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REWARD: "Relating Extreme Weather to Atmospheric circulation using a Regionalised Dataset". Progress Report 01.01.1996 - 30.09.1996

E.J.Førland (ed), H.Alexandersson, P.Frich, I.Hanssen-Bauer, R.Heino, J.Helminen, T.Jónsson, Ø.Nordli, T.Pálsdottir, T.Schmith, H.Tuomenvirta, O.E.Tveito

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TITLE

REWARD

"Relating Extreme Weather to Atmospheric circulation using a Regionalised Dataset"

Progress-Report 01.01.1996-30.09.1996

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PROJECT CONTRACTORS

NORDISK MINISTERRÅDs MILJØFORSKNINGSPROGRAM 1996-97

and

THE NORDIC METEOROLOGICAL INSTITUTES

SUMMARY

This progress report for the NMR financed project "REWARD" covers the periode 01.01.1996-30.09.1996

An English summary is given on page 2

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REWARD : «RELATING EXTREME WEATHER TO ATMOSPHERIC CIRCULATION USING A REGIONALISED DATASET»

1. SUMMARY

The «REWARD»-project is a continuation and extension of analysis work commenced under the NMR-supported project «North Atlantic Climatological Dataset» (NACD) (Dahlström et al.,1995, Frich et al., 1996). As the budget from Nordisk Ministerråd (NMR) was reduced to about 20% of the amount suggested in the original REWARD proposal, a revised project plan was outlined at a project meeting in Oslo 4-5. March 1996 (Førland, 1996).

In the REWARD-project, special focus is put upon whether the globally observed climate warming has caused any increase of extreme climatic events in the Nordic area. The key to understanding climatic change and variability in the Nordic region, is to analyse how different atmospheric circulation patterns influence surface climate. In REWARD, long-term series of surface pressure is used to describe the atmospheric circulation in the Nordic region during the last 100 years. These long-term circulation variations are then linked to variations in climatic elements. The resulting linking of extreme weather with circulation will probably also be an important tool to predict consequences of climate changes.

In the first phase of REWARD, the main emphasis has been put on preparation of data series of extremes, but also some preliminary analyses have been carried out (see section 3). These preliminary analyses indicate that the minimum temperature has increased in Fennoscandia since the end of the last century, and that this increase has been most prominent during the spring. The diurnal temperature range has decreased by 0.2-0.4 °C during the last 40 years. For maximum 1-day precipitation, there are large differences in trend patterns for the various stations, but there is a tendency of a rising trend during the last years at most stations.

The preliminary results of linking variations in circulation pattern to variations in climate elements for Jutland and Western Norway, are promising. For Western Norway there is also a clear relationship between changes in circulation and changes in precipitation distribution. For one station in Sweden (Härnösand), preliminary tests show that during autumn, significant circulation anomalies are coupled to extreme precipitation events.

2. ACTIVITIES

Nordic series of monthly values of climatic extremes are prepared for the period 1890-1995. For some stations even data back to the early 1880's are included, while other stations have substantially shorter records (cfr. Appendix 2). The station network is mainly based on the NACD-stations (Frich et al.,1996), and presently 10 Finnish, 5 Icelandic, 17 Norwegian and 20 Swedish stations are included in REWARD. Main focus is put on daily maximum and minimum temperatures, and on maximum 1-day precipitation amount. An extensive quality control has been performed, and numerous errors have been replaced by correct values. Presently, no statistical tests for possible inhomogeneities have been performed on the series of extremes, but for all NACD-stations the homogeneity of annual and seasonal values of temperature and precipitation is thoroughly checked within the NACD-project (Frich et al., 1996). Some preliminary results of the trend studies of extremes of temperature and precipitation are presented in section 3.1 and 3.2.

Programs for fitting extreme value distribution (EVD) functions to long Nordic temperature series are developed, and applied to some series of minimum and maximum temperature (see section 3.5).

The extensive pressure dataset obtained within the WASA-project (Schmith et al., 1996) will be used to explore possible links between the dataset of extremes within REWARD and the atmospheric circulation. Within WASA about 20 stations with air pressure from northern Europe have been digitized, reduced to mean sea level and checked thoroughly. Data coverage in time is approximately 1880-1995 and data density in time is mainly three observations per day. The data set is available, and programmes have been developed to calculate geostrophic winds and to combine the REWARD and WASA data sets. Preliminary tests (Härnösand, autumn) show that significant circulation anomalies are coupled to extreme precipitation amounts.

The relationship between atmospheric circulation and orographic precipitation has been studied both for western Jutland, western Norway (Tveito, 1996) and for western Spitsbergen (Førland et al., 1996). Some preliminary results are presented in section 3.3 and 3.4.

A first («kick-off») meeting in REWARD was held in Oslo 4-5 March 1996 with ten participants. All Nordic countries were represented at the meeting.

3. MAIN RESULTS

3.1 Trends in minimum and maximum temperatures, and diurnal temperature range

The mean minimum and maximum temperature series from Norway, Sweden and Finland were studied for trends. All data used in research was original without any homogeneity testing. Therefore, no individual series were studied at this stage. Only national or Fennoscandian averages were used in analysis, because most of inhomogeneities are believed to be random and cancel out each other in large samples. However, it turned out that this assumption is not true for early parts of the series. More research is needed on the systematic inhomogeneities. The homogeneity tested Fennoscandian mean temperatures offered a good reference level for the original minimum and maximum series.

