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ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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SUMMARY

This pilot project was undertaken as a result of various activities in Europe in the field of photochemical air pollution after 1970. Of special importance was the OECD "Ad hoc Group of Experts on Photochemical Oxidants and their Precursors in the Atmosphere", acting from 1973 to 1978. In 1978 the Norwegian Institute for Air Research (NILU) hosted a planning conference on future research co-operation on long range transport of photochemical oxidants. The present study was the outgrowth of some of the recommendations from that conference. Economic support has been obtained from the National Swedish Environment Protection Board and the Norwegian Ministry of Environment.

In December 1979 a questionnaire was sent to selected individuals and institutions in 10 countries in north-western Europe asking for information on measurements from the years 1976-79. Ozone data turned out to be available from eight countries: Austria, Belgium, Federal Republic of Germany, Finland, Netherlands, Norway, Sweden and United Kingdom*. The data were not fully consistent with respect to time periods , site selection criteria, and measurement and calibration methods.

The ozone data have been compared with the reference levels of 100, 150 and 200 ppb. These levels have been chosen as a matter of convenience, and they do not indicate a lower limit of environmental or health effects of ambient ozone concentrations. Most of the ambient air quality standards for ozone range from 60 ppb to 120 ppb.

With one exception, all the hourly ozone concentrations exceeding 200 ppb were measured in England or Netherlands in 1976, or at Illmitz, Austria, in 1979. The highest 1-hour ozone concentration discussed in this report is 258 ppb, measured at Harwell, England, on 5 July 1976. However, concentrations up to 0.27 ppm have earlier been reported from Vlaardingen, Netherlands, on 8 May 1976.

*The interpretation and views expressed in this report are those of the authors, and are not necessarily shared by the organisations who supplied data.

Most high ozone concentrations occurred in high pressure situations. When a high pressure area was located over central Europe, Scandinavia or Finland, the concentrations were often high in all the examined regions in north-western Europe. With a high pressure ridge over central Europe, or with the high pressure centre over the North Sea, the concentrations could still be high on the European continent and in Great Britain, but significantly lower in Scandinavia. In other cases, with cyclonic circulation and low pressure areas over central Europe, the concentrations could still be high in Scandinavia, but significantly lower in other parts of north-western Europe.

At the Austrian station Illmitz, located in a rural area 65 km southeast of Vienna, the concentrations were high throughout April to September 1979. On 164 days, out of a total of 183 days, the maximum hourly concentrations exceeded 100 ppb, and on 90 days the maximum concentration exceeded 150 ppb.

Eight time periods with high ozone levels have been studied in more detail, with respect to synoptic weather situations, local meteorological conditions and trajectory analysis, in order to assess the origin and transport of the polluted air masses. During these time periods, or episodes, the highest ozone concentrations were reached when local precursors were emitted into polluted air transported from other source regions during weather conditions conducive to oxidant formation. A good example of an episode of this kind occurred in June/July 1976, with very high ozone levels in many parts of north-western Europe and especially in England.

Other time periods, which have been treated in more detail, are 16-30 August 1976, 12-15 June 1977, 2-12 July 1977, 28 July - 1 August 1978, 20-23 August 1978, 12-20 May 1979, and 30 May - 8 June 1979. For each of the episodes, it was attempted to assess whether local and mesoscale formation, or long range transport played the most important role. In some cases only one of the formation scales was dominant, while in other cases

ozone production on several scales may have acted together.

Due to the methodology used and the limited amount of measurement data, it was not possible to indicate quantitatively the role of the various formation scales. Thus the influence of the various precursor source regions on the concentrations at the various receptor points has not been quantitatively assessed.

In most parts of north-western Europe the maximum ozone concentrations are as high as, and in some cases higher than, the threshold levels associated with plant damage and health effects.

The need for further, concerted studies of photochemical oxidants in Europe is clearly apparent. Such studies should include:

- Emission inventories of oxides of nitrogen and volatile organics, from both natural and anthropogenic sources.
- An investigation of the role of natural organics in the large scale photochemical oxidant formation and transport.
- Photochemical models on the relevant time and spatial scales, including improved synoptic transport models for stagnant situations.
- A consistent data base of ambient air concentrations, including tropospheric measurements above the surface layer (e.g., aircraft, towers).
- Studies on injuries to commercial crops and natural vegetation.

Studies should also definitely be carried out in other parts of Europe. The Austrian data indicate that high concentrations may be expected in the vicinity of major urban areas in some parts of central Europe. Furthermore, parts of the Mediterranean coast from Spain to Turkey may well turn out to be present or future problem areas with respect to photochemical air pollution.

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PHOTOCHEMICAL OXIDANTS IN NORTH-WESTERN EUROPE 1976-79. A PILOT PROJECT.

1 INTRODUCTION

1.1 Background

This pilot project has emerged as result of a growing concern about photochemical air pollution in Europe during the last decade. From studies conducted in several countries it had become increasingly clear that the formation and transport of photochemical oxidants was a problem, either potential or already manifest. In addition, it had become evident that oxidants and their precursors could be transported over many hundreds of kilometres thus affecting countries other than those of the precursor sources.

In the third report from the OECD "Ad hoc Group of Experts on Photochemical Oxidants and their precursors in the Atmosphere", it was concluded that this long range transport implies that emission control on a local scale may be grossly insufficient in the areas of Europe and eastern North America (OECD, 1978). There was also a strong feeling among members of the OECD Group of Experts, that further studies were necessary in order to describe in greater detail, and as quantitatively as possible, the oxidant production and transport on a continental scale.

In 1978 the Norwegian Institute for Air Research (NILU) hosted a planning conference on future research co-operation in the field of long range transport of photochemical oxidants (NILU, 1978). Participants from 12 countries in Europe and North America were present. The conclusions from the conference contained several proposals for future research work, both on a national basis and in the form of international co-operation, covering the main research areas: emissions, transformation, ambient measurements, effects, as well as integrated modelling studies.

The present study has been proposed as a result of the recommendations of the planning conference, and is focusing on large scale oxidant episodes in north-western Europe 1976-79. Economic support has been obtained from the National Swedish Environment Protection Board and the Norwegian Ministry of Environment.

The term "pilot project" has been chosen in order to emphasize that the subject by no means has been covered in full detail. It is strongly hoped that more thorough and concerted efforts will follow, either through one of the relevant European organisations or as an ad hoc effort of the countries concerned.

1.2 Organisation of the project

In December 1979, a questionnaire was sent to individuals and institutions in 10 countries in north-western Europe, asking for information on measurements of ozone and other secondary air pollutants for the years 1976-79. Data turned out to be available from eight countries: Austria, Belgium, Federal Republic of Germany, Finland, Netherlands, Norway, Sweden and United Kingdom. More specific requests were sent in the spring and summer of 1980. A list of the contact persons and institutions, whose contribution is gratefully acknowledged, is given in Appendix A.

On the basis of the information received, eight episodes were selected for further detailed examination. For these episodes, daily air trajectories at the 850 mb level arriving in various parts of Europe, were calculated. The episodes were then characterised by means of the ozone data, air trajectories, weather maps and other available information.

In Section 2 a list of the ozone monitoring stations is given. In Section 3 the days with high maximum ozone concentration are categorised according to the large scale weather patterns (German "Grosswetterlagen" GWL, (Hess and Brezowski, 1969)). In Section 4 the ozone episodes are discussed. Suggestions for future work are given in Section 5.

1.3 Literature survey

In the following a brief literature survey is given, covering work on the transport of photochemical oxidants in north-western Europe. The survey is not complete, but is intended to give information on some of the main activities in this field over the past 10 years.

Atkins et al. (1972) described a situation in June/July 1971, when a high pressure area over the North Sea and Scandinavia was causing light easterly winds over southern England. The air masses were hazy with high concentrations of particulate sulphate and ozone. The ozone concentrations were just in excess of 100 ppb at Harwell, England. The photochemical processes were thought to be a major cause of the oxidation of sulphur dioxide. Precursor source areas in continental Europe were indicated.

Cox et al. (1975) reported on measurements of ozone and halocarbons at the English east coast and the Irish south coast in August 1973, which indicated transport of polluted air masses from the European continent. Transport times of 1-2 days were calculated from air trajectories. Maximum ozone concentrations of 100-150 ppb were reached at all the sites. The diurnal concentration variation was more pronounced at the inland stations than at the coast. This difference was attributed to differences in the nocturnal build-up of ground-based inversions.

Grennfelt (1975,1976) has measured ozone in the Gothenburg area since 1972. Ozone concentrations have exceeded levels of 100-200 ppb during several episodes every year, and the highest levels were reached at a coastal station not influenced by local sources. When the high ozone concentrations were associated with long range transport, the visibility was often low and the concentration of particulate sulphate high. When mesoscale production and transport seemed to dominate, the high ozone levels were not associated to the same degree with the other "smog" indicators.

Fricke and Rudolf (1977) have reported on a flight from Munich to Rotterdam in July 1975, with high pressure and light winds over central Europe. Ozone levels of 60-165 ppb were measured, and the maximum levels occurred ca 1000 m above ground. In addition to the large-scale oxidant generation, local build-up was found downwind of major urban/industrial centres. Above ca 1000 m the ozone concentration decreased with increasing height, indicating the anthropogenic origin of the photochemical pollution.

Guicherit and van Dop (1977) have examined ozone episodes in western Europe between 1971 and 1975 by means of data submitted by the Federal Republic of Germany, France, Italy, Sweden and U.K., as well as data from the Netherlands. The described episodes occurred in September/October 1971, August 1973, August 1974 and July/August 1975. During these periods a stagnating anticyclone was situated over western Europe, and the concentrations of ozone could reach 100 ppb and above over distances of more than a thousand kilometres. The high ozone levels generally persisted for several days. From trajectory analyses, an indication of source areas was given. The data from Sweden pointed to source areas in south and southwest, while the data from U.K. and central Europe pointed to sources east of the receptor points. Many of the air trajectories were very short, however, indicating production over several days associated with stagnating air masses.

Apling et al. (1977), and Ball and Bernard (1978) have reported ozone concentrations in south-eastern England during the summer of 1976. This particular summer was extremely hot and dry, and the maximum hourly ozone concentration was 258 ppb (Harwell, 5 July 1976). The air trajectories indicated transport of pollutants from the European continent. Significant ozone production from English precursors was also apparent.

Becker et al. (1979) have reported on a series of studies in the Cologne/Bonn area in 1975-78. For the episode in June/July 1976, their conclusion was similar to that of the English groups, namely that local emissions had contributed significantly to the ozone levels, in addition to the large scale formation and transport. The local influence was assessed by simultaneous measurements of olefins, PAN and ozone.

The general ozone level in the summer of 1978 was higher than in 1977 but lower than in 1976 in the Cologne/Bonn and Frankfurt areas. When large-scale production and transport were dominating, the highest concentrations were reached at the rural monitoring stations.

Altena and Schneider (1978) have reported on a flight along the border between the Netherlands and the Federal Republic of Germany 24 August 1976. The weather conditions were favourable for large scale oxidant formation and the general ozone level reached 100 ppb. In the urban/industrial plumes, ozone scavenging by nitric oxide (NO) dominated over the ozone build-up, reducing the ozone level to ca 40 ppb. There was no concentration variation with height up to ca 1000 m during the noon/afternoon hours when the flight took place. During a second flight on 21 December 1977 the maximum ozone concentration was below 60 ppb.

Harrison and Holman (1979) and Harrison and McCartney (1980) have discussed measurements at a rural site in north-western England, near Lancaster, in 1977 and 1978. During episodes in May and June 1978, two types of air masses were identified, one from the North Sea and northern England and one from the European continent and southern England. A contribution of 50-80 ppb of ozone was attributed to long range transport, with an addition of 20-50 ppb from English sources. Some cases of transport from southern Scandinavia to northern England were found. The measurement data were compared with model calculations by Hov et al. (1978), simulating long range ozone generation and transport.

The model calculations of Hov et al. (1978) describe situations where air parcels travel over emission areas, rural areas and ocean surfaces. The calculations were carried out for several days showing the feasibility of ozone transport over long distances (∿ 1000 km). In aging air masses, the diurnal ozone concentration variation was not pronounced, due to the depletion of NO and NO_2.

Schjoldager et al. (1978) and Schjoldager (1979,1980) reported on ambient ozone measurements carried out in southern Norway (59-60°N) since 1975. During episodes in the summer months, with meteorological conditions conducive to oxidant formation, high concentrations of ozone (up to 200 ppb) occurred. During the episodes, land/sea breeze often prevailed for several days. In some cases, long range transport of oxidants and oxidant precursors from the major source areas in Great Britain and the European continent had probably occurred, while in other cases local and mesoscale production and transport seemed to dominate. Due to the variable climate at latitudes around 60°N, both the total number of episodes and the relative number of local/mesoscale and transport episodes could vary considerably from one year to the next. The highest ozone concentrations often occurred during combined local/mesoscale or mesoscale/transport episodes.

Some interesting cases of transport have been described by Derwent et al. (1978), viz. ozone intrusion from the stratosphere to the lower troposphere. In March 1974 and March 1977 ozone levels above 100 ppb were reached over short periods in rural areas during weather conditions not favouring photochemical oxidant formation. An examination of the vertical structure of the atmosphere gave evidence of stratospheric intrusion, which was further supported by the low concentrations of halocarbons during the episodes. A comparison of urban and rural ozone data indicated no contribution from the stratosphere to the urban ozone levels.

In a collection of articles, edited by Guicherit (1978), on the photochemical smog formation in the Netherlands, both field and laboratory data, as well as model simulation studies are presented. A summary of measurement data from 1971 to 1977 shows that the highest ozone concentrations occurred in 1976, with a maximum 1-h concentration of 0.27 ppm at Vlaardingen on 8 May 1976.

Ozone studies employing tobacco plants as indicators have been carried out since the beginning of the 1970's in Belgium, Denmark, Federal Republic of Germany, Finland, Netherlands, Sweden, Switzerland, and United Kingdom (e.g., Braun, 1974; Posthumus 1976; Ashmore et al., 1978; Skärby et al., 1979). It has been shown that injuries to tobacco leaves caused by ozone occur in all of these countries. So far, the only country to have a programme for continuous measurements on ozone damage to tobacco plants is the Netherlands. Many European countries, however, have started research on the effects of ozone on crops and vegetation.

2 LIST OF OZONE MONITORING STATIONS

2.1 Austria

Station: IMP, Vienna

Type: Urban, 1 m above street level.
Altitude: 180 m.
Latitude: 48°13'N. Longitude: 16°22'E.
Period: July-September 1976, March-September 1977, 1978 and 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency (Federal Register, 1971).
Comment: Measurements of hydrocarbons (HC) and oxides of nitrogen (NO_x) also available.

Station: AfL, Vienna

Type: Urban, 14 m above street level.
Altitude: 193 m.
Latitude: 48°13'N. Longitude: 16°22'E.
Period: March-July 1976, May-September 1977, March-July 1978, September 1978, March-September 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency (Federal Register, 1971).
Comment: HC and NO_x measurements also available.

Station: Illmitz

Type: Rural, 65 km southeast of Vienna.
Altitude: 119 m
Latitude: 47°46'N. Longitude: 16°46'E.
Period: May-September 1978, April-September 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency (Federal Register, 1971).
Comment: NO_x measurements also available.

Station: Röschitz

Type: Rural, 65 km northwest of Vienna.
Altitude: 282 m
Latitude: 48°40'N. Longitude: 15°53'E.
Period: April - September 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency (Federal Register, 1971).
Comment: NO_x measurements also available.

2.2 Belgium

Station: R 822

Type: Suburban/industrial, 3 m above surface.
Altitude: 8 m
Latitude: 51°16'N. Longitude: 4°22'E.
Period: March - September 1979.
Measurement method: Chemiluminescence.

Station: R 801

Type: Urban
Altitude:
Latitude: 51°13'N. Longitude: 4°26'E.
Period: March - September 1979.
Measurement method: Chemiluminescence.
Comments: HC and NO_x data are available from 13 and 18 Belgian stations, respectively.

2.3 Federal Republic of Germany

Station: Zentralstation, Frankfurt

Type: Urban
Altitude:
Latitude: Longitude:
Period: June-August 1976, June-July 1977,
June-August 1978, May-July 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: UV-absorption.

Station: Feldberg, Frankfurt

Type: Rural, mountain station.
Altitude: 805 m
Latitude: Longitude:
Period: March - September 1976, 1977 and 1978.
Measurement method: Chemiluminescence.
Calibration method: UV-absorption.

Station: Venusberg, Bonn

Type: Suburban
Altitude: 220 m
Latitude: Longitude:
Period: March - September 1976, 1977 and 1978.
Measurement method: Chemiluminescence.
Calibration method: UV-absorption.
Comment: Ozone data from five other stations in the Cologne-Bonn area are available. The names of the stations are: Eifelwall, Godorf, Bonn Universität, Ölberg and Michelsberg. NO_x and HC data are also available from several stations.

2.4 Finland

Station: Helsinki

Type: Urban
Altitude:
Latitude: 60°N. Longitude: 25°E.
Period: April - August 1979.
Measurement method: Chemiluminescence (Rhodamine B).

