Scenarios of extreme precipitation of duration 1 and 5 days for Norway caused by climate change

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Scenarios of extreme precipitation of duration 1 and 5 days for Norway due to climate change

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Preface

The project “Klimautvikling og kraftpotensiale”is a co-operation between the Norwegian Meteorological Institute (met.no) and the Norwegian Water Resources and Energy Directorate (NVE). The project is financed by the Norwegian Electricity Industry Association (EBL) and will be completed during the period 2001-2002.

Possible climate change presents a great challenge for water resources management in general, and specifically for safety, operations and the economy of hydraulic structures. This report assesses the effects of climate change on extreme precipitation regimes in Norway, for the durations 1 and 5 days.

Oslo, November 2002

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Summary

Based on downscaled precipitation values from the global climate model of the Max Planck Institute in Hamburg time series of twenty years have been generated to describe the current climate of 1980-1999 (control data) and the future climate of 2030-2049 (scenario data). These time series serve as training data for a precipitation simulation model Randomised Bartlett-Lewis Rectangular Pulse Model (RBLRPM), and time series of length thousand years have been generated to assess possible changes in the extreme precipitation regime due to climate change. Due to uncertainties in the downscaled values, only relative changes in extreme values between the two series were analysed. The analysis of changes in extreme value patterns simulated show tendencies towards increased extreme values and seasonal shifts for the scenario period, although the regional variability is significant.

1.Introduction

For obvious reasons, the hydro electrical producing community is interested in assessing the effects of possible climatic change on extreme values of precipitation. A change in the precipitation regime of extreme values can have major impact on safety, operations and the economy of hydraulic structures.

The output from the atmospheric models (control data and scenario data) is unsuited for extreme value analysis in that they operate on spatial scales incompatible with the scales for which estimates of extreme values of precipitation is needed (e.g. various hydrological applications, transportation, biology, agriculture etc.). The problem of reducing the spatial scales (i.e. downscaling) to scales suitable for hydrological analysis (e.g. point scale) has been a major research task in the RegClim project (Iversen et al. 1997). Two methods have been investigated. *Dynamical downscaling*, where output from a large scale atmospheric models (climate model) is used as input for a regional weather forecast model of high spatial resolution (Bjørge et al. 2000). *Empirical downscaling* uses the correlation between local observations of climatic parameters and large scale patterns of air pressure (Hanssen-Bauer et al. 2001). The data used for extreme value analysis and as training data for a precipitation simulation model is dynamically downscaled precipitation. For extreme value analysis, it is of crucial importance that the variance of the data in question is well estimated. Imbert (2002), compared the statistical properties of observed and modelled (control climate) extreme value series and found discrepancies in both the mean and the variance. In order to take into account the uncertainty associated with the downscaling procedure on the climatic output, we decided to carry out the extreme value analysis on simulated control and scenario data, and analyse the relative differences between the extreme values of the two series. If both data series have errors, the relative difference between them could still give valuable information on possible change in extreme value patterns.

The motivation of the chosen approach for estimating precipitation values of high return periods, is based on the limited length of available time series. The length of the time series of observed data, modelled data of the current climate and modelled data for future climate is in the order of a few decades, which is insufficient for estimation of extreme values of low probability of occurrence. The chosen approach is basically to train a simulation model (see section 3) with available data and produce time series of sufficient length to give the extreme value analysis credibility. It can be argued that no new statistical information is provided beyond that of the calibration data. However, information is added in that the simulation model extrapolates, from a limited amount of data, a certain physical structure of temporal rainfall. A way of justifying the appropriateness of the temporal structure is the fact that the simulation model reproduces properties of the observations over a range of temporal scales. The simulation model has been used to estimate design rainfall for durations ranging from one hour to one day (Smithers at al. 2002). Also, at the Norwegian Water Resources and Energy Directorate

(NVE), a project is initiated to estimate design floods by using simulated precipitation and temperature together with a rainfall-runoff model (Astrup et al. 2002).

2.Data

Dynamically downscaled time series (see Bjørge et al. 2000) are provided for several points over Norway, where meteorological stations, considered to be regionally representative, are operative. The time series are generated from the atmospheric model ECHAM4/OPYC3 GSDIO of the Max Planck Institute, Hamburg, Germany, and are time series of daily values of a "control period" (1980-1999) and a "scenario period" (2030-2049). The data series are hereafter referred to as "control data"and "scenario data" The points, or meteorological stations, are chosen in such a way that 12 of the 13 climatic regions, defined according to Roald et al (2000) are represented. Figure 1 shows the location of the meteorological stations and the climatic regions.

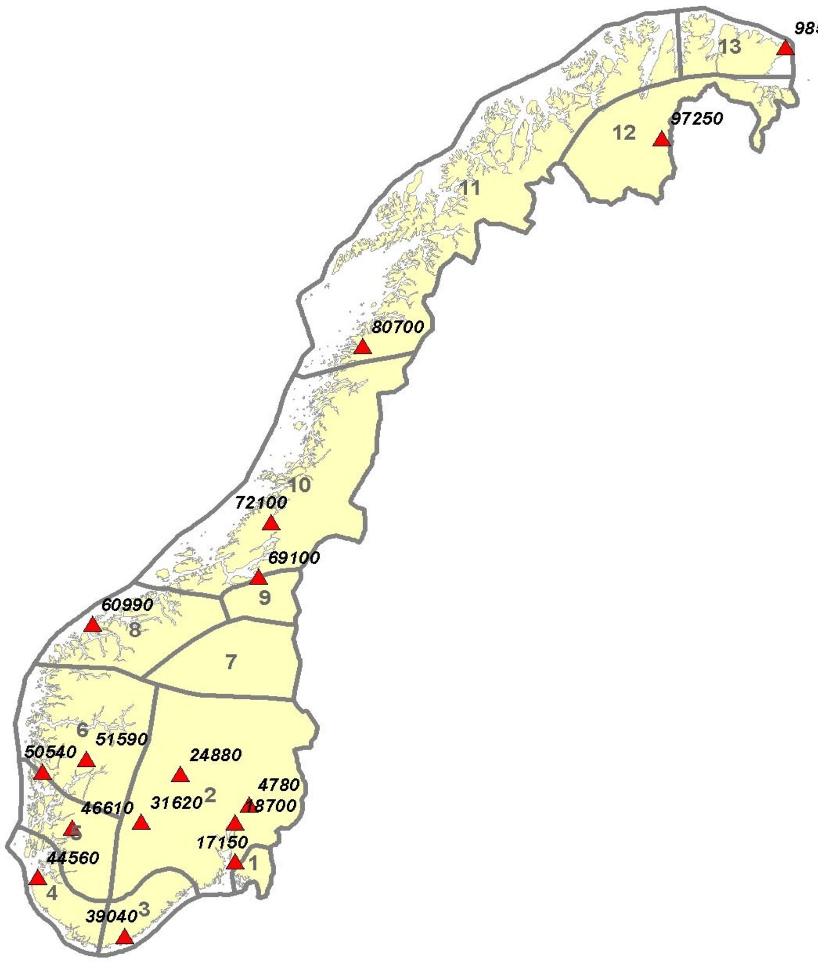

Figure 1 Location of metetorological stations and climatic regions

Considerable uncertainty is associated to how well the downscaled climatic output corresponds to real observations, i.e. does the time series of the control period for a certain station have similar statistical characteristics to that of observations? This question is important if we were to assess the actual magnitude of the extreme values. Imbert (2002) reported discrepancies between control data and observations, which could influence inferences on extreme values. In this study we compare statistics (mean and standard deviation) on extreme value samples (annual maxima series, AMS) for observations and control data (see tables in section 4). Large discrepancies are observed, but we cannot state that systematic differences are present, like a consistent increase or decrease of the statistical parameters for the different data sets.

3. Methodology

The model chosen to simulate precipitation time series is the Poisson process based (independent and exponentially distributed inter-arrival times) Bartlett-Lewis Rectangular Pulse Model, or more specifically the Randomised Bartlett-Lewis Rectangular Pulse Model (RBLRPM) (Onof and Wheater, 1993; Onof, 2000). This model is chosen because the Bartlett-Lewis approach to the clustering of cells within larger storms is used in the current developments in spatio-temporal rainfall modelling (Onof, 2000). In the Bartlett-Lewis Rectangular Pulse Model, storms arrive according to a Poisson process with parameter λ. Each storm is followed by a Poisson process of cell arrivals with parameter β, which has a finite duration V. V is chosen as an exponentially distributed random variable with parameter γ. The precipitation is then added to this wet/dry picture in the form of precipitation pulses of exponentially distributed intensity (parameter $1/\mu_x$) and independently exponentially distributed duration with parameter η. In order to improve the reproduction of dry periods, the parameters η, β and γ are considered to be random variables, thus the *Randomised* BLRPM. The total number of parameters is now 6. The model assumes stationary precipitation data, so to take the variability across the year into account, each month is considered separately. Inter-annual variability was not considered for the modelling of precipitation. Analytical relations between monthly rainfall statistics such as the probability of a dry day, mean duration of a dry period, mean, variance, and autocovariance and monthly values of the above parameters can be found in Onof and Weather (1993) and Onof et al (1994).

RPBLRPM was calibrated from the twenty years of data for both control and scenario data and twenty years were simulated and validated against the original time series. The validation consisted of a visual comparison between values of the original and the simulated data of monthly values of mean, variance, autocorrelation, probability of a dry day and duration of dry periods.

With the RPBLRPM, 1000 years of data was simulated for the control data and for the scenario data. Standard frequency analysis was performed on the AMS derived from the simulated 1000 year series.