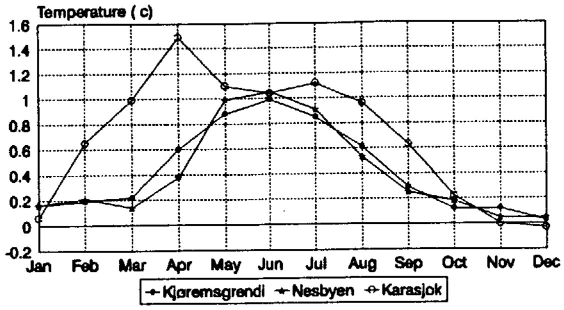
Minimum and maximum temperatures

The average of 49 stations was used to describe Fennoscandian temperature variations. The mean minimum temperatures show irregular increase in Fennoscandia since the end of the last century. The warming of spring has been strongest. Also linear trends in summer and autumn show some increase. There is no clear trend in winter temperatures. However, a comparison of mean, maximum and minimum temperatures show that there seems to be some systematic error in the 19th century measurements, very likely related to minimum observations. Therefore, the size of the observed minimum temperature warming, (annual/spring) 0.4/0.9 °C since the period 1901-1930 compared to the last 30-years (1966-1995), and especially the 1.1/1.9 °C warming from the period 1873-1902, is uncertain.

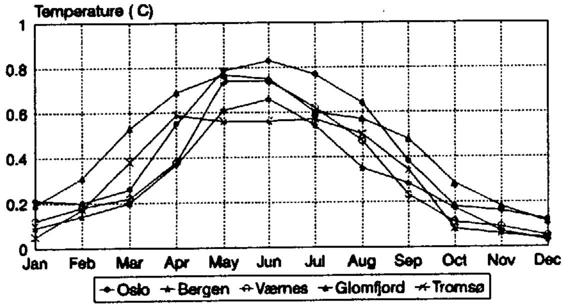
The range of mean difference between mean and maximum temperatures is fairly stable throughout the whole period of observations. However, the corresponding range between mean and minimum temperatures is about one order of magnitude greater in the pre-1920s observations than during the latter half of this century. It is difficult to imagine any climatic reason for so dramatic change. Some systematic error due to changes(s) in observation practises is a likely reason.

Effects of changes in definition of «minimum temperature day»

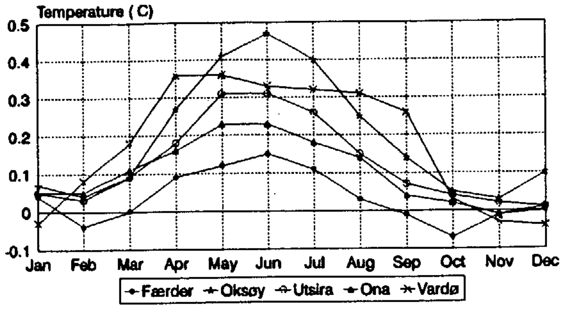
A change of practise in the Norwegian network occurred 1 January 1938 when the day for computation of minimum temperature was changed from $(8 - 8)^h$ to $(19 - 19)^h$. The effect of this change was calculated by use of daily values during the period 1957 (1951) to 1995 for a selection of stations, figure 1. In this period the minimum thermometer was read twice a day 7^h (8^h) and 19^h. Thus it was possible to compare the present procedure with the practice during the period 1894 - 1937.



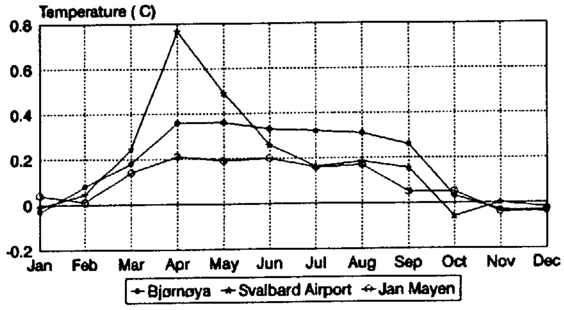
a) Continental stations



b) Inner fjord and coastal stations



c) Stations on small islands (lighthouse stations)



d) Arctic stations

***Figure 1** Mean monthly difference between daily minimum temperature computed according to different definitions of the minimum temperature day, the interval $(19 - 19)^h$ minus $(8 - 8)^h$.*

It is readily seen from figure 1 that for most stations and seasons the effect of the change is rather dramatic and the series should thus be adjusted to keep homogeneity. The effect seems to be closely connected to the daily temperature range and is largest at continental stations. At stations on very small islands like Færder it is negligible compared to other sources of inhomogeneity. In the Arctic and Northern Norway the difference may reach its maximum value in early spring. Midwinter, however, when the sun is under the horizon and temperature dips and tops are randomly distributed throughout the day, the change of practise has no effect.

