceedances

Ozone concentrations in excess of the information threshold were reported from monitoring sites in seventeen EU Member States and four non-member countries (Table 2.1).

The occurrences of exceedance, expressed as the percentage of stations with recorded exceedances, were lower than any recorded in the last ten summers. In contrast to the summer of 2006, no exceedances occurred in the northern part of Europe.

Table 2.2, Figure 2.1 and Figure 2.6 present the seasonal behaviour of hourly exceedances. The highest number of exceedances ([3]) occurred during July when approximately 62 % of all observed information threshold exceedances and about 66 % of alert threshold exceedances were recorded. The percentage for June (only 6 % for information threshold and 11 % for alert threshold exceedances) is exceptionally low compared with previous years and relates to the colder weather. The occurrence of alert threshold exceedances is also lower compared with previous years (Table 3.1).

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

Long-term objective (LTO) exceedances during the summer of 2007 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 83 % of all stations reported at least one exceedance. There was not one day without an exceedance in Europe in the summer of 2007. The occurrence of exceedances was lower than in the summer of 2006 (Table 3.1).

These exceedances are summarised on a monthly basis in Table 2.4, and on a day-by-day per country basis in Figure 2.6.

The highest number of exceedances occurred during April (24 % of all observed exceedances) and July (23 %). The quotient for April is exceptionally high compared with previous years (lower than 10 % in

([3]) 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 one-hour thresholds during the summer of 2007 on a country-by-country basis

Country	No. of stations (¹)	Stations with exceedance (²)					No. of days with exceedance (³)		Maximum observed one-hour concentration (µg/m³)	Occurrence of exceedances (⁴)				Average duration of exceedances (hour)	
		(number)		(%)		(%)									
Austria	122	71	6	58	5	8	17	4	257	1.8	3.1	0.1	1.2	3.2	1.1
Belgium	39	8	0	21	-	-	2	-	199	0.2	1.0	-	-	2.0	-
Bulgaria	13	5	0	38	-	-	12	-	218	1.0	2.6	-	-	1.7	-
Cyprus	2	0	0	-	-	-	-	-	160	-	-	-	-	-	-
Czech Republic	71	37	1	52	1	3	8	1	240	0.8	1.5	0.0	1.0	3.1	4.0
Denmark	7	0	0	-	-	-	-	-	159	-	-	-	-	-	-
Estonia	7	0	0	-	-	-	-	-	149	-	-	-	-	-	-
Finland	14	0	0	-	-	-	-	-	159	-	-	-	-	-	-
France	439	89	3	20	1	3	36	4	308	0.4	2.2	0.0	1.7	2.0	1.0
Germany	286	68	3	24	1	4	9	1	282	0.3	1.1	0.0	1.0	2.6	1.3
Greece	23	14	7	61	30	50	30	6	320	4.1	6.8	0.5	1.6	2.5	1.7
Hungary	21	10	1	48	5	10	7	2	256	1.3	2.7	0.1	2.0	2.9	1.0
Ireland	9	0	0	-	-	-	-	-	149	-	-	-	-	-	-
Italy	235	144	21	61	9	15	95	16	479	3.9	6.4	0.2	2.1	3.4	2.2
Latvia	6	0	0	-	-	-	-	-	141	-	-	-	-	-	-
Lithuania	15	0	0	-	-	-	-	-	145	-	-	-	-	-	-
Luxembourg	5	0	0	-	-	-	-	-	175	-	-	-	-	-	-
Malta	4	2	0	50	-	-	4	-	203	1.0	2.0	-	-	2.5	-
Netherlands	40	1	0	3	-	-	3	-	189	0.1	3.0	-	-	1.7	-
Poland	68	12	0	18	-	-	5	-	209	0.3	1.4	-	-	2.8	-
Portugal	56	25	3	45	5	12	19	1	269	1.1	2.5	0.1	1.0	2.7	1.0
Romania	27	5	3	19	11	60	30	10	363	1.2	6.6	0.4	3.3	1.5	1.3
Slovak Republic	13	6	1	46	8	17	8	1	270	1.1	2.3	0.1	1.0	2.9	1.0
Slovenia	12	6	1	50	8	17	12	1	243	2.5	5.0	0.1	1.0	3.5	1.0
Spain	367	31	1	8	0	3	24	1	288	0.1	1.6	0.0	1.0	1.7	1.0
Sweden	12	0	0	-	-	-	-	-	144	-	-	-	-	-	-
United Kingdom	99	0	0	-	-	-	-	-	168	-	-	-	-	-	-
EU area	**2 012**	**534**	**51**	**27**	**3**	**10**	**142**	**34**	**479**	**0.9**	**3.4**	**0.0**	**1.7**	**3.0**	**1.8**
Bosnia-Hercegovina	1	0	0	-	-	-	-	-	169	-	-	-	-	-	-
Croatia	2	1	0	50	-	-	4	-	187	2.0	4.0	-	-	1.5	-
Iceland	3	0	0	-	-	-	-	-	106	-	-	-	-	-	-
Liechtenstein	1	0	0	-	-	-	-	-	171	-	-	-	-	-	-
Macedonia, FYR of	13	10	1	77	8	10	42	4	256	6.5	8.4	0.3	4.0	5.3	4.0
Norway	8	0	0	-	-	-	-	-	132	-	-	-	-	-	-
Serbia	1	1	1	100	100	100	2	1	277	2.0	2.0	1.0	1.0	2.5	1.0
Switzerland	21	5	1	24	5	20	20	2	270	1.7	7.2	0.1	2.0	3.3	2.0
Whole area	**2 062**	**551**	**54**	**27**	**3**	**10**	**144**	**35**	**479**	**0.9**	**3.5**	**0.0**	**1.8**	**3.1**	**1.9**

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

- Not applicable.

(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.

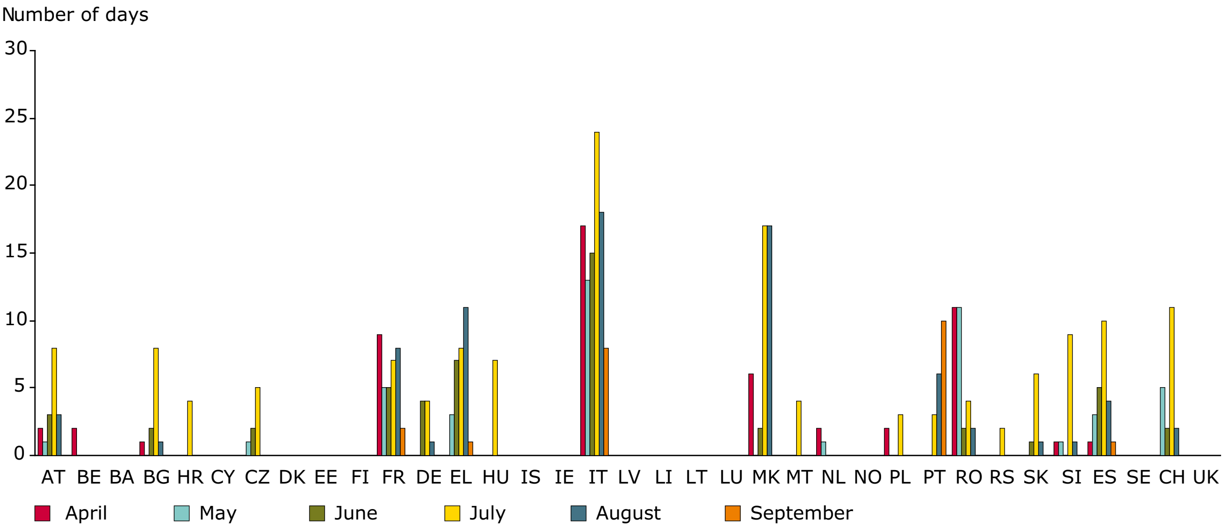
Table 2.2 Overview of exceedances of one-hour thresholds during the summer of 2007, on a month-by-month basis

Month	Stations with exceedance (2)					Total no. of exceedances		No. of days with exceedance (3)		Maximum observed one-hour concentration (µg/m³)	Occurrence of exceedances (4)				Average duration of exceedances (hour)	
	(number)		(%)		(%)											
April	65	3	3	0	5	103	4	21	3	308	0.0	0.2	0.0	0.1	1.8	1.0
May	117	3	6	0	3	220	6	23	6	363	0.1	0.4	0.0	0.1	2.7	1.5
June	72	6	3	0	8	119	11	25	8	479	0.1	0.2	0.0	0.2	2.0	1.7
July	434	40	21	2	9	1 206	63	29	12	320	0.6	2.2	0.0	1.2	3.5	2.1
August	149	11	7	1	7	263	12	29	6	274	0.1	0.5	0.0	0.2	2.6	1.2
September	20	0	1	-	-	34	0	17	0	225	0.0	0.1	-	-	1.8	-

Note: (2)–(4) see notes to 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 the summer of 2007 (only countries that delivered data are shown)

