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A Database of methane concentrations as measured in The Netherlands and Europe

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ABSTRACT

Data on methane measurements at four locations in the Netherlands and three locations in northwest Europe over the period 1990-1994 were collected and entered in a database. Besides meteorological data as measured by KNMI near the measuring sites, were included also. The sources and formats of the data, the processing procedures and the databases themselves together with timeseries of the CH_4 concentrations, are described in this report.

SAMENVATTING

Om meer inzicht te verkrijgen in de emissies en bronnen en putten van methaan op kleine schaal is het project "Bronnen, ruimtelijke opschaling en validatie van methaanemissies in Nederland en West-Europa" gestart in de 2e fase van het Nationaal Onderzoeksprogramma Mondiale Luchtverontreiniging en Klimaatverandering (NOP-2).
Het doel van dit project is om een gevalideerde database van CH_4 emissies te realiseren op schalen van 5x5 km en 25x25 km voor Nederland en Europa respectievelijk, voor de belangrijkste broncategorieën. Validatie van de CH_4 emissies gebeurt door resultaten van berekeningen met atmosfeermodellen, die de emissiedatabase als input gebruiken, te vergelijken met metingen van CH_4 in de buitenlucht.
Een product van dit project is een gegevensbestand van methaanconcentraties zoals gemeten in Nederland en Europa. In dit rapport worden de gegevens van metingen van methaan zoals ze zijn uitgevoerd op 4 locaties in Nederland en op 3 locaties in noord-west Europa gedurende de periode 1990-1994 bijeengebracht. Behalve gegevens over CH_4 concentraties in de buitenlucht, zijn ook meteorologische gegevens, zoals gemeten door het KNMI in de buurt van de Nederlandse CH_4 meetstations, in de database opgenomen.
De bronnen van de gegevens, het gegevensformaat, de procedures voor gegevensbewerking en de gegevensbestanden die zijn gemaakt om de data op een systematische manier op te kunnen slaan worden beschreven. Verder worden tijdreeksen van de metingen over de periode 1990-1994 gepresenteerd. De tijdreeksen laten zien dat op de "achtergrondstations" in Europa ver van de brongebieden variaties in de dagelijkse CH_4 concentraties in de orde van 100 ppb kunnen voorkomen. Deze variaties zijn groot in vergelijking met de mondiale seizoensvariatie van circa 20-25 ppb en de mondiale trend van circa +10 ppb/jaar. Dagelijkse variaties in de CH_4 concentraties zoals die zijn gemeten in Nederland temidden van bronnen kunnen een factor 10 groter zijn (variaties van meer dan 1000 ppb komen voor) dan variaties op de achtergrondstations. Verschillen tussen de stations in Nederland (de ruimtelijke variaties) zijn in het algemeen veel kleiner dan de dagelijkse variaties.

SUMMARY

The project "Sources , regional scaling and validation of CH_4 emissions from the Netherlands and Northwest Europe" is carried out in the framework of Phase 2 of the National Research Programme on Global Air Pollution and Climate Change (NRP-2) in order to increase our knowledge on methane emissions on a small-scale
This project aims specifically at the development of a validated CH_4 emission database for the main source categories on a scale of 5x5 km for the Netherlands and 25x25 km and for Europe. CH_4 emissions are validated in this project by comparing results of atmospheric models which use this emission database as input, with measured CH_4 concentrations.
The data on methane measurements at four locations in the Netherlands and three locations in northwest Europe over the period 1990-1994 were collected and entered into a database. Besides data on CH_4 concentrations also meteorological data as measured by KNMI near the measuring sites were also included.
Sources and formats of the data, processing procedures and the databases themselves which are constructed to include the data in a systematic way are described.
Time series of the CH_4 measurements over the period 1990-1994 are also shown in this report. These time series show that daily concentration variations to about 100 ppb at the remote stations may occur; these are large with respect to the global seasonal variation (20-25 ppb) or the global long term trend (+10 ppb/yr). Daily concentration variations as measured in such source areas as the Netherlands may be 10 times more (up to 1000 ppb) than at the remote stations. Concentration differences between the different measuring stations near to each other in the Netherlands occur but are small compared to the daily variations.

1. INTRODUCTION

1.1. CH_4 budgets

Methane is a greenhouse gas which is present in the atmosphere as a natural compound. However, most (estimated at up to 70%) of the present global CH_4 emissions are due to human activities, resulting in a large increase in the atmospheric methane concentrations. Methane concentrations have risen steadily from about 700 ppb in pre-industrial times to over 1700 ppb in recent years. However, despite efforts in recent years to increase our knowledge on sources and sinks of methane on a global scale the contribution of the different sources and their spatial distribution is still not accurately known. The IPCC Second Assessment Report (1995) notes a difference of over 10% in global CH_4 fluxes between bottom-up emission estimates and top-down budget analyses based on modelling is noted (Tables 1, 2 and 3). At a national scale the uncertainty range in methane emission can be about 25% as for instance for the Netherlands (Table 4). The CH_4 emission range in the different source categories are much larger reaching up to a factor of 4-5 (see Tables 1 and 4).

Table 1 Source categories and global contributions to emissions as described by IPCC WG-1 (IPCC 1995)

CH_4 Sources	Tg/yr	Total Tg/yr
Antropogenic		
Fossil fuel		100 (70-120)
Nat gas	40 (25-50)	
Coal mines	30 (15-45)	
Petrolium Ind	15 (5-30)	
Coal combustion	?	
Biogenic		275 (200-350)
Entric ferm	85 (65-100)	
Rice	60 (20-100)	
Biomass	40 (20-80)	
Landfills	40 (20-70)	
Animal waste	25 (20-30)	
Domestic sewage	25 (15-80)	
Total antropogenic		**375 (300-450)**
Natural		
Wetlands	115 (55-150)	
Termites	20 (10-20)	
Oceans	10 (5-50)	
Other	15 (10-40)	
Total natural		**160 (110-210)**
Total identified sources		**535 (410-660)**

A Top-down budget analysis leads to:

Table 2 CH_4 budget; CH_4 sinks

CH_4 Sinks	Tg/yr
Tropospheric OH	490 (405-575)
Stratosphere	40 (32-48)
Soils	30 (15-45)
Total atmospheric sinks	**560 (460-660)**

Table 3 CH_4 budget; atmospheric increase

CH_4 Atmospheric Increase	Tg/yr
	37 (35-40)

The figures in Table 2 and 3 refer to a 1980-1990 (ten-year) average. A top-down budget analysis shows a total of implied sinks and atmospheric increase of 560+37 = 597 Tg(CH_4)/yr (IPCC, 1995). A bottum-up emission inventory of different source categories leads to a total of 535 Tg/yr implying an imbalance between sources and sinks of about 62 Tg(CH_4)/yr.
The estimated uncertainty in the emission of different sources on smaller spatial scales is much larger. Table 4 below shows emission (Tg) and emission ranges for different source categories in the Netherlands (van. Amstel et al., 1993)

Table 4 CH_4 emission and emission ranges between parentheses for different source categories in the Netherlands (van Amstel et al., 1993)

CH_4 emission 1991	(kTon)
Gas production	60 (43-76)
Gas transportation	7 (2-12)
Gas distribution	84 (71-97)
Oil production	17 (1-34)
Combustion	23 (16-31)
Wetlands	70 (40-120)
Inland and coastal waters	35 (24-60)
Small water bodies	16 (8-24)
Ruminants	424 (297-551)
Animal waste	109 (76-142)
Landfills	377 (178-576)
Sewage treatment	3
Water production	2
Total	1227 (761-1728)

Individual researchers have also come up with their own estimates.
The et al. (1995) present an overview of a range of CH4 emissions as used by atmospheric modelers.

1.2. The NOP-research project: CH_4 emissions on a European scale

The Project "Sources, regional scaling and validation of CH_4 Emissions from the Netherlands and Northwest Europe" was started in September 1995 in the framework of Phase 2 of the National Research Programme on Global Air Polution and Climate Change (NRP-2) to increase knowledge on methane sources on a small scale. Specifically, this project was to establish a validated CH_4 emission database for different source categories on a scale of 5x5 km for the Netherlands and 25x25 km for Europe.

The emission inventories in this project are based on the LOTOS and EDGAR databases as managed by TNO and RIVM (Olivier et al., 1995). These emission inventories are to be used as input for Eulerian 3-D atmospheric dispersion models such as MOGUNTIA on a global scale (The et al. 1995) and the LOTOS and EUROS model on a continental scale (Roemer, 1996; Zhang, 1996) and as an input for the Langrangian COMET model (Veldkamp et al., 1995).
The emissions are validated by comparing results of model calculations with the results of CH_4 measurements in the atmosphere.
In this project a new method for validation of CH_4 emissions will be developed by applying a Kalman filter as a data assimilation method which uses both measurements and results of the EUROS model. The methane emission from the grid cells is updated with the Kalman filter in combination with a "smoother algorithm" in the 3-D EUROS model and using the time-series of CH_4 measurements at different locations in the Netherlands and Europe as input (Zhang, 1996).
Analysis of emission sources of CH_4 based on atmospheric CH_4 data alone will be carried out by statistical methods such as Principal Component Analysis (Janssen et al., 1989) and time-variant linear regression methods as Kalmanfiltering (Visser and Molenaar, 1995).

In this (NRP-2) project continuous measurements are carried out at five sites in the Netherlands: Kollumerwaard, Arnhem, Cabauw, Petten and Delft. Besides the measuring results from this project CH_4 measurements from elsewhere in Europe, carried out for a number of years in the Eurotrac-Tor project in Birkeness, Zeppelinfjellet and Macehead have also been collected in this database.
This report presents the measuring results of the NRP and TOR projects along with a description of the databases. A short description of CH_4 data, available from the WMO-WCCD data set for several measuring locations in Europe has also been added to the report along with the results of a few Internet searches for CH_4 measuring data. In the future, more searches will be carried out to collect more CH_4 measuring data in Europe from other databases. Finally the validation of emission databases carried in this project may support both scientific and policy oriented activities on emission inventories and the development of an independent instrument for improving IPCC Guidelines for emission inventories. This will improve National Emission Inventories (the "National Communications" for the FCCC) or monitoring compliance to a Greenhouse Gas Protocol.

2. MEASUREMENT RESULTS

A map of TOR measuring stations is shown in Figure 1.