2.5 Netherlands

Station: Delft

Type: Suburban
Altitude: 1.5 m
Latitude: 52°00'N. Longitude: 4°23'E.
Period: March - September 1976, 1977, 1978 and 1979.
Measurement methods: Galvanometric (1976, 1977)
colorimetric (1978), chemiluminescence, ethylene (1979).
Calibration method: Electrochemistry (1976), gas phase titration (1977-79).

Station: Terschelling

Type: Rural
Altitude: 4 m
Latitude: 53°24'N. Longitude: 5°21'E.
Period: June - August 1978.
Measurement method: Chemiluminescence (ethylene).
Calibration method: Gas phase titration.
Comment: Ozone data from many other stations in the Netherlands are available, as well as data on HC and NO_x. Measurements of peroxyacetyl nitrate (PAN) and peroxybenzoyl nitrate (PBzN) have also been performed (Guicherit, 1978).

2.6 Norway

Station: Maridalen, Oslo

Type: Rural, 15 km north of Oslo
Altitude: 165 m
Latitude: 60°00'N. Longitude: 10°48'E.
Period: May - September 1977, June - September 1978,
May - September 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency
(Federal Register, 1971).

Station: Bjørnstad, Telemark

Type: Suburban/industrial
Altitude: 30 m
Latitude: 59°09'N. Longitude: 9°38'E.
Period: May - September 1976, May - August 1977,
May - September 1978.
Measurement method: Chemiluminescence (Rhodamine B).
Calibration method: Same as Maridalen.

Station: Langesund, Telemark

Type: Suburban/coastal
Altitude: 10 m
Latitude: 59°01'N. Longitude: 9°45'E.
Period: April - September 1979.
Measurement method: Chemiluminescence (Rhodamine B).
Calibration method: Same as Maridalen.

Station: Haukenes, Telemark

Type: Rural
Altitude: 30 m
Latitude: 59°12'N. Longitude: 9°29'E.
Period: April - September 1979.
Measurement method: Chemiluminescence (Rhodamine B).
Calibration method: Same as Maridalen.
Comment: Ozone data from three other stations are available in 1978-79. HC and NO_x data are available from some of the Telemark stations.

2.7 Sweden

Station: Rörvik

Type: Rural/coastal
Altitude: 20 m
Latitude: 57°25'N. Longitude: 11°56'E.
Period: May - September 1976, 1977, 1978 and 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: KI, Environmental Protection Agency (Federal Register, 1971).
Comment: NO_x data also available.

Station: Göteborg

Type: Urban, 20 m above street level.
Altitude: 25 m
Latitude: 57°43'N. Longitude: 12°00'E.
Period: May - September 1976, 1977, 1978 and 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: Same as Rörvik.

Comment: HX and NO_x data also available.
Ozone data from two stations at the Swedish east coast (Stockholm and Nyköping) are available in 1976. (Killingmo and Möllergren, 1978).

2.8 United Kingdom

Station: WSL

Type: Suburban/rural
Altitude: 100 m
Latitude: 51°53'N. Longitude: 00°12'W
Period: April - September 1977, March - September 1978, March - September 1979.
Measurement method: Chemiluminescence (ethylene).
Calibration method: Neutral buffered KI, cross-referenced with UV-absorption.

Station: London

Type: Urban
Altitude: 6 m
Latitude: 51°29'N. Longitude: 00°08'W.
Periode: March - September 1976, March - September 1977, March - September 1978, March - September 1979.
Measurement and calibration method: Same as WSL.

Station: Islington

Type: Urban
Altitude: 20 m
Latitude: 51°32'N. Longitude: 00°06'W.
Period: July - September 1976, March - September 1977, March - July 1978.
Measurement and calibration method: Same as WSL.

Station: Sibton

Type: Rural
Altitude: 46 m
Latitude: 52°18'N. Longitude: 01°28'E.
Period: July - September 1976, March - September 1977,
March - September 1978, April - September 1979.
Measurement and calibration method: Same as WSL.

Station: Canvey

Type: Suburban/rural
Altitude: 3 m
Latitude: 51°32'N. Longitude: 00°34'E.
Period: May - September 1977, March - September 1978 and 1979.
Measurement and calibration method: Same as WSL.

Station: Harrow

Type: Suburban
Altitude: 60 m
Latitude: 51°34'N. Longitude: 00°21'W.
Period: August - September 1979.
Measurement and calibration method: Same as WSL.

In addition to these six stations, data from four other U.K. stations are available from the oxidant episode in June-July 1976: MRC City, GLC County Hall, GLC Hainault, GLC Teddington. Further, data from Harwell were made available for certain episodes in 1977 and 1978.

Some episode data from Lancaster for 1977 and 1978 are available in the literature (Harrison and Holman, 1979; Harrison and Mc Cartney, 1980).

3 SUMMARY OF OZONE MEASUREMENTS

3.1 High concentrations of ozone

The following summaries give concentrations exceeding the reference values of 100, 150 and 200 ppb. The choice of these levels was a matter of convenience, and does not imply any opinion as to the lower limit of environmental or health impact of ambient ozone concentrations. Most ambient air quality standards for hourly ozone concentration range between 60 ppb and 120 ppb.

Many factors make a comparison from year to year, or from country to country difficult. As was seen in Section 2, both the number of stations and their type (urban, suburban, rural) vary from year to year. Furthermore, the meteorological conditions favourable for oxidant formation can vary considerably from one year to the next. Finally, the data are not consistent with respect to calibration methods. The following Tables 1 through 6 should be interpreted with this in mind.

From the stations listed in Section 2, the highest ozone concentration was 258 ppb, measured at Harwell, England, 5 July 1976. However, Guicherit (1978) has earlier reported a maximum 1-hour ozone concentration of 0.27 ppm (270 ppb) at Vlaardingen, Netherlands, 8 May 1976.

The concentrations higher than or equal to 200 ppb are given in Table 1. The German "Grosswetterlagen" (GWL) categories for the days are also given. GWL daily categories are published by the Meteorological Service of the Federal Republic of Germany. Some relations between GWL and high ozone concentrations are discussed in more detail in Subsection 3.2. In addition to the values from 1976, several high concentrations occurred in Austria in 1979 at the site Illmitz, 65 km southeast of Vienna. A summary of the Austrian data is given in Subsection 3.3.

Table 1: Hourly ozone concentrations higher than or equal to 200 ppb.

Station	Date	Maximum concentration (ppb)	No. of hours with concentration ≥ 200 ppb	GWL
Illmitz, Austria	15 Apr 79	205	3	Ü
	7 Jun 79	220	2	BM
	11 Jun 79	213	2	BM
	15 Aug 79	249	3	HFA
	22 Aug 79	203	2	TRW
	14 Sep 79	208	2	NWA
Venusberg, Bonn, Federal Republic of Germany	12 Jul 77	202	1	HNA
Delft, Netherlands	76	200		
Vlaardingen, Netherlands	8 May 76	270		SEA
Vlissingen, Netherlands	76	220		
Haamstede, Netherlands	76	200		
WSL, United Kingdom	3 Jul 76	207	2	HNA
Harwell, United Kingdom	2 Jul 76	> 220	6	BM
	3 Jul 76	> 220	7	HNA
	4 Jul 76	230	4	HNA
	5 Jul 76	258	6	HNA
	6 Jul 76	204	1	HNA
	7 Jul 76	212	2	HNA
MRC City, United Kingdom	25 Jun 76	201	2	HM
	26 Jun 76	203	2	HM
	27 Jun 76	200	1	HM
	3 Jul 76	> 200	1	HNA
GLC Teddington, United Kingdom	28 Jun 76	211	1	HM

The number of days with maximum hourly concentration exceeding 100 ppb and 150 ppb is given on a country basis for the period May-August each year in Table 2. Again, the high concentrations during the warm and dry summer of 1976 are evident, as well as the very large number of high concentrations in Austria in 1979. As said earlier, the comparison from year to year, or from country to country, should not be carried out, because of the inconsistencies in the data base. The number of days with high concentrations may have been underestimated for the Netherlands and the Federal Republic of Germany, because more ozone data than those discussed in this report, are available (see Section 2).

Table 2: Number of days with one or more hourly ozone concentration higher than or equal to the reference values of 100 ppb and 150 ppb, May-August, 1976, 1977, 1978 and 1979.

	Reference value (ppb)	1976	1977	1978	1979
Austria	100	5	15	30	115
	150	0	2	1	65
Belgium	100				6
	150				1
Federal Republic of Germany	100	31	6	9	1
	150	6	2	1	0
Finland	100				1
	150				0
Netherlands	100	29	2	3	7
	150	5	0	0	0
Norway	100	6	1	3	4
	150	0	0	0	2
Sweden	100	12	2	14	7
	150	0	0	0	2
United Kingdom	100	28	13	7	3
	150	14	1	0	1

3.2 Co-variation with the large scale weather pattern ("Grosswetterlagen", GWL)

In Table 3 the number of days with maximum hourly ozone concentration higher than or equal to 100 ppb is listed, as well as the total number of days for each GWL category. The English data are grouped under "Great Britain", the Belgian, Dutch and German data are grouped under "European Continent", and the Norwegian and Swedish data are grouped under "Scandinavia". The Austrian data are treated separately in Subsection 3.3.

It is seen from Table 3 that even if high ozone levels are strongly associated with some weather categories, e.g., HM, BM, HNA, HFA and HNFA, the majority of these weather events did not necessarily imply high ozone concentrations. Thus, it seems that the large scale weather pattern does not alone determine the sufficient conditions for ozone formation. An exception to this is the category HM, showing high ozone concentrations in Great Britain and the European Continent during 16 of a total of 27 days.

Table 3: Number of days with maximum 1-hour ozone concentration higher than or equal to 100 ppb for various categories of large scale weather pattern during May-August 1976-79.
EC: European Continent (Belgium, Netherlands, Federal Republic of Germany.
GB: Great Britain (United Kingdom)
SC: Scandinavia (Norway, Sweden).

Description	Abbreviation	EC	GB	SC	Total days
A. Grosswetterlagen der zonalen Zirkulationsform					
1. Westlage, antizyklonal	WA	1		1	27
2. Westlage, zyklonal	WZ	3		1	61
3. Südliche Westlage	WS				6
4. Winkelförmige Westlage	WW	1		1	7
B. Grosswetterlagen der gemischten Zirkulationsform					
5. Südwestlage, antizyklonal	SWA				
6. Südwestlage, zyklonal	SWZ				4
7. Nordwestlage, antizyklonal	NWA				11
8. Nordwestlage, zyklonal	NWZ				19
9. Hoch über Mitteleuropa	HM	16	16	8	27
10. Hochdruckbrücke (Rücken) über Mitteleuropa	BM	16	8	1	54
11. Tief Mitteleuropa	TM			1	15
C. Grosswetterlagen der meridionalen Zirkulationsform					
12. Nordlage, antizyklonal	NA	1			8
13. Nordlage, zyklonal	NZ				16
14. Hoch Nordmeer-Island, antizyklonal	HNA	10	10		23
15. Hoch Nordmeer-Island, zyklonal	HNZ		1		17
16. Hoch Britische Inseln	HB		1	2	16
17. Trog Mitteleuropa	TRM				17
18. Nordostlage, antizyklonal	NEA	2	2	1	22
19. Nordostlage, zyklonal	NEZ	1	2	1	26
20. Hoch Fennoskandien, antizyklonal	HFA	8	3	5	24
21. Hoch Fennoskandien, zyklonal	HFZ				13
22. Hoch Nordmeer-Fennoskandien, antizyklonal	HNFA	4	2	4	12
23. Hoch Nordmeer-Fennoskandien, zyklonal	HNFZ		1	2	11
24. Südostlage, antizyklonal	SEA	3	3	1	4
25. Südostlage, zyklonal	SEZ				
26. Südlage, antizyklonal	SA				
27. Südlage, zyklonal	SZ			2	2
28. Tief Britische Inseln	TB			2	13
29. Trog Westeuropa	TRW	1	1	4	34
Übergang	Ü	2	1	1	3
Sum		69	51	38	492

In Table 4 certain weather patterns are grouped together in order to examine some differences between Scandinavia and the rest of Europe. The relative occurrence of high ozone levels during the categories HM, HFA and HNFA was similar for the three regions. For the categories BM, HNA and SEA there were still many high values on the European Continent and in Great Britain, but considerably fewer in Scandinavia. The opposite was the case for the categories HNFZ, SZ, TB and TRW. For these there were few high values on the European Continent and in Great Britain, but many in Scandinavia. At least some of these categories may be associated with transport of air pollutants to Scandinavia from other parts of Europe.

Table 4: Number of days with maximum 1-hour ozone concentration higher than or equal to 100 ppb for various groups of large scale weather pattern categories, May-August 1976-79.

EC : European Continent (Belgium, Netherlands, Federal Republic of Germany)
GB : Great Britain (United Kingdom)
SC : Scandinavia (Norway, Sweden).

Category	EC		GB		SC	
	No	%	No	%	No	%
HM, HFA, HNFA	28	41	21	41	17	45
BM, HNA, SEA	29	42	21	41	2	5
HNFZ, SZ, TB, TRW	1	1	2	4	10	26
Other	11	16	7	14	9	24
Sum	69	100	51	100	38	100

The weather patterns favourable for ozone formation, given in Tables 3 and 4, are as expected not very different from those during the episodes earlier reported by Guicherit and van Dop (1977) and Becker et al.(1979).

3.3 Summary of the Austrian ozone data

As mentioned earlier, the ozone concentrations at Illmitz, 65 km southeast of Vienna, were high throughout the period April to September 1979. In Table 5 the hourly ozone concentrations are compared with the reference values of 100 ppb and 150 ppb on a monthly basis. The length of the period was 183 days.

Table 5: Number of days with maximum hourly ozone concentrations higher than or equal to 100 ppb and 150 ppb at Illmitz, Austria, April-September 1979.

Reference value	April	May	June	July	August	September	Sum
100 ppb	24	31	28	27	29	25	164
150 ppb	9	21	18	10	16	16	90

The highest hourly ozone value was 249 ppb, on 15 August 1979 (Table 1).

The days with hourly ozone concentration higher than or equal to 100 ppb are grouped according to the GWL system in Table 6. The high concentrations occurred during a larger variety of weather situations than in the regions discussed in subsection 3.2.

Table 6: Number of days with maximum 1-hour ozone concentration (C) higher than or equal to 100 ppb for various categories of large scale weather pattern, for all Austrian stations during May-August 1976-78, and for Illmitz during April - September 1979.

Description	Abbreviation	All Austrian stations May-August 1976-78 C>100 ppb	All Austrian stations May-August 1976-78 Total days	Illmitz April-September 1979 C>100 ppb	Illmitz April-September 1979 Total days
A. Grosswetterlagen der zonalen Zirkulationsform					
1. Westlage, antizyklonal	WA	2	23	8	9
2. Westlage, zyklonal	WZ	7	44	21	22
3. Südliche Westlage	WS		6		
4. Winkelförmige Westlage	WW	6	7		
B. Grosswetterlagen der gemischten Zirkulationsform					
5. Südwestlage, antizyklonal	SWA				
6. Südwestlage, zyklonal	SWZ			4	4
7. Nordwestlage, antizyklonal	NWA	3	6	8	8
8. Nordwestlage, zyklonal	NWZ		18	6	7
9. Hoch über Mitteleuropa	HM	6	20	11	12
10. Hochdruckbrücke (Rücken) über Mitteleuropa z	BM	5	29	32	34
11. Tief Mitteleuropa	TM		15	2	3
C. Grosswetterlagen der meridionalen Zirkulationsform					
12. Nordlage, antizyklonal	NA		8		
13. Nordlage, zyklonal	NZ	1	16		
14. Hoch Nordmeer-Island, antizyklonal	HNA	6	20	3	3
15. Hoch Normeer-Island, zyklonal	HNZ		11	5	6
16. Hoch Britische Inseln	HB		7	7	9
17. Trog Mitteleuropa	TRM	1	12	7	8
18. Nordostlage, antizyklonal	NEA		22		
19. Nordostlage, zyklonal	NEZ		26	4	8
20. Hoch Fennoskandien, antizyklonal	HFA	2	20	5	5
21. Hoch Fennoskandien, zyklonal	HFZ		8	3	5
22. Hoch Normeer-Fennoskandien, antizyklonal	HNFA		4	8	8
23. Hoch Normeer-Fennoskandien, zyklonal	HNFZ	2	11	1	3
24. Südostlage, antizyklonal	SEA		4		
25. Südostlage, zyklonal	SEZ				
26. Südlage, antizyklonal	SA			5	5
27. Südlage, zyklonal	SZ		2		
28. Tief Britische Inseln	TB	4	7	9	9
29. Trog Westeuropa	TRW	5	20	14	14
Übergang	Ü		3	1	1
Sum		50	369	164	183

4 SELECTED EPISODES

This section contains a discussion of selected time periods during which the ozone concentrations exceeded 100 ppb at several stations. The discussion is based on daily weather maps, including the synoptic weather situation and the local meteorological conditions, as well as 850 mb air trajectories. The latter were calculated as parts of OECD's "Long range transport of air pollutants" (LRTAP) in 1976 and 1977 (OECD, 1977) and ECE's "European monitoring and evaluation programme" (EMEP) in 1978 and 1979 (ECE, 1977). The 850 mb trajectories should not be used to identify definite precursor source regions, but only as rough indicators of the air flow aloft, especially during high pressure situations when the trajectories are more uncertain.

