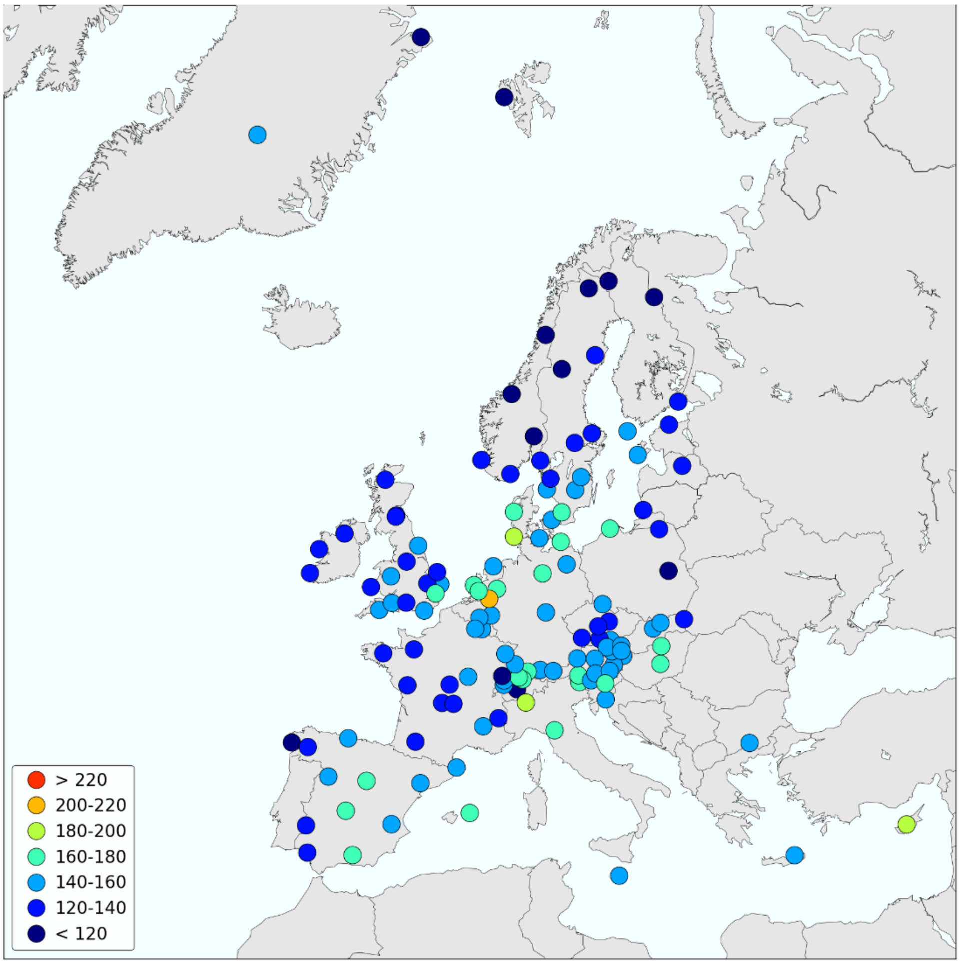
EMEP/CCC-Report 2/2023

EMEP

Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe

Ozone measurements 2021

Anne-Gunn Hjellbrekke and Sverre Solberg



Maximum ozone concentration 2021 µg/m^3

NILU
PO Box 100, NO-2027 Kjeller, Norway
Chemical Co-ordinator Centre of EMEP (CCC)

NILU : EMEP/CCC-Report 2/2023
REFERENCE : O-7726
DATE : SEPTEMBER 2023
ISBN : 978-82-425- 3131-5
ISSN : 2464-3920

EMEP Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Ozone measurements 2021

Anne-Gunn Hjellbrekke and Sverre Solberg

NILU
PO Box 100, NO-2027 Kjeller, Norway

Contents

Page

List of tables and figures

Ozone measurements 2021

1. Introduction

Ozone is a natural constituent of the atmosphere and plays a vital role in many atmospheric processes. However, man-made emissions of volatile organic compounds and nitrogen oxides have increased the photochemical formation of ozone in the troposphere. Until the end of the 1960s, the problem was basically believed to be one of the big cities and their immediate surroundings. In the 1970s, however, it was found that the problem of photochemical oxidant formation is much more widespread. The ongoing monitoring of ozone at rural sites throughout Europe shows that episodes of high concentrations of ground-level ozone occur over most parts of the continent every summer. During such episodes, the ozone concentrations can reach values above ambient air quality standards over large regions and lead to adverse effects for human health and vegetation. Historical records of ozone measurements in Europe and North America indicate that in the last part of the nineteenth century, the values were only about half of the average surface ozone concentrations measured in the same regions during the last 10-15 years (Bojkov, 1986; Volz and Kley, 1988).

The formation of ozone is due to a large number of photochemical reactions taking place in the atmosphere and depends on the temperature, humidity and solar radiation as well as the emissions of nitrogen oxides and volatile organic compounds. Together with the non-linear relationships between the primary emissions and the ozone formation, these effects complicate the abatement strategies for ground-level ozone and makes photochemical models crucial in addition to the monitoring data.

The EMEP ozone data from 2021 is presented in this report, which aims to give a short summary of the measurement data. A complete set of data can be downloaded from the web at https://ebas.nilu.no/data-access.

2. Critical levels

Ozone concentrations vary widely from region to region, with the time of year, and with time of day. Typically, high concentrations of ozone are observed in periods with anticyclonic conditions. Such episodes may lead to adverse environmental effects such as impact on human health, agricultural crops, forests and materials. National authorities and international organisations have therefore defined threshold levels for ozone. Within the World Health Organization (WHO), these are called “air quality guidelines”, within EU “target value”, “long-term objective” etc. and within The United Nations Economic Commission for Europe (UNECE) “critical levels”. The values of the various threshold levels vary among these organisations and, additionally, the health-based indicators are normally based on concentration (µg/m^3), whereas those related to vegetation are based on mixing ratio (ppb). An overview of various levels relevant for vegetation and human health is given in Table 1 and Table 2, respectively.

Table 1: Limit values for the protection of vegetation.

AOT40 (ppb hours)	Period	Reference	Comment
3000	3 months	CLRTAP (2011)	Critical level for crops and natural vegetation 1)
5000	1 April - 1 Oct	CLRTAP (2011)	Critical level for forest 1)
6000	3.5 months	CLRTAP (2011)	Critical level for horticultural crops
9000	1 May – 1 Aug	EU (2008)	EU's target value for vegetation 2,3)
3000	1 May - 1 Aug	EU (2008)	EU's long-term objective for vegetation 2,3)

1) ECE's AOT values should be based on the hours with global incoming radiation > 50 W/m^2
2) EU's AOT values should be based on the period 08-20 CET
3) The EU directive uses µg/m^3 and a factor 2 µg/m^3 = 1 ppb

Table 2: Limit values for the protection of human health.

Value (µg/m^3)	Averaging time (hours)	Ref	Description
180	1	EU (2008)	EU's information threshold
240	1	EU (2008)	EU's alert threshold
120	8 1)	EU (2008)	EU's target value. 8-hour mean value not to be exceeded on more than 25 days per year averaged over 3 years.
120	8 1)	EU (2008)	EU's long-term objective.
100	8 1)	WHO (2006)	WHO's air quality guideline
60	Peak season 2)	WHO (2021)	WHO 2021 air pollution guidelines

1) The highest 8-hour running mean value for each day calculated such that the 8-hour periods are assigned to the day on which the period ends.
2) Average of daily maximum 8-hour mean ozone concentration in the six consecutive months with the highest six-month running-average ozone concentration.

Within UNECE, scientific evidence has suggested that AOT40 based critical levels for vegetation (Gothenburg Protocol of 1999) should be replaced by stomatal flux-based critical levels. Flux-based critical levels have been developed to reflect that the real impacts depend on the amount of the pollutant transported into the leaves, whereas AOT40 is only based on the concentration of ozone in the atmosphere at the top of the plant canopy (Mills et al., 2011). Concentration-based critical levels (AOT_x) for estimating the risk of damage to vegetation are, however, still included where climatic data or suitable flux models are not available.

The concentration-based critical level is 3000 ppbh (3-months period) for agricultural crops and (semi-)natural vegetation and 5000 ppbh (6-months period) for forest trees. The former critical level for forest was 10 000 ppbh, and the new, lower level is seen as a clear improvement (CLRTAP, 2011). The "Modelling and mapping manual" strongly recommends that the critical levels should be based on the concentrations at the canopy-height, whereas the measurements normally are taken at 2 m height above ground. When meteorological measurements are not available, it is recommended to adjust the measured data to values relevant for the canopy-height by applying a given vertical profile depending on the type of vegetation.

Furthermore, the period for calculation of AOT40 should reflect the true growing season and should thus be adapted to the climate of the various regions in Europe, as specified in the Mapping Manual (CLRTAP, 2011). This leads to large differences in the applied period, from March-May in East Mediterranean to June-August in North Europe, which in turn has major consequences for the calculated AOT values. Since the aim of the present report is to document the general status of the ozone levels and not to provide any effect-based calculations, the same 3-months period (May-July) is used for all stations. This also corresponds to the period stated in the EU directive. Moreover, no adjustment of the measured values to take the canopy-height into account is done in this report. The measurement data are used directly.

EU has in the ozone directive (2002/3/EC) and the ambient air quality directive (2008/50/EC), defined a number of target values and long-term objectives for the protection of vegetation and human health. The target value for human health is 120 µg/m^3 (8h mean) which is not to be exceeded on more than 25 days per year averaged over 3 years. For protection of vegetation, AOT40 (May-July) should not exceed 18 000 µg/m^{3}h averaged over five years. In addition, information should be given to the population when hourly means exceed 180 µg/m^3 and an alert warning should be issued if hourly means exceed 240 µg/m^3.

EU's long-term objective for the protection of human health defines 120 µg/m^3 as the maximum daily 8-hour mean value to occur within a calendar year. The long-term objective for the protection of vegetation is defined as an AOT40-value of 6000 µg/m^{3}h for the period May-July. Community progress towards attaining the long-term objective using the year 2020 as a benchmark, shall be reviewed.

WHO has also defined air quality guidelines for the protection of human health and provided a guideline for ground-level ozone, in 2005 (WHO, 2006). WHO provided a revised set of guidelines in 2021 (WHO, 2021). The new guideline is 60 ug/m^3 as an average of the daily maximum 8h mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration. Additionally, within both WHO, EU and UN-ECE the parameter SOMO35, defined as the sum of maximum 8-hour ozone levels over 35 ppb, is used as an indicator for health effects without any specified threshold level.