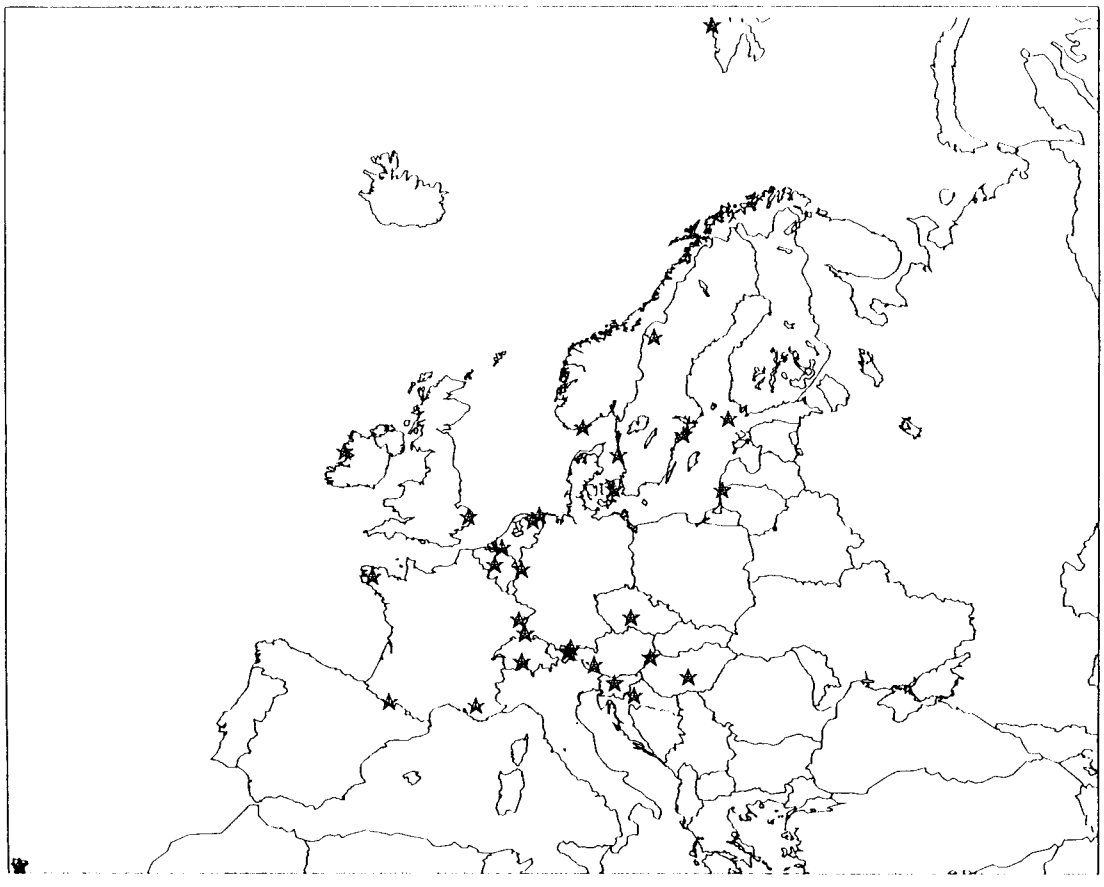

Figure 1: The location of the TOR measuring stations

In the TOR database managed by RIVM, CH_4 measurements are available for the measuring stations Birkeness, Zeppelinfjellet and Macehead and Kollumerwaard for a limited time period (Beck et al, 1996). CH_4 measurements in the Netherlands were carried out in Arnhem, Cabauw and Delft in the framework of NRP Phase 1. Measurements are not always carried out at the same stations and in the same period so at the moment the concentration database is rather scattered emphasising the very importance of continuity in measurements for analysis.

Table 5. Available data of CH_4 concentrations in Europe

	Period	1990	1991	1992	1993	1994	1995	1996
Arnhem [1)]		April	May	x	June	May	x	running
Cabauw [1)]					April	x	x	running
Delft [1)]						x	Sept	running
Kollumerwaard [1,2)]			July	x	x	x	x	running
Petten [1)]							March	running
Birkeness [2)]		x	x					
Macehead [2)]		x	x					
Zeppelinfjellet [2)]		x	x					
Baltic Sea [3)]				Aug	x	x	x	running
Heiney (Iceland) [3)]				Sept	x	x	x	?
Lambedousa [4)]				May	x	x	x	?
Macehead [3)]				x	x	x	x	running
Ocean M [3)]	1983-1996	x	x	x	x	x	x	running

1) NRP CH_4 measuring network - hourly averaged concentrations

2) TOR O3/CH_4 measuring network - daily averaged concentrations

3) WCDC database Tokyo - flask measurements by event (hourly sample)

4) WCDC database Tokyo flask measurements (daily average)

N.B. Measuring results of the WCDC database are not included in this report. Results of the NRP-2 CH_4 measurements in 1995, 1996 and 1997 and of the CH_4 measuring data from other databases will be reported in future data reports.

X = measurements available

name of month= start of measurements

2.1. Time-series of CH_4 concentrations

Time-series of CH_4 concentrations are shown in the following figures are based on calculated daily averages.