For the purposes of this study the following episodes were selected:

1. 19 June - 17 July 1976
2. 16-30 August 1976
3. 12-15 June 1977
4. 2-12 July 1977
5. 28 July - 1 August 1978
6. 20-23 August 1978
7. 12-20 May 1979
8. 30 May-8 June 1979

It should be noted that these episodes were not the only ones of interest during the four year period. One occurred in the beginning of June 1978 when a large high pressure area covered central Europe, and the ozone levels approached 150 ppb in Austria, Federal Republic of Germany, Netherlands, Sweden and United Kingdom.

For each of the selected episodes, the daily (12 GMT) weather maps are given for every day or every second day. The weather maps are from Weather Log, published by the British Meteorological Office. Further, air trajectories at the 850 mb level are presented. For the years 1976 and 1977, 48-h trajectories are given, while 96-h trajectories are given for 1978 and 1979.

The trajectories arrive at the locations given in Table 7.

Table 7: List of end locations of 850 mb trajectories.

No.	Name	Latitude	Longitude	Notes
1	Illmitz, Austria	47°46'N	16°46'E	
2	Deuselbach, Federal Republic of Germany	49°46'N	7°03'E	
3	Waldorf, Federal Republic of Germany	52°48'N	10°45'E	
4	Den Helder, Netherlands	52°25'N	4°47'E	1976 and 1977
	Appelscha, Netherlands	52°57'N	6°18'E	1978 and 1979
5	Cottered, U.K.	51°56'N	0°05'W	
6	Rörvik, Sweden	57°25'N	11°56'E	
7	Vasser, Norway	59°04'N	10°26'E	

For each episode, the daily maximum 1-hour ozone concentrations are listed for the stations available. Finally, short summaries are given of wind velocity and temperature at the ground level, and the total amount of clouds. The summaries are based on the German "Europäischer Wetterbericht" (Deutscher Wetterdienst, 1976-79) and attempt to give average values for the three regions, north European continent, England and southern Scandinavia.

4.1 Episode 19 June-17 July 1976

This episode has earlier been discussed in the literature by Apling et al. (1977) and Ball and Bernard (1978). It was characterized by high pressure centres over various parts of Europe with abnormally warm and dry weather. According to Weather Log (1976), the hot spell in Great Britain was "probably unprecedented in length and intensity since the eighteenth century".

The weather maps for every second day of the period are given in Figure 1. In the beginning of the period the high pressure centre moved eastward from the Atlantic Ocean covering large parts of central Europe, while a low pressure area was located south of Iceland. The high pressure centre later moved slowly towards the Norwegian Sea. A summary of the local conditions of wind, cloud cover, and temperature is given in Appendix B1. During most of the period the wind speed was low and the maximum temperatures exceeded 25°C. The wind direction was often "variable". The skies were mostly clear, except for the first and last days in the period.

In Figure 2 the 48-h air trajectories at the 850 mb level, arriving at 12 GMT on every second day, are presented for the seven locations given in Table 7. The air trajectories indicate transport aloft from the west during the first days of the period. Towards the end of June the transport to Scandinavia and Great Britain was from the southwest, while there was variable transport on the continent. In the beginning of July the air aloft moved clockwise around the high pressure centre in the North Sea. Between 5 and 15 July there was generally no large scale transport aloft, and this lasted until the end of the period when a cold front approached from the Atlantic Ocean.

The maximum hourly ozone concentrations are given on a daily basis in Table 8. The ozone concentrations were high all over Europe, reaching 129 ppb in Austria, 186 ppb in Germany, 191 ppb in the Netherlands, 258 ppb in Great Britain, and 125 ppb in Sweden.

The highest concentrations in England have earlier been explained as a combination of ozone transport from the European continent and local and mesoscale formation (Apling et al,, 1977; Ball and Bernard, 1978). This explanation may in general be valid for other countries as well. During the long-lasting high pressure situation, transboundary air pollution probably affected large parts of Europe, interacting with the locally emitted oxidant precursors.

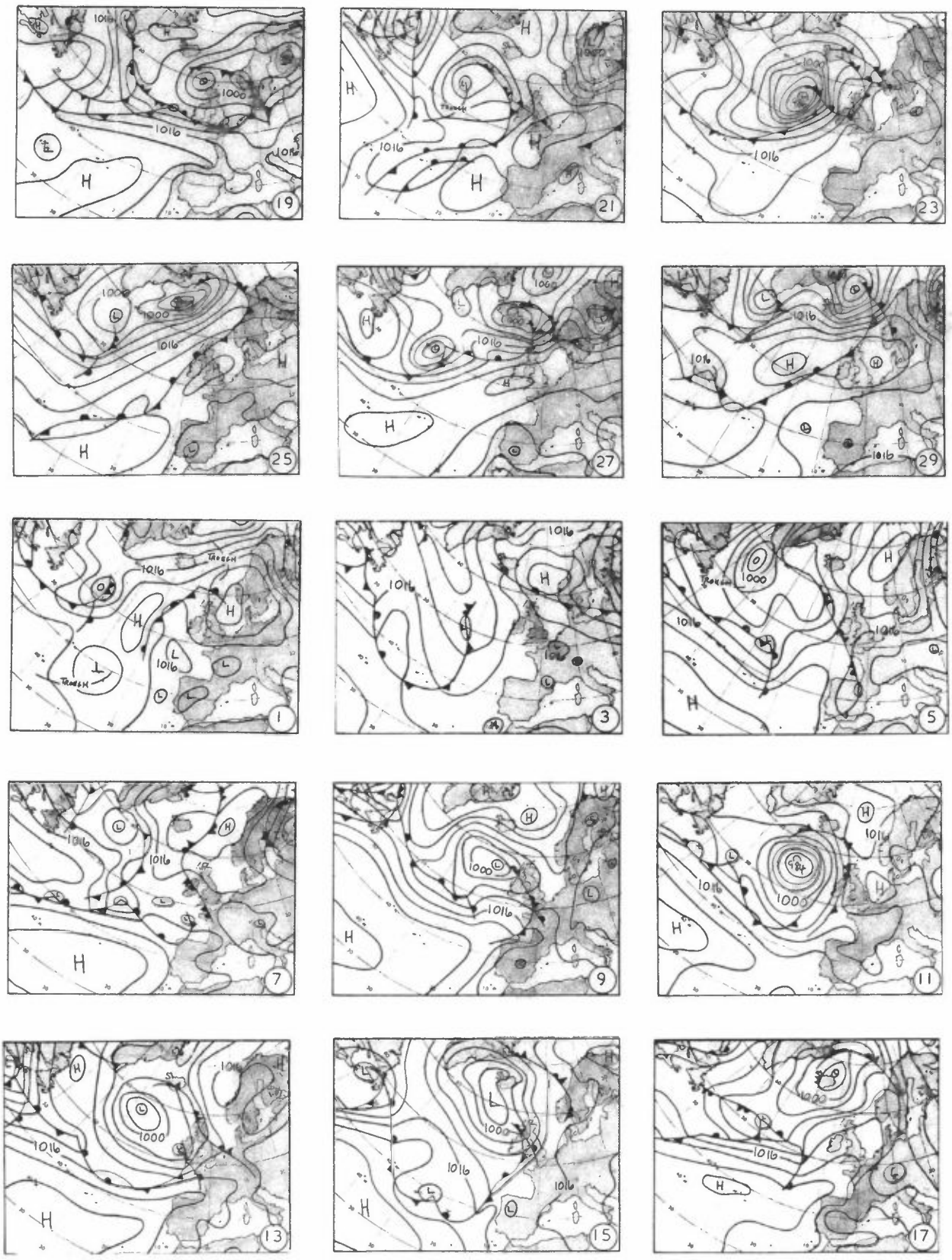

Figure 1: Daily weather maps at 12 GMT for every second day, 19 June-17 July 1976 (British Meteorological Office, 1976).

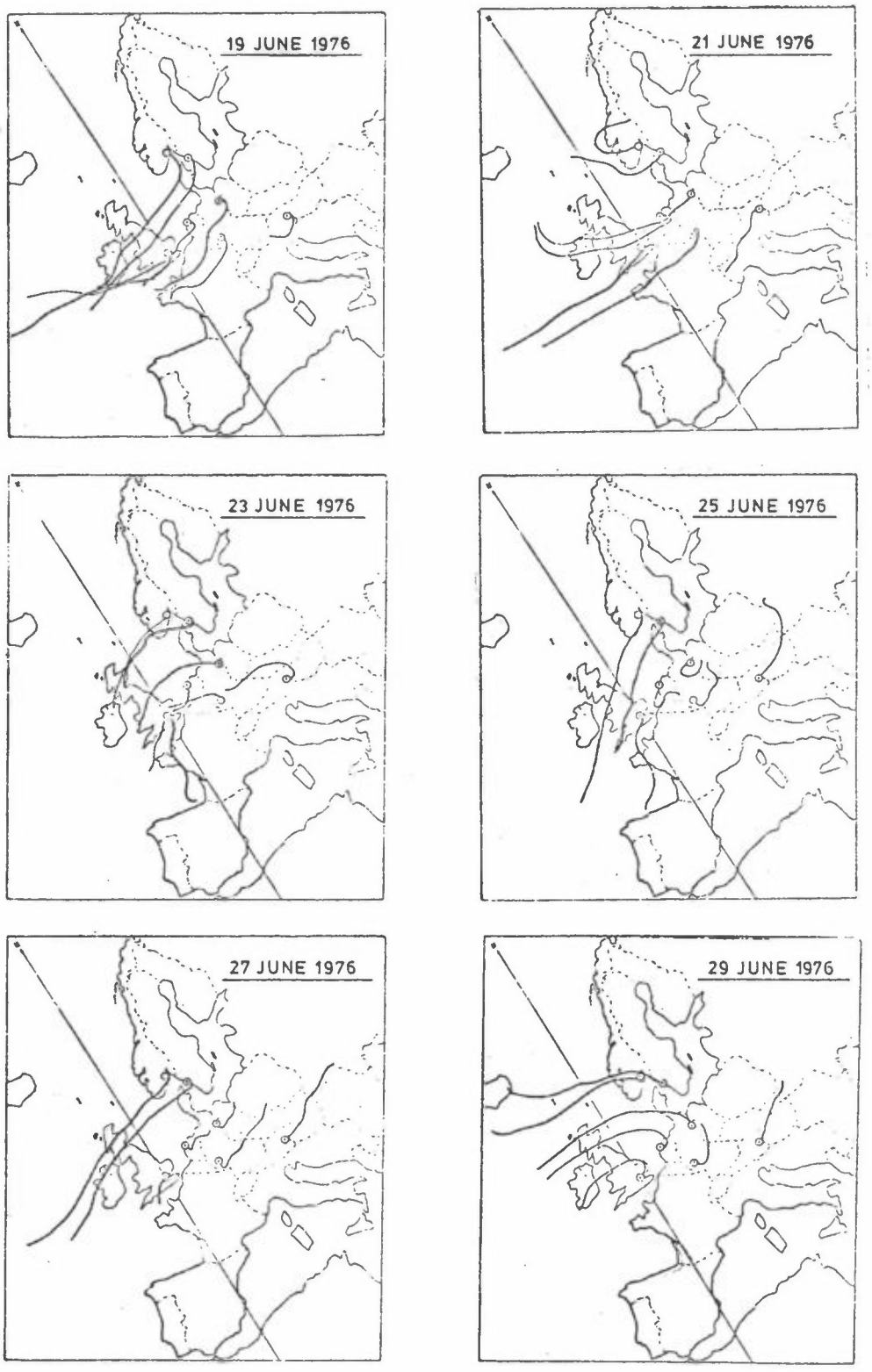

Figure 2: 48-h air trajectories at the 850 mb level arriving at 12 GMT on every second day, 19 June - 17 July 1976.

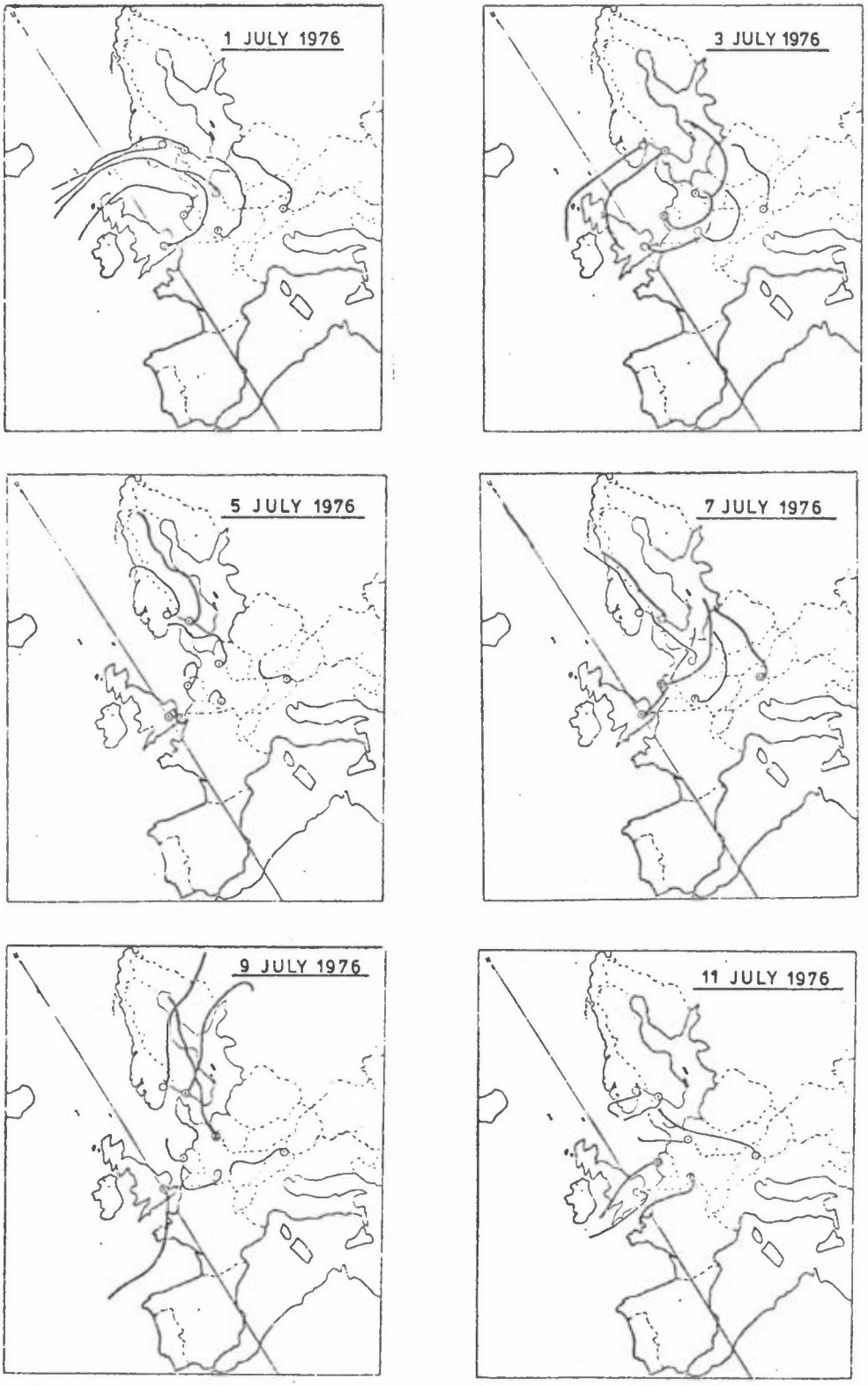

Figure 2 continued

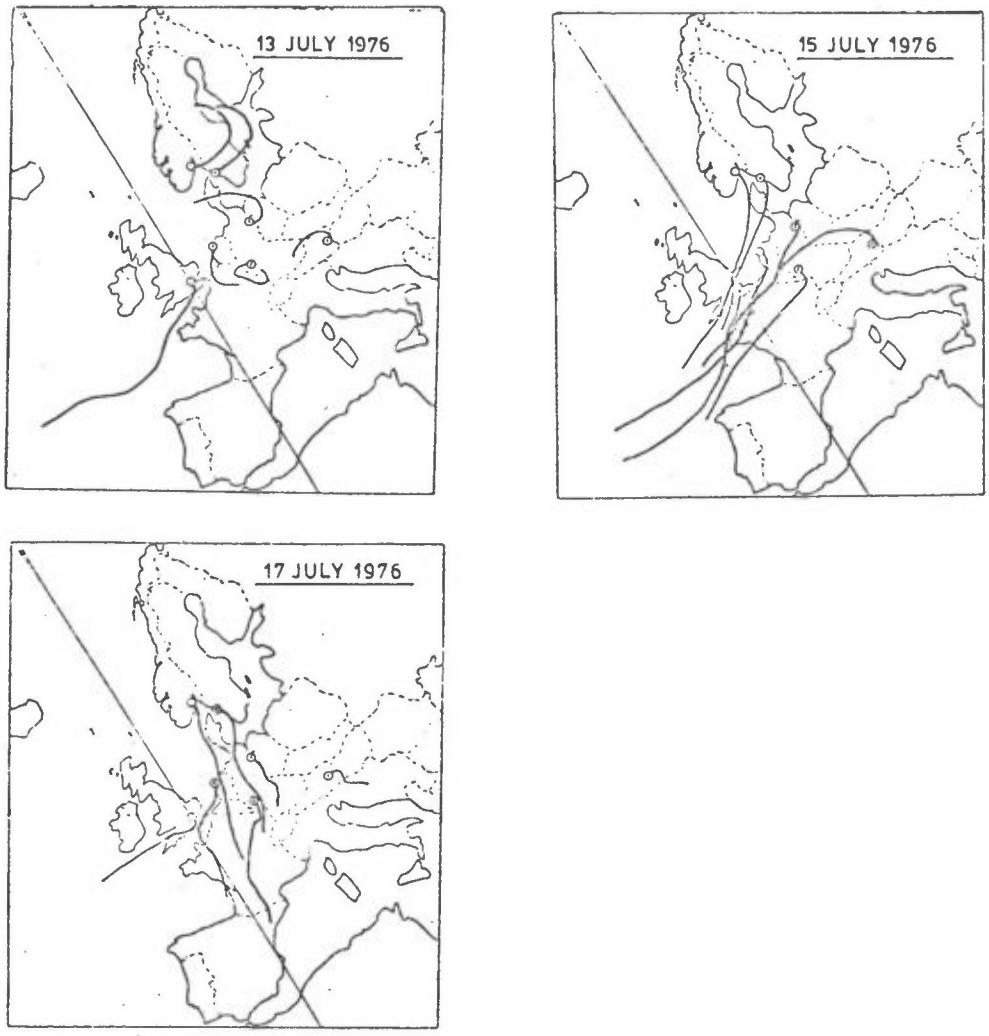

Figure 2 continued

Table 8: Maximum hourly ozone concentrations ppb), and large scale weather pattern (GWL), 19 June - 17 July 1976.