4. Results

The results of the frequency analysis for the different meteorological stations are presented in tables and on maps. The chosen extreme value distribution for the simulated series is indicated in the tables as either GEV, general extreme value distribution, or as LN3, the three parameter log normal distribution. The parameters of the distributions were estimated by probability weighted moments and maximum likelihood respectively (Hosking and Wallis, 1997). The extreme values estimated from the simulated series are compared to extreme values estimated from observed series, which are estimated by a Gumbel distribution (Haan, 1977) and by the NERC method (NERC, 1975). Again we stress that, given that the downscaled values are uncertain, we base the discussion of the changes in extreme values on the relative differences between the control and scenario data.

In Annexe A the relative changes in extreme values for different return periods are visualised on maps. In the following, an analysis of extreme values is performed for each point/meteorological station.

A source of uncertainty that has to be taken into account is the simulation model, RPBLRPM itself. Although the simulated series have been validated on monthly mean values for different statistics, a much more demanding test is the comparison of the extreme values. Table 4.1 shows the mean and standard deviation of the extreme value series of the original control data (20 years) and the simulated control data (1000 years).

Table 4.1 Comparison of mean and standard deviation of extreme value series from original control data (20 years) and simulated control data (1000 years). (+) and (-) indicate higher and lower, respectively than the parameters of the control data (20 years).

Station	**Control data – original (20 years)**		**Control data – simulated (1000 yrs)**	
	mean	**std.dev**	**Mean**	**std.dev**
17150	38.4	12.5	44.7 (+)	19.9 (+)
4780	37.2	16.1	35.3 (-)	9.4 (-)
18700	38.3	14.6	37.8 (-)	9.8 (-)
24880	41.2	11.1	35.5 (-)	13.9 (+)
31620	35.2	8.8	36.7 (+)	10.5 (+)
39040	41.6	7.8	41.8 (+)	9.1 (+)
44560	53.8	9.8	55.3 (+)	18.6 (+)
46610	50.9	8.6	58.7 (+)	15.4 (+)
50540	79.8	22.3	76.5 (-)	23.1 (+)
51590	53.2	10.0	57.2 (+)	17.2 (+)
60990	56.3	18.9	49.2 (-)	12.9 (-)
69100	34.6	5.6	35.4 (+)	8.6 (+)
72100	43.3	14.7	41.0 (-)	11.4 (-)
80700	55.5	19.3	46.5 (-)	11.5 (-)
97250	23.1	6.2	20.9 (-)	5.6 (-)
98550	22.5	10.2	22.7 (+)	8.4 (-)

As Table 4.1, shows, no systematic deviations between the original control data (20 years) and the simulated control data (1000 years) can be observed. The mean is increased for 8 stations out of 16 for the 1000 year series and the standard deviation is increased for 9 stations out of 16.

4.1 Station 17150 Rygge, Region 1.

Agreement between estimated extreme values from observed data and control data

Table 4.1.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.1.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (GEV). Pm and Ps are mean and standard deviation of extreme value series.

Station 17150, Rygge			
	Observed (1955-2001)		**Control data**
	Descriptive statistics		
Pm	37.8		38.4 (from 20 years sample)
Ps	10.0		12.5 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**GEV**(from 1000 years sample)
5	45.0	45.0	55.1
10	50.0	51.0	67.4
50	63.0	69.0	101.6
100	69.0	78.0	119.8
500	81.0	104.0	172.8
1000	87.0	118.0	201.3

We observe from Table 4.1.1 that the simulated extreme values correspond badly to the estimated extreme values from the observed series. The variability of the extreme values of the control data is higher than the observed, and the variability of the extreme values from the simulated series is enhanced still (see Table 4.1), which explains the rather large deviations of the estimated extreme values.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.1.2.

Table 4.1.2. Extreme values estimates for control and scenario data for 17150, region 1.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	44.7	24.6	22.8	31.2	34.3
Ps	19.9	13.9	14.2	15.7	16.6
P5	55.1	30.9	29.2	40.6	43.0
P10	67.4	39.1	37.6	50.1	52.8
P50	101.6	63.3	62.9	74.5	80.1
P100	119.8	76.9	77.3	86.5	94.4
P500	172.8	118.4	122.4	118.5	135.3
P1000	201.3	141.9	148.3	134.3	156.9
Distribution	GEV	GEV	GEV	GEV	GEV

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.7	9.7	8.9	11.7	13.4
Ps	6.7	4.2	5.6	5.4	5.4
P5	20.1	12.1	11.1	14.8	16.2
P10	24.4	14.8	14.6	18.2	19.7
P50	36.2	21.8	25.2	26.9	29.1
P100	42.1	25.2	31.0	31.1	33.9
P500	58.4	34.2	48.3	42.0	46.8
P1000	66.6	38.6	57.6	47.2	53.3
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	44.5	27.0	26.5	20.7	35.0
Ps	20.9	16.7	10.9	13.9	19.5
P5	54.5	33.7	33.7	28.7	45.6
P10	67.1	43.2	40.4	37.2	58.1
P50	103.9	72.9	56.2	59.6	91.1
P100	124.2	90.3	63.5	70.9	107.5
P500	185.8	146.6	81.8	102.2	151.0
P1000	220.3	180.0	90.3	118.1	172.5
Distribution	GEV	GEV	GEV	GEV	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.9	11.9	10.2	7.6	13.8
Ps	6.6	5.2	5.1	4.6	6.1
P5	20.4	13.1	12.9	10.8	17.9
P10	24.7	16.3	16.2	13.6	21.7
P50	36.6	26.1	24.8	20.1	30.5
P100	41.7	31.4	29.1	22.9	34.4
P500	57.1	47.2	40.7	29.9	44.0
P1000	64.7	55.5	46.4	33.0	48.3
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	0.99	1.10	1.16	0.66	1.02
Ps	1.05	1.20	0.77	0.88	1.17
P5	0.98	1.09	1.15	0.70	1.06
P10	0.99	1.10	1.07	0.74	1.1
P50	1.02	1.15	0.89	0.8	1.13
P100	1.04	1.17	0.82	0.81	1.14
P500	1.08	1.24	0.66	0.86	1.11
P1000	1.09	1.27	0.61	0.88	1.1

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.01	1.23	1.15	0.65	1.02
Ps	0.99	1.24	0.91	0.85	1.13
P5	1.01	1.08	1.16	0.73	1.1
P10	1.01	1.10	1.11	0.74	1.1
P50	1.01	1.20	0.98	0.74	1.05
P100	0.99	1.25	0.94	0.74	1.01
P500	0.98	1.38	0.84	0.71	0.94
P1000	0.97	1.44	0.81	0.70	0.91

We observe from Table 4.1.2 that the scenario values have a 9% increase for the annual values of duration one day, whereas there is a minor decrease for the 5-day duration. For the one-day duration there is a major shift in seasonality with increase in winter and autumn precipitation and a decrease for spring and summer. For the five-day duration we have a major increase in winter precipitation and a decrease for the other seasons.

4.2 Station 4870 Gardermoen, Region 2.

Agreement between estimated extreme values from observed data and control data

Table 4.2.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.2.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 4870 Gardermoen			
	Observed (1957-2001)		**Control data**
	Descriptive statistics		
Pm	36.0		37.2 (from 20 years sample)
Ps	8.2		16.1 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	41.0	41.0	41.1
10	46.0	47.0	47.1
50	57.0	63.0	61.6
100	61.0	72.0	68.4
500	72.0	97.0	85.7
1000	76.0	110.0	93.9

We observe from Table 4.2.1 that the simulated extreme values correspond well (as a compromise) to the estimated extreme values from the observed series. The variability of the extreme values of the control data is higher than the observed, but the variability and mean of the extreme values from the simulated series are very close to those of the observed (see Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.2.2.

Table 4.2.2. Extreme values estimates for control and scenario data for 4780, region 2.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	35.3	21.4	21.9	30.2	27.7
Ps	9.4	8.3	7.0	9.9	7.3
P5	41.1	26.4	26.8	36.3	33.2
P10	47.1	31.6	31.0	42.5	37.4
P50	61.6	44.7	40.5	57.9	46.2
P100	68.4	50.9	44.6	65.1	49.8
P500	85.7	66.6	54.5	83.5	58.1
P1000	93.9	74.2	58.9	92.2	61.7
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	15.7	9.0	10.2	12.2	12.7
Ps	4.5	3.5	3.7	4.2	4.3
P5	18.7	11.3	12.7	14.9	15.5
P10	21.5	13.4	14.9	17.5	18.2
P50	27.7	18.6	20.0	23.6	24.4
P100	30.5	20.9	22.2	26.3	27.1
P500	37.3	26.8	27.7	33.1	34.0
P1000	40.3	29.5	30.2	36.2	37.1
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	40.8	25.6	24.5	26.2	34.9
Ps	13.1	10.4	9.8	11.8	12.1
P5	49.6	32.1	30.8	33.1	43.3
P10	57.6	38.6	36.9	40.6	50.6
P50	76.2	54.6	51.6	59.6	67.1
P100	84.4	62.0	58.3	68.7	74.4
P500	104.7	80.9	75.1	92.3	92.0
P1000	113.9	89.7	82.9	103.7	99.9
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.4	10.7	10.6	10.3	13.6
Ps	5.1	3.9	5.2	4.0	4.0
P5	19.3	13.2	13.2	12.7	16.7
P10	22.6	15.6	16.5	15.3	18.9
P50	31.0	21.5	25.7	21.8	23.8
P100	35.1	24.1	30.3	24.9	25.8
P500	45.9	30.7	43.0	32.9	30.3
P1000	51.1	33.8	49.4	36.8	32.3
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.16	1.20	1.12	0.87	1.26
Ps	1.39	1.25	1.4	1.19	1.66
P5	1.21	1.22	1.15	0.91	1.30
P10	1.22	1.22	1.19	0.96	1.35
P50	1.24	1.22	1.27	1.03	1.45
P100	1.23	1.22	1.31	1.06	1.49
P500	1.22	1.21	1.38	1.11	1.58
P1000	1.21	1.21	1.41	1.12	1.62

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.04	1.19	1.04	0.84	1.07
Ps	1.13	1.11	1.41	0.95	0.93
P5	1.03	1.17	1.04	0.85	1.08
P10	1.05	1.16	1.11	0.87	1.04
P50	1.12	1.16	1.29	0.92	0.98
P100	1.15	1.15	1.36	0.95	0.95
P500	1.23	1.15	1.55	0.99	0.89
P1000	1.27	1.15	1.64	1.02	0.87

We observe from Table 4.2.2 that the scenario values have a 20 % increase for the annual values of duration one day, and a similar increase for the 5-day duration. For the one-day duration there is an increase for all seasons and most pronounced for spring and autumn. For the five-day duration we have an increase in winter and spring and small changes for summer and autumn.