a) Information threshold exceedances



b) Alert threshold exceedances

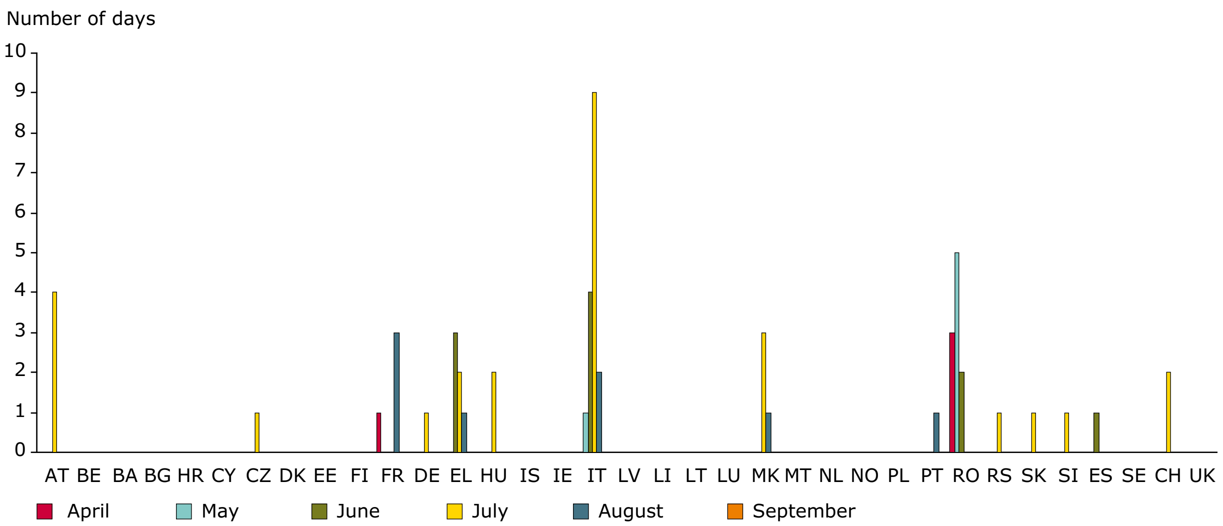
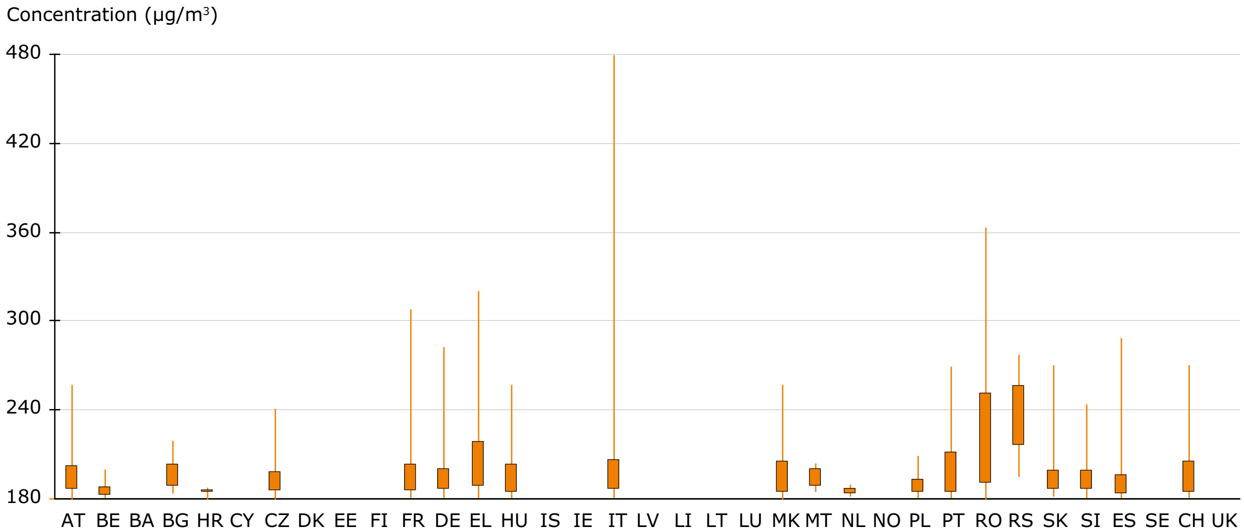


Figure 2.2 Frequency distribution of concentrations in excess of the one-hour information threshold during summer 2007 (only countries that delivered data are shown)



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

previous summers) and is in direct connection to the meteorological situation (warmer winter followed by warmer spring).

The frequency distribution of 8-hour ozone concentrations exceeding the long-term objective level is shown in Figure 2.4. At the European level, 25 % of maximum 8-hour concentrations of all the observed exceedances were below 125 µg/m³ (125 µg/m³ in 2005 and 2004, 127 µg/m³ in 2006). The highest values of the 75th percentile of all maximum concentrations in a country during exceedances were below 140 µg/m³ (143 µg/m³ in 2004, 144 µg/m³ in 2005, 148 µg/m³ in 2006).

2.3 Geographical distribution of ozone air pollution

The spatial distribution throughout Europe of various exceedance parameters of ozone air pollution is similar from year-to- year. In 2007, the highest ozone levels were found in southern and central Europe, where widespread exceedances of both the threshold and target values for the protection of human health occurred. Western, north-western and northern Europe were not as widely affected as in previous summers.

The lowest ozone levels occurred in the Baltic States, Scandinavia and a large part of western Europe, with exceedances of no more than one or two days for the information threshold and the long-term objective for the protection of human health level (LTO).

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 the summer of 2007 was less than in the previous four summers. An area with more than 10 exceedance days in the summer of 2007 covered northern Italy and several other, more isolated locations.

The geographical distribution of the number of days on which LTO was exceeded is shown in Map 2.2. The areas where the observed number of days was more than 25 with respect to LTO exceedance (exceedance of TV) were more restricted than in the previous five summers. The target value was exceeded in approximately 28 % of

Table 2.3 Overview of exceedances of the long-term objective for the protection of human health during the summer of 2007 on a country-by-country basis

Country	No. of stations (1)	Stations with LTO exceedance (2) (number)	(%)	Stations with TV exceedance (number)	(%)	No. of days with LTO exceedance (3)	Maximum observed 8-hour concentration (μg/m³)	Occurrence of LTO exceedances (4)	
Austria	122	116	95	77	63	136	219	32.0	33.6
Belgium	39	38	97	-	-	29	171	8.7	8.9
Bulgaria	13	10	77	4	31	107	208	18.5	24.1
Cyprus	2	2	100	1	50	84	147	42.5	42.5
Czech Republic	71	70	99	43	61	98	203	27.2	27.6
Denmark	7	5	71	-	-	16	157	3.7	5.2
Estonia	7	4	57	-	-	5	128	1.0	1.8
Finland	14	3	21	-	-	3	139	0.2	1.0
France	439	415	95	78	18	135	201	14.8	15.6
Germany	286	277	97	74	26	102	206	19.0	19.6
Greece	23	18	78	9	39	143	225	25.4	32.4
Hungary	21	17	81	12	57	108	231	34.0	41.9
Ireland	9	4	44	-	-	10	140	1.2	2.8
Italy	235	207	88	128	54	174	275	35.1	39.9
Latvia	6	1	17	-	-	2	125	0.3	2.0
Lithuania	15	7	47	-	-	6	140	0.6	1.3
Luxembourg	5	4	80	1	20	32	158	14.2	17.8
Malta	4	4	100	1	25	52	178	15.5	15.5
Netherlands	40	32	80	-	-	33	175	4.5	5.7
Poland	68	51	75	16	24	91	185	15.0	20.0
Portugal	56	41	73	8	14	90	218	10.5	14.3
Romania	27	17	63	8	30	152	253	16.2	25.8
Slovak Republic	13	13	100	9	69	88	203	36.9	36.9
Slovenia	12	12	100	8	67	126	193	43.6	43.6
Spain	367	260	71	71	19	180	184	11.8	16.7
Sweden	12	5	42	-	-	15	139	2.0	4.8
United Kingdom	99	30	30	-	-	17	148	0.5	1.7
EU area	**2 012**	**1 663**	**83**	**548**	**27**	**183**	**275**	**17.8**	**21.5**
Bosnia-Hercegovina	1	1	100	-	-	2	-	2.0	2.0
Croatia	2	2	100	1	50	52	169	29.5	29.5
Iceland	3	0	-	-	-	-	-	-	-
Liechtenstein	1	1	100	-	-	14	156	14.0	14.0
Macedonia, FYR of	x	x	x	x	x	x	x	x	x
Norway	8	2	25	-	-	4	127	0.6	2.5
Serbia	1	1	100	-	-	14	178	14.0	14.0
Switzerland	21	21	100	14	67	106	226	33.1	33.1
Whole area	**2 049**	**1 691**	**83**	**563**	**27**	**183**	**275**	**17.9**	**21.6**

Notes: x No data delivered from FYR of Macedonia.

- 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.

Table 2.4 Overview of exceedances of the long-term objective for the protection of human health during the summer of 2007 on a month-by-month basis

Month	Stations with LTO exceedance (²) (number)	[%]	Total number of exceedances	No. of days with LTO exceedance (³)	Maximum observed 8-hour concentration (µg/m³)	Occurrence of LTO exceedances (⁴)	
April	1 343	66	8 743	30	194	4.3	5.2
May	1 287	63	6 252	31	253	3.1	3.7
June	1 231	60	5 829	30	275	2.8	3.4
July	1 217	59	8 248	31	272	4.0	4.9
August	1 225	60	5 880	31	218	2.9	3.5
September	385	19	1 624	30	183	0.8	1.0

Note: (²)–(⁴) see notes to 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 the summer of 2007 (only countries that delivered data are shown)

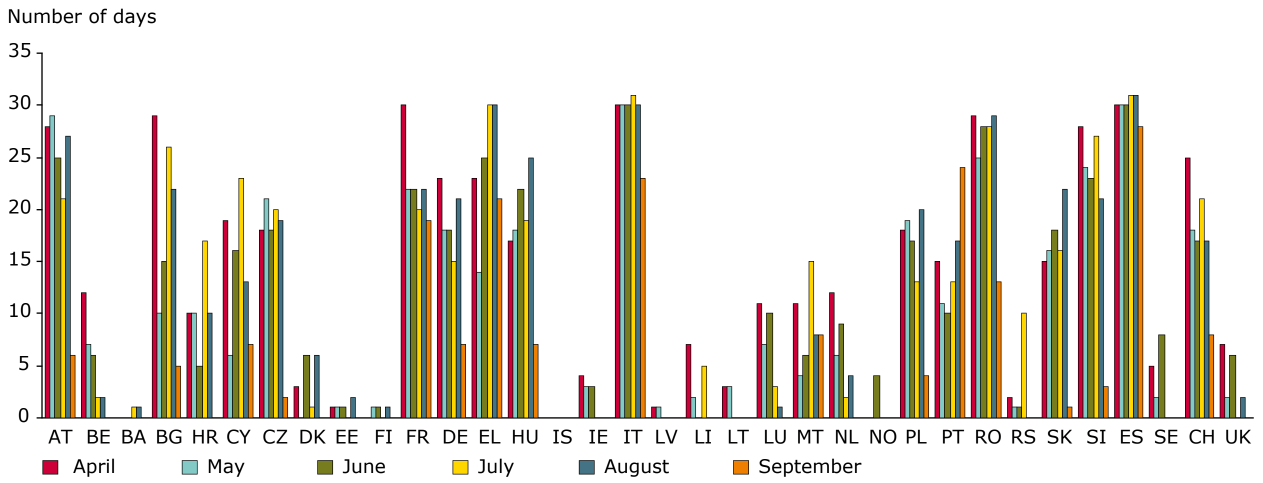
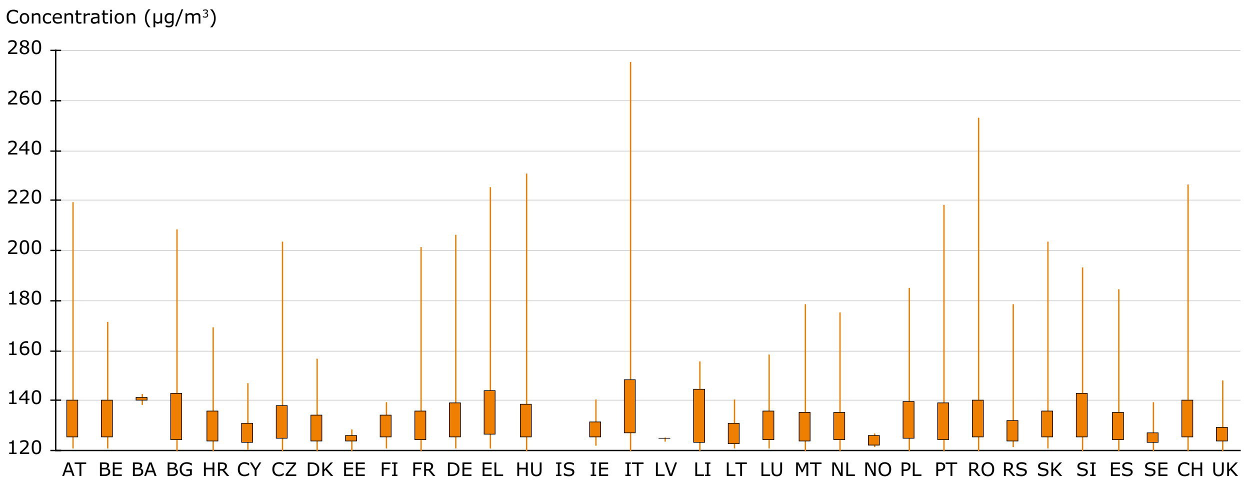