	JUNE 1976											JULY 1976																		
Date / Station	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Afl, Wien	119	79	63	63	78	50	80	95	84	129	89	68	72	61	103	93	100	48		72	83	43	50						
Zentralstation, Frankf.	98	63	116	186	87	127				121	124	95	110	116	160	171	173	77	100	174	103	93	112	143	48	110	94	119	152
Feldberg, Frankfurt	92	57	63	89	82		83	48	46	53	54	38		101	148	138	122	78	89	140	98	86							
Venusberg, Bonn	52	36	45	104	70	75	82	70	70	101	75	61	62	73	94	130	115	76	82	170	73	48	79	86	38	47	45	64	65
Delft, Netherlands	45	36	64	119	119	191	151	119	154	96	46	69	47											68	42	43	86	95	57
Harwell, England				149	116	122	162				160	111	172	>220	>220	230	258	204	212	196	62	72	118	171					
WSL, England				64	101	83	115	139	149	143	97	75	117	125	207	152	138	164	118	139	57	76	122	164					
NRC City, England				60	72	96	201	203	200	138	78	75	96	169	>200	156	106	125	104	111	34	73	81	99					
Körvik, Sweden	96	90	59	57	74	73	119	114	97	58	99	70	80	87	73	89	68	97	85	71	49	73	64	73	93	107	96	125	93
Björnstad, Norway	69	55	70	62	42		70	101	84	54	55	69	48	89				93	104	67	57	78	67	70	70	86	85	104	73
GWL	WZ	WZ	WZ	HM	HM	HM	HM	HM	HM	HM	BM	BM	BM	BM	BM	HNA	HNA	HNA	HNA	HNA	HNFA	HNFA	HNFA	HFA	HFA	HFA	HFA	HFA	BM

4.2 Episode 16-30 August 1976

An anticyclone persisted over the north-estern part of Europe during most of the period, with its centre moving between the British Isles and Scandinavia (Figure 3). The summary of weather conditions is given in Appendix B2. The temperature was generally 20-25°C, dropping to 15-20°C towards the end of the period. The local winds were variable but the wind speed was generally low.

The 850 mb trajectories indicate slow transport aloft, mainly from the north and northeast in the first part of the period. Around 25 August the trajectories indicate no systematic transport aloft. At the end of the period, the transport aloft was from the south or southeast (Figure 4).

The maximum hourly ozone concentrations exceeded 100 ppb in Norway on 19-20 August, and at most of the stations on 25-26 August, as given in Table 9. Towards the end of the period the concentration level dropped in central Europe and Great Britain, but remained high in parts of Scandinavia.

The high concentrations in Norway on 19-20 August have earlier been explained as mesoscale ozone production with a possible contribution from transport from distant sources around the high pressure centre in the North Sea (Schjoldager *et al.*, 1978). The high concentrations in large parts of Europe on 25-26 August can probably be explained by large scale production with a significant contribution on the local and mesoscale. The skies were generally clear on those days with the maximum temperatures approaching 30°C in Great Britain and central Europe.

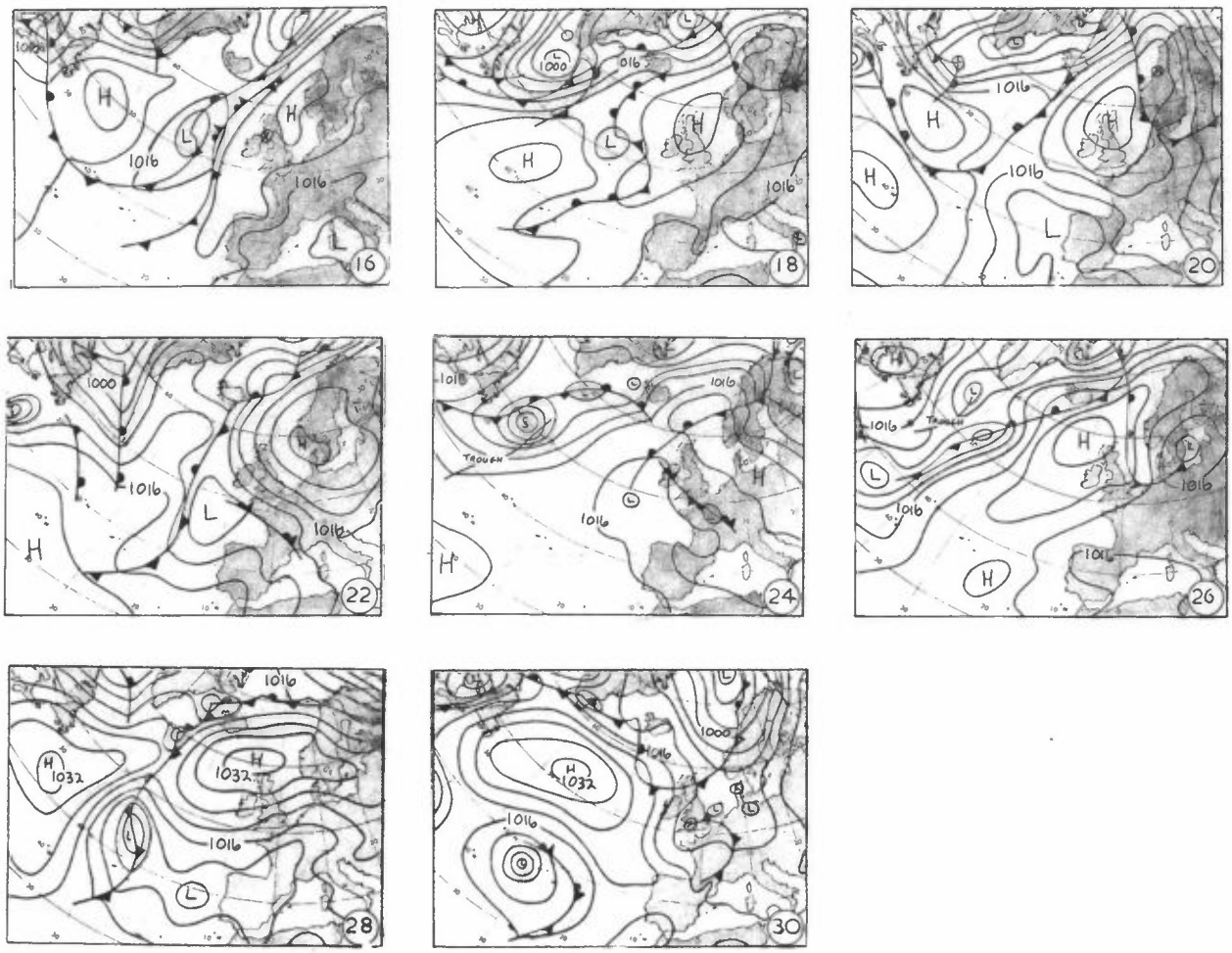

Figure 3: Daily weather maps at 12 GMT for every second day, 16-30 August 1976 (British Meteorological Office, 1976).

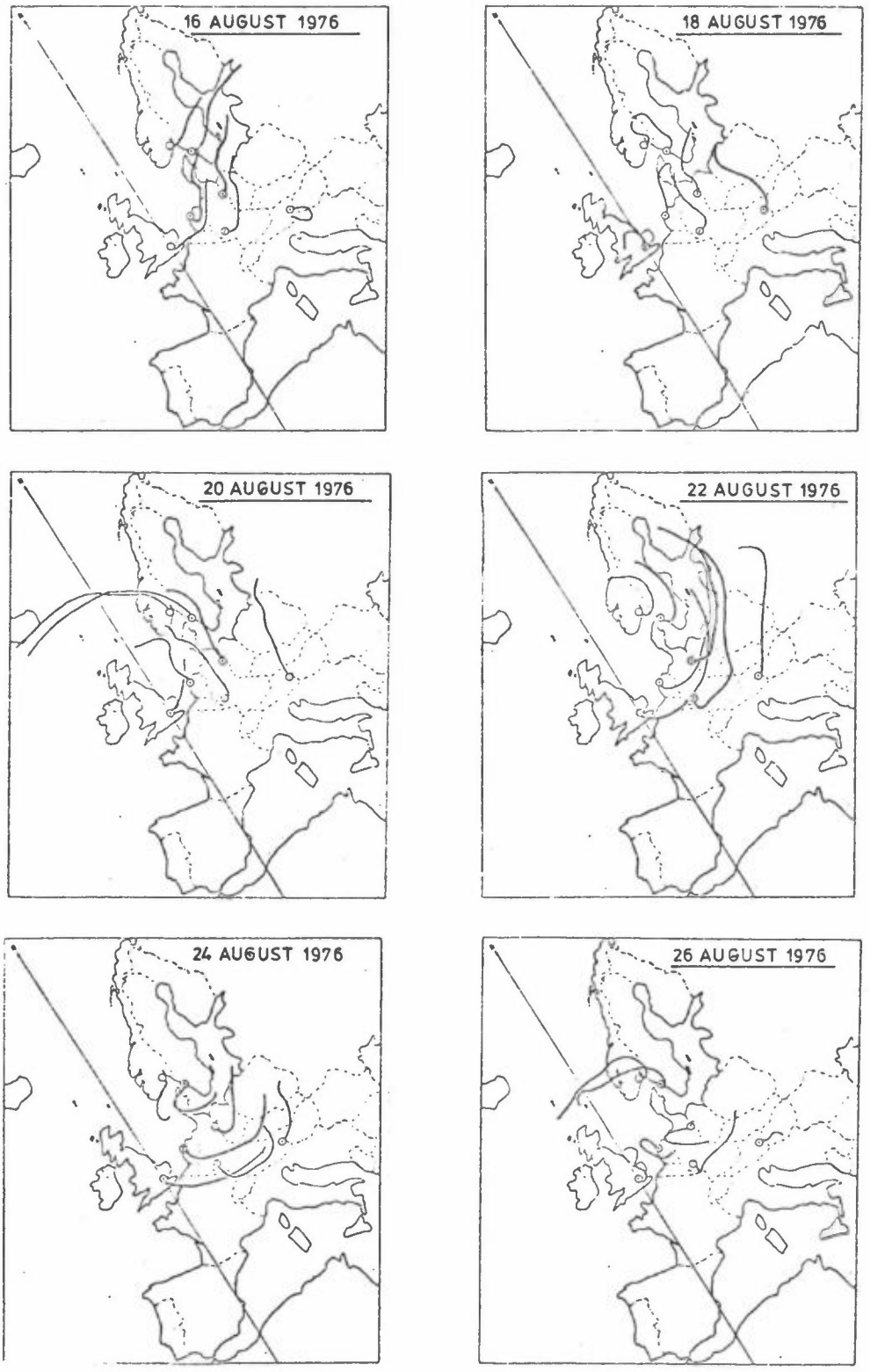

Figure 4: 48-h air trajectories at the 850 mb level, arriving at 12 GMT on every second day, 16-30 August 1976.

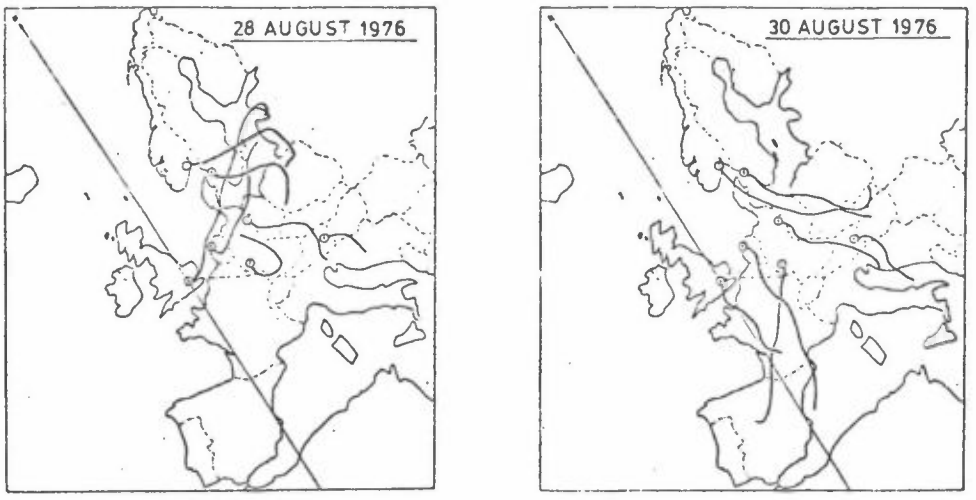

Figure 4 continued.

Table 9: Maximum hourly ozone concentrations (ppb), and large scale weather patterns (GWL), 16-30 August 1976.

Date	August, 1976															
Station	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Zentralstation, Frankf.	67	64	48	59	71	53	56	50	67	80	142	61	79	81	49	
Feldberg, Frankfurt	70	64	63	67	66	56	61	61	67	76	102	73	52	50	36	
Venusberg, Bonn	38	38	89	33	37	39	33	35	54	49	109	23	38	31	27	
Delft, Netherlands	52	43	43	44	55	63	50	42	65	111			33	18	33	
Islington, England	59	68	57	58	76	60	77	62	85	106	98	30	38	49	46	
London, England	44	54	38	40	58	50	67	67	90	112	89	40	41	46	49	
Sibton, England	74								92	83						
Rörvik, Sweden	91	89	82	88	70	64	75	92	88	110	68	70	91	114	115	
Björnstad, Norway	71	87	68	121	114	77	77	87	92	111	116	83	100	20		
GWL	NEA	NEA	HB	HB	HB	HFA	HFA	HFA	HM	HM	HM	NEZ	NEZ	SZ	SZ	

The high concentrations in Sweden and partly in Norway on 28-30 August were probably due to transport from the eastern part of central Europe. This was confirmed by low visibility and relatively high concentrations of particulate sulphate in southern Scandinavia.

4.3 Episode 12-15 June 1977

A high pressure area moved slowly from northern Scandinavia to northern Great Britain, while a low pressure area moved from southern France to Poland (Figure 5). It was generally cloudy in southern England. Over the continent it was partly clear in the first part, but cloudy in the last part of the period, while the opposite was true for southern Scandinavia. The temperatures were generally high in Scandinavia and on the continent.

The 850 mb trajectories indicate transport aloft from the south in the first part of the episode, shifting to east in northern Europe later in the period (Figure 6).

In Canvey, England, the ozone concentration was high on 12-13 June, while the other English stations had significantly lower concentrations (Table 10). The concentrations were also high in Austria. In Delft, Netherlands, and Maridalen, Norway the concentrations exceeded 100 ppb on 15 June.