4.3 Station 18700 Blindern, Region 2.

Agreement between estimated extreme values from observed data and control data

Table 4.3.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.3.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (GEV). Pm and Ps are mean and standard deviation of extreme value series.

Station 18700, Blindern			
	Observed (1937-2001)		**Control data**
	Descriptive statistics		
Pm	35.9		38.3 (from 20 years sample)
Ps	8.7		14.6 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**GEV** (from 1000 years sample)
5	42.0	42.0	44.7
10	47.0	48.0	50.5
50	58.0	64.0	63.5
100	63.0	73.0	69.1
500	74.0	98.0	82.4
1000	78.0	112.0	88.3

We observe from Table 4.3.1 that the simulated extreme values correspond well (as a compromise) to the estimated extreme values from the observed series. The variability of the extreme values of the control data is higher than the observed, while the variability and mean of the extreme values from the simulated series are closer to those of the observed (see Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.3.2.

Table 4.3.2. Extreme values estimates for control and scenario data for 18700, region 2.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	37.8	23.1	22.9	31.6	29.8
Ps	9.8	9.7	8.6	9.7	8.4
P5	44.7	28.6	28.8	38.7	35.9
P10	50.5	34.6	34.04	44.3	40.8
P50	63.5	51.1	46.0	56.2	51.3
P100	69.1	59.6	51.2	61.2	55.7
P500	82.4	83.6	64.0	72.7	66.1
P1000	88.3	96.2	69.7	77.7	70.7
Distribution	GEV	GEV	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.7	9.5	10.8	12.8	13.6
Ps	4.6	3.8	4.6	3.9	4.4
P5	19.8	11.6	13.9	15.6	16.7
P10	22.5	14.0	16.7	17.9	19.3
P50	29.0	20.4	23.2	23.2	25.1
P100	31.9	23.5	26.0	25.5	27.7
P500	39.2	31.8	32.8	30.9	33.7
P1000	42.6	35.9	35.9	33.3	36.4
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	42.3	25.2	26.3	29.8	35.4
Ps	12.8	10.1	10.8	11.6	12.0
P5	51.2	31.9	33.3	37.7	43.4
P10	58.9	37.9	40.0	44.7	50.8
P50	76.5	53.4	56.2	60.9	68.0
P100	84.2	60.7	63.5	68.1	75.6
P500	102.8	79.0	82.0	85.7	94.4
P1000	111.2	87.7	90.6	93.7	103.0
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.7	10.7	10.9	11.9	14.0
Ps	4.2	3.5	4.3	4.1	4.3
P5	19.7	13.2	13.9	14.9	16.9
P10	22.3	15.3	16.5	17.2	19.5
P50	28.0	19.9	22.3	22.4	25.5
P100	30.5	21.8	24.9	24.6	28.2
P500	36.5	26.4	31.1	29.7	34.8
P1000	39.2	28.5	33.9	31.9	37.8
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.12	1.09	1.15	0.94	1.19
Ps	1.31	1.04	1.26	1.20	1.43
P5	1.15	1.12	1.16	0.97	1.21
P10	1.17	1.10	1.18	1.01	1.25
P50	1.20	1.05	1.22	1.08	1.33
P100	1.22	1.02	1.24	1.11	1.36
P500	1.25	0.94	1.28	1.18	1.43
P1000	1.26	0.91	1.30	1.21	1.46

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1	1.13	1.01	0.93	1.03
Ps	0.91	0.92	0.93	1.05	0.98
P5	0.99	1.14	1	0.96	1.01
P10	0.99	1.09	0.99	0.96	1.01
P50	0.97	0.98	0.96	0.97	1.02
P100	0.96	0.93	0.96	0.96	1.02
P500	0.93	0.83	0.95	0.96	1.03
P1000	0.92	0.79	0.94	0.96	1.04

From Table 4.3.2, we see that the scenario values have a 20 % increase for the annual values of duration of one day, and a small decrease for the 5-day duration. For the one-day duration there is a shift in seasonality with increase for spring, summer and autumn and a decrease for winter precipitation. For the five-day duration the changes are small except for a decrease in winter precipitation.

4.4 Station 24880, Nesbyen, Region 2.

Agreement between estimated extreme values from observed data and control data

Table 4.4.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.4.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 24880, Nesbyen			
	Observed (1977-2001)		**Control data**
	Descriptive statistics		
Pm	29.1		41.2 (from 20 years sample)
Ps	10.3		11.1 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	36.0	36.0	43.9
10	42.0	41.0	52.7
50	55.0	56.0	74.7
100	61.0	64.0	85.0
500	74.0	87.0	111.7
1000	80.0	99.0	124.4

We observe from Table 4.4.1 that the simulated extreme values are higher than the estimated extreme values from the observed series. The variability of the extreme values of the control data is higher than the observed, and this variability is slightly increased in the simulated series while the mean for the simulated series is closer to that of the observed (see Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.4.2.

Table 4.4.2. Extreme values estimates for control and scenario data for 24880, region 2.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	35.5	20.1	24.1	27.3	21.9
Ps	13.9	6.2	8.0	15.2	12.7
P5	43.9	24.4	29.4	36.5	30.2
P10	52.7	28.2	34.3	46.1	38.0
P50	74.7	36.9	45.6	69.9	56.4
P100	85.0	40.7	50.7	81.2	64.8
P500	111.7	49.9	63.1	109.9	85.4
P1000	124.4	54.2	68.7	123.6	94.8
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	15.3	8.8	11.7	10.4	9.5
Ps	5.8	3.1	3.9	5.7	5.7
P5	18.5	10.7	14.3	13.8	12.6
P10	22.2	12.6	16.7	17.4	16.3
P50	31.9	17.6	22.1	26.5	26.0
P100	36.6	20.0	24.4	30.8	30.8
P500	49.3	26.0	30.1	41.9	43.7
P1000	55.4	28.9	32.7	47.1	50.1
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	42.4	20.8	24.1	35.6	34.3
Ps	13.5	5.5	7.4	13.8	12.0
P5	51.5	25.0	29.6	44.5	42.5
P10	59.7	28.0	33.8	53.1	49.7
P50	78.8	34.4	43.0	73.5	66.4
P100	87.3	36.9	46.8	82.8	73.7
P500	108.0	42.8	55.8	105.9	91.4
P1000	117.5	45.3	59.6	116.7	99.4
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	18.2	9.4	12.0	14.5	14.3
Ps	6.1	3.1	4.7	5.5	5.4
P5	21.8	11.6	15.2	17.7	17.2
P10	25.7	13.5	18.1	21.2	20.6
P50	35.6	17.8	24.7	30.1	29.8
P100	40.3	19.8	27.6	34.4	34.4
P500	52.6	24.5	34.6	45.5	46.7
P1000	58.5	26.6	37.8	50.8	52.9
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.19	1.03	1	1.30	1.57
Ps	0.97	0.89	0.93	0.91	0.94
P5	1.17	1.02	1.01	1.22	1.41
P10	1.13	0.99	0.99	1.15	1.31
P50	1.05	0.93	0.94	1.05	1.18
P100	1.03	0.91	0.92	1.02	1.14
P500	0.97	0.86	0.88	0.96	1.07
P1000	0.94	0.85	0.87	0.94	1.05

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.19	1.07	1.03	1.39	1.50
Ps	1.05	1	1.21	0.96	0.95
P5	1.18	1.08	1.06	1.28	1.37
P10	1.16	1.07	1.08	1.22	1.26
P50	1.12	1.01	1.12	1.14	1.15
P100	1.10	0.99	1.13	1.12	1.12
P500	1.07	0.94	1.15	1.09	1.07
P1000	1.06	0.92	1.16	1.08	1.06

From Table 4.4.2, we see that the annual values for both durations have an increase for the smaller return periods, while the difference is small for the high return periods. Also the shift in seasonality is small.

4.5 Station 31620, Møsstrand, Region 2.

Agreement between estimated extreme values from observed data and control data

Table 4.5.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.5.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (GEV). Pm and Ps are mean and standard deviation of extreme value series.

Station 31620, Møsstrand			
	Observed (1980-2001)		**Control data**
	Descriptive statistics		
Pm	27.6		35.2 (from 20 years sample)
Ps	7.1		8.8 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**GEV** (from 1000 years sample)
5	32.0	32.0	43.2
10	36.0	37.0	49.3
50	45.0	51.0	64.2
100	49.0	58.0	71.1
500	58.0	80.0	88.7
1000	62.0	91.0	97.1

We observe from Table 4.5.1 that the simulated extreme values are higher than the estimated extreme values from the observed series. The mean and the variability of the extreme values of the control data is higher than the observed and further increased slightly for the simulated series (see Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.5.2.