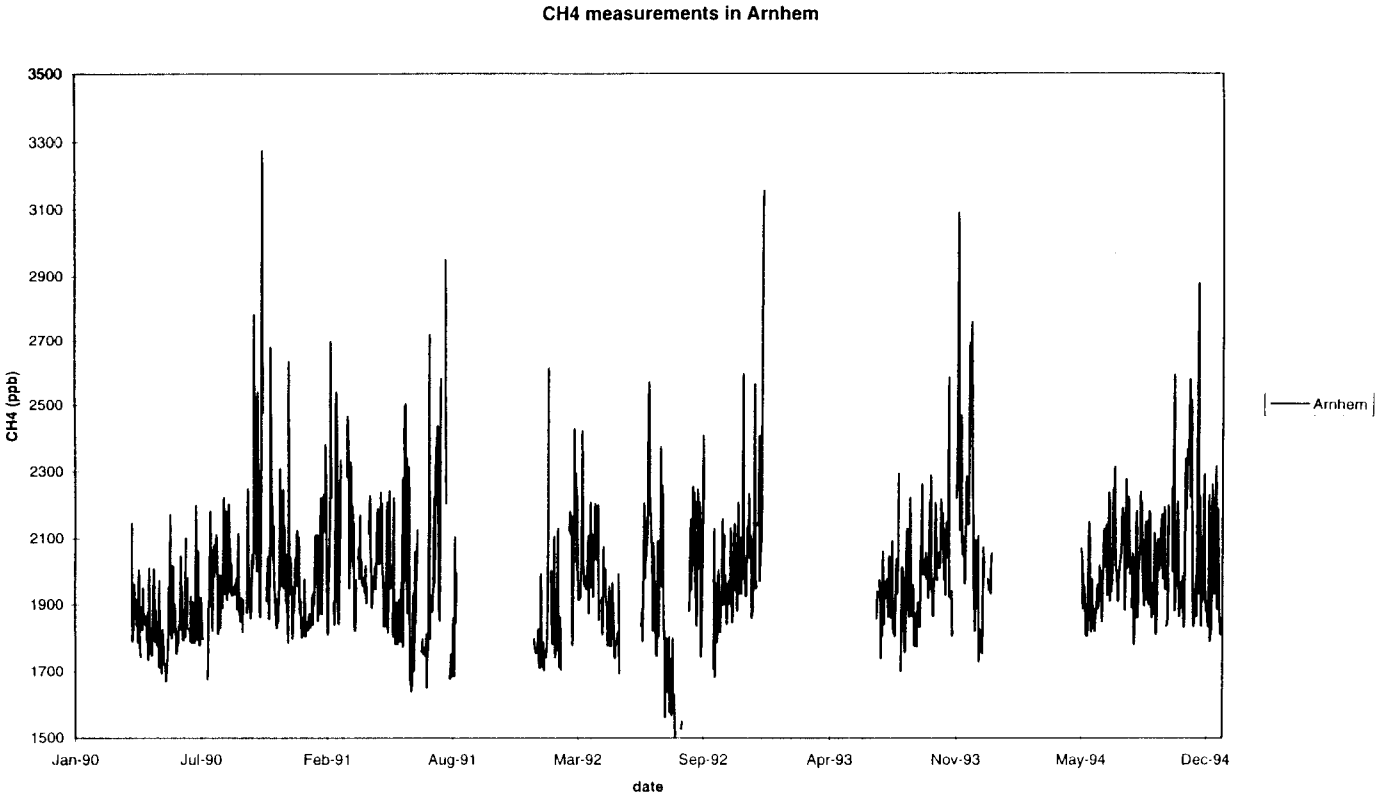

Figure 2 Results of CH_4 measurements in Arnhem for the years 1990-1994

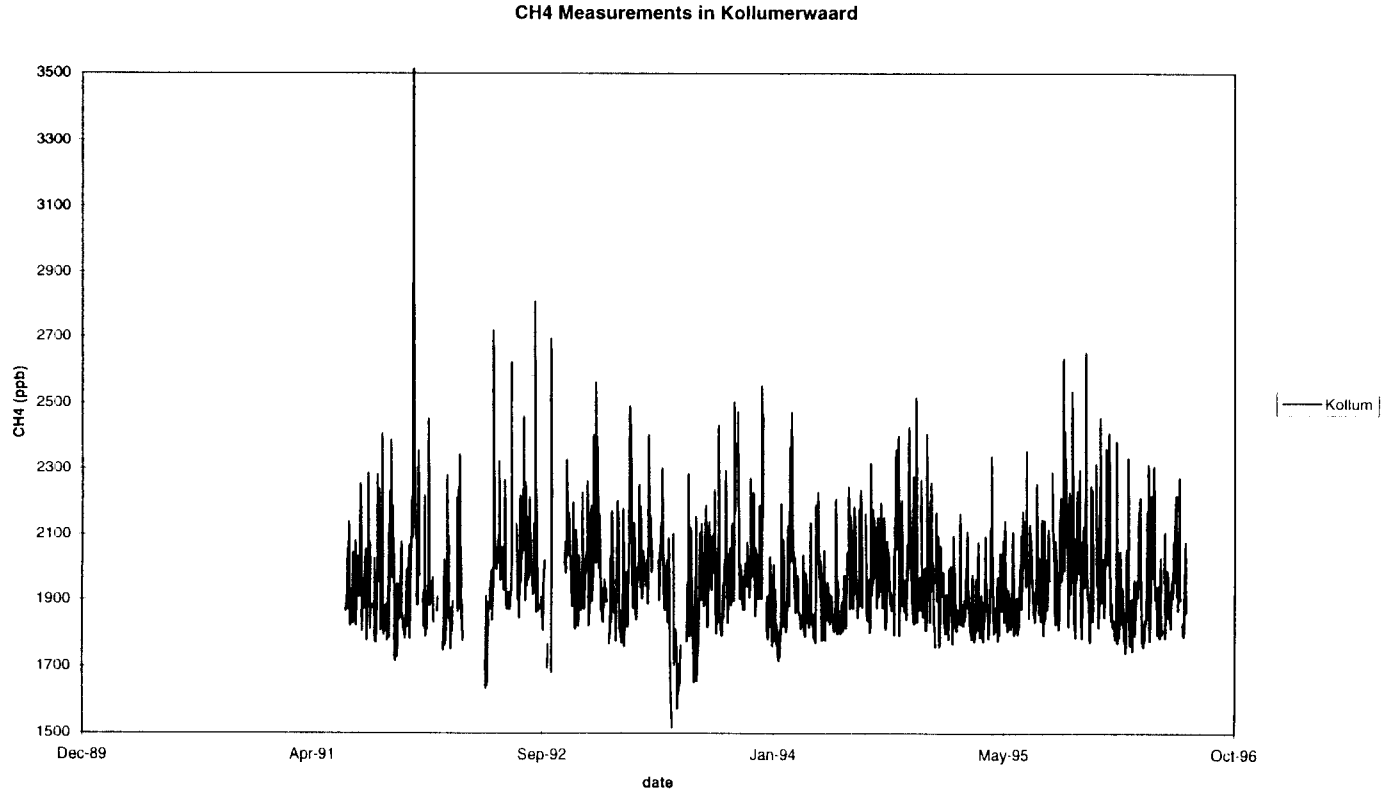

Figure 3 Results of CH_4 measurements in Kollumerwaard for the years 1990-1994

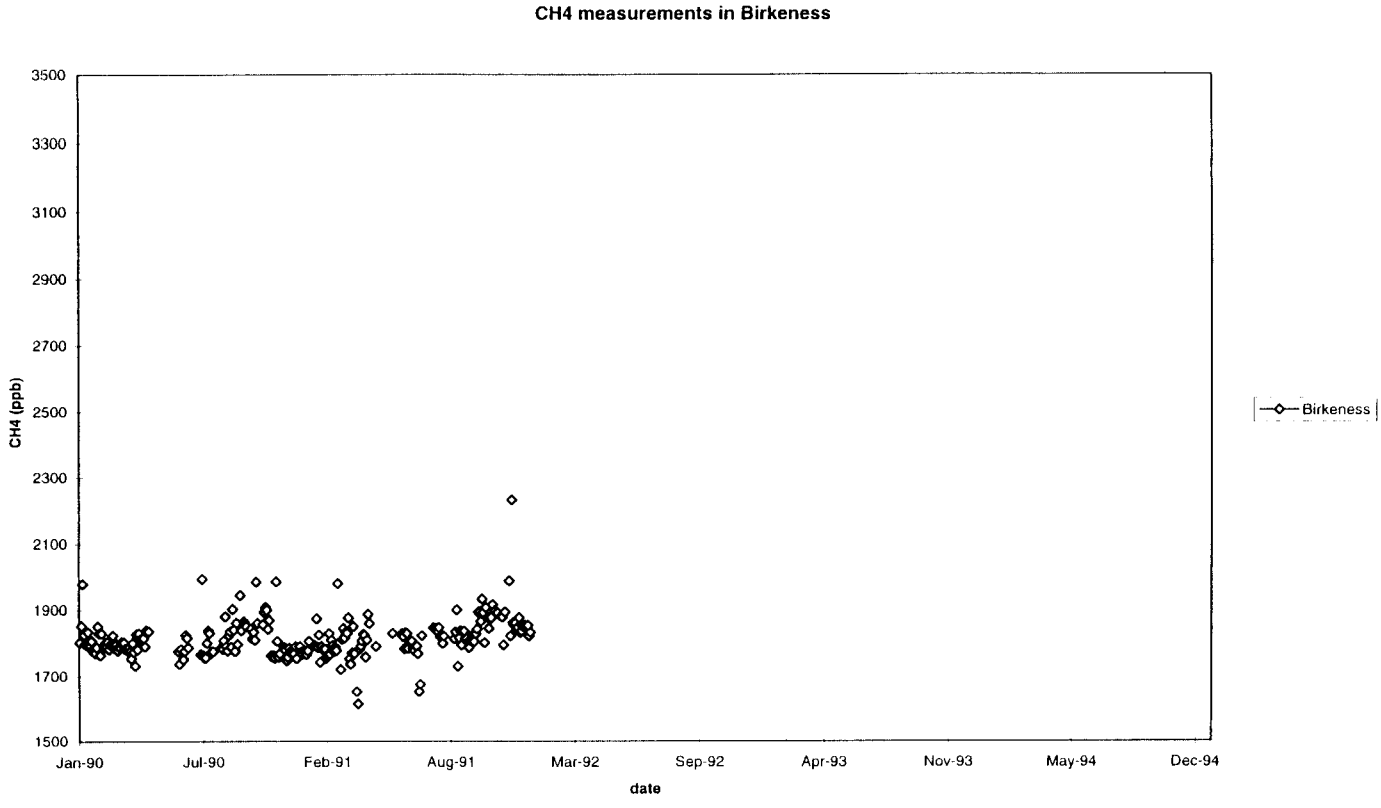

Figure 4 Results of CH_4 measurements in Birkeness for the years 1990-1991

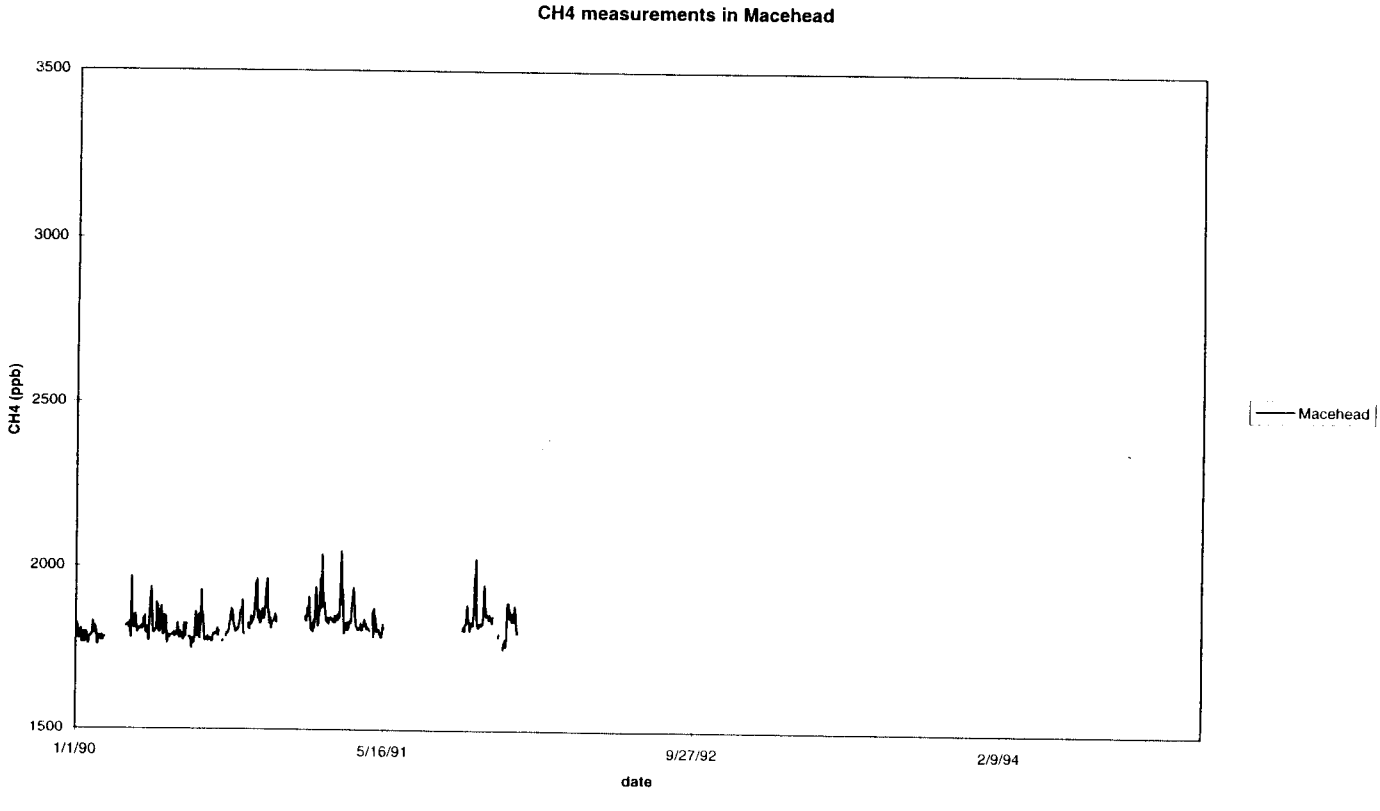

Figure 5 Results of CH_4 measurements in Macehead for the years 1990-1991

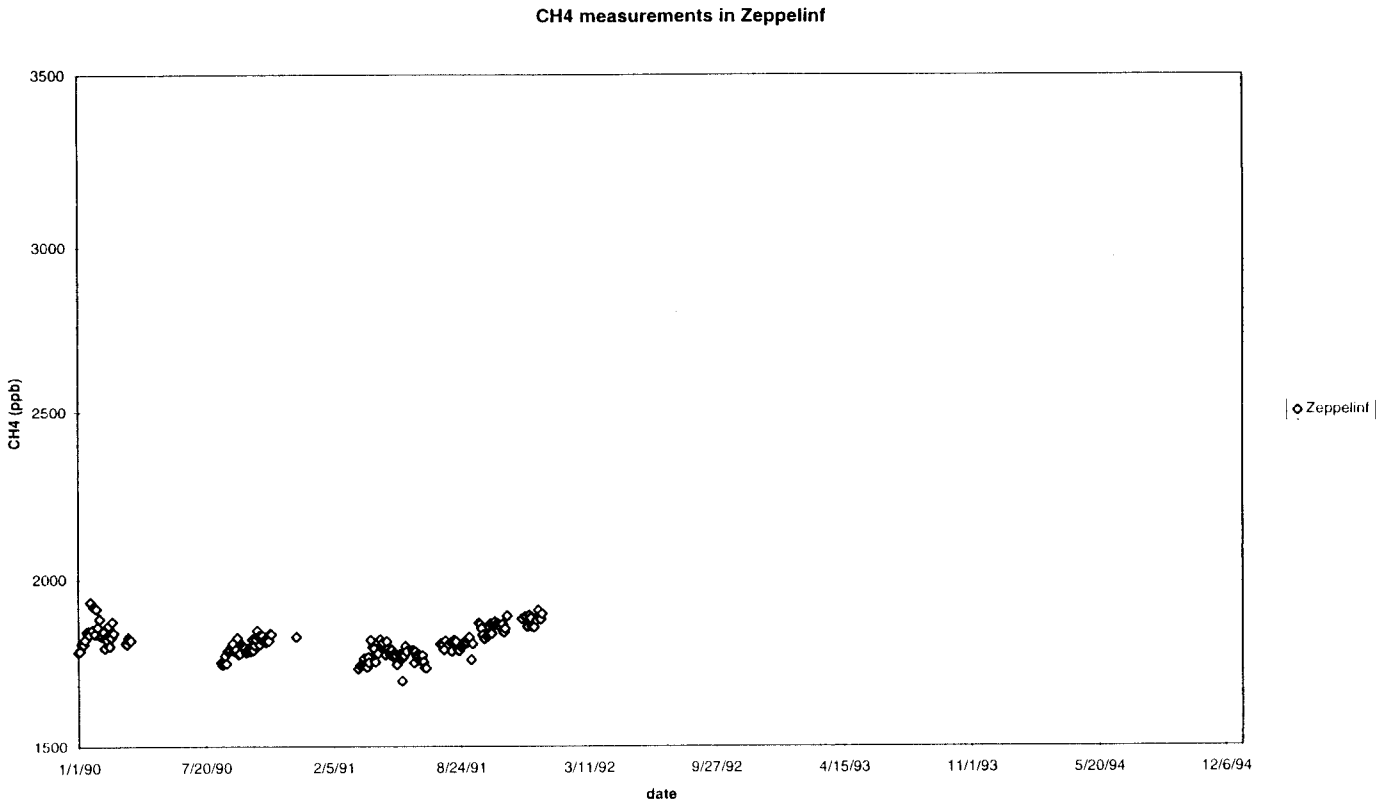

Figure 6 Results of CH_4 measurements in Zeppelinfjellet for the years 1990-1991