Flux-based critical levels for various types of vegetation have been approved for inclusion in the LRTAP Convention's modelling and mapping manual (CLRTAP, 2011). The DO_3SE -model is used to estimate the stomatal ozone flux as a function of the ozone concentration at the leaf boundary layer, the transfer of ozone across this boundary layer, the stomatal conductance to ozone and the ozone deposition to the leaf cuticle. The accumulated stomatal flux over a specified time interval is estimated by the parameter POD_Y (the Phytotoxic Ozone Dose over a threshold flux of Y nmol m^{-2} PLA s^{-1}|). In this context, Y represents a detoxification threshold, below which it is assumed that any ozone absorbed by the plant will be detoxified. Thus, POD_Y can be described as the "effective dose" or "effective flux". POD_Y is the flux-based analogy to the concentration-based AOT.

3. Measurement network

Surface ozone measurements have been a part of the EMEP extended (voluntary) measurement activities since the third phase (1 January 1984–31 December 1986). The systematic collection and checking of data within EMEP, did not start until 1 January 1987. The measurement of ozone data within the EMEP region was a continuation of the OECD's oxidant data collection programme OXIDATE. Ozone data from the OXIDATE-project have been reported in three reports (Grennfelt and Schjoldager, 1984; Grennfelt et al., 1988 and 1989).

This report presents surface ozone data measured at rural background EMEP-sites during 2021, with emphasis on statistical summaries and geographical distributions. Earlier reports are listed in Annex 5.

Table 3 and Figure 1 show the location of the monitoring stations reporting data from whole or part of 2021. In total, 138 stations from 26 different countries reported data. One of these sites (Ispra) is operated by the Commission of the European communities in Italy.

Table 3: List of EMEP ozone monitoring stations in operation 2021.

Code	Station name	Latitude	Longitude	Altitude
AT0002R	Illmitz	47°46'00"N	16°46'00"E	117
AT0005R	Vorhegg	46°40'40"N	12°58'20"E	1020
AT0030R	Pillersdorf bei Retz	48°43'16"N	15°56'32"E	315
AT0032R	Sulzberg	47°31'45"N	09°55'36"E	1020
AT0034G	Sonnblick	47°03'16"N	12°57'30"E	3106
AT0038R	Gerlitzen	46°41'37"N	13°54'54"E	1895
AT0040R	Masenberg	47°20'53"N	15°52'56"E	1170
AT0041R	Haunsberg	47°58'23"N	13°00'58"E	730
AT0042R	Heidenreichstein	48°52'43"N	15°02'48"E	570
AT0043R	Forsthof	48°06'22"N	15°55'10"E	581
AT0045R	Dunkelsteinerwald	48°22'16"N	15°32'48"E	320
AT0046R	Gänserndorf	48°20'05"N	16°43'50"E	161
AT0047R	Stixneusiedl	48°03'03"N	16°40'36"E	240
AT0048R	Zoebelboden	47°50'19"N	14°26'29"E	899
AT0049R	Grebenzen bei St. Lamprecht	47°02'25"N	14°19'48"E	1648
AT0050R	Graz Lustbuehel	47°04'01"N	15°29'37"E	481
BE0001R	Offagne	49°52'40"N	05°12'13"E	430
BE0032R	Eupen	50°37'46"N	06°00'04"E	295
BE0035R	Vezin	50°30'12"N	04°59'22"E	160
BG0053R	Rojen peak	41°41'45"N	24°44'19"E	1750
CH0001G	Jungfraujoch	46°32'51"N	07°59'06"E	3578
CH0002R	Payerne	46°48'47"N	06°56'41"E	489
CH0003R	Tänikon	47°28'47"N	08°54'17"E	539
CH0004R	Chaumont	47°02'59"N	06°58'46"E	1137
CH0005R	Rigi	47°04'03"N	08°27'50"E	1031
CH0053R	Beromünster	47°11'23"N	08°10'32"E	797
CY0002R	Agia Marina	35°02'21"N	33°03'29"E	532
CZ0001R	Svratouch	49°44'06"N	16°02'03"E	735
CZ0003R	Košetice (NOAK)	49°35'00"N	15°05'00"E	534
CZ0005R	Churanov	49°04'00"N	13°36'00"E	1118
DE0001R	Westerland	54°55'32"N	08°18'35"E	12
DE0002R	Waldhof	52°48'08"N	10°45'34"E	74
DE0003R	Schauinsland	47°54'53"N	07°54'31"E	1205
DE0007R	Neuglobsow	53°10'00"N	13°02'00"E	62
DE0008R	Schmücke	50°39'00"N	10°46'00"E	937
DE0009R	Zingst	54°26'00"N	12°44'00"E	1
DE0054R	Zugspitze-Schneefernhaus	47°24'59"N	10°58'47"E	2671
DK0005R	Keldsnor	54°44'47"N	10°44'10"E	10
DK0010G	Villum Research Station, Station Nord	81°36'00"N	16°40'12"W	20
DK0012R	Risoe	55°41'37"N	12°05'09"E	3
DK0025G	Summit	72°34'48"N	38°28'48"W	3238
DK0031R	Ulborg	56°17'26"N	08°25'39"E	10
EE0009R	Lahemaa	59°30'00"N	25°54'00"E	32
EE0011R	Vilsandi	58°23'00"N	21°49'00"E	6
ES0001R	San Pablo de los Montes	39°32'52"N	04°20'55"W	917
ES0005R	Noia	42°43'41"N	05°55'25"W	683

Table 3, cont.

Code	Station name	Latitude	Longitude	Altitude
ES0006R	Mahón	39°52'00"N	04°19'00"E	78
ES0007R	Víznar	37°14'00"N	03°32'00"W	1265
ES0008R	Niembro	43°26'32"N	04°51'01"W	134
ES0009R	Campisábalos	41°16'52"N	03°08'34"W	1360
ES0010R	Cabo de Creus	42°19'10"N	03°19'01"E	23
ES0011R	Barcarrota	38°28'33"N	06°55'22"W	393
ES0012R	Zarra	39°05'10"N	01°06'07"W	885
ES0013R	Penausende	41°17'00"N	05°52'00"W	985
ES0014R	Els Torms	41°24'00"N	00°43'00"E	470
ES0016R	O Saviñao	43°13'52"N	07°41'59"W	506
ES0017R	Doñana	37°01'50"N	06°19'55"W	5
FI0009R	Utö	59°46'45"N	21°22'38"E	7
FI0018R	Virolahti III	60°31'48"N	27°40'03"E	4
FI0022R	Oulanka	66°19'13"N	29°24'06"E	310
FI0096G	Pallas (Sammaltunturi)	68°00'00"N	24°09'00"E	340
FR0008R	Donon	48°30'00"N	07°08'00"E	775
FR0009R	Revin	49°54'00"N	04°38'00"E	390
FR0010R	Morvan	47°16'00"N	04°05'00"E	620
FR0013R	Peyrusse Vieille	43°37'00"N	00°11'00"E	200
FR0014R	Montandon	47°18'00"N	06°50'00"E	836
FR0015R	La Tardière	46°39'00"N	00°45'00"W	133
FR0016R	Le Casset	45°00'00"N	06°28'00"E	1750
FR0017R	Montfranc	45°48'00"N	02°04'00"E	810
FR0018R	La Coulonche	48°38'00"N	00°27'00"W	309
FR0023R	Saint-Nazaire-le-Désert	44°34'10"N	05°16'44"E	605
FR0025R	Verneuil	46°48'53"N	02°36'36"E	182
FR0028R	Kergoff	48°15'43"N	02°56'38"W	307
FR0030R	Puy de Dôme	45°46'00"N	02°57'00"E	1465
GB0002R	Eskdalemuir	55°18'47"N	03°12'15"W	243
GB0006R	Lough Navar	54°26'35"N	07°52'12"W	126
GB0013R	Yarner Wood	50°35'47"N	03°42'47"W	119
GB0014R	High Muffles	54°20'04"N	00°48'27"W	267
GB0015R	Strath Vaich Dam	57°44'04"N	04°46'28"W	270
GB0031R	Aston Hill	52°30'14"N	03°01'59"W	370
GB0033R	Bush	55°51'31"N	03°12'18"W	180
GB0037R	Ladybower Res.	53°23'56"N	01°45'12"W	420
GB0038R	Lullington Heath	50°47'34"N	00°10'46"E	120
GB0039R	Sibton	52°17'38"N	01°27'47"E	46
GB0043R	Narberth	51°14'00"N	04°42'00"W	160
GB0045R	Wicken Fen	52°17'54"N	00°17'34"W	5
GB0048R	Auchencorth Moss	55°47'32"N	03°14'34"W	260
GB0049R	Weybourne	52°57'02"N	01°07'19"E	16
GB0050R	St. Osyth	51°46'41"N	01°04'56"E	8
GB0052R	Lerwick	60°08'21"N	01°11'07"W	85
GB0053R	Charlton Mackrell	51°03'23"N	02°41'00"W	54
GB1055R	Chilbolton Observatory	51°08'59"N	01°26'18"W	78
GR0001R	Aliartos	38°22'00"N	23°05'00"E	110
GR0002R	Finokalia	35°19'00"N	25°40'00"E	250
HU0002R	K-puszta	46°58'00"N	19°35'00"E	125
HU0017R	Nyirjes	47°53'59"N	19°56'48"E	670
IE0001R	Valentia Observatory	51°56'23"N	10°14'40"W	11
IE0031R	Mace Head	53°10'00"N	09°30'00"W	15
IT0004R	Ispra	45°48'00"N	08°38'00"E	209
IT0009R	Mt Cimone	44°11'00"N	10°42'00"E	2165
IT0014R	Capo Granitola	37°34'16"N	12°39'35"E	5
IT0019R	Monte Martano	42°48'20"N	12°33'56"E	1090
LT0015R	Preila	55°21'00"N	21°04'00"E	5
LV0010R	Rucava	56°09'43"N	21°10'23"E	18
LV0016R	Zoseni	57°08'07"N	25°54'20"E	188
MK0007R	Lazaropole	41°32'10"N	20°41'38"E	1332
MT0001R	Giordan lighthouse	36°04'24"N	14°13'09"E	167
NL0007R	Eibergen	52°05'00"N	06°34'00"E	20
NL0009R	Kollumerwaard	53°20'02"N	06°16'38"E	1
NL0010R	Vredepeel	51°32'28"N	05°51'13"E	28
NL0091R	De Zilk	52°18'00"N	04°30'00"E	4
NL0644R	Cabauw Wielsekade	51°58'28"N	04°55'25"E	1

Table 3, cont.