Table 4.5.2. Extreme values estimates for control and scenario data for 31620, region 2.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	36.7	22.6	20.7	30.2	29.0
Ps	10.5	8.8	9.6	8.5	10.1
P5	43.2	28.3	26.9	35.8	33.9
P10	49.3	33.8	32.8	41.1	40.4
P50	64.2	46.6	47.0	53.3	58.3
P100	71.1	52.4	53.4	58.8	67.5
P500	88.7	66.7	69.4	72.4	92.9
P1000	97.1	73.3	76.8	78.6	105.8
Distribution	GEV	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.8	9.7	9.1	14.3	13.3
Ps	4.4	3.2	3.8	4.5	4.2
P5	19.9	12.0	11.6	17.4	16.2
P10	22.6	13.9	14.0	20.1	18.7
P50	28.4	18.0	19.4	26.1	24.3
P100	31.0	19.7	21.9	28.7	26.7
P500	37.1	23.8	27.9	34.9	32.4
P1000	39.8	25.7	30.6	37.7	34.9
Distribution	LN3	LN3	LN3	LN3	GEV

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	39.7	21.7	19.1	34.4	30.9
Ps	12.8	7.6	8.6	14.2	8.2
P5	47.6	25.2	25.0	43.5	36.9
P10	55.7	30.0	30.3	52.3	41.6
P50	75.4	43.9	42.4	73.3	51.5
P100	84.6	51.1	47.8	82.8	55.6
P500	108.0	71.7	60.9	106.7	65.1
P1000	119.0	82.3	66.9	117.8	69.1
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	16.8	9.7	8.5	14.3	13.4
Ps	5.0	2.9	3.8	5.3	3.8
P5	19.8	11.6	10.2	17.4	16.2
P10	23.0	13.4	12.6	20.7	18.5
P50	31.1	17.5	19.4	29.1	23.3
P100	34.9	19.4	22.9	33.1	25.3
P500	44.9	23.9	32.9	43.4	30.1
P1000	49.7	26.0	38.0	48.3	32.1
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.08	0.96	0.92	1.14	1.07
Ps	1.22	0.86	0.90	1.67	0.81
P5	1.10	0.89	0.93	1.22	1.09
P10	1.13	0.89	0.92	1.27	1.03
P50	1.17	0.94	0.90	1.37	0.88
P100	1.19	0.98	0.90	1.41	0.82
P500	1.22	1.07	0.88	1.47	0.70
P1000	1.23	1.12	0.87	1.50	0.65

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1	1	0.93	1	1.01
Ps	1.14	0.91	1	1.18	0.90
P5	0.99	0.97	0.88	1	1
P10	1.02	0.96	0.9	1.03	0.99
P50	1.10	0.97	1	1.11	0.96
P100	1.13	0.98	1.05	1.15	0.95
P500	1.21	1	1.18	1.24	0.93
P1000	1.25	1.01	1.24	1.28	0.92

From Table 4.5.2, we see that the annual values for both durations have an increase in the neighbourhood of 20 %. For the one-day duration there is a seasonality shift with increased precipitation in winter and summer, and a decrease for spring and autumn. For the five-day duration, there is a seasonality shift with increased precipitation for spring and summer, with small changes for winter and autumn.

4.6 Station 39040, Kjevik, Region 3.

Agreement between estimated extreme values from observed data and control data

Table 4.6.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.6.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 39040, Kjevik			
	Observed (1946-2001)		**Control data**
	Descriptive statistics		
Pm	59.6		41.6 (from 20 years sample)
Ps	15.3		7.8 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	70.0	70.0	48.1
10	79.0	78.0	53.6
50	99.0	102.0	65.9
100	107.0	114.0	71.3
500	127.0	147.0	84.2
1000	135.0	163.0	90.0

We observe from table 4.6.1 that the simulated extreme values are lower than the estimated extreme values from the observed series. The mean and variability of the extreme values of the control data are strongly reduced compared to the observed, and the simulated values are close to the control data.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.6.2.

Table 4.6.2. Extreme values estimates for control and scenario data for 39040, region 3.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	41.8	29.2	26.4	32.4	36.0
Ps	9.1	8.4	8.0	10.0	9.4
P5	48.1	35.2	32.3	39.5	43.1
P10	53.6	40.2	37.0	45.4	48.4
P50	65.9	51.2	47.0	58.8	59.4
P100	71.3	55.8	51.1	64.5	63.9
P500	84.2	66.9	60.9	78.2	74.1
P1000	90.0	71.8	65.1	84.4	78.4
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	19.1	12.5	11.7	12.8	16.0
Ps	5.8	4.7	4.8	4.6	5.5
P5	23.0	15.5	15.1	15.6	19.6
P10	26.5	18.4	18.0	18.5	23.0
P50	34.7	25.7	24.7	25.7	30.8
P100	38.4	29.1	27.6	29.1	34.3
P500	47.3	37.7	34.8	37.7	43.0
P1000	51.4	41.8	38.0	41.8	47.0
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	53.3	35.0	28.4	40.8	41.9
Ps	18.9	13.6	11.3	18.6	15.5
P5	64.1	42.8	35.7	51.3	50.6
P10	76.1	51.1	42.7	63.1	60.5
P50	107.2	73.1	59.4	93.7	86.2
P100	122.2	84.2	67.1	108.5	98.8
P500	161.7	114.8	86.1	147.5	131.9
P1000	180.8	130.4	94.9	166.4	148.1
Distribution	LN3	GEV	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	21.4	15.3	12.2	14.8	16.6
Ps	7.4	6.9	5.4	6.2	5.5
P5	25.5	18.8	15.6	18.4	19.8
P10	30.3	22.9	18.9	22.2	23.3
P50	42.7	34.8	27.4	32.0	32.2
P100	48.8	41.2	31.4	36.8	36.4
P500	64.9	60.3	42.1	49.9	47.5
P1000	72.8	70.7	47.4	56.4	52.8
Distribution	LN3	GEV	GEV	GEV	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.28	1.20	1.08	1.26	1.16
Ps	2.08	1.62	1.41	1.86	1.65
P5	1.33	1.22	1.11	1.30	1.17
P10	1.42	1.27	1.15	1.39	1.24
P50	1.63	1.43	1.26	1.59	1.45
P100	1.71	1.51	1.31	1.68	1.55
P500	1.92	1.72	1.41	1.89	1.78
P1000	2.01	1.82	1.46	1.97	1.89

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.12	1.22	1.04	1.16	1.04
Ps	1.28	1.47	1.13	1.35	1.00
P5	1.11	1.21	1.03	1.18	1.01
P10	1.14	1.24	1.05	1.20	1.01
P50	1.23	1.35	1.11	1.25	1.05
P100	1.27	1.42	1.14	1.26	1.06
P500	1.37	1.60	1.21	1.32	1.10
P1000	1.42	1.70	1.25	1.35	1.12

From table 4.6.2 we observe a significant increase for the simulated scenario extreme values. The annual value of one day duration is doubled, while the 5 day duration have an increase of 40 %. For both durations there is an increase for all seasons. There is only a minor shift in seasonality for the one day duration. For the 5 day duration the winter has the most obvious increase.

4.7 Station 44560 Sola, Region 4.

Agreement between estimated extreme values from observed data and control data

Table 4.7.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.7.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 44560, Sola			
	Observed (1953-2001)		**Control data**
	Descriptive statistics		
Pm	43.7		53.8 (from 20 years sample)
Ps	14.2		9.8 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	53.0	53.0	66.7
10	62.0	60.0	78.4
50	80.0	79.0	107.4
100	88.0	89.0	120.9
500	106.0	118.0	155.4
1000	113.0	133.0	171.8

We observe from Table 4.7.1 that the simulated extreme values are higher than the estimated extreme values from the observed series. The mean of the simulated extreme values is higher than the observed. The variability is also higher (see Table 4.1), although the variability in the control data is increased compared to the observed extreme values.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.7.2.

Table 4.7.2. Extreme values estimates for control and scenario data for 44560, region 4.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	55.3	43.9	32.6	30.6	44.0
Ps	18.6	15.0	15.8	11.1	18.0
P5	66.7	54.5	41.4	36.5	54.8
P10	78.4	63.5	51.4	43.5	66.2
P50	107.4	83.5	77.7	62.4	94.4
P100	120.9	92.1	90.6	71.7	107.7
P500	155.4	112.7	124.7	96.9	141.9
P1000	171.8	121.9	141.3	109.3	158.1
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	24.9	19.8	14.5	14.2	19.7
Ps	8.3	6.5	7.0	5.6	7.4
P5	28.6	24.6	18.3	17.5	23.7
P10	33.9	28.3	22.8	20.2	28.5
P50	49.2	36.0	34.6	26.1	41.0
P100	57.2	39.2	40.4	28.7	47.2
P500	79.9	46.4	55.9	34.6	63.8
P1000	91.6	49.5	63.5	37.2	72.0
Distribution	LN3	LN3	LN3	GEV	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	64.8	54.5	32.0	33.4	50.7
Ps	19.7	18.9	11.6	15.2	19.1
P5	76.3	66.4	38.7	41.6	63.7
P10	88.8	78.3	45.8	51.3	75.3
P50	120.5	107.1	64.5	77.0	102.0
P100	135.7	120.4	73.9	89.7	113.7
P500	175.1	154.0	99.6	123.7	142.3
P1000	194.1	169.8	112.7	140.5	155.2
Distribution	LN3	LN3	GEV	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	28.6	24.4	14.8	14.2	22.0
Ps	8.6	8.8	5.8	5.7	8.1
P5	34.3	30.3	17.7	17.9	28.7
P10	39.6	35.7	21.4	21.5	33.5
P50	51.8	48.2	31.6	29.9	42.9
P100	57.3	53.8	36.7	33.7	46.6
P500	70.6	67.5	50.8	43.1	54.7
P1000	76.7	73.8	57.9	47.5	58.0
Distribution	LN3	LN3	LN3	LN3	gam2

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.17	1.24	0.98	1.09	1.15
Ps	1.06	1.26	0.73	1.37	1.06
P5	1.14	1.22	0.93	1.14	1.16
P10	1.13	1.23	0.89	1.18	1.14
P50	1.12	1.28	0.83	1.23	1.08
P100	1.12	1.31	0.82	1.25	1.06
P500	1.13	1.37	0.80	1.28	1.00
P1000	1.13	1.39	0.80	1.29	0.98

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.15	1.23	1.02	1.00	1.12
Ps	1.04	1.35	0.83	1.02	1.09
P5	1.20	1.23	0.97	1.02	1.21
P10	1.17	1.26	0.94	1.06	1.18
P50	1.05	1.34	0.91	1.15	1.05
P100	1.00	1.37	0.91	1.17	0.99
P500	0.88	1.45	0.91	1.25	0.86
P1000	0.84	1.49	0.91	1.28	0.81

From table 4.7.2 we see that the scenario values have a nearly 15 % increase for the annual values of duration one day, and a corresponding decrease for the 5 day duration. For both durations there is a shift in seasonality with increased extreme events in summer and winter and decrease or unchanged conditions in spring and autumn.