2.2. Spatial variations

As can be seen in Table 5 several measuring stations operated simultaneously for some of the period. An analysis of the differences between stations can give some insight in the spatial variations in concentrations and the contribution of regional or local sources.

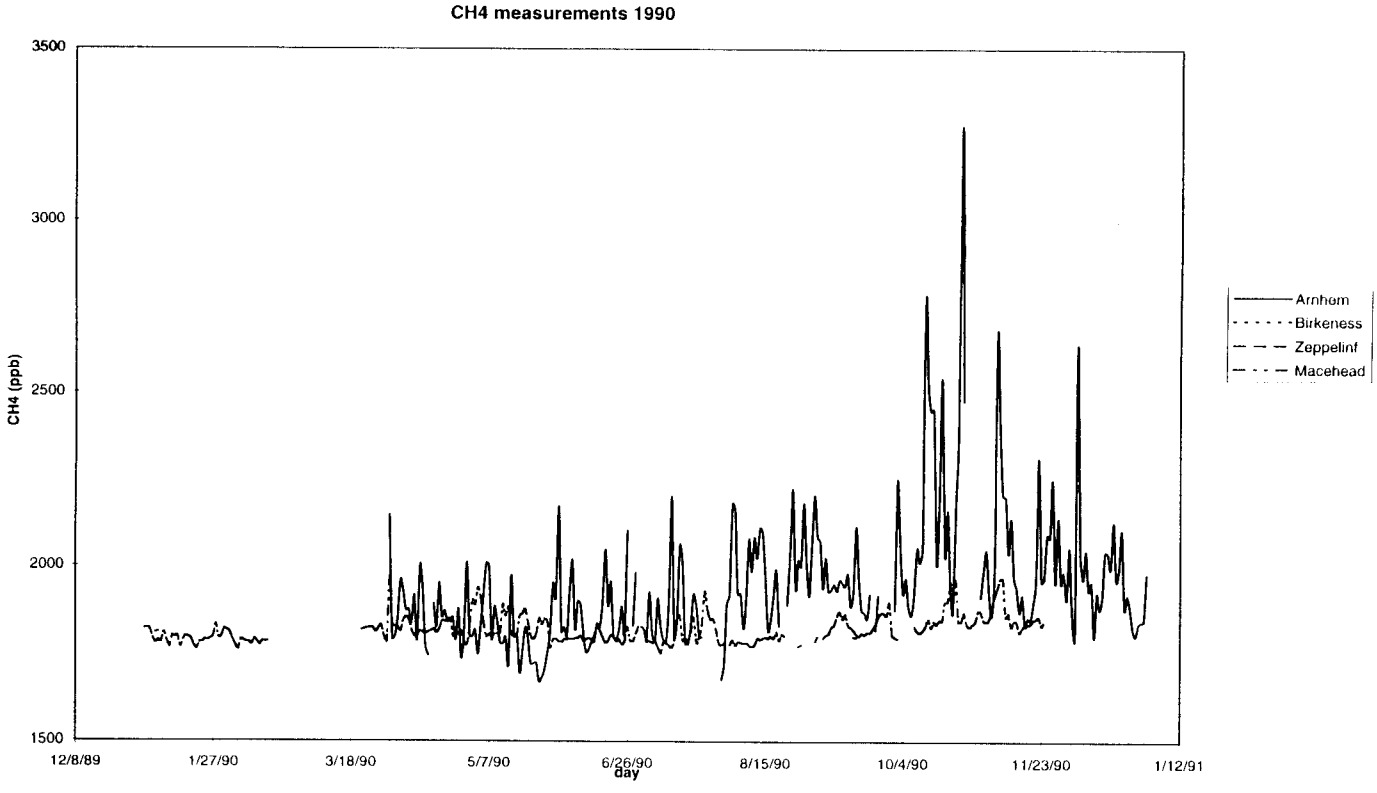

Figure 7 Results of measurements in Arnhem, Birkeness, Macehead and Zeppelinfjellet in 1990

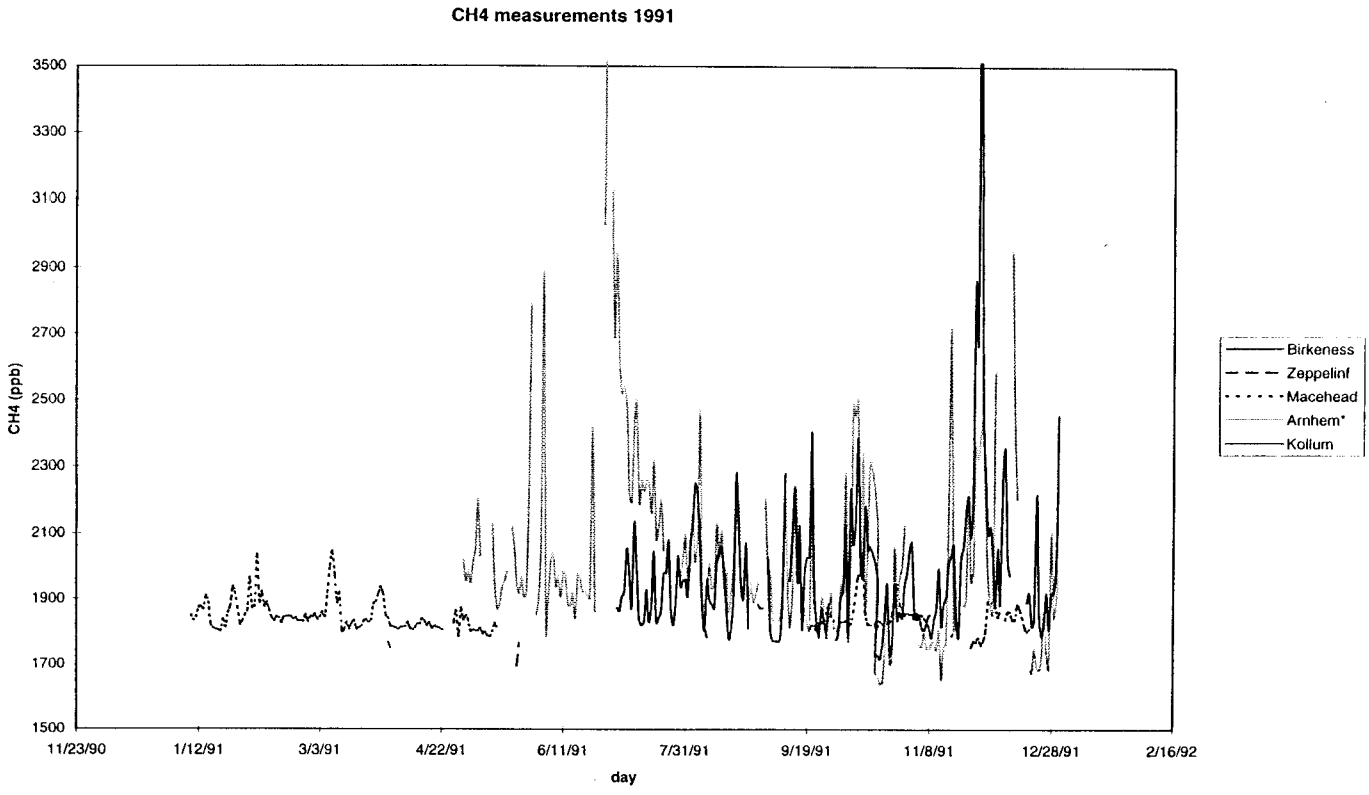

Figure 8 Results of measurements in Arnhem, Birkeness, Kollumerwaard, Macehead and Zeppelinfjellet in 1991