Figure 2.4 Frequency distribution of concentrations in excess of the long-term objective for the protection of human health during the summer of 2007 (only countries that delivered data are shown)



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

the assessed area and affected approximately 28 % of the total population in the assessed territory (Table 2.5) ([4]).

The background to these maps is the number of exceedance days from the rural stations interpolated by the ordinary kriging method (Cressie, 1993) — a geostatistical method based on knowledge of the air quality field spatial structure ([5]). The colour coding is standard for station symbols as well as for interpolated maps.

2.4 Main ozone episode

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 of mechanisms involving photochemical reactions of nitrogen oxides, chained with oxidative decomposition of VOCs, carbon monoxide (CO) and methane, initiated by hydroxyl radicals.

Episodes with elevated ozone levels occur during periods of warm, sunny weather. The level of ozone concentration depends on meteorological conditions. The largest ozone episodes with the highest ozone concentrations occur in areas of high air pressure (anticyclones). Within the high air pressure areas, the prevailing 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 is shown in Tables 2.2 and 2.4. The distribution of daily-based exceedances for the entire continent of Europe is shown in Figure 2.5 whilst the distribution of exceedances per day and per country during the summer of 2007 are shown in Figure 2.6. To demonstrate the relationship 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 the summer of 2007, the most outstanding ozone episode occurred on 14-21 July. During this period, 45 % of the total number of exceedances of the information threshold, 39 % of exceedances of the alert threshold, and 12 % of exceedances of the long-term objective were observed.

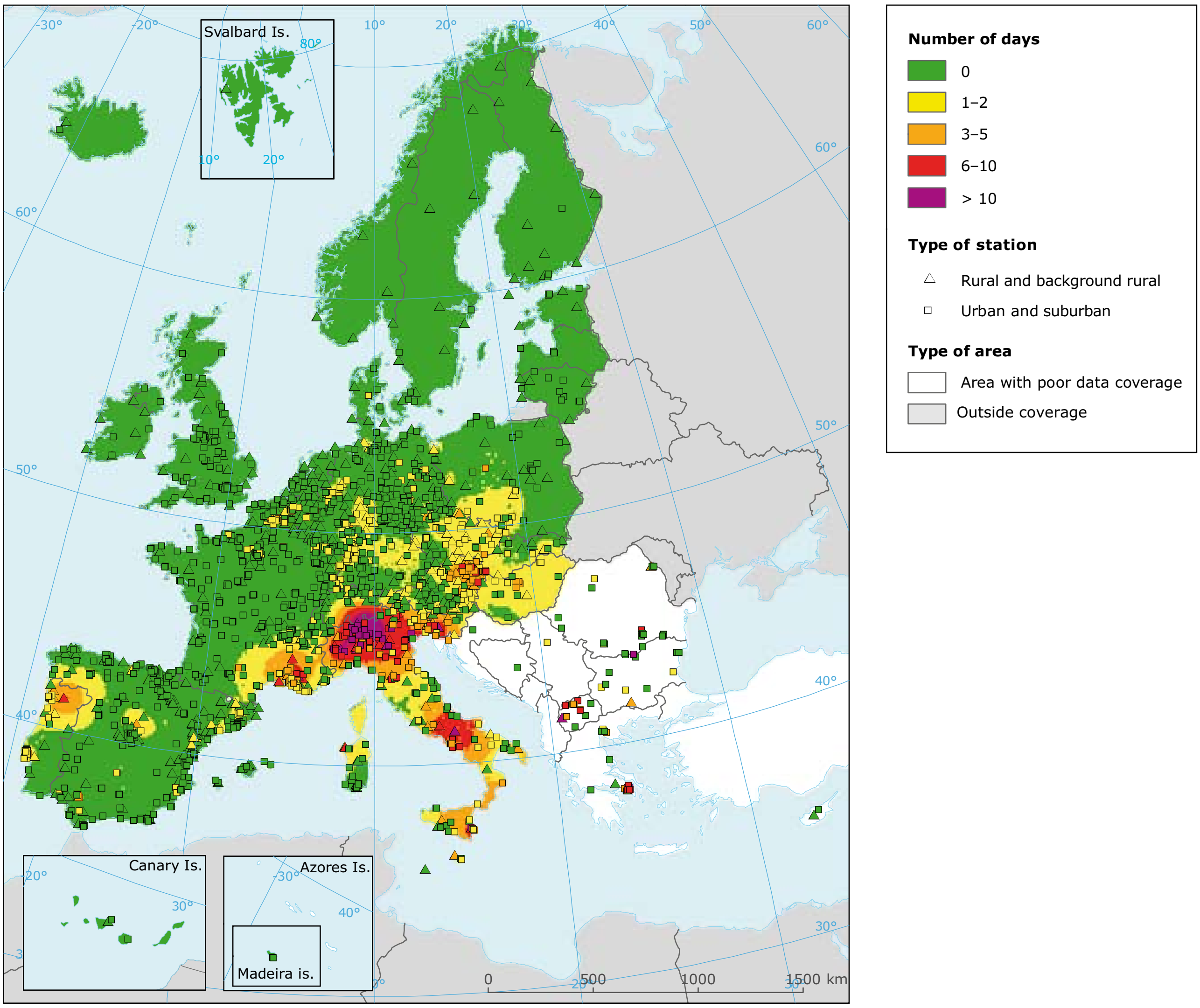
Areas with elevated ozone concentrations during this episode covered a large area of the continent, mainly across central and southern Europe. The situation was characterised by long-lasting extensive areas of high air pressure spread over continental Europe. The highest pressure was situated just over Central and Southern Europe, where the highest ozone concentrations were also measured. Western Europe was under the influence of predominantly low pressure at the time and, therefore, ozone levels here were rather lower. The end of the episode is directly connected to a low pressure shift from the Atlantic Ocean to the continent. The evolution of ozone concentrations

([4]) Due to an improved applied methodology (see the following note) the percentage shares of affected area and population are not exactly comparable with those in the reports for 2004, 2005 and 2006 summers. If the same methodology was applied as in previous reports estimated percentage shares of affected area and population for the whole of Europe would be slightly lower (24.8 and 26.1 % respectively, see http://air-climate.eionet.europa.eu/reports for details).

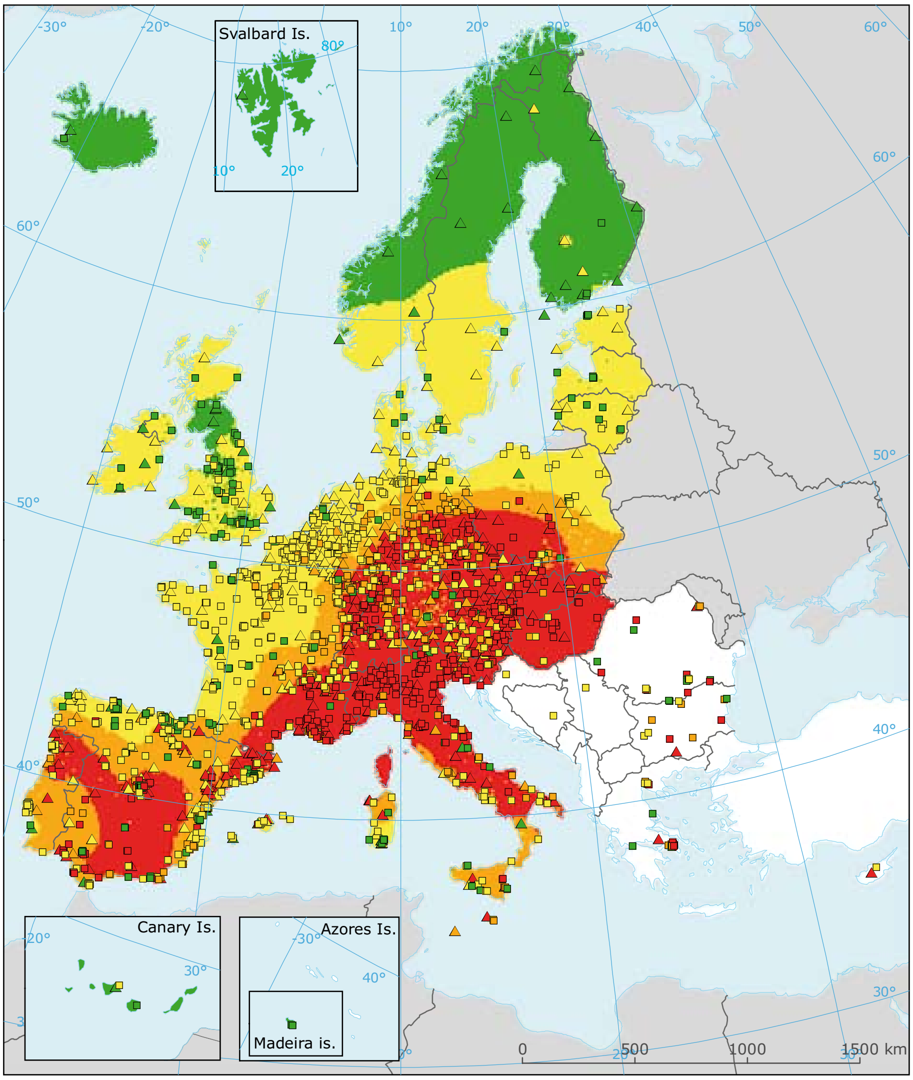
([5]) The use of kriging is supported by works dealing with spatial mapping development (possibility of using the kriging method in case of interpolating the number of exceedances — de Kassteele, 2005).
Ozone exceedances are interpolated separately for rural and urban areas. The reason is the different character of urban and rural air pollution concentration fields. The final map is constructed by merging separately created rural and urban maps. In 2007 a European-wide, population density grid was used for merging both the rural map and the urban map into one combined map. Both the rural and the urban maps were created for the entire continent of Europe. The population density grid helps to determine which part of the area the respective map is used for (Horálek *at al.*, 2007). Using a population density map for assessing air quality in urban areas enables the situation in urban areas to be estimated without measurement and thus it improves overall assessment in comparison with the methodology used in previous reports.
The density of ozone monitoring sites is too low to provide reliable estimates of spatial distribution by interpolation for the south-eastern part of Europe and, therefore, no spatial distribution is shown in these areas.
The type of station was unknown for approximately 6 % of stations. This fact could affect the precision of mapping in some areas.

and the meteorological situation on selected days during the ozone episode in July 2007 are depicted in Map 2.3 (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 elevated ozone concentrations with the areas of the highest temperatures and high air pressure.