4.8 Station 46610 Sauda, Region 5.

Agreement between estimated extreme values from observed data and control data

Table 4.8.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.8.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (GEV). Pm and Ps are mean and standard deviation of extreme value series.

Station 46610 Sauda			
	Observed (1954-2001)		**Control data**
	Descriptive statistics		
Pm	71.0		50.9 (from 20 years sample)
Ps	15.2		8.6 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**GEV** (from 1000 years sample)
5	81.0	81.0	69.2
10	90.0	90.0	78.5
50	110.0	116.0	100.2
100	118.0	129.0	110.0
500	137.0	164.0	133.8
1000	145.0	182.0	144.7

From Table 4.8.1 we see that the simulated extreme values for all return periods are reduced compared to the observed series as a consequence of decreased mean in the control data. There is a decrease in the variability of the control extreme values compared to observed series as well (Table 4.1), but this is not reflected in the simulated control extreme values.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.8.2

Table 4.8.2. Extreme values estimates for control and scenario data for 46610, region 5.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	58.7	49.8	35.6	35.9	46.4
Ps	15.4	16.1	13.6	11.3	14.3
P5	69.2	61.0	45.0	43.7	56.5
P10	78.5	70.5	53.1	50.5	65.0
P50	100.2	92.4	71.5	66.3	84.0
P100	110.0	102.0	79.6	73.2	92.2
P500	133.8	124.9	99.0	90.0	111.7
P1000	144.7	135.1	107.6	97.6	120.5
Distribution	GEV	GEV	GEV	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	30.7	25.7	17.7	18.3	24.2
Ps	8.6	8.4	7.7	5.7	7.6
P5	36.0	31.3	22.3	22.3	29.7
P10	41.5	36.4	27.2	25.8	34.1
P50	54.8	48.5	39.5	33.5	44.0
P100	61.0	53.9	45.3	36.9	48.1
P500	76.8	67.1	60.4	45.0	58.0
P1000	84.3	73.2	67.6	48.7	62.4
Distribution	LN3	LN3	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	71.9	56.4	37.3	41.1	62.0
Ps	21.7	17.6	16.4	15.8	21.8
P5	83.0	69.9	46.6	50.9	72.9
P10	96.9	79.7	57.1	60.5	86.8
P50	134.7	100.0	84.2	84.6	125.2
P100	153.7	108.2	97.3	96.1	144.8
P500	205.5	126.9	131.8	126.2	198.4
P1000	231.4	134.8	148.6	140.8	225.4
Distribution	LN3	LN3	LN3	GEV	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	34.8	27.8	18.3	19.9	29.9
Ps	9.0	9.3	8.4	6.4	8.4
P5	40.7	34.5	23.1	24.5	35.6
P10	46.3	40.0	28.5	28.2	40.7
P50	59.6	52.0	42.3	36.6	52.3
P100	65.6	57.2	49.0	40.1	57.4
P500	80.7	69.2	66.6	48.4	69.8
P1000	87.7	74.5	75.1	51.9	75.4
Distribution	LN3	LN3	LN3	GEV	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.22	1.13	1.05	1.14	1.34
Ps	1.41	1.09	1.21	1.40	1.52
P5	1.20	1.15	1.04	1.16	1.29
P10	1.23	1.13	1.08	1.20	1.34
P50	1.34	1.08	1.18	1.28	1.49
P100	1.40	1.06	1.22	1.31	1.57
P500	1.54	1.02	1.33	1.40	1.78
P1000	1.60	1.00	1.38	1.44	1.87

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.13	1.08	1.03	1.09	1.24
Ps	1.05	1.11	1.09	1.12	1.11
P5	1.13	1.10	1.04	1.10	1.20
P10	1.12	1.10	1.05	1.09	1.19
P50	1.09	1.07	1.07	1.09	1.19
P100	1.08	1.06	1.08	1.09	1.19
P500	1.05	1.03	1.10	1.08	1.20
P1000	1.04	1.02	1.11	1.07	1.21

From table 4.8.2 we observe an increase of 60 % for the scenario values for the annual values of duration one day. It is expected that this increase will occur in spring, summer and autumn. In winter, the conditions are unchanged. For the 5 day duration we only notice a minor increase for the annual values. Still, the scenario extreme values for the winter are unchanged. All other seasons have an increase.

4.9 Station 50540 Bergen, Region 6.

Agreement between estimated extreme values from observed data and control data

Table 4.9.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.9.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 50540 Bergen			
	Observed (1983-2001)		**Control data**
	Descriptive statistics		
Pm	68.4		79.8 (from 20 years sample)
Ps	16.7		22.3 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	80.0	80.0	92.0
10	90.0	89.0	106.1
50	111.0	115.0	138.9
100	120.0	127.0	153.5
500	141.0	163.0	189.3
1000	150.0	181.0	205.6

We observe from Table 4.9.1 that the simulated extreme values are higher than the estimated extreme values from the observed series. The mean and the variability of the extreme values of the control data are higher than the observed, but the statistical properties of the simulated series correspond quite good with the original control values (Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.9.2.

Table 4.9.2. Extreme values estimates for control and scenario data for 50540, region 6.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	76.5	61.8	50.2	39.9	60.8
Ps	23.1	24.1	18.3	12.3	19.7
P5	92.0	78.1	61.5	48.5	73.6
P10	106.1	92.7	73.0	55.8	85.9
P50	138.9	126.5	101.5	72.4	114.9
P100	153.5	141.4	114.8	79.5	128.0
P500	189.3	177.9	148.7	96.7	160.7
P1000	205.6	194.4	164.8	104.4	175.8
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	38.6	29.5	26.6	20.5	31.0
Ps	11.3	10.8	11.3	5.9	9.8
P5	45.8	36.7	33.8	24.9	37.9
P10	52.7	43.3	40.8	28.3	43.6
P50	69.5	58.7	57.9	35.4	56.5
P100	77.4	65.5	65.8	38.4	62.0
P500	97.4	82.3	85.5	45.1	74.9
P1000	106.9	90.0	94.7	48.1	80.6
Distribution	GEV	LN3	LN3	LN3	GEV

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	90.6	80.5	47.1	54.1	70.8
Ps	23.5	25.2	14.1	16.4	21.9
P5	107.5	98.6	57.0	65.8	86.9
P10	121.3	113.4	65.4	75.5	99.6
P50	151.6	146.1	84.2	97.1	126.9
P100	164.5	160.0	92.4	106.4	138.4
P500	194.9	192.9	111.9	128.4	165.0
P1000	208.3	207.5	120.6	138.2	176.6
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	45.5	39.8	23.7	27.3	34.8
Ps	13.5	15.5	8.6	7.1	9.9
P5	53.3	49.4	29.5	32.8	42.4
P10	61.9	59.2	34.7	36.8	47.9
P50	83.7	82.8	46.9	45.1	59.3
P100	94.2	93.8	52.4	48.3	63.9
P500	121.6	121.5	65.7	55.3	74.4
P1000	134.8	134.5	71.7	58.1	78.9
Distribution	LN3	LN3	LN3	GEV	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.18	1.30	0.94	1.36	1.16
Ps	1.02	1.05	0.77	1.33	1.11
P5	1.17	1.26	0.93	1.36	1.18
P10	1.14	1.22	0.90	1.35	1.16
P50	1.09	1.15	0.83	1.34	1.10
P100	1.07	1.13	0.80	1.34	1.08
P500	1.03	1.08	0.75	1.33	1.03
P1000	1.01	1.07	0.73	1.32	1.00

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.18	1.35	0.89	1.33	1.12
Ps	1.19	1.44	0.76	1.20	1.01
P5	1.16	1.35	0.87	1.32	1.12
P10	1.17	1.37	0.85	1.30	1.10
P50	1.20	1.41	0.81	1.27	1.05
P100	1.22	1.43	0.80	1.26	1.03
P500	1.25	1.48	0.77	1.23	0.99
P1000	1.26	1.49	0.76	1.21	0.98

From table 4.9.2 we observe that the scenario values have an increase for events of high frequency (annual values, duration one day) and unchanged conditions for rare events. This pattern can be identified for some seasons as well. We also observe a shift in seasonality with decrease in spring and increase in summer. For the 5 day duration there is a 26 % increase for annual values and a shift in seasonality with decrease in spring and increase in winter and summer.

4.10 Station 51590 Voss, Region 6.

Agreement between estimated extreme values from observed data and control data

Table 4.10.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.10.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 51590, Voss			
	Observed (1967-2001)		**Control data**
	Descriptive statistics		
Pm	44.8		53.2 (from 20 years sample)
Ps	9.5		10.0 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	51.0	58.0	68.6
10	57.0	68.0	79.2
50	69.0	87.0	104.1
100	74.0	114.0	115.2
500	86.0	129.0	142.8
1000	91.0	238.0	155.4

It seems difficult to compare observed with simulated data as the estimated extreme values from the observed data differs considerably due to choice of method. The overestimation for events of high frequency can be explained by higher mean for the control data than observed extreme values. The variability is also significantly higher in the simulated data compared to the observed (Table 4.1). For high return periods the extreme values lie between the estimates from the Gumbel and NERC distribution.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.10.2.