The local meteorological conditions in England were not conducive to ozone formation on 12-13 June, and the high concentrations recorded at Canvey could perhaps be explained by transport from distant sources. The high concentrations in Norway have earlier been explained mainly by local and mesoscale ozone generation and transport (Schjoldager, 1979). It may also be suggested that distant sources east or southeast of Scandinavia may have contributed because the visibility in southern Sweden was low on 13 June. The high concentrations in Delft, Netherlands, may

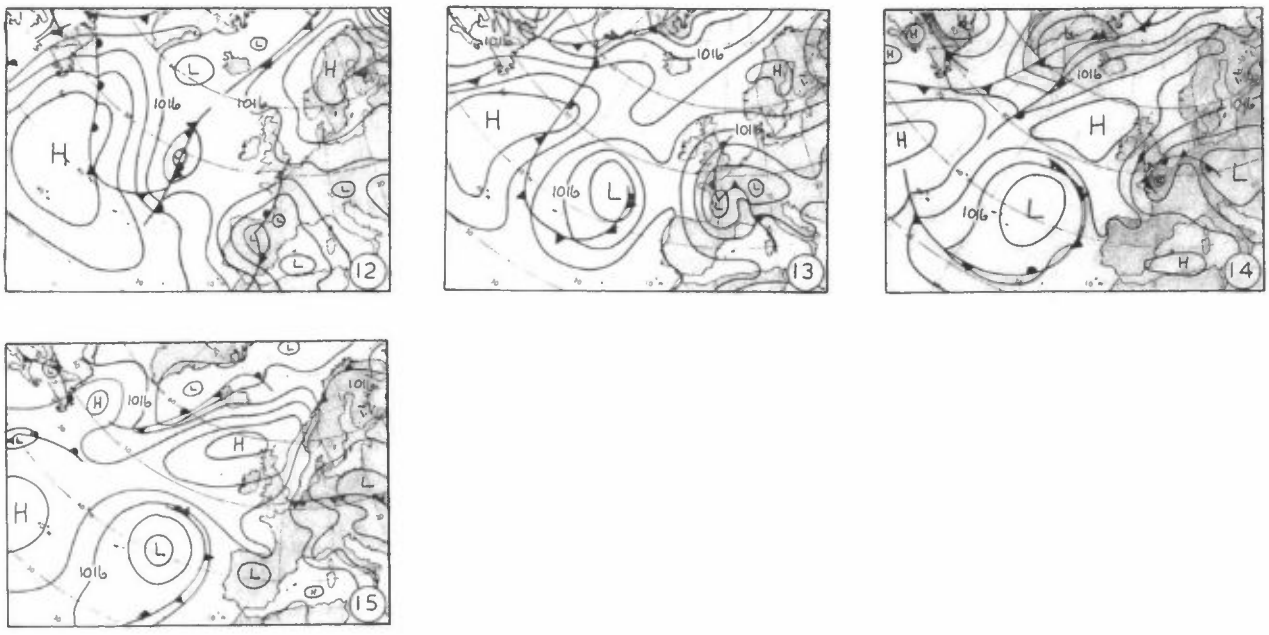

Figure 5: Daily weather maps at 12 GMT, 12-15 June 1977 (British Meteorological Office, 1977).

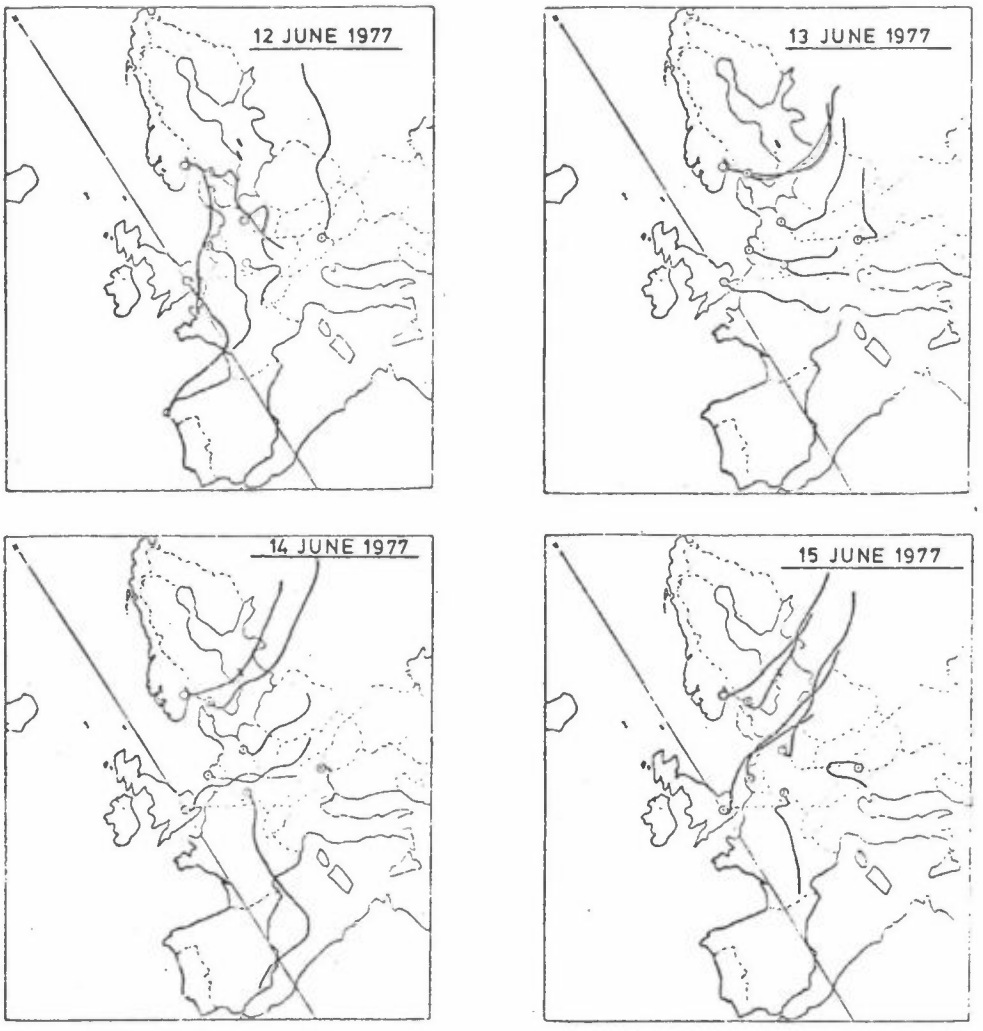

Figure 6: 48-h air trajectories at the 850 mb level arriving at 12 GMT, 12-15 June 1977.

Table 10: Maximum hourly ozone concentrations (ppb), and large scale weather patterns (GWL), 12-15 June 1977 and 2-12 July 1977.

Date	June 1977				July 1977											
Station	12	13	14	15	2	3	4	5	6	7	8	9	10	11	12	
AfL, Wien	111	115			60	84	59	54	41	38	81	49	50	51	54	
Zentralstation, Frankfurt	66	73	47													
Feldberg, Frankfurt									60	49	50	38	42	74	115	
Venusberg, Bonn	53	79	76	32	60	91				53	70	56	76	189	202	
Delft, Netherlands	58	66	65	101	59	119	104	82	78	58	78	58	62	49	72	
Canvey, England	142	179	54	43	108	137	137	100	93	81	77	63	69	62	65	
WSL, England	37	43	37	39	77	135	100	84	63	49		52	52	41	34	
Sibton, England	84	93	54		91	113				66	61	61	62	45	47	
Rörvik, Sweden	74	91														
Maridalen, Norway	92	76	93	109	82	82	99	91	77	62	70	69	82	70	52	
GLW	TRW	HNFZ	HNFZ	HNFZ	HM	HM	HM	NEZ	NEZ	NEZ	NEZ	NEZ	HNA	HNA	HNA	

be explained by transport from the east, because the weather conditions were not favourable for local oxidant formation.

4.4 Episode 2-12 July 1977

The surface pressure gradients were generally small over the European continent during most of the period, and the surface winds were therefore light and variable (Figure 7). The local meteorological conditions seemed to be generally conducive to oxidant formation even if the skies were partly cloudy. The temperatures were typically 25°C (Appendix B4).

The 850 mb trajectories indicate transport aloft to central Europe from the west in the beginning of the period, shifting to northeast later on. The transport to Scandinavia was generally from the north throughout the period (Figure 8).

The maximum hourly ozone concentrations exceeded 100 ppb both in England and the Netherlands, and were close to 100 ppb in Norway (Table 10).

The local and mesoscale emissions have probably played an important role in the beginning of the period, when the transport to England and central Europe was limited or from the west, and the transport to Scandinavia was from the north.

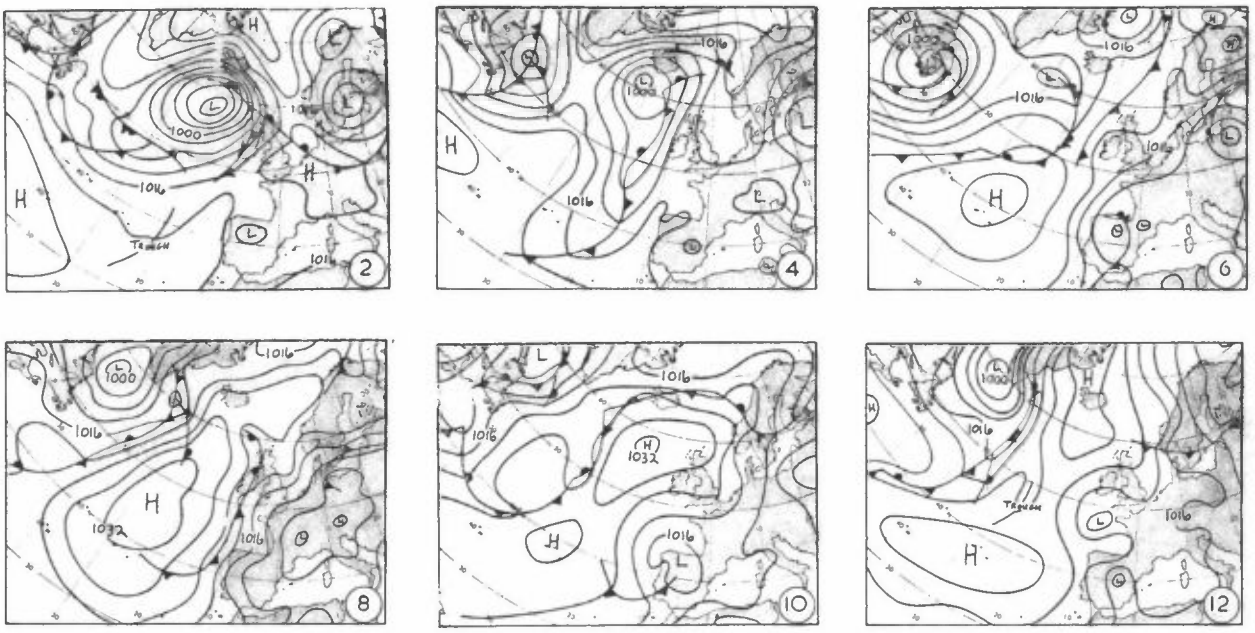

Figure 7: Daily weather maps at 12 GMT for every second day 2-12 July 1977 (British Meteorological Office, 1977).

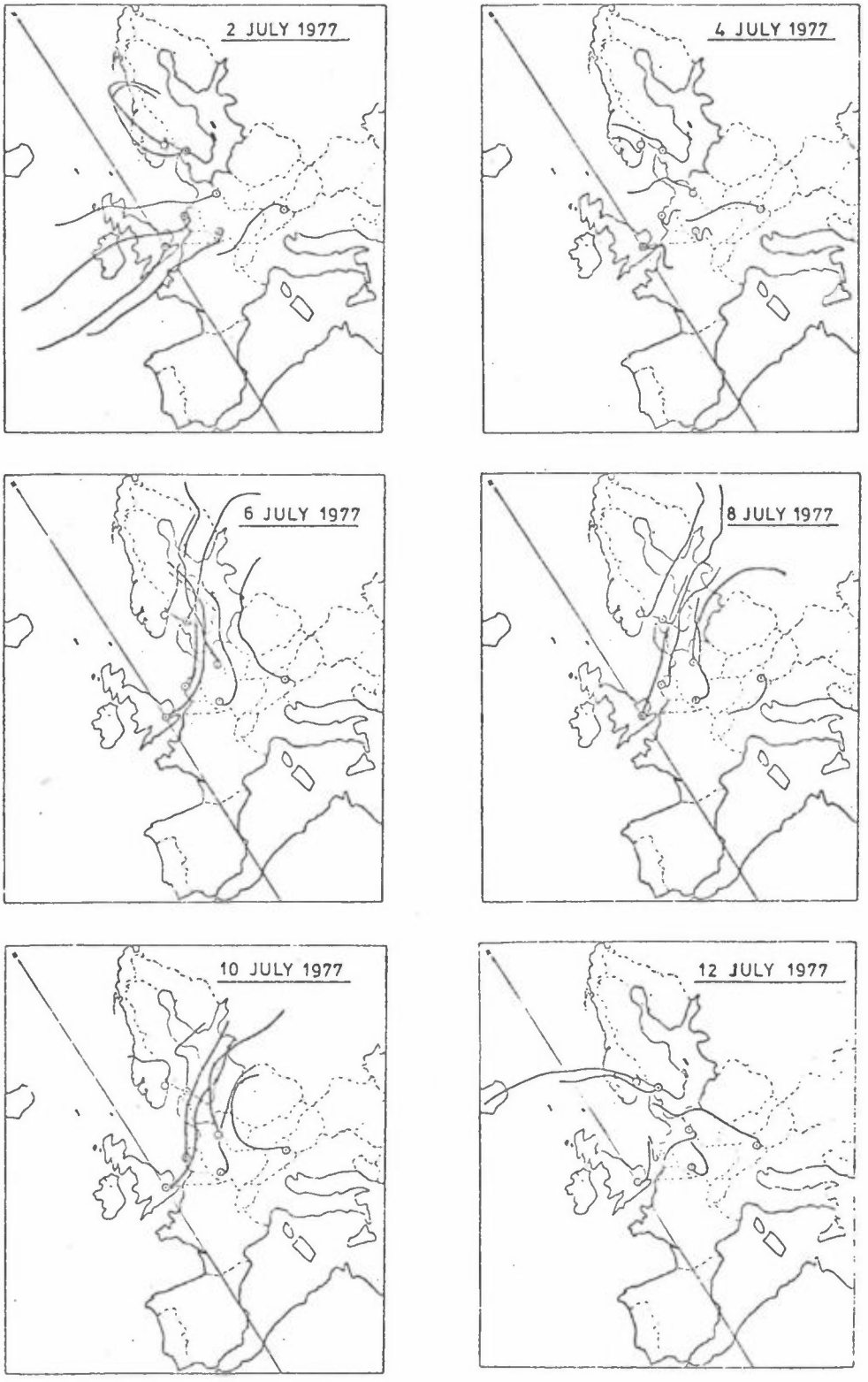

Figure 8: 48-h air trajectories at the 850 mb level arriving at 12 GMT on every second day 2-12 July 1977.

4.5 Episode 28 July - 1 August 1978

A high pressure area covering western USSR and Scandinavia, persisted throughout the period and later moved eastwards (Figure 9), giving light winds and warm weather in continental Europe. In England, it was colder and more cloudy than on the Continent (Appendix B5).

The 850 mb trajectories indicate transport to western Europe from the west and southwest in the beginning, changing to south and southeast at the end of the period. The trajectories to Austria were from the east or northeast (Figure 10).

The maximum ozone concentrations were relatively low in England and the Netherlands, except for one day at Sibton, England. In Austria, the Federal Republic of Germany, and southern Scandinavia the concentrations exceeded 100 ppb (Table 11).

It is likely that oxidant transport played an important role in Scandinavia and probably also in Austria and the Federal Republic of Germany. Because of pronounced land/sea breeze circulations in southern Scandinavia, the mesoscale contribution cannot be discounted.

4.6 Episode 20-23 August 1978

A weak anticyclone was located over western USSR while another was located between Ireland and south-western Europe. A low pressure area moved from Iceland to the Norwegian Sea. A cold front passed western Europe from the west on 22-23 August (Figure 11). The local weather conditions were favourable for oxidant formation in parts of central Europe with light winds and high temperatures, but not in England and Scandinavia (Appendix B6). The 96-h air trajectories at the 850 mb level indicate general transport from the west for Austria (Figure 12).

