Topic report | 3/2003

Air pollution by ozone in Europe in summer 2003

Overview of exceedances of EC ozone threshold values during the summer season April–August 2003 and comparisons with previous years

Report to the European Commission by the European Environment Agency, European Topic Centre on Air and Climate Change based on data provided in the framework of Council Directive 92/72/EEC on air pollution by ozone by 15 September 2003

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Executive summary

In the period 1995–2003 of reporting under the old ozone directive, there has been little or no change in the reported exceedances of ozone threshold values. This is not unexpected as reductions in the EU emissions of nitrogen oxides and non-methane volatile organic compounds, the main ozone precursors, have so far been limited — about 30 % between 1990 and 2000.

The threshold for warning the population continues to be exceeded on a few occasions each year, while the threshold for informing the population is exceeded at most stations in most countries (outside northern Europe and Ireland) each year, generally more so in warm summers.

These exceedances are likely to recur in years with temperatures above the long-term average until there is a substantially larger decrease in precursor emissions. A further reduction of about 30 % is foreseen towards 2010 under the national emission ceilings directive.

While peak ozone concentrations seem to go down, ozone concentration statistics relevant to the target values set in the new ozone directive show little or no reduction in the period 1996–2000. Very few stations actually show a significant downward trend for these statistics.

Under current legislation and with the rate of turnover of the vehicle fleet, further reductions will gradually occur towards 2010, and further reductions may be necessary to achieve the target values of the new ozone directive.

Note that, due to the uncertainties caused by year-to-year meteorological variations and the changes in the monitoring station configuration, these conclusions are tentative.

Contents

DISCLAIMER

The information describing the situation during summer 2003 is partly based on non-validated data from national monitoring networks and hence should be regarded as preliminary.

Summary

Ground-level ozone is one of the air pollutants of most concern in Europe in 2003. Concentrations in the lower atmosphere continue to exceed thresholds established in EU legislation to protect human health and prevent damage to ecosystems, agricultural crops and materials.

According to Council Directive 92/72/EEC on air pollution by ozone, EU Member States have to inform the public when hourly average ozone concentrations exceed the information threshold of 180 µg/m³ and the warning threshold of 360 µg/m³ to enable the population concerned to take all appropriate preventive protective action. Member States also have to provide information on airborne ozone concentrations in their territory on an annual basis to the European Commission before 1 July of the following year. Additionally, exceedances of the threshold values for population information and warning, as set in the directive, must be reported to the Commission within one month after an occurrence.

Directive 92/72/EEC has been repealed and a new Ozone Directive 2002/3/EC has been in force as of 9 September 2003. In this directive, the information threshold is the same as in the old directive; the hourly average concentration of 240 µg/m³, measured over three consecutive hours, is set as an alert threshold.

This summary presents a first evaluation of the observed exceedances of the population information and warning threshold values for ozone during summer 2003 (April–August). Information is based on data from national monitoring networks which have not yet been validated due to the tight reporting schedule and hence the conclusions drawn need to be considered as preliminary. The agreed deadline for transmitting data for this report was 15 September 2003.

All the EU Member States provided information on observed exceedances in time, or indicated that no exceedances had been observed. In addition, nine acceding countries (the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia), two accession countries (Bulgaria and Romania) and five non-EU countries (Former Yugoslav Republic of Macedonia (FYROM), Iceland, Liechtenstein, Norway and Switzerland) provided information on observed exceedances upon request of the European Environment Agency (EEA).

Data were reported to the Agency in summer 2003 from a total of 1 805 ozone monitoring stations, 1 624 of which are located within EU Member States.

In order to provide information as soon as possible, summaries of the data as provided monthly by the countries have been made available on the website of the European Topic Centre on Air and Climate Change (ETC-ACC) on reception: http://etc-acc.eionet.eu.int/databases/o3excess.

From an evaluation of the exceedances, the following initial conclusions have been drawn for the situation during summer 2003:

- Exceptionally long-lasting and spatially extensive episodes of high ozone concentrations occurred, mainly in the first half of August. These episodes appear to be associated with the extraordinarily hot temperatures over wide areas of Europe.

Exceedance of the warning threshold

- Exceedance of the warning threshold (hourly average concentrations of 360 µg/m³) occurred in France for two hours at one station during August and in Italy and Romania in June for one hour at one station in each country. The maximum hourly ozone concentration reported in 2003 was 417 µg/m³ at a monitoring station in France. For comparison, during the summer of 2002, when temperatures did not reach as high as in 2003, the threshold value for warning the population was exceeded a similar number of times and the highest hourly ozone concentration reported was 391 µg/m³. Similar small numbers of exceedance of the warning threshold value occurred in earlier years. Hence, these exceedances are rare and are not strongly correlated with temperature.

Exceedance of the information threshold

- Exceedance of the information threshold (hourly average concentrations of 180 μg/m³) occurred in 23 of the 31 countries reporting, 11 of them EU Member States. About 68 % of all stations (1 220 stations) reported one exceedance or more. On average, 5.4 exceedances per operational station were reported.

- The spatial distribution of exceedances of this threshold observed in summer 2003 was much more extensive than in previous summers. With the exception of the northern part of Europe, at least one day's exceedance of this threshold was recorded in most of the countries reporting in summer 2003. The area with more than 10 exceedance days in 2003 covered mainly south-western Germany, Switzerland, northern and south-eastern France, Belgium, northern and central Italy and central Spain.

Preview: Exceedance of the new alert threshold

- Ozone concentrations reported in 2003 have been compared with the alert threshold value as defined in the new ozone directive (hourly average concentration of 240 μg/m³, measured over three consecutive hours). Single hourly average ozone concentrations higher than 240 μg/m³ were reported from the monitoring sites of 15 countries (Austria, Belgium, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland and the United Kingdom). On average, an exceedance of the new 240 μg/m³ alert threshold was observed in summer 2003 at 27 % of the stations which reported an exceedance of the 180 μg/m³ information threshold.

Trends in ozone statistics and precursor emissions

- An analysis of trends over the past 12 years indicates that in the European Union the average number of hours per station when ozone concentration exceeded the information threshold of 180 μg/m³ was higher in summer 2003 than in all previous years. In France, this average number of exceedance hours was one third higher than in 1994, another year with frequent exceedances and a warm summer.

- The variation in the numbers of exceedance over the years cannot be explained by the variation in the emissions of ozone precursors since these emissions decreased gradually by about 30 % between 1990 and 2000. The closer correlation of exceedance numbers with temperature suggests that, if climate change were to result in warmer summers in Europe, more frequent exceedances of the ozone information threshold would be expected at the current emission levels.

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 of ozone formation. Ozone is a strong photochemical oxidant. In elevated concentrations, it causes serious health problems and damage to ecosystems, agricultural crops and materials.

Harmful ozone concentrations are observed over the whole of Europe (Beck et al., 1998; de Leeuw et al., 1999; Hjellbrekke and Solberg, 2002). Formation of ozone takes place at various space- and timescales: the high emission density of reactive precursors in urban areas can lead to high ozone concentrations within the city or at short distances downwind. But ozone precursors may also be transported over distances of hundreds to thousands of kilometres, resulting in ozone formation far from the sources. Episodes of high concentrations of ozone typically occur in situations with high atmospheric pressure and temperature inversions. Under these stagnant conditions, emissions of ozone precursors are only slowly dispersed in the atmosphere and chemical reactions leading to the ozone formation take place as in an immense vessel with a diameter of hundreds of kilometres.

In view of the harmful effects of photochemical pollution in the lower levels of the atmosphere, the Council adopted in 1992 Directive 92/72/EEC on air pollution by ozone (the ozone directive). The directive entered into force in March 1994. It established procedures for harmonised monitoring of ozone concentrations, for exchange of information, for communication with and alerting of the population regarding ozone, and to optimise the action needed to reduce ozone formation.

Article 6 of the directive specifies how the information on monitoring results must be provided by the Member States to the European Commission. Regarding the time frame, two main types of reporting can be distinguished. Information on exceedances of the so-called information threshold (Article 6(2)) and warning threshold (Article 6(3)) for the ozone concentration is to be provided within one month after an occurrence. Information on exceedances of all threshold values given in Article 6 must be provided within six months following the annual reference period (Article 6(1)). Article 7 of the directive stipulates that the Commission shall at least once a year evaluate the data collected under the directive.

On 9 March 2002, the new Directive 2002/3/EC of the European Parliament and of the Council relating to ozone in ambient air was published. Directive 2002/3/EC, also known as the third daughter directive to the Air Quality Framework Directive 96/62/EC, sets primarily long-term objectives, target values, an alert threshold and an information threshold for ozone to avoid, prevent or reduce harmful effects on human health and the environment. It provides for 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, and promotes increased cooperation between the Member States in reducing ozone levels.

The previous Directive 92/72/EEC was repealed on 9 September 2003. By this date, Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with Directive 2002/3/EC. From 2004 onwards, the Member States will transfer provisional data on exceedances of the information threshold and the new alert threshold for ozone as required by Article 10 of Directive 2002/3/EC.

The present report gives an overview of the situation during summer 2003 based on data reported largely under the previous ozone directive. Unless explicitly stated otherwise, references in this report refer to Directive 92/72/EEC.

Overviews for the period 1994–2002 have been prepared by the European Topic Centre on Air and Climate Change (ETC-ACC). Previous reports are available from the Internet site of the EEA: http://www.eea.eu.int/. Chapter 4

provides a comparison over the period 1995–2003.

The data reported here do not cover all ozone monitoring stations in the European Union. To be included in this report, the data must satisfy certain criteria stipulated in the directive, concerning *inter alia* measuring methods, sampling methods, station siting, quality assurance and documentation.

The available information, submitted under Directive 92/72/EEC, allows an evaluation of the occurrence of exceedance of the alert threshold but is insufficient to evaluate whether ozone concentrations are above the alert threshold of the new directive during three consecutive hours.

A valuable source of information is the report *Pollution par l'ozone au cours de l'été 2003* issued by the French Ministry of the Environment and Sustainable Development: http://www.environnement.gouv.fr/actua/com2003/septembre/3-bilan-ozone-ete2003.htm. This report assesses the ozone episodes in August 2003 mainly in France, based on numerical dispersion modelling, and it also presents a comparison with previous years for ozone monitoring sites in France. A relevant German report (*Die Ozonepisode im Juli/August 2003*, LUA Nordrhein-Westfalen) was brought to the authors' attention at the proofreading stage of this report.

2. Data reporting

2.1. Introduction

According to Directive 92/72/EEC, EU Member States must inform the Commission on a monthly basis in cases where exceedances of the population information or warning threshold values for ozone are observed. In this report, an assessment is made of the 2003 summer season, based on the exceedances of these thresholds for ozone, which were transmitted by the Member States after the end of each month.

In addition to this monthly-based reporting on exceedances of ozone thresholds in the current summer, Member States have to provide the following information for the annual reference period based on validated data for the previous year:

- maximum, median and 98th percentile value of one-hour and eight-hour average ozone concentrations;
- location, date and duration of periods during which threshold values as presented in Table 2.1 are exceeded and the maximum concentrations recorded during each occurrence.

In the new Directive 2002/3/EC, the information threshold is defined similarly to Directive 92/72/EEC as one-hour average concentrations of 180 µg/m^3. Directive 2002/3/EC sets the alert threshold as one-hour average concentrations of 240 µg/m^3 and stipulates that for the implementation of short-term action plans (as described in Article 7) the exceedance of the threshold should be measured (or predicted) for three consecutive hours.