Diurnal temperature range (DTR)
Figure 2 shows the DTR in Norway, Sweden and Finland as calculated from available data. There is a remarkable agreement between the three series since the 1910s. However, it must be emphasised that the Norwegian series are formed on only one or two stations before 1931. The same applies to Finnish series before 1905. The last century part of the Finnish series is based on the hourly measurements in Helsinki. The Swedish average is calculated from ten stations starting already in 1881.

The reliable part of DTR series (1931-1995) shows that there has been a 0.2-0.4 °C decrease in the DTR during the last 40 years. However, 50 years ago, the DTR was only slightly larger than now. The earlier, less reliable part, of the series suggests that the DTR was in the 1920s and 1930s at as low level as during the last decade.

Earlier studies have revealed that the recent decrease of the DTR is quite certainly related to the increase in cloudiness (Tuomenvirta and Heino, 1996). It is planned to study this connection also during the whole century, but the quality of cloudiness data may not be good enough. Unfortunately, also the measurements of sunshine duration are sparse. Possible links with circulation patterns will be studied with circulation types calculated from the surface pressure series (Schmith et al., 1996). At the moment, it can only be shown that the annual correlation betwen the Fennoscandian mean temperature and the DTR is about -0.5. During the recent decades, the DTR decrease has been faster than one would expect from the mean temperature increase.

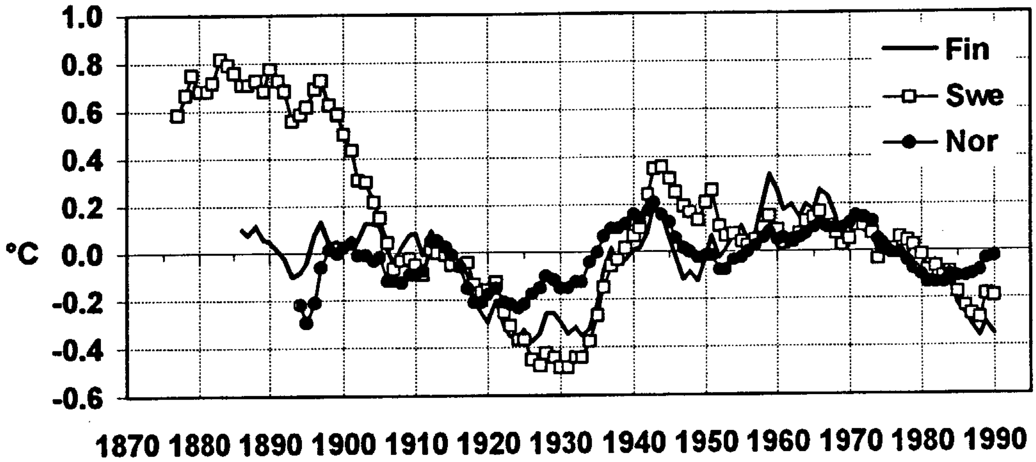


Figure 2. *10-year moving averages of diurnal temperature range (DTR) anomalies from 1961-1990 period in Finland, Sweden and Norway. For number of stations used in calculations see text.*

3.2 Trends in daily maximum precipitation

The annual precipitation has increased over large parts of Northern Europe during the last years (Førland et al., 1996). An important issue is whether the maximum daily precipitation also has increased. If so, it would have serious consequences for flooding, and should be taken care of in estimations of probable precipitation extremes.

The preliminary analysis of maximum 1-day precipitation does not indicate any distinct, common pattern in the trend curves from the various stations. Trend curves from some selected stations are shown in Figure 3. The figure also shows that amongst the REWARD-stations, the highest 1-day precipitation (187 mm) is recorded in Härnösand, while Bjørnøya has the lowest (41 mm/day). It should