Table 4.10.2. Extreme values estimates for control and scenario data for 51590, region 6.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	57.2	47.5	36.7	33.2	42.4
Ps	17.2	17.1	14.3	11.5	15.6
P5	68.6	59.4	45.2	41.1	53.0
P10	79.2	69.6	54.3	48.1	62.3
P50	104.1	92.9	77.2	64.0	83.9
P100	115.2	103.1	88.0	71.0	93.5
P500	142.8	127.6	116.1	87.9	116.7
P1000	155.4	138.6	129.5	95.6	127.3
Distribution	LN3	LN3	LN3	LN3	GEV

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	30.8	25.3	20.5	17.7	22.7
Ps	8.7	8.2	8.4	5.8	8.3
P5	36.8	31.2	26.0	21.7	28.5
P10	42.1	36.1	31.1	25.2	33.4
P50	54.0	46.5	43.6	33.4	44.7
P100	59.2	50.9	49.4	37.0	49.6
P500	71.7	61.3	64.3	45.7	61.4
P1000	77.4	65.8	71.4	49.7	66.6
Distribution	LN3	LN3	GEV	LN3	GEV

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	63.7	53.0	34.5	39.9	53.5
Ps	16.6	15.4	10.0	12.9	17.6
P5	74.2	63.0	41.5	49.1	65.3
P10	84.2	72.6	47.5	56.6	76.1
P50	108.7	95.2	60.8	73.0	101.3
P100	120.2	105.4	66.5	80.0	112.5
P500	149.6	130.9	80.2	96.1	140.1
P1000	163.5	142.7	86.4	102.9	152.8
Distribution	GEV	LN3	LN3	GEV	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	34.5	29.6	19.3	20.3	28.0
Ps	9.5	9.7	6.3	5.8	9.0
P5	39.6	34.9	23.8	24.7	33.7
P10	45.7	41.1	27.5	27.9	39.3
P50	61.8	57.6	35.8	34.6	52.8
P100	69.8	65.7	39.4	37.3	59.1
P500	91.1	87.4	47.7	43.5	74.8
P1000	101.6	98.0	51.4	46.1	82.1
Distribution	LN3	LN3	GEV	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.11	1.12	0.94	1.20	1.26
Ps	0.97	0.90	0.70	1.12	1.13
P5	1.08	1.06	0.92	1.19	1.23
P10	1.06	1.04	0.87	1.18	1.22
P50	1.04	1.02	0.79	1.14	1.21
P100	1.04	1.02	0.76	1.13	1.20
P500	1.05	1.03	0.69	1.09	1.20
P1000	1.05	1.03	0.67	1.08	1.20

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.12	1.17	0.94	1.15	1.23
Ps	1.09	1.18	0.75	1.00	1.08
P5	1.08	1.12	0.92	1.14	1.18
P10	1.09	1.14	0.88	1.11	1.18
P50	1.14	1.24	0.82	1.04	1.18
P100	1.18	1.29	0.80	1.01	1.19
P500	1.27	1.43	0.74	0.95	1.22
P1000	1.31	1.49	0.72	0.93	1.23

From table 4.10.2 we see that the simulated scenarios indicate 5-10 % higher extreme values than the control climate for the annual values of duration one day. Again we observe decreasing extreme events as the return period increase. We also observe a shift in seasonality with decrease in spring and increase in summer and autumn. For the 5 day duration the scenario data have a 30 % increase for the annual values, which mainly occur in autumn and winter. In spring and summer the tendency is decreasing.

4.11 Station 60990 Vigra, Region 8.

Agreement between estimated extreme values from observed data and control data

Table 4.11.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.11.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 60990, Vigra			
	Observed (1958-2001)		**Control data**
	Descriptive statistics		
Pm	44.9		56.3 (from 20 years sample)
Ps	11.2		18.9 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	52.0	52.0	58.1
10	59.0	59.0	65.8
50	73.0	78.0	83.3
100	80.0	88.0	91.0
500	94.0	116.0	109.3
1000	100.0	131.0	117.6

We observe from Table 4.11.1 that the simulated extreme values correspond well to the estimated extreme values for the observed series, at least for high return periods. The mean and variability of the simulated extreme values are very close to those of the observed (see Table 4.1), although the statistical characteristics for the control data set are not satisfactory.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.11.2.

Table 4.11.2. Extreme values estimates for control and scenario data for 60990, region 8.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	49.2	37.4	34.1	31.2	40.6
Ps	12.9	11.9	12.2	9.7	13.0
P5	58.1	45.0	42.4	38.0	50.0
P10	65.8	52.4	49.8	43.7	57.7
P50	83.3	70.0	67.0	56.9	74.4
P100	91.0	78.0	74.7	62.7	81.6
P500	109.3	97.9	93.5	76.5	98.4
P1000	117.6	107.2	102.0	82.7	105.8
Distribution	LN3	LN3	GEV	GEV	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	26.5	20.1	18.0	15.7	21.3
Ps	7.9	6.3	7.4	4.9	7.8
P5	31.3	24.4	22.7	19.3	26.6
P10	36.1	28.2	27.0	22.1	31.3
P50	48.4	36.9	37.7	28.2	42.2
P100	54.3	40.7	42.6	30.7	47.1
P500	70.2	49.8	55.2	36.4	59.0
P1000	78.1	54.0	61.1	38.8	64.4
Distribution	GEV	LN3	GEV	GEV	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	57.8	50.9	28.8	35.5	44.6
Ps	16.1	18.5	8.6	9.0	12.7
P5	69.3	64.3	35.1	42.3	53.8
P10	78.8	75.2	40.1	47.3	61.2
P50	99.9	98.2	50.8	57.9	77.4
P100	108.9	108.9	55.2	62.3	84.3
P500	130.3	132.4	65.3	72.2	100.4
P1000	139.8	142.8	69.6	76.5	107.5
Distribution	LN3	LN3	GEV	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	30.2	25.8	15.4	18.1	23.4
Ps	10.0	11.2	4.8	5.0	6.8
P5	35.7	32.4	19.0	21.7	28.4
P10	41.8	39.5	21.7	24.6	32.4
P50	58.4	57.5	27.5	31.1	41.1
P100	66.9	66.1	29.8	33.9	44.7
P500	91.0	88.3	35.0	40.4	53.2
P1000	103.5	99.0	37.1	43.2	57.0
Distribution	GEV	LN3	GEV	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.17	1.36	0.84	1.14	1.10
Ps	1.25	1.55	0.70	0.93	0.98
P5	1.19	1.43	0.83	1.11	1.08
P10	1.20	1.44	0.81	1.08	1.06
P50	1.20	1.40	0.76	1.02	1.04
P100	1.20	1.40	0.74	0.99	1.03
P500	1.19	1.35	0.70	0.94	1.02
P1000	1.19	1.33	0.68	0.93	1.02

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.14	1.28	0.86	1.15	1.10
Ps	1.27	1.78	0.65	1.02	0.87
P5	1.14	1.33	0.84	1.12	1.07
P10	1.16	1.40	0.80	1.11	1.04
P50	1.21	1.56	0.73	1.10	0.97
P100	1.23	1.62	0.70	1.10	0.95
P500	1.30	1.77	0.63	1.11	0.90
P1000	1.33	1.83	0.61	1.11	0.89

We observe for table 4.11.2 that the scenario values have a 20 % and 30 % increase for the annual values of duration one day and 5 day respectively. For the one day duration there is a shift in seasonality with 30 % increase in winter and a similar decrease in spring. For the 5 day duration the increase in winter is even more pronounced, while there is a minor increase in summer and a decrease in spring and autumn.

4.12 Station 69100 Værnes, Region 9/10.

Agreement between estimated extreme values from observed data and control data

Table 4.12.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.12.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 69100 Værnes			
	Observed (1946-2001)		**Control data**
	Descriptive statistics		
Pm	33.2		34.6 (from 20 years sample)
Ps	9.9		5.6 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	40.0	40.0	41.1
10	46.0	45.0	46.5
50	58.0	62.0	58.9
100	64.0	70.0	64.5
500	76.0	95.0	78.3
1000	81.0	108.0	84.6

From table 4.12.1 we see that the simulated extreme values correspond well to the estimated extreme values from the observed series. The mean and variability from the two series are close(see Table 4.1), although the variability of the control data is considerably lower than the observed.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.12.2.

Table 4.12.2. Extreme values estimates for control and scenario data for 69100, region 9/10.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	35.4	27.0	24.0	29.1	26.7
Ps	8.6	8.2	7.5	7.2	8.9
P5	41.1	32.3	29.2	34.5	32.4
P10	46.5	37.4	33.7	38.7	37.8
P50	58.9	49.6	44.2	47.4	50.6
P100	64.5	55.2	48.9	51.1	56.5
P500	78.3	69.1	60.1	59.4	71.3
P1000	84.6	75.6	65.1	63.0	78.2
Distribution	LN3	LN3	LN3	LN3	GEV

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	19.6	15.1	13.3	15.5	14.1
Ps	4.8	4.6	4.5	4.2	5.0
P5	22.9	18.4	16.5	18.5	17.4
P10	25.8	21.1	19.2	21.0	20.5
P50	32.4	27.1	25.1	26.4	27.7
P100	35.3	29.6	27.6	28.7	31.0
P500	42.3	35.5	33.5	34.1	39.0
P1000	45.5	38.1	36.0	36.5	42.6
Distribution	LN3	LN3	GEV	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	42.2	27.7	23.0	37.0	33.2
Ps	11.6	6.7	6.6	12.8	9.5
P5	49.3	32.7	27.4	45.2	39.9
P10	56.6	36.5	31.5	53.2	45.5
P50	74.7	44.9	41.1	72.4	58.1
P100	83.1	48.4	45.5	81.3	63.5
P500	104.6	56.5	56.2	103.5	76.3
P1000	114.8	60.0	61.1	113.9	82.0
Distribution	LN3	LN3	LN3	LN3	GEV