Code	Station name	Latitude	Longitude	Altitude
NO0002R	Birkenes II	58°23'19"N	08°15'07"E	219
NO0015R	Tustervatn	65°50'00"N	13°55'00"E	439
NO0039R	Kårvatn	62°47'00"N	08°53'00"E	210
NO0042G	Zeppelin mountain (Ny-Ålesund)	78°54'24"N	11°53'18"E	474
NO0043R	Prestebakke	59°00'00"N	11°32'00"E	160
NO0052R	Sandve	59°12'00"N	05°12'00"E	15
NO0056R	Hurdal	60°22'21"N	11°04'41"E	300
PL0002R	Jarczew	51°49'00"N	21°59'00"E	180
PL0003R	Sniezka	50°44'00"N	15°44'00"E	1603
PL0004R	Leba	54°45'00"N	17°32'00"E	2
PL0005R	Diabla Gora	54°09'00"N	22°04'00"E	157
SE0005R	Bredkälen	63°51'00"N	15°20'00"E	404
SE0013R	Esrange	67°53'00"N	21°04'00"E	475
SE0014R	Råö	57°23'38"N	11°54'50"E	5
SE0018R	Asa	57°09'52"N	14°46'57"E	180
SE0019R	Östad	57°57'09"N	12°24'11"E	65
SE0020R	Hallahus	56°02'34"N	13°08'53"N	190
SE0022R	Norunda Stenen	60°05'09"N	17°30'19"E	45
SE0032R	Norra-Kvill	57°49'00"N	15°34'00"E	261
SE0035R	Vindeln	64°15'00"N	19°46'00"E	225
SE0039R	Grimsö	59°43'41"N	15°28'19"E	132
SI0008R	Iskrba	45°34'00"N	14°52'00"E	520
SI0031R	Zarodnje	46°25'43"N	15°00'12"E	770
SI0032R	Krvavec	46°17'58"N	14°32'19"E	1740
SK0002R	Chopok	48°56'00"N	19°35'00"E	2008
SK0004R	Stará Lesná	49°09'00"N	20°17'00"E	808
SK0006R	Starina	49°03'00"N	22°16'00"E	345
SK0007R	Topolniky	47°57'36"N	17°51'38"E	113

The monitoring stations are selected by the countries. Information about the ozone data quality, calibration and maintenance procedures was in 2000 collected from the participants (Aas et al., 2000).

The UV absorption method is the only measurement method in use in 2021. The monitors measure the mixing ratio (in nmol/mol), whereas all data presented in this report are given in µg/m^3. The CCC accepts data submissions in both nmol/mol and ug/m3, however, if submitting in ug/m3 the temperature and pressure used to convert from nmol/mol to ug/m3 should be provided in the meta data. The only site not using the standard conditions of 20 C and 1013 hPa is the high-altitude site Jungfraujoch, where annual mean conditions (-8˚C, 653 hPa) are used. For sites reporting in mixing ratio, data are converted to ug/m3 using standard conditions, corresponding to a conversion factor of 2.0.

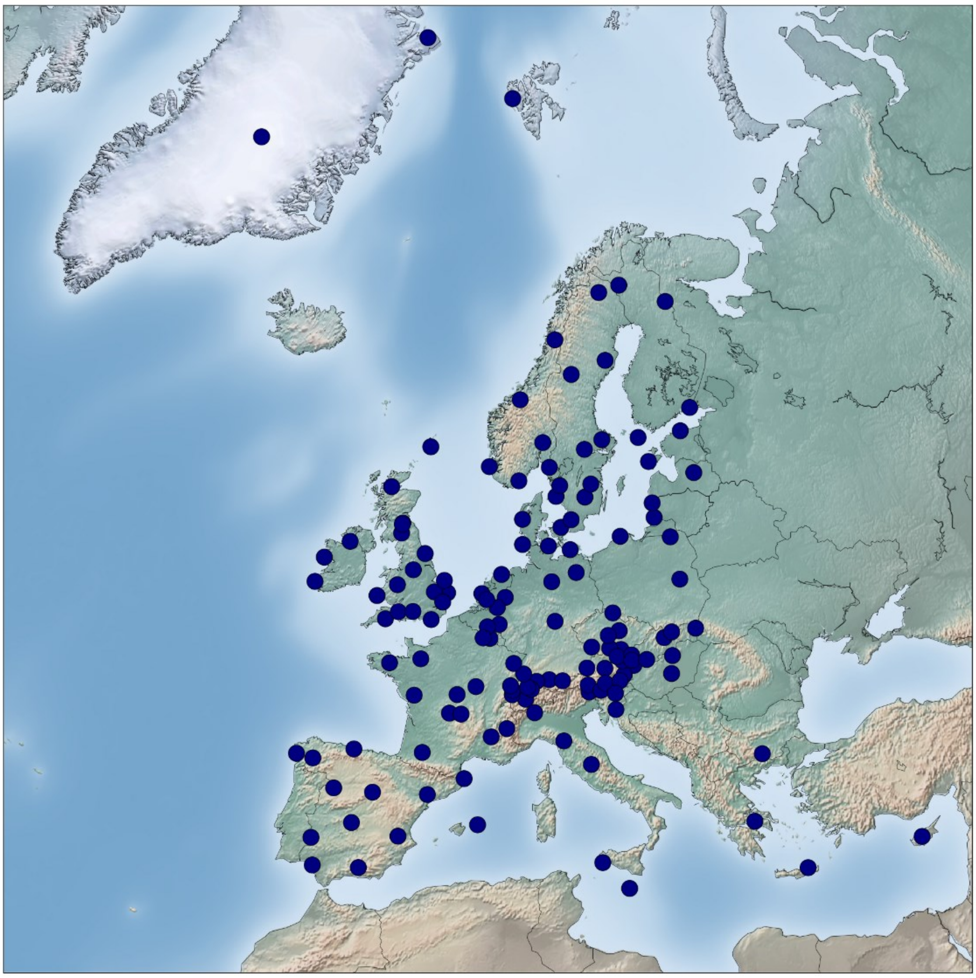


Figure 1: Location of the monitoring stations in 2021.

4. Data completeness

The annual means and data capture (number of valid measurements in percent of the total number of measurements) for each station is given in Table 1, Annex 1. The data capture is in general good, 121 stations have a data capture above 90%.

Missing data in the measurement series may be critical when calculating aggregated ozone metrics, especially in summer when the highest ozone concentrations occur. In particular, calculations of AOT40 values may be strongly affected by missing data, and a correction is necessary in order to obtain comparable calculations. In the mapping of AOT40, a data capture of 85% is required and an adjustment proportional to the number of missing data is applied, i.e. exposure index divided by the fraction of data available. This correction gives a good approximation when the missing data are randomly scattered throughout the dataset, but a better correction is needed for larger gaps in the dataset. Calculations of percentiles are less sensitive to missing data, and a data capture of 75% is regarded as sufficient for the mapping.

5. Concentration summaries and episodes

Overall, the number of ozone exceedances for regional sites in 2021 was very low, and concentrations above 200 µg/m^3 were only measured at one site, Vredepeel, which is unusual comparing with the last years. During the past decades, the summers of 2003 and 2006 had very large number of exceedances, principally due to very warm weather during summer (EEA, 2011).

The highest one-hour ozone concentrations in 2021 were measured at Vredepeel, the Netherlands (201 µg/m^3, June 14), at Ispra, Italy (191 µg/m^3, July 23) and Agia Marina, Cyprus (190 µg/m^3, July 30) (Figure 2; Table A.1, Annex 1). The lowest maximum concentrations were measured at Zeppelin Mountain at Spitsbergen (95 µg/m^3) and Villum Research Station on Greenland (101 µg/m^3).

As documented in the EMEP Status Report 1/2023 (Fagerli et al., 2023) and the Interim Annual Assessment Report for 2021 (Tarrason et al., 2022), 2021 was a particularly ozone poor year. Tarrason et al explain this with a combination of cooler summer temperatures over Central Europe in 2021 due to a La Niña effect and a marginal effect from Covid lockdown measures although this was very much reduced in 2021 compared to 2020. They estimate that the European NOx emission reduction in 2021 due to lockdown was of the order of only 3 %. The effect on European ozone would thus be minor. Likely, the effect of lower summer surface temperatures over Central Europe is thought to be the main reason for the low ozone levels and few exceedances in 2021.

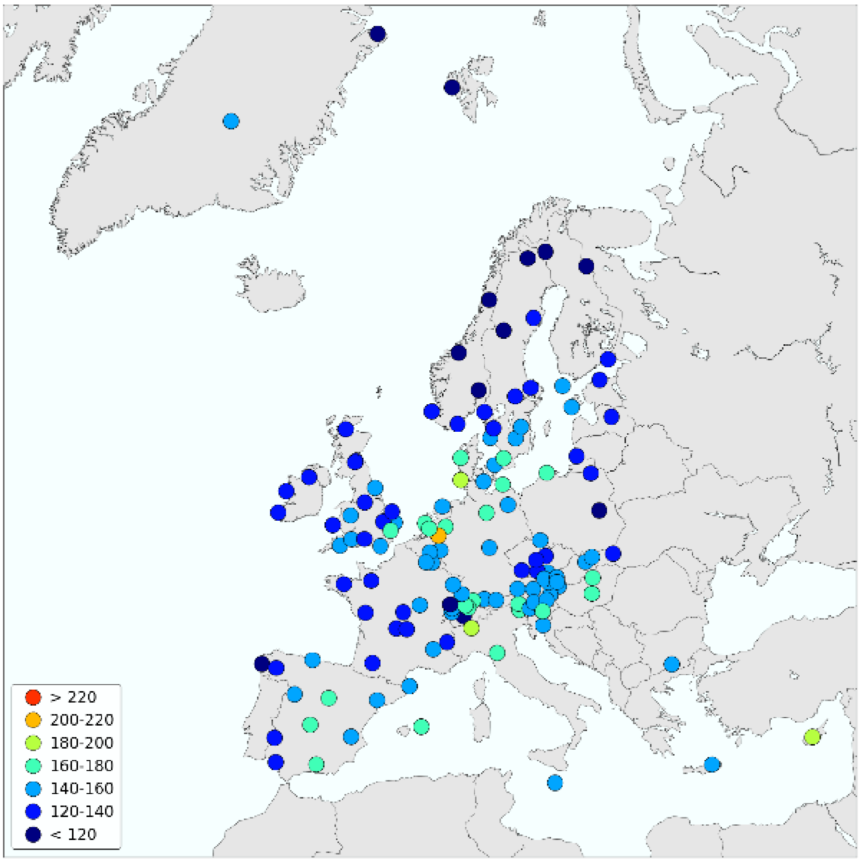


Figure 2: Maximum concentration 2021. Unit µg/m^3

Southeast Europe, including the Mediterranean plus the Baltic, and the southern part of Scandinavia was an exception to this meteorological pattern and showed significantly higher summer temperatures than the summer averages. Of these regions, only southeast Europe has the potential to form ozone in significant quantities which is seen from Figure 2, showing highest levels in Italy, Crete and Cyprus. In contrast to this, the highest hourly ozone levels occurred in June the Netherlands (Table A.1, Annex 1) and this corresponds to the June ozone episode discussed in the EMEP Status Report 1/2023 (Fagerli et al., 2023).