An evaluation of the data reported for the year 2002 will be included in a forthcoming EEA report on air pollution in Europe, which additionally covers the information collected under the EU exchange of information decision (Decision 97/101/EC).

The formats for information and data exchanges have been defined in Directive 92/72/EEC. In view of the increasing amount of data requiring processing, as well as the improvement in the transfer of data relating to the implementation of Directive 92/72/EEC, the Commission prepared an update in April 1996 of the required data exchange format. The major changes concern the transfer of additional information:

- type of station: definition of the location of stations as recommended in the exchange of information decision;
- altitude of stations as recommended by the expert group established under the old ozone directive;
- nitrogen oxides (NO_x) and volatile organic compound (VOC) data, according to Annex 2.3 to the ozone directive;
- file names: it is recommended to define unique names for all files in order to improve the management and transfer of the data files.

After 1996, no further modifications in data requirements and data exchange formats have been made. Non-EU countries were requested to submit their data in agreement with these data exchange formats. Information submitted using the air quality DEM (data exchange module, a software tool developed by the ETC-ACC (see, for example, Sluyter and Schoorl, 1999) to facilitate data flows under the exchange of information decision) is also accepted.

Threshold values for ozone concentrations (µg/m^3; ref. Directive 92/72/EEC) — Table 2.1.

Threshold for:	Concentration	Averaging period (hours)
health protection	110	8
vegetation protection	200	1
vegetation protection	65	24
population information	180	1
population warning	360	1

2.2. Data reported over summer 2003

For this report, the agreed deadline for transmitting data was 15 September 2003. All EU Member States provided information on

observed exceedances in time, or indicated that no exceedances had been observed. In addition, nine acceding countries (the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia), two accession countries (Bulgaria and Romania) and five non-EU countries (Former Yugoslav Republic of Macedonia, Iceland, Liechtenstein, Norway and Switzerland) provided information upon request of the European Environment Agency. The Commission and the EEA greatly appreciated that most countries transmitted August exceedance data before the formal deadline as set in the directive.

As in the last six years (1997–2002), Ireland and Finland confirmed no exceedance of the 180 µg/m^3 threshold in 2003. Also, in Denmark, Estonia, Latvia, Lithuania, Norway and Sweden no exceedances were observed. Iceland reported surprisingly one exceedance in April; this is to be verified. Table 2.2 presents an overview of observed exceedances per country per month. Note that the information used in this report is mainly based on non-validated monitoring data and/or on incomplete information on monitoring networks.

Since only exceedances of thresholds were reported, there is no evidence whether stations were operational continuously during summer 2003 (April–August). It is possible that ozone concentrations exceeded a threshold at a site but this was not reported

Table 2.2. **Overview of observed exceedances per month per participating country in 2003**

	April	May	June	July	August
Austria	—	p	p	p	p
Belgium	—	p	p	p	p
Denmark	—	—	—	—	—
Finland	—	—	—	—	—
France	p	p	p	p	p, w
Germany	—	p	p	p	p
Greece	p	p	p	p	p
Ireland	—	—	—	—	—
Italy	p	p	p, w	p	p
Luxembourg	—	—	p	p	p
Netherlands	—	—	p	p	p
Portugal	—	p	p	p	p
Spain	—	p	p	p	p
Sweden	—	—	—	—	—
United Kingdom	p	p	p	p	p
Bulgaria	p	—	—	—	p
Czech Republic	—	—	p	p	p
Estonia	—	—	—	—	—
Hungary	—	—	p	—	p
Latvia	—	—	—	—	—
Lithuania	—	—	—	—	—
Malta	—	—	—	p	p
Poland	p	—	p	p	p
Romania	—	p	p, w	—	p
Slovakia	p	p	p	p	p
Slovenia	—	—	p	p	p
Accession countries	p	—	p	p	p
Iceland	p	—	—	—	—
Liechtenstein	—	—	—	p	p
Norway	—	—	—	—	—
Switzerland	—	p	p	p	p

NB: p: exceedance of the population information threshold reported; w: exceedance of the warning threshold reported; —: no exceedance reported.

because the monitoring station was temporarily out of operation. Nevertheless, general experience with contemporary, automatically operated ozone monitors is that such situations are not frequent.

In this report, exceedances are counted on a daily basis, i.e. a day on which a threshold is exceeded during at least one hour is counted as one exceedance.

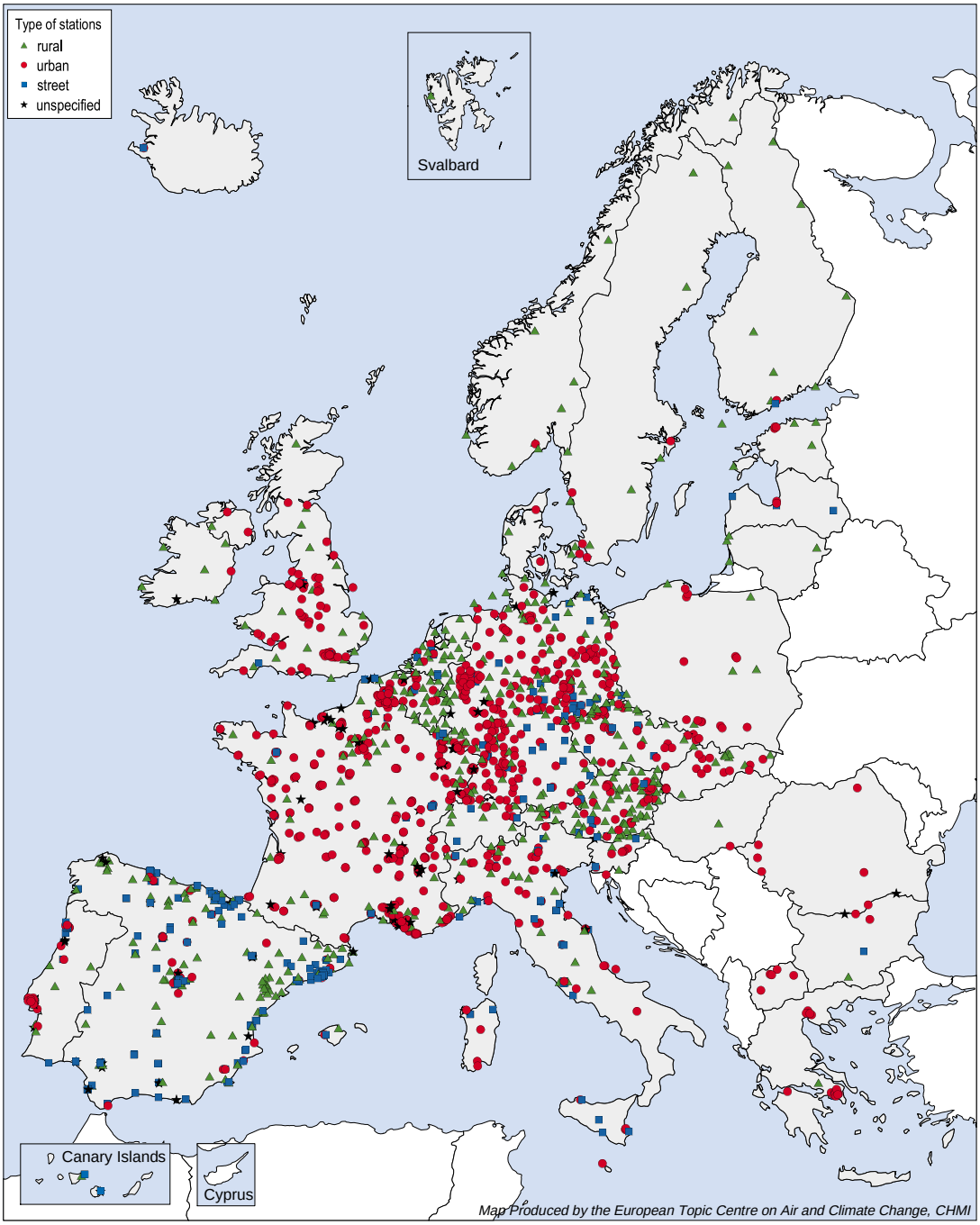
A summary of monthly reported data has been presented and regularly updated on the ETC-ACC web page: http://etc-acc.eionet.eu.int/databases/o3excess.

2.3. The ozone monitoring network in 2003

Most of the countries provided information on the operational ozone monitoring network in summer 2003 (number of monitoring stations, coordinates, station type, etc.) or reported that it was the same as in 2002. For the countries for which no actual information has been submitted, it has been assumed that the network configuration of the annual period 2002 was also in place during the summer of 2003.

Map 2.1 presents the location of all ozone monitoring stations assumed to be operational in the reporting countries during the 2003 summer season. In total 1 805 ozone monitoring stations were operational in summer 2003. Of these, 1 624 stations are located within the EU, 497 stations are situated in rural areas, 857 stations are in the urban environment, 312 stations are classified as street stations and 139 stations are characterised as industrial stations or the monitoring environment is not specified. The number of stations reporting during the 2003 summer differed only slightly from the two previous years (1 842 stations in 2001, 1 718 stations in 2002).

Map 2.1. **Location of ozone monitoring stations as reported by Member States and other European countries in the framework of the ozone directive for the reference period 2003**



3. Information for summer 2003

3.1. Summary of exceedances reported

The threshold value for warning the public (one-hour concentration > 360 µg/m³) was exceeded in August in France (twice at one station) and in Italy and Romania at one station (in each country) in June (Table 3.1). No further exceedances of the warning threshold have been reported for the European territory for the reporting period April–August 2003.

By comparison, in summer 2002, the warning threshold was exceeded in June at one station in France and Italy and at three stations in Spain. In 2001, the warning threshold was exceeded in March at the French station Marignane Ville (maximum concentration 387 µg/m³). The annual 2001 reporting presented two additional exceedances of this warning threshold at one station in Italy (369 µg/m³ in August) and at one station in Spain (470 µg/m³ in November). In the annual reports for 2000, only Italy had exceedances of this threshold, on three occasions at two stations.

Therefore, despite exceptionally long-lasting warm weather conditions during the 2003 summer affecting the whole territory of southern, western and central Europe, the number of exceedances of the warning level in 2003 does not differ substantially from the number of exceedances found in previous years with closer-to-average summers. This changes rather drastically if exceedances of lower thresholds are considered.

Table 3.2 presents a general overview of the observed exceedances of the threshold for informing the public (one-hour concentration > 180 µg/m³) during the period April–August 2003 per country. Since the number of stations differs widely from country to country, the absolute number of exceedance days is not suitable for comparison of the situation in different countries. Therefore, the concept of 'occurrence of exceedance' has been introduced. Occurrence of exceedance is defined 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. Although this parameter is more comparable between countries, the differences in networks, in particular the ratio between street, urban and rural stations, limit the comparability.

With respect to EU Member States, in Denmark, Finland, Ireland and Sweden no exceedances of the public information threshold were observed. Finland and Ireland have not reported any exceedance during the last seven summer seasons (1997–2003). From the other participating countries, Estonia, Latvia, Lithuania and Norway did not observe exceedance of the population information threshold in summer 2003.

For those countries that reported exceedances, the number of exceedance days per country ranged from 1 (Iceland) to 108 (Italy). During 137 days within the April–August 2003 period of 153 days, there was at least one station in all reporting countries where an exceedance was observed. About 68 % of all stations reported one or more exceedances. On average 8.0 exceedances were observed this summer at stations which recorded at least one exceedance. The average maximum hourly concentration during an exceedance of the threshold was 202 µg/m³.