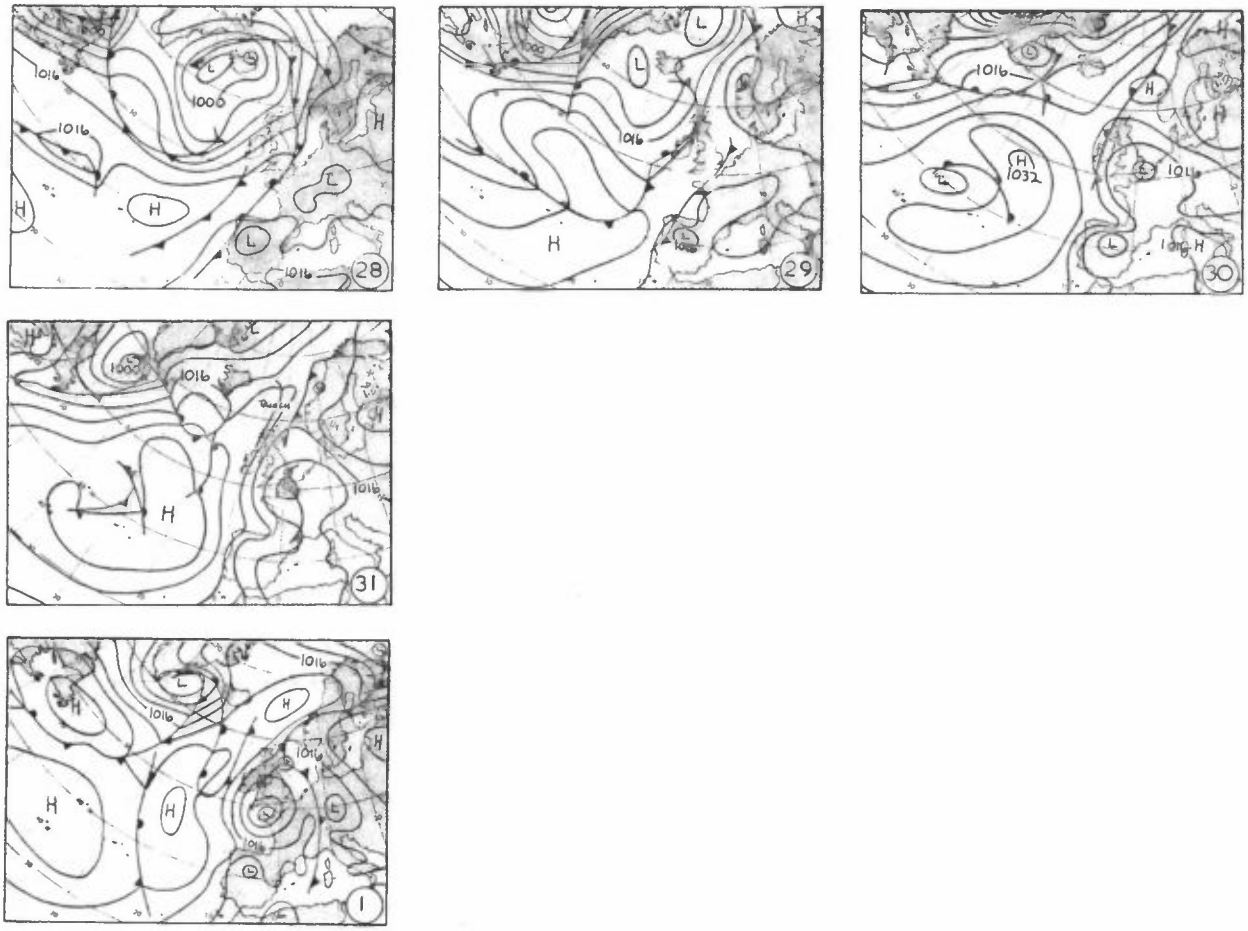

Figure 9: Daily weather maps at 12 GMT, 28 July-1 August 1978 (British Meteoroloigcal Office, 1978).

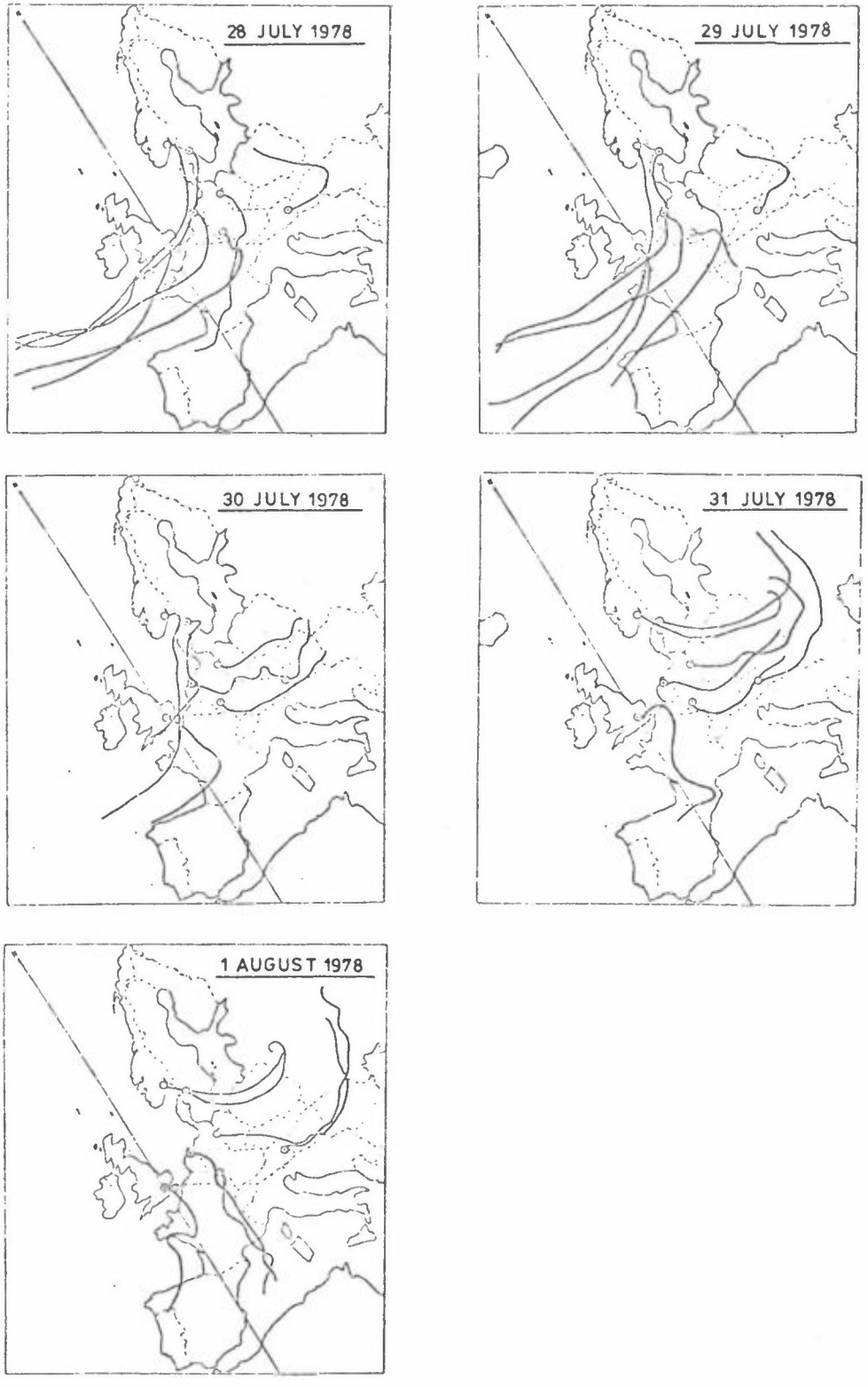

Figure 10: 96-h air trajectories at the 850 mb level arriving at 12 GMT, 28 July - 1 August 1978.

Table 11: Maximum hourly ozone concentrations (ppb), and large scale weather pattern (GWL), 28 July - 1 August 1978 and 20-23 August 1978.

Date	July 1978			August 1978		August 1978			
Station	28	29	30	31	1	20	21	22	23
Illnitz, Austria	112	115	94	90	102	82	105	111	115
Zentralstation, Frankfurt	80					88	114	112	59
Feldberg, Frankfurt	123	108	122		66	105	125	155	85
Venusberg, Bonn	91		106	94	41	93	80	155	35
Delft, Netherlands	77	65	75	55	34	90	60	49	26
Terschelling, Netherlands	81	79	89	91	53	81		47	43
Harwell, England	59	87	52	49	65	67	40	36	42
WSL, England	28	78	61	41	43	76	28	21	20
Sibton, England	68	120					67	49	46
Rörvik, Sweden	95	105	117	90	98	73	77	90	50
Trosby, Norway	61	116	110	110	69				
Maridalen, Norway						82	92	90	36
GWL	HFA	HFA	HFA	HFA	TB	BM	BM	BM	NWA

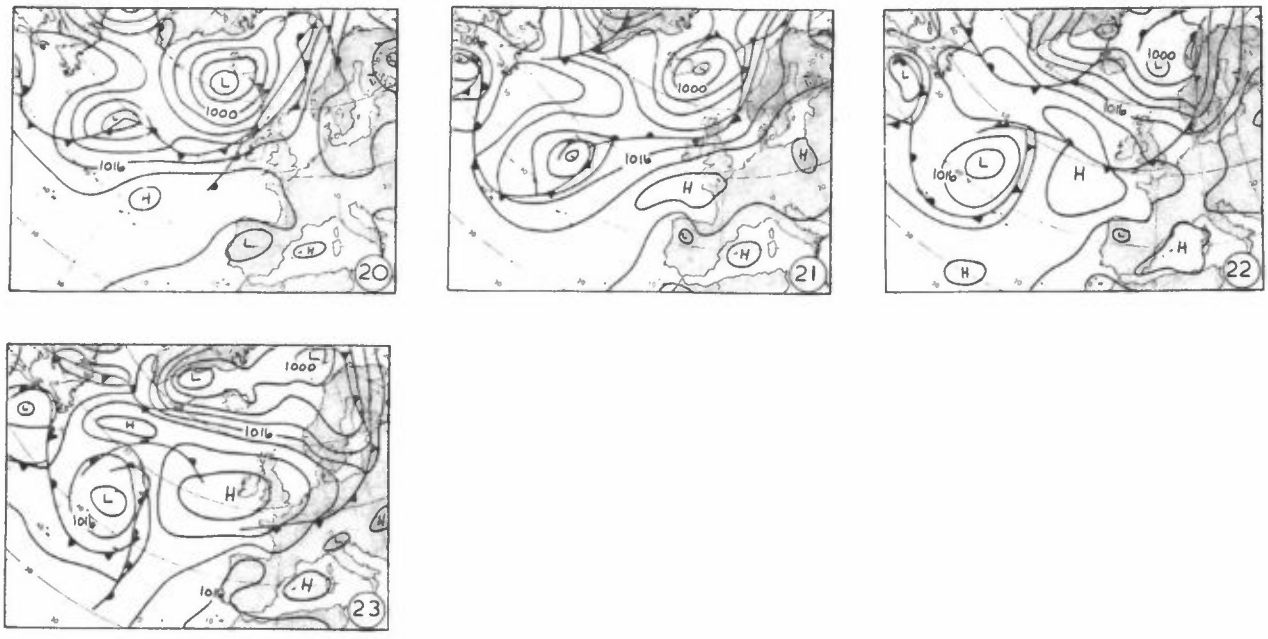

Figure 11: Daily weather maps at 12 GMT, 20-23 August 1978. (British Meteorological Office, 1978).

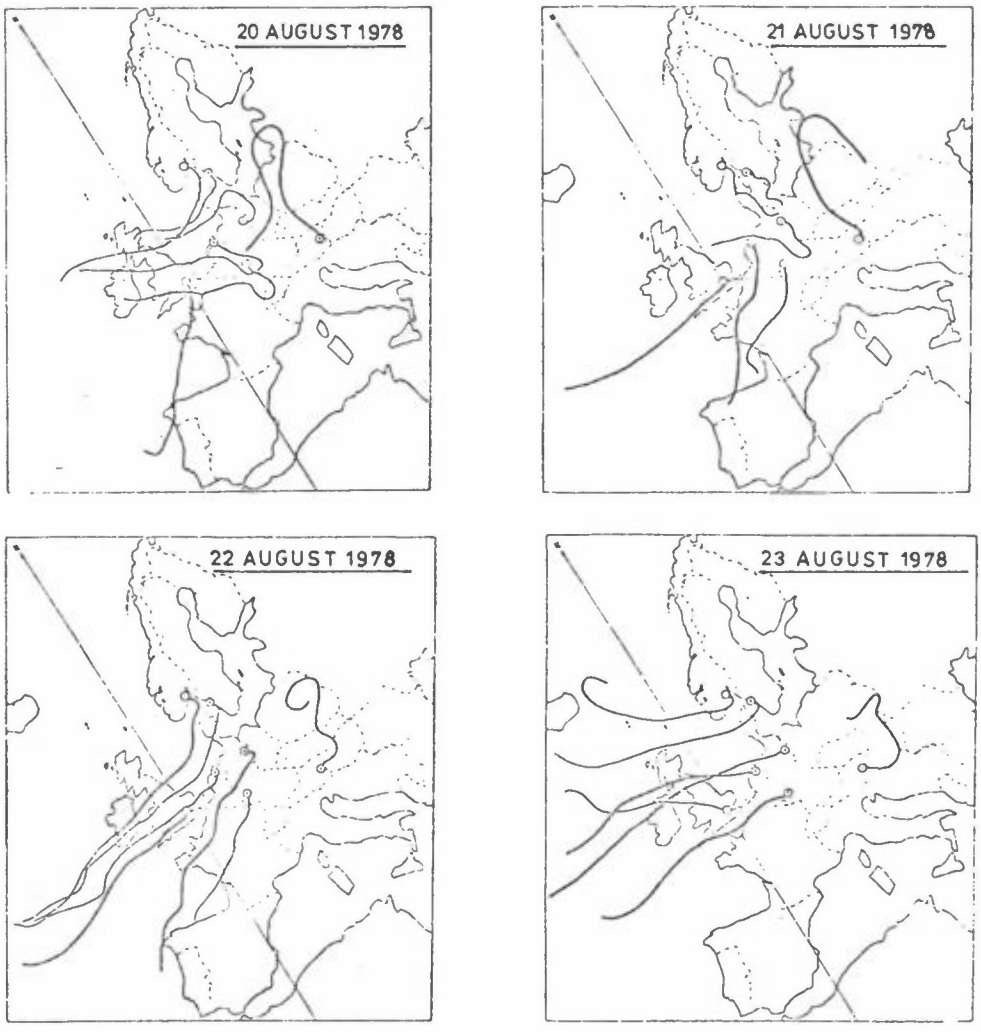

Figure 12: 96-h air trajectories at the 850 mb level, arriving at 12 GMT, 20-23 August 1978.

The maximum ozone concentrations were above 100 ppb in Austria and the Federal Republic of Germany, and around 90 ppb in Scandinavia. At all stations the concentrations were substantially reduced after the cold front had passed. The cold front did not, however, pass Austria and the concentrations there stayed high througout the period (Table 11).

The high concentrations in Norway occurred late in the evenings. In Sweden the highest concentrations were associated with hazy air masses. This indicates that long range transport had played an important role. The high concentrations in Frankfurt and Bonn may have had a significant influence of local and meso-scale ozone production.

4.7 Episode 12-20 May 1979

During the first part of the period, an anticyclone over England and continental Europe gave light winds and relatively warm weather. A low pressure centre approaching from the Atlantic Ocean strengthened the winds and caused cloudiness and lower temperatures during the last part (Figure 13). A cold front passed over Europe 16-17 May. The local weather conditions may be classified as conducive to oxidant formation in central Europe and England on 14-16 May (Appendix B7).

The 96-h air trajectories at the 850 mb level indicate transport aloft from the west in the first part of the period. Around 15-16 May the transport directions were variable, with the air masses staying over central Europe for several days. After the cold front had passed, the trajectories show transport around the low pressure centre in the North Sea (Figure 14).

The ozone concentrations in Austria were high througout the period. The concentrations were also high in Belgium, Netherlands and parts of England on 13-15 May, and in Sweden on 15-16 May (Table 12).

The high concentrations in England, Belgium and the Netherlands cannot be easily explained by transport from distant sources. It must then be assumed that local and mesoscale production had occurred. For Sweden, however, a typical transport situation is indicated, with high ozone concentrations measured prior to a cold front passage.

4.8 Episode 30 May - 8 June 1979

An anticyclone stagnated over Scandinavia during most of the period, and the pressure gradients over Europe were generally small (Figure 15). The local weather was fair in southern Scandinavia and on the continent. In England it was much more cloudy (Appendix B8).

The air trajectories indicate transport from the south to western Europe in the beginning. Later the transport had a significant easterly component, changing to west at the end of the period (Figure 16).

The ozone concentrations were high in Austria and low in England throughout the period (Table 12). Maximum concentrations exceeding 100 ppb also occurred in Belgium and the Federal Republic of Germany. In Sweden the maximum hourly concentrations were 80-150 ppb. In Norway the maximum concentration on a regional basis was ca 90 ppb, with a maximum of 197 ppb downwind of an industrial area (Schjoldager, 1980).