As a consequence of the low ozone concentrations, exceedances of the information threshold of 180 µg/m^3 were observed at just four sites in 2021 (Agia Marina, Ispra, Vredepeel and Westerland), far less than the usual 20-30 sites. In the unusual warm summers of 2003 and 2006, the information threshold was exceeded at 81 and 69 sites respectively.

Graphical distributions of the 95-percentile for stations with data capture higher than 75% are shown in Figure 23. The lowest values are found in Scandinavia, Ireland and the UK, where the 95-percentiles are below 90 µg/m^3. The concentrations are higher in France, Poland and the Baltics, where the 95-percentiles generally ranges from 100-120 µg/m^3, and at its highest in the Southeastern parts of Europe and around the Mediterranean, where the 95-percentile values are above 120 µg/m^3.

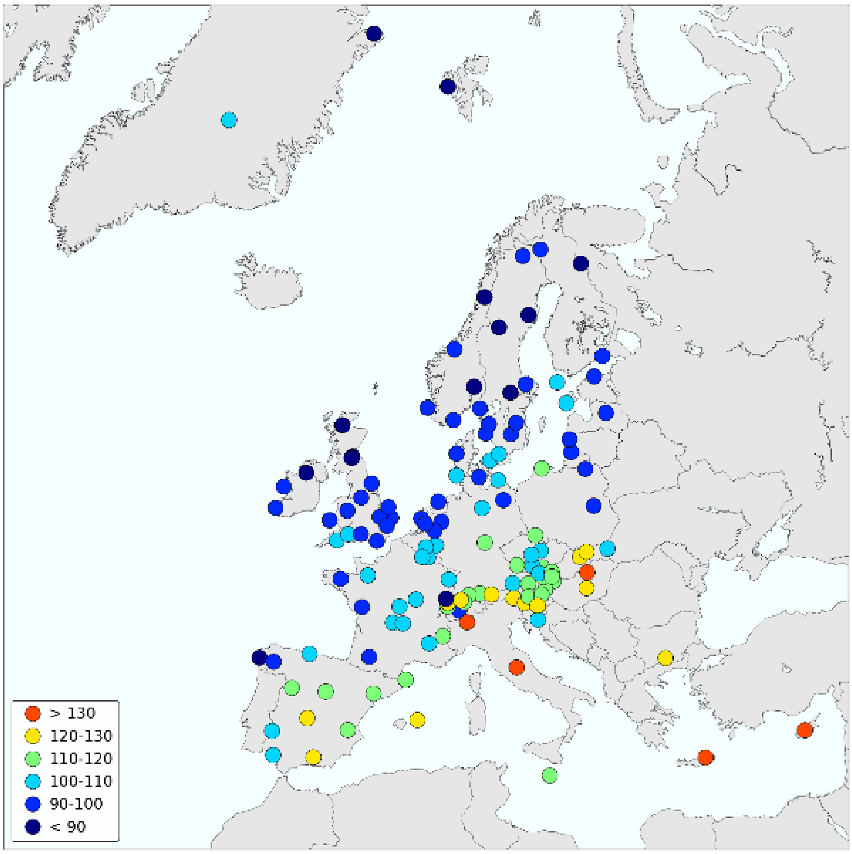


Figure 3: Hourly 95-percentile April-September 2021. Unit µg/m^3

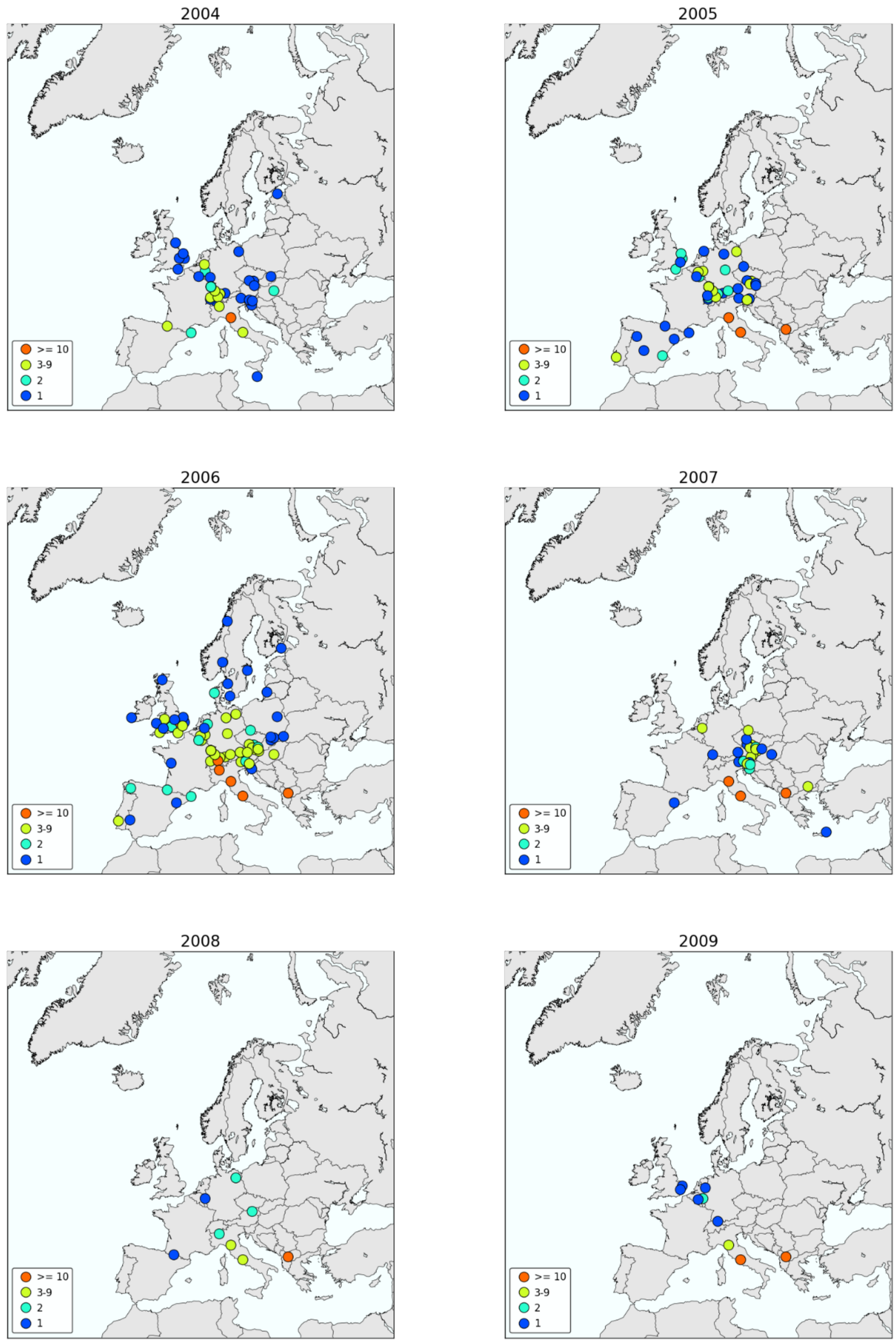


Figure 4: Number of exceedances of the threshold value of 180 µg/m^3 2004-2021. (Unit: number of days.) Stations with zero exceedances are not shown.

Figure 4, cont.:

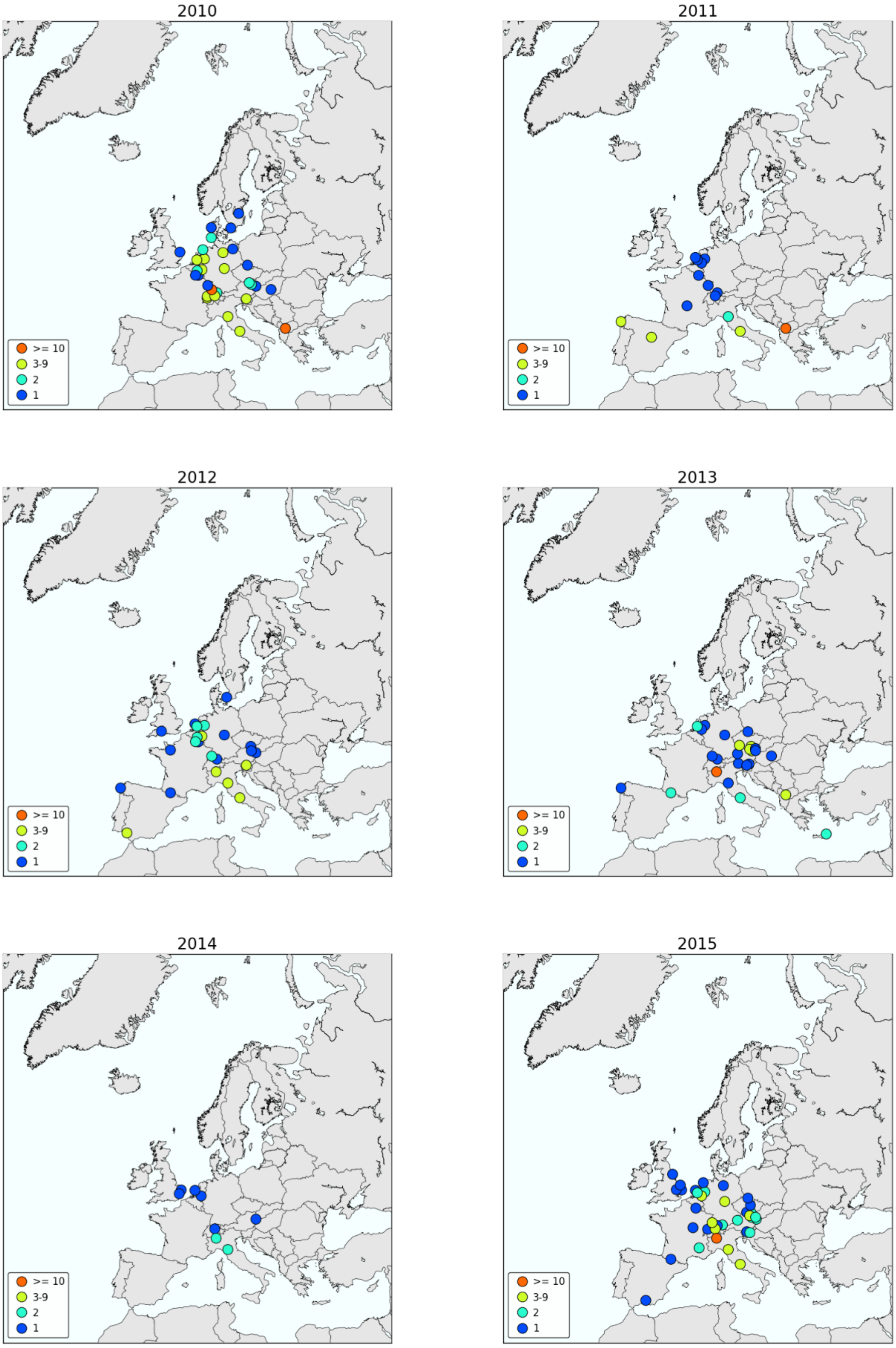
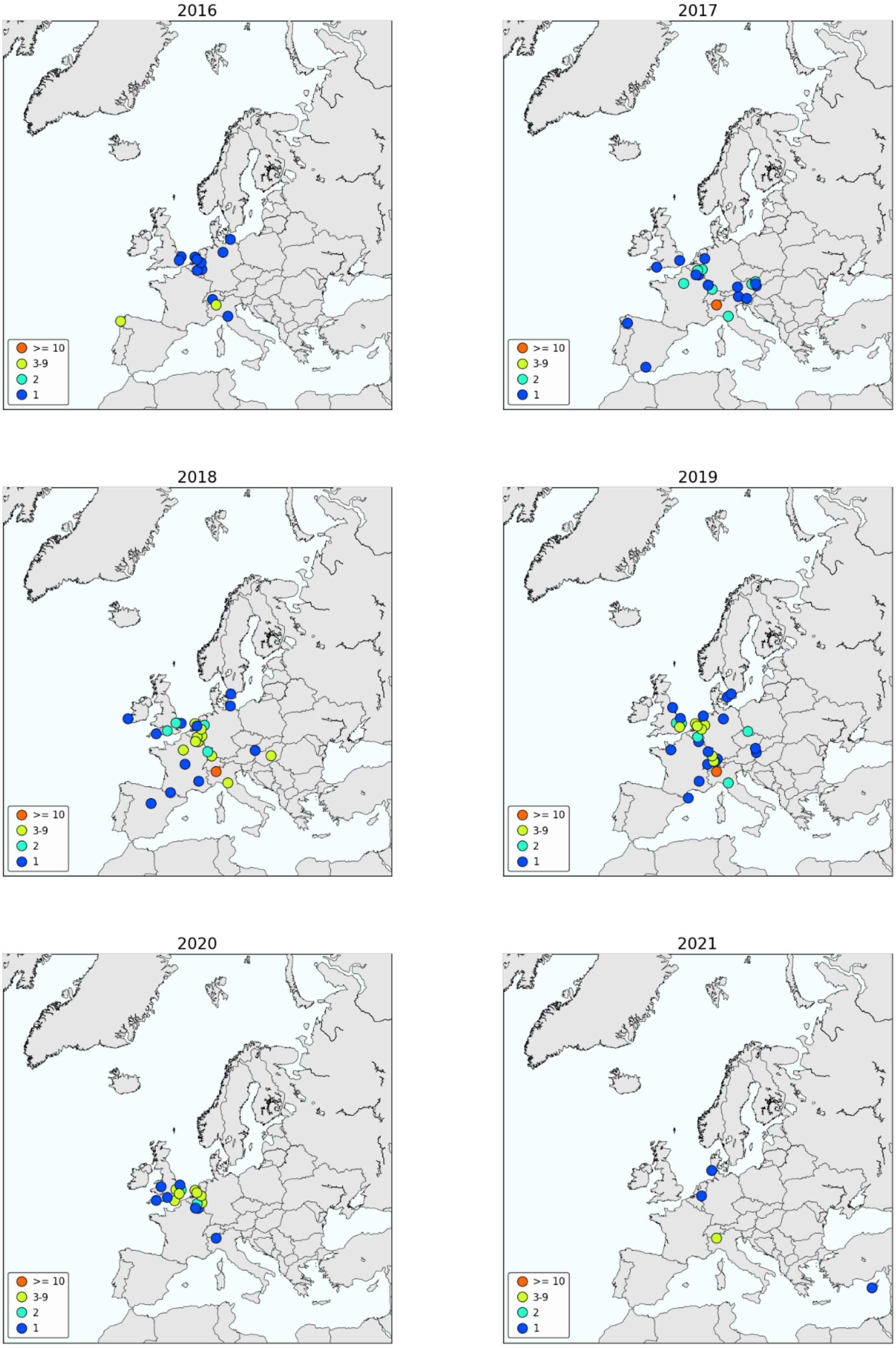


Figure 4, cont.:



6. Calculation of AOT40

AOT40 for forest and agricultural crops for 2021 are shown in Table A.1, Annex 1, and the corresponding geographical distributions of AOT40 are shown in Figure 5. The maps of AOT40 show a general increasing gradient from west to east and from north to south. Low values are found in most parts of Northern Europe, while the highest values are found in Central Europe. Two sites in Europe, both in Eastern Mediterranean (Greece, Cyprus) had 3-months AOT40 (May-July) values above 15 000 ppbh. The critical level for forest (5 000 ppbh) for 6-months AOT40 (April-September) was exceeded at numerous sites in Central, Eastern and Southern Europe.

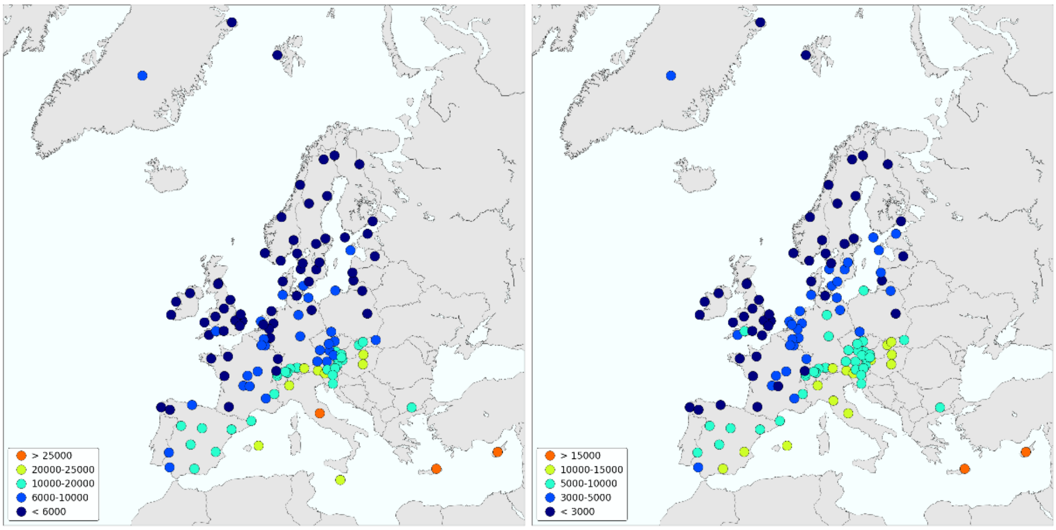


Figure 5: AOT40 2021 08-20 CET; April-September (left) and May-July (right). Unit: ppb hours.

7. Update

The data compiled in this report represent the quality assured and quality-controlled data at present. If errors are detected in the future, the data will be corrected in the database. It is important that users make certain they have access to the most recent version of the data. For the data presented here, the latest alteration was August, 2023.

All EMEP measurement data can be downloaded at http://ebas.nilu.no/data.access or sent upon request to ebas@nilu.no. Information on EMEP and the measurement network are available at http://www.emep.int and http://www.nilu.no/projects/ccc.

8. References

Aas, W., Hjellbrekke, A.-G., Schaug, J. (2000) Data quality 1998, quality assurance and field comparisons. Kjeller, Norwegian Institute for Air Research (EMEP/CCC-Report 6/2000).

Ashmore, M.R., Wilson, R.B., eds. (1992) Critical levels of air pollutants for Europe. Background papers prepared for UN-ECE workshop on critical levels, Egham, U.K. 23-26 March 1992. London, Department of the Environment.

Bojkov, R.D. (1986) Surface ozone during the second half of the nineteenth century. *J. Clim. Appl. Meteorol., 25*, 343-352.

CLRTAP (2011) Mapping critical levels for vegetation. In: *Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trend, chapter 3*.
URL: http://icpvegetation.ceh.ac.uk/manuals/mapping_manual.html.

Collivignarelli, M.C., Abbà, A., Bertanza, G., Pedrazzani, R., Ricciardi, P., Carnevale, M. M. (2020) Lockdown for CoViD-2019 in Milan: What are the effects on air quality?. *Sci.Total Environ.*, *732,* 139280.
URL: https://doi.org/10.1016/j.scitotenv.2020.139280.

EEA (2011) Air pollution by ozone across Europe during summer 2010. Copenhagen, European Environment Agency (EEA Technical report No 6/2011). URL: http://www.eea.europa.eu/publications/air-pollution-by-ozone-across.

Fagerli, H. et al. (2023) EMEP status report 1/2023. Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. Oslo, Norwegian Meteorological Institute MSC-W (EMEP report 1/2023). URL: https://emep.int/publ/reports/2023/EMEP_Status_Report_1_2023.pdf

Forberg, E., Aarnes, H., Nilsen, S., Semb, A. (1987) Effect of ozone on net photosynthesis in oat (*Avena sativa*) and duckweed (*Lemna gibba*). *Environ. Poll., 47,* 285-291.