Map 2.1 Number of days with concentrations above the information threshold



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



Number of days

- 0
- 1–15
- 16–25
- > 25

Type of station

- △ Rural and background rural
- □ Urban and suburban

Type of area

- Area with poor data coverage
- Outside coverage

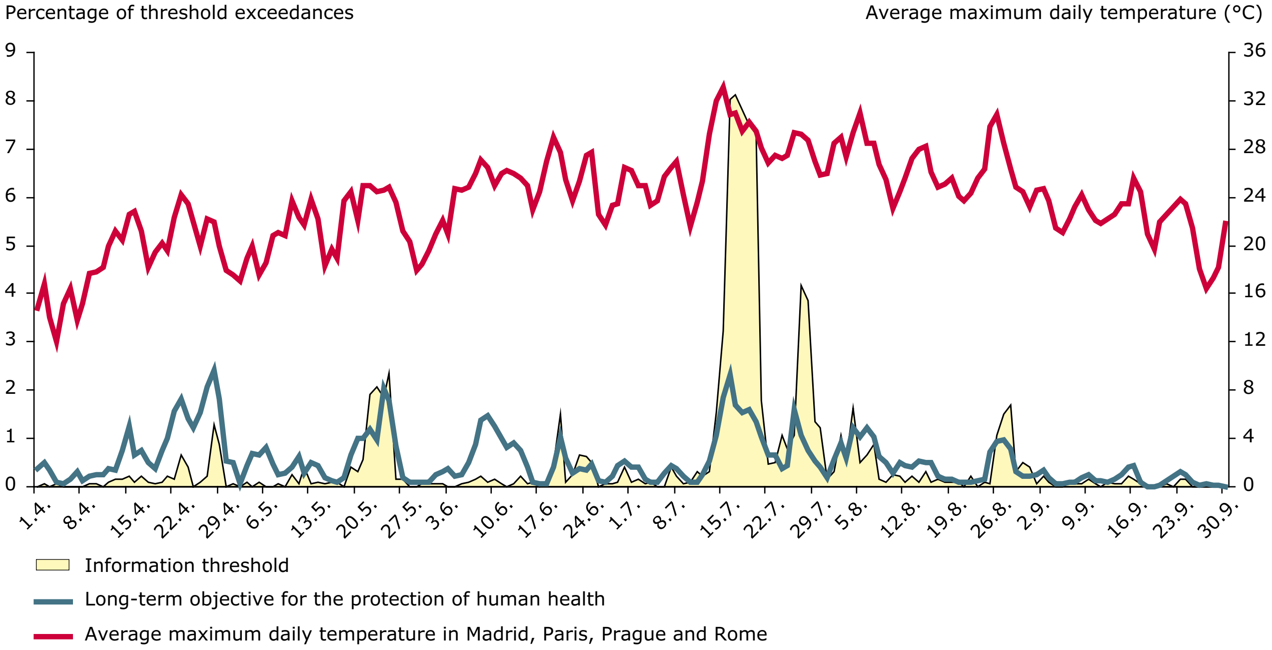
Table 2.5 Overview of estimated percentage of area and population * resident in areas with ozone levels higher than the target value for the protection of human health during the summer of 2007 on a country-by-country basis (only countries with spatial interpolation in Map 2.2 are shown) **

Country	Area (%)	Population (%)
Austria	98	89
Belgium	0	0
Czech Republic	96	74
Denmark	0	0
Estonia	0	0
Finland	0	0
France	24	19
Germany	46	26
Hungary	99	98
Iceland	0	0
Ireland	0	0
Italy	74	66
Latvia	0	0
Lithuania	0	0
Luxembourg	0	0
Malta	0	0
Netherlands	0	0
Norway	0	0
Poland	26	25
Portugal	30	15
Slovakia	100	100
Slovenia	99	94
Spain	42	21
Sweden	0	0
Switzerland	94	73
United Kingdom	0	0
Total	**28**	**28**

Notes: * The JRC population dataset CLC2000 has been used for the affected population estimate, http://dataservice.eionet.europa.eu/dataservice/metadetails.asp?id=830. The ORNL Global Population Dataset version 2002 has been used in areas not covered by JRC dataset, http://www.ornl.gov/sci/landscan (the area related to calculations in this report covers Iceland, Norway and Switzerland). These datasets are hardly comparable in the population specific values. Nevertheless, both datasets can be used together for the calculation of percentage of affected population because only the spatial distribution of the population is used.

** The data on affected area and population are indicative because the interpolation grid is 10 kilometers.

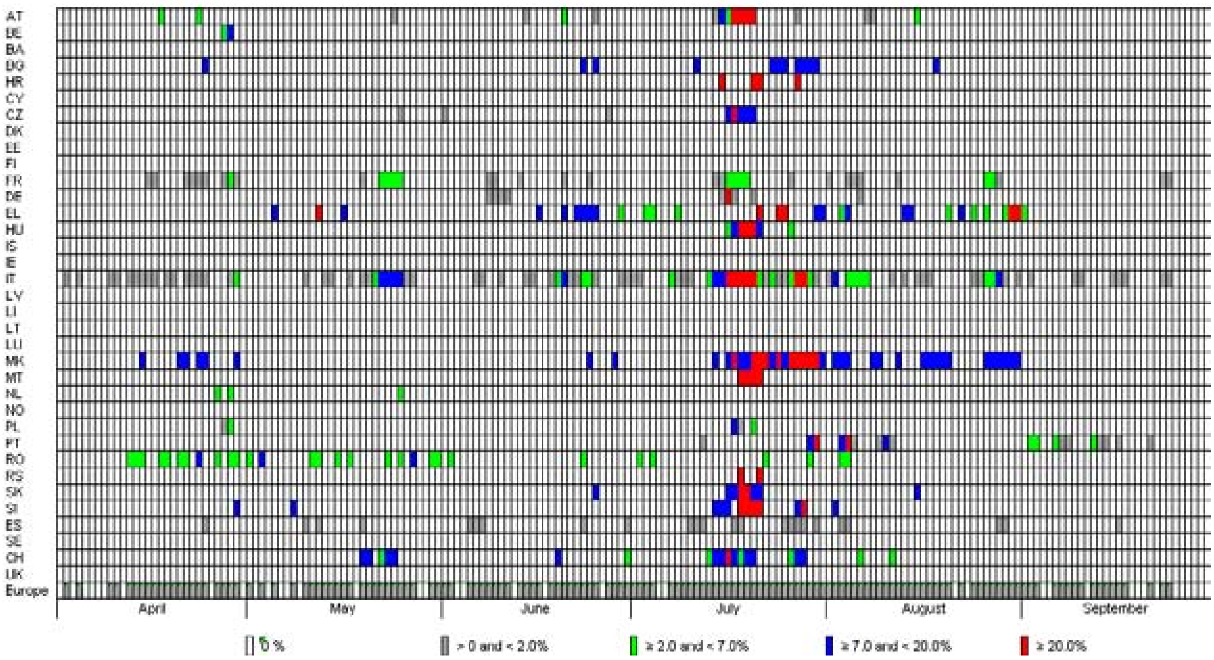
Figure 2.5 Distribution of exceedances during the summer of 2007 on a day-by-day basis



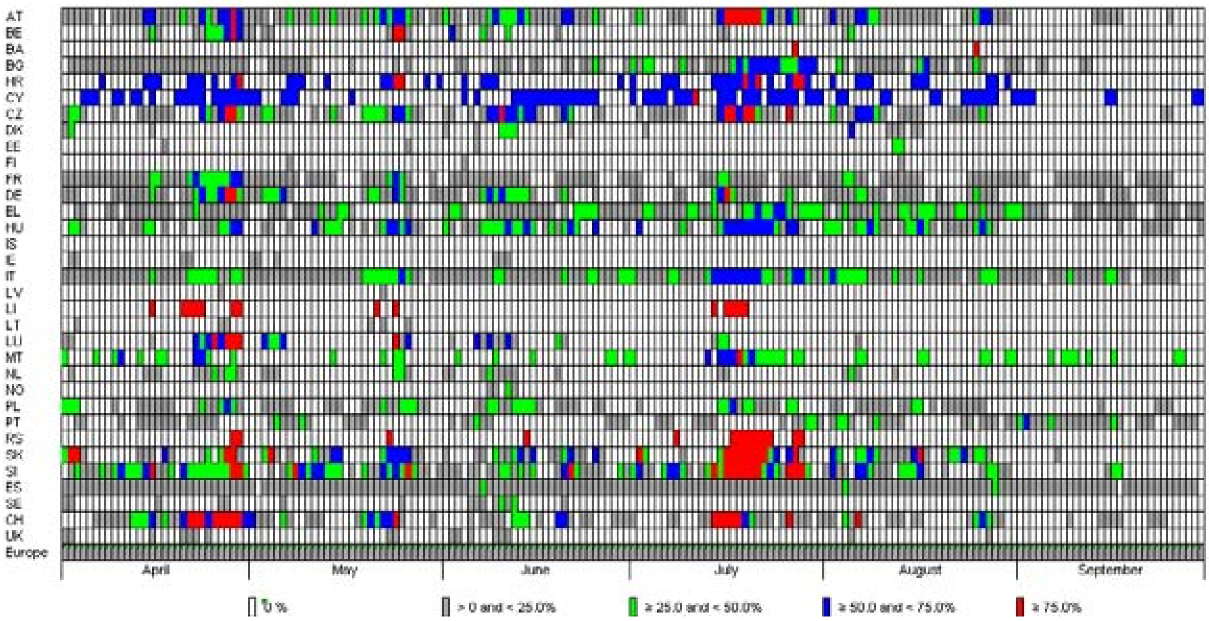
Note: The left y-axis represents the percentage of exceedances observed during a particular day. The total number of exceedances of the information threshold and the long-term objective for protection of human health is 100 %, respectively.