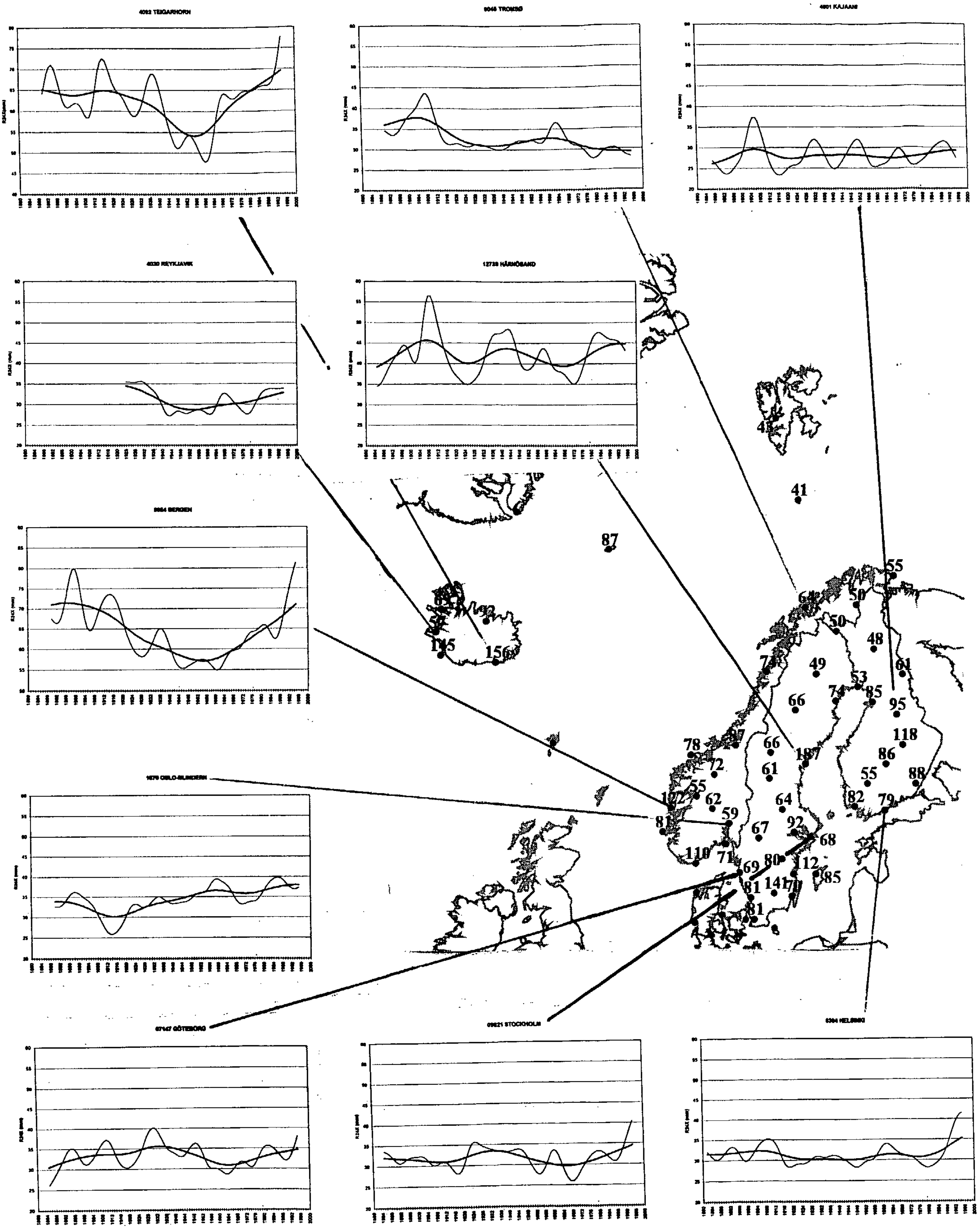


Figure 3. *Maximum 1-day precipitation (mm) 1880-1995: Observed maximum (map) and filtered timeseries. (Standard deviation of trend curve filters are 3 years (thin line) and 9 years (solid line)*

however be mentioned that more than 200 mm/day has been observed at some Nordic stations. Figure 3 is probably the first ever compilation of maximum 1-day precipitation for stations over the whole Nordic region, and a first step against the project aims of establishing a «Nordic Atlas of Extremes».

3.3 Orographic precipitation in Western Norway

There is a high correlation between the onshore (zonal) component and precipitation amount in western Norway (Figure 4). In earlier studies (Tveito, 1996) this relationship has been examined for single precipitation series.

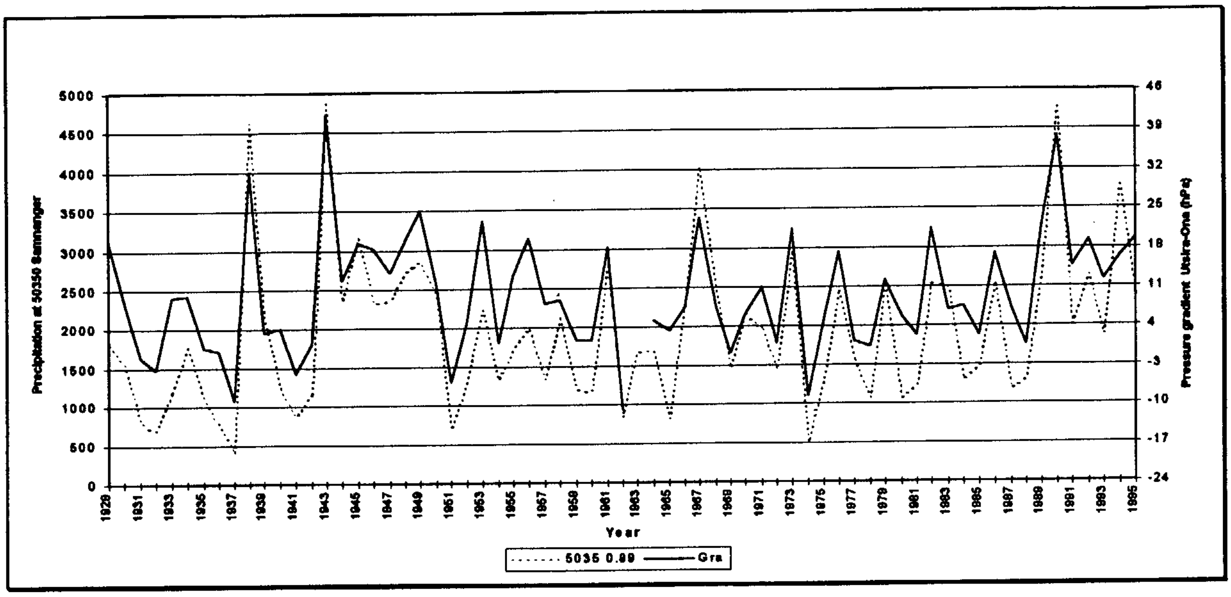


Figure 4: Precipitation at 50350 Samnanger (dashed line) and the Utsira-Ona pressure gradient (solid line), spring season 1929-1995. The correlation coefficient is 0.89.

