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DEPOSITION OF SULPHUR IN EUROPE:

Methods to construct unbiased source-receptor matrices from data of a limited period (1976-1982)

A meteorological contribution to the
IIASA RAINS model

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Abstract

The IIASA-RAINS (Regional Acidification INformation and Simulation) model consists of three submodels:

- Energy-emissions-submodel
- Atmospheric-submodel
- Forest-Soil-pH-submodel

The frame of the atmospheric submodel is a Source-receptor-matrix (SRM), which describes the atmospheric transport of the SO_2 emissions from the source areas and the dry + wet depositions in the receptor places, on an annual base.
The routine SRM however is only based on the meteorology of the two year period oct '78 - sept '80, but the frequency distribution of the observed general circulation patterns during this period deviated in many aspects from the long term climatic average. Monthly SRM's are available from the limited period 1-1-1978 - 31-10-1982.
This report describes some subjective and objective methods for the construction of annual, seasonal and monthly standard SRM's, based on the data of the 5 year period, which are in accordance with the long term climatic frequency distribution of atmospheric circulations. A proposal is made for the construction of SRM's for (atmospheric) favourable and unfavourable seasons, 6-months and 12-months periods, to be informed about the possible variance in the values of the standard SRM's.

0. Project description and objectives

The objective of the Atmospheric Processes submodel in the IIASA-RAINS = (Regional Acidification INformation and Simulation) model is the computation of the sulphur deposition in Europe due to the sulphur emissions in each country.
This relation is given by a source-receptor-matrix (SRM). The SRM's are computed on a monthly base, by using the observed meteorology. The variance from month to month in the deposited sulphur amounts depends on the variability of the general atmospheric circulation and the emissions.
The atmospheric submodel however, in use until 1985, consists of an annual routine SRM, which is constructed from the data of the two year period 1 Oct 78 - 30 Sept 1980.
Even annual and bi-annual SRM's will still deviate from the long term climatic average, which is usually based on a 30-year period.
Since 58 monthly SRM's have been computed, during the period 1-1-78 - 31 oct 1982, more data than used for the routine period are available as a base for the construction of standard SRM's. These should be based on a selection of SRM's, in such a way that the associated frequency distribution of the contributing general atmospheric circulations will be the same as the long term climatic average frequency distribution.
The standard seasonal, semi-annual and annual SRM's may be used under the assumption that until the year 2050 no (significant) climatic change will occur.
Using the spectrum of general atmospheric circulations which have occurred in the past, a meteorological sensitivity analysis of the atmospheric sub model can be undertaken by computing the sulphur depositions on selected (threatened) areas for both favourable and unfavourable meteorological seasons or years.

1. Introduction

As a part of the cooperation of IIASA with the UN Economic Commission of Europe (UN-ECE) an acid rain model is developed at IIASA which yields the sulphur deposition and environmental impact of acid rain in Europe as a function of the SO_2 emissions.

One of the submodels describes the atmospheric transport, transformation and deposition of sulphur. This Atmospheric-Processes-submodel computes the sulphur deposition in Europe due to the sulphur emissions in each country and then adds the contributions from each country together to compute the total sulphur deposition at any location in Europe. The submodel consists of a source-receptor matrix (SRM) which gives the amount of sulphur deposited in a grid square (roughly 100 x 100 km^2) due to sulphur emissions in each country in Europe (Alcamo et al., 1984) (Fig. 1.1 and table 1.1).

The source-receptor matrix is based on a model of long range transport of air pollutants in Europe (LRTAP-model). This model is developed to estimate the sulphur import-export balance of the European OECD countries (OECD: Organisation of Economic Cooperation and Development). Monitoring and evaluation of the long range transport of air pollutants continued after 1977 under the cooperative EMEP-programme (EMEP: European Monitoring and Evaluation Project) (Eliassen et al., 1983).
This LRTAP-model accounts for the effects of wind, precipitation and other meteorological and chemical variables on sulphur deposition. A full discussion of this model is given by Eliassen and Saltbones (1983).
The context of this model within current practice of long-range modeling is described by Fisher (1984) and Lamb (1984).
The model predicts concentrations of sulphurdioxyde (SO_2) and sulfate (SO_4) at the center of 150 x 150 km^2 grid elements. Every 6 hours air trajectories are computed backward from the center of each grid element. They are followed for 96 hours, based on the observed meteorological parameters and atmospheric circulation. In the model the mixing height is constant and equal to 1000 m. The model assumes uniform mixing of the sulphur compounds, released from each grid element up to the mixing height. The mass balance equation for SO_2 and SO_4 along each trajectory is

solved.
The computation of the air trajectories along which pollutants are transported, depends on the choice of the wind vector. In the EMEP-LRTAP-model the trajectories are obtained by using the wind at the 850 mbar level (about 1500 m).

The model is too demanding computationally (in terms of data and time) to be used directly as a submodel of the IIASA RAINS model. Therefore it is used to construct the "Source-receptor matrix", schematically represented in Fig. 1.1 and table 1.1.

2. The routine Source-Recepter-Matrix

Until 1985 the scenarios which have been computed with the IIASA RAINS model were based on a source-receptor-matrix (SRM) of a two-year simulation run, using 1978-1980 data. (Period Oct. 1978-Sept. 1980). The SRM gives the total (i.e. dry plus wet) annual sulphur deposition in each grid square throughout Europe. (Alcamo et al., 1984).

The inaccuracies of the Atmospheric Processes Submodel depend on various assumptions concerning
- the structure of the EMEP-LRTAP-model (for example 96 hr trajectories)
- the model parameters
  - the sulphur chemistry
  - the height of the mixing layer
  - the wind vector
  - the precipitation (duration, intensity, amount, geographical distribution pattern).
- the variability in the general atmospheric circulation patterns.

At a meeting of experts held at Friedrichshafen (FRG) in Dec. 1983 the experts agreed that the annual and monthly budgets (the quantity of sulphur compounds emitted by a country minus the quantity deposited within the same country) (see e.g. table 1.1) were of great value provided they were interpreted in the light of intrinsic and unavoidable uncertainties, such as precise emission data or meteorological variability, which must be added to the uncertainties arising from the model itself and from errors

in ground measurements of concentrations of pollutants.
When applied to environmental issues with reasonably long time scales, it was felt unrealistic to expect budget values to have an accuracy better than a factor of two. In this context the budgets were already regarded as useful.
In general, optimum modelling accuracy was expected between 100 and 1000 km from major sources of pollution (WMO, 1984).

- Since the figures of the Source Receptor Matrix will be used in forecast scenarios for the next decades, one has to consider that the correlation between emissions and depositions, given by the routine SRM are only based on a two-year period. The question is whether the frequency distribution of the atmospheric circulation patterns which occurred during this period deviated from the normal (= climatic) long-term mean values or not. And if they did, how much!

- Furthermore the assumption is made that the frequency distribution of the different atmospheric circulation patterns in the next 10-50 years will not deviate significantly from that of the past 30 years or a longer period. This means that the starting point is that no climate change will occur.

- In the framework of these assumptions the IIASA RAINS model needs an Atmospheric Processes Submodel which is based on a Source Receptor Matrix which is representative for a climate frequency distribution of the different atmospheric circulation patterns.

- However, the period during which calculations were made with the routine LRTAP-model of MSC-W (Meteorological Synthesizing Centre-West) at Oslo covers the years 1978-1982, exclusive Nov. + Dec. 1982, which means that 58 monthly SRM's are available. (Eliassen et al., 1984).

- No further runs with this simple routine model are planned. Calculations from 1983 and onwards will be carried out using a new and slightly more sophisticated model which includes a variable mixing height and an exchange mechanism with the free troposphere. However, these model runs are postponed until the ongoing updating of the emission map has been

completed.
Since 1980 will be a basis year for planned emission reductions in many countries, the above mentioned new model has been run to cover this year (model version 6, mentioned in EMEP/MSC-W Report 1/82, section 3.6). The results from the new model run are compared with routine model results and with measured data from the EMEP network (Eliassen et al., 1984).

- When the frequency-distribution of the different atmospheric circulation patterns during the two year run from Oct. 1978 - Sept. 1980 deviates from the climatic frequency distribution, we have to investigate the possibility to construct a standard SRM which is based on an other selection of months (out of the 58 months which are available now), which is more in accordance with the climatic average.

3. The climatological normal frequency distribution of atmospheric circulation types

In the general atmospheric circulation pattern over the area of the East Atlantic and the European Continent 29 distinct "circulation types" can be distinguished. The classification according to the system of Hess and Brezowsky (1952) is based on a division in three main types, subdivided in so called "Grosswetterlagen" (GWL's) (Fig. 3.1).

- The zonal or west circulations, a mainly west-east orientated airstream, in main lines parallel to the latitudes, caused by an almost stationary high pressure area at the earthsurface extending from the Azores towards the Mediterranean and by low pressure areas moving E or NE from the Atlantic via the British Isles towards Central- and Northern Europe.

- The meridional circulations, mainly north-south or south-north orientated, caused by a quasi-stationary high pressure area at the earth surface between 50° NL and 70° NL, which is blocking the zonal circulation over Europe completely.
  During the north-circulations the anticyclone lies over the eastern part of the North Atlantic Ocean. Depressions are then moving from Greenland over South-Scandinavia and the Northsea towards the Alps and sometimes still more southerly.
  Some of the meridional circulation types are associated with a quasi stationary low pressure area at low latitudes, in which the depressions which are crossing Europe are caught at the end of their track. During North circulations cold but not polluted arctic air is transported far southwards. During the south-circulations the anticyclone covers Southeast- and East-Europe. The low pressure areas are now moving north. Warm subtropical air is transported polewards. Air pollution from Central- and Western-Europe is transported towards Scandinavia.

- The half-meridional circulations, are mainly NW-ly or SW-ly airstreams. Northwest circulations occur when the subtropical anticyclone at the earth surface moves northward onto about 50° NL (low latitude blocking). During the Southwest-circulations the anticyclone is situated over the Mediterranean and SE-Europe. When it is situated over Central Europe (HM

= Hoch Mittel Europa) or when it has its axis West-East from, the British Isles over Central Europe to East Europe, (BM = Brücke Mittel Europa) then the air movement over West- and Central Europe is normally very weak. Many "episodes" with air pollution are associated with these types.

The classification of general atmospheric circulation patterns is characterized by the following types: (fig. 3.1)

W_s: southerly orientated
W_a: anticyclonic West circulation
W_z: cyclonic

BM: Ridge of high pressure (W to E) over Central Europe
HM: Anticyclone over Central Europe

SW_a: Anticyclonic Southwest circulation
SW_z: Cyclonic Southwest circulation

NW_a: Anticyclonic Northwest circulation
NW_z: Cyclonic Northwest circulation

HN_a: Anticyclone over NE-part anticyclonic over Central Europe
HN_z: of the Atlantic Ocean cyclonic over Central Europe

HB: Anticyclone over British Isles

N_a: Anticyclonic Northern circulation
N_z: Cyclonic Northern circulation

T_rM: Trough of low pressure over Central Europe
TM: Low pressure over Central Europe

TB: Low pressure over the British Isles
T_rW: Trough of low pressure over Western Europe

S_a: Anticyclonic Southern circulation
S_z: Cyclonic Southern circulation

SE_a: Anticyclonic Southeastern circulation
SE_z: Cyclonic Southeastern circulation

HF_a: Anticyclone over anticyclonic over Central Europe
HF_z: Finland and Scandinavia cyclonic over Central Europe

HNF_a: Anticyclone over Finland, anticyclonic over Central Europe
HNF_z: Scandinavia and Northern cyclonic over Central Europe
part of the Atlantic Ocean

NE_a: Anticyclonic Northeast circulation
NE_z: Cyclonic Northeast circulation

Ww: (Winkelwest): West circulation over East Atlantic and British Isles, sharply turning northwards over West- and Central Europe.

ü: (übergang): transition between two circulation types; not to classify.

The average frequency for different combined classes, in percentages, based on the period 1881-1961, is the following:

	N	NE	E	SE	S	SW	W	NW	Ww	BM	HM	TM
Winter	8.9	3.6	8.5	4.7	7.2	5.7	25.0	11.8	3.3	6.1	12.8	2.4
Spring	16.8	6.8	10.4	5.1	7.2	2.9	19.2	11.6	2.2	4.2	9.1	3.7
Summer	13.7	6.7	4.1	0.4	6.4	1.8	29.0	17.3	2.1	5.6	10.2	2.1
Autumn	10.5	3.0	6.3	4.7	9.4	4.4	23.8	11.7	3.0	8.3	12.1	2.4

$N = N_a + N_z + HB + HN_a + HN_z$
$E = HF_a + HF_z + HNF_a + HNF_z$
$S = S_a + S_z + T_rW + TB$
$W = W_s + W_z + W_a$

$NE = NE_a + NE_z$
$SE = SE_a + SE_z$
$SW = SW_a + SW_z$
$NW = NW_a + NW_z + T_rM$

There is a connection between circulation types and advected air masses. The air masses provide the weather various properties. For example circulation type, air mass and season determine strongly the height of the mixing layer during day time. The measured or computed transport and distribution pattern of air pollution during a special period (season, year) is in a high degree correlated with the circulation types which occurred during that period.

The GWL's (general atmospheric circulations) are classified daily from 1881. From year to year, but also from month to month, the frequency distribution shows a large variability.
But during a sequence of many years the mean frequency distribution stabilizes.

The classification method for the period 1881-1949 differs somewhat from the period 1949-1984. Short interruptions of 2 days in a sequence of, for example, 8 days were not classified separately, just like transition circulations (ü = übergangslage). Even when no climatological differences have occurred between the period 1881-1949 and 1949-1984 some variance in the frequency numbers of both the periods may be expected.

The mean frequency distribution of the available period 1881-1955 is given in table 3.1

The climatological normal frequency distribution, determined by the period 1949-1980, is given in tabel 3.2. It should be mentioned that this period has an overlap of 7 years (1949-1955) with the preceding period.

Based on the monthly frequency distributions (given in numbers of days) the annual and seasonal frequency distributions can be derived. (Summer = April-September; winter = October-March). They are given in the lower three rows in tables 3.1 and 3.2.

The numbers of the three westerly (= zonal) circulations: W_s, W_a, W_z (resp. west, southerly situated, west, anticyclonic, and west, cyclonic) are practically equal in both periods.

circulation type		W_s	W_a	W_z
winter	1881-1955	9	10	26
	1949-1980	7	7	27
summer	1881-1955	3	12	31
	1949-1980	4	13	24
year	1881-1955	12	22	57
	1949-1980	11	20	57

Larger differences are observed at the blocking circulations as there are BM (ridge of high pressure over Central Europe), HM (High over Central Europe), NW_a (Northwest Anticyclonic), HN_a (high over NE-Atlantic, anticyclonic over Central Europe) and TrW (Trough over W-Europe).

circulation type		BM	HM	(BM+HM)	NW_a	HN_a	(NW_a+HN_a)	T_rW
winter	1881-1955	12	21	33	7	5	12	4
	1949-1980	15	15	30	2	3	5	6
summer	1881-1955	10	19	29	11	9	20	4
	1949-1980	14	12	26	4	5	9	11
year	1881-1955	22	40	62	18	14	32	8
	1949-1980	29	27	66	6	8	14	17

Since both BM and HM are associated with rather similar meteorological conditions we see that the large differences disappear when the classes are combined. On an annual base: 62 in the first period to 66 in the latter period.