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	21.3	15.8	12.8	17.5	16.9
Ps	5.0	4.4	3.6	5.6	4.7
P5	24.8	19.2	15.6	21.2	20.3
P10	27.9	21.7	17.6	24.6	23.0
P50	34.7	26.9	21.8	32.5	28.7
P100	37.7	29.0	23.5	36.1	31.0
P500	44.8	33.6	27.4	44.9	36.5
P1000	48.0	35.4	29.0	48.9	38.8
Distribution	LN3	GEV	LN3	GEV	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.19	1.03	0.96	1.27	1.24
Ps	1.35	0.82	0.88	1.78	1.07
P5	1.20	1.01	0.94	1.31	1.23
P10	1.22	0.98	0.93	1.37	1.20
P50	1.27	0.91	0.93	1.53	1.15
P100	1.29	0.88	0.93	1.59	1.12
P500	1.34	0.82	0.94	1.74	1.07
P1000	1.36	0.79	0.94	1.81	1.05

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.09	1.05	0.96	1.13	1.20
Ps	1.04	0.96	0.80	1.33	0.94
P5	1.08	1.04	0.95	1.15	1.17
P10	1.08	1.03	0.92	1.17	1.12
P50	1.07	0.99	0.87	1.23	1.04
P100	1.07	0.98	0.85	1.26	1.00
P500	1.06	0.95	0.82	1.32	0.94
P1000	1.05	0.93	0.81	1.34	0.91

We observe from table 4.12.2 that the scenario values have a 36 % increase for the annual values of duration one day, whereas there is a minor increase for the 5 day duration. For the one day duration there is at shift in seasonality with decrease in winter and spring and increase in summer and autumn. For the 5 days event we observe an increase in summer and decrease for all other seasons.

4.13 Station 72100 Namdalseid, Region 10.

Agreement between estimated extreme values from observed data and control data

Table 4.13.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.13.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 72100 Namdalseid			
	Observed (1895-2001)		**Control data**
	Descriptive statistics		
Pm	39.7		43.3 (from 20 years sample)
Ps	11.4		14.7 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	47.0	47.0	48.2
10	54.0	53.0	55.3
50	69.0	71.0	72.5
100	75.0	81.0	80.5
500	89.0	107.0	100.5
1000	96.0	121.0	109.9

We observe from table 4.13.1 that there is good correspondence between simulated and observed extreme values as mean and variability for both series are almost identical (Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.13.2

Table 4.13.2. Extreme values estimates for control and scenario data for 72100, region 10.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	41.0	32.7	29.3	27.7	28.5
Ps	11.4	11.4	12.3	8.6	9.0
P5	48.2	40.9	36.9	33.8	35.3
P10	55.3	47.6	44.4	38.9	40.5
P50	72.5	62.4	63.3	50.3	51.2
P100	80.5	68.7	72.4	55.2	55.6
P500	100.5	83.5	96.4	66.6	65.7
P1000	109.9	90.1	108.1	71.6	70.1
Distribution	LN3	LN3	GEV	GEV	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	20.9	16.2	14.1	13.6	14.6
Ps	7.0	6.0	7.0	4.5	5.4
P5	24.2	20.1	17.0	16.8	18.5
P10	28.7	23.7	21.4	19.4	21.6
P50	41.1	32.5	34.5	25.0	28.4
P100	47.5	36.6	41.6	27.3	31.2
P500	65.1	46.8	62.0	32.8	37.9
P1000	74.1	51.6	72.8	35.1	40.8
Distribution	LN3	GEV	LN3	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	40.2	35.2	25.8	26.2	31.2
Ps	8.9	10.6	8.3	6.7	7.9
P5	47.0	43.3	32.0	31.1	37.2
P10	51.9	49.2	36.6	35.0	41.5
P50	62.0	61.5	46.3	43.3	50.4
P100	66.1	66.5	50.3	46.8	53.9
P500	75.3	77.9	59.3	54.9	61.9
P1000	79.3	82.8	63.1	58.4	65.2
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	20.6	17.5	13.4	13.3	16.0
Ps	4.8	5.4	4.8	3.3	4.4
P5	24.1	21.5	16.8	15.9	19.3
P10	26.9	24.6	19.7	17.8	21.9
P50	33.0	31.1	26.1	21.5	27.2
P100	35.6	33.8	28.9	23.0	29.4
P500	41.7	40.1	35.7	26.4	34.5
P1000	44.4	42.7	38.7	27.9	36.8
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	0.98	1.08	0.88	0.95	1.09
Ps	0.78	0.93	0.67	0.78	0.88
P5	0.98	1.06	0.87	0.92	1.05
P10	0.94	1.03	0.82	0.90	1.02
P50	0.86	0.99	0.73	0.86	0.98
P100	0.82	0.97	0.69	0.85	0.97
P500	0.75	0.93	0.62	0.82	0.94
P1000	0.72	0.92	0.58	0.82	0.93

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	0.99	1.08	0.95	0.98	1.10
Ps	0.69	0.90	0.69	0.73	0.81
P5	1.00	1.07	0.99	0.95	1.04
P10	0.94	1.04	0.92	0.92	1.01
P50	0.80	0.96	0.76	0.86	0.96
P100	0.75	0.92	0.69	0.84	0.94
P500	0.64	0.86	0.58	0.80	0.91
P1000	0.60	0.83	0.53	0.79	0.90

We observe from table 4.13.2 that the scenario values have a 30 % and 40 % decrease for the annual values of one day and 5 day duration respectively. The extreme events in spring are nearly halved, but the other seasons do also have a decrease.

4.14 Station 80700 Glomfjord, Region 11.

Agreement between estimated extreme values from observed data and control data

Table 4.14.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.14.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 80700 Glomfjord			
	Observed (1954-2001)		**Control data**
	Descriptive statistics		
Pm	83.6		55.5 (from 20 years sample)
Ps	28.6		19.3 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	104.0	104.0	54.4
10	120.0	115.0	61.4
50	157.0	145.0	77.5
100	173.0	159.0	84.6
500	209.0	199.0	101.8
1000	224.0	220.0	109.7

We observe from Table 4.14.1 that the simulated extreme values correspond badly to the estimated extreme values from the observed series. The mean and the variability of the extreme values of the control data are significant lower than the observed (Table 4.1), which explains the rather large deviations of the simulated extreme values. This is rather a special location that is subject to special weather patterns like residual tropical cyclones and extreme low pressure events during winter, both which are difficult to model with a GCM.

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.14.2.

Table 4.14.2. Extreme values estimates for control and scenario data for 80700, region 11.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	46.5	37.0	30.0	26.5	39.7
Ps	11.5	10.6	9.4	9.9	13.0
P5	54.4	44.8	36.8	34.2	48.7
P10	61.4	51.0	42.3	39.6	56.6
P50	77.5	64.1	54.5	50.5	74.2
P100	84.6	69.5	59.6	54.9	82.0
P500	101.8	82.2	71.4	64.6	100.5
P1000	109.7	87.7	76.5	68.6	108.8
Distribution	LN3	LN3	GEV	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	26.3	20.7	15.5	13.5	20.4
Ps	7.8	8.0	6.6	5.9	7.8
P5	31.7	26.2	20.0	18.0	25.8
P10	36.4	31.0	24.0	21.3	30.4
P50	47.2	42.1	33.2	28.0	41.1
P100	51.9	46.9	37.3	30.8	45.8
P500	63.3	58.6	47.2	36.9	57.1
P1000	68.4	63.8	51.7	39.5	62.1
Distribution	LN3	GEV	LN3	LN3	GEV

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	49.3	38.6	27.8	30.1	39.9
Ps	15.4	16.4	12.2	9.9	13.3
P5	59.2	49.0	35.3	36.8	49.4
P10	68.8	58.9	43.0	42.8	57.3
P50	91.9	83.6	62.0	56.7	74.8
P100	102.5	95.3	70.9	62.9	82.4
P500	129.1	125.4	93.6	78.0	100.4
P1000	141.4	139.8	104.3	84.8	108.3
Distribution	LN3	GEV	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	25.0	18.1	13.6	14.7	20.5
Ps	8.7	8.7	6.2	5.0	7.6
P5	30.4	23.3	17.5	18.1	25.2
P10	35.9	28.8	21.4	21.1	30.0
P50	49.4	42.5	30.8	28.2	41.6
P100	55.8	49.0	35.2	31.4	47.0
P500	72.0	65.6	46.1	39.2	60.7
P1000	79.6	73.5	51.2	42.7	67.1
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.06	1.04	0.93	1.14	1.01
Ps	1.34	1.55	1.30	1.00	1.02
P5	1.09	1.09	0.96	1.08	1.01
P10	1.12	1.15	1.02	1.08	1.01
P50	1.19	1.30	1.14	1.12	1.01
P100	1.21	1.37	1.19	1.15	1.00
P500	1.27	1.53	1.31	1.21	1.00
P1000	1.29	1.59	1.36	1.24	1.00

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	0.95	0.87	0.88	1.09	1.00
Ps	1.12	1.09	0.94	0.85	0.97
P5	0.96	0.89	0.88	1.01	0.98
P10	0.99	0.93	0.90	0.99	0.99
P50	1.05	1.01	0.93	1.01	1.01
P100	1.08	1.04	0.94	1.02	1.03
P500	1.14	1.12	0.98	1.06	1.06
P1000	1.17	1.15	0.99	1.08	1.08

From table 4.14.2 we see that the scenario values have a 29 % increase for the annual values of duration one day and a 17 % increase for the 5 day duration. The most pronounced increase occurs in winter. For the one day duration we observe an increase in spring and summer as well, while the 5 day duration experience further increase in summer and autumn.