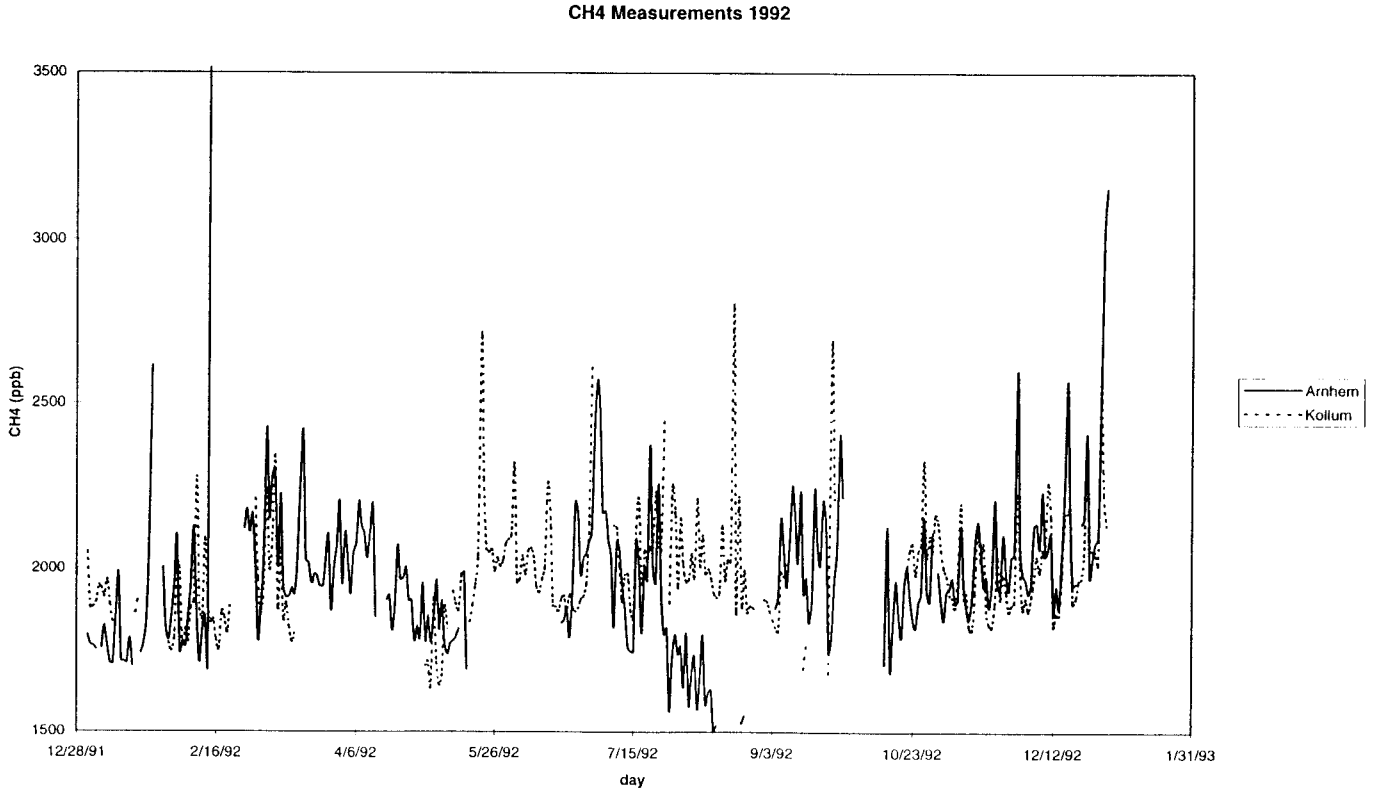

Figure 9 Results of measurements in Arnhem and Kollumerwaard in 1992

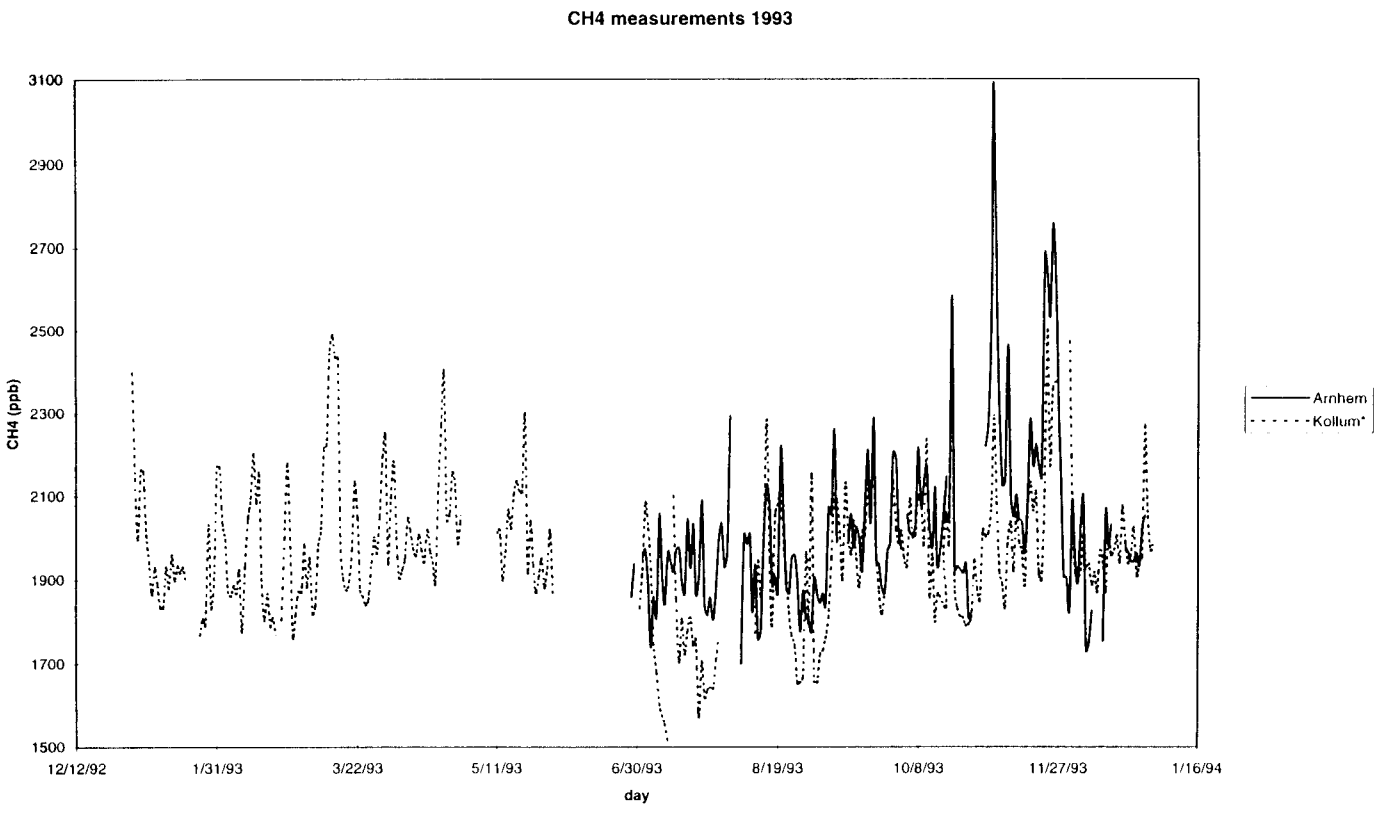

Figure 10 Results of measurements in Arnhem and Kollumerwaard in 1993

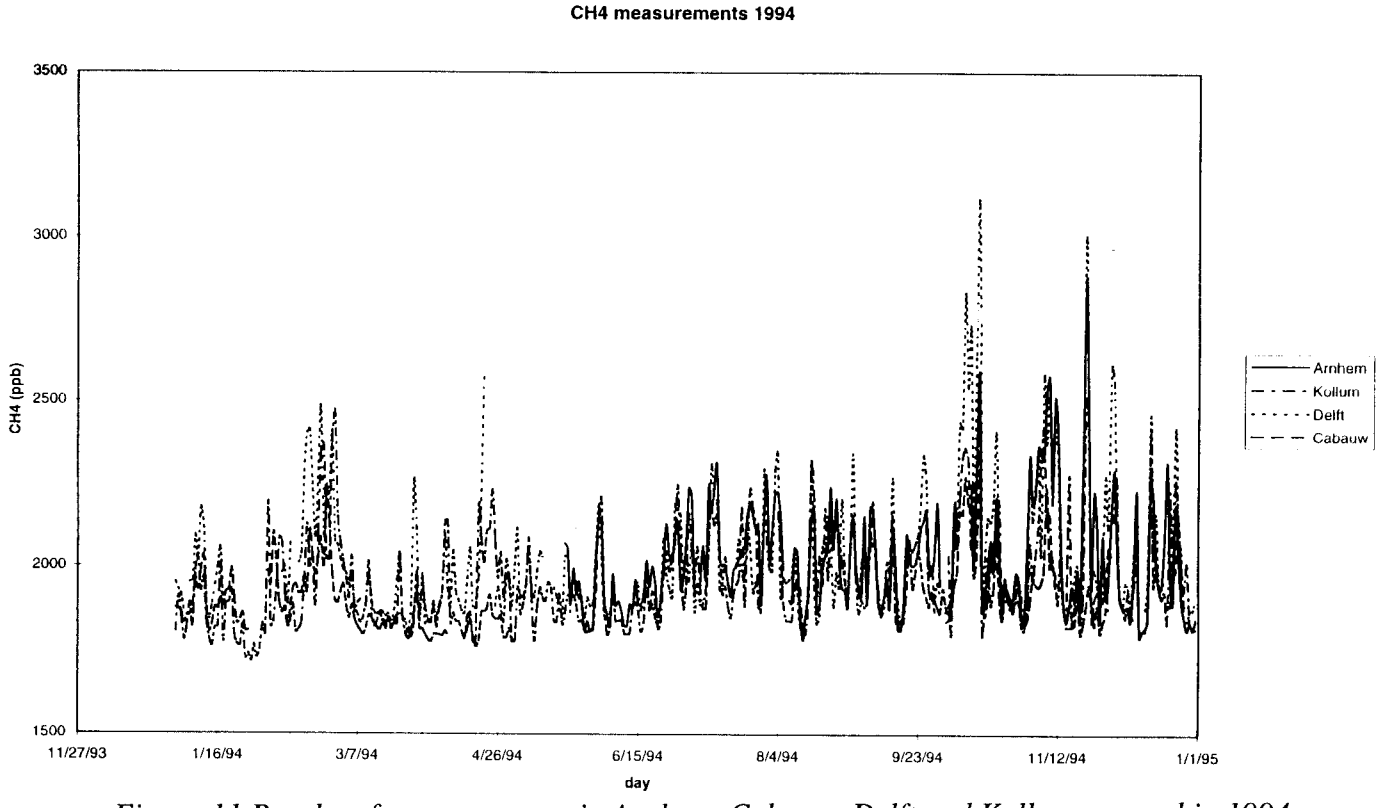

Figure 11 Results of measurements in Arnhem, Cabauw, Delft and Kollumerwaard in 1994

3. DESCRIPTION OF THE DATA BASES

The measuring results as presented in the previous chapter are derived from several different sources. The original data have been elaborated and stored separately in newly constructed databases. The original sources and their formats will be described first.