Exceedances of the threshold value for warning the public (one-hour ozone concentration > 360 µg/m³) in 2003 — Table 3.1.

Country	Station	Date	Time/duration (hours)	Maximum concentration (µg/m³)
France	Sausset les Pins	3 August	14.00/2	417
Romania	CL-C1 Chiciu	14 June	19.00/1	394
Italy	Varenna	12 June	18.00/1	368
France	Sausset les Pins	5 August	13.00/1	363

Table 3.2. **Summary of exceedances of the threshold value for information of the public (one-hour ozone concentration > 180 µg/m³) during summer 2003 (April–August) on a country-by-country basis**

	Number of stations (1)	Number of stations with exceedance		Number of days with exceedance (2)	Maximum observed concentration (µg/m³)	Averaged maximum concentration (µg/m³) (3)	Occurrence of exceedances (4)		Average duration of exceedances (hours)
Austria	116	94	81 %	47	263	195	4.3	5.2	3.1
Belgium	38	37	97 %	20	296	207	8.6	8.9	3.9
Denmark	7	0	0 %	0	< 180	< 180			
Finland	11	0	0 %	0	< 180	< 180			
France	451	367	81 %	78	417	200	7.4	9.1	3.1
Germany	363	303	83 %	62	334	203	5.7	6.9	4.1
Greece	23	17	74 %	92	302	208	19.3	26.1	2.8
Ireland	7	0	0 %	0	< 180	< 180			
Italy	122	82	67 %	108	368	205	13.4	19.9	4.0
Luxembourg	6	5	83 %	21	254	199	9.5	11.4	3.2
Netherlands	36	30	83 %	13	276	208	3.4	4.1	3.2
Portugal	42	30	71 %	23	297	206	3.0	4.2	2.1
Spain	310	111	36 %	69	310	200	1.6	4.6	2.5
Sweden	12	0	0 %	0	< 180	< 180			
United Kingdom	80	45	56 %	37	249	201	2.0	3.5	3.0
EU area	1 624	1 121	69 %	134	417	202	5.7	8.3	3.5
Bulgaria	2	2	100 %	3	240	203	1.5	1.5	4.0
Cyprus (5)	—	—	—	—	—	—	—	—	—
Czech Republic	61	49	80 %	27	236	192	2.1	2.6	2.8
Estonia	7	0	0 %	0	< 180	< 180			
Hungary	2	2	100 %	4	186	185	2.0	2.0	2.5
Latvia	6	0	0 %	0	< 180	< 180			
Lithuania	3	0	0 %	0	< 180	< 180			
Malta	1	1	100 %	4	195	187	4.0	4.0	1.8
Poland	23	11	48 %	19	227	193	1.4	3.0	2.6
Romania	10	3	30 %	8	394	246	0.8	2.7	2.1
Slovakia	23	8	35 %	37	301	198	3.2	9.3	4.2
Slovenia	10	7	70 %	25	243	193	3.9	5.6	3.3
Accession countries	148	83	56 %	68	394	195	2.0	3.5	3.1
Accession countries	5	2	40 %	27	235	199	5.6	14.0	2.8
Iceland	2	1	50 %	1	214	214	0.5	1.0	1.0
Liechtenstein	1	1	100 %	2	209	196	2.0	2.0	2.5
Norway	12	0	0 %	0	< 180	< 180			
Switzerland	13	12	92 %	58	266	203	15.2	16.5	3.8
Whole area	1 805	1 220	68 %	137	417	202	5.4	8.0	3.4

(1) Number of stations implemented in the framework of the ozone directive.
(2) The number of calendar days on which at least one exceedance was observed.
(3) Average of all maximum concentrations recorded during exceedances.
(4) Left figure: averaged over all stations reported; right figure: averaged over all stations which reported at least one exceedance.
(5) No information available.

Table 3.3 summarises the exceedances on a monthly basis. The largest number of exceedances occurred during the three summer months (June, July and mainly August) in 2003; almost every day, an exceedance was observed at at least one of the reporting stations (see Section 3.3, Figure 3.5).

Figure 3.1 presents the number of days per month on which at least one station in a country recorded an exceedance. This figure

Summary of exceedances of the threshold value for information of the public (one-hour ozone concentration > 180 µg/m³) during summer 2003 (April–August) on a month-by-month basis

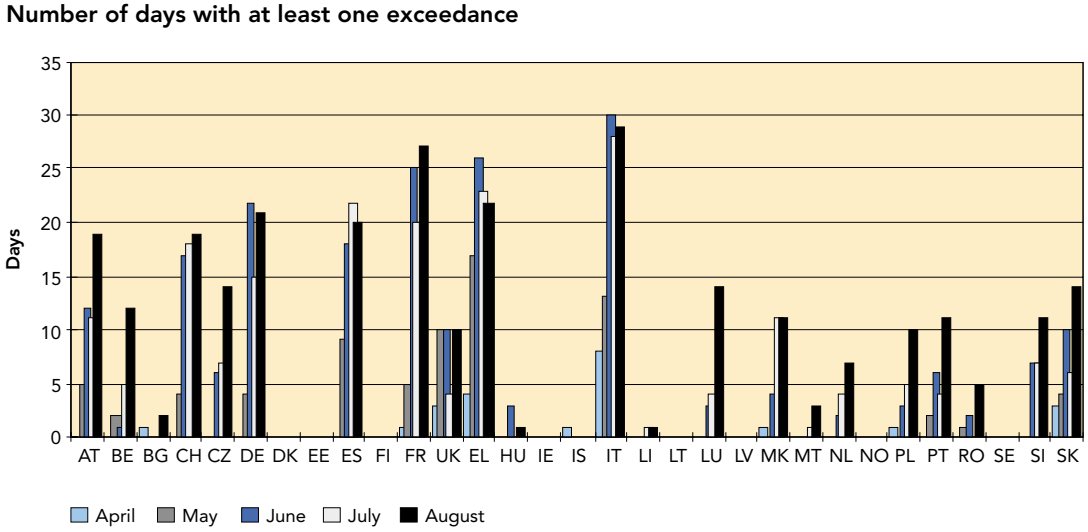
Table 3.3.

	Number of stations with exceedance (1)	Maximum observed concentration (µg/m³)	Average maximum concentration (µg/m³) (2)	Occurrence of exceedances (3)		Average duration of exceedances (hours)
April	23	242	193	0.0	1.5	2.1
May	174	300	199	0.2	1.8	2.2
June	463	394	201	0.9	3.3	3.0
July	666	297	199	1.0	2.8	3.1
August	1 146	417	203	3.4	5.3	3.7

(1) The theoretical maximum is 1 805 stations (all stations which are assumed to be operational in the reporting European countries during summer 2003); at 1 220 stations, one exceedance or more have been observed.
(2) Average of all maximum concentrations recorded during exceedances.
(3) Left figure: averaged over all stations in operation; right figure: averaged over all stations which reported at least one exceedance.

Number of days on which at least one exceedance of the threshold value for information of the public (one-hour ozone concentration > 180 µg/m³) was observed per country and per month during summer 2003

Figure 3.1.



reflects for most countries the seasonal behaviour seen in Table 3.3.

The average occurrence of exceedances (in days) in each country of the threshold value for information of the public by station type (rural, urban, street and other) is presented in Figure 3.2. The average occurrence rate is expected to decrease in general in the order rural background–urban background–street, since local emissions of nitrogen oxides are expected to deplete ozone increasingly going from rural background to street stations. For some countries, this decrease is apparent (Belgium, France, the United Kingdom, Italy and the Netherlands). However, in summer 2003, the average occurrence rate for rural and urban stations is rather comparable or even contradictory to expectation (Austria, Germany, Poland, Portugal, Slovakia, Slovenia, Spain and Switzerland). A possible explanatory factor is the dominant transboundary character of the episodes in summer 2003.

Figure 3.3 shows the frequency distribution of hourly ozone concentrations exceeding the information threshold. The data show that during 25 % of all observed exceedances, the maximum hourly concentration recorded was below 207 µg/m³. The highest values of the 75th percentile of all maximum concentrations in a country during exceedances were below 305 µg/m³, which is markedly higher than the maximum 75th percentile value during summer 2002 (219 µg/m³) and 2001 (208 µg/m³).

As pointed out previously, exceedance of the new alert threshold (240 µg/m³) as set in the third daughter Directive 2002/3/EC is to be reported from 2004 onwards. The reported data on exceedances of the information threshold were compared with the number of

Figure 3.2. **Average occurrence of exceedances (in days) of the threshold value for information of the public (one-hour ozone concentration > 180 µg/m³) by station type (rural background, urban background, street and other) and country during summer 2003**

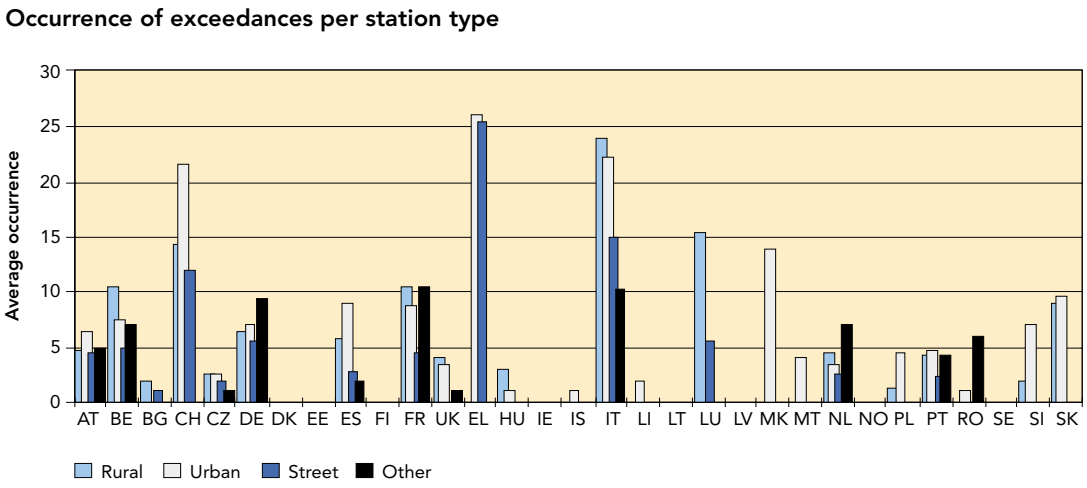
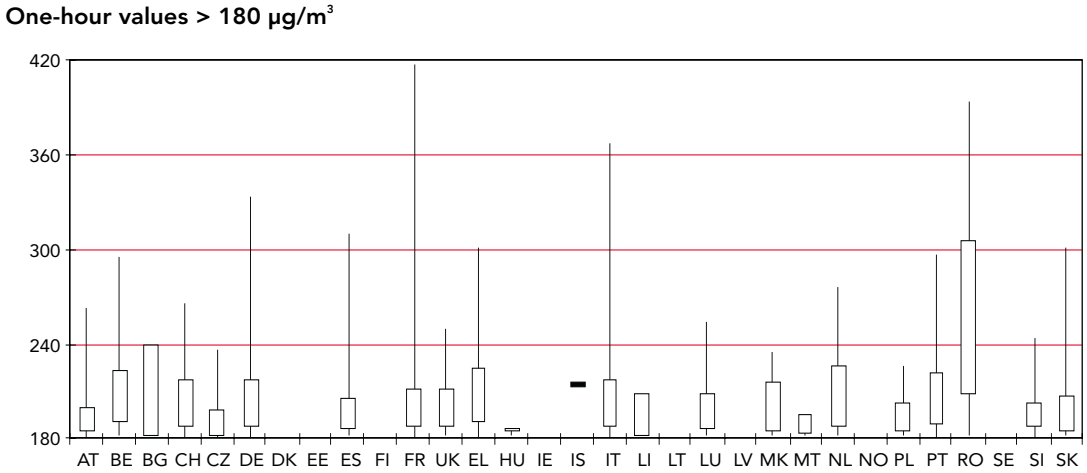


Figure 3.3. **Top: Frequency distribution of ozone concentrations in excess of the 180 µg/m³ information threshold value for hourly values (April–August 2003). Frequency distributions are presented as Box-Jenkins plots indicating the minimum, the 25th percentile, the 75th percentile and the maximum value.**
Bottom: total number of exceedances (#ex) and number of reporting stations (#st) per country.