More evident is the higher frequency of NW_a + HN_a (32 to 14), associated with a more northward position of the subtropical (Azores) anticyclone in the 1881-1955 period.

From the figures we may conclude that the frequency distribution of GWL's which will be used to construct a Standard Source Receptor Matrix has to fit as good as possible to the distribution of 1949-1980, but that small deviations may be accepted.

4. Frequency distribution of the circulation types of the routine SRM

The routine SRM is based on the meteorology of the period oct 1978 - sept 1980. The monthly, seasonal and annual frequency distributions of this period are given in table 4.1.
The combination of the seasonal and annual frequency numbers of the routine period with those of the 1881-1955 and 1949-1980 periods is given in table 4.2.

Important differences between the climatic seasonal mean values and those of the Oct 78 - Sep 80 period are:

winterseason:

Routine period (Oct 78 - Sep 80)		-	period: $\frac{1881-1955}{1949-1980}$
W_a:	13	-	$\frac{10}{7}$
BM:	31.5	-	$\frac{12}{15}$
HM:	8	-	$\frac{21}{15}$
NW_a+NW_z	4.5	-	$\frac{14}{11}$
HN_a+HN_z+HB	0	-	$\frac{12}{12}$
TM:	1.5	-	$\frac{5}{4}$
SE_z	11.5	-	$\frac{4}{5}$

summerseason:

Routine period (Oct 78 - Sep 80)		-	period: $\frac{1881-1955}{1949-1980}$
W_a	6.5	-	$\frac{12}{13}$
BM	24	-	$\frac{10}{14}$
NW_z	5	-	$\frac{8}{9}$
HN_a	1.5	-	$\frac{9}{5}$
T_rM	4	-	$\frac{7}{9}$
TM	8.5	-	$\frac{5}{4}$
S_a	9	-	$\frac{2}{2}$
HF_z+HNF_a	17.5	-	$\frac{4}{6}$

The annual mean frequencies during the routine period have also to be compared with the frequencies of the climatic period. The differences may be prudently translated in the possible effects which may be expected in the SO_2-transport and the SO_2 deposition. Some of them are given below.

year

	Routine period '78-'80	– $\frac{1881-1955}{1949-1980}$	
BM	55,5	– $\frac{22}{29}$:	Higher concentrations in Central Europe by local contribution
HM	21	– $\frac{40}{27}$:	Less transport from W-Europe towards Scandinavia
SW_a	3,5	– $\frac{7}{10}$:	Less transport from W-Europe towards Scandinavia
NW_z	7	– $\frac{15}{18}$:	Less transport from W-Europe towards S-Germany and the Alps
HN_a	1,5	– $\frac{14}{8}$:	Less transport from Central and East-Europe towards S-Germany and the Alps.
HB	7	– $\frac{11}{11}$:	Idem.
T_rM	9,5	– $\frac{14}{17}$:	Less local rainout and washout near source areas in West, Central and East-Europe.
S_a	16,5	– $\frac{8}{7}$:	More transport from W- and Central Europe towards S-Scandinavia.
SE_z	11,5	– $\frac{6}{6}$:	More transport from Central and East-Europe towards S-Scandinavia.
HF_z	13,5	– $\frac{3}{6}$:	Idem.
HNF_a	9	– $\frac{5}{5}$:	More transport from East-Europe towards W- and SW-Europe
NE_{a+z}	10,5	– $\frac{20}{16}$:	Less transport from East-Europe towards Germany and the Alps.
Ww	4,5	– $\frac{9}{12}$:	Less transport from Eastern-Europe towards Sweden and Finland.

When on an annual base the meteorology of the routine SRM period is compared to the climatic average, the differences can be translated in effects of transport and deposition of SO_2 for the different areas of the receptor countries mentioned here above. In summary the author's idea is as follows:

Central Europe:	Local SO_2-contribution ca. twice as much as normal (55 days to 29 normal). Rainout and washout from local sources 1.5 times smaller than normal contribution from East-European sources about half the normal value.
Scandinavia: (mainly Southern part)	Transport from West-European sources about 15% less than normal (40 to 45 days). Twice as much transport from Central-Europe (40 days, compared to 20 normal). Advection from Eastern Europe 30% more than normal (31 days to 24).
South-Germany: and the Alps	Less contribution from W-European sources (40% of normal), Central-European sources (50% of normal) and East-European sources (60% of normal).
West- and Southwest-Europe	Contribution of local sources by rainout and washout only 50% of normal (on 9 instead of 17 days). More transport from Eastern European countries (9 days, compared to 5 normal).

- The conclusion from these remarks may be that the routine SRM offers a distorted picture with respect to the deposition in South-Germany (the Black Forest) and the Alps. They receive during normal climatic circumstances presumably twice as much SO_2 from West, Central and East-European sources as shown in the routine SRM.
  On the contrary Scandinavia - especially South-Sweden and South-Finland - receives in the routine SRM about 40% more SO_2 from Central Europe and

Eastern-Europe than during normal weather conditions.

Improvement of the routine SRM, which is used to study the effects of different energy and abatement scenarios, is desirable.

5. The construction of a standard annual and semi annual source receptor matrix

The routine SRM, based on a period of only 24 months can be replaced by a standard SRM, which is better in agreement with the normal climatology of the weather circulation types. For the construction 58 months SRM's are available, covering the period Jan 1978 - Oct 1982.
Climatological evidence showed that there are only very weak correlations between the distribution of circulation types from one month to another.

In other words the behaviour of the weather systems over a period of a month is independent of the circulation patterns during the preceding month. This means that the SRM's from month to month may be considered to be meteorologically indepent of each other.

To construct standard SRM's (monthly, seasonal or annual) all the 58 monthly SRM's or a selection out of this number, may be used.

For different purposes, like run-off of the spring snow melt in Scandinavia, variable effects on the vegetation during winter, spring or summer, it is desirable to have the disposal over "normal" monthly and seasonal SRM's.
Based on the available 58 separate monthly SRM's the construction of a "normal" year and even a "normal" summer and winter halfyear, is much easier than the construction of a "normal" season of three months or separate "normal" months.

First we will construct a SRM for a normal winter half year (Oct - March) and for a normal summer half year (Apr - Sept), which together furnish a "normal" annual SRM.
Afterwards we will look whether it is possible to construct shorter term

SRM's.

The distribution of the atmospheric circulation types for Europe (the "Grosswetterlagen") of the separate 58 available months is given in table 5.1. in number of days per month.
The scheme, covering the years 1978-1982, is given per square as follows:

GWL
a b in which "a" means the number of days on which GWL "X" occurred in
c 1978, "b" the number in 1979, "c" in 1980, "d" in 1981 and "e" in
d e 1982.

The mean annual, mean winter and summer halfyear frequency distribution, derived from the 58 months is given in the lower three rows of table 5.1.
Three questions arise now:

- does this distribution better fit to the climatic normal distribution than the mean distribution derived from the period Oct 78 - Sept 80.
- are there still deviations between these 5-year mean distribution and the normal one.
- if so, is it possible by rejecting some abnormal monthly frequency distributions, to reach an improvement which agrees with the desired climatic distribution.

All the distributions can be compared with each other in table 5.2 which contains for each of the 30 separate "Grosswetterlagen" the number of days they occurred on an average in the winter halfyear, summer halfyear and the whole year during the periods:

- 1881-1955
- 1949-1980
- 1978 (Oct) - 1980 (Sept)
- 1978-1982 (28 months of the winter halfyear, 30 of the summer, 58 in total).

The conclusion is that the use of 58 months leads to an important improvement relative to 1978-1980, especially when "similar" circulation patterns are grouped together.

- The winterhalfyear:

Reduction of BM-circulations with 5.5 days, but BM + HM still 4 days more than normal. SW_a + SW_z increase with 4 days and are now in agreement with the long year average. The same holds for the improvement with 7 days of NW_z. Also TM, T_rW, S_z, SE_a fit better and are of the same order as normal. SE_z reduced with 3.5 days, but is still 3 days too high compared to the climatic normal.

Improvements also for HF_a (from 7.5 to 5), HF_z (from 5 to 3).

In some cases even worse results were obtained. Ww-circulations reduced from 4.5 to 2, but had to increase to 7! The most remarkable deterioration however is observed in the westerly circulations W_s, which increased from 10.5 to 14, and W_z, increasing from 26.5 to 34, against which W_a improved only with a 4 days decrease from 13 to 9. So the total deteoration is 7 days.

Compared with the long term averages the period 1978-1982 shows during the winterhalfyear a mean of 57 days with West to Southwest circulations against 41 days normal.

It is striking that HB which occurs during 6 days normally and HN_z, with 3 days, have not occurred during 1978-1982 at all in the 6 months from October to April.

- The summerhalfyear:

The improvement for the summer halfyear is still better than for the winterhalfyear. It works out for practically all the circulation types. The most important contribution is reached in the westerly circulations (W_s, W_a, W_z), which are better in accordance now with the 1949-1980 period than by using the years 78-80. The same holds also for the BM+HM (= anticyclonic) circulations, the SW_a + SW_z etc.

- The annual frequency-distribution:

A combination of the winterhalfyear and the summerhalfyear shows an improvement in the frequency distribution of BM, SW_a + SW_z, NW_z, HN_a, S_a, SE_a + SE_z, HF_z, HNF_a + HNF_z - circulations. On the contrary there is also some deteoration as there is an unacceptable increase in W_s-circulations from 13.5 to 20, while it has to be 11 days.

The conclusion is that by using all the available months of the 1978-1982-period an important improvement in the construction of climatic normal SRM's will be achieved, but that some frequency distributions still differ "too much" of the climatic mean values.
For the construction of a standard SRM it will be necessary to select those monthly SRM's out of the available ones which contribute in such a way that they are based on a frequency distribution of circulation pattern which still better correspond with the climatic normal distribution of the 49-80 period.
For this purpose some of the available 58 months are excluded. This exclusion has an empirical base. The combination of months of which the frequency distribution of the Grosswetterlagen correspond the best with the mean climatic frequency distribution (1949-1980) is chosen by 'trial and error'.
As a result it is possible to achieve this accordance by using 21 of the 28 available wintermonths and 26 of the 30 available summermonths.
The comparison is given in table 5.3.
The improvement in the winterhalfyear counts especially for W_s and W_z, both reduced with 4 days, BM, reduced with 3 days, however W_a increased with 3 days, from 9 to 12. All the other differences with the original use of the 28 available months are 2 days or less.
Also the still existing differences with the distribution of the 49-80 period are given. The largest, in days, is for BM (23 against 15 normal), but the rather similar circulation types BM and HM together count for 33 (against 30 in the 49-80 period and 33 in the 1881-1955 period) and this is acceptable.

In the summerhalfyear frequency distribution the differences with the climatic averages, in number of days, are at most 3 days. Negative and positive deviations for similar circulation types are mainly compensating each other.

Adding the summer and winterhalfyear we get an annual frequency distribution which deviates at most 7 days (Ww: -7 and BM: +7). The loss of 7 Ww days is compensated by the gain of 8 W_s + W_a + W_z days, which furnisch rather similar weather types over a big part of Europe. The excess of +7 BM is partly compensated by the rather similar HM which counts for -4 days.

The better accordance has been achieved by using the selection, given in table 5.4. consisting of the following contributing months:

winterhalfyear:

		used	excluded
	January:	79, 80, 81, 82	1978
	February:	78, 80, 81, 82	1979
	March:	79, 81, 82	1978, 1980
21 months	October:	79, 80, 81, 82	1978
	November:	78, 79, 80	1981
	December:	78, 79, 80,	1981

summerhalfyear:

	April:	78, 79, 80, 81, 82	
	May:	78, 79, 80, 81, 82	
	June:	78, 80, 81	1979, 1982
26 months	July:	78, 79, 80, 81, 82	
	Aug:	79, 80, 81, 82	1978
	Sept:	78, 79, 81, 82	1980

It is correct to remark that during one special circulation type, even when this is regarded in the same period of the year, the trajectories of the advected air and the other meteorological parameters will not be always exact the same. This means that a sequence of similar "Grosswetterlagen" unavoidably will lead to some range in both the transport and the deposition of air pollution.

But mainly we may expect that the larger the number of days will be of the different GWL's which contribute to the construction of the standard SRM, the smaller the range in the deposition figures will be, due to the meteorological variability within the separate GWL's.

This means that it is desirable to use as much as possible contributing months as a base for the SRM-construction.

By excluding still some more months which contribute to the annual and semi-annual SRM's it is possible to achieve a still somewhat better corresponding frequency distribution of GWL's compared to the climatic period 49-80, but the question is whether the gain of such a small improvement will not be lost by the increasing variancy in the contributing weather phenomena which reduces again the reliability of the SRM. Therefore it is recommended to use the proposed months for the construction of both the semi-annual and annual SRM's.

6. The construction of seasonal and monthly SRM's

6.1 The subjective approach

In continuation of the construction of a standard annual and semi-annual SRM, the question arises whether it is possible to construct also 4 standard seasonal and 12 standard monthly SRM's by using the data of the 5 year period 1978-1982.

A very simple approach could be to divide the semi-annual winter SRM and summer SRM by two in order to get SRM's for the autumn, winter, spring and summer season respectively. One difficulty in this respect is that September is part of the summerhalfyear, but October plus November of the winterhalfyear. Together however they contribute to the autumn season. A similar problem relates for March plus April, associated to the winterhalfyear, and May, which belongs to the summerhalfyear, but together they make the spring. Therefore it would be better to return to the basic monthly data and to investigate the seasons separately, given by the following usual combinations,

	December		March
winter	January	spring	April
	February		May
	June		September
summer	July	autumn	October
	August		November

The mean frequency distribution of the general atmospheric circulation patterns for West-, Central- and East-Europe (Grosswetterlagen) in number of days per season is given in table 6.1.1 (for the winter and the spring)

and in table 6.1.2 or the summer and autumn). This mean frequency distribution, taken from the period 1949-1980, is compared with the observed frequency distribution during the 5 years 1978-1982.
For each of the separate GWL's the differences between the two periods, are also given, in number of days per season (tables 6.1.1 and 6.2.2). Averaged over all the 30 GWL's, the mean absolute deviation $\|\overline{\Delta}\|$, in number of days, is

	winter	spring	summer	autumn
$\|\overline{\Delta}\|$:	1.44	1.25	1.30	1.37

This means that the period 1978-1982 looks rather representative for the long term average, since a deviation of only 1.3 days has the same order of magnitude like the normal meteorological variability. Looking somewhat closer however some circulation types show larger deviations in number of days than other ones. Larger than 3.0 days these are for the 4 seasons -which have a length of 90-92 days-respectively:

GWL	W_s	W_z	BM	HM	HN_a	HB	N_z	S_a	Ww
winter:	+5,4		+4,1	-3,2				+3,3	
spring:			+3,0		-3,0				
summer:							+3,4		
autumn:		+6,9	+7,3			-3,3			-3,7

Excluding some months, which contribute to the average seasonal values, in order to reduce these large differences, would mean a small improvement only.
This exclusion procedure should be based on those months which contribute mostly to the large positive excesses. The negative deviations may be then reduced when the total number of these GWL's stay the same for the whole season but the number of months which contribute to the average seasonal values are also reduced.