Figure 2.6 Distribution of exceedances during the summer of 2007 on a day-by-day basis per country in percentage of stations with exceedances of

a) Information threshold exceedances

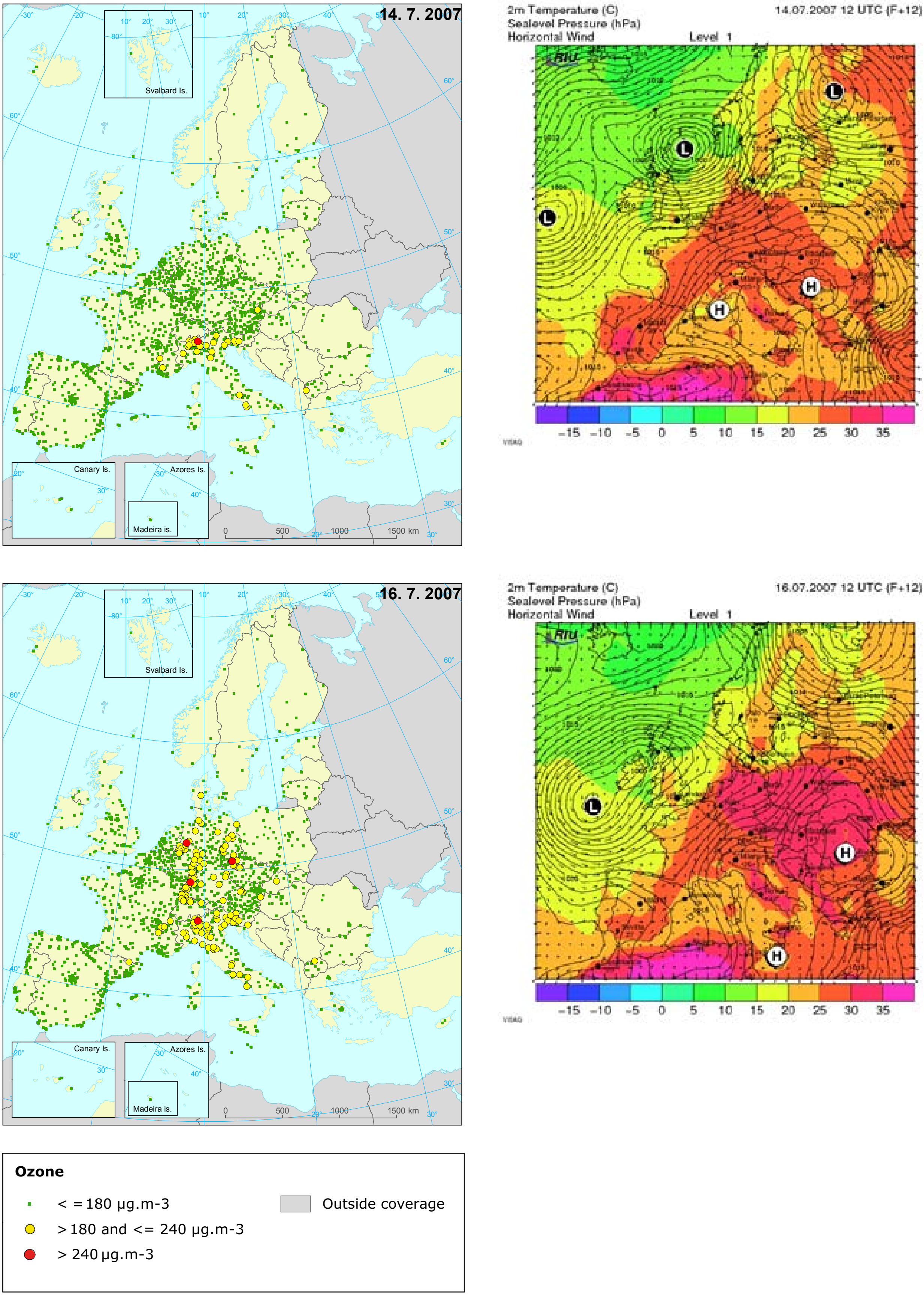


b) Long-term objective for the protection of human health exceedances

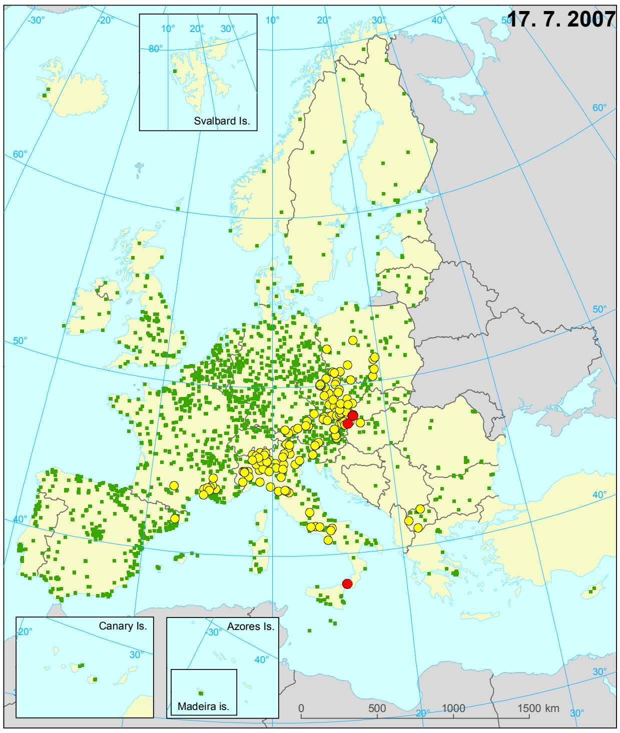


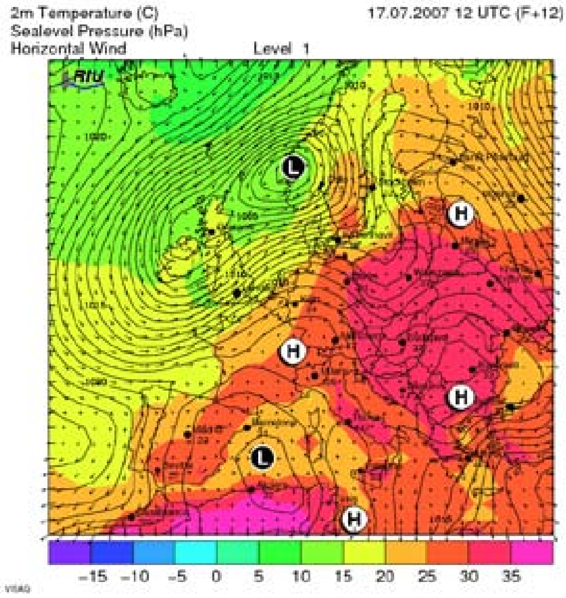
Note: Colours represent the percentage of stations with observed exceedances during a particular day. The total number of stations (see Table 2.1) for any particular country is 100 %.

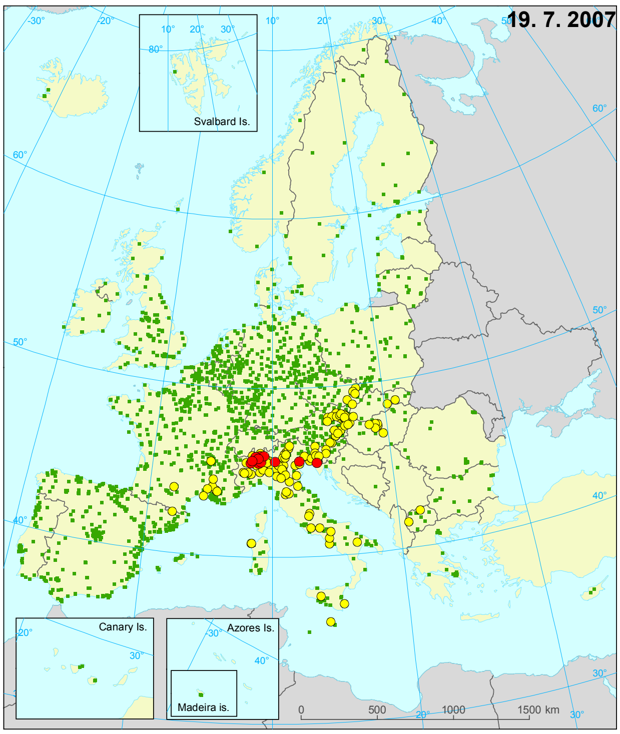
Map 2.3 Selected days during the ozone episode in July 2007; maximum hourly concentrations (µg/m³), all station types

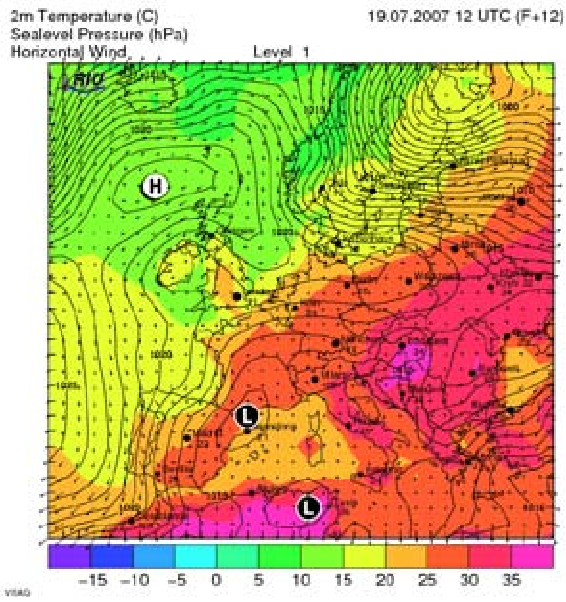


Map 2.3 Selected days of the ozone episode in July 2007; maximum hourly concentrations (μg/m³), all station types (contd)