It may be suggested that the high concentrations in central Europe were due to local and mesoscale formation with some enhancement from long range transport. For southern Scandinavia transport from distant sources was probably important in

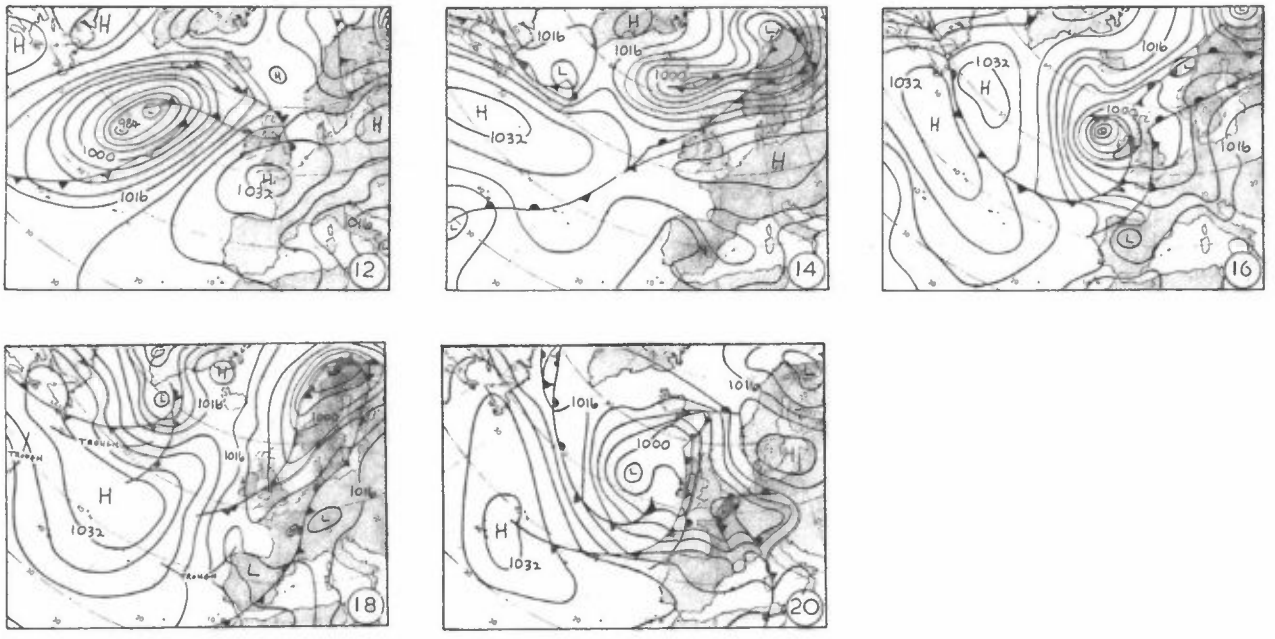

Figure 13: Daily weather maps at 12 GMT for every second day, 12-20 May 1979 (British Meteorological Office, 1979).

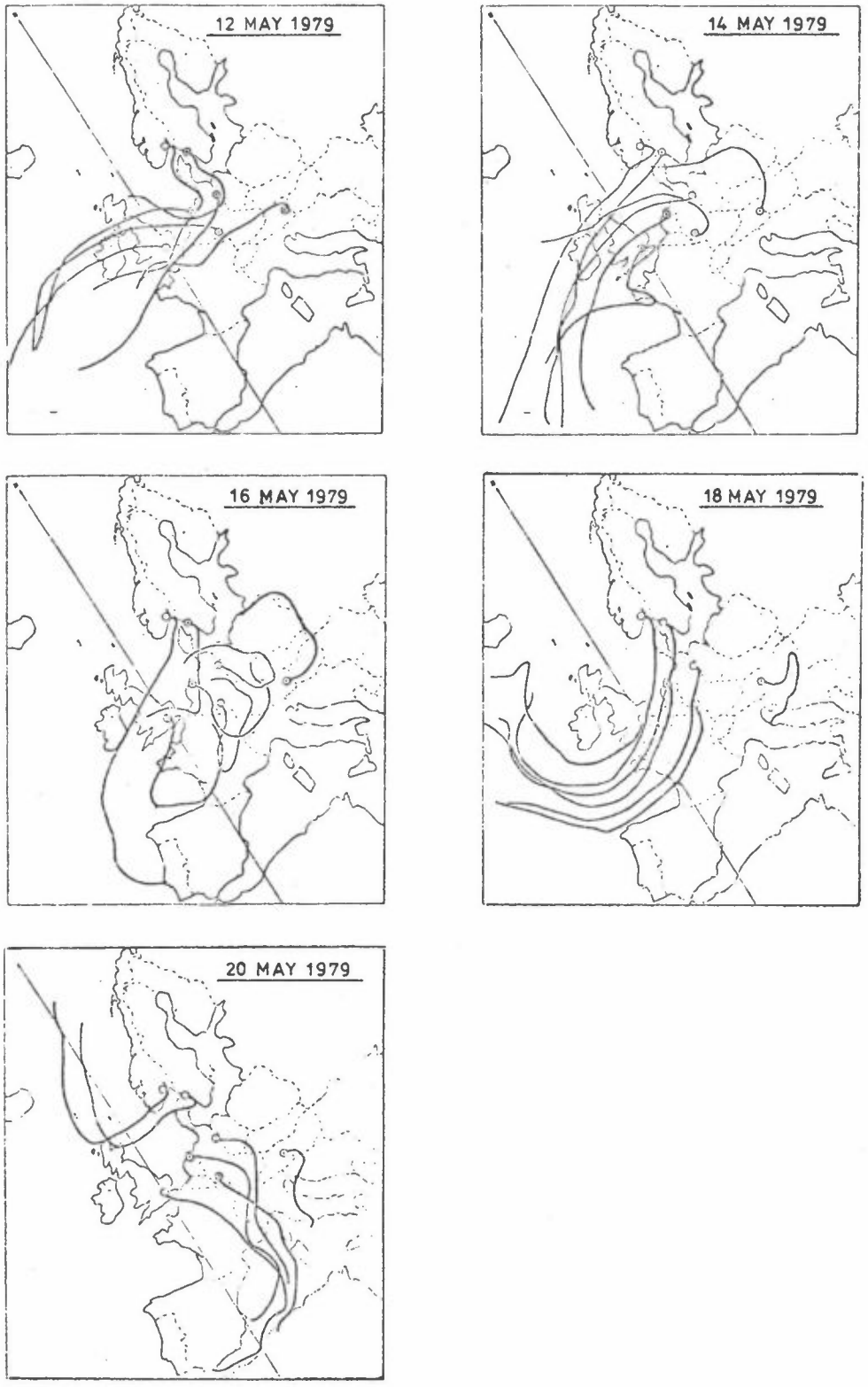

Figure 14: 96-h air trajectories at the 850 mb level, arriving at 12 GMT on every second day, 12-20 May 1979.

Table 12 : Maximum hourly ozone concentrations (ppb), and large scale weather patterns (GWL), 12-20 May 1979 and 30 May - 8 June 1979.

Date	May, 1979										May, 1979	June, 1979								
Station	12	13	14	15	16	17	18	19	20		30	31	1	2	3	4	5	6	7	8
AfL, Wien	37	42	88	95	80	83	84	122	96		92	100	108	119	119	128	99	154	160	70
Illmitz, Austria	126	137	164	161	145	150	157	190	161		161	183	189	186	198	193	180	166	220	161
Röschnitz, Austria	62	79	85	82	94	95	97	141	90		107	111	99	98						84
Zentralstation, Frankf.	29	38	47	62	74	17	22	48	40		50	122	48	66	63	78	70	23	42	30
Delft, Netherlands	41	65	102	128	86	45	44	46	27		28	56	53	40	66	78	47	48	41	65
Canvey, England	88	62	83	93		40	40	55	31		45	23	58	41	65	65	44	42	30	41
WSL, England	31	33	38	71	64	28	26	50	24		40		29	27	25	56	25	23	17	28
Sibton, England	42	70	100	83	83	36	43	45	35		56	43	53	44	77	75	61	47	43	60
Rörvik, Sweden	76	64	88	100	198		73	82	78		114	112	150	114	80	95	90	92	84	
Langesund, Norway			51	65	57	91	62	61	54		57	94	90	70	61	65	71	93	90	64
R 801, Belgium	51	117	45	73	45	32	26	58	28											
R 822, Belgium	35	66	78	96	75	42	37	48	31			47	44	39	100	63		37		28
Helsinki, Finland	53	56	54	48	52	83	84	57	61		63	56	44	57	50	51	54	57	57	59
GWL	BM	BM	BM	BM	TRW	TRW	TRW	TRW	TB		HNFA	HNFA	HNFA	HNFA	HNFA	HNFA	HNFA	HNFA	BM	BM

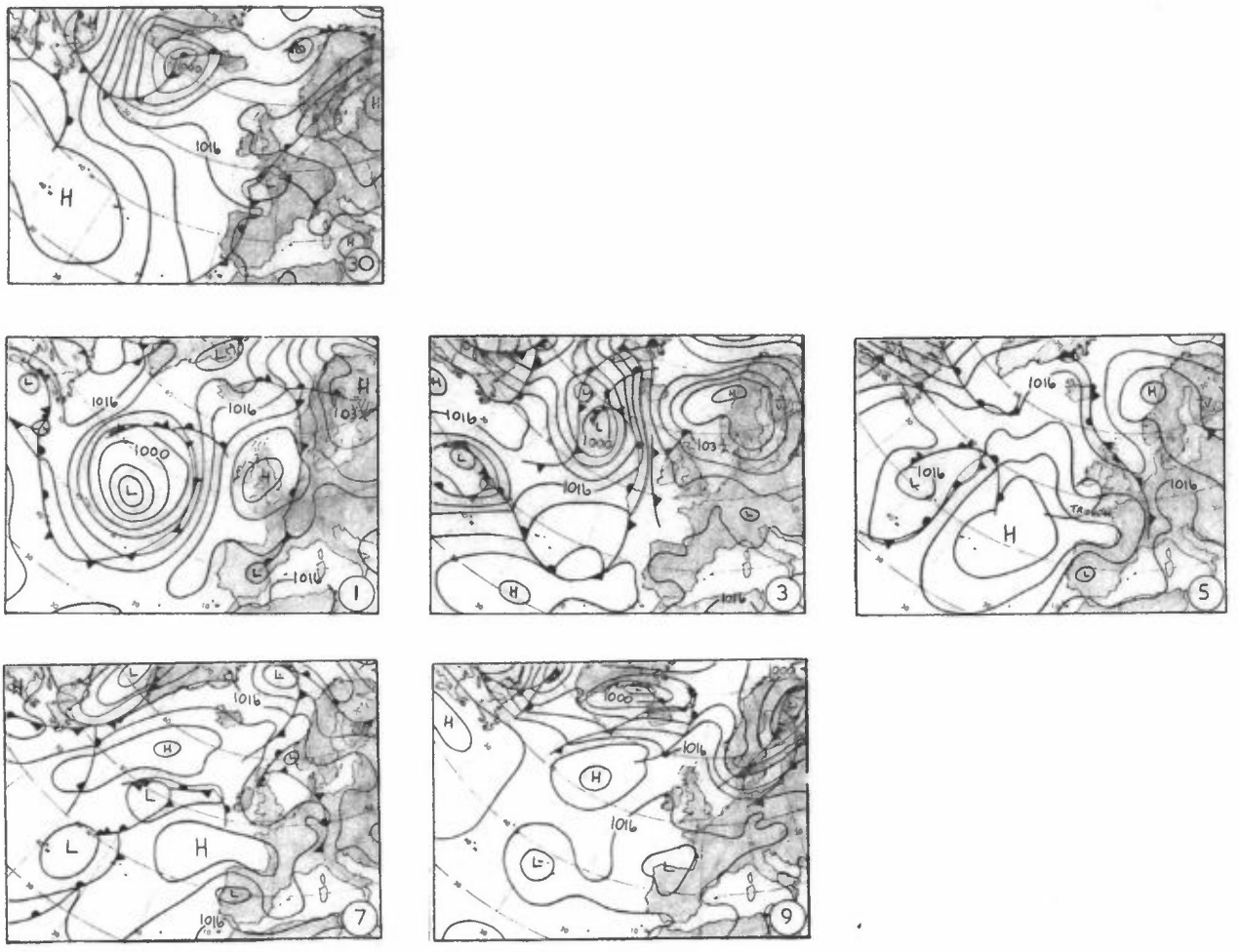

Figure 15: Daily weather maps at 12 GMT for every second day, 30 May - 9 June 1979 (British Meteorological Office, 1979).

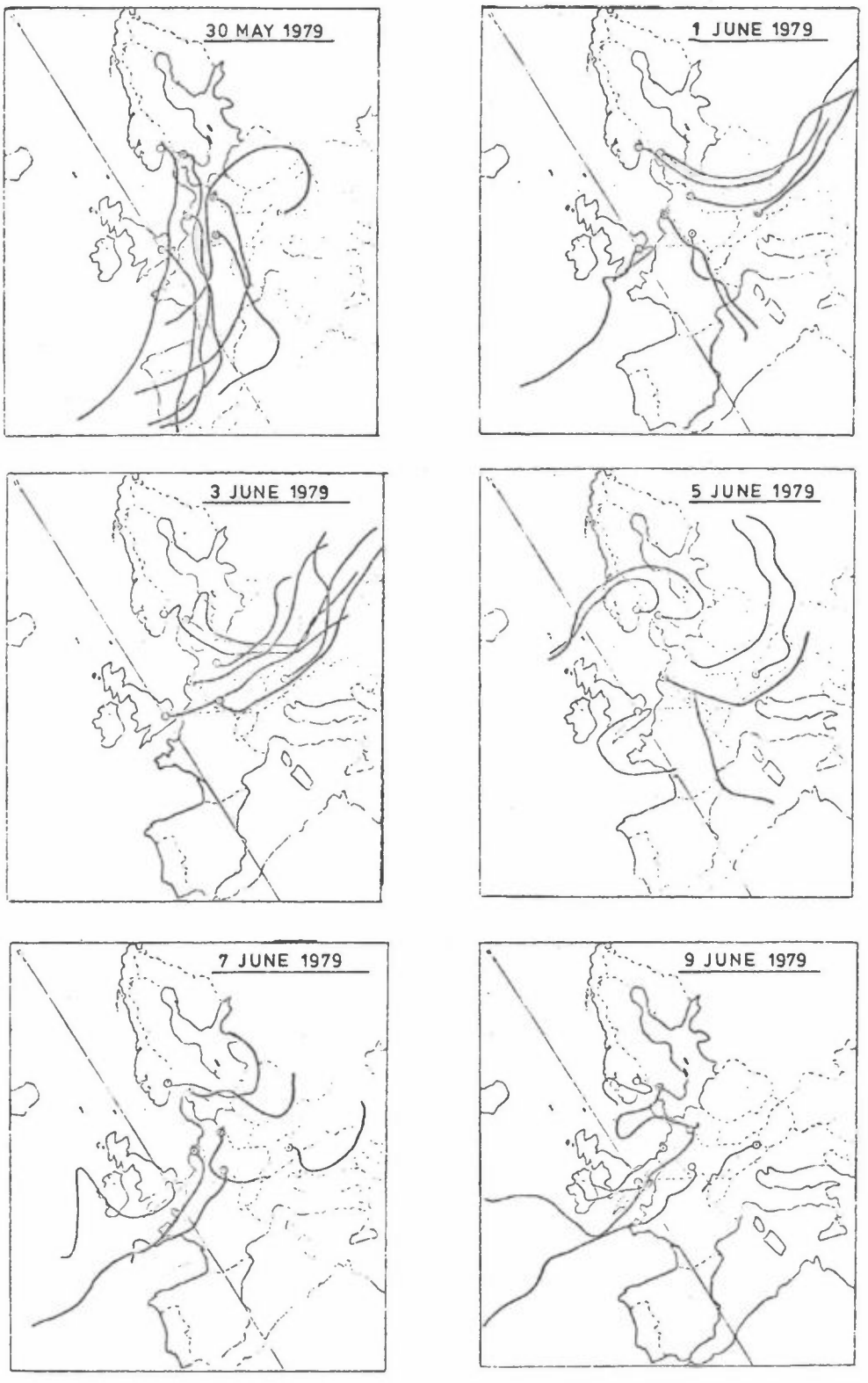

Figure 16: 96-h air trajectories at the 850 mb level, arriving at 12 GMT on every second day, 30 May-9 June 1979.

the first part of the period, but local and mesoscale production appear to have contributed significantly during last part of the period.

5 DISCUSSION AND SUGGESTIONS FOR FUTURE WORK

The information presented in this report is intented to provide a brief survey of some aspects of photochemical oxidant formation in Europe. The study has largely followed along the lines of similar previous studies (e.g., Cox et al., 1975; Guicherit and van Dop, 1977), and it generally confirms the earlier findings.

The basic mechanism of ozone formation during photochemical oxidant episodes is understood in general. Ozone is produced during high pressure situations with light winds and warm and sunny weather. Because the precursor source areas are distributed all over north-western Europe, the ozone generation can take place over large areas, and precursors, as well as the secondary pollutants, can be transported over large distances. The maximum ozone levels as high as, and in some cases higher than the threshold levels associated with plant damage and health effects (National Academy of Sciences, 1977; World Health Organization, 1978; Environmental Protection Agency, 1978).

A more complete picture of the oxidant situation is not, however, available at present. There are major gaps both in the data base, and the tools for analysis, and hence in the general understanding of the phenomenon.

Among the many aspects of photochemical air pollution, which should be subjects for further investigation, the following can be mentioned:

- An emission inventory for north-western Europe of oxides of nitrogen and volatile organics. The emissions should be given for grid squares of, say ca 100x100 km, with diurnal variations included, if possible.
- The role of natural organics in the large scale photochemical oxidant formation. Even if the natural organics are not believed to play a significant role on the local scale and the mesoscale, a possible contribution during multi-day photochemical oxidant episodes should not be discounted.
- The transport of air pollutants during high pressure situations. In these cases air trajectories are often highly uncertain. The high concentrations of photochemical oxidants are, however, most likely to occur during these weather situations. The need for more research on this aspect is thus obvious.
- Large scale photochemical transport models. These models will be necessary to increase the general understanding and especially to predict the effect of future emission controls.
- A consistent data base of relevant air concentrations. Consistency in measurement and calibration methods, as well as in the criteria for sampling sites is essential.
- Measurements above the surface layer. Aircraft measurements are of value to determine the horizontal and vertical extent of high concentrations. Measurements from meteorological towers are of value to study the diurnal concentration variation above the nocturnal surface inversion layer.
- Effects studies, especially plant damage, showing the present extent of plant injuries and indicating the risk of further injuries if the concentration levels increase. The studies should include both commercial crops (e.g., vegetables) and natural vegetation (e.g., coniferous forests).