Such an improvement can be made when the following contributing months are rejected:

winterseason: Dec 81, Jan 78, Febr 79
spring : --
summer : July 82, Aug 78
autumn : Sept 80, Oct 78, Oct 80, Nov 81

As a result of this procedure the mean absolute deviation $\|\bar{\Delta}\|$ changes only in the winter and autumn.

	$\|\bar{\Delta}\|$ (all available months)	$\|\bar{\Delta}\|$ (selected months)
winter	1.44	1.25
spring	1.26	1.26
summer	1.30	1.30
autumn	1.37	1.30

The improvement for the winter, by excluding Dec 81, Jan 78 and Febr 79 is illustrated by the following reductions of the frequency excesses:

		was		becomes
winter:	W_s :	+5.4	→	0.0
	BM :	+4.1	→	+3.8
	HM :	-3.2	→	-2.2
	SW_z:	-1.9	→	-1.2

However, there are also some negative effects due to increasing excesses:

	was		becomes
W_a :	-1.4	→	+2.3
W_z :	-1.8	→	-2.5
N_z :	+3.3	→	+1.8
S_a :	+3.3	→	+4.2

For the overall long range transport these negative effects have no important consequences. W_a and W_z are rather similar, so +2.3 is compensated by -2.5.

The S_a excess is +4.2, enlarged by the two days of SE_a + SE_z (1.2 + 0.8), which means 6 days too much transport from central and eastern Europe towards Scandinavia. This effect is only partly compensated by -2.7 days of T_rM and +3.1 days with extra northerly transport by $N_a + N_z$ circulations. So the proposed solution to compute the winter SRM looks the best possible fit in accordance with the climatic normal frequency distribution of circulation patterns.

For the summer the aim is to reduce the excess of transport from northerly directions towards the Alps, in the 1978-1982 period, given by

NW_a : +0.7
NW_z : −2.8
HN_a : +0.9
HN_z : +1.3
HB : +2.5
N_a : +1.7
N_z : +3.4

which means a total of 7.7 days
too much transport from N-ly directions

By excluding July 82 and Aug 78 the achieved reduction amounts 4.4 days:

NW_a : +0.5
NW_z : −2.5
HN_a : +1.3
HN_z : +1.8
HB : +0.4
N_a : −0.2
N_z : +2.0

total 3.3 days too much transport
from N-ly directions

By this operation the westerly circulations show some negative effects:

	was		becomes
W_s :	+2.2	→	+2.8
W_a :	−1.9	→	−2.6
W_z :	+0.8	→	+3.1
Total	+1.1	→	+3.2

This increase of 2 days, on a total amount of 25 days, must be accepted as the price for the reduction of the northerly circulations which furnishes a better picture for the Alps.

The corrections for the autumn season concern the reduction of the excess of +6.9 days W_z (wet cyclonic westerly circulations), of +7.3 BM (dry anticyclonic weather with mainly small transport over Central Europe), -3.3 days HB (dry N-NW transport over the western and central part of the European continent, and of -3.7 days with Ww, which means less transport from central and eastern Europe to Scandinavia.

A complete correction by excluding some months is not feasible without creating shortcomings elsewhere.
A good proposal seems to be to accept the rejection of sept 80, oct 78, oct 80 and nov 81. This results in:

	was		becomes	
W_s :	+1.8	→	+2.7	the reduction of W_z from 6.9 to 3.0 has as a consequence an increase of W_s with 0.9 and W_a with 2.9 on a normal total of 20 days (W_s + W_a + W_z) this means still + 9.6 days, i.e. ca 50% too much westerly circulations
W_a :	+1.0	→	+3.9	
W_z :	+6.9	→	+3.0	
BM :	+7.3	→	+0.5	important improvement
HM :	-1.6	→	+0.2	
HB :	-3.3	→	-3.3	no improvement
Ww :	-3.7	→	-3.4	

So we have to keep in mind that the autumns of 78-82 were characterized by an intensification of westerly circulations. This effect is difficult to eliminate.
So the climatic reliability of the standard autumn SRM will be smaller than those of the three other seasons.

A final question on request of the working group of the third submodel, the FOREST-SOIL pH-sub-model, concerns the availability of 12 separate standard monthly SRM's, especially in relation to the aquatic impact of acidification during the spring melt-water run-off.

The problem arises how to construct reliable standard monthly SRM's when only 5 SRM's for each of the month's are available.

The smaller the time periods are taken, the greater the probability of important differences in sulphur deposition between the climatic mean amounts and the computed budgets derived from the period 1978-1982, due to the greater variability in the frequency distribution of GWL's, in days per month.

This is illustrated by table 6.1.3 and 6.1.4, which contain the climatic frequency distribution of GWL's (in days per month) during the 1949-1980 period and also during the 5 years of the 1978-1982 period. The differences between both the frequency distributions are also given.

As is evident from table 6.1.3 and 6.1.4 the number of GWL-types of which the occurrence differs more than +0.5 or -0.5 days from the climatic average frequency, is rather big.

This number ranges from 14 in October to 22 in January, on a total of 30, as is given in table 6.1.5.
Some circulation types occur 5 or 6 days per month more than normal. And, when a circulation type does not occur at all, this may mean 2 to 3 days less than normal.

So the construction of standard monthly SRM's requests some ingenuity.

A simple solution may be to equalize each of the 3 months of every season, which means for example that December, January and February are characterized by one third of the winterseason, etc.

A second proposal is based on the idea that the negative and positive deviations in sulphur deposition with respect to the monthly mean value will have the same order of magnitude for each month of the year.
Looking to threatened areas a selection could be made of the poorest and also of the most favourable month of January, February etc. The mean SRM has to be situated anywhere between those two extremes. When the mean SRM, based on these two extremes, does not differ much of the one, constructed by taking one third of the seasonal standard SRM, this average SRM could

be taken as the best standard monthly SRM.

It is clear that a simple receipt for the construction of standard monthly SRM's is difficult to give. In this stage it looks the best to make a choice for one third of the seasonal ones.

Next have to be determined the deviations between the thus constructed standard monthly SRM and each of the five separate months to get an idea about the character and the order of magnitude of these deviations in sulphur budgets.

Perhaps a study of these deviations may indicate the direction in which the preliminary standard monthly SRM's have to be corrected.

6.2 The objective approach

It is also possible to construct in an objective way an SRM from data of a relatively short period. Here also the Grosswetterlage (GWL) is used as a daily classification of the general circulation type in the area considered.

We shall demonstrate the method on the following example: we wish to determine a climatologically representative SRM (CRSRM) for the winter half year from data of a few winters only. Assume that we have at our disposal an ensemble of SRM's of m months. We consider in this example months in the winter half year only and assume that these months are statistically independent samples of the general circulation. (Usually calculations concern a few years only so that the typical order of magnitude of m is ~ 10-20. It is unlikely that the total ensemble is climatologically representative. Normally we need at least 10 winterhalfyears, which means 60 months, to construct an average picture which hardly differs from the 30 year climatological mean.

Now we classify each day of each month according to its GWL. (For the purpose here we use a reduced classification scheme of 16 GWL's (cf. table 6.2.1.) and compose m monthly frequency distributions of GWL's. Table 6.2.2. shows that large differences occur between the monthly frequency distributions of the period 1978-1982 and the climatological frequency distribution of GWL's. Even the ensemble of m (=28) months still shows considerable deviations from the climatological distribution (last column of table 6.2.2).

It is proposed to construct a CRSRM not by just adding the monthly data, but by carrying out a weighted average, such that the weighted ensemble obtains, as close as possible, the climatological SRM. The mathematical procedures to determine these weighting factors are outlined below.

As already stated it is assumed that we have an ensemble of m months. When we classify the GWL into k(=15) classes, we obtain the matrix elements p_{ij} as the frequency of occurrence of GWL class i (i=1...k) in month j(j=1...m). (See table 6.2.2). When to each month a weighting factor g_j is assigned, it is required that

$$\sum_{j=1}^{m} g_j \, p_{ij} = P_i \qquad (i=1...k), \qquad (6.1)$$

where P_i is the climatological frequency distribution of the GWL's. Further we have the normalisation condition

$$\sum_{j=1}^{m} g_j = 1 \qquad (6.2)$$

If we consider (6.2) as the (k+1)th equation, Eqs. (6.1) and (6.2) can be combined as

$$\sum_{j=1}^{m} g_j \, p_{ij} = P_i \qquad (i=1...k+1), \qquad (6.3)$$

with $p_{k+1,j}$ and $P_{k+1} = 1$ (j=1...m).

Eq. (6.3) forms a set of k+1 linear equations (assumed independent) with m ($g_1...g_m$) unknowns.

For the solution of Eq. (6.3) three cases are distinguished:

(i) m > k+1, the system is undetermined; (ii) m=k+1, there is a unique solution and (iii) m < k+1, in general no solution.

(i) m > k+1.

There exists an infinite number of solutions for the set g_j. A selection of a particular set can be obtained by imposing an extra condition to g_j, for example, that the g_j-values are as close as possible to one (in the least square sense) or

$$\sum_{j=1}^{m} (g_j-1)^2 \text{ is minimal.} \tag{6.4}$$

Eq. (6.4) is equivalent with the condition that the variance of g_j is minimal (cf. Eq. 6.2), or

$$\sum_{j=1}^{m} g_j^2 \text{ is minimal} \tag{6.5}$$

The set equations (6.3 and 6.5) can be solved by the introduction of the function F, defined by

$$F = \sum_{j=1}^{m} g_j^2 + \sum_{i=1}^{k+1} \lambda_i \left(\sum_{j=1}^{m} g_j\, p_{ij} - P_i \right), \tag{6.6}$$

where λ_i ($i=1\ldots k+1$) are undetermined factors (Lagrangian multipliers). Eqs. (6.3, 6.5) are equivalent with the requirement that F is minimal, as can be easily verified. The values of g_j and λ_i for which F attains a minimum can be found by differentiation
to any variable g_r($1=r\ldots m$) and λ_q ($q=1\ldots,k+1$),
$\partial F/\partial g_r = 0$ and $\partial F/\partial \lambda_q = 0$ leading to set linear equations

$$\begin{aligned} &2\, g_r + \sum_{i=1}^{k+1} \lambda_i\, p_{ir} = 0 \qquad (r=1\ldots m) \\ &\sum_{j=1}^{m} g_j\, p_{qj} - P_q = 0 \qquad (q=1\ldots k+1). \end{aligned} \tag{6.7}$$

This set of m+k+1 equations and unknowns can be solved by standard numerical routines. We give the solution for the data of table 6.2.2., where $k=15$ and $m=28$. The weighting factors g_j are listed in table 6.2.3.

(ii) $m=k+1$

In this case Eq. (6.3) can be solved directly giving a unique set of weighting factors g_j. For the example we have lumped the matrix in table 6.2.2. and retained the first 16 months only. The corresponding g_j's are given in table 6.2.3.

(iii) $m < k+1$

Here no exact solution exists, but it is possible to obtain more or less close approximate solutions, by a least squares procedure (still with the constraint $\Sigma g_j = 1$).

We define $G(g_1 \ldots g_m, \lambda)$ as

$$G = \sum_{i=1}^{k} \left(\sum_{j=1}^{m} g_j\, p_{ij} - P_i \right)^2 + \lambda \left(\sum_{j=1}^{m} g_j - 1 \right) \tag{6.8}$$

and require that G be minimal: $\partial G/\partial g_r = 0$ $(r=1 \ldots m)$ and $\partial G/\partial\lambda=0$. These conditions yield

$$\begin{aligned} 2 \sum_{i=1}^{k} \sum_{j=1}^{m} g_j\, p_{ij}\, p_{ir} &= 2 \sum_{i=1}^{k} p_{ir}\, P_i - \lambda \quad (r=1 \ldots m) \\ \sum_{j=1}^{m} g_j &= 1 \end{aligned} \tag{6.9}$$

Introducing $\pi_{jr} \equiv \sum_{i=1}^{k} p_{ij}\, p_{ir}$ we have

$$\begin{aligned} \sum_{j=1}^{m} g_j\, \pi_{jr} + \tfrac{1}{2}\lambda &= \sum_{i=1}^{k} p_{ir}\, P_i \quad (r=1 \ldots m) \\ \sum_{j=1}^{m} g_j &= 1, \end{aligned} \tag{6.10}$$

which is a set of $m+1$ linear equations with $m+1$ unknowns. In the example we have limited the number of m to 6 (winter period of one year (1979)

only). The results are given in table 6.2.3.
Of course in this case it is not possible to reconstruct the climatological distribution exactly. In table 6.2.4 we give the climatological distributions, the winter 1979 distribution and the reconstructed GWL distribution. We observe that the 4th GWL (which occurred on 51 days in 1979) is reduced to 37 days in the weighted average, while the frequency of the other GWL's remain more or less unchanged.

For the construction of a CRSRM the procedure is now straightforward. Let the SRM of month j be represented by SRM_j. The CRSRM is then obtained from the relation

$$CRSRM = \sum_{j=1}^{m} g_j \, (SRM)_j . \qquad (6.11)$$

It would be interesting to compare the CRSRM's obtained by either method (i), (ii) and (iii) and the subjective method of the preceding section. Note that we have imposed no bounds on the values of g_j, so that some g_j's may be negative. According to (6.11) this might in principle result in a few negative matrix elements of the final CRSRM, which would be unrealistic. When this would appear to be a serious matter, other, more complicated, mathematical procedures could be followed, which ensure for example that $0 \leq g_j \leq 1$ for all j.

Finally it should be noted that by similar methods it is possible to construct SRM's for individual GWL's. For example consider a matrix element (Q_j) of the SRM of month j, and imagine that each GWL (i) contributed q_i to Q_j according to its frequency of occurrence, p_{ij}. Hence

$$\sum_{i=1}^{k} q_i \, p_{ij} = Q_j \quad (j=1 \ldots m) \qquad (6.12)$$

The q_i's can be obtained by similar methods as indicated above. A draw back of the method is that the procedure leading to the set of q_i's should be repeated for each matrix element of the SRM's resulting in lengthy numerical procedures.

7. Comparison of the *standard annual* SRM with the *routine annual* SRM.

The question which now arises, is the study of the order of magnitude of the *improvement* which has been reached by the substitution of the former *routine annual* SRM by the advised *standard annual* SRM.