Table 6 Measuring stations and their coordinates

Station	**Location**
Arnhem	51-59-30 N ; 5-52-30 E
Birkeness	58-23-00 N ; 8-15-00 E
Cabauw	51-58-16 N ; 4-55-36 E
Delft	52-00-00 N ; 4-02-50 E
Kollummerwaard	53-20-02 N ; 6-16-38 E
Macehead	53-19-34 N ; 9-54-14 W
Zeppelinfjellet	78-54-00 N ; 11-53-0 E

3.1. Original datasources

Table 7 An overview of the measuring stations, the original datasources and dataformat

Station	Source	ISO format	Averaging Time	Name of datafiles	Measuring period
Arnhem	4 disks	x	15 min	AR900405.ISO AR900904.ISO AR910104.ISO* AR910504.ISO AR910904.ISO AR920104.ISO AR920504.ISO AR920904.ISO AR930604.ISO AR931003.ISO AR940504.ISO AR940904.ISO	1-4-1990 to 1-1-1995
Birkeness	TOR database	x	24 hour	90-01-01-08-00 91-01-01-08-00	1990 1991
Cabauw	e-mail ECN	x	30 min	c:\MAIL\Cabauw.zip	1-3-1993 (0:30) 31-3-96 (23:30)
Delft	1 disk 1 disk	x x	15 min 15 min	CH_4_NOP.ISO CH_4_ISO.95	1994 1-9-1995 31-12-1995
Kollumerwaard	TOR database 1 disk	x x	15 min 15	91-7-01-00-00 91-10-01-00-00 92-01-01-00-00 92-04-01-00-00 92-07-01-00-00 92-10-01-00-00 93-01-01-00-00 93-07-01-00-00 KOL941006	1-7-1991 to 1-1-1994 1-1-1994 to 1-7-1994
Macehead	TOR database	x	15 min	88-02-01-01-00 88-03-01-01-00 88-04-01-01-00 ..... each month to 91-12-01-01-00	1 febr 1988 to 1 jan 1992
Zeppelinfjellet	TOR database	x	15 min	90-01-01-08-00 91-01-01-08-00	1990 1991

Datafiles

All the CH_4 concentration data in the different source files were in ISO-7168-1985(E) format. They were compiled to yearly totals and processed and stored in the database as UNIX datafiles with extension .ux

users3/aps/leonja/ch4mdata/ch4isofor/*namestationyear*.ux

For an example see Appendix 1: "users3/aps/leonja/ch4mdata/ch4isofor/kollum91.ux "

3.2. Data processing and new databases

3.2.1. Conversion from ISO format to hourly and daily averages

The data in the original datasources were ordened into 12 columns according to the ISO-7168-1985(E) format . In the following steps the CH_4 data were processed to hourly and daily averages taking missing values into account. Hourly values were calculated using the number of measurements in that hour. If there were only "missing values" in a specific hour; that hour also received the label "missing", which was -88.

The hourly values were stored in the datafile:

Huggins: users3/aps/leonja/ch4mdata/ch4rijtje/*namestation**2**_year*

For example : users3/aps/leonja/ch4mdata/ch4rijtje/koll2_91

The daily averages were stored in the datafile:

Huggins: users3/aps/leonja/ch4mdata/ch4rijtje/*namestation**3**_year*

For example : users3/aps/leonja/ch4mdata/ch4rijtje/koll3_91

Details of these procedures are described in Appendix 2.

3.2.2. Plots of daily averages

The daily averages of methane concentrations at the different stations for the period 1990-1994 along with the data (mmddyy) were also gathered in one EXCEL spreadsheet:

Huggins: users3/aps/leonja/ch4mdata/methjaar.xls (Appendix 2)

The data in this spreadsheet were used to produce the time-series as shown in the figures 2 - 12.

3.3. Meteorological information

Meteorological information is necessary to analyse the concentration fluctuations at the different stations. Besides the results of CH_4 measurements at the four measuring sites in The Netherlands meteorological information for the year 1994 as measured by KNMI at sites nearby is also included in the database. Both CH_4- and meteorological data are taken on a hourly basis. Table 8 shows the corresponding CH_4 - and meteorological measuring sites, Table 9 the format of the data and Table 10 the measured meteorological parameters at the sites. The data are from The Royal Dutch Meteorological Institute (KNMI) and were extracted from the RIL+ database at the Laboratory of Air Research of RIVM and stored as EXCEL speadsheets (one year = 8760 hours).

Table 8 Corresponding CH_4 and meteorological measuring sites

CH_4 measuring site	**Meteorological measuring site**
Kollumerwaard	Lauwersoog
Arnhem	Deelen
Cabauw (200m)	Cabauw (200m)
Delft	Rotterdam

Table 9 database of meteorological information

Station	**Period**	**Format**	**Averaging period**	**Source**	**Filename**
Lauwersoog	1994	ascii	hourly	RIL+	metlau94.xls

The data are stored in:

Huggins: users3/aps/leonja/ch$_4$mdata/meteo/*namestationyear.xls* see Appendix 3

Table 10 Measured meteorological parameters at each site on a hourly basis

1	Temperature	(T)	0.1 ^{0}C
2	Relative Humidity	(RH)	%
3	Pressure	(P)	mbar
4	Amount of rain	(DQ)	0.1 mm
5	Rain time	(DT)	0.1 uur
6	Insolation	(Q)	j/m^2
7	Wind direction	(WD)	degrees
8	Wind velocity	(WV)	0.1 m/s
9	Stability	(PQ)	Pasquill-class

4. DISCUSSION AND REMARKS

4.1. The data

Availablity

Despite the measuring efforts at several stations it appeared difficult to establish continuous methane data records. A substantial number of values are missing. The number of measuring stations in Europe with continuous records of methane is also very limited. Three of the measuring stations (Macehead, Birkeness and Zeppelinfjellet) are situated in very remote locations and the data of the Dutch measuring stations are the only data measured in source areas in this database. The results of a quick scan on the Internet to detect data sets of CH_4 concentrations is decribed in Appendix 4.

Measurements

- CH_4 concentrations are reported in ppb's with one ppb significance.
- Daily variations at remote locations can be very small so it is important to establish the conditions at which the measurements are carried out in order to be able to establish measuring errors. Intercomparison campaigns are advised and in our project the measurements are subjected to regular (2x per year) ring tests. Local standards for CH_4 used by the three measuring institutes are brought together at the most accurate measuring site and compared at the same time.
- It is then necessary to establish whether the reported values are related to "ambient air" (including water vapour) or are reported in "dry air". The Delft and Cabauw measurements are carried out in "ambient air" and the Kollumerwaard and Arnhem measurements in "dry air" (without water vapour). The presence of water vapour may cause a difference up to 20 ppb CH_4 (H_2O = 1%). If necessary the data in the database are corrected for the content of water vapour according to the method reported by Leung and Le (1994) and using the meteorological data of the KNMI measuring station nearby. Figure 12 shows the effect of the water vapour correction on the CH_4 concentration measured in Delft.
- All data are in UTC except those from Zeppelinfjellet, Birkeness, Kollumerwaard and Delft which are in UTC+1. In Zeppelinfjellet and Birkeness daily averages are reported so these daily values are shifted upward by one hour with respect to the others. (i.e. Zeppelinfjellet = Others + One hour). Because only daily averages are stored in the databases this shift cannot be taken into account at the moment.

Notes:
- It is important to establish whether the measurement data refer to the past or preceeding hour.
- It should be determined before whether 00h00 or 24h00 is used as time.
- The "starting hour" for our measurements is 00h00 and all concentrations refer to an average over the past period so the first "reported hour" is 01h00.

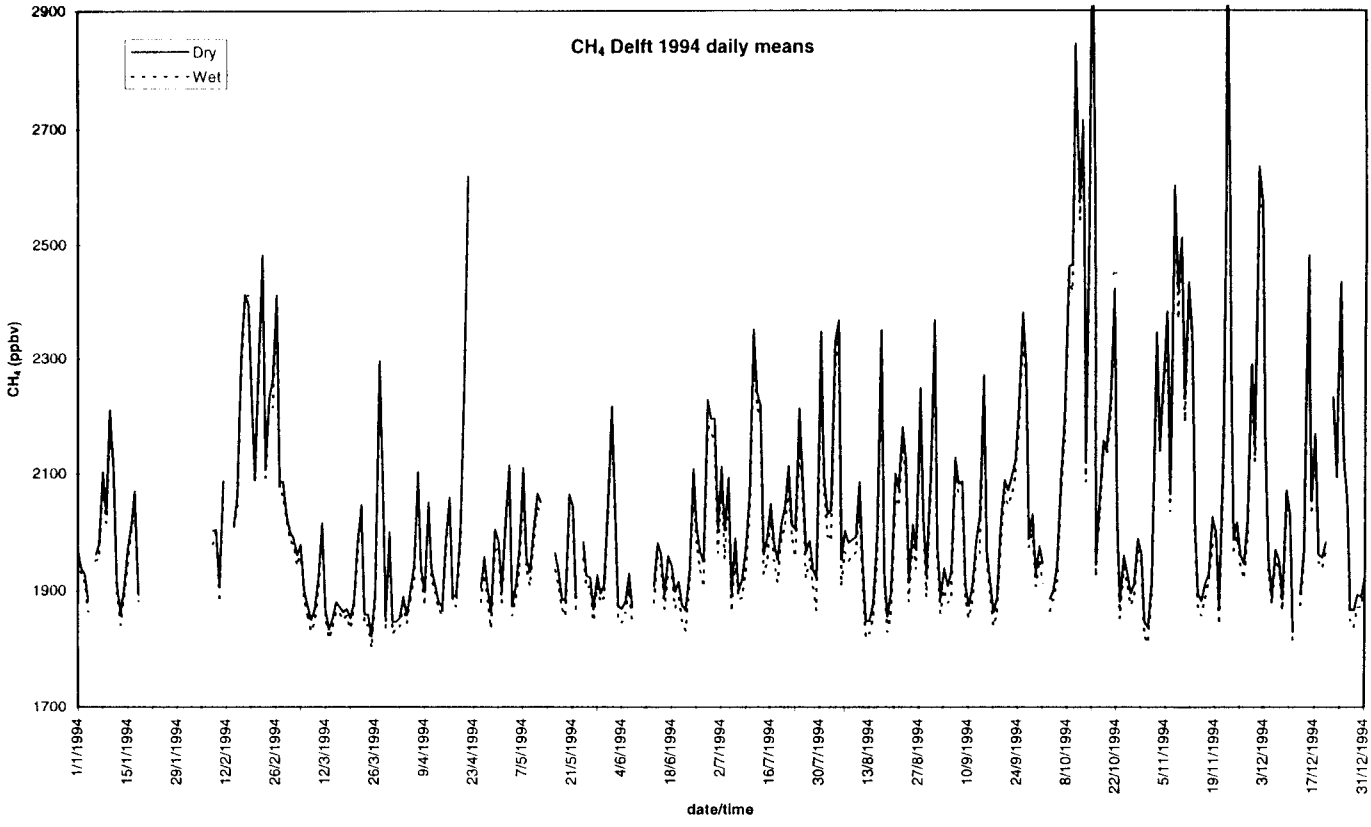

Figure 12 Differences between measured CH_4 in ambient air and calculated CH_4 in dry air for Delft.