Führer, J., Achermann, B., eds. (1994) Critical levels for ozone. A UN-ECE workshop report. Bern, Swiss Federal Station for Agricultural Chemistry.

Grange, S. K., Lee, J.D., Drysdale, W.S., Lewis, A.C., Hueglin, C., Emmenegger, L. and Carslaw, D.C. (2021) COVID-19 lockdowns highlight a risk of increasing ozone pollution in European urban areas. *Atmos. Chem. Phys., 21*, 4169–4185.
URL: https://doi.org/10.5194/acp-21-4169-2021.

Grennfelt, P., Hoem, K., Saltbones, J., Schjoldager, J. (1989) Oxidant data collection in OECD-Europe 1985-87 (OXIDATE). Report on ozone, nitrogen dioxide and peroxyacetyl nitrate. October 1986-March 1987, April-September 1987 and October-December 1987. Lillestrøm (NILU OR 63/89).

Grennfelt, P., Saltbones, J., Schjoldager, J. (1988) Oxidant data collection in OECD-Europe 1985-87 (OXIDATE). Report on ozone, nitrogen dioxide and peroxyacetyl nitrate. October 1985 – March 1986 and April – September 1986. Lillestrøm (NILU OR 31/88).

Grennfelt, P., Schjoldager, J. (1984) Photochemical oxidants in the troposphere: a mounting menace. *Ambio, 13*, 61-67.

Henne, S., Brunner, D., Folini, D., Solberg, S., Klausen, J., Buchmann, B. (2010) Report on supersite representativeness and representativeness assessment method. *Atmos. Chem. Phys., 10*, 3561-3581.

Kärenlampi, L., Skärby, L., eds. (1996) Critical levels for ozone in Europe. Testing and finalizing the concepts. UN-ECE Workshop Report. Kuopio, University of Kuopio.

Menut, L., Bessagnet, B., Siour, G., Mailler, S., Pennel, R., Cholakian, A., (2020) Impact of lockdown measures to combat Covid-19 on air quality over western Europe. *Sci. Total Environ., 741,* 140426. URL: https://doi.org/10.1016/j.scitotenv.2020.140426.

Mills, G., Pleijel, H., Braun, S., Büker, P., Bermejo, V., Calvo, E., Danielsson, H., Emberson, L., González Fernández, I., Grünhage L., Harmens, H., Hayes, F., Karlsson, P.-E., Simpson, D. (2011) New stomatal flux-based critical levels for ozone effects on vegetation. *Atmos. Environ., 45*, 5064-5068. URL: hhtps.//10.1016/j.atmosenv.2011.06.009.

Ordóñez, C., Garrido-Perez, J. M., García-Herrera, R. (2020) Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes. *Sci. Total Environ.,* 141322. URL: https://doi.org/10.1016/j.scitotenv.2020.141322.

Overland, J., Hanna, E., Hanssen-Bauer, I., Kim, S.-J., Walsh, J. E., Wang, M., Bhatt, U. S., Thoman, R. L., and Ballinger, T. J. (2019) Surface Air Temperature, in Arctic Report Card 2019. NOAA. URL: https://arctic.noaa.gov/Portals/7/ArcticReportCard/Documents/ArcticReportCard_full_report2019.pdf.

Roemer, M., Boersen, G., Builtjes, P., Esser, P. (1996) The budget of ozone and precursors over Europe calculated with the LOTOS-model. In: *Trends of tropospheric ozone over Europe*. By M. Roemer. Amsterdam, University of Utrecht. pp. 93-116.

Tarrasón, L., Hamer, P., Fjæraa, A.M., Meleux, F., Colette, A., Ung, A., Kuenen, J., Droste, A., Guevara, M. (2022) Interim Annual Assessment Report for 2021. European air quality in 2021. Copernicus Atmosphere Monitoring Service (CAMS) /ECMWF Copernicus Report. URL: https://policy.atmosphere.copernicus.eu/reports/CAMS271_IAR_2021_Final.pdf

Volz, A., Kley, D. (1988) Evaluation of the Montsouris series of ozone measurements made in the nineteenth century. *Nature, 332*, 240-242.

WHO (2006) Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen, World Health Organization Regional Office for Europe.

WHO (2021) WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. URL: https://apps.who.int/iris/handle/10665/345329

WMO (2020) WMO Statement on the State of the Global Climate in 2019. (WMO-No. 1248). URL: https://library.wmo.int/index.php?lvl=notice_display&id=21700#.YUBmwn2xWUk.

9. Acknowledgements

A large number of co-workers in participating countries have been involved in the many steps of collection of EMEP's measurement data. A list of participating institutes can be seen below. The staff at CCC wishes to express their gratitude and appreciation for continued good co-operation and efforts.
Closer at home, secretarial work, data flow and data base maintenance has been performed by Berit Modalen, Ann Mari Fjæraa and Mona Waagsbø.

10. List of participating institutions

Armenia	Environmental Monitoring and Information Center
Austria	Umweltbundesamt Provincial Government of Tyrol Provincial Government of Carinthia Environment Institute Vorarlberg Provincial Government Styria Provincial Government Salzburg Provincial Government Lower Austria
Belgium	Belgian Interregional Environment Agency (IRCEL – CELINE)
Bulgaria	Executive Environment Agency of Bulgaria
Commission of the European Communities	Joint Research Center. EC-JRC
Cyprus	Ministry of Labour and Social Insurance
Czech Republic	Czech Hydrometeorological Institute
Denmark	Department of Environmental Science, Aarhus University
Estonia	Estonian Environmental Research Centre
Finland	Finnish Meteorological Institute (FMI)
France	IMT Lille Douai
Germany	Umweltbundesamt
Greece	University of Crete Hellenic Ministry of the Environment and Energy
Hungary	Hungarian Meteorological Service
Ireland	Environmental Protection Agency (EPA) Ricardo – AEA
Italy	CNR-ISAC
Latvia	Latvian Environment, Geology and Meteorology Agency
Lithuania	SRI Center for Physical Sciences and Technology
Macedonia	Ministry of Environment and Physical Planning
Malta	Department of Geoscience, University of Malta
Netherlands	National Institute for Public Health and the Environment (RIVM)
Norway	The climate and environmental research institute NILU
Poland	Institute of Meteorology and Water Management Institute of Environmental Protection
Slovakia	Slovak Hydrometeorological Institute
Slovenia	Slovenian Environment Agency
Spain	Ministerio para la Transicion Ecologica, Agencia Estatal de Meteorologia
Sweden	Swedish Environmental Research Institute (IVL)
Switzerland	Swiss Federal Laboratory of Materials Science and Technology (EMPA)
United Kingdom	Ricardo – AEA

Annex 1

Statistical summary 2021

Table A.1: Statistical summary of ozone data 2021.

Station code	Station name	Annual average µg/m³	Annual data capture %	95-percentile Apr-Sep µg/m³	99-percentile Apr-Sep µg/m³	Maximum concentration		# days>180 days	AOT40 08-20 Apr-Sep ppbh	AOT40 08-20 May-Jul ppbh	SOMO35 ppbd
						Value µg/m³	Date				
AT0002R	Illmitz	60,6	94,5	117,6	137,2	162,4	2020-05-19	0	15528	7176	3139
AT0005R	Vorhegg	69,2	93,6	111,0	129,5	148,9	2020-07-10	0	8211	3386	2787
AT0030R	Pillersdorf bei Retz	62,0	94,4	115,8	126,2	142,3	2020-05-09	0	12845	5604	2769
AT0032R	Sulzberg	77,8	95,3	125,3	136,2	158,1	2020-08-01	0	14648	6582	3845
AT0034G	Sonnblick	94,3	92,8	121,8	131,5	145,5	2020-08-02	0	49232	23259	11011
AT0038R	Gerlitzen	88,3	95,3	120,2	132,5	147,2	2020-08-02	0	16396	6939	4868
AT0040R	Masenberg	77,1	95,2	119,5	130,2	167,3	2020-07-31	0	12014	5181	3521
AT0041R	Haunsberg	68,5	94,9	121,9	136,2	161,0	2020-07-31	0	12492	5959	3244
AT0042R	Heidenreichstein	55,6	94,1	110,9	121,1	135,2	2020-04-09	0	9669	4118	2202
AT0043R	Forsthof	64,4	95,1	113,0	126,0	142,1	2020-07-31	0	10066	4362	2666
AT0045R	Dunkelsteinerwald	49,9	95,1	107,9	122,1	144,2	2020-08-12	0	8102	3309	1879
AT0046R	Gänserndorf	55,3	95,2	113,3	127,9	152,9	2020-05-19	0	12395	6044	2548
AT0047R	Stixneusiedl	59,8	95,5	112,2	131,7	151,9	2020-05-19	0	12244	5881	2724
AT0048R	Zoebelboden	72,7	92,0	118,1	134,3	151,4	2020-07-31	0	9764	3959	2994
AT0049R	Grebenzen bei St. Lamprecht	85,2	90,5	116,4	129,7	138,2	2020-04-10	0	11674	4907	4186
AT0050R	Graz Lustbuehel	55,0	94,8	112,8	125,0	138,2	2020-04-10	0	9334	3987	2496
BE0001R	Offagne	61,4	97,2	119,0	137,5	186,0	2020-09-16	1	12349	4768	2270
BE0032R	Eupen	56,9	94,2	119,5	145,6	189,0	2020-08-08	3	12978	5666	2139
BE0035R	Vezin	52,7	95,6	122,5	153,0	211,5	2020-08-12	2	13263	5590	2214
BG0053R	Rojen peak	88,5	94,2	124,3	134,0	148,4	2020-08-23	0	18603	7252	5108
CH0001G	Jungfraujoch	69,1	96,9	90,7	98,0	109,9	2020-07-05	0	26346	12815	6706
CH0002R	Payerne	53,3	99,2	115,9	131,8	152,3	2020-07-31	0	13376	6280	2552
CH0003R	Tänikon	53,6	99,3	120,8	134,4	161,6	2020-08-11	0	14819	7039	2712
CH0004R	Chaumont	79,6	95,7	128,8	139,3	152,9	2020-06-25	0	17329	7304	3824
CH0005R	Rigi	78,8	99,3	126,0	136,2	153,0	2020-06-25	0	17815	8119	3903
CH0053R	Beromũnster	70,1	99,1	124,9	138,9	158,1	2020-07-31	0	16735	7589	3218
CY0002R	Ayia Marina	93,8	95,4	129,2	138,1	153,4	2020-03-05	0	26914	12573	5974