Further interesting points are the existing *differences* between the *four available* SRM's:

- the "old" *routine* annual SRM
- the "average" (5-year) *annual* SRM, by using all the available months
- the "advised" *standard annual* SRM
- the "objective" annual SRM, based on the mathematical solutions.

The observed differences will give a good impression of the effect of a part of the atmospheric variability during the 1978-1982 period on the (computed) *total annual* sulphur depositions of the SRM's.
They also will give an idea of the effect on the *distribution* of the contributions from the different source-countries.

The results of this study will be published as a separate IIASA-Report.

8. A meteorological sensitivity analysis of the atmospheric sub-model.

In order to be informed about the meteorological sensitivity of the *standard SRM's* of the atmospheric submodel, the order of magnitude of the *possible* range in the amounts of the computed sulphur depositions *on selected areas*, *due to the possible variability* of the general weather circulation, has to be studied now.

If enough different meteorological situations, i.e. *a large number of monthly SRM's*, should have been available, the *standard deviation* of the figures, collected in the standard SRM, could be determined statistically. But since only 5 years - which means 5 months of January, 5 months of February, etc. - are available for application of such a sensitivity test, another method has to be followed.

A long term analysis of observed monthly frequency distributions of atmospheric circulation patterns, with the aim to make long range weather forecasts, has demonstrated that no correlation exsists between these patterns from one month to the next of from the one season to another, exept in very exceptional cases.

As a result of this "limited memory" of the atmosphere it is possible that "unfavourable" months may follow each other for longer time series, like also "favourable" months.

This opens a way to construct for different selected areas of Europe, which are threatened by forest die-back, SRM's for very poor seasons and also for very favourable seasons.

Addition of the poorest months of December, January and February leads to a poor winter. On the contrary the most favourable three months give an indication of a favourable winter with low depositions.
When these two extreme SRM's are compared with the standard SRM, the possible range of the values of the standard SRM can be determined.

The same construction can be applied for half a year and for a whole year, but we have to keep in mind that the probability that the atmosphere will demonstrate such a long continuous serie of poor or favourable months, becomes smaller the longer the time serie is chosen.

It would be interesting to investigate the negative and the positive deviations from the standard SRM-values. In this stage it is an open question if they both have the same order of magnitude.
It is very unlikely that all the blocs of the 5 months of January, February etc., are characterized by the occurrence of both an equal negative and positive deviation of the atmospheric circulations for each of the investigated areas.

Perhaps, some of the available 58 months will show the most extreme negative or positive deviation from the standard SRM-figures which may be possible.
Buth the largest observed deviations of the majority of the available

months will be smaller than what could be possible during extreme favourable or unfavourable atmospheric circulation patterns.

Thus it will not be simply to construct the most probable extreme favourable and unfavourable semi-annual and annual SRM.
Compared to the uncertainties of the intrinsic properties of the LRTAP-model which is used or the uncertainties of the applied analytical solution of the model, it will be sufficient to get a good impression what already may be concluded from the available results of the 5 years which have been run.

By using the available extreme SRM's of the available separate months, we can start to construct a favourable and also an unfavourable:

- winter season
- spring season
- summer season
- autumn season

- winterhalfyear
- summerhalfyear
- whole year

This has to be done for different selected areas. A proposal may be:
- Southern Scandinavia, Finland
- The black Forest, the Alpcountries (Austria + Switzerland)
- Central Germany, the Netherlands.

The construction has to be based on the available monthly SRM's.

The observed frequency distribution of the atmospheric circulation patterns give already a first indication of the occurrence of an unfavourable or a favourable month. Many northerly circulations will be favourable for Scandinavia and unfavourable for the northern Alps and the Black Forest.

An excess of S-SE-ly circulations will be unfavourable for Fennoscandia (Finland, Sweden, Norway), due to the SO_2 sources in Central Europe.

But it will be very difficult to select the best and the poorest months for the different selected areas only on observed frequency distributions of GWL's.
The distribution of the upstreams situated SO_2 sources is of such a

fundamental importance, that it looks the best first to use the monthly SRM's and afterwards to study what type of circulation patterns will be favourable or unfavourable for the different investigated areas.

9. Conclusions

Part of the Atmospheric-Processes-submodel is a routine source-receptor matrix (SRM).
This SRM is based on a two year simulation run from oct 78 - sept 80. This period however was characterized by a frequency distribution of the contributing atmospheric circulation patterns which deviated in many aspects from the long term climatic frequency distribution.

Since from the period Jan 78 - oct 82, 58 monthly SRM's are available instead of the 24 of the routine period, these data yield the possibility to construct 4 seasonal and 2 semi-annual SRM's and one whole year standard SRM which cover much better the climatological weather patterns than the routine SRM. This construction can be based on both subjective and objective methods.
By rejecting the contribution of the following months, the seasons will be in good accordance with the climatic long term averages:

	To reject:	Contributing months
winter:	Dec 81, Jan 78, Febr 79	Dec + Jan + Febr
spring:	no	March + April + May
summer:	July 82, Aug 78	June + July + August
autumn:	Sept 80, Oct 78, Oct 80, Nov 81	Sept + Oct + Nov

For the winterhalfyear standard SRM the months which have to be excluded are:
Oct 78, Nov 81, Dec 81, Jan 78, Febr 79, March 78, March 80.

For the summerhalfyear standard SRM the months which have to be excluded, are:
June 79, June 1982, August 78, Sept 80.

The annual standard SRM can be simply based on the sum of the two semi-annual standard SRM's.

10. Samenvatting en conclusies.

In maart 1983 werd de "Conventie van Genève" inzake grensoverschrijdende luchtverontreiniging geratificeerd. Dit betekende dat de landen van zowel west- als oost-Europa belast werden met de controle en het beleid inzake deze vorm van luchtverontreiniging.

Verantwoordelijk voor de uitvoering van de conventie is de ECE (Economische Commissie voor Europa van de Verenigde Naties). De aard en de omvang van het probleem is geïnventariseerd door de OECD te Parijs, (organisatie voor de Economische Samenwerking en Ontwikkeling in Europa).

Voor het toekomstig beleid heeft de ECE de medewerking ingeroepen van het IIASA (International Institute for Applied Systems Analysis) te Laxenburg, Oostenrijk. Bij het IIASA is een computermodel ontwikkeld dat door de beleidsmakers (bv. Europees Parlement) gebruikt kan worden bij de controlepolitiek op bv. de depositie van zure neerslag t.g.v. SO_2.
Dit ACID-RAIN-MODEL bestaat uit 3 submodellen:

- Energiebehoefte-SO_2-emissie-submodel
- Atmosferisch-submodel
- Bos-bodem-pH-submodel.

Het atmosferisch submodel speelt een wezenlijke rol. Het dient een klimatologisch representatief beeld te geven van de aard en omvang van de grensoverschrijdende transporten en de droge en natte depositie.
De berekeningen daarvan worden met behulp van de opgetreden meteorologische gegevens aan de hand van een LRTAP-model (long range transport of air pollution) uitgevoerd in Oslo en Moskou, MSC-W en MSC-E (Meteorologic Synthesizing Centre West and East). De uitkomsten zijn op maandbasis verwerkt in bron-ontvanger-matrices, SRM's (Source Receptor Matrix).
Zo'n matrix geeft, in tonnen SO_2, weer hoeveel SO_2 elk van de Europese landen exporteert en importeert, opgesplitst naar de diverse landen van ontvangst en van herkomst.

De routine matrix van het atmosferisch submodel is een jaarmatrix,

gebaseerd op de opgetreden atmosferische circulaties uit de periode 1 oct 1978 t/m sept 1980.
De frekwentieverdeling van de opgetreden circulaties over deze twee jaar vertoont evenwel belangrijke verschillen met de klimatologische frekwentieverdeling over de periode 1950-1980.
Het gerechtvaardigde vermoeden bestaat dan ook dat de SO_2-import en exportpercentages, zoals vermeld in de routine SRM, op jaarbasis, zal verschillen met die van een klimatologische "normaal" periode, uitgaande van dezelfde emissie-randvoorwaarde.
Omdat inmiddels 58 maand-SRM's van het tijdvak 1 Jan 1978 t/m Oct 1980 ter beschikking staat, is het mogelijk standaard-SRM's te construeren op maand-, seizoen- en jaarbasis die representatief zijn voor klimatologische frekwentieverdelingen van atmosferische circulatietypen.
Dit rapport geeft aan hoe deze constructie op zowel subjectieve als objectieve wijze kan plaatsvinden.
Naast de vervaardiging van standaard SRM's voor het atmosferisch submodel wordt aangegeven op welke wijze een meteorologische gevoeligheidsanalyse kan worden uitgevoerd.

Voor enkele bedreigde milieugebieden in Europa (bv. het Zwarte Woud, Zuid-Scandinavië e.d.) bestaat nu ook de mogelijkheid om SRM's te "componeren" die representatief zijn voor gunstige en ongunstige maanden, seizoenen en jaren.

Klimatologisch "normale" maanden, seizoenen en zelfs jaren, voor wat betreft de verdeling van circulatietypen, komen slechts zelden voor. Voor beleidsmakers is het dus zinvol om een indruk te hebben van de spreiding die rondom de waarden, vermeld in de klimatologische "standaard"-SRM's, mogelijk zijn.
De mogelijke afwijkingen van de standaardwaarden t.g.v. de veranderlijkheid in de atmosferische stromingspatronen kunnen van doorslaggevende betekenis zijn bij het uitstippelen van beleids- en bestrijdingsmaatregelen.

11. Acknowledgements

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He also thanks Mrs. A.J. de Bree-van Dolderen who typed this report.

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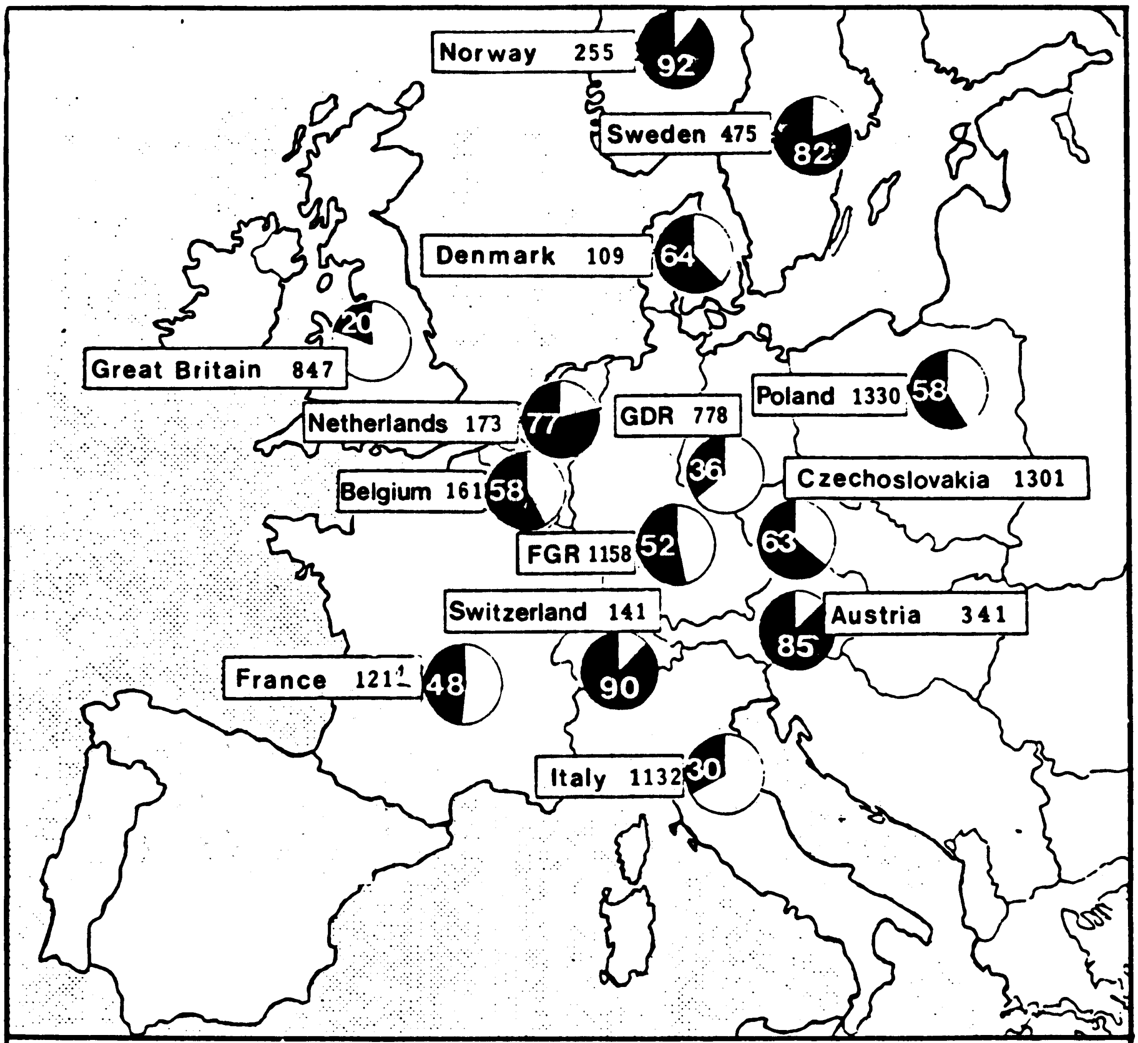
13. Graphs, figures, tables

FIGURE 1.1 : SOURCE OF 1980 DEPOSITION OF SULPHUR IN EUROPE



Belgium 161 Average Monthly Deposition of Sulphur (100 metric tonnes).

50 Percentage of deposition received from other countries.

SOURCE: UNECE - EMEP Programme 1983.