A preliminary study of the correlation coefficient between the pressure gradient Utsira-Ona, representing the zonal component, and approximately 150 homogeneous precipitation series has been carried out. Monthly, seasonal and annual correlation coefficients are calculated for the individual precipitation series. These results are further analysed in GIS (Geographical Information System) to establish maps showing continuous correlation coefficient fields. Maps are derived for the entire period (1929-90), and for the two normal periods 1931-60 and 1961-90. For the spring season (Figure 5) there are significant differences between the periods in some areas. These differences show similar characteristics as the results obtained by Førland et.al (1996). The results indicate a shift in circulation from south-westerly to more westerly winds.

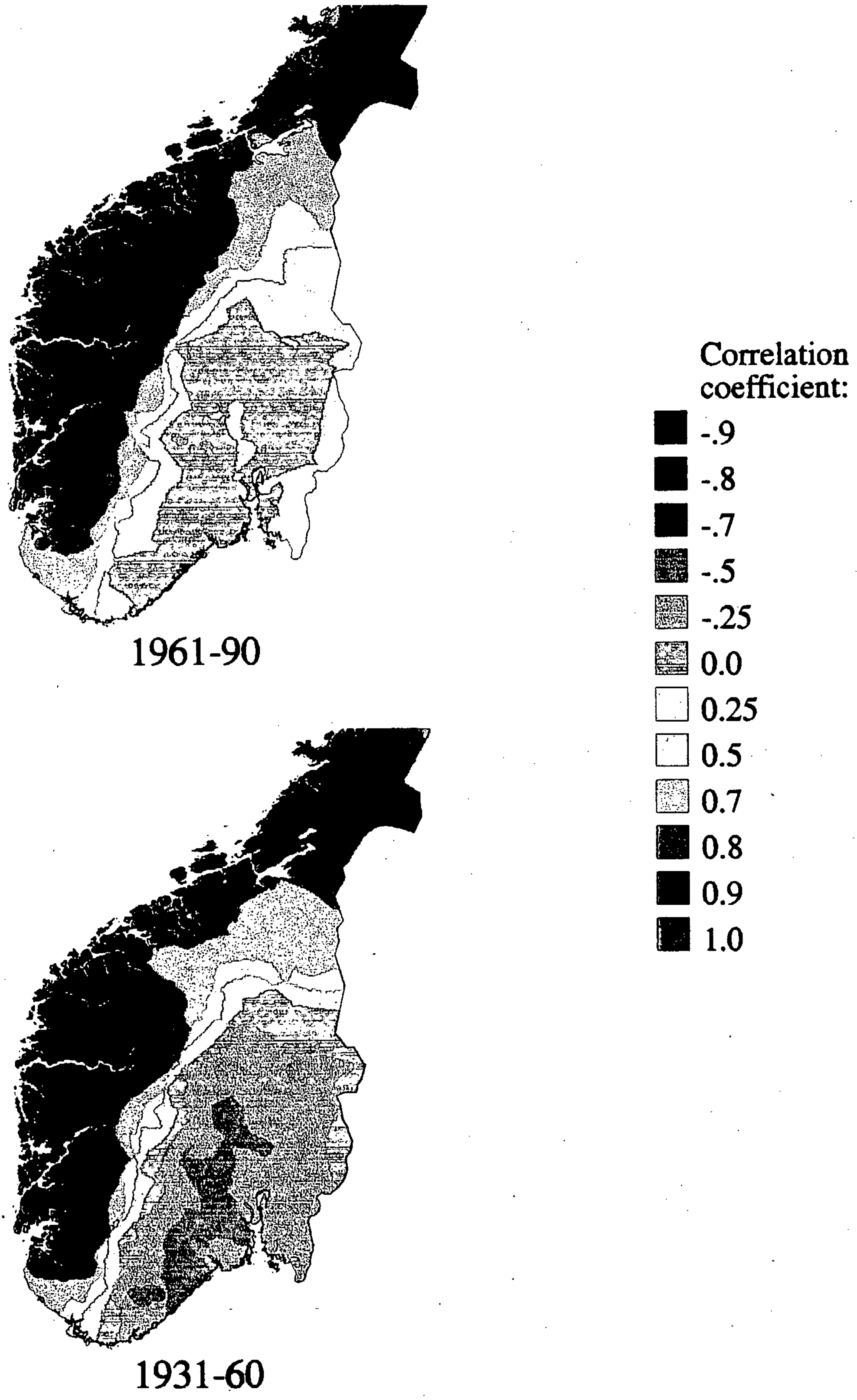


Figure 5: Map of correlation coefficient between precipitation series and zonal component in the spring season for the periods 1931-60 and 1961-90.