	AT	BE	BG	CH	CZ	DE	DK	EE	ES	FI	FR	UK	EL	HU	IE	IS
#ex	493	328	3	198	128	2 080			508		3 350	156	443	4		1
#st	94	37	2	12	49	303			111		367	45	17	2		1

	IT	LI	LT	LU	LV	MK	MT	NL	NO	PL	PT	RO	SE	SI	SK
#ex	1 632	2		57		28	4	123		33	127			39	74
#st	82	1		5		2	1	30		11	30			7	8

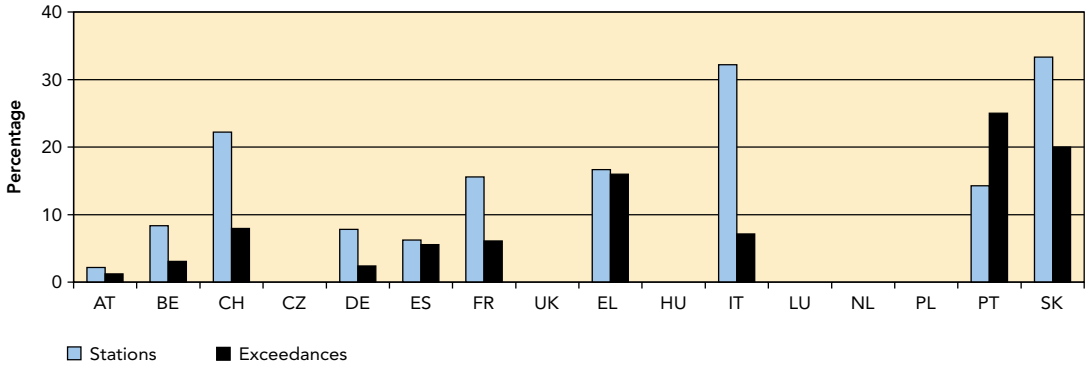
exceedances of this alert threshold. Ozone concentrations higher than 240 µg/m³ were reported from the monitoring stations of 15 countries (Austria, Belgium, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland and the United Kingdom).

On average, at 27 % of the stations which report an exceedance of the 180 µg/m³ information threshold, an exceedance of the 240 µg/m³ alert threshold was observed (11 % in 2002). In total, 720 exceedances of the alert threshold were counted, i.e. during about 6 % of the reported exceedances of the information threshold, the maximum concentration reached a level above

Number of stations reporting any exceedance of the alert threshold value (Directive 2002/3/EC, 240 µg/m³) expressed as a percentage of the total number of stations and number of reported exceedances expressed as a percentage of the number of reported exceedances of the information threshold value (180 µg/m³), respectively, during summer 2003

Figure 3.4.

Fraction of the number of stations and exceedances of the new 240 µg/m³ threshold



240 µg/m³. The ratio of the number of exceedances of the 180 µg/m³ level and the number of exceedances of 240 µg/m³ threshold varied greatly across the reporting countries (see Figure 3.4). The situation in each country (number, location and type of station, local meteorological conditions) may be an important factor in determining this ratio; the figure suggests a higher ratio for the south European countries. As discussed earlier, the hot summer of 2003 is hardly reflected in the exceedances of the warning level of 360 µg/m³, but quite clearly in exceedances of the 180 µg/m³ threshold.

3.2. Geographical distribution

Maps 3.1 and 3.2 show the geographical distribution of the number of days on which the threshold value for information of the public was exceeded. Map 3.1 depicts urban and traffic stations and stations of unspecified type.

Map 3.2 presents rural and urban stations whereby data are interpolated using simple inverse distance weighting. Combining rural and urban background stations leads to a rather homogeneous map. The whole northern part of Europe (the Baltic States, Finland, Iceland ([1]), Ireland, Norway, Scotland and Sweden) had no days with exceedance of the information threshold as in previous years. For the south-eastern part of Europe, the density of ozone monitoring sites is too low to provide reliable estimations of the spatial distribution by interpolation, so the exceedance data are presented for rural stations with an arbitrary radius of representativeness of 100 km and urban stations with a radius of 20 km.

In summer 2003, the spatial extent of the exceedances observed was much larger than in previous more normal summers. With the exception of the northern part of Europe, more than one day with exceedance was recorded in most of the European countries. The area with more than 10 exceedance days covered in 2003 mainly south-western Germany, Switzerland, northern and south-eastern France, Belgium, northern and central Italy and central Spain. The areas with the highest number of exceedance days correspond to regions with the highest density of ozone precursor emissions from traffic and industrial production.

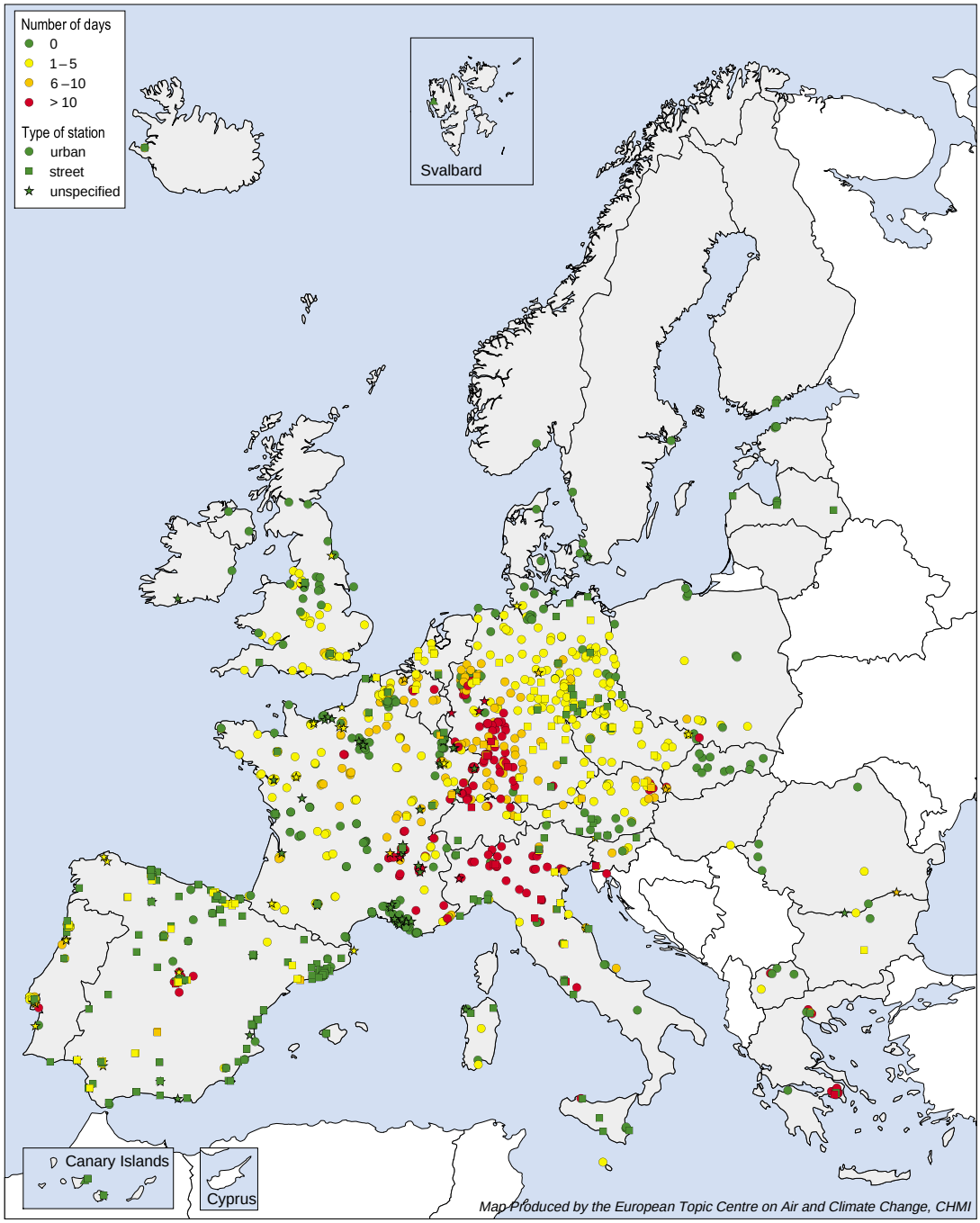
3.3. Main ozone episodes

Ozone formation in the atmosphere is a complicated non-linear photochemical process. In the troposphere (the lower part of the atmosphere), the 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 (OH) radicals. 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 and NO_x concentrations. In urban areas where NO_x concentrations are usually higher with respect to the optimal

(1) Iceland reported in 2003 one quite unexpected and probably unreliable exceedance in April. In the mapping, this exceedance was not taken into account.

Map 3.1.

Number of exceedances of the threshold value for the information of the public (one-hour ozone concentration > 180 µg/m³) observed at urban/street stations and stations of unspecified type in the EU and other countries, summer 2003 (April–August)