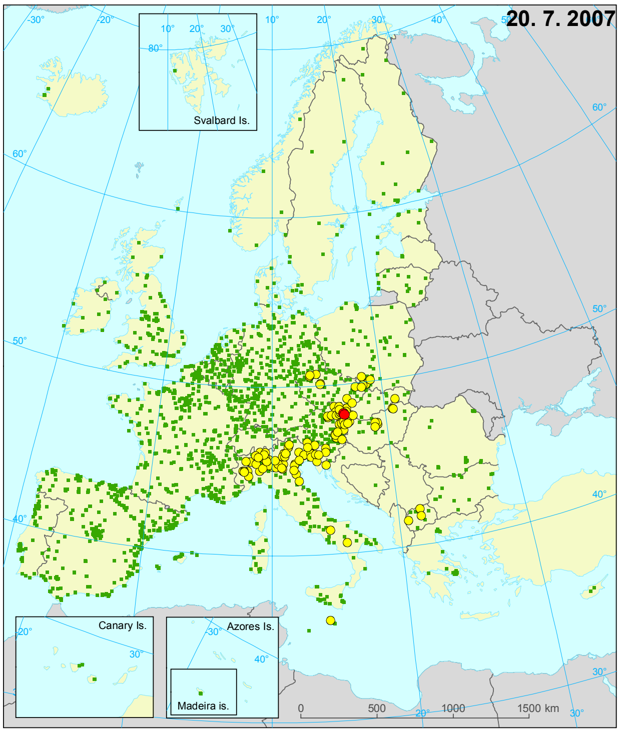


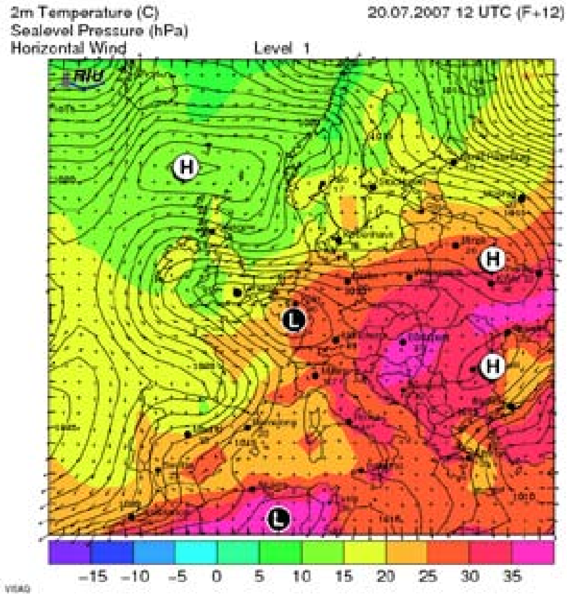


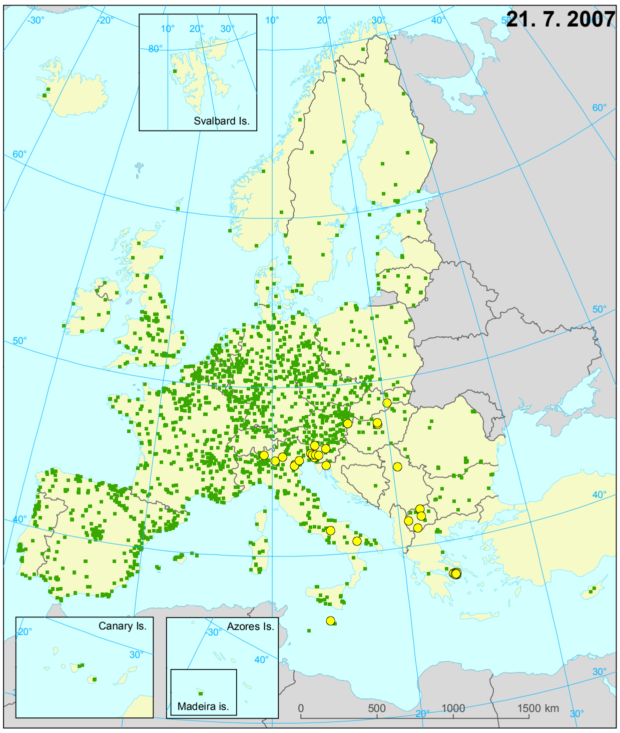
Ozone

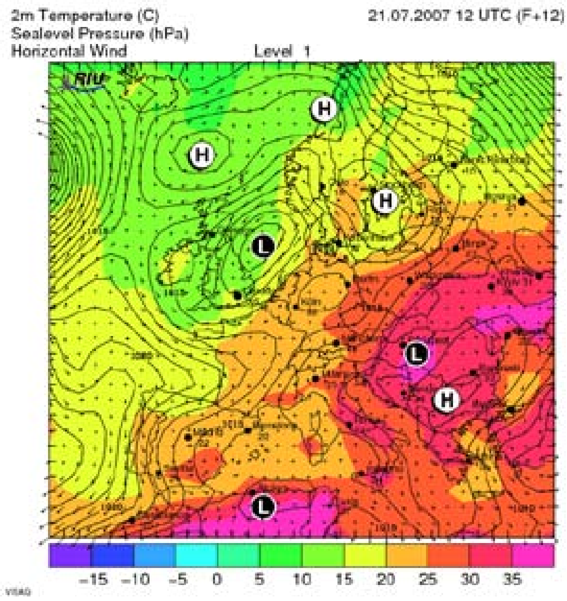
- < = 180 μg.m-3
- > 180 and <= 240 μg.m-3
- > 240 μg.m-3
- Outside coverage

Map 2.3 Selected days of the ozone episode in July 2007; maximum hourly concentrations (µg/m³), all station types (contd)









Ozone

- < = 180 µg.m-3
- > 180 and <= 240 µg.m-3
- > 240 µg.m-3

Outside coverage

3 Comparison with previous years

Ozone levels in the summer of 2007 were compared with the summer ozone concentrations from 1997 to 2005 stored in AirBase, and the summer 2006 data submitted under the Ozone Directive. Only time series that included more than 75 % of valid, measured data during the summers of 1997–2005 were selected for comparison. Data stored in AirBase are validated; whilst 2006 and 2007 summer data are provisional and only partly validated. In the first half of the 1990's, ozone data coverage was not representative over Europe, and the data in AirBase is not comparable. Networks in Europe have changed over the years. Some of the observed changes might be caused by changes in location or density of the networks.

As described in previous chapters, ozone concentrations over Europe vary widely, partly due to large variations in climate over the continent. Stations were divided into four regions to analyse inter-annual variations in the trend of ozone levels due to climatic differences over Europe, based on last year's experience and this summer's data (see key for Figure 3.1).

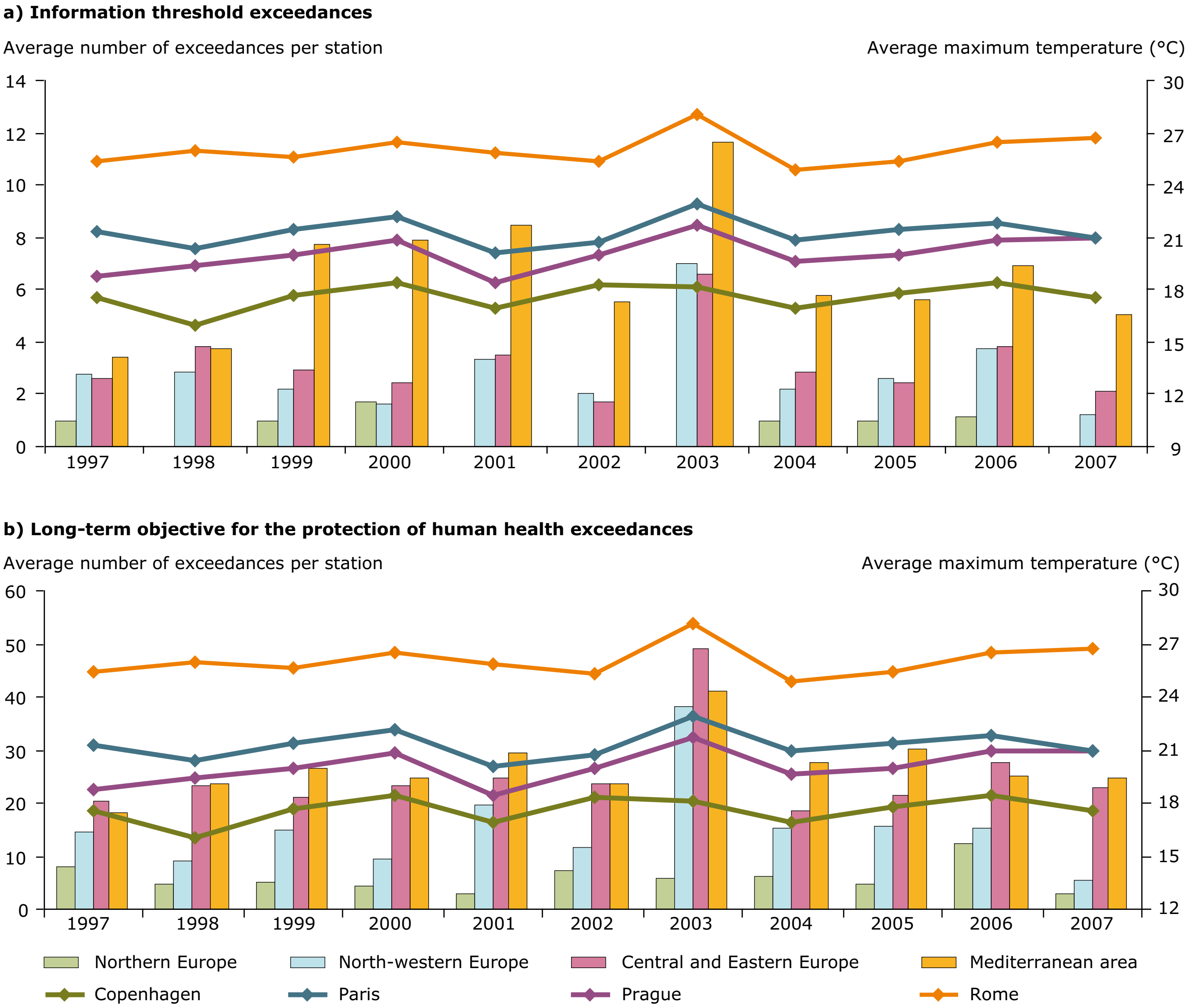
The analysis clearly shows that a frequent occurrence of exceedances was quite common in the Mediterranean area. The number of occurrences in southern Europe was lower between 1999 and 2001 than in the extreme summer of 2003 (EEA, 2003) which saw a very large number of occurrences. This was also the case in more northern parts of Europe. While the situation during the summers of 2004 and 2005 returned to 'normal' (EEA, 2005; EEA, 2006) the summer of 2006 (EEA, 2007a) showed considerable differences in climatic conditions between northern Europe and other parts of the continent. No exceedances of the information threshold in northern Europe were significant in the hot summer of 2003, during which period maximum values were observed elsewhere in the continent. Ozone levels during the summer of 2007 rank among the lowest in the past decade (see Table 3.1 for detailed year-by-year information).