3.4 Orographic precipitation in Jutland

Analysis of two homogenised precipitation series from western Jutland shows that the precipitation has gradually increased during winter period (Oct.-Mar.). This has been further investigated using a downscaling technique rather similar to Kaas et al. (1996), based on monthly mean MSLP-data on a 5x5 deg. grid (Trenberth and Paolino (1980). The preliminary results (Figure 6) show that large scale circulation variability can explain a large fraction of the variability, but there is a tendency for increasing residuals (=observed - hindcasted) through time, a candidate for climatic change indicator?

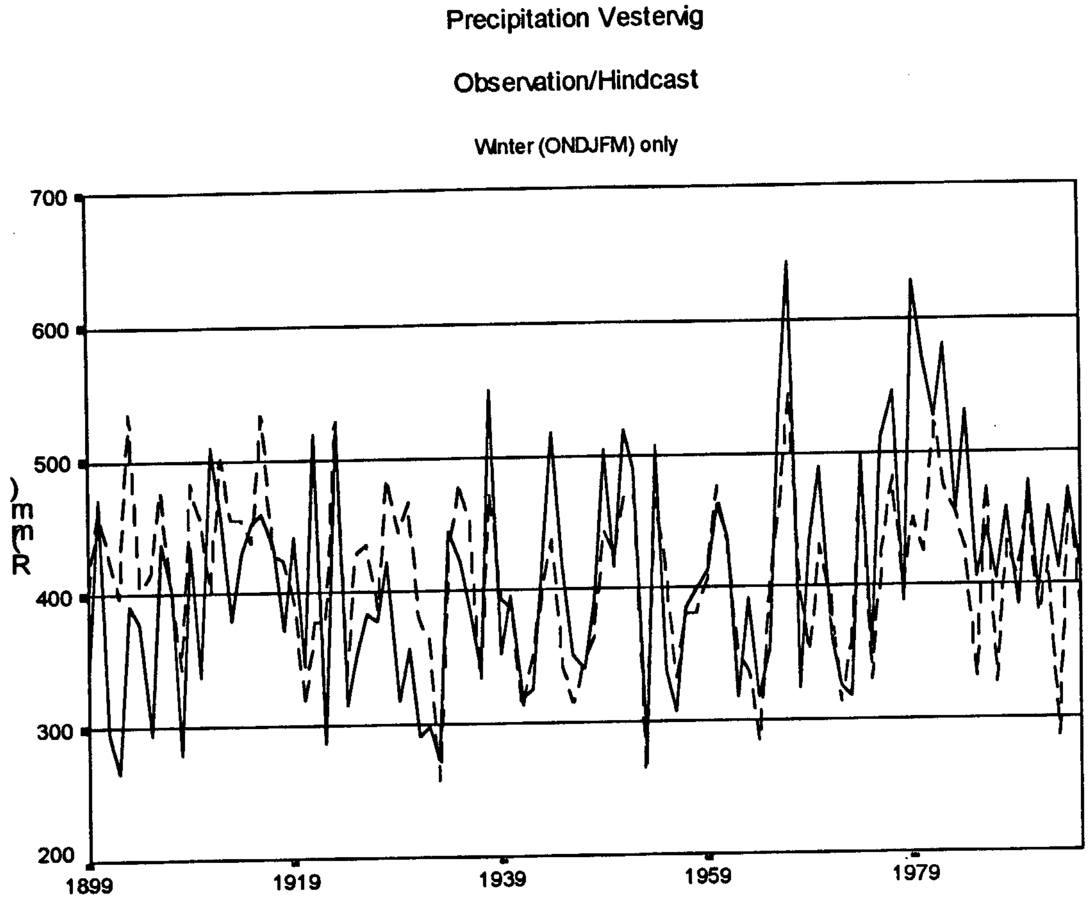


Figure 6. *Precipitation from Vestervig in western Jutland. Full curve is observed winter (ONDJFM) sum. Broken line is the corresponding hindcasted values. Correlation coefficient between the two time series is 0.79.*

3.5 Extreme value distribution

In addition to any trends in extreme temperature and precipitation values over the Nordic region, it is of considerable interest to assess the extreme value distributions and return periods of these elements, and also to detect eventual changes in the parameter values of the extreme value distributions.

At this stage, some preliminary extreme value distribution evaluations for REWARD-series for January minimum temperature and July maximum temperature have been carried out. The evaluations have covered the three General Extreme-Value (GEV) distribution 3-parameter methods. The preliminary estimates for Oslo indicated a Weibull (GEV Type III) distribution, whereas for Stockholm both estimates gave a Gumbel (GEV Type I) distribution.