4.2. Measured concentrations

An overview based on the figures 2 - 11 shows that:

- daily concentration variations to about 100 ppb at the remote locations occur. These are large with respect the global seasonal variation ($\pm$ 20-25 ppb) or the global long-term trend (+ 10 ppb/yr);
- seasonal variations at the remote stations are much larger (up to 100 ppb) than the global average; this will require further analysis;
- daily concentration variations as measured in such source areas as The Netherlands may be 10 times more (up to 1000 ppb) than at the remote stations;

- concentration differences between the different measuring locations near to each other in the Netherlands occur but are small compared to the daily variations; this will require further reseach;
- comparing time-series of CH_4 with other components may give more insight in the contribution of different (anthropogenic- and natural/biogenic) sources;
- the measured differences in concentrations and concentration variations at different locations give another picture than the global figures often reproduced. A further analysis on whether these differences can be interpreted in terms from different contributions of different sources could be fruitful;
- the data will be analyzed using the inversed modelling techniques as described in the introduction.

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APPENDIX 1 An example of a CH_4 datafile in ISO format

1854	-88	1775	1786	1769	1780	1778	1806	1758	1829	1807	1779
1785	-88	1847	1800	1827	1795	1821	1830	1838	1800	1816	1883
1771	-88	1769	1843	1782	1848	1797	1758	1836	1812	1833	1802
1792	-88	1815	1791	1882	1815	1788	1807	1780	1800	1776	1781
1795	-88	1810	1888	1853	1809	1857	1805	1815	1819	1875	1823
1856	-88	1840	1791	1908	-88	1852	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
-88	-88	-88	-88	-88	-88	-88	1840	1834	1802	1821	-88
1816	-88	1820	1852	1827	1858	1884	1821	1865	1842	1887	1835
1879	-88	1934	1898	1863	1867	1858	1857	1863	1852	1854	1883
1881	-88	1880	1938	1881	1874	1953	1865	1904	1830	1893	1899
1943	-88	1928	1916	1917	1909	1936	1857	1876	1912	1959	-88
1912	-88	1905	1905	1908	1862	1906	1884	1873	1860	1886	1954
1907	-88	1882	1908	1905	-88	1949	1885	1908	1817	1891	1839
1883	1840	-88	1822	1837	1820	1828	1884	1861	1822	1829	1855
1834	-88	1837	1831	1833	1800	1806	1804	1835	1860	1838	1804
1828	-88	1838	1844	1809	1842	1826	1935	1888	1898	1903	1884
1902	-88	1857	1852	1901	1836	1898	1832	1875	1878	1904	1874
1898	-88	1836	1916	1846	1853	1830	1886	1852	1902	1814	1852
1880	-88	1894	1842	1925	1849	1870	1856	1871	1893	1923	-88
1923	-88	1896	1914	1832	1881	1899	1906	1893	1980	1852	1895
1918	-88	1912	1862	1926	1900	1882	1855	1909	1985	1887	1912
1835	-88	1835	1902	1882	1892	1899	-88	1930	1896	1875	1848
1899	1864	-88	1885	1866	1923	1872	1963	1902	1914	-88	1915
1943	-88	1955	1918	1952	1914	1899	1926	1947	1904	1965	1954
1866	-88	1896	1889	1897	1932	1884	1903	1898	1911	1906	1886
1853	-88	1966	1908	1967	1914	1953	1946	1924	1933	1935	1931
1884	-88	1936	1926	1883	1932	1961	1921	1987	1872	1962	1880
1975	-88	1915	1914	1912	1886	1909	1945	1885	1936	1937	1963
1868	-88	1899	1961	1902	1910	1923	1871	1907	1868	1979	1878
1912	-88	1887	1904	1848	1799	1859	1849	1884	1946	1893	1908
1900	-88	1883	1842	1889	1832	1893	1834	1841	1879	1871	-88
1832	1842	-88	1816	1844	1837	1889	1857	1865	1862	1889	1859
1850	-88	1903	1904	1841	1930	1841	1932	1885	1891	1901	1876
1880	-88	1921	1893	2023	2064	2079	1947	1988	1989	2033	1988
1958	-88	2005	2159	2020	2097	2123	2190	2127	2118	2194	2101
2232	-88	2147	2139	2136	2149	2160	2158	2166	2188	2149	2214
2170	-88	2215	2272	2216	2243	2214	2189	2226	2175	2265	2191
2197	-88	2158	2169	2160	2112	2112	2085	2052	2074	2040	2045

APPENDIX 2 DATA PROCESSING

A.2.1. Conversion from ISO-format to one column

The data in the original data sources were ordered into 12 columns according to ISO-7168-1985(E) format (see Appendix 1). For quarterly values this means 35040 data tems in one year and with 12 data tems in one line this means 2920 or 5839 data lines if two data lines are separated by an empty line. Therefore a substantial number of data for one year which cannot be handled easily by using a spreadsheet.
As a first step in solving this the raw data were displayed sequentially in one column and split into datafiles. each containing one year's data by using the Fortran program: "Jaarkolom_1" or "Sorteer_1" (if the data are already split into different years).
N.B. Two lines of 12 data can be separated by an empty line. In this case an additional "read" statement should be included in the program as is indicated in *italics*
The processed data are stored in the datafile:

Huggins: users3/aps/leonja/ch_4mdata/ch_4rijtje/*namestation**1**_year*

For example: users3/aps/leonja/ch_4mdata/ch_4rijtje/koll1_91

N.B. One should take leap year's into consideration.

A. 2.2. Hourly values

The next step was to convert the quarterly (KEMA and TNO) or half-hourly (ECN) values to hourly values by using the Fortran program : "Sorteer_2". Missing values should be taken into account in calculating hourly averages. Hourly values were calculated using the number of measurements available. If there were only "missing values" in a specific hour that hour also received the label "missing" which was: -88. The hourly values were stored in the datafile:

Huggins: users3/aps/leonja/ch_4mdata/ch_4rijtje/*namestation**2**_year*

For example : users3/aps/leonja/ch_4mdata/ch_4rijtje/koll2_91

A.2.3. Daily values

Because only daily averages were available for the stations Birkeness, Macehead and Zeppelinfjellet, the hourly data of the remaining stations were used to calculate daily averages also using the Fortan program: "Sorteer 3" In this program missing values are also taken into account. Daily values were calculated using the number of measurements which were available. The daily averages were stored in the datafile:

Huggins: users3/aps/leonja/ch_4mdata/ch_4rijtje/*namestation**3**_year*

A.2.4. Missing values

In the Unix datafiles

Huggins: users3/aps/leonja/ch_4mdata/ch_4rijtje/*namestation*$_i$*_year*

missing values are indicated as -88. To produce the plots of the time series in the EXCEL spreadsheet the missing values are represented as cells containing "blancs".

N.B. Cells which contain a #N/A (Not Available) content will interpolate between missing data which is not wanted .

A.2.5. Codes

The codes of the Fortran programs

- Jaarkolom_1
- Sorteer_1
- Sorteer_2
- and part of the EXCEL spreadsheet Huggins: users3/aps/leonja/ch_4mdata/methjaar.xls

respectively follow

```
      Program Jaarkolom_1

c234567890123456789012345678901234567890123456789012345678901234567890123456789012

c     Dit programma zet de data van twaalf kollommen (TOR-isoformat)
c     achter elkaar in een kolom en
c     breekt vervolgens deze eenskolomsdatafile
c     op in brokken van een jaar of gedeelten van een jaar
      Dimension A(60000)
      Dimension B(20000)
      Dimension C(20000)
      Dimension D(20000)
      Dimension E(20000)

c234567890123456789012345678901234567890123456789012345678901234567890123456789012
      open (unit=10,file="/users3/aps/leonja/ch4mdata/ch4sort/cabauw.ux"
     &,iostat=ierr,err=80)
      open (unit=20,file="/users3/aps/leonja/ch4mdata/ch4sort/kolom")
      open (unit=25,file="/users3/aps/leonja/ch4mdata/ch4sort/jaar0")
      open (unit=30,file="/users3/aps/leonja/ch4mdata/ch4sort/jaar1")
      open (unit=35,file="/users3/aps/leonja/ch4mdata/ch4sort/jaar2")
      open (unit=40,file="/users3/aps/leonja/ch4mdata/ch4sort/jaar3")
      open (unit=50,file="/users3/aps/leonja/ch4mdata/ch4sort/jaar4")

      write (6,*) "begin opdracht"

c     Alleen in een kolom zetten in bestand "kolom"

      j=1

      do i=1,5000

       read (10,*,end=15) d1,d2,d3,d4,d5,d6,d7,d8,d9,d10,d11,d12
       write (20,*) d1
       A(j)=d1
       write (20,*) d2
       j=j+1
       A(j)=d2
       write (20,*) d3
       j=j+1
       A(j)=d3
       write (20,*) d4
       j=j+1
       A(j)=d4
       write (20,*) d5
       j=j+1
       A(j)=d5
       write (20,*) d6
       j=j+1
       A(j)=d6
       write (20,*) d7
       j=j+1
       A(j)=d7
       write (20,*) d8
       j=j+1
```

```
        A(j)=d8
        write (20,*) d9
        j=j+1
        A(j)=d9
        write (20,*) d10
        j=j+1
        A(j)=d10
        write (20,*) d11
        j=j+1
        A(j)=d11
        write (20,*) d12
        j=j+1
        A(j)=d12
        j=j+1
       end do

 15    continue

c      Inlezen van "kolom" in A(i) en A(i) wegschrijven in "jaar0"
       do i=1,54095
        write (25,*) A(i)
       end do


c      Wegschrijven van jaar 1 (1993) in B(j)
       j=1

       do i=1,14688
        B(j)=A(i)
        write (30,*) B(j)
        j=j+1
       end do


c      Wegschrijven van jaar 2 (1994) in C(j)
       j=1

        do i=14689,32208
         C(j)=A(i)
         write (35,*) C(j)
         j=j+1
       end do

c      Wegschrijven van jaar 3 (1995) in D(j)
       j=1
       do i=32209,49728
        D(j)=A(i)
        write (40,*) D(j)
        j=j+1
       end do

c      Wegschrijven van jaar 4 (1996) in E(j)
       j=1
       do i=49729,54096
        E(j)=A(i)
        write (50,*) E(j)
        j=j+1
       end do

 35    continue
       write (6,*) "einde opdracht"

 80    continue
       write(*,'("file error=,",i6)')ierr
       end
```

```
      Program sorteer_1
c     Dit programma zet de data van twaalf kollommen (TOR-isoformat)
c     achter elkaar in een rij
      open (unit=10,file="/users3/aps/leonja/ch4mdata/ch4sort/mace90.ux
     &",iostat=ierr,err=20)
      open (unit=20,file="/users3/aps/leonja/ch4mdata/ch4sort/mace3_90"
     &)
      write (6,*) "begin opdracht"

      do i=1,10000
       read (10,*,end=15) d1,d2,d3,d4,d5,d6,d7,d8,d9,d10,d11,d12
       write (20,*) d1
       write (20,*) d2
       write (20,*) d3
       write (20,*) d4
       write (20,*) d5
       write (20,*) d6
       write (20,*) d7
       write (20,*) d8
       write (20,*) d9
       write (20,*) d10
       write (20,*) d11
       write (20,*) d12

       read (10,*, end =15)

      end do

15    continue
      write (6,*) "einde opdracht"
20    continue
      write(*,'("file error=",i6)')ierr
      end
```