Emitter countries ——>

```
MEAN ANNUAL DEPOSITION FOR THE PERIOD   78 10  1 12   TO   82 10  1  6
TOTAL (DRY+WET) DEPOSITION OF SULPHUR
HORISONTAL - EMITTERS
VERTICAL   - RECEIVERS
UNIT       - 1000.TONNES SULPHUR  PER YEAR
       AL    A    B   BG   CS   DK   SF    F  DDR    D   GR    H   IS  IRL    I    L   NL    N   PL    P    R    E    S   CH   TR   SU   UK   YU   RE  IND  SUM
AL     12    0    0    3    2    0    0    3    2    1    3    3    0    0   12    0    0    0    1    0    1    1    0    0    0    0    1   19    1   14   85
A       0   62    3    0   46    0    0   26   31   40    0   16    0    0   72    1    2    0   17    0    1    4    0    4    0    2   11   42    0   36  422
B       0    0   84    0    2    0    0   34    3   29    0    0    0    0    1    1    6    0    1    0    0    1    0    0    0    0   21    0    0   12  198
BG      2    1    0  199   11    0    0    3    9    6    9   17    0    0   12    0    0    0   10    0   23    2    0    0    5   13    2   57    1   35  413
CS      0   15    5    1  440    1    0   24  131   59    0   61    0    0   24    1    4    0   88    0    5    2    0    2    0    7   14   43    0   37  969
DK      0    0    2    0    4   47    0    5   14   14    0    1    0    0    1    0    2    0    6    0    0    0    2    0    0    1   15    1    0   14  132
SF      0    0    3    1   10    5   92    7   25   20    0    4    0    0    2    0    3    2   22    0    1    0   17    0    0   53   20    4    0   65  363
F       0    2   41    0   15    1    0  750   33  124    0    2    0    3   48    6   17    0    9    3    0   94    1    9    0    1  122    5    2  205 1505
DDR     0    2   10    0   64    4    0   25  536  103    0    5    0    0    5    1    8    0   29    0    1    1    1    1    0    3   28    7    0   30  913
D       0    9   45    0   60    6    0  136  149  500    0    7    0    1   31    6   27    0   24    0    1    9    1    8    0    3   88   15    0   96 1388
GR      4    1    0   39    5    0    0    4    5    5  111    7    0    0   20    0    0    0    4    0    5    3    0    0    5    5    2   37    2   36  305
H       0   11    1    3   56    0    0    9   25   17    0  227    0    0   36    0    1    0   29    0   11    1    0    0    0    5    5   93    0   24  560
IS      0    0    0    0    0    0    0    0    0    1.   0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0    2    0    0   20   26
IRL     0    0    0    0    0    0    0    2    1    2    0    0    0   22    0    0    0    0    0    0    0    1    0    0    0    0   15    8    0   32   80
I       0    8    3    2   17    0    0   68   17   29    1   14    0    0  948    1    2    0   11    0    2   22    0    8    0    2   13   73    6  103 1355
L       0    0    1    0    0    0    0    4    0    2    0    0    0    0    0    4    0    0    0    0    0    0    0    0    0    0    1    0    0    1   14
NL      0    0   21    0    3    0    0   19    7   51    0    0    0    0    1    0   53    0    1    0    0    1    0    0    0    0   33    1    0   14  210
N       0    0    5    0    9    9    2   15   26   25    0    2    0    1    2    0    5   24   14    0    0    2   11    0    0    9   53    3    0   92  314
PL      0    9   11    3  168   10    1   36  270  106    1   48    0    1   26    2   10    0  776    0    8    3    5    1    1   36   41   45    0   90 1712
P       0    0    0    0    0    0    0    2    0    2    0    0    0    0    0    0    0    0    0   25    0   16    0    0    0    0    1    0    0   30   80
R       1    5    2   35   49    1    0   11   35  123    5   91    0    0   34    1    2    0   54    0  192    2    1    1    4   53    5  143    1   70  927
E       0    0    3    0    2    0    0   44    6   22    0    0    0    0    4    1    3    0    1   11    0  429    0    1    0    0   17    1    3  113  665
S       0    1    7    1   22   23   12   19   53   45    0    6    0    1    7    1    7   18   41    0    2    2  100    0    0   27   51    8    0  139  587
CH      0    1    2    0    4    0    0   29    6   19    0    1    0    0   45    0    1    0    2    0    0    4    0   16    0    0    7    3    0   21  165
TR      1    1    8   37    8    0    0    5    9    6   25   10    0    0   16    0    1    0    9    0    8    4    0    0  209   23    2   30    2   93  603
SU      4   17   23   83  221   30   60   82  342  233   27  135    0    3  108    5   29    6  538    0  139   11   45    4   534273  126  232   31098 7972
UK      0    0    9    0    5    1    0   35   12   26    0    1    0    8    1    1    7    0    4    0    0    5    0    0    0    1  790    1    0   87  996
YU      4   19    3   39   52    1    0   32   35   30    6   86    0    0  193    1    3    0   30    0   17   10    0    2    1   10   13  678    3  105 1377
       AL    A    B   BG   CS   DK   SF    F  DDR    D   GR    H   IS  IRL    I    L   NL    N   PL    P    R    E    S   CH   TR   SU   UK   YU   RE  IND  SUM
```

Receiver countries ——>

Table 1.1: Calculated European sulphur budget for a 4-year period starting 1 October 1978. Unit: 10^3 tonnes of sulphur per annum.

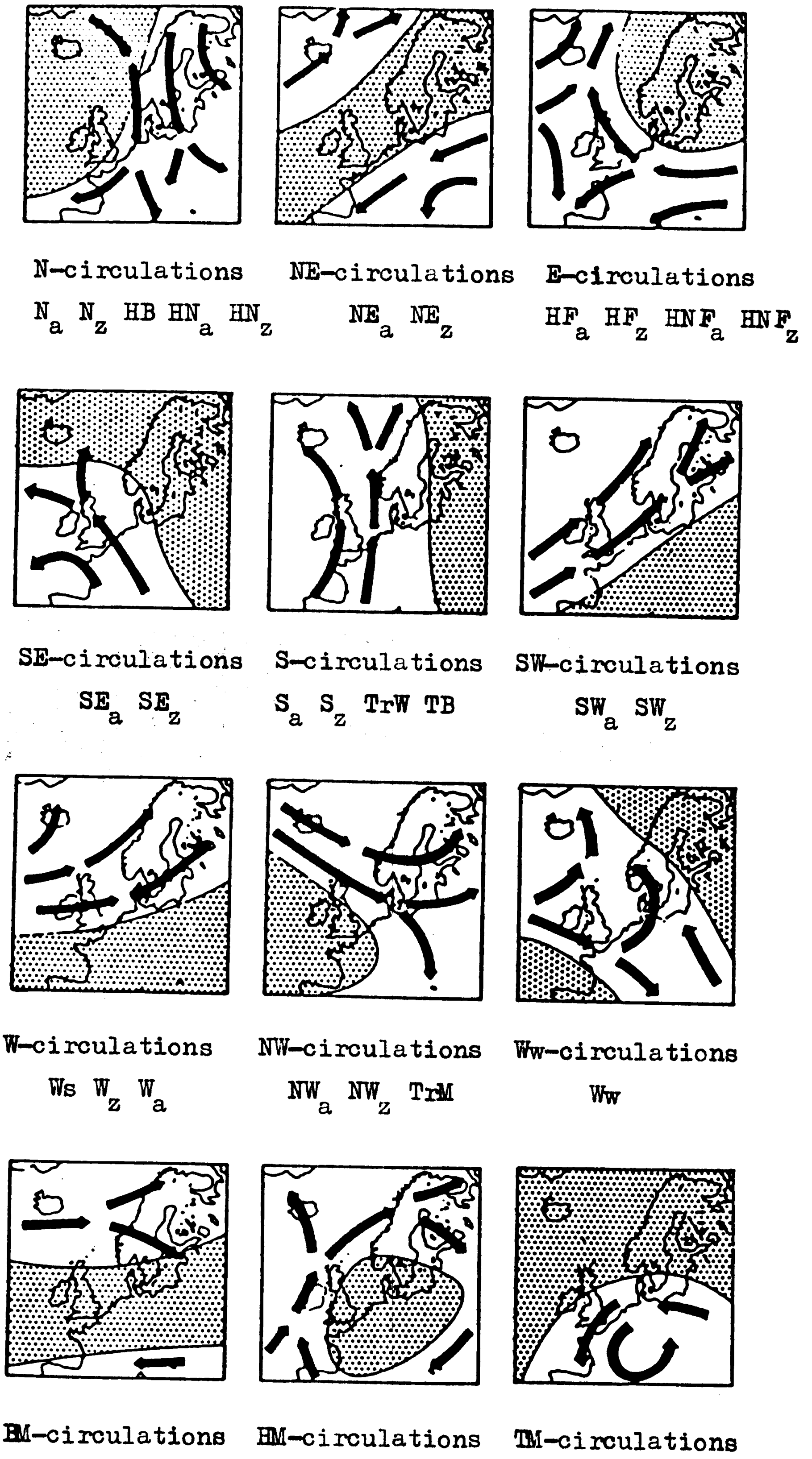
Depositions from emitter countries are given in vertical columns, depositions to receiver countries in horizontal rows. IND signifies indeterminate wet depositions. Total estimated deposition is given as SUM in the right-hand column.

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	Ü
Dec	1.9	1.2	5.3	2.8	3.1	0.9	0.6	0.9	1.6	0.6	0.3	0.6	0.3	0.3	0.9	0.6	0.6	0.6	0.9	0.6	0.9	0.6	1.6	0.3	0.3	0.3	0.6	-	1.6	-
Jan	1.2	1.9	4.0	1.2	4.7	0.9	0.9	1.2	1.5	0.6	0.3	0.6	0.0	0.6	0.9	1.2	0.3	0.3	1.2	0.3	0.6	1.2	2.1	0.3	0.3	0.0	1.2	-	1.2	-
Febr	1.7	1.4	3.7	1.4	4.0	0.8	0.3	1.1	1.1	0.6	0.3	1.1	0.1	0.6	1.1	0.8	0.6	0.6	0.6	0.6	0.6	0.8	1.7	0.3	0.6	0.6	1.4	-	0.6	-
March	1.8	1.5	3.4	0.9	3.4	0.6	0.3	1.2	0.9	0.9	0.6	1.2	0.3	1.2	1.6	1.2	0.3	0.6	0.6	0.3	0.9	0.9	0.9	0.3	0.1	1.2	1.9	-	0.9	-
April	0.9	1.5	3.9	1.8	2.1	0.6	0.1	1.2	1.2	1.8	0.2	1.2	0.3	0.3	1.2	1.8	1.2	0.9	0.6	0.1	0.9	0.9	1.5	0.3	0.6	0.3	2.4	-	0.3	-
May	0.3	1.2	3.7	0.9	3.1	0.3	0.3	1.2	0.6	1.9	0.6	1.2	0.9	1.5	1.2	1.2	1.2	0.9	0.3	0.0	0.6	0.3	1.2	0.3	1.2	0.9	2.8	-	0.3	-
June	0.3	1.5	5.1	1.2	3.0	0.3	0.3	2.4	1.2	2.1	0.6	1.2	0.9	1.8	0.9	0.6	0.6	0.6	0.1	0.0	0.3	0.1	0.6	0.1	0.6	0.3	2.7	-	0.6	-
July	0.6	2.5	6.5	1.6	3.4	0.3	0.1	3.1	2.2	0.9	0.3	0.6	0.6	0.9	1.2	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.6	0.1	0.1	0.1	2.2	-	0.3	-
Aug	0.6	3.1	7.1	2.4	3.1	0.3	0.3	2.5	1.6	0.9	0.3	0.9	0.6	0.6	0.6	0.6	1.2	0.9	0.1	0.0	0.1	0.1	0.6	0.1	0.1	0.1	1.9	-	0.9	-
Sept	0.3	2.4	4.5	2.1	4.8	0.3	0.1	1.2	1.2	1.2	0.1	1.2	0.3	0.9	1.2	0.6	0.3	0.6	0.9	0.1	0.6	0.3	1.2	0.1	0.3	0.1	1.8	-	0.6	-
Oct	1.2	1.9	4.7	2.2	3.7	0.9	0.6	0.9	0.9	1.2	0.6	0.9	0.1	0.6	1.2	0.6	0.6	0.9	0.9	0.3	1.2	0.3	1.6	0.3	0.3	0.3	0.9	-	0.6	-
Nov	0.9	1.8	4.5	3.0	2.4	0.9	0.9	1.2	1.2	0.6	0.3	0.9	0.3	0.6	1.2	0.9	0.6	0.6	1.5	0.3	1.2	0.6	0.9	0.3	0.3	0.3	0.3	-	1.2	-
1881/1955 year	12	22	57	22	40	7	5	18	15	14	4	11	5	11	14	10	8	8	8	3	8	6	15	3	5	5	20	-	9	-
oct - march WINTER	9	10	26	12	21	5	4	7	7	5	2	5	1	4	7	5	3	4	6	2	5	4	9	2	2	3	6	-	6	-
apr - sept SUMMER	3	12	31	10	19	2	1	11	8	9	2	6	4	7	7	5	5	4	2	1	3	2	6	1	3	2	14	-	3	-

Table 3.1. : Frequency distribution of atmosferic circulation patterns (Groszwetterlagen) during 1881 - 1955, in number of days, per month, per winter half year , per summer half year and per year. (NE_z and Ü were not classified during this period.)

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	Û
Dec	2.0	1.3	5.8	3.2	2.2	0.9	1.1	0.3	1.7	0.5	0.5	0.6	0.2	1.0	1.9	0.3	0.4	0.8	0.8	0.5	0.7	0.5	0.6	0.7	0.1	0.5	0.4	0.8	0.8	0.3
Jan	1.2	1.2	5.3	2.6	2.2	0.8	2.1	0.3	2.2	0.7	0.7	0.8	0.3	1.0	1.0	0.2	0.7	0.4	0.5	0.5	0.8	0.6	1.1	0.5	0.3	1.1	0.2	0.6	1.2	0.3
Febr	1.7	0.4	4.2	2.1	2.2	0.3	1.3	0.6	1.2	0.5	0.9	1.5	0.1	0.8	1.2	0.9	0.5	0.5	0.8	0.7	0.8	1.4	0.8	0.2	0.6	0.8	0.4	0.1	0.7	0.1
March	0.5	1.2	4.0	1.4	2.1	0.9	0.9	0.7	1.6	0.6	1.0	1.3	0.3	1.0	0.7	1.0	01	1.3	0.7	0.4	1.5	1.2	1.9	08	0.6	0.4	0.7	0.6	1.3	0.3
April	0.6	1.4	2.3	2.0	1.4	0.5	1.1	0.3	1.8	0.9	0.4	1.6	0.6	1.3	2.4	1.3	0.4	21	0.9	0.3	0.6	0.1	0,6	0.3	0.4	1.5	1.0	1.1	0.6	0.4
May	0.7	0.7	3.3	1.4	1.3	0.7	1.4	0.3	1.2	1.5	1.4	0.8	0.5	1.3	1.2	0.6	1.7	1.9	0.2	0.0	0.8	0.2	1.3	0.7	1.3	1.0	1.4	1.3	0.6	0.5
June	0.7	2.4	3.8	2.3	2.5	0.4	0.5	0.9	1.3	0.8	0.9	0.8	0.9	0.7	1.1	0.5	0.8	1.7	0.2	0.0	0.3	0.1	1.0	0.7	0.5	0.7	0.9	1.5	0.8	0.4
July	0.4	3.0	5.5	2.4	2.0	0.7	0.7	1.3	2.8	0.7	0.5	0.5	0.0	0.8	1.6	0.5	1.0	0.9	0.0	0.0	0.0	0.0	1.0	0.3	0.6	0.7	0.9	1.2	0.8	0.3
Aug	0.9	2.5	4.9	3.0	2.1	1.5	0.8	0.5	0.7	0.4	0.3	0.4	0.2	0.7	1.6	0.7	1.3	2.3	0.2	0.1	0.1	0.0	1.4	0.7	0.3	0.8	0.9	0.8	0.8	0.3
Sept	0.3	2.8	3.9	3.0	2.6	0.8	1.1	0.9	1.2	1.1	0.2	1.2	0.1	0.2	1.1	0.3	0.7	1.7	1.1	0.2	0.5	0.2	1.1	0.6	0.1	0.3	0.3	0.3	1.6	0.6
Oct	0.5	2.0	3.2	3.3	4.2	1.7	1.5	0.2	1.3	0.3	0.4	1.2	0.1	0.6	1.2	1.0	0.7	1.3	1.0	0.6	1.0	0.5	1.3	0.4	0.0	0.0	0.2	0.3	1.0	0.3
Nov	1.0	1.5	4.6	2.5	2.3	0.5	1.3	0.1	1.2	0.3	0.1	0.9	0.0	0.9	2.0	0.9	0.8	1.8	0.8	1.1	0.2	0.5	0.6	0.7	0.3	0.8	0.2	0.4	1.7	0.3
1949/80 year	11	20	51	29	27	10	14	6	18	8	7	11	3	10	17	8	9	17	7	5	7	6	12	6	5	9	7	9	12	4
oct - march WINTER	7	7	27	15	15	5	8	2	9	3	3	6	1	5	8	4	3	6	5	4	5	5	6	3	2	4	2	3	7	2
apr - sept SUMMER	4	13	24	14	12	5	6	4	9	5	4	5	2	5	9	4	6	11	2	1	2	1	6	3	3	5	5	6	5	2

Table 3.2. : Frequency distribution of atmosferic circulation patterns (Groszwetterlagen) during 1949 - 1980, in number of days, per month, per winter half year, per summer half year and per year.