The emissions of ozone precursors, weighted according to their contribution to ozone formation (de Leeuw, 2002), were reduced over the period 1990-2004 by about 40 % in the EU25 Member States (32 % emission reduction of NO_x and 44 % of VOC emissions). Over the periods 1996–2004 and 2001–2004 the decrease in total emissions was 24 % and 8 % respectively. The development of ozone concentrations during the last decade are not in line with these emission changes. Neglecting the high concentrations in 2003, caused by the extremely favourable conditions for ozone formation in that year in most of Europe, the rural data show no trend at all while the traffic and urban stations suggest some tendency to increase. This increase can be explained by less ozone depletion due to decreasing NO_X emissions. (EEA, 2007b; Mol *et al.*, 2007)

At the current level of precursor emissions, the year-to-year variation of occurrence of ozone threshold exceedances is induced substantially by meteorological 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. This correspondence can also be demonstrated by charting the daily maximum temperatures averaged for the period of April to September of a particular year observed in four capital cities in selected regions (Paris (FR), Prague (CZ), Rome (IT)) and Copenhagen (DK)) in relation to the number of exceedances as shown in Figure 3.1.

A long-term trend in exceedances trend since 1990 is shown in Figure 3.2. Several countries with at least a 15-year long data series available from several stations were selected as an example. The summers of 1990, 1994 and 1995 belong to those with the highest ozone levels, as well as the summer of 2003. The conspicuous influence of higher numbers of LTO exceedances from stations with elevations higher than 800m above sea level in Austria (AT) compared with other countries, is also apparent.

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

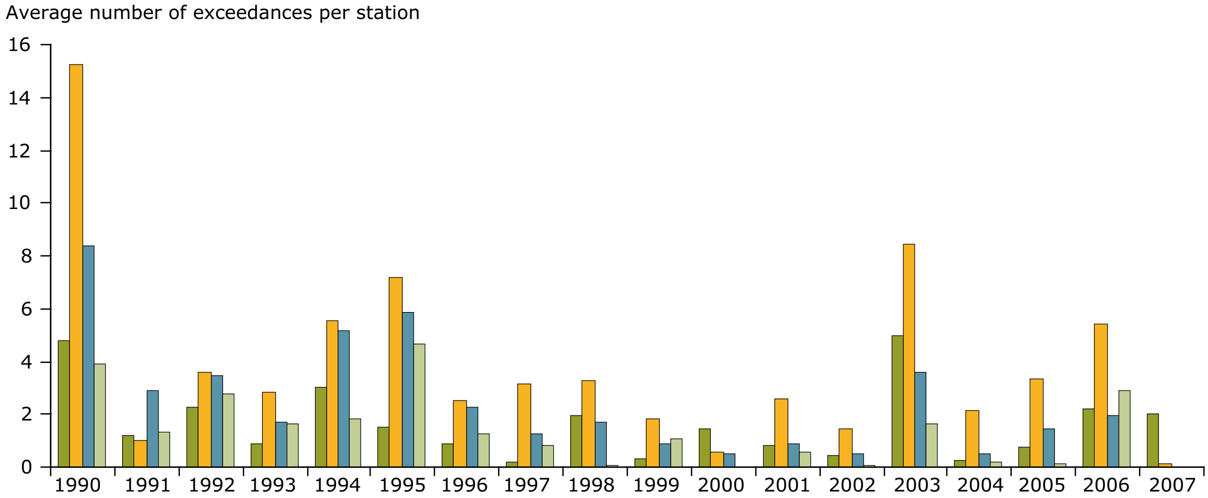


Note: Northern Europe: Iceland, Denmark, Norway, Sweden, Finland, Estonia, Lithuania, Latvia.
North-western Europe: the United Kingdom, Ireland, the Netherlands, Belgium, Luxembourg, France north of 45 ° latitude.
Central and eastern Europe: Germany, Poland, the Czech Republic, Slovakia, Hungary, Austria, Switzerland, Liechtenstein, Romania, Bulgaria.
Mediterranean area: France south of 45 ° latitude, Portugal, Spain, Andorra, Monaco, Italy, San Marino, Slovenia, Croatia, Greece, Bosnia-Hercegovina, Serbia, Montenegro, FYR of Macedonia, Albania, Cyprus, Malta.

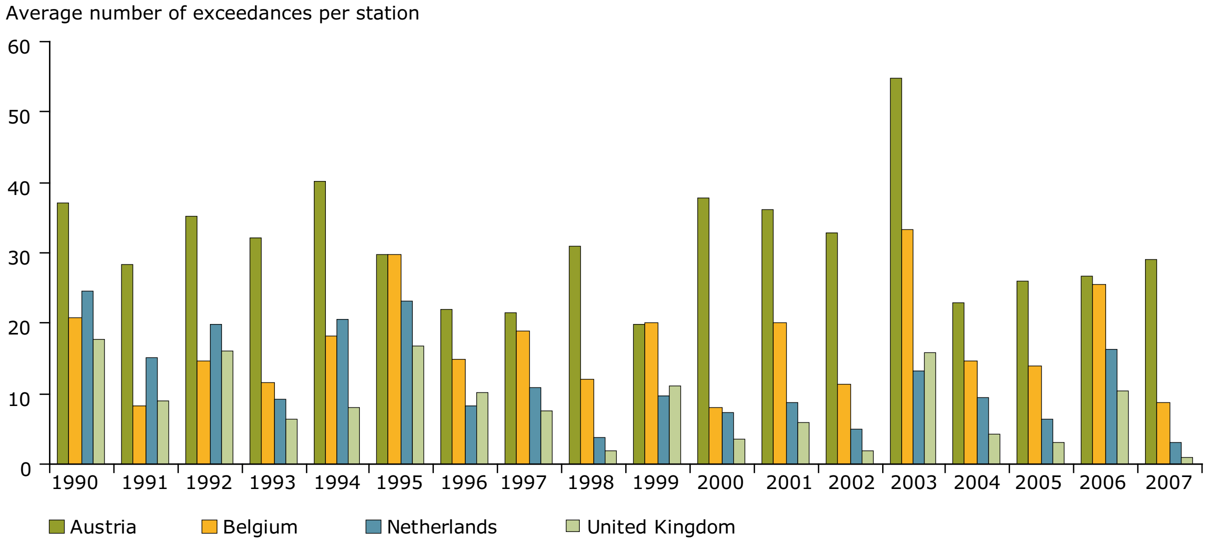
Source: Source of the temperature data: http://www.wunderground.com.

Figure 3.2 Average occurrence (the number of exceedances per station) for stations, which reported at least one exceedance *, observed during the year's summer season in selected countries

a) Information threshold exceedances



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



Note: * Only for stations with at least a 15-year long data series.

Table 3.1 Overview of exceedances observed during the summer season in Europe for various years

a) Information threshold exceedances

Summer season	No. of stations (1)	Stations with exceedance (2)					No. of days with exceedance (3)		Maximum observed one-hour concentration (μg/m³)	Occurrence of exceedances (4)				Average duration of exceedances (hour)	
		(number)		(%)		(%)									
1997	861	344	16	40	2	5	82	4	315	1.1	2.8	0.0	1.3	2.7	1.7
1998	892	469	65	53	7	14	76	11	370	1.9	3.6	0.1	1.6	3.4	2.1
1999	1 337	405	47	30	4	12	132	41	829	1.3	4.3	0.1	3.2	3.1	3.7
2000	1 405	560	44	40	3	8	113	26	473	1.4	3.5	0.1	2.0	2.9	2.0
2001	1 571	702	89	45	6	13	123	43	470	2.3	5.1	0.1	2.4	3.1	2.1
2002	1 668	560	65	34	4	12	105	16	391	1.1	3.2	0.1	2.0	2.8	2.0
2003	1 786	1 203	318	67	18	26	150	62	418	5.5	8.2	0.4	2.3	3.9	2.2
2004	1 889	626	43	33	2	7	117	16	396	1.3	3.9	0.0	1.9	3.2	2.0
2005	2 002	848	68	42	3	8	135	32	457	1.6	3.8	0.1	2.1	3.1	2.3
2006	2 069	1 161	102	56	5	9	135	48	370	2.7	4.9	0.1	1.9	3.4	3.6
2007	2 062	551	54	27	3	10	144	35	479	0.9	3.5	0.0	1.8	3.1	1.9

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

(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.

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

Summer season	No. of stations (1)	Stations with LTO exceedance (2) (number)	(%)	Stations with TV exceedance (number)	(%)	No. of days with LTO exceedance (3)	Maximum observed 8-hour concentration (μg/m³)	Occurrence of LTO exceedances (4)	
1997	861	748	87	219	25	182	252	16.1	18.5
1998	892	742	83	250	28	177	330	17.1	20.6
1999	1 337	1 109	83	375	28	183	409	16.3	19.6
2000	1 405	1 156	82	381	27	179	266	15.7	19.1
2001	1 571	1 320	84	568	36	183	320	20.0	23.8
2002	1 668	1 368	82	457	27	183	310	16.5	20.1
2003	1 786	1 557	87	1 143	64	183	297	36.0	41.3
2004	1 889	1 541	82	470	25	183	364	16.1	19.8
2005	2 002	1 671	83	636	32	183	334	18.6	22.3
2006	2 064	1 754	85	861	42	183	336	22.7	26.7
2007	2 049	1 691	83	563	27	183	275	17.9	21.6

Notes:

(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.

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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 µg/m³ and 240 µg/m³) 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 µg/m³, 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 2007

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 were operated mostly throughout the whole period April–September 2007. However, it is possible that some exceedances were not reported due to monitoring station temporarily being 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.

The proportion of stations for which the percentage of valid one-hour measurements during summer 2007 was at least 75 % was reported from 1 414 (i. e. 95 %) of stations for which the information on number of valid one-hour measurements was reported by the countries (1492 stations, i.e. 72 % of all operational stations, Table A.1).

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 2007

Map A.1 presents the location of all ozone-monitoring stations assumed to be operational in the reporting countries during the 2007 summer season. In total, 2062 ozone-monitoring sites were operational in summer 2007, out of which 2012 are located within the EU area. The number of stations reporting during summer has gradually increased in recent ten years (Table 3.1).

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, 476, i.e. approximately 23 % are traffic or industrial stations (thereby not fulfilling the requirements), and were included in 2007 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 6 % of stations the type of station was not known.