Station code	Station name	Annual average µg/m³	Annual data capture %	95-percentile Apr-Sep µg/m³	99-percentile Apr-Sep µg/m³	Maximum concentration		# days>180 days	AOT40 08-20 Apr-Sep ppbh	AOT40 08-20 May-Jul ppbh	SOMO35 ppbd
						Value µg/m³	Date				
CZ0001R	Svratouch	68,8	93,2	116,7	128,1	142,0	2020-08-13	0	14446	6079	2885
CZ0003R	Kosetice	60,9	94,3	111,3	122,3	140,8	2020-04-17	0	10873	3956	2301
CZ0003R	Kosetice, Tower height 50 m	68,3	97,5	117,4	130,2	142,0	2020-08-09	0	15319	6235	2869
CZ0003R	Kosetice, Tower height 8 m	61,1	92,7	109,7	121,2	133,1	2020-08-08	0	11331	4486	2124
CZ0003R	Kosetice, Tower height 230 m	76,4	97,4	121,7	133,5	151,5	2020-09-16	0	16638	6840	3635
CZ0005R	Churanov	73,5	92,0	116,7	126,3	139,3	2020-05-08	0	12689	5266	2954
DE0001R	Westerland	68,5	97,5	102,7	127,0	151,0	2020-08-16	0	7328	2913	2411
DE0002R	Waldhof	54,6	95,7	118,3	141,5	177,4	2020-09-23	0	12655	4802	2277
DE0003R	Schauinsland	75,1	93,5	122,0	131,0	159,1	2020-07-31	0	13036	5490	2952
DE0007R	Neuglobsow	51,9	98,7	108,1	128,3	160,6	2020-09-23	0	9073	3258	1956
DE0008R	Schmücke	71,3	95,1	122,8	135,8	152,0	2020-04-24	0	13380	4825	3052
DE0009R	Zingst	61,7	95,5	102,9	123,6	153,4	2020-09-23	0	7249	3081	1884
DE0054R	Schneefernerhaus	92,3	98,3	123,5	132,7	145,6	2020-08-01	0	19603	8746	5599
DK0005R	Keldsnor	61,3	89,9	96,9	122,3	147,9	2020-08-16	0	3767	1393	1379
DK0010G	Villum Research Station, Nord	65,9	88,2	87,4	94,1	104,8	2020-04-18	0	735	26	1274
DK0012R	Risoe	62,3	91,4	103,7	125,4	151,4	2020-08-15	0	6534	2453	1795
DK0025G	Summit	79,9	99,2	103,1	112,5	123,5	2020-05-20	0	6445	4460	2710
DK0031R	Ulborg	61,8	88,1	94,2	113,0	152,9	2020-08-07	0	3648	1181	1343
EE0009R	Lahemaa	52,5	99,8	90,2	101,2	122,3	2020-06-28	0	2367	1547	938
EE0011R	Vilsandi	67,0	99,5	97,0	111,7	127,4	2020-06-29	0	4008	2189	1964
ES0001R	San Pablo de los Montes	79,6	97,7	120,8	131,9	163,2	2020-07-23	0	15189	8634	3746
ES0005R	Noya	55,7	99,2	83,9	102,8	120,9	2020-05-21	0	632	147	509
ES0006R	Mahón	79,2	97,4	115,1	126,1	141,9	2020-07-08	0	11208	4597	3664
ES0007R	Víznar	80,4	98,6	117,8	129,1	142,7	2020-07-24	0	16986	10027	3895
ES0008R	Niembro	73,0	97,8	101,7	115,3	132,8	2020-05-28	0	6077	2936	2572
ES0009R	Campisabalos	72,1	97,3	113,6	129,5	164,0	2020-08-14	0	14385	7787	3208
ES0010R	Cabo de Creus	74,7	97,8	112,8	123,3	138,9	2020-09-13	0	10768	4487	2990
ES0011R	Barcarrota	60,4	99,0	116,6	128,3	147,6	2020-07-17	0	12349	7254	2546
ES0012R	Zarra	76,1	98,4	110,9	120,4	137,0	2020-07-24	0	13509	6655	3112

Station code	Station name	Annual average µg/m³	Annual data capture %	95-percentile Apr-Sep µg/m³	99-percentile Apr-Sep µg/m³	Maximum concentration		# days>180 days	AOT40 08-20 Apr-Sep ppbh	AOT40 08-20 May-Jul ppbh	SOMO35 ppbd
						Value µg/m³	Date				
ES0013R	Penausende	67,9	98,7	107,8	119,0	138,5	2020-07-27	0	8349	5094	2188
ES0014R	Els Torms	70,3	98,6	111,7	122,6	142,7	2020-07-31	0	12940	6230	2965
ES0016R	O Saviñao	59,3	96,5	99,4	116,8	154,3	2020-08-06	0	4462	2423	1554
ES0017R	Doñana	63,6	97,3	111,6	124,7	138,3	2020-05-21	0	12323	6812	3201
FI0009R	Utö	64,6	99,0	91,5	105,2	130,4	2020-06-27	0	2448	1407	1247
FI0018R	Virolahti III	51,8	99,6	85,9	100,1	135,7	2020-06-15	0	1753	1328	686
FI0022R	Oulanka	56,0	99,5	83,0	88,9	98,5	2020-05-26	0	613	333	636
FI0096G	Pallas (Sammaltunturi)	62,0	99,2	83,7	89,1	95,0	2020-04-21	0	528	296	871
FR0008R	Donon	67,8	98,3	118,9	132,7	163,0	2020-07-31	0	11326	4595	2395
FR0009R	Revin	64,2	93,7	122,9	139,9	182,0	2020-09-16	1	11516	3921	2392
FR0010R	Morvan	67,7	99,5	115,9	127,9	152,1	2020-09-17	0	13875	5326	2680
FR0013R	Peyrusse Vieille	61,0	97,9	103,0	114,9	130,9	2020-07-09	0	5102	2561	1541
FR0014R	Montandon	55,9	95,7	106,0	117,9	129,9	2020-07-31	0	7886	3601	1619
FR0015R	La Tardière	58,4	99,6	109,0	122,9	148,9	2020-09-17	0	7629	4066	1663
FR0016R	Le Casset	86,5	94,9	121,9	129,9	144,9	2020-07-30	0	20160		4382
FR0017R	Montfranc	73,8	98,8	113,9	122,9	141,9	2020-09-17	0	10691	4879	2677
FR0018R	La Coulonche	67,1	99,2	119,0	134,9	170,0	2020-08-10	0	9321	4279	2199
FR0023R	Saint-Nazaire-le-Désert	59,2	98,1	116,9	131,9	157,0	2020-09-04	0	14662	6848	2856
FR0025R	Verneuil	56,5	99,6	110,9	123,9	148,9	2020-09-17	0	10105	4203	2083
FR0028R	Kergoff	65,5	97,6	109,9	135,9	169,0	2020-08-09	0	7315	3987	1885
FR0030R	Puy de Dôme	83,0	95,0	120,1	131,7	170,8	2020-08-07	0	13994	5578	3963
GB0002R	Eskdalemuir	57,8	79,1	86,5	98,2	112,7	2020-05-07	0			668
GB0006R	Lough Navar	50,1	99,7	87,5	111,6	134,1	2020-06-01	0	2388	1441	774
GB0013R	Yarner Wood	64,5	96,4	113,4	146,5	200,8	2020-05-09	1	8467	4613	2076
GB0014R	High Muffles	53,2	53,2	85,1	96,8	118,9	2020-09-15	0			186
GB0015R	Strath Vaich Dam	64,6	98,8	87,9	96,2	121,4	2020-06-01	0	1790	914	1331
GB0031R	Aston Hill	66,2	98,8	107,8	132,8	186,9	2020-08-12	1	5992	2859	1808
GB0033R	Bush	57,6	99,3	85,0	97,9	128,1	2020-07-31	0	1171	714	702
GB0037R	Ladybower Res.	58,9	97,0	99,3	127,9	168,0	2020-06-24	0	4830	2646	1267
GB0038R	Lullington Heath	65,6	97,3	120,0	157,1	205,2	2020-06-24	4	9462	3926	2355

Station code	Station name	Annual average µg/m³	Annual data capture %	95-percentile Apr-Sep µg/m³	99-percentile Apr-Sep µg/m³	Maximum concentration Value µg/m³	Maximum concentration Date	# days>180 days	AOT40 08-20 Apr-Sep ppbh	AOT40 08-20 May-Jul ppbh	SOMO35 ppbd
GB0039R	Sibton	58,6	99,8	105,8	148,6	215,9	2020-07-31	2	7990	3523	1777
GB0043R	Narberth	60,7	99,2	98,9	121,1	151,7	2020-06-24	0	3747	2092	1250
GB0045R	Wicken Fen	54,3	99,5	105,6	150,9	192,6	2020-06-24	4	7977	3630	1708
GB0048R	Auchencorth Moss	58,9	99,2	86,7	98,5	131,2	2020-07-31	0	1638	1019	737
GB0049R	Weybourne	59,2	99,2	96,9	123,4	206,6	2020-07-31	1	4344	2379	1439
GB0050R	St. Osyth	58,7	99,5	106,0	146,9	217,2	2020-07-31	4	7837	3625	1814
GB0052R	Lerwick	70,4	96,6	93,4	106,2	125,9	2020-06-27	0	2492	1360	1837
GB0053R	Charlton Mackrell	59,2	94,1	102,0	127,4	155,5	2020-05-09	0	5340	2953	1537
GB1055R	Chilbolton Observatory	58,4	98,7	112,2	142,3	182,9	2020-08-11	1	8758	4047	1938
GR0001R	Aliartos	63,3	72,8	113,0	125,0	151,0	2020-05-20	0	16928		3000
GR0002R	Finokalia	93,5	79,6	126,1	134,9	144,9	2020-04-12	0	23039	10920	4689
HU0002R	K-puszta	52,1	97,5	117,2	131,6	154,7	2020-07-31	0	16538	7498	2976
HU0017R	Nyirjes	78,6	83,9	122,8	136,5	150,8	2020-05-19	0	18013	7150	3536
IE0001R	Valentia Observatory	64,2	99,9	87,2	109,0	128,7	2020-05-31	0	1396	980	1339
IE0031R	Mace Head	71,1	99,7	93,4	112,7	130,7	2020-05-30	0	2647	1680	1973
IT0004R	Ispra	45,7	97,8	133,9	150,2	181,2	2020-06-24	1	22074	11870	3573
IT0009R	Mt Cimone	95,0	96,0	128,3	142,0	163,0	2020-08-10	0	24819	11052	6005
IT0014R	Capo Granitola	78,6	76,9	112,0	121,7	132,9	2020-04-11	0	17199	8322	3604
IT0019R	Monte Martano	77,5	97,1	112,5	122,1	137,0	2020-08-22	0	12801	5385	2965
LT0015R	Preila	60,6	98,6	96,0	107,0	135,0	2020-08-17	0	3277	1687	1810
LV0010R	Rucava	56,2	88,4	94,5	104,9	123,3	2020-03-28	0	3214	1444	1565
LV0016R	Zoseni	55,7	89,8	86,8	94,1	121,5	2020-03-28	0	1262	415	830
MT0001R	Giordan lighthouse	87,2	81,3	111,3	122,5	132,3	2020-04-13	0	16660	7470	3777
NL0007R	Eibergen	46,1	98,7	112,9	140,6	166,4	2020-08-06	0	8854	3566	1681
NL0009R	Kollumerwaard	52,5	98,5	96,5	128,8	147,2	2020-08-13	0	5074	1754	1330
NL0010R	Vredepeel	48,9	98,6	116,5	160,1	208,0	2020-08-11	5	11195	4945	2046
NL0091R	De Zilk	55,9	98,0	114,4	163,2	222,7	2020-08-07	7	9665	3873	2068
NL0644R	Cabauw Wielsekade	48,9	98,6	113,4	153,5	201,8	2020-08-11	4	9222	3876	1792