Some of these aspects are already being investigated by various research groups.

It should also be pointed out that other parts of Europe may experience concentration levels of photochemical oxidants as high or higher than these shown in this report. Of special importance is the entire southern part of Europe. The total precursor emissions there are smaller than in north-western Europe, but the weather of southern Europe is much more sunny and warm. It may well turn out that in all the Mediterranean countries, from Spain to Turkey, oxidant levels exceeding internationally accepted threshold values, can occur. Studies in these regions of Europe are thus highly desirable.

The Austrian ozone data also indicate that high concentrations can occur in parts of central Europe. Measurements downwind of other major metropolitan areas of central Europe will give insight into this aspect.

5.1 Suggestions for future measurement programmes

In future multi-country measurement programmes it must be assured that a common calibration method is used. Alternatively, a common set of calibration methods giving equivalent results can be employed. The most recently developed calibration methods for ozone are the ultraviolet absorption and gas phase titration. Wet chemical methods with a known and constant bias relative to the other calibration methods (e.g., Bergshoeff et al., 1980) may also be used.

In order to study large scale photochemical oxidant formation and transport in north-western Europe, rural monitoring sites should be preferred to avoid local influence. The local influence can affect results both ways by providing either favourable production conditions during warm and sunny weather, or nitric oxide sources for ozone scavenging.

For a minimum sampling network in north-western Europe a distance of about 300 km between neighbouring stations may be recommended. The number of stations in each country would then roughly be:

Country	No of stations
Austria	2
Belgium	1
Denmark	1-2
Federal Republic of Germany	3
Finland	2
France	2-3
Ireland	1
Netherlands	1
Norway	2-3
Sweden	2-3
United Kingdom	2-3

The air pollutants of interest may tentatively be grouped into priority categories as follows:

First priority: Ozone (continuous)
Second priority: Sulphate (24-h)
Visibility (at least once per day)
Nitric acid (24-h)
PAN (continuous, if possible)
Third priority: Oxides of nitrogen (continuous)
Volatile organics (continuous)
Sulphur dioxide (24-h)

The quality of the measurement data should be assured by regular intercalibration procedures and station performance audits.

6 CONCLUSIONS

In this report ground-level ozone data from eight European countries from the years 1976-79 have been studied. The eight countries are: Austria, Belgium, Federal Republic of Germany, Finland, Netherlands, Norway, Sweden and United Kingdom.

With one exception, all the hourly ozone concentrations exceeding 200 ppb were measured in England or Netherlands during 1976, or at Illmitz, Austria during 1979. The highest 1-hour ozone concentration discussed in this report is 258 ppb, measured at Harwell, England, on 5 July 1976. However, concentrations up to 0.27 ppm have earlier been reported from Vlaardingen, Netherlands, on 8 May 1976.

Most high ozone concentrations occurred with stagnating anticyclones. When a high pressure area was located over central Europe, Scandinavia or Finland, the concentrations were often high over all the examined regions in north-western Europe. With a high pressure ridge over central Europe, or with the high pressure centre over the North Sea, the concentrations could still be high on the European continent and in Great Britain, but significantly lower in Scandinavia. In cases with cyclonic circulations and low pressure areas over central Europe, the concentrations could still remain high in Scandinavia, but were significantly lower in other parts of north-western Europe.

At the Austrian station Illmitz, located in a rural area 65 km southeast of Vienna, the concentrations were high throughout the period April to September 1979. On 164 days of a total of 183 days, the maximum hourly concentration exceeded 100 ppb, and on 90 days the maximum concentrations exceeded 150 ppb.

Eight time periods have been studied in more detail with respect to synoptic weather situation, local meteorological conditions and trajectory analyses, in order to assess the origin and

transport of the polluted air masses. In each of the four years two high ozone episodes were examined. In some cases long range transport appeared to be more important than the local and mesoscale ozone formation, while the contrary was the case on other occasions. Due to the methodology used and the limited amount of measurement data, it was impossible to assess quantitatively the role of the various production scales. Thus it has not been possible to evaluate quantitatively the influence of the various precursor source regions on the ozone concentrations at the various receptor points.

The highest ozone concentrations were reached during weather conditions conducive to oxidant formation when local precursors were emitted into polluted air masses transported from other source regions. A good example of an episode of this kind is the situation in England during the hot spell in June/July 1976.

In most parts of north-western Europe the maximum ozone concentrations are as high as, and in some cases higher than, the threshold levels associated with plant damage and health effects.

The need for further, concerted studies of photochemical oxidants in Europe is clearly present. Such studies should include:

- An emission inventory of oxides of nitrogen and volatile organics, both natural and anthropogenic.
- An investigation of the role of natural organics in the large scale photochemical oxidant formation and transport.
- Photochemical models on the relevant time and spatial scales, including improved synoptic transport models for stagnant situations.

- A consistent data base of ambient air concentrations, including troposhperic measurements above the surface layer (e.g., aircraft, towers).
- Studies on injuries to commercial crops and natural vegetation.

Studies should also definitely be carried out in other parts of Europe. As the Austrian data indicate, high concentrations may be expected in the vicinity of major urban areas in parts of central Europe. Furthermore, the Mediterranean coast from Spain to Turkey may well turn out be a present or future problem area of photochemical air pollution.

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APPENDIX A

LIST OF PERSONS/INSTITUTIONS HAVING SUBMITTED DATA

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APPENDIX B

Daily weather summaries at 12 GMT

Wind f: wind speed m/s
d: wind direction
("Var" means "variable")

Clouds Sky coverage, total amount
0 : No clouds
8 : Completely overcast

Temp. Temperature (^{o}C)

The summaries are based on the German "Europäischer Wetterbericht" (Deutscher Wetterdienst, 1976-79).

APPENDIX B1

WEATHER SUMMARY (12 GMT) 19 June - 17 July 1976

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
19.6.		Shetland Finland	5	W	7-8	20	5	W	7	15	5	W-SW	8	10
20.		Scandinavia	5	W	8	15	5	NW	5	15	3	SW	7-8	15
21.	North France	Finland	3	W	5	20	3	SW	5	20	5	NW	4	15
22.	Netherlands	"	1	Var	5	20-25	1	Var	5	20-25	3	W	5	15
23.	North Germany		1	Var	2	25-30	1	SW	2	25-30	1	Var	2	20
24.	Poland	Iceland	1	Var	1-5	25-30	1	SW	3	25	3	Var	6	20
25.	Azores-Poland	"	1	Var	1	30	1	Var	1	25-30	3	SW	1	20-25
26.	" "	Iceland, Shetland	1	E	0-1	30	1	Var	0	30	3	W,SW	1	25
27.	" "	Iceland	1	E	1	30	1	Var	0-1	25-30	5	W	3	20-25
28.	British Isles	Iceland, Finland	1	Var	0-1	25-30	1	NE	1	25-30	5	W,NW	1	20
29.	North Sea	Jan Mayen, NW USSR	1	NE	1	25-30	3	E	0	25-30	1	W	1	20
1.7.	North Sea	Spitsbergen	1	NE	0-1	30	3	E	0-1	25-30	1-3	Var	0-1	20-25
2.	Denmark		1	E	0	30	1-3	E	0	30	1-3	Var	0-1	20
3.	Denmark-North Sea	Southern Norway	1	Var	0-1	30	3	E	2	30	1	Var	5	20-25
4.	Norwegian Sea		1	Var	0-1	30	3	E	2	25-30	1	Var	1-7	20
5.	Denmark-Norwegian Sea		1	NE	0-5	25-30	3	E	2	25-30	3	Var	2	20-25
6.	" "		3	E	1	25	3	E	0-1	25-30	1	W	1	20-25
7.	Norwegian Sea		3	E	0-1	25-30	1	E	0	25	1-3	Var	0-2	20-25
8.	" "		1	Var	0-3	25-30	1	Var	0	25	3	NE	7	15-20

APPENDIX B1 cont.

WEATHER SUMMARY (12 GMT) 19 June - 17 July 1976

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
9.		West of Ireland	3	Var	6	25	3	S	7	20-25	1	Var	7	20
10.		" " "	1	Var	2-6	20-25	1	Var	2-6	20	3	Var	1-5	20-25
11.		" " "	1	Var	1-3	25	3	Var	0-5	20-25	3	Var	7	15-20
12.	Norwegian Sea	" " "	1	Var	1-3	25	3	SE	5	25	1-3	E	3-6	20
13.	" "	" " "	3	Var	7	20-25	3	SW	7	20	1-3	Var	2	20-25
14.	" "	" " "	1	Var	7	20-25	3	W	7	20	1	S	1-8	20-25
15.	Germany	" " "	1	W	4	25	3	SW	7	20	3	S-W	5	20
16.	Western USSR	Iceland	3	SW	7	30	1	Var	7	20	3	S-SW	1-6	25
17.	" "	"	1	Var	1-8	20-30	1	Var	3	20	3	S-SW	1-7	20

APPENDIX B2

WEATHER SUMMARY (12 GMT) 16-30 August 1976

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
16.8.	Scandinavia		1	Var	1	20-25	1	E	2	20-25	1	Var	2	25
17.	North Sea		1	NE-NW	2-8	20-25	1	Var	1	25	1	Var	1	25
18.	" "		1	Var	3	20-25	1	E	3	20	1	Var	1	25
19.	Scotland		1	Var	1-7	20-25	3	E	2	20-25	1-3	NW-NE	1-6	25
20.	British Isles		3	Var	1-7	20-25	3	N	3	20-25	3	NW-NE	7	20
21.	Southern Scandinavia		3	E	0-2	20	3	E	2	20	1	Var	1	20
22.	" "		3	E	1-2	20	5	SE	0	20-25	1	Var	1	25
23.	Scandinavia		3	E	0	20-25	3	SE	1	25	1	Var	1	25
24.	North Sea-Balkan		1	E	0	25	1	E	0	25-30	3	W	1	20-25
25.	British Isles-Balkan		1	Var	0	25-30	1	E	0	25-30	3	W	0-4	20
26.	Scotland		3	Var	1-7	20-25	3	NE	1-8	20-25	3	N	3	20
27.	North of Scotland		3	N	6	20	5	NE	3-7	15-20	3	NE	2	15-20
28.	Faeroe Islands-Scandinavia		3	E	3-7	15-20	5	NE	7	15-20	1	Var	1-7	20
29.	Baltic Sea	Jan Mayen	3	SE-E	6	20-25	3	E	6	20	3	S	2	25
30.	Western USSR	Norwegian Sea	3	SW	7	20	1	SW	8	15-20	3	S	3-8	15-20

APPENDIX B3

WEATHER SUMMARY (12 GMT) 12-15 June 1977

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
12.6.	Scandinavia-Ural		1	NE	5	20	1	E	8	15	1-3	Var	6	15-20
13.	Nortwest USSR	South France	3	E	1	30	3	N	8	15-20	1-3	Var	7	20
14.	Scandinavia-West USSR	France	1	Var	6	20-25	3-5	NE	8	15	1-3	Var	2	25
15.	West USSR, Scotland	Poland	1-3	SW	8	15-20	3-5	N	8	10-15	1	Var	3	25-30

APPENDIX B4

WEATHER SUMMARY (12 GMT) 2-12 July 1977

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
2.7.	West Central Europe	North Atlantic Baltic Sea	1-3	Var	1-7	20	1-3	S	1	20	5	NW	5	15-20
3.	" "	North Atlantic West USSR	1	Var	1-4	25	1	Var	1	25	1-3	Var	4	20
4.	North Sea	" " "	1-3	Var	2	25	3	E	3	25	1-5	Var	4	20
5.	Barents Sea	Iceland	3	NE	2	25	3	E	5	25	3	NE	3	25
6.	Kola	Poland	3	Var	0-3	25	3	NE	4	25	3-5	NE	3-7	30
7.	Kola-Finland	Poland	1-3	NE	6	20	3	NE	2	25	1-5	E	6	20-25
8.	Kola, Norwegian Sea	Poland	3	NE	3-7	20-25	3	NNE	7	20	3-5	NE	1	15-20
9.	West USSR, North Atlantic	East Europe	1	NE	7	20	3	NE	3	20	1-3	Var	1	25
10.	" "	" "	1	N	5	25	3	NE	3	20	1-3	Var	1	20-25
11.	" "	" "	1	Var	1	25	3	NE	3	20	3	Var	1	20-25
12.	North Atlantic	Finland	3	Var	1	25	3	NE	4	20	1-3	Var	3-8	20

APPENDIX B5

WEATHER SUMMARY (12 GMT) 28 JULY - 1 AUGUST 1978

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
28.7.	West USSR	Iceland	1	SW	3-5	25-30	3	SW	2	20-25	1	Var	4	20
29.	Norway-West USSR		1	NE	3-5	25-30	1	Var	8	20-25	1	S-SV	4	20-25
30.	" "	France	3	SE	0	30	1	Var	8	15-20	1	Var	1-3	25
31.	West USSR-Finland		3	SE	0-8	25-30	5	N	8	15-20	3	SE	0-3	25-30
1.8.	West USSR	English channel	1-3	Var	4-8	20-25	3	SE	7	15-20	3	SE	2	25-30

APPENDIX B6

WEATHER SUMMARY (12 GMT) 20-23 AUGUST 1978

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
20.8.	Baltic Sea	Iceland	1	SE	0-2	25	1	W	5	20-25	1	SW	1-4	20
21.	Baltic Sea, Bretagne	Iceland	1	Var	1-8	25	1	SW	6	20	3	S	4	20
22.	West USSR	Norwegian Sea	1	Var	0-2	25-30	3	SW	7	20	3	SW	8	15-20
23.	South Europe-West Ireland		1-3	Var	4	20	1	NE	4	20	3	W	3	15-20

APPENDIX B7

WEATHER SUMMARY (12 GMT) 12-20 MAY 1979

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
12.5.	English Channel-Western USSR		1	NW	3-8	15-20	1	W	8	15	1	Var	8	10
13.	English Channel	Iceland	1	Var	3-6	15-20	3	Var	4	20	3	SW	7	10
14.	North Europe	Iceland	1	Var	0-5	20	1	Var	1	20-25	3	SW	7	10-15
15.	East Central Europe	Norwegian Sea	1	Var	0	25	1	Var	2	25	3	SW	0-8	15
16.		West of Scotland	5	S	1-3	25	5	SW	6	20	3	S	0-8	20
17.		Scotland	3-5	SW	8	15	5	S	6	15	1	SW	8	10-15
18.	France	North Norway, Central Europe	1-5	Var	6	15	1	Var	6	15	3	SW	8	10-15
19.	Nortwest Europe	North Norway, East Central Europe	1	Var	4	15-20	1	SW	2	15	5	SW	5-8	10
20.	Baltic Sea	English Channel	3	S-SE	7	20	3	E	8	10	3	Var	1	10-15

APPENDIX B8

WEATHER SUMMARY (12 GMT) 30 MAY-8 JUNE 1979

Date	High pressure centre	Low pressure centre	North European Continent				England				Southern Scandinavia			
			Wind		Clouds	Temp.	Wind		Clouds	Temp.	Wind		Clouds	Temp.
			f	d			f	d			f	d		
30.5.	West USSR		3	E	4-7	25	3	E	8	15-20	1-3	Var	7	15
31.	West USSR-Norwegian Sea		3	Var	0-6	20-30	1	W	7	15	3	E	2-8	20-25
1.6.	England, Finland		3	Var	0-6	20-25	3	NE	7	15-20	3	SE	1	25-30
2.	Norwegian Sea		1	Var	0-8	20-30	5	NE	4	20	1-3	NE	0-4	20-30
3.	Scandinavia		3	E	0-6	25-30	1	N	8	15	3	NE	3-6	20
4.	Scandinavia		1	Var	2-6	25-30	1-3	Var	8	15-20	1	Var	0-2	20-25
5.	Scandinavia-Black Sea		1	Var	1-8	20-25	1	W	6	15-20	1	SE	1	25
6.	Scandinavia-Black Sea		3	W	1-8	20	3	Var	7	15	1	SE	1-5	25
7.	Central Europe		1-3	W-SW	1-8	15-20	3	N-NW	7	15	1	Var	1	25
8.	Central Europe		3	SW	6	15-20	1	SW	7	15-20	1-3	W	8	10-15

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Ozondata for åra 1976-79 er samlet inn fra åtte land: Østerrike, Belgia, Vest-Tyskland, Finland, Nederland, Norge, Sverige og U.K. Dager med høy ozonkonsentrasjon er gruppert på grunnlag av værforholdene på stor skala. En mer detaljert vurdering er foretatt for åtte episoder med høye konsentrasjoner i flere land.

TITLE

ABSTRACT (max. 300 characters, 5-10 lines)

Ambient ozone data have been examined from eight countries for the years 1976-79: Austria, Belgium, Federal Republic of Germany, Finland, Netherlands, Norway, Sweden and United Kingdom. The data have been categorised according to the large scale weather pattern. For eight episodes with high ozone concentrations in several countries, more detailed meteorological assessments have been carried out.

**Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C