Table A.1 Overview of available information on number of valid one-hour measurements during the summer of 2007 on a country-by-country basis

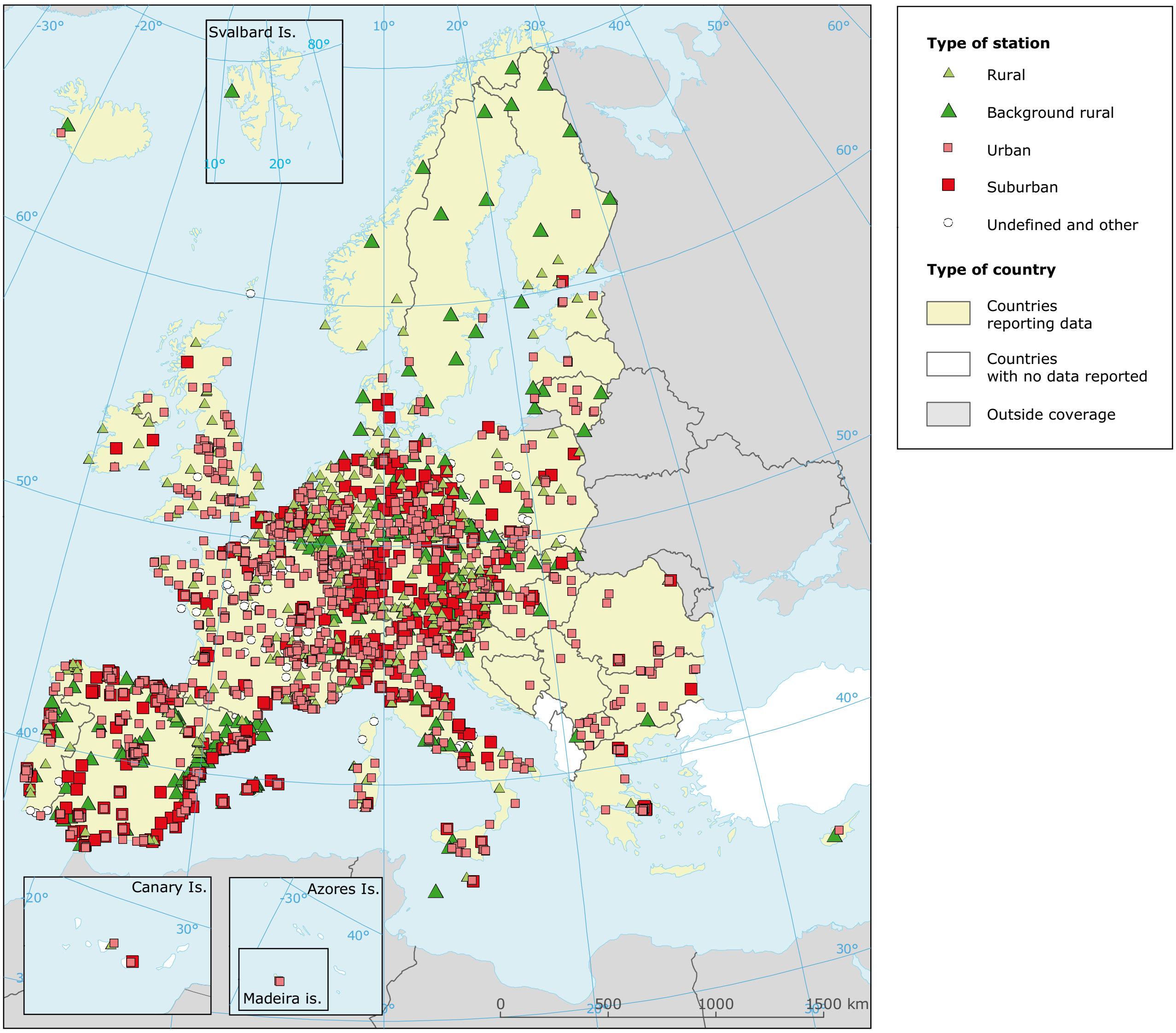
Country	Stations with available information ([1]) (%)	Stations with at least 75 % of valid one-hour data ([2]) (%)
Austria	96	98
Belgium	97	95
Bulgaria	85	100
Cyprus	100	100
Czech Republic	99	96
Denmark	100	100
Estonia	100	100
Finland	100	100
France	100	95
Germany	0	-
Greece	100	65
Hungary	81	88
Ireland	100	100
Italy	0	-
Latvia	100	67
Lithuania	87	92
Luxembourg	100	100
Malta	100	50
Netherlands	93	100
Poland	85	91
Portugal	82	100
Romania	96	65
Slovak Republic	100	100
Slovenia	100	100
Spain	100	96
Sweden	100	100
United Kingdom	93	96
Bosnia and Herzegovina	100	100
Croatia	100	100
Iceland	100	33
Liechtenstein	100	100
Macedonia, FYR of	100	92
Norway	100	100
Serbia	100	100
Switzerland	100	100
Total	**72**	**95**

Notes: - Not applicable.

([1]) The percentage of stations for which the information on number of valid one-hour measurements during summer 2007 was reported by the country.

([2]) The percentage of stations from ([1]) for which the percentage of valid one-hour measurements during summer 2007 was at least 75 %.

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**



Annex 3 Near real-time ozone data exchange

Information regarding ozone exceedances is currently provided through monthly reporting by Member States and summarised in this summer report.

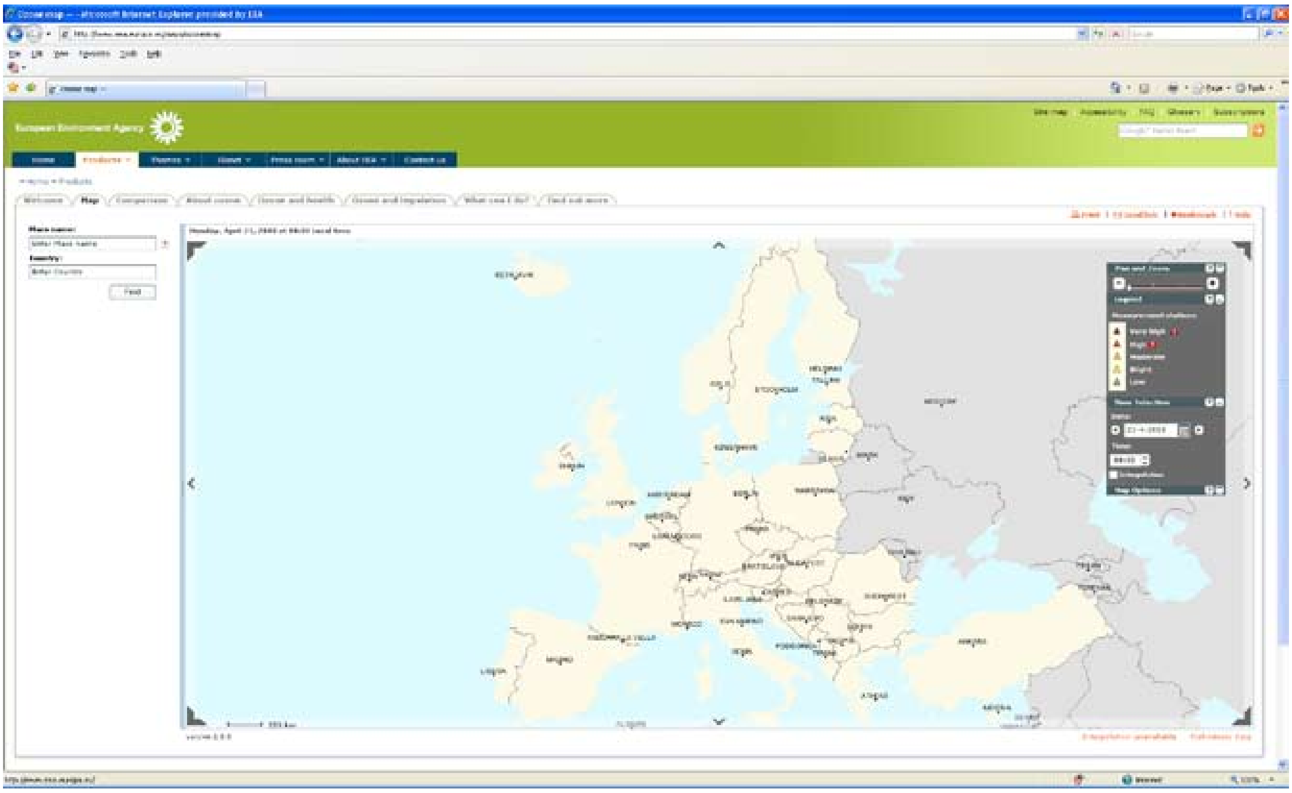
In order to streamline reporting while providing an updated service, the current monthly ozone reporting can be effectively replaced by the near real-time data exchange of ozone (Map A.2). EEA has already established the ozone web which is a pilot GIS-based system for collecting, providing and visualizing near real-time ambient ozone levels across Europe. It was developed by the EEA as a joint European project and provides up-to-date information in the form of maps and graphs and also provides background information on ozone and its health impacts.

Data from more than 700 air quality measurement stations across Europe are transmitted to the EEA in Copenhagen on an hourly basis. The information is provided by national and regional organisations in 20 countries on a voluntary basis and aims at use by the general public. Since the data must be as 'real-time' as possible, the data are displayed as soon as practical after the end of each hour.

The air quality data used in the website are preliminary. The data may change when they are validated hence they are not used for legal compliance reporting. Use restrictions on some data may apply.

In the map, the ozone level is illustrated by colours. The colour scheme is linked to threshold values in EU legislation. A statistical calculation (interpolation) is carried out on the ozone data received by the EEA to provide an estimate of the ozone status in areas between measurement stations. Before the result of the calculation is shown on the

Map A.2 Ozone pollution across Europe — near real-time ozone data exchange



map, a number of conditions have to be satisfied by the input data and the resulting calculation. These conditions are:

- The number of stations is greater than 500 and data is received from more than 80 % of the providers.
- The density pattern of stations from which data is received is not significantly different from what is normally expected.
- The root mean squared error value (RMSE) from a cross validation test carried out between data from 10 % of the data received against the result of the interpolation calculation is less than 20 μg/m^3.

Pilot verification of the 'fitness for use' of the information provided in the real-time data to replace the summer ozone report was presented at the 12th Eionet Workshop on Air Quality Management and Assessment (http://air-climate.eionet.europa.eu/docs/meetings/071015_12th_EIONET_AQ_WS/14_NRT_O3_and_pot_SOR_Berkhout.pdf).

European Environment Agency

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