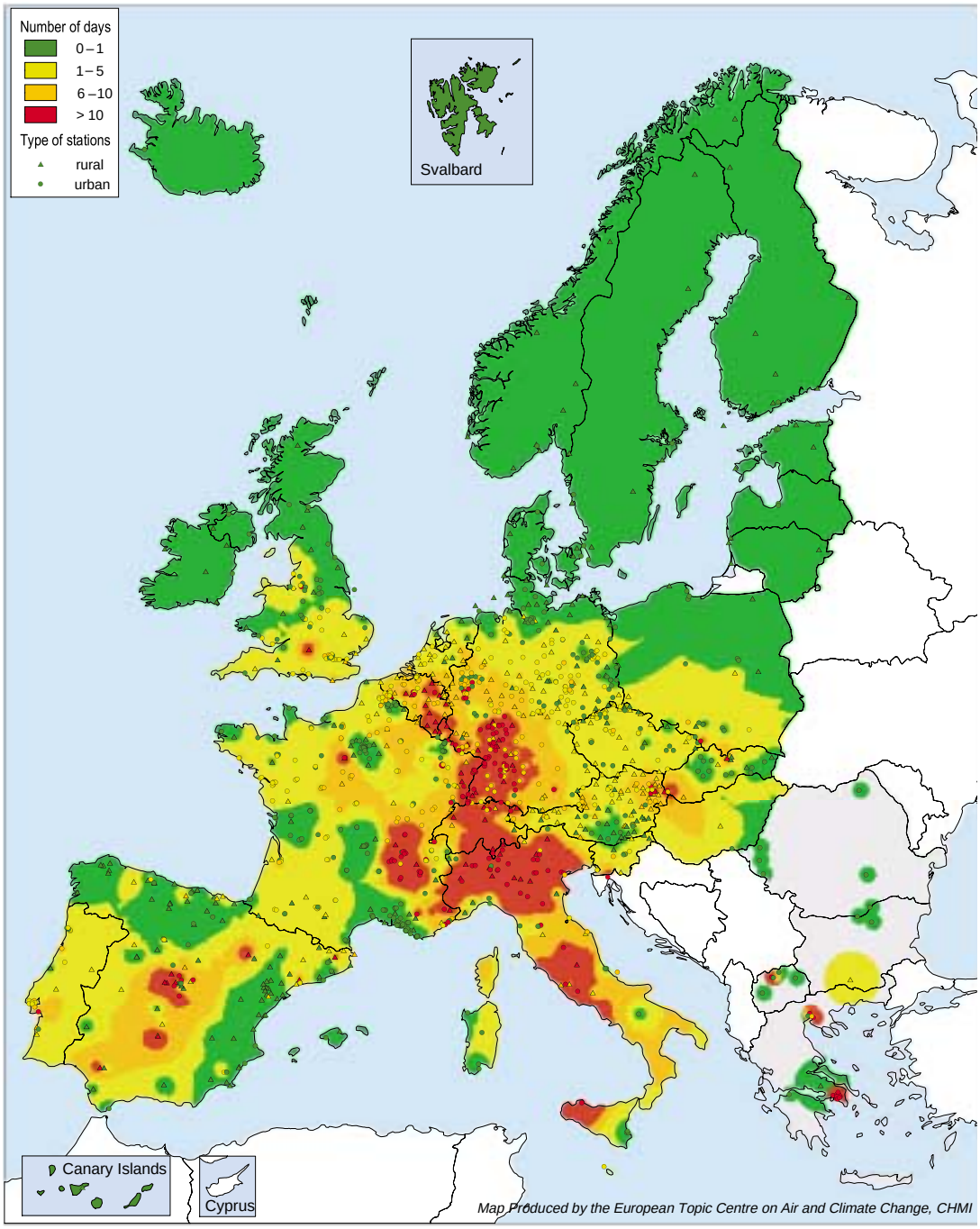


VOC/NO_x ratio for maximum ozone formation, ozone concentrations may be lower than the rural ('background') concentrations due to chemical scavenging by locally emitted nitrogen oxides and because of terminating reactions of NO_x with OH radicals which prevail in NO_x-rich regions of city centres.

Episodes, i.e. periods with elevated ozone levels, mainly occur during periods of warm sunny weather. In Mediterranean countries, with prolonged spells of hot and sunny weather during the summer, ozone can quickly be formed and high concentrations can occur on many days and in the vicinity of urban centres. In northern Europe, the build-up of ozone is slower due to the more moderate weather conditions. Here, the highest levels are usually found further downwind of cities. Ozone and ozone precursors can be transported over hundreds to thousands of kilometres.

Number of exceedances of the threshold value for the information of the public (one-hour ozone concentration > 180 µg/m³) observed at rural and urban background stations, summer 2003 (April–August), interpolated using inverse distance weighting

Map 3.2.



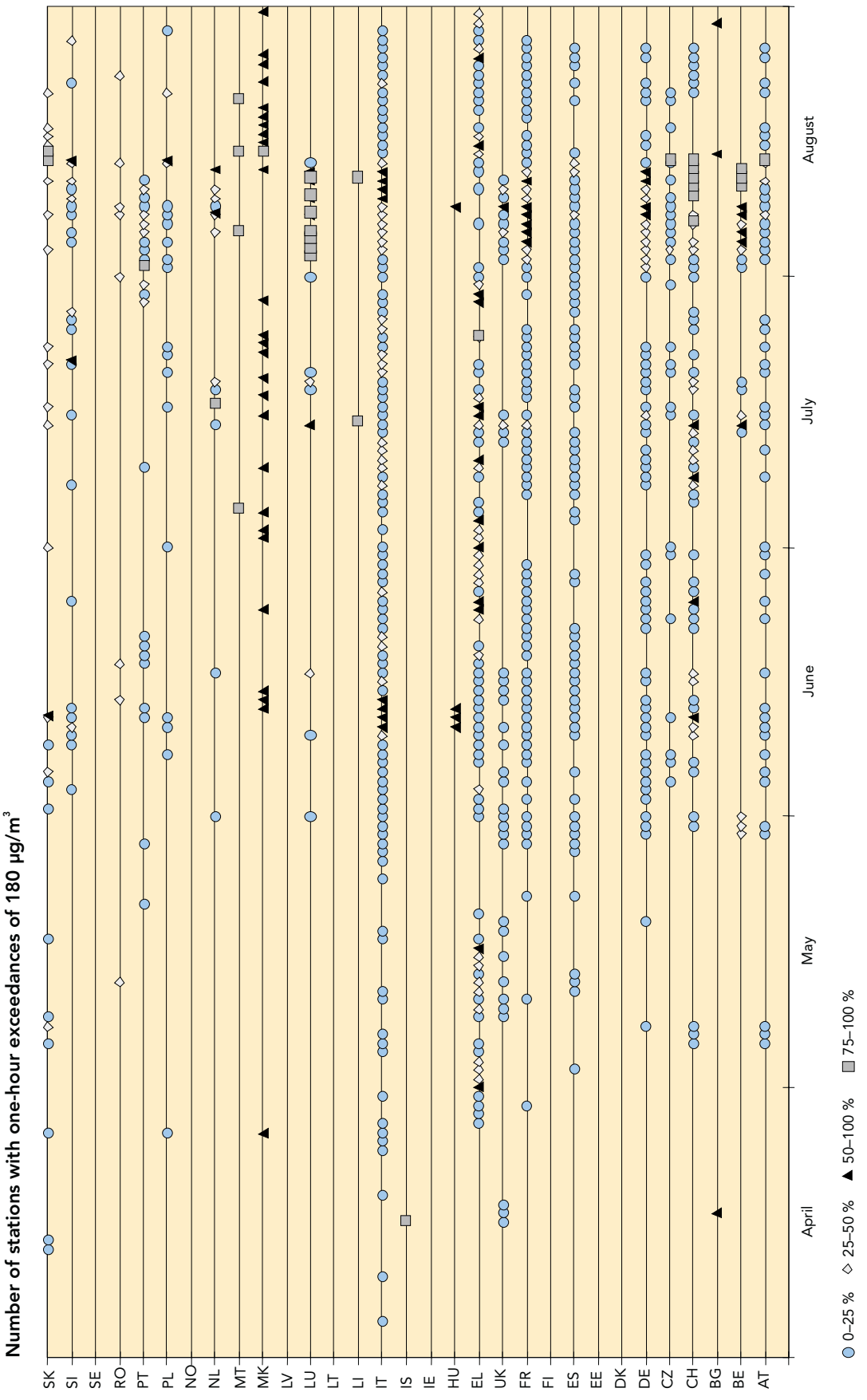
In south European countries exceedances are already observed in April and early May (see Figure 3.5 (2)). In June, July and August, exceedances are observed all over Europe except in the most northern countries. As mentioned before, weather conditions are important for the occurrence or non-occurrence of ozone episodes.

Weather conditions during the first half of August 2003, characterised by exceptionally high temperatures even at nights and covering large parts of southern, western and central Europe, caused a long-lasting episode with elevated ozone concentrations.

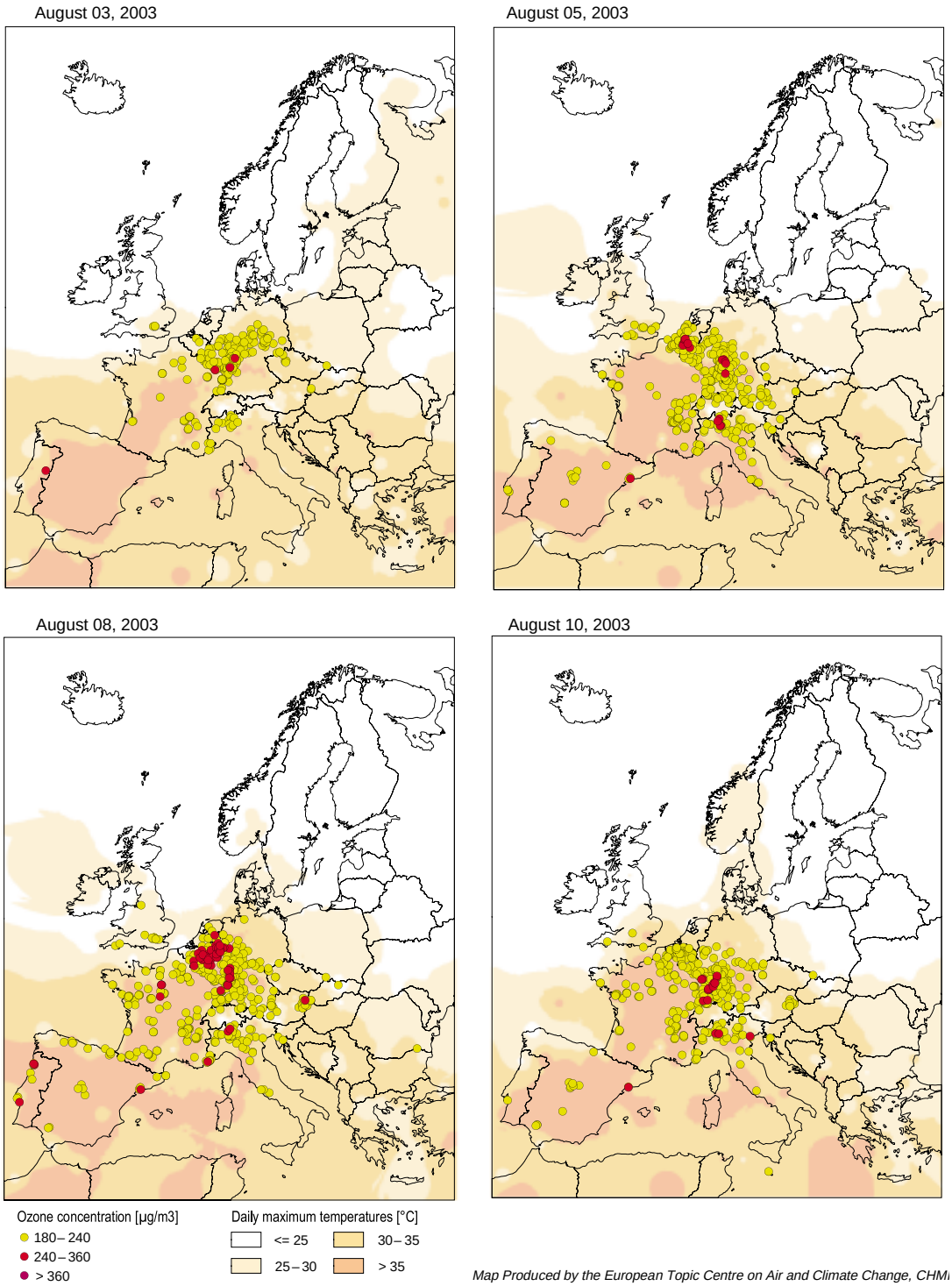
The exceptionally long-lasting period of high ozone concentrations was reported by all the

(2) A table indicating per day and per country the number of stations where the information threshold value has been exceeded is available upon request. Requests can be sent to: Libor Cernikovsky, Czech Meteorological Institute, Ostrava, Czech Republic. Email: cernikov@chmi.cz