Program sorteer2

```
c    Dit programma maakt van kwartierwaarden uurwaarden
c    Bij gemiddelde berekening wordt rekening gehouden met missing values
     Dimension A(4)
     open (unit=10,file="/users3/aps/leonja/ch4mdata/ch4sort/delft1_94
    &".iostat=ierr,err=30)
     open (unit=20,file="/users3/aps/leonja/ch4mdata/ch4sort/delft2_94
    &")
     write (6,*) "begin opdracht"

     do j=1,10000
      k=0
      uur=0
       do i=1,4
       read (10,*,end=25) A(i)
       if (A(i).eq.-88.0) goto 10
       k=k+1
       uur=uur+A(i)

  10   continue

       enddo

       if (A(1) .eq. -88.0 .and.  A(2) .eq. -88.0
      &  .and. A(3) .eq. -88.0 .and. A(4) .eq. -88.0) then
       goto 15
       endif
       uurgem=uur/k
       goto 16


  15   uurgem = -88.0

  16   write (20,*) uurgem

       enddo

  25   continue
       write (6,*) "einde opdracht"
  30   continue
       write(*,'("file error=",i6)')ierr

       end
```

	Date	Arnhem	Kollum	Delft	Cabauw
1	1/1/94		1805.43	1951.041	1876.062
2	1/2/94		1910.159	1930.729	1872.625
3	1/3/94		1847.381	1913.333	1862.958
4	1/4/94		1780.531	1864.642	1831.958
5	1/5/94		1817.968		1853.354
6	1/6/94		1891.09	1951.428	1853.224
7	1/7/94		1821.926	1954.479	1887.416
8	1/8/94		1985.655	2092.604	1964.562
9	1/9/94		2031.173	2016.77	1929.479
10	1/10/94		1926.503	2176.875	1986.145
11	1/11/94		1966.048	2116.93	2030.625
12	1/12/94		1834.604	1894.76	1876.312
13	1/13/94		1785.305	1841.833	1806.782
14	1/14/94		1761.655	1888.213	1826.875
15	1/15/94		1816.767	1943.262	1878.333
16	1/16/94		1818.839	2004.27	1872.791
17	1/17/94		2007.583	2051.041	1903.02
18	1/18/94		1777.445	1882.5	1883.5
19	1/19/94		1887.336		1923.571
20	1/20/94		1892.402		1931.5
21	1/21/94		1927.336		1994.208
22	1/22/94		1795.635		1907.333
23	1/23/94		1766.308		1829.708
24	1/24/94		1763.926		1842.145
25	1/25/94		1826.489		1860.625
26	1/26/94		1725.166		1808.604
27	1/27/94		1739.013		1807.294
28	1/28/94		1716.406		
29	1/29/94		1765.61		
30	1/30/94		1727.781		
31	1/31/94		1749.628		
32	2/1/94		1829.465		
33	2/2/94		1798.464		
34	2/3/94		2195.444		1983.75
35	2/4/94		1820.142		1946.437
36	2/5/94		1832.96		2100.937
37	2/6/94		1949.322		2001.416
38	2/7/94		2084.121		1894.666
39	2/8/94		2073.555	1979.522	1861.145
40	2/9/94		1924.842	1998.887	1876.145

APPENDIX 3 METEOROLOGICAL DATA

Station: Rotterdam									
Project knmi	knmi	knmi	knmi	knmi	knmi	knmi	knmi	knmi	knmi
Unit 0.1 o C	%	0.1 mm	0.1 uur	0.1 mbar	J/cm2	graden	0.1 m/s		pq-klasse
Method -	-	-	-	-	-	-	-		-
Hour\Compor T	RH	DQ	DT	P	Q	WD	WV		PQ
--- ---	---	---	---	---	---	---	---		---
01/01/1994 0 28	96	0	0	10044	0	270	35		5
01/01/1994 0 30	92	0	0	10054	0	280	40		5
01/01/1994 0 28	91	0	0	10063	0	280	45		5
01/01/1994 0 27	91	0	0	10071	0	280	40		5
01/01/1994 0 30	89	0	0	10081	0	270	45		5
01/01/1994 0 26	89	0	0	10089	0	270	40		5
01/01/1994 0 15	94	0	0	10097	0	260	25		6
01/01/1994 0 16	95	0	0	10108	0	250	40		5
01/01/1994 0 20	96	0	0	10117	8	250	35		2
01/01/1994 1 39	93	0	0	10126	31	260	40		3

APPENDIX 4 ELECTRONICALLY AVAILABLE DATA

Electronically available data on methane measurements in Europe

A search on the Internet (WWW) has been made in an attempt to extend the number of measuring stations in the database. The search was aimed at finding methane measurement data for Europe, especially for non-background locations. The result of this search was limited. The sites that contain at least some data on measurements of methane or could lead to such data will be discussed below.

URL: http://www.icf.de/UISonline
The city of Berlin has a Air Quality Monitoring Network called BLUME (German for 'flower' and an acronym for Berliner LUftgüte MEβnetz). Methane may be measured in this network regularly.

URL: http://JCDC.kishou.go.jp/jcdc.html
Here CH_4-data from at least two measuring sites are given in graphs. These sites are however located in Japan. Also available from this site are the data from the NOAA/CMDL Flask Network available as ASCII downloadable files containing monthly means for several sites across the globe. Drawbacks of these data include the fact that they are older than we would like (newest 1993) and that the measurements sites in Europe are those already known to us from the TOR database like e.g. Mace Head in Ireland. These sites are also background locations. On the subsite URL: http://JCDC.kishou.go.jp/wcdc.html valuable data from the European measuring stations Baltic Sea, Heiney (Iceland), Lambedousa (Italy), Macehead (Ireland) and Ocean M (Atlantic Ocean, west of Bergen, Norway), became available, see also Chapter 2.

URL: http://ccg1.cmdl.noaa.gov/flask.html
Here the Carbon Cycle Group I makes the NOAA/CMDL Flask Network data available for downloading. An FTP-site can be found at:
ftp://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/FTP_SITEINT_DIS/readmes/gas.html#500
See http:daac.gsfc.nasa.gov for instructions for a telnet connection, including the usename and password.

URL: http://www.ubavie.gv.at/info/emi/luft.htm
On this site the Umweltbundesamt of Austria makes it clear that they run a nationwide air quality monitoring network. It is, however, unclear whether they do or do not measure methane.

URL: http://www.bacd.rl.ac.uk
This site of the British Atmospheric Data Centre, has methane data available on-line that originates from satellite measurements (UARS, NIMBUS7). However, no reliable data of CH_4 in the troposphere are available.

URL: http://www.environ.se/forskn/milforsk/kommled/luftled.htm
Here the Swedish EPA, Naturvårdsverket, provides names of their researchers involved in air- related research and on a connected page a listing of projects. None of the projects mentioned seems to be directed at a routine measurement of ambient methane concentrations.

URL: http://www.eea.dk
The European Environmental Agency (EEA) gives considerable information and links to other European sites in its WWW pages in Copenhagen, Denmark. As an example one can find the European Topic Centre for Air Quality (ETCAQ) in the EIONET listing which is on:
URL: http://www.etcaq.rivm.nl
No actual data or meta-data on measurement of methane could be found at the web-site of the European Environment Agency. Nor could it be found at the European Topic Centre for Air Quality linked site. These sites may however prove very useful in providing names (including addresses, some with E-mail) of European organisations that may provide CH_4 data.

With some effort similar sites to those for Berlin, Sweden and Austria could be located for most European countries and for many of the major cities. None of them gave clear information on the presence or availibility of methane measurement data.

URL: http://cdiac.ESD.ORNL.GOV/cdiac
The Carbon Dioxide Information Analysis Centre has much data on Global Change. For instance, one can find the Trends'93 data on-line. A quotation taken from a page at the CDIAC-site:
"Due to funding cuts it will be impossible for CDIAC to continue printing the Trends series, however, CDIAC staff continue to work on compiling this report! Until it is possible to resume printing, Trends will be a dynamic WWW document. The most current version of the Trends volume is what appears on the CDIAC Home Page (url: http://cdiac.esd.ornl.gov/trends_html/trends). As new data become available, the appropriate sections in Trends will be modified and new machine-readable data files will be placed in the CDIAC anonymous FTP area under "/pub/trends".
Recent additions include ...
Updates through 1995 for the atmospheric CO2 concentration records from Amsterdam Island (Gaudry et al.) [September 5, 1996]"

URL: http://blueskies.sprl.umich.edu/geia
This is the location for the Global Emissions Inventory Activity or GEIA. As the name already states in a clear manner this site is mainly aimed at emission inventories and not at measurement of ambient concentrations.

URL: http://www.unep.ch
The United Nation Environment Program has a Web-site in Geneva, Switzerland. Here the documents of many conventions, including the Convention on Climate Change, can be found. Links to other UN-organisations, like the Framework Committee on Climate Change (FCCC) and the Intergovernmental Panel on Climate Change (IPCC), are available.

To conclude the global part of this listing, there is the Information Highway to the Global Environment. On this site you can find a directory of organizations and institutes active in environmental monitoring. This list is organised alphabetically by country. The Universal Resource Locator for this site is:
URL: http://www.gsf.de/UNEP/contents.html

The WMO WCDC database in Tokio

CH_4 concentration data measured in Europe could be obtained from the WMO-WCDC database in Tokio as decribed in Chapter 2 for the measuring stations Baltic Sea, Heiney (Iceland), Lambedousa (Italy), Macehead (Ireland) and Ocean M (Atlantic Ocean West of Bergen, Norway) at URL: http://JCDC.kishou.go.jp/wcdc.html

Posting

A second approach to electronically gathering European methane data was made by posting a message to the UseNet newsgroup sci.geo.meteorology. The sci.geo.meteorology seems to be the most relevant newsgroup for this, as was judged by the topics of the messages already present.
As of yet no results of this action have been received.