N-circulations NE-circulations E-circulations

N_a N_z HB HN_a HN_z NE_a NE_z HF_a HF_z HNF_a HNF_z

SE-circulations S-circulations SW-circulations

SE_a SE_z S_a S_z TrW TB SW_a SW_z

W-circulations NW-circulations Ww-circulations

Ws W_z W_a NW_a NW_z TrM Ww

BM-circulations HM-circulations TM-circulations

Fig.3.1. Schematic classification of the dominant airflows over Western Europe. In the dotted areas the pressure is high. The arrows are mainly related to the layers above 850 mbar.

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	û
Dec	9 0	0 6	0 12	2 3			4 0							0 2	0 2					5 0		4 3	6 0					1 0	0 3	
Jan	0 2		5 2	4 6			3 0						7 0	0 5			3 3				4 3			0 5		4 0			0 3	1 2
Febr	10 0	1 0	4 7	5 8		0 3		0 3											0 8		5 0					3 0				
March		6 0	10 7						0 4						0 2	3 0		12 0				0 10		0 5				0 3		
April			2 2		0 7				6 3			0 5		0 3	3 0	3 8	3 0		5 0						0 1	3 0		4 0		1 1
May	0 5			9 0			4 0		1 0		0 3		0 3		5 0		7 0		3 4				0 6		2 3		0 7			
June	0 1		0 5	16 0				1 0				4 0	0 4	0 6		0 3	0 5	3 0			0 3			0 3	6 0					
July		4 0	12 15		0 4			4 0		3 0	3 0	5 0		0 3		0 3									0 6					
Aug		0 4	5 5	0 3	7 0						3 0			0 4				7 0	0 3		0 3		4 0	5 6						0 3
Sept		5 0	3 10	9 11	5 3			3 0											0 3				1 0	0 3				4 0		
Oct				20 5	1 0	4 0		2 0											3 4	0 6		0 6	0 9						0 1	1 0
Nov		13 0	0 6	0 10	12 13	0 0									3 4			0 4										2 0	0 2	0 1
Oct '78 – Sept '80 year	13,5	19.5	56	55,5	21	3.5	5.5	6.5	7	1.5	4.5	7	7	11.5	9.5	10	10.5	13	16.5	5.5	9	11.5	13	13.5	9	5	3.5	7	4.5	5
oct – march WINTER	10.5	13	26.5	31,5	8	3.5	3.5	2.5	2	0	0	0	3.5	3.5	5.5	1.5	3	8	7.5	5.5	6	11.5	7.5	5	0	3.5	0	3	4.5	2.5
apr – sept SUMMER	3	6.5	29.5	24	13	0	2	4	5	1.5	4.5	7	3.5	8	4	8,5	7.5	5	9	0	3	0	5,5	8.5	9	1.5	3.5	4	0	2.5

Table 4.1. : Frequency distribution of atmosferic circulation patterns (Groszwetterlagen) during the " routine " period October 1978 – September 1980 , per month, winter and summer half year and per year.

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	ü
winter	+	+		++	—		-		—	-	-	-										+								
1881 1955	9	10	26	12	21	5	4	7	7	5	2	5	1	4	7	5	3	4	6	2	5	4	9	2	2	3	6	-	6	—
1949 1980	7	7	27	15	15	5	8	2	9	3	3	6	1	5	8	4	3	6	5	4	5	5	6	3	2	4	2	3	7	2
rout. per.	10.5	13	26.5	31.5	8.0	3.5	3.5	2.5	2	0	0	0	3.5	3.5	5.5	1.5	3	8	7.5	5.5	6	11.5	7.5	5	0	3.5	0	3	4.5	2.5
summer		-	+	++		-	-		-	-				+	-	+		-	++					+	+				-	
1881 1955	3	12	31	10	19	2	1	11	8	9	2	6	4	7	7	5	5	4	2	1	3	2	6	1	3	2	14	-	3	—
1949 1980	4	13	24	14	12	5	6	4	9	5	4	5	2	5	9	4	6	11	2	1	2	1	6	3	3	5	5	6	5	2
rout. per.	3	6.5	29.5	24	13	0	2	4	5	1.5	4.5	7	3.5	8	4	8.5	7.5	5	9	0	3	0	5.5	8.5	9	1.5	3.5	4	0	2.5
year			+	++	-	-	—		—	-		-	+		—			-	++			+		++	+	-	-		- -	
1881 1955	12	22	57	22	40	7	5	18	15	14	4	11	5	11	14	10	8	8	8	3	8	6	15	3	5	5	20	-	9	—
1949 1980	11	20	51	29	27	10	14	6	18	8	7	11	3	10	17	8	9	17	7	5	7	6	12	6	5	9	7	9	12	4
rout. per.	13.5	19.5	56	55.5	21	3.5	5.5	6.5	7	1.5	4.5	7	7	11.5	9.5	10	10.5	13	16.5	5.5	9	11.5	13	13.5	9	5	3.5	7	4.5	5
winter 1		45		31		9		14		7			10		12		7		8		9		14				8		6	—
2		41		30		13		11		6			11		12		9		9		10		13				7		7	2
3		50		39		7		4.5		0			7		7		11		13		17.5		16				3		4.5	2.5
summer 1		46		29		3		19		11			17		12		9		3		5		9				17		3	—
2		41		26		11		13		9			12		13		17		3		3		14				14		5	2
3		39		37		2		9		6			18.5		12.5		12.5		9		3		15.5				16.5		0	2.5
year 1		91		60		12		33		18			27		24		16		11		14		23				25		9	—
2		82		56		24		24		15			23		25		26		12		13		27				21		12	4
3		89		76		9		13.5		6			25.5		19.5		23.5		22		20.5		31.5				195		4.5	5

Table 4.2. : Frequency distribution of the atmosferic circulation patterns (Groszwetterlagen) during the periods 1881-1955, 1949-1980 and the routine period oct.1978-sept.1980, per year and per winter and summer half year. In the lower 3 rows the frequency distributions for a combination of similar circulation patterns for the same periods. **Deviations** between the climatic period 1949-1980 and the routine period of 3-6 days are indicated with + or - ; deviations of 7 days or more with + + or - - .

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	TrW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	ü
Dec	9 3 20	6 9	12 10	2 3			4		2 7					6 2	2		4			5		4 3	6					1 1	3	
Jan	2 4		12 5 2 3	8 6 4 11 4	5		3 5		8 6				7	5 4	2		2 3 3		2 8		4 3	5		5	3	4			3	2 1 1
Febr	10	1 4	4 7 7 1	3 5 8 2	6 5	3 5		3	3	6					3	4 2			7 8		5 3 3	5	6	4		5 3				
March	3	6	16 10 7 11	5 11		3	12		4			2	2	6	2 3	3	2 3	12		8		4 10		5				3		1 1
April			2 2	3 7	3 7 2		5		6 3 3 3		4	2 5 7		3 5 6	5 3	8 3	3	3	5	1 2	4	1	3		6 1	11 3 3		4		1 1 1
May	3 5		3	9 4	1 8		4 6		3 1 5 1		3		3		5	6	7 4	2 3 4 8	10				4 6	4 8	3 2		8 7 3			1 1
June	1 20		8 5 1	3 16 3	6 2	3	5	3 1		5	6	4	4	6 6		3	4 5	3 4	1	3	3 3			3	6		5			
July		3 4 4	3 12 15 7	3 3	4 3			3 4 3	4 3	4 3	3 3	5 12		3	4 3	3		4 2					4 3 5		6 1				3 4	1 1
Aug		3 4 6 6	5 5 14	5 3 4	7 3			3	3	2	3		3 7	10 4	1		3	7 2	3		3		4	6 5	4	2	3	4	4	3 1
Sept	3	8 5 2 3	9 3 10 5 8	11 9 6	5 3 4 3	3	10 6	8 3		3				2	2 1				3	3			1	3				4		1
Oct	2 4 8	3	14 12	20 5 5 6	1 4	4	2	2	2					2	2 5	4	2	3 4 2	3 4	6	3	6	2 9						1	1 1 1
Nov		13	6 6 14	10 3	12 3	6			4 7	4			3		3 4			4					2		3	3	3	2 2	2	1
1978-1982 year	20.3	18.6	57.5	43.7	19.9	5.7	12.8	6.7	16.2	5.5	4.4	7.4	6.0	14.2	10.4	7.4	9.5	13.7	11.2	5.8	7.1	8.1	11.4	8.8	7.1	7.0	5.8	4.3	4.1	4.5
oct - march WINTER	13.9	9.0	34.1	25.9	7.7	4.5	5.6	1.1	9.2	2.1	0	0.4	2.6	5.4	5.6	2.8	4.3	5.3	6.8	4.0	4.5	7.9	5.4	3.0	1.3	3.2	0.6	1.9	1.9	2.1
apr - sept SUMMER	6.4	9.6	23.4	17.8	12.2	1.2	7.2	5.6	7.0	3.4	4.4	7.0	3.4	8.8	4.8	4.6	5.2	8.4	4.4	1.8	2.6	0.2	6.0	5.8	5.8	3.8	5.2	2.4	2.2	2.4

Table 5.1. : Frequency distribution of atmosferic circulation patterns (Groszwetterlagen) during the investigated period 1978 - 1982, with the except of november 1982 and december 1982, given in number of days. The distribution of the different years per square is as follows:

'78 '79
'80
'81 '82

Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	ü
winter half y																														
1881 1955	9	10	26	12	21	5	4	7	7	5	2	5	1	4	7	5	3	4	6	2	5	4	9	2	2	3	6	-	6	-
1949 1980	**7**	**7**	**27**	**15**	**15**	**5**	**8**	**2**	**9**	**3**	**3**	**6**	**1**	**5**	**8**	**4**	**3**	**6**	**5**	**4**	**5**	**5**	**6**	**3**	**2**	**4**	**2**	**3**	**7**	**2**
rout. per.	10^5	13	26^5	31^5	8	3^5	3^5	2^5	2	0	0	0	3^5	3^5	5^5	1^5	3	8	7^5	5^5	6	11^5	7^5	5	0	3^5	0	3	4^5	2^5
1978 1982	14	9	34	26	8	5	6	1	9	2	0	0	3	5	6	3	4	5	7	4	4	8	5	3	1	3	1	2	2	2
summer half y																														
1881 1955	3	12	31	10	19	2	1	11	8	9	2	6	4	7	7	5	5	4	2	1	3	2	6	1	3	2	14	-	3	-
1949 1980	**4**	**13**	**24**	**14**	**12**	**5**	**6**	**4**	**9**	**5**	**4**	**5**	**2**	**5**	**9**	**4**	**6**	**11**	**2**	**1**	**2**	**1**	**6**	**3**	**3**	**5**	**5**	**6**	**5**	**2**
rout. per.	3	6^5	29^5	24	13	0	2	4	5	1^5	4^5	7	3^5	8	4	8^5	7^5	5	9	0	3	0	5^5	8^5	9	1^5	3^5	4	0	2^5
1978 1982	6	10	23	18	12	1	7	6	7	4	4	7	3	9	5	5	5	9	4	2	3	0	6	6	6	4	5	2	2	2
year																														
1881 1955	12	22	57	22	40	7	5	18	15	14	4	11	5	11	14	10	8	8	8	3	8	6	15	3	5	5	20	-	9	-
1949 1980	**11**	**20**	**51**	**29**	**27**	**10**	**14**	**6**	**18**	**8**	**7**	**11**	**3**	**10**	**17**	**8**	**9**	**17**	**7**	**5**	**7**	**6**	**12**	**6**	**5**	**9**	**7**	**9**	**12**	**4**
rout. per.	13^5	19^5	56	55^5	21	3^5	5^5	6^5	7	1^5	4^5	7	7	11^5	9^5	10	10^5	13	16^5	5^5	9	11^5	13	13^5	9	5	3^5	7	4^5	5
1978 1982	20	19	57	44	20	6	13	7	16	6	4	7	6	14	11	8	9	14	11	6	7	8	11	9	7	7	6	4	4	4

Table 5.2. : Frequency distribution of the atmosferic circulation patterns (Groszwetterlagen) during the periods 1881-1955, 1949-1980, the routine period oct 1978-sept 1980 and the investigated period 1978-1982, given in number of days, for the winter half year (oct - march), the summer half year (april - sept) and year. The climatic normal distribution is taken over 1949 - 1980.

	Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	TrW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	Ü
winter half year	81–55	9	10	26	12	21	5	4	7	7	5	2	5	1	4	7	5	3	4	6	2	5	4	9	2	2	3	6	–	6	–
	49–80	7	7	27	15	15	5	8	2	9	3	3	6	1	5	8	4	3	6	5	4	5	5	6	3	2	4	2	3	7	2
	rout. per.	10^5	13	26^5	31^5	8	3^5	3^5	2^5	2	0	0	0	3^5	3^5	5^5	1^5	3	8	7^5	5^5	6	11^5	7^5	5	0	3^5	0	3	4^5	2^5
	28 months	14	9	34	26	8	5	6	1	9	2	0	0	3	5	6	3	4	5	7	4	4	8	5	3	1	3	1	2	2	2
	21 sel months	10	12	30	23	10	5	7	1	7	3	0	1	2	7	6	4	3	7	8	3	5	6	7	3	2	3	0	2	3	2
	diff.w 49–80	+3	+5	+3	+8	-5		-1	-1	-2		-3	-5	+1	+2	-2			+1	+3	-1		+1	+1			-1	-2	-1	-4	·
summer half year	81–55	3	12	31	16	19	2	1	11	8	9	2	6	4	7	7	5	5	4	2	1	3	2	6	1	3	2	14	–	3	–
	49–80	4	13	24	14	12	5	6	4	9	5	4	5	2	5	9	4	6	11	2	1	2	1	6	3	3	5	5	6	5	2
	rout. per.	3	6^5	29^5	24	13	0	2	4	5	1^5	4^5	7	3^5	8	4	8^5	7^5	5	9	0	3	0	5^5	8^5	9	1^5	3^5	4	0	2^5
	30 months	6	10	23	18	12	1	7	6	7	4	4	7	3	9	5	5	5	9	4	2	3	0	6	6	6	4	5	2	2	2
	26 sel. months	3	10	25	13	13	2	8	5	8	3	5	7	3	8	6	5	5	9	4	2	2	0	7	6	5	5	6	3	2	3
	diff.w 49–80	-1	-3	+1	-1	+1	-3	+2	+1	-1	-2	+1	+2	+1	+3	-3	+1	-1	-2	+2	+1	·	-1	+1	+3	+2	·	+1	-3	-3	+1
year	81–55	12	22	57	22	40	7	5	18	15	14	4	11	5	11	14	10	8	8	8	3	8	6	15	3	5	5	20	–	9	–
	49–80	11	20	51	29	27	10	14	6	18	8	7	11	3	10	17	8	9	17	7	5	7	6	12	6	5	9	7	9	12	4
	rout. per.	13^5	19^5	56	55^5	21	3^5	5^5	6^5	7	1^5	4^5	7	7	11^5	9^5	10	10^5	13	16^5	5^5	9	11^5	13	13^5	9	5	3^5	7	4^5	5
	58= months	20	19	57	44	20	6	13	7	16	6	4	7	6	14	11	8	9	14	11	6	7	8	11	9	7	7	6	4	4	4
	47 sel months	13	22	55	36	23	7	15	6	15	6	5	8	5	15	12	9	8	16	12	5	7	6	14	9	9	10	6	5	5	5
	diff.w 49–80	+2	+2	+4	+7	-4	-3	+1		-3	-2	-2	-3	+2	+5	-5	+1	-1	-1	+5				+2	+3	+4	+1	-1	-4	-7	+1

Table 5.3.: Frequency distribution of atmospheric circulation types (Groszwetterlagen) in number of days for: 1881–1955, 1949–1980 (climatic normal period), the routine period (Oct.78–Sept.80), 28 available wintermonths and 30 available summermonths, 21 selected winter months, 26 selected summermonths, 47 selected months for the construction of a standard SRM and the differences between the selected months and the 1949–1980 period.

	winter h y			summer half year						winter h y		
month year	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1978	☒		☒					☒		☒ Ro	Ro	Ro
1979	Ro	☒ Ro	Ro	Ro	Ro	☒ Ro	Ro	Ro	Ro	Ro	Ro	Ro
1980	Ro	Ro	☒ Ro	Ro	Ro	Ro	Ro	Ro	☒ Ro			
1981											☒	☒
1982						☒					Msg	Msg

Table 5.4. : Available monthly SRM's, the selection for the "routine" SRM and the advised selection for the construction of semi annual and annual standard SRM's.

Ro : months, used for the routine SRM

Msg: missing months

☒ : rejected months

	Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	û
winter	'49-'80	4.9	2.9	15.3	7.9	6.6	2.0	4.5	1.2	5.1	1.7	2.1	2.9	0.6	2.8	4.1	1.4	1.6	1.7	2.1	1.7	2.3	2.5	2.5	1.4	1.0	2.4	1.0	1.5	2.7	0.7
	'78-'82	10.3	4.3	13.5	12.0	3.4	1.7	2.6	0.6	5.6	1.3	0.0	0.0	1.5	3.6	1.5	1.3	2.6	0.0	5.4	1.0	3.9	3.6	2.6	1.9	0.6	2.6	0.0	0.4	1.3	0.9
	$\overline{\lvert\Delta\rvert}=1.44$	+5.4	+1.4	-1.8	+4.1	-3.2	-0.3	-1.9	-0.6	+0.5	-0.4	-2.1	-2.9	+0.9	+0.8	-2.6	-0.1	+1.0	-1.7	+3.3	-0.7	+1.6	+1.1	+0.1	+0.5	-0.4	+0.2	-1.0	-1.1	-1.4	+0.2
	Exclusive 3 months	4.9	5.2	12.8	11.7	4.4	2.2	3.3	0.8	5.2	1.6	0.0	0.0	1.9	4.6	1.4	1.6	1.6	0.0	6.3	1.4	3.5	3.3	3.2	2.5	0.8	2.5	0.0	0.5	1.6	1.1
	Δ	0.0	+2.3	-2.5	+3.8	-2.2	+0.2	-1.2	-0.4	+0.1	-0.1	-2.1	-2.9	+1.3	+1.8	-2.7	+0.2	0.0	-1.7	+4.2	-0.3	+1.2	+0.8	+0.7	+1.1	-0.2	+0.1	-1.0	-1.0	-1.1	+0.4
	$\overline{\lvert\Delta\rvert}=1.25$																														
spring	'49-'80	1.8	3.3	9.6	4.8	4.8	2.1	3.4	1.3	4.6	3.0	2.8	3.7	1.4	3.6	4.3	2.9	2.2	5.3	1.8	0.7	2.9	1.5	3.8	1.8	2.3	2.9	3.1	3.0	2.5	1.2
	'78-'82	2.2	1.0	10.2	7.8	4.2	0.6	5.4	0.0	5.8	0.0	1.4	3.2	1.0	4.0	3.6	3.8	3.8	6.4	3.0	2.2	0.8	3.0	2.6	3.4	2.4	3.4	3.6	1.4	0.0	1.4
	$\overline{\lvert\Delta\rvert}=1.25$	+0.4	-2.3	+0.6	+3.0	-0.6	-1.5	+2.0	-1.3	+1.2	-3.0	-1.4	-0.5	-0.4	+0.4	-0.7	+0.9	+1.6	+1.1	+1.2	+1.5	-2.1	+1.5	-1.2	+1.6	+0.1	+0.5	+0.5	-1.6	-2.5	+0.2
	Exclusive May '79	2.4	1.3	10.9	6.4	4.5	0.6	4.9	0.0	6.0	0.0	1.5	3.4	1.1	4.3	2.8	4.3	2.6	6.2	3.2	2.4	0.9	3.2	2.8	3.6	2.1	3.6	3.9	1.5	0.0	1.5
	Δ	+0.6	-2.0	+1.3	+1.6	-0.3	-1.5	+1.5	-1.3	+1.4	-3.0	-1.3	-0.3	-0.3	+0.7	-1.5	+1.4	+0.4	+0.9	+1.4	+1.7	-2.0	+1.7	-1.0	+1.8	-0.2	+0.7	+0.8	-1.5	-2.5	+0.3
	$\overline{\lvert\Delta\rvert}=1.26$																														

Table 6.1.1. Mean frequency distribution of atmospheric circulation types (Groszwetterlagen) in number of days during the winterseason (Dec. Jan. Febr.) and the spring season (March, April,May) of the period 1949-1980, 1978-1982 and 1978-1982 with the exclusion of some months. Excluded winter months are Jan.'78, Febr.'79 and Dec.'81. In spring is excluded May '79, but the advantages are considered to be of the same order as the disadvantages. Δ means the deviation with each of the Groszwetterlagen of the reference period '49-'80.

	Period ↓	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	TrM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	$\hat{u}$
summer	'49-'80	2.0	7.9	14.2	7.7	6.6	2.6	2.0	2.7	4.8	1.9	1.7	1.7	1.1	2.2	4.3	1.7	3.1	4.9	0.4	0.1	0.4	0.1	3.4	1.7	1.4	2.2	2.7	3.5	2.4	1.0
	'78-'82	4.2	6.0	15.0	8.0	5.0	0.6	1.0	3.4	2.0	2.8	3.0	4.2	2.8	5.6	1.6	1.2	2.4	4.4	0.8	0.6	1.8	0.0	3.2	2.8	3.4	0.4	1.6	0.8	2.2	1.2
	$\lvert\bar{\Delta}\rvert=1.30$	+2.2	-1.9	+0.8	+0.3	-1.6	-2.0	-1.0	+0.7	-2.8	+0.9	+1.3	+2.5	+1.7	+3.4	-2.7	-0.5	-0.7	-0.5	+0.4	+0.5	+1.4	-0.1	-0.2	+1.1	+2.0	-1.8	-1.1	-2.7	-0.2	+0.2
	Exclusive 2 months	4.8	5.3	17.3	7.4	5.1	0.7	1.2	3.2	2.3	3.2	3.5	2.1	0.9	4.2	1.8	1.4	2.1	4.6	0.9	0.7	2.1	0.0	2.5	3.2	3.7	0.5	1.8	0.9	1.6	1.2
	Δ	+2.8	-2.6	+3.1	-0.3	-1.5	-1.9	-0.8	+0.5	-2.5	+1.3	+1.8	+0.4	-0.2	+2.0	-2.5	-0.3	-1.0	-0.3	+0.5	+0.6	+1.7	-0.1	-0.7	+1.5	+2.3	-1.7	-0.9	-2.6	-0.8	+0.2
	$\lvert\bar{\Delta}\rvert=1.30$																														
autumn	'49-'80	1.8	6.3	11.7	8.8	9.1	3.0	3.9	1.2	3.7	1.7	0.7	3.3	0.2	1.7	4.3	2.2	2.2	4.8	2.9	1.9	1.7	1.2	3.0	1.7	0.4	1.1	0.7	1.0	4.3	1.2
	'78-'82	3.6	7.3	18.6	16.1	7.5	2.8	3.9	2.8	2.8	1.5	0.0	0.0	0.6	0.9	3.6	0.9	0.4	2.8	2.1	1.9	0.6	1.3	3.0	0.6	0.6	0.6	0.6	1.7	0.6	0.9
	$\lvert\bar{\Delta}\rvert=1.37$	+1.8	+1.0	+6.9	+7.3	-1.6	-0.2	0	+1.6	-0.9	-0.2	-0.7	-3.3	+0.4	-0.8	-0.7	-1.3	-1.8	-2.0	-0.8	0	-1.1	+0.1	0	-1.1	+0.2	-0.5	-0.1	+0.7	-3.7	-0.3
	Exclusive 4 months	4.5	10.2	14.7	9.3	9.3	2.7	5.4	3.3	1.8	2.1	0.0	0.0	0.0	0.6	4.5	1.2	0.6	3.0	1.2	2.7	0.9	1.8	3.6	0.0	0.9	0.9	0.0	2.4	0.9	0.9
	Δ	+2.7	+3.9	+3.0	+0.5	+0.2	-0.3	+1.5	+2.1	-1.9	+0.4	-0.7	-3.3	-0.2	-1.1	+0.2	-1.0	-1.6	-1.8	-1.7	+0.8	-0.8	+0.6	+0.6	-1.7	+0.5	-0.2	-0.7	+1.4	-3.4	-0.3
	$\lvert\bar{\Delta}\rvert=1.30$																														

Table 6.1.2.:Mean frequency distribution of atmospheric circulation types (Groszwetterlagen) in number of days during the summer season (June,July,Aug.) and autumn season (Sep.,Oct.,Nov.) of the period 1949-1980, 1978-1982 and 1978-1982 with the exclusion of some months. Exluded summer months are July '82 and August '78. In the autumn period are excluded :Sep.'80, Oct. '78 and '80, and Nov.'81.
Δ means the deviation with each of the Groszwetterlagen of the reference period '49-'80.