Figure 3.5. **Qualitative overview of exceedances of the 180 mg/m³ threshold value for the information of the public for ozone during the period April-August 2003. The symbols represent the percentage of stations that observed at least one exceedance of the threshold during a particular day**



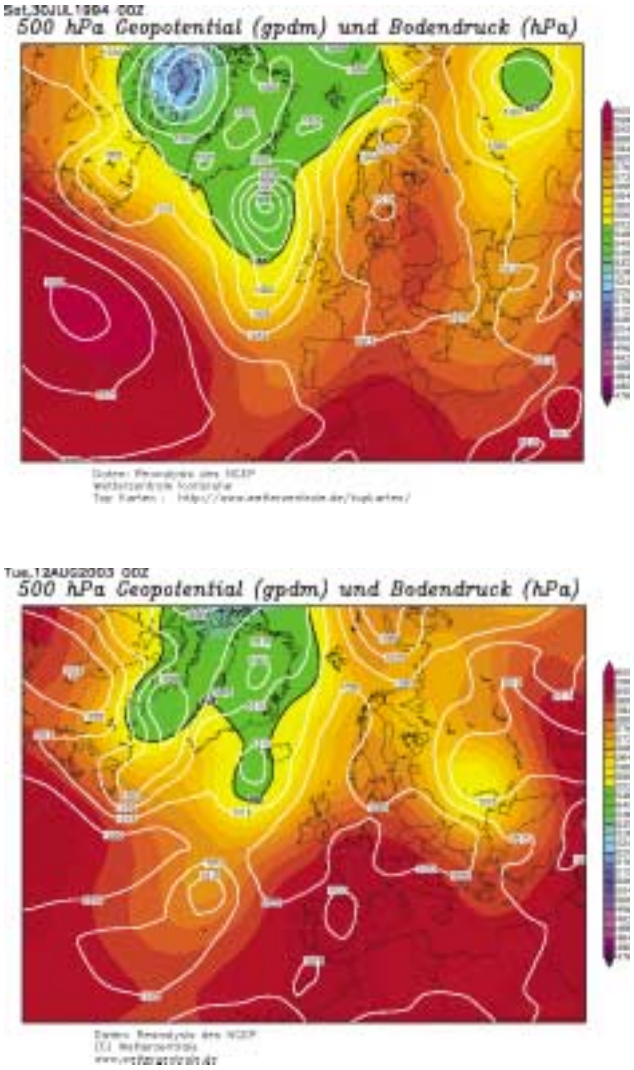
Example of a smog episode: stations that reported an hourly ozone concentration in excess of 180 µg/m³, 3, 5, 8 and 10 August 2003 (all station types) Map 3.3.



countries except the north European countries. During this episode, hourly ozone concentrations exceeded even 240 µg/m³ at a large number of sites in Belgium, northern France and north-western Germany and also 360 µg/m³ at one site in France. The most affected areas were those with the highest density of ozone precursor emissions from traffic and industrial production.

The meteorological situation in the first half of August 2003 was characterised by a long-lasting high-air-pressure area above south-western Europe. During the ozone episode in the first half of August, the axis of the high-pressure ridge was located above France, western Germany, Switzerland and northern Italy (Figure 3.6, bottom). This meteorological situation remained almost

Figure 3.6. **Fields of ground pressure on 30 July 1994 (top) and on 12 August 2003 (bottom) (http://www.wetterzentrale.de/topkarten/fsreaeur.html)**



unchanged for the whole first half of August. In the high-pressure area, stagnant conditions were associated with long-lasting high ozone concentrations.

An overview of the sites where exceedances were observed during the first half of August 2003 is presented in Map 3.3. The maximum daily temperatures are shown as a legend of this map.

3.4. Measures taken against elevated ozone concentrations in summer 2003 in Europe

The report published by the French Ministry of the Environment and Sustainable Development (http://www.environnement.gouv.fr/actua/com2003/septembre/3-bilan-ozone-ete2003.htm) summarises measures taken in summer 2003 predominantly by France but also by other European countries to diminish elevated ozone concentrations in Europe.

Note that the measures considered here were those taken locally and at the time of occurrence of high ozone concentrations. Due to the long-range transport character of ozone, the effective abatement of ozone episodes necessitates that measures be taken several days in advance of such episodes in the wide surroundings. Structural emission reductions across Europe as agreed in the national emission ceilings directive and the Gothenburg Protocol to the Convention on Long-range Transboundary Air Pollution are more effective. Of course, in the case of severe ozone episodes, every measure with positive effect is to be considered.

In France in summer 2003, measures for reducing the emission of ozone precursors were taken immediately after the information

threshold had been exceeded. The measures predominantly involved speed reduction on highways by 20–30 km, which was expected to decrease the emission of ozone precursors from traffic (Paris and Lyon agglomeration, Bouches du Rhône). Checks on the attainment of speed limits were stricter and police systematically inspected the technical condition of vehicles. Industrial enterprises were requested to reduce emissions by limiting production or by postponing production contributing to the emission of ozone precursors to some later period. Systematic inspection was carried out to verify how these measures were respected. The French report does not provide an evaluation of the effects of the measures taken.

Other European countries adopted different measures on their territory. In the United Kingdom, the Department for Environment, Food and Rural Affairs issued general recommendations appealing to the public for voluntary measures.

In some cantons in Switzerland, regulations to reduce the speed of cars to decrease the emission of ozone precursors were implemented. Authorities in some countries (e.g. Germany) considered short-term measures as not sufficiently effective; they preferred the adoption of long-term measures to decrease the emission of ozone precursors enabling future attainment of the threshold values set by Directive 2002/3/EC.

4. Comparison with previous years

In Figure 4.1, a comparison of the average exceedance duration and the average number of exceedances of the information threshold per monitoring station (occurrence) during these years is presented ([3]). The average occurrence in 2003 presented in Figure 4.1 was the highest in the last nine years.

Whereas Figure 4.1 reflects the situation in the European Union (EU-15), Figure 4.2 indicates differences in distinct parts of Europe and their association with year-to-year variation of weather conditions.

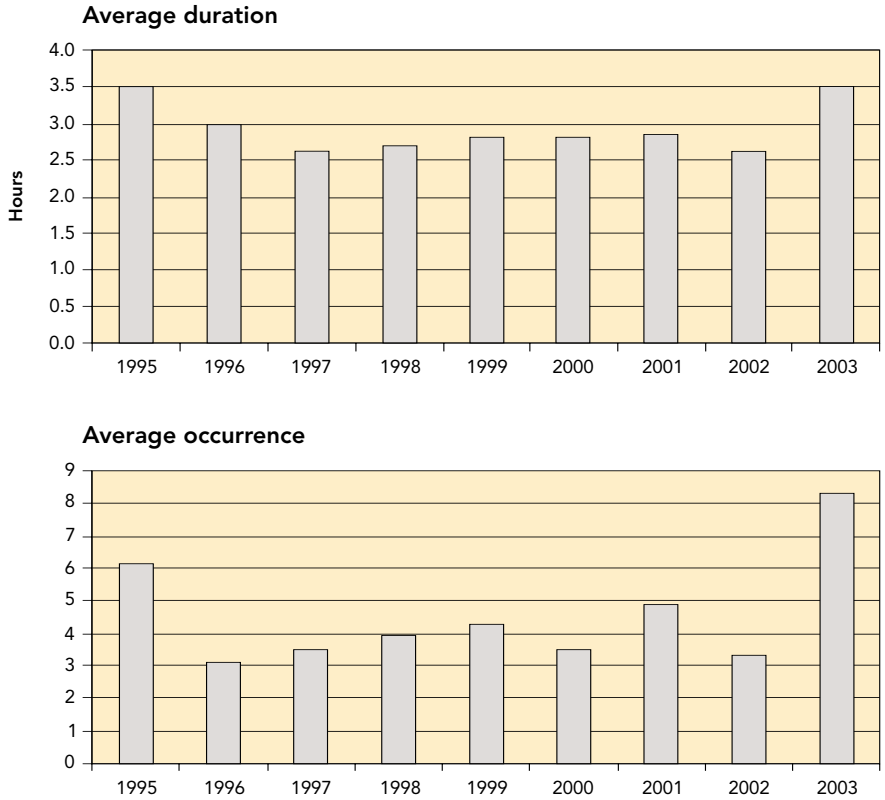
The effect of a quite exceptional summer in 2003 with an extraordinarily long period of high temperatures on a large territory of Europe is visible in both figures.

From Figure 4.2, it can be seen that the number of hours with exceedance correlates with year-to-year changes of summer average temperatures. Correlation of high ozone concentrations with temperature has been found in most ozone studies.

Warm and sunny weather enhances ozone concentrations because:

- emissions of volatile hydrocarbons (particularly evaporative losses and vegetation emissions) increase with increasing temperature;
- higher insolation results in more rapid photochemical processes;
- high temperature results in more rapid chemical ozone formation.

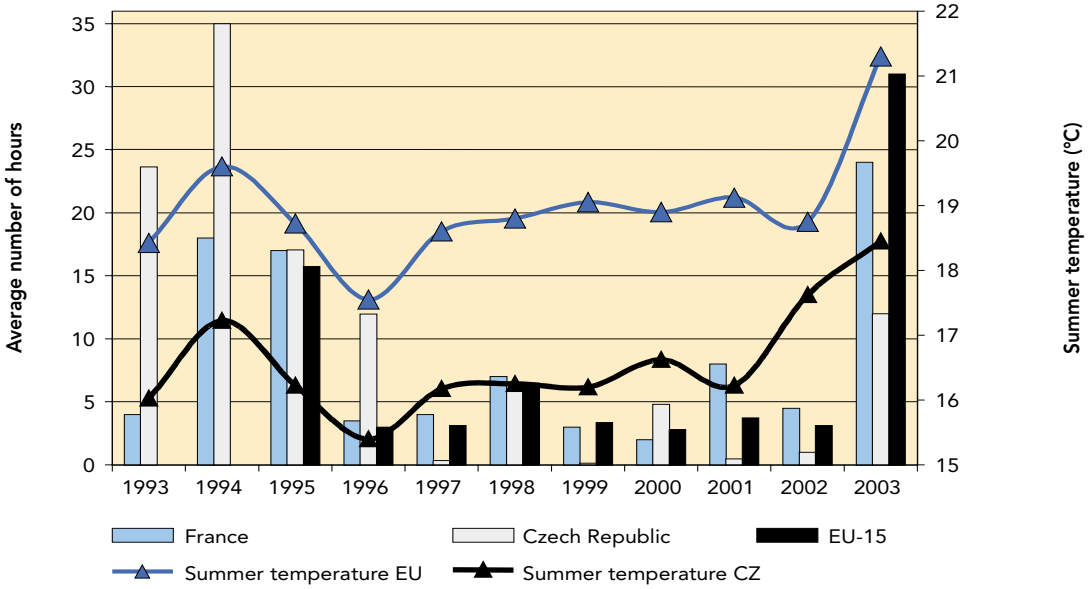
Figure 4.1. **Average duration of exceedances of the information threshold value in hours (top), and average occurrence (the number of exceedances per station) (bottom) for stations which reported at least one exceedance observed during the year (bottom); EU-15 stations only**



(3) Note that for the period 1995–2001 information is available for 12 months per year, whereas for 2002 and 2003 information is available for only five months.

Total number of hours with ozone concentration higher than 180 µg/m³ divided by the number of operational stations for France, the Czech Republic (CZ) and the European Union; average temperature for the period May–August for the Czech Republic and western Europe (http://www.klimadiagramme.de/Europa/special01.htm)

Figure 4.2.