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APPENDIX 2. STATION LIST (Preliminary list of series of maximum 1-day precipitation)

The columns are presenting: National station number, Country code, WMOno, Station name, Latitude, Longitude, Altitude (m a.s.l.), NACD-Element code (602=Maximum daily precipitation), Start of series, Mean and maximum 1-day value (mm)

NatNo	Ctry	WMO	St.Name	Lat	Long	Alt	Elem	Start	Mean	Max
0304	FIN	2978	HELSINKI	60.1 N	24.57 E	4	602	1882	31.4	79.3
1101	FIN	2972	TURKU	60.31 N	22.16 E	51	602	1891	31.3	82.1
1202	FIN	-9999	TAMPERE	61.28 N	23.44 E	85	602	1891	27.5	55.6
1701	FIN	2958	LAPPEENRANTA	61.05 N	28.09 E	105	602	1887	29.9	88.1
2425	FIN	-9999	JYVÄSKYLÄ	62.12 N	25.43 E	137	602	1891	32	86.2
3602	FIN	-9999	KUOPIO	62.54 N	27.41 E	119	602	1891	28.3	118
4601	FIN	2897	KAJAANI	64.17 N	27.4 E	132	602	1887	28.1	95
5404	FIN	-9999	OULU	65.02 N	25.29 E	13	602	1891	26.9	85.4
6801	FIN	2896	KUUSAMO	65.59 N	29.13 E	263	602	1909	25.8	61
7501	FIN	2836	SODANKYLÄ	67.22 N	26.39 E	179	602	1908	25.7	48.2
4013	IS	4013	STYKKISHOLMUR	65.05 N	22.44 W	8	602	1890	32.9	69
4030	IS	4030	REYKJAVIK	64.08 N	21.54 W	52	602	1924	30.9	57
4048	IS	4048	VESTMANNAEYJAR	63.24 N	20.17 W	118	602	1890	52.3	145
4063	IS	4063	AKUREYRI	65.41 N	18.05 W	23	602	1925	25.2	92
4092	IS	4092	TEIGARHORN	64.18 N	15.12 W	14	602	1890	62.1	156
9995	N	1001	JAN MAYEN	70.56 N	8.4 W	10	602	1922	31.3	87
9984	N	1008	SVALBARD LUFTHAVN	78.15 N	15.28 E	28	602	1957	15.8	43.2
9045	N	1026	TROMSØ	69.39 N	18.56 E	100	602	1890	32.7	64
9971	N	1028	BJØRNØYA	74.31 N	19.01 E	16	602	1926	18.4	41.5
9725	N	1065	KARASJOK	69.28 N	25.31 E	129	602	1890	23.8	50.7
9855	N	1098	VARDØ	70.22 N	31.05 E	14	602	1893	24.8	55
8229	N	1153	BODØ	66.49 N	13.59 E	39	602	1891	39.4	74
6248	N	1212	ONA	62.52 N	6.32 E	13	602	1919	42.4	78.2
1674	N	1235	KJØREMSGR./DOMBÅS	62.06 N	9.03 E	626	602	1890	26.7	72
6910	N	1271	VÆRNES/TR.HEIM	63.28 N	10.56 E	12	602	1890	36.8	87.6
5054	N	1316	BERGEN-FR.BERG	60.24 N	5.19 E	41	602	1890	64.3	122.3
5413	N	1355	LÆRDAL	61.04 N	7.31 E	36	602	1890	27.3	55
2488	N	1372	NESBYEN	60.34 N	9.07 E	167	602	1897	28.4	62.7
4730	N	1403	UTSIRA FYR	59.18 N	4.53 E	55	602	1920	39.5	81.3
3910	N	1448	OKSØY FYR	58.04 N	8.03 E	9	602	1890	45.7	110.5
2750	N	1482	FERDER FYR	59.02 N	10.32 E	6	602	1890	36.3	71.4
1870	N	1492	OSLO-BLINDERN	59.57 N	10.43 E	94	602	1890	34.4	59.8
5343	S	-9999	LUND	55.42 N	13.12 E	50	602	1885	32.5	81.2
6240	S	-9999	HALMSTAD	56.4 N	12.55 E	25	602	1885	34.1	81.4
6452	S	2648	VÄXJÖ	56.52 N	14.48 E	166	602	1885	32.8	141
6641	S	2670	KALMAR	56.43 N	16.17 E	15	602	1885	29.4	70.4
7147	S	2516	GÖTEBORG	57.46 N	11.53 E	20	602	1885	33.2	69.9
7647	S	2559	VÄSTERVIK	57.43 N	16.28 E	33	602	1885	36	112.9
7840	S	2592	VISBY	57.4 N	18.2 E	42	602	1885	29.6	85.7
8524	S	2582	LINKÖPING	58.24 N	15.32 E	64	602	1885	30.2	80.8
9322	S	2584	KARLSTAD	59.21 N	13.28 E	46	602	1885	32.3	67
9635	S	2418	VÄSTERÅS	59.35 N	16.37 E	6	602	1885	32	92.5
9821	S	2462	STOCKHOLM	59.2 N	18.03 E	44	602	1885	31.7	68.3
10537	S	2433	FALUN	60.37 N	15.37 E	160	602	1885	31.6	64.8
12402	S	2433	SVEG	62.01 N	14.21 E	360	602	1885	31.2	61.3
12738	S	-9999	HÄRNÖSAND	62.37 N	17.56 E	8	602	1885	42.2	187.3
13411	S	2226	ÖSTERSUND	63.11 N	14.29 E	376	602	1885	27.6	66.8
15772	S	2104	STENSELE	65.04 N	17.09 E	325	602	1885	29.7	66.2
16179	S	-9999	PITEÅ	65.19 N	21.29 E	6	602	1885	31.6	74.5
16395	S	2196	HAPARANDA	65.49 N	24.08 E	5	602	1885	27.2	53
16988	S	2142	JOKKMOKK	66.37 N	19.38 E	260	602	1885	27	49
19283	S	2080	KARESUANDO	68.26 N	22.29 E	327	602	1885	23.1	50.2

APPENDIX 3: National Reports

4.1 Denmark (DMI)

The main effort at DMI this year, has been to publish and distribute the North Atlantic Climatological Dataset (Frich et al. 1996, enclosed). In addition, the completion of the WASA dataset (Schmith et al., in prep.) has also occupied considerable ressources. Both these datasets form important bases for the REWARD project.