Station code	Station name	Annual average µg/m³	Annual data capture %	95-percentile Apr-Sep µg/m³	99-percentile Apr-Sep µg/m³	Maximum concentration		# days>180 days	AOT40 08-20 Apr-Sep ppbh	AOT40 08-20 May-Jul ppbh	SOMO35 ppbd
						Value µg/m³	Date				
NO0002R	Birkenes II	57,0	98,7	87,2	101,7	126,1	2020-08-17	0	1955	773	852
NO0015R	Tustervatn	62,3	99,5	87,0	92,4	118,4	2020-01-08	0	985	259	1223
NO0039R	Kårvatn	53,7	92,3	86,8	99,7	111,7	2020-06-28	0	1568	536	1185
NO0042G	Zeppelin mnt (Ny-Ålesund)	64,9	99,3	81,9	91,0	99,6	2020-05-15	0	350	53	959
NO0043R	Prestebakke	58,6	97,1	92,6	111,9	134,4	2020-08-08	0	3394	1084	1196
NO0052R	Sandve	65,6	99,5	91,5	102,7	124,9	2020-06-27	0	2952	1422	1623
NO0056R	Hurdal	52,0	98,8	86,0	101,1	131,2	2020-08-08	0	1657	461	801
PL0002R	Jarczew	41,5	99,9	88,8	102,2	127,1	2020-03-28	0	2321	675	743
PL0003R	Sniezka	74,8	98,6	117,1	130,7	144,2	2020-04-24	0	9694	3760	3338
PL0004R	Leba	59,2	100,0	99,6	117,9	139,2	2020-08-21	0	5225	2124	1841
PL0005R	Diabla Gora	51,4	98,4	97,0	114,5	143,1	2020-08-22	0	4914	2470	1370
SE0005R	Bredkälen	58,1	99,8	87,1	95,9	143,9	2020-06-11	0	1322	355	1040
SE0013R	Esrange	64,0	99,8	89,4	95,4	104,6	2020-04-21	0	1631	695	1255
SE0014R	Råö	62,5	99,7	97,2	117,1	136,7	2020-08-06	0	3828	1639	1500
SE0018R	Asa	51,4	96,2	91,1	104,8	129,4	2020-08-15	0	2879	902	998
SE0019R	Östad	53,0	99,9	92,0	108,1	142,0	2020-08-09	0	3554	1409	1240
SE0020R	Hallahus	58,8	98,4	99,9	121,4	145,1	2020-09-23	0	5243	1938	1468
SE0022R	Norunda Stenen	54,1	99,8	94,3	108,2	138,4	2020-09-24	0	3713	1604	1217
SE0032R	Norra-Kvill	62,5	96,7	99,6	114,2	137,3	2020-09-24	0	4163	1785	1355
SE0035R	Vindeln	53,2	94,9	86,1	92,7	98,6	2020-04-21	0	1137	283	729
SE0039R	Grimsö	52,3	96,4	87,4	102,4	119,2	2020-06-27	0	2028	833	842
SI0008R	Iskrba	66,9	34,3	135,3	146,9	151,7	2020-04-13	0			1744
SI0031R	Zarodnje	69,8	93,7	112,5	123,7	136,1	2020-04-13	0	10567	4358	2907
SI0032R	Krvavec	84,6	92,3	123,1	138,0	149,7	2020-04-13	0	12918	5698	4311
SK0002R	Chopok	90,8	94,4	122,3	132,0	173,0	2020-05-31	0	18421	7919	5782
SK0004R	Stará Lesná	57,2	95,2	108,0	119,0	134,0	2020-04-09	0	9348	3826	2254
SK0006R	Starina	53,9	95,7	102,0	114,0	132,0	2020-03-29	0	6976	2497	1677
SK0007R	Topolniky	25,0	44,1	91,8	103,0	113,2	2020-09-10	0			130

Annex 2

List of data reports

Ozone measurements in the ECE region January 1985–December 1985. Report no. 1.
EMEP/CCC-Report 3/89 by U. Feister and U. Pedersen.
Potsdam/Lillestrøm, Meteorological Service of the GDR/Norwegian Institute for Air Research, 1989.

Ozone measurements January 1986–December 1986. Report no. 2.
EMEP/CCC-Report 8/90 by U. Feister, U. Pedersen, E. Schulz and S. Hechler.
Lillestrøm, Norwegian Institute for Air Research, 1990.

Ozone data report 1988.
EMEP/CCC-Report 1/92 by U. Pedersen.
Lillestrøm, Norwegian Institute for Air Research, 1992.

Ozone data report 1989.
EMEP/CCC-Report 2/93 by U. Pedersen and I.M. Kvalvågnes.
Lillestrøm, Norwegian Institute for Air Research, 1993.

Ozone measurements 1990–1992.
EMEP/CCC-Report 4/95 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 1995.

Ozone measurements 1993–1994.
EMEP/CCC-Report 1/96 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 1996.

Ozone measurements 1995.
EMEP/CCC-Report 3/97 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 1997.

Ozone measurements 1996.
EMEP/CCC-Report 3/98 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 1998.

Ozone measurements 1997.
EMEP/CCC-Report 2/99 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 1999.

Ozone measurements 1998.
EMEP/CCC-Report 5/2000 by A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 2000.

Ozone measurements 1999.
EMEP/CCC-Report 1/2001 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2001.

Ozone measurements 2000.
EMEP/CCC-Report 5/2002 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2002.

Ozone measurements 2001.
EMEP/CCC-Report 4/2003 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2003.

Ozone measurements 2002.
EMEP/CCC-Report 2/2004 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2004.

Ozone measurements 2003.
EMEP/CCC-Report 4/2005 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2005.

Ozone measurements 2004.
EMEP/CCC-Report 2/2006 by A.M. Fjæraa.
Kjeller, Norwegian Institute for Air Research, 2006.

Ozone measurements 2005.
EMEP/CCC-Report 2/2007 by A.M. Fjæraa and A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 2007.

Ozone measurements 2006.
EMEP/CCC-Report 2/2008 by A.M. Fjæraa and A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 2008.

Ozone measurements 2007.
EMEP/CCC-Report 2/2009 by A.M. Fjæraa and A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 2009.

Ozone measurements 2008.
EMEP/CCC-Report 2/2010 by A.M. Fjæraa and A.-G. Hjellbrekke.
Kjeller, Norwegian Institute for Air Research, 2010.

Ozone measurements 2009.
EMEP/CCC-Report 2/2011 by A.-G. Hjellbrekke, S. Solberg and A.M. Fjæraa.
Kjeller, Norwegian Institute for Air Research, 2011.

Ozone measurements 2010.
EMEP/CCC-Report 2/2012 by A.-G. Hjellbrekke, S. Solberg and A.M. Fjæraa.
Kjeller, Norwegian Institute for Air Research, 2012.

Ozone measurements 2011.
EMEP/CCC-Report 3/2013 by A.-G. Hjellbrekke, S. Solberg and A.M. Fjæraa.
Kjeller, Norwegian Institute for Air Research, 2013.

Ozone measurements 2012.
EMEP/CCC-Report 2/2014 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2014.

Ozone measurements 2013.
EMEP/CCC-Report 2/2015 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2015.

Ozone measurements 2014.
EMEP/CCC-Report 3/2016 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2016.

Ozone measurements 2015.
EMEP/CCC-Report 2/2017 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2017.

Ozone measurements 2016.
EMEP/CCC-Report 2/2018 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2018.

Ozone measurements 2017.
EMEP/CCC-Report 2/2019 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2019.

Ozone measurements 2018.
EMEP/CCC-Report 2/2020 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2020.

Ozone measurements 2019.
EMEP/CCC-Report 2/2021 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2021.

Ozone measurements 2020.
EMEP/CCC-Report 2/2022 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, Norwegian Institute for Air Research, 2022.

Ozone measurements 2021.
EMEP/CCC-Report 2/2023 by A.-G. Hjellbrekke and S. Solberg.
Kjeller, NILU, 2023.

NILU

The climate and environmental research institute NILU is an independent, non-profit research institution established in 1969. Through its research NILU increases the understanding of atmospheric composition, climate change, air quality, environmental contaminants, health effects, sustainable systems, circular economy, and digitalisation. Based on its research, NILU markets integrated services and products within analysing, monitoring, and consulting. NILU is concerned with increasing public awareness about climate change and environmental pollution.

NILU's values: *Integrity - Competence - Benefit to society*
NILU's vision: *Create sustainable development through internationally leading climate and environmental research*

NILU
P.O. Box 100, NO-2027 Kjeller, Norway

E-mail: nilu@nilu.no
http://www.nilu.no
Enterprise no.: 941 705 561

ISBN: 978-82-425- 3131-5
ISSN: 2464-3920

NILU