In the period considered, the annual total emissions of ozone precursors decreased continuously. Between 1990 and 2000, total EU-15 emissions of NO_x and non-methane volatile organic compounds (NMVOCs) decreased by almost 30 %; emissions of CO decreased by 39 %. Between 1996 and 2000, NO_x and NMVOC emissions decreased by about 15 % (EEA, 2003). The year 1994 was not a year with exceptionally high annual average emissions either. The large variations shown in Figure 4.2 are therefore not or weakly related to the emissions, but more to the meteorological situation.

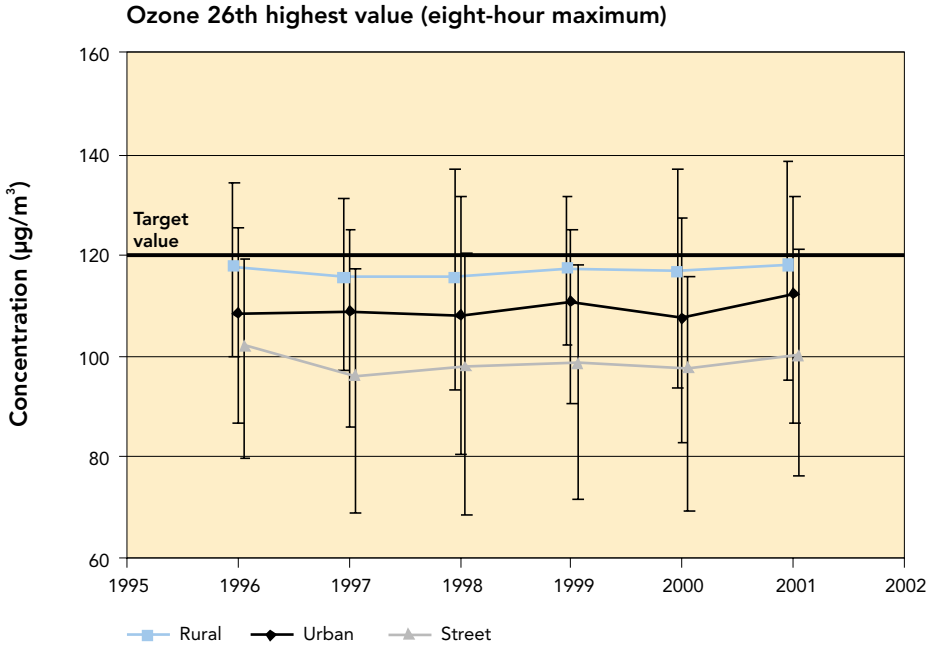
Figure 4.2 suggests that if climate change were to result in warmer summers in Europe, we could expect more frequent exceedances of ozone thresholds at the current emission levels.

The figure also indicates that whereas the average number of exceedance hours was highest in France and the EU in 2003 it was apparently lower in the Czech Republic in comparison with 1994 when the summer average temperature was significantly lower in comparison with the summer average temperature in 2003. The number of exceedance hours in 2003 was even lower than in other summers with a much lower average temperature.

The explanation may be found in different meteorological situations at the end of June 1994 and in the first half of August 2003. In Figure 3.6, fields of ground pressure on 30 July 1994 and on 12 August 2003 are shown. Whereas in the first half of August 2003 the area of the most stagnant and hot air was above northern France, Belgium, western Germany, Switzerland and northern Italy, central Europe (the Czech Republic) was affected by prevailing air flow from the north transporting much cleaner air into this territory. By contrast, at the end of July 1994, the high-pressure area of relatively stagnant air masses was above the Czech Republic and high long-lasting ozone concentrations were recorded here.

The analysis of time course/trends is strongly affected by changes in monitoring networks. Over the years, the number of reporting stations, and hence the territorial coverage, has increased significantly. This increase is not consistent over all countries and this may introduce bias. In some years, information from one or two large Member States is missing. Moreover, the ratio between the number of stations located in urban and rural areas has changed over the year; within a country, the configuration of the monitoring network may show large variation in number and location of stations. Detection of possible ozone trends therefore calls for a more in-depth analysis using the information on a station-by-station basis while influence of meteorological parameters has to be taken into account.

Figure 4.3. **Annual variations of the 26th highest maximum daily eight-hour mean ozone concentration. Average value over all stations which reported data over at least five years in the period 1996–2001**



The tails of the vertical bars present the 10th and 90th percentile values.

4.1. Trends of statistics relevant to the new ozone directive

The new Ozone Directive 2002/3/EC has introduced, next to information thresholds, two target values to be attained by 2010. The target value for the protection of human health is defined as a maximum daily eight-hour mean value of 120 µg/m³ not to be exceeded on more than 25 days averaged over three years; the target value for the protection of vegetation is defined as an AOT40 value of 18 000 µg/m³.h calculated from May to July during daylight hours (between 8.00 and 20.00 CET), averaged over five years. A long-term objective for the protection of vegetation was introduced as an AOT40 of 6 000 µg/m³.h.

A recent re-evaluation of the health effects of ozone exposure (WHO, 2003) indicates that there is little evidence for a level below which no effects on health are expected. In view of this, a trend in annual mean concentrations might form a proxy for the trend in long-term exposure of the population.

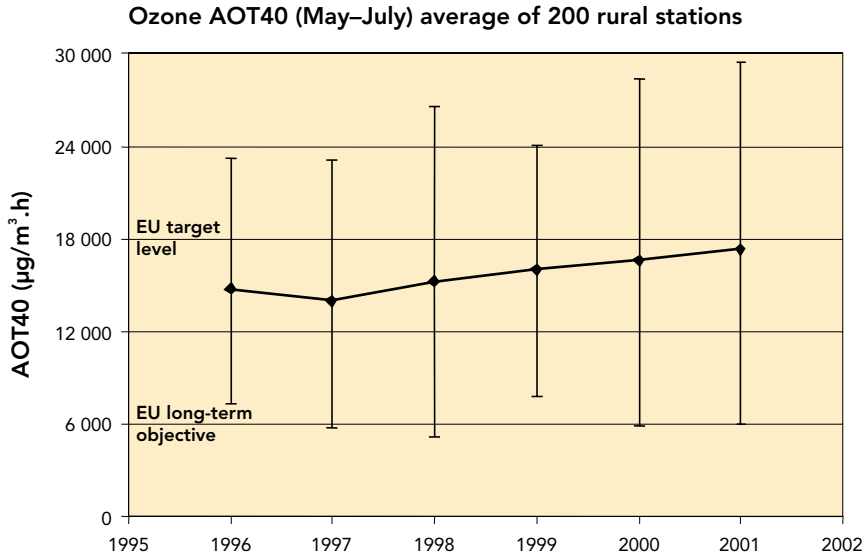
These targets differ greatly in their definition from the threshold values defined in the old directive (92/72/EEC). Information submitted under the 1992 directive is not suitable for a trend analysis. The present analysis is therefore based on information submitted under the exchange of information decision. Data up to 2001 are now available from AirBase (http://air-climate.eionet.eu.int/databases/airbase.html). In analysing recent trends, a compromise between conflicting criteria, 'a long time series' and 'a large number of stations giving a representative picture for central and western Europe' was found by analysing the period 1996–2001. A six-year period is in general too short to draw firm conclusions on a systematic change in concentrations. Nevertheless, for each station that reported data for at least five of the six years, a trend analysis was applied using the Mann-Kendall test. This non-parametric test is particularly useful since missing values are allowed and the data do not need to conform to any particular distribution. Moreover, as only the relative magnitudes of the data rather than their actual measured values are used, this test is less sensitive towards incomplete data capture and/or special meteorological conditions. In all calculations presented below, a significance level $\alpha = 0.10$ has been adopted.

4.1.1. Target value for the protection of human health

To follow progress towards the 2010 human health target value, the 26th highest maximum daily eight-hour mean ozone concentration is examined. As 25 exceedances per year are allowed, the 26th highest value should have dropped below the 120 µg/m³ by 2010.

Annual variations of the ozone AOT40 value (May–July). Averaged value over all rural stations which reported data over at least five years in the period 1996–2001

Figure 4.4.



The tails of the vertical bars present the 10th and 90th percentile values.

The change in this statistic from 1996 to 2001 is presented in Figure 4.3.

The systematic difference in ozone concentration depending on station type (decreasing in the order rural–urban background–street) is clearly seen. At a large fraction of rural and urban stations, the 2010 target value is exceeded. The 90th percentile at street stations is around 120 µg/m³, indicating that 10 % of the street stations (in 2001, 13 stations) are above the 2010 target value. The year-to-year variation of the statistic averaged over all stations is small. The analysis of the trends at individual stations shows that there is no significant trend at the majority of stations although at most of them there is a tendency for increasing concentrations. At 99 of the 673 stations included in the analysis, a significant trend (half downward, half upward) is found. In Map 4.1, showing all stations, no distinct regions with increasing or decreasing trends can be detected.

A similar map including all urban stations gives a similar mixed pattern; the map of rural stations suggests a decreasing trend in the UK and Scandinavia. However, these findings must be interpreted carefully since on the short timescales considered here meteorological inter-annual variations might play an important role.

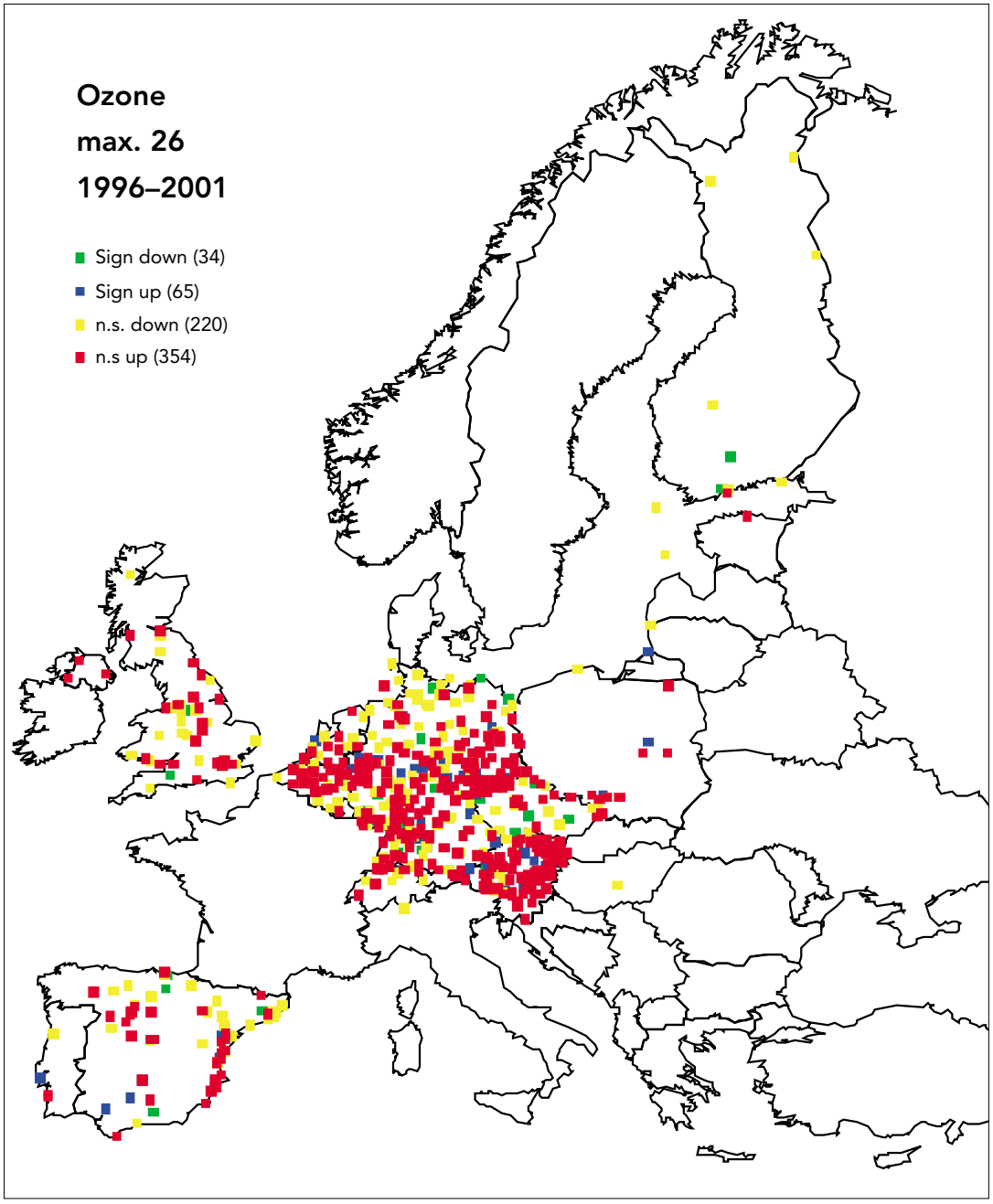
4.1.2. Target value for the protection of vegetation