	Period!	W_S	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	T_rM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	WW	ü
Jan.	'49-'80	1.2	1.2	5.3	2.6	2.2	0.8	2.1	0.3	2.2	0.7	0.7	0.8	0.3	1.0	1.0	0.2	0.7	0.4	0.5	0.5	0.8	0.6	1.1	0.5	0.3	1.1	0.2	0.6	1.2	0.3
	'78-'82	1.2	0.0	4.4	6.6	1.0	0.0	1.6	0.0	2.8	0.0	0.0	0.0	1.4	1.8	0.4	0.0	1.6	0.0	2.0	0.0	1.4	1.0	0.0	1.0	0.6	0.8	0.0	0.0	0.6	0.8
	Δ	0	− 1.2	− 0.9	+ 4.0	− 1.2	− 0.8	− 0.5	− 0.3	+ 0.6	− 0.7	− 0.7	− 0.8	+ 1.1	+ 0.8	− 0.6	− 0.2	+ 0.9	− 0.4	+ 1.5	− 0.5	+ 0.6	+ 0.4	− 1.1	+ 0.5	+ 0.3	− 0.3	− 0.2	− 0.6	− 0.6	+ 0.5
Febr.	'49-'80	1.7	0.4	4.2	2.1	2.2	0.3	1.3	0.6	1.2	0.5	0.9	1.5	0.1	0.8	1.2	0.9	0.5	0.5	0.8	0.7	0.8	1.4	0.8	0.2	0.6	0.8	0.4	0.1	0.7	0.1
	'78-'82	2.0	1.0	3.8	3.6	2.2	1.6	0.0	0.6	0.6	1.2	0.0	0.0	0.0	0.0	0.6	1.2	0.0	0.0	3.0	0.0	2.2	1.0	1.2	0.8	0.0	1.6	0.0	0.0	0.0	0.0
	Δ	+ 0.3	+ 0.6	− 0.4	+ 1.5	00	+ 1.3	− 1.3	0	− 0.6	+ 0.7	− 0.9	− 1.5	− 0.1	− 0.8	− 0.6	+ 0.3	− 0.5	− 0.5	+ 2.2	− 0.7	+ 1.4	− 0.4	+ 0.4	+ 0.6	− 0.6	+ 0.8	− 0.4	− 0.1	− 0.7	− 0.1
March	'49-'80	0.5	1.2	4.0	1.4	2.1	0.9	0.9	0.7	1.6	0.6	1.0	1.3	0.3	1.0	0.7	1.0	0.1	1.3	0.7	0.4	1.5	1.2	1.9*	0.8	0.6	0.4	0.7	0.6	1.3	0.3
	'78-'82	0.6	1.0	8.8	3.2	0.0	0.6	2.4	0.0	0.8	0.0	0.0	0.4	0.4	1.2	1.0	0.6	1.0	2.4	0.0	1.6	0.0	2.8	0.0	1.0	0.0	0.0	0.0	0.6	0.0	2.2
	Δ	+ 0.1	− 0.2	+ 4.8	+ 1.8	− 2.1	− 0.3	+ 1.5	− 0.7	− 0.8	− 0.6	− 1.0	− 0.9	+ 0.1	+ 0.2	+ 0.3	− 0.4	+ 0.9	+ 1.1	− 0.7	+ 1.2	− 1 5	+ 1.6	− 1.9	+ 0.2	− 0.6	− 0.4	− 0.7	0	− 1.3	+ 1.9
April	'49-'80	0.6	1.4	2.3	2.0	1.4	0.5	1.1	0.3	1.8	0.9	0.4	1.6	0.6	1.3	2.4	1.3	0.4	2.1	0.9	0.3	0.6	0.1	0.6	0.3	0.4	1.5	1.0	1.1	0.6	0.4
	'78-'82	0.0	0.0	0.8	2.0	2.4	0.0	1.0	0.0	3.0	0.0	0.8	2.8	0.0	2.8	1 6	2.2	0.6	0.6	1.0	0.6	0.8	0.2	0.6	0.0	1.4	3.4	0.0	0.8	0.0	0.6
	Δ	− 0.6	− 1.4	− 1.5	0	+ 1.0	− 0.5	− 0.1	− 0.3	+ 1.2	− 0.9	+ 0.4	+ 1.2	− 0.6	+ 1.5	− 0.8	+ 0.9	+ 0.2	− 0.5	+ 0.1	+ 0.3	+ 0.2	+ 0.1	0	− 0.3	+ 1.0	+ 1.9	− 1.0	− 0.3	− 0.6	+ 0.2
May	'49-'80	0.7	0.7	3.3	1.4	1.3	0.7	1.4	0.3	1.2	1.5	1.4	0.8	0.5	1.3	1.2	0.6	1.7	1.9	0.2	0.0	0.8	0.2	1.3	0.7	1.3	1.0	1.4	1.3	0.6	0.5
	'78-'82	1 6	0.0	0.6	2.6	1.8	0.0	2.0	0.0	2.0	0.0	0.6	0.0	06	0.0	1.0	1.0	2.2	3.4	2.0	0.0	0.0	0.0	2.0	2.4	1.0	0.0	3.6	0.0	0.0	0.4
	Δ	+ 0.9	− 0.7	− 2.7	+ 1.2	+ 0.5	− 0.7	+ 0.6	− 0.3	+ 0.8	− 1.5	− 0.8	− 0.8	+ 0.1	− 1.3	− 0.2	+ 0.4	+ 0.5	+ 1.5	+ 1.8	0	− 0.8	− 0.2	+ 0.7	+ 1.7	− 0.3	− 1.0	+ 1.8	− 1.3	− 06	− 0.1
June	'49-'80	0.7	2.4	3.8	2.3	2.5	0.4	0.5	0.9	1.3	0.8	0.9	0.8	0.9	0.7	1.1	0.5	0.8	1.7	0.2	0.0	0.3	0.1	1.0	0.7	0.5	0.7	0.9	1.5	0.8	0.4
	'78-'82	4.2	0.0	2.8	4.4	1.6	0.6	1.0	0.8	0.0	1.0	1.2	0.8	0.8	2.2	0.0	0.6	1.8	1.4	0.2	0.6	1.2	0.0	0.0	0.6	1.2	0.0	1.0	00	00	00
	Δ	+ 3.5	− 2.4	− 1.0	+ 2.1	− 0.9	+ 0.2	+ 0.5	− 0.1	− 1.3	+ 0.2	+ 0.3	0	− 0.1	+ 1.5	− 1.1	+ 0.1	+ 1.0	− 0.3	0	+ 0.6	+ 0.9	− 0.1	− 1.0	− 0.1	+ 0.7	− 0.7	+ 0.1	− 1.5	− 0.8	− 0.4

Table 6.1.3.: Mean frequency distribution of atmospheric circulation types (Groszwetterlagen) in number of days per month (Jan.–June) of the periods 1949–1980 and 1978–1982, with the differences between both distributions, (Δ). Note: * (March, '49–'80; HF_a) = 12 days in 1974 and 11 days in 1976 !!

	Period	W_s	W_a	W_z	BM	HM	SW_a	SW_z	NW_a	NW_z	HN_a	HN_z	HB	N_a	N_z	T_rM	TM	TB	T_rW	S_a	S_z	SE_a	SE_z	HF_a	HF_z	HNF_a	HNF_z	NE_a	NE_z	Ww	ü
July	'49-'80	0.4	3.0	5.5	2.4	2.0	0.7	0.7	1.3	2.8	0.7	0.5	0.5	0.0	0.8	1.6	0.5	1.0	0.9	0.0	0.0	0.0	0.0	1.0	0.3	0.6	0.7	0.9	1.2	0.8	0.3
	'78-'82	0.0	2.2	7.4	1.2	1.4	0.0	0.0	2.0	1.4	1.4	1.2	3.4	0.0	0.6	1.4	0.6	0.0	1.2	0.0	0.0	0.0	0.0	2.4	0.0	1.4	0.0	0.0	0.0	1.4	0.4
	Δ	−0.4	−0.8	+1.9	−1.2	−0.6	−0.7	−0.7	+0.7	−1.4	+0.7	+0.7	+2.9	0	−0.2	−0.2	+0.1	−1.0	+0.3	0	0	0	0	+1.4	−0.3	+0.8	−0.7	−0.9	−1.2	+0.6	+0.1
Aug.	'49-'80	0.9	2.5	4.9	3.0	2.1	1.5	0.8	0.5	0.7	0.4	0.3	0.4	0.2	0.7	1.6	0.7	1.3	2.3	0.2	0.1	0.1	0.0	1.4	0.7	0.3	0.8	0.9	0.8	0.8	0.3
	'78-'82	0.0	3.8	5.6	2.4	2.0	0.0	0.0	0.6	0.6	0.4	0.6	0.0	2.0	2.8	0.2	0.0	0.6	1.8	0.6	0.0	0.6	0.0	0.8	2.2	0.8	0.4	0.6	0.8	0.8	0.8
	Δ	−0.9	+1.3	+0.7	−0.6	−0.1	−1.5	−0.8	+0.1	−0.1	0	+0.3	−0.4	+1.8	+2.1	−1.4	−0.7	−0.7	−0.5	+0.4	−0.1	+0.5	0	−0.6	+1.5	+0.5	−0.4	−0.3	0	0	+0.5
Sep.	'49-'80	0.3	2.8	3.9	3.0	2.6	0.8	1.1	0.9	1.2	1.1	0.2	1.2	0.1	0.2	1.1	0.3	0.7	1.7	1.1	0.2	0.5	0.2	1.1	0.6	0.1	0.3	0.3	0.3	1.6	0.6
	'78-'82	0.6	3.6	7.0	5.2	3.0	0.6	3.2	2.2	0.0	0.6	0.0	0.0	0.0	0.4	0.6	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.2	0.6	0.0	0.0	0.0	0.8	0.0	0.2
	Δ	+0.3	+0.8	+3.1	+2.2	+0.4	−0.2	+2.1	+1.3	−1.2	−0.5	−0.2	−1.2	−0.1	+0.2	−0.5	−0.3	−0.7	−1.7	−0.5	+0.4	−0.5	−0.2	−0.9	0	−0.1	−0.3	−0.3	+0.5	−1.6	−0.4
Oct.	'49-'80	0.5	2.0	3.2	3.3	4.2	1.7	1.5	0.2	1.3	0.3	0.4	1.2	0.1	0.6	1.2	1.0	0.7	1.3	1.0	0.6	1.0	0.5	1.3	0.4	0.0	0.0	0.2	0.3	1.0	0.3
	'78-'82	2.8	0.6	5.2	7.2	1.0	0.8	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.4	1.4	0.8	0.4	1.8	1.4	1.2	0.6	1.2	2.2	0.0	0.0	0.0	0.0	0.0	0.2	0.6
	Δ	+2.3	−1.4	+2.0	+3.9	−3.2	−0.9	−1.1	+0.2	−0.9	−0.3	−0.4	−1.2	−0.1	−0.2	+0.2	−0.2	−0.3	+0.5	+0.4	+0.6	−0.4	+0.7	+0.9	−0.4	0	0	−0.2	−0.3	−0.8	+0.3
Nov	'49-'80	1.0	1.5	4.6	2.5	2.3	0.5	1.3	0.1	1.2	0.3	0.1	0.9	0.0	0.9	2.0	0.9	0.8	1.8	0.8	1.1	0.2	0.5	0.6	0.7	0.3	0.8	0.2	0.4	1.7	0.3
	'78-'81	0.0	3.3	7.0	3.2	1.5	1.5	0.0	0.0	2.8	1.0	0.0	0.0	0.7	0.0	1.8	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0	0.7	0.8	0.7	1.0	0.5	0.3
	Δ	−1.0	+1.8	+2.4	+1.7	−0.8	+1.0	−1.3	−0.1	+1.6	+0.7	−0.1	−0.9	+0.7	−0.9	−0.2	−0.9	−0.8	−0.8	−0.8	−1.1	−0.2	−0.5	−0.1	−0.7	+0.4	0	+0.5	+0.6	−1.2	0
Dec.	'49-'80	2.0	1.3	5.8	3.2	2.2	0.9	1.1	0.3	1.7	0.5	0.5	0.6	0.2	1.0	1.9	0.3	0.4	0.8	0.8	0.5	0.7	0.5	0.6	0.7	0.1	0.5	0.4	0.8	0.8	0.3
	'78-'81	8.0	3.8	5.5	1.2	0.0	0.0	1.0	0.0	1.8	0.0	0.0	0.0	0.0	2.0	0.5	0.0	1.0	0.0	0.0	1.2	0.0	1.8	1.5	0.0	0.0	0.0	0.0	0.5	0.7	0.0
	Δ	+6.0	+2.5	−0.3	−2.0	−2.2	−0.9	−0.1	−0.3	+0.1	−0.5	−0.5	−0.6	−0.2	+1.0	−1.4	−0.3	+0.6	−0.8	−0.8	+0.7	−0.7	+1.3	+0.9	−0.7	−0.1	−0.5	−0.4	−0.3	−0.1	−0.3

Table 6.1.4.: Mean frequency distribution of atmospheric circulation types (Groszwetterlagen) in number of days per month (July - Dec.) of the periods 1949–1980 and 1978–1982, with the differences between both the distributions, Δ .

Table 6.1.5.

	pos dev	neg dev	total dev	$\lvert\overline{\Delta}\rvert$	Δ_{extr}^{+}	Δ_{extr}^{-}
January	9	13	22	0.8	4.0	1.2
February	8	10	18	0.7	2.2	1.5
March	8	12	20	1.0	4.8	2.1
April	7	9	16	0.7	1.9	1.5
May	10	9	19	0.9	1.8	2.7
June	8	9	17	0.8	3.5	2.4
July	8	10	18	0.7	2.9	1.4
August	8	9	17	0.6	2.1	1.5
September	6	10	16	0.8	3.1	1.7
October	7	7	14	0.8	3.9	3.2
November	9	12	21	0.8	2.4	1.3
December	7	12	19	0.9	6.0	2.2

Numbers of circulation types of which the mean monthly frequency during the 1978-1982 period deviated more than 0.5 day compared with the mean monthly frequency during the climatic reference period 1949-1980.
The average absolute deviation for all the circulation types is given by $\lvert\overline{\Delta}\rvert$. Te extreme deviations by Δ_{extr}^{+} and Δ_{extr}^{-}.
The total number of circulation types is 30.

Table 6.2.1. A reduced Grosswetterlage classification.

1	Ws
2	Wa
3	Wz
4	BM, HM
5	SWa, SWz
6	NWa, SWz
7	HNa, NWz
8	HB, Na, Nz
9	TrM, TM
10	TB, TrW, Sa, Sz
11	SEa, Sez
12	HFa, HFz, HNFz
14	Ww
15	ü

Table 6.2.2.: Frequency of occurrence of the 15 classes of table 6.2.1. (in days) during the winter half year. (1= Jan '78, 2= Febr '78, 3= March '78, 4= Oct '78, 5= Nov '78, 6= Dec '78, 7= Jan '79 etc). The last two columns are the added totals of the climatological distribution and af the selection of the 28 winter months respectively.

	→ month j = 1.....28																													
	1978						1979						1980						1981						1982				1949 – 1980	1978 – 1982
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	climat. distr.	28 – months distr.
GWL-class ℓ=1....15 ↓	31	28	31	31	30	31	31	28	31	31	30	31	31	29	31	31	30	31	31	28	31	31	30	31	31	28	31	31		
1						9		10					2			2		3			3	4		20	4			8	33	65
2					13			1	6			6						9								4		3	33	42
3	12		16				5	4	10		6	12	2	7	7	14	6	10	3	7		12	14			1	11		126	159
4	8	3	5	21	12	2	4	5		5	13	3	6	8		5			16	6			3		4	7	11	10	140	157
5				4		4	3							3			6				15	2			5	5			60	47
6				2										3	4		4	2	8	3		2	7	7	6				51	48
7		6															4												29	10
8			2				7					2	5			2		6	4		6		3				2		56	39
9	2	7			3				3		4	2			2	2						5				2	3	4	56	39
10	4	7	8	3		5	3		12	10	4		3	8		3					2	6		4	8		3	2	85	95
11	5					4	4	5		6		3	3		10					8	4					3		3	46	58
12		5				6	4	3		9			5		5	2	5			4						6			60	54
13					2	1									3		5	1					3		3				33	18
14										1	2	3	3																33	9
15				1			1				1		2			1					1				1		1	1	9	10

Table 6.2.3. Weighting factors (g_j x100) for the cases $m > k+1$, $m = k+1$ and $m < k+1$ (m = number of months, k = number of GWL's (here $k=15$)).

	month	m = 28	m = 16	m = 6
1978	1 jan	1.5	-84.7	17.9
	2 feb	12.3	17.2	20.7
	3 mar	2.9	54.2	16.4
	4 oct	-6.2	34.6	4.8
	5 nov	5.8	-13.5	14.3
	6 dec	8.5	15.2	25.9
1979	7	5.5	25.1	
	8	4.5	8.4	
	9	-5.7	12.6	
	10	5.9	-16.8	
	11	21.1	40.8	
	12	14.9	34.9	
1980	13	8.3	-17.2	
	14	3.3	-20.0	
	15	4.0	43.2	
	16	-14.2	-34.0	
	17	7.5		
	18	-0.6		
1981	19	8.3		
	20	-11.0		
	21	7.7		
	22	5.7		
	23	12.7		
	24	-2.1		
1982	25	3.5		
	26	-2.3		
	27	-1.1		
	28	-1.1		

Table 6.2.4. The climatological (winter) GWL distribution, GWL_c, the GWL distribution of the winter of 1978, GWL_{1978} and the reconstructed distribution according to the procedure (iii), GWL^*_{1978}.

GWl class	GWL_c (days)	GWL_{1978}	GWL^*_{1978}
1	7	9	14
2	7	13	11
3	27	28	29
4	30	51	37
5	13	8	7
6	11	2	1
7	6	6	7
8	12	2	2
9	12	12	13
10	18	27	29
11	10	9	12
12	13	11	16
13	7	3	3
14	7	0	0
15	2	1	1