A preliminary analysis of precipitation in western Jutland has been carried out. Some results are presented in section 3.4. This work will be continued in 1997 by applying (non-linear) analog methods to days with precipitation exceeding 10mm, based on WASA-dataset.

4.2 Finland (FMI)

The extremal temperature and precipitation series were prepared for the same 10 stations as in the NACD project. The minimum and maximum thermometers were introduced into Finnish station network during the first decade of this century. However, hourly observations made in Helsinki can in some cases be used to lengthen the Helsinki series back to 1881. Largest daily precipitation amounts within month have been reported in the yearbooks since the 1890s. The records of the other REWARD extreme precipitation element (number of days with prec.>10mm) cover typically eighty years. Again, a bit longer records were available from Helsinki. All data was quality controlled, but not homogeneity tested as in the NACD project.

FMI collected extreme temperature series from all countries available. The clear increase of minimum temperatures was shown and recent Nordic scale DTR variations were documented. Some preliminary results of the trend studies are presented in section 3.1.

Programs for fitting extreme value distribution (EVD) functions to long Nordic temperature series were developed. EVDs can be used in calculations of return periods of rare events. Examples are given in section 3.5.

Material of various extremes is being collected. This activity directly contributes also to the production of Nordic Atlas on Extremes.

The effect of urbanisation on several climatological elements was presented in Conference on Urban Climatology, Essen, Germany, 10-14 June 1996 (Heino, 1996). An article on the subject has been submitted for review.

It has been decided that FMI will host the third REWARD Seminar in Helsinki in February 1997. The planning of the Seminar were started, including request for financial support from NorFa.

4.3 Norway (DNMI)

Series of extremals of temperature and precipitation for 17 Norwegian stations were prepared for the period 1890-1995. The series were quality checked, and corrected for digitizing errors. Plots of the time series were used to detect suspicious values. No statistical tests for possible inhomogeneities have been performed on the series of extremes, but for all stations the homogeneity of annual and seasonal values of temperature and precipitation is thoroughly checked within the NACD-project (Frich et al., 1996).

DNMI has the main responsibility of analysing maximum 1 day precipitation within REWARD, and some preliminary results from the analysis are presented in section 3.2.

It has been documented that the change in the definition of «minimum temperature day» from 07-07h to 19-19h in 1938, has a dramatic effect on the mean monthly minimum temperatures (see section 3.1).

The relationship between atmospheric circulation and orographic precipitation has been studied both for Western Norway (Tveito, 1996) and for western Spitsbergen (Førland et al., 1996). Some preliminary results are presented in section 3.4.

DNMI arranged the first («kick-off») meeting in REWARD in Oslo 4-5 March 1996 with ten participants. All Nordic countries were represented at the meeting.

4.4 Sweden (SMHI)

Data that have been digitized or retreived from the archives at SMHI:

05343 Lund, 06240 Halmstad, 06452 Växjö*, 06641 Kalmar, 07147 Göteborg*,
07647 Västervik*, 07840 Visby*, 08524 Linköping, 09322 Karlstad*, 09635 Västerås,
09821 Stockholm*, 10537 Falun*, 12402 Sveg*, 12738 Härnösand*, 13410 Östersund*,
15772 Stensele*, 16179 Piteå, 16395 Haparanda*, 16988 Jokkmokk*, 19283 Karesuando*

For these stations daily maximum precipitation (for each month) and corresponding dates now exist on computer medium for the period 1885-1995. For stations marked with an * also maximum and minimum temperatures and corresponding dates exist (also 1885-1995).

An extensive quality control has been performed and numerous errors have been replaced by correct numbers.

Precipitation data have been homogenized with the same factors as in the NACD data set. Temperature data are not adjusted for possible non-homogeneities.

The extensive pressure data set obtained within the WASA-project will be used to explore possible links between the extreme data set within REWARD and the atmospheric circulation. Within WASA about 20 stations with air pressure from northern Europe have been digitized, reduced to mean sea level and checked thoroughly. Data coverage in time is approximately 1880-1995 and data density in time is mainly three observations per day. The data set is available at SMHI and programmes have been developed to calculate geostrophic winds and to combine the REWARD and WASA data sets. Preliminary tests (Härnösand, autumn) show that significant circulation anomalies are coupled to extreme precipitation amounts.

Linking extreme weather with circulation can become an important tool to predict consequences of climate changes. But the value of this very special data set with extreme values and corresponding dates is in itself very large.