In an analysis of recent trends (1996–2001), about 200 rural stations which have provided AOT40 values for at least five annual periods have been included. Although the variation in measured AOT40 values is large, the overall average value has shown an increasing tendency over the last few years (see Figure 4.4). Only at a small number of stations is there a significant upward trend (34 stations) or downward trend (8 stations). Non-significant tendencies are found at the majority of stations. Note that only at 10 % of the stations are the current values of the statistic below the long-term objective. The selected stations are not representative of the situation in the whole of Europe (see Map 4.2). However, comparing Map 4.2 with a map of the AOT40 levels in a given year (see, for example, EEA, 2003) suggests, generally, that in the regions with low AOT40 values (the UK and Scandinavia) a decreasing tendency is observed, while in regions with high values (north-western and central Europe) an increasing tendency is observed.

In conclusion, the concentration statistics relevant to effects on human health and the environment do not show a clear decrease in the period 1996–2001.

In the report on ozone in Europe in the summer of 2002, it was found that annual average concentrations and 50 percentile values may have had a small increasing trend, while peak ozone concentrations, expressed as 98 percentiles or as number of exceedance days tended to decrease in the period 1994.

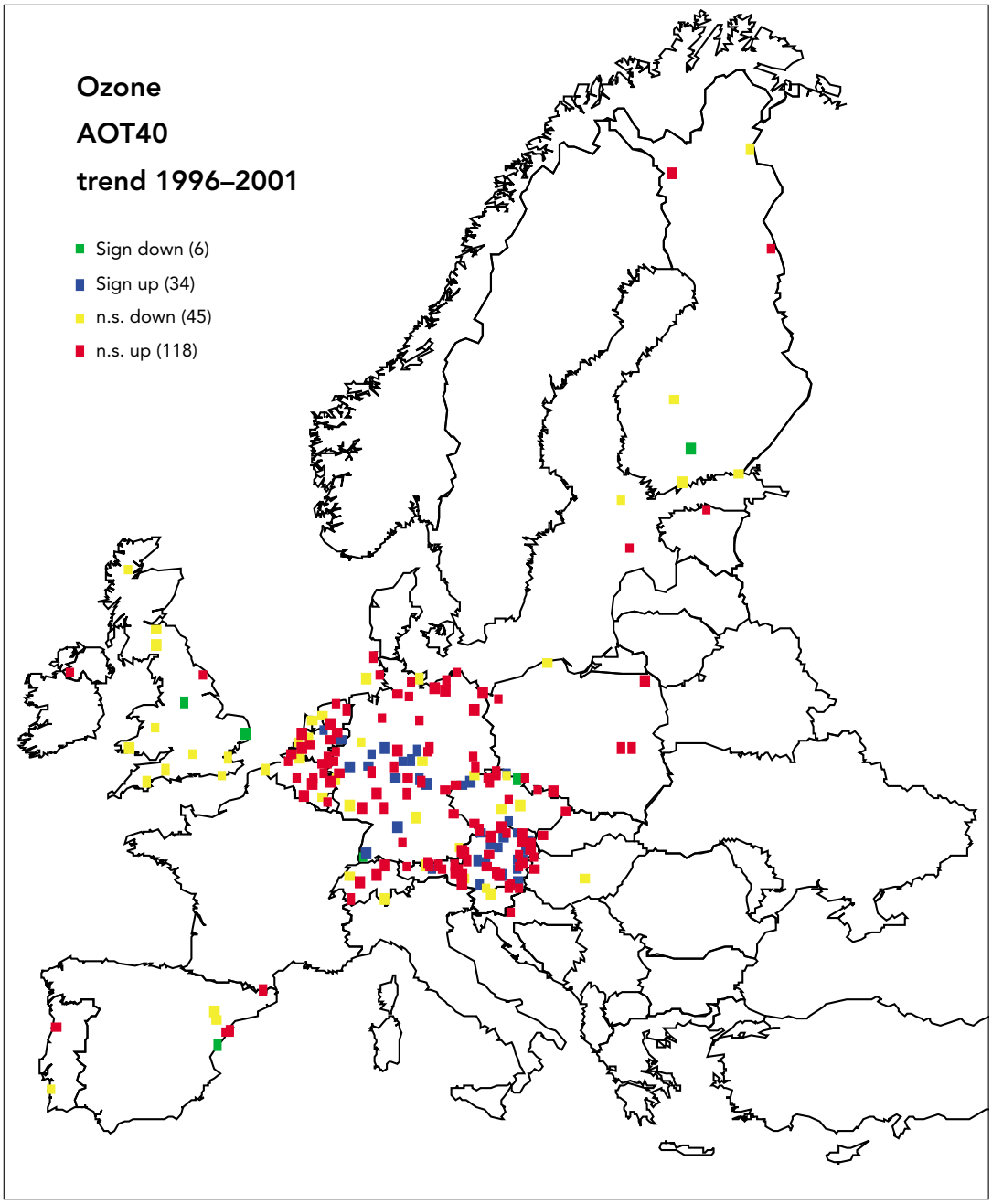
Map 4.1. **Classification of observed trends in the 26th highest maximum daily eight-hour mean concentration at all stations that reported data for at least five years in the period 1996–2001**



Model calculations indicate that small to moderate (25 %) emission reductions in ozone precursors as realised in this period have resulted in rather small changes in AOT40, AOT60 and daily maximum ozone concentrations (EMEP, 2003, in particular p. B.53). Much larger emission reductions, 70–80 % of the 1990 emissions, are required to effectively abate air pollution by ozone in Europe. Such emission reductions will not under current legislation be achieved until beyond 2010 (EEA, 2003b; 2001); a further reduction of about 30 % is foreseen towards 2010 under the national emission ceilings directive.

Classification of observed trends in the AOT40 value at all rural stations which reported data for at least five years in the period 1996–2001

Map 4.2.



5. Conclusions

This report presents a first evaluation of the reported exceedances of the threshold values for information and warning of the public during summer 2003. Information is based on non-validated monitoring data and hence the conclusions drawn are preliminary.

The following conclusions can be drawn from the analyses and summary presented in this report.

In the period 1995–2003 of reporting under the old ozone directive there has been little or no change in the reported exceedances of ozone threshold values. This is not unexpected as reductions in the EU emissions of nitrogen oxides and non-methane volatile organic compounds, the main ozone precursors, have so far been limited — about 30 % between 1990 and 2000.

The threshold for warning the population continues to be exceeded on a few occasions each year, while the threshold for informing the population is exceeded at most stations in most countries (outside northern Europe and Ireland) each year, generally more so in warm summers.

These exceedances are likely to recur in years with temperatures above the long-term average until there is a substantially larger decrease in precursor emissions. A further reduction of about 30 % is foreseen towards 2010 under the national emission ceilings directive.

While peak ozone concentrations seem to go down, ozone concentration statistics relevant to the target values set in the new ozone directive show little or no reduction in the period 1996–2000. Very few stations actually show a significant downward trend for these statistics.

Under current legislation and with the rate of turnover of the vehicle fleet, further reductions will gradually occur towards 2010, and further reductions may be necessary to achieve the target values of the new ozone directive.

Note that these conclusions are tentative, due to the uncertainties caused by year-to-year meteorological variations and the changes in the number and distribution of monitoring stations included in reporting under the ozone directives.

More detailed conclusions are listed below.

- Exceptionally long-lasting and spatially extensive episodes of high ozone concentrations occurred, mainly in the first half of August. These episodes appear to be associated with the extraordinarily hot temperatures over wide areas of Europe.

Exceedance of the warning threshold

- Exceedance of the warning threshold (hourly average concentrations of 360 µg/m^3) occurred in France for two hours at one station during August and in Italy and Romania in June for one hour at one station in each country. The maximum hourly ozone concentration reported in 2003 was 417 µg/m^3 at a monitoring station in France. For comparison, during the summer of 2002, when temperatures did not reach as high as in 2003, the threshold value for warning the population was exceeded a similar number of times and the highest hourly ozone concentration reported was 391 µg/m^3. Similar small numbers of exceedance of the warning threshold value occurred in earlier years. Hence, these exceedances are rare and are not strongly correlated with temperature.

Exceedance of the information threshold

- Exceedance of the information threshold (hourly average concentrations of 180 µg/m^3) occurred in 23 of the 31 countries reporting, 11 of them EU Member States. About 68 % of all stations (1 220 stations) reported one exceedance or more. On average, 5.4 exceedances per operational station were reported.

- The spatial distribution of exceedances of this threshold observed in summer 2003 was much more extensive than in previous summers. With the exception of the northern part of Europe, at least one day's

exceedance of this threshold was recorded in most of the countries reporting in summer 2003. The area with more than 10 exceedance days in 2003 covered mainly south-western Germany, Switzerland, northern and south-eastern France, Belgium, northern and central Italy and central Spain.

Preview: Exceedance of the new alert threshold

- Ozone concentrations reported in 2003 have been compared with the alert threshold value as defined in the new ozone directive (hourly average concentration of 240 µg/m³, measured over three consecutive hours). Single hourly average ozone concentrations higher than 240 µg/m³ were reported from the monitoring sites of 15 countries (Austria, Belgium, France, Germany, Greece, Italy, Luxembourg, the Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland and the United Kingdom). On average, an exceedance of the new 240 µg/m³ alert threshold was observed in summer 2003 at 27 % of the stations which reported an exceedance of the 180 µg/m³ information threshold.

Trends in ozone statistics and precursor emissions

- An analysis of trends over the past 12 years indicates that in the European Union the average number of hours per station when ozone concentration exceeded the information threshold of 180 µg/m³ was higher in summer 2003 than in all previous years. In France, this average number of exceedance hours was one third higher than in 1994, another year with frequent exceedances and a warm summer.

- The variation in the numbers of exceedance over the years cannot be explained by the variation in the emissions of ozone precursors since these emissions decreased gradually by about 30 % between 1990 and 2000. The closer correlation of exceedance numbers with temperature suggests that, if climate change were to result in warmer summers in Europe, more frequent exceedances of the ozone information threshold would be expected at the current emission levels.

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