4.15 Station 97250 Karasjok, Region 12.

Agreement between estimated extreme values from observed data and control data

Table 4.15.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.15.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 97250 Karasjok			
	Observed (1957-2001)		**Control data**
	Descriptive statistics		
Pm	24.9		23.1 (from 20 years sample)
Ps	8.0		6.2 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**LN3** (from 1000 years sample)
5	30.0	30.0	24.8
10	35.0	34.0	28.1
50	45.0	48.0	35.5
100	50.0	55.0	38.7
500	60.0	76.0	46.3
1000	64.0	87.0	49.7

We observe from Table 4.15.1 that the simulated extreme values are lower than the estimated extreme values from the observed series. The variability of the control data are lower than the observed, and the variability of the extreme values from the simulated series is enhanced still (Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.15.2.

Table 4.15.2. Extreme values estimates for control and scenario data for 97250, region 12.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	20.9	9.5	11.4	19.0	14.7
Ps	5.6	3.2	3.7	5.1	6.2
P5	24.8	11.8	13.9	22.9	18.4
P10	28.1	13.7	16.2	25.8	22.3
P50	35.5	17.9	21.3	31.6	31.8
P100	38.7	19.7	23.5	34.0	36.3
P500	46.3	24.0	29.0	39.3	47.6
P1000	49.7	25.9	31.4	41.5	52.9
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	9.0	4.7	5.3	8.0	6.4
Ps	2.4	2.1	1.3	2.2	2.4
P5	10.7	6.0	6.3	9.7	7.8
P10	12.1	7.3	7.0	10.9	9.4
P50	15.6	10.6	8.5	13.6	13.3
P100	17.1	12.1	9.0	14.7	15.3
P500	20.9	16.1	10.3	17.2	20.3
P1000	22.6	17.9	10.8	18.3	22.8
Distribution	LN3	LN3	GEV	LN3	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	23.1	9.5	10.6	22.2	16.1
Ps	6.1	2.6	4.0	6.4	4.3
P5	27.2	11.3	13.1	26.7	19.3
P10	30.9	12.8	15.6	30.6	21.7
P50	39.2	16.3	21.9	39.1	26.7
P100	42.9	17.9	24.9	42.7	28.7
P500	51.8	21.6	32.4	51.5	33.1
P1000	55.8	23.3	35.9	55.4	34.9
Distribution	LN3	LN3	LN3	LN3	GEV

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	9.8	4.4	4.8	9.3	7.2
Ps	2.4	1.1	1.5	2.7	1.8
P5	11.5	5.2	5.9	11.3	8.5
P10	13.0	5.8	6.8	12.8	9.6
P50	16.0	7.2	8.8	16.0	11.6
P100	17.3	7.7	9.6	17.3	12.5
P500	20.4	9.0	11.7	20.4	14.4
P1000	21.7	9.5	12.6	21.7	15.2
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.11	1.00	0.93	1.17	1.10
Ps	1.09	0.81	1.08	1.25	0.69
P5	1.10	0.96	0.94	1.17	1.05
P10	1.10	0.93	0.96	1.19	0.97
P50	1.10	0.91	1.03	1.24	0.84
P100	1.11	0.91	1.06	1.26	0.79
P500	1.12	0.90	1.12	1.31	0.70
P1000	1.12	0.90	1.14	1.33	0.66

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.09	0.94	0.91	1.16	1.13
Ps	1.00	0.52	1.15	1.23	0.75
P5	1.07	0.87	0.94	1.16	1.09
P10	1.07	0.79	0.97	1.17	1.02
P50	1.03	0.68	1.04	1.18	0.87
P100	1.01	0.64	1.07	1.18	0.82
P500	0.98	0.56	1.14	1.19	0.71
P1000	0.96	0.53	1.17	1.19	0.67

From table 4.15.2 we see that the scenario values have a 12 % increase for the annual values of duration one day and a smaller decrease for the 5 day duration. For both durations there are a shift in seasonality with increase in spring and summer and decrease in winter and autumn.

4.16 Station 98550 Vardø, Region 13.

Agreement between estimated extreme values from observed data and control data

Table 4.16.1 below displays estimated extreme values from observed data and the simulated control data. The descriptive statistics (**Pm** and **Ps**) for the control data are estimated from data generated by the atmospheric model.

Table 4.16.1. Comparison of extreme daily values estimated from observed series (Gumbel and NERC) and for control series (LN3). Pm and Ps are mean and standard deviation of extreme value series.

Station 98550 Vardø			
	Observed (1951-2001)		**Control data**
	Descriptive statistics		
Pm	24.0		22.5 (from 20 years sample)
Ps	7.9		10.2 (from 20 years sample)
	Estimated extreme values		
Return period (T)	**Gumbel**	**NERC**	**GEV** (from 1000 years sample)
5	29.0	29.0	28.1
10	34.0	33.0	33.4
50	44.0	46.0	45.9
100	48.0	53.0	51.6
500	58.0	74.0	65.9
1000	62.0	85.0	72.7

We observe from Table 4.16.1 that the simulated extreme values correspond well to the estimated extreme values from the observed series. The variability of the extreme values of the control data is higher than the observed, while the variability and mean of the extreme values from the simulated series are closer to those of the observed (Table 4.1).

Comparison of extreme values estimated from simulated series of control and scenario data

The estimated extreme values for the control data and the scenario data and the ratio between the estimated values can be seen in Table 4.16.2.

Table 4.16.2. Extreme values estimates for control and scenario data for 98550, region 13.

CONTROL (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	22.7	10.9	11.1	21.5	14.3
Ps	8.4	2.9	3.8	9.0	4.3
P5	28.1	12.9	13.6	27.5	17.3
P10	33.4	14.6	16.0	33.1	19.9
P50	45.9	18.5	21.8	45.9	25.8
P100	51.6	20.2	24.4	51.7	28.5
P500	65.9	24.2	31.0	65.8	34.8
P1000	72.5	26.0	34.1	72.3	37.7
Distribution	LN3	LN3	LN3	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	9.1	5.9	5.3	7.8	7.0
Ps	2.7	1.6	1.7	3.0	1.8
P5	10.7	7.0	6.4	9.7	8.2
P10	12.4	8.0	7.4	11.6	9.3
P50	16.8	10.3	9.8	16.2	11.7
P100	18.9	11.3	10.9	18.5	12.7
P500	24.3	13.8	13.7	24.3	15.2
P1000	26.9	14.9	15.0	27.1	16.2
Distribution	LN3	LN3	GEV	GEV	LN3

SCENARIO (1000 years)

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	26.0	12.7	13.0	23.6	18.6
Ps	10.1	3.6	4.3	11.1	5.5
P5	31.9	15.3	15.9	30.4	22.5
P10	38.3	17.4	18.5	37.4	25.7
P50	54.6	22.0	24.6	54.7	32.9
P100	62.4	23.9	27.4	62.8	35.9
P500	82.8	28.5	34.2	83.5	43.1
P1000	92.6	30.5	37.3	93.3	46.3
Distribution	LN3	LN3	GEV	LN3	LN3

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	11.0	6.4	5.8	9.0	9.2
Ps	3.6	1.8	1.8	4.0	2.8
P5	13.2	7.7	7.0	11.4	11.0
P10	15.5	8.8	8.1	13.9	12.7
P50	21.2	11.3	10.5	20.0	16.7
P100	23.8	12.4	11.6	22.9	18.4
P500	30.6	14.9	14.2	30.4	22.7
P1000	33.9	16.1	15.4	33.9	24.7
Distribution	LN3	LN3	LN3	LN3	LN3

Ratio between SCENARIO and CONTROL

Duration 1 day	Year	Winter	Spring	Summer	Autumn
Pm	1.15	1.17	1.17	1.10	1.30
Ps	1.20	1.24	1.13	1.23	1.28
P5	1.14	1.19	1.17	1.11	1.30
P10	1.15	1.19	1.16	1.13	1.29
P50	1.19	1.19	1.13	1.19	1.28
P100	1.21	1.18	1.12	1.21	1.26
P500	1.26	1.18	1.10	1.27	1.24
P1000	1.28	1.17	1.09	1.29	1.23

Duration 5 days	Year	Winter	Spring	Summer	Autumn
Pm	1.21	1.08	1.09	1.15	1.31
Ps	1.33	1.13	1.06	1.33	1.56
P5	1.23	1.10	1.09	1.18	1.34
P10	1.25	1.10	1.09	1.20	1.37
P50	1.26	1.10	1.07	1.23	1.43
P100	1.26	1.10	1.06	1.24	1.45
P500	1.26	1.08	1.04	1.25	1.49
P1000	1.26	1.08	1.03	1.25	1.52

From table 4.16.2 we see that the scenario data have a 25-30 % increase for the annual values for both durations. The increase occurs for all seasons. For the one day duration the increase is most pronounced in winter, summer and autumn. For the 5 day duration the increase mainly occurs in summer and autumn.

5. Discussion and conclusions

Whereas it is difficult to give a short summary of the results, the general impression of changes in the extreme precipitation regime due to possible climatic change is toward increased extreme values and seasonal shifts. The difference between control climate and scenario climate tends to be more dramatic for the short duration (1-day) than for the longer duration (5-days), although examples of the opposite are found. Neither the seasonality shifts or the relative changes in extreme values are consistent from one duration to another. The regional changes is therefore described separately for each of the 13 regions:

Region 1

The scenario values have an increase for the annual values of duration one day, whereas there is a minor decrease for the 5-day duration. For both durations we observe a significant increase of precipitation in winter, and a decrease in spring and summer.

Region 2

Totally 4 stations are investigated in region 2. Even though the region is assumed to be homogeneous, the variability within the region is noticeable; at least for analysis of seasonal values.

The simulated extreme values show that a 25 % increase in the scenario data is realistic for annual values. For the one day duration there is a shift in seasonality with increased extreme precipitation in autumn, but significant increases also occur in summer and spring for some of the stations. For the 5 days rainfall event the most pronounced increase occur in spring. Again we stress that the variability within the region makes it difficult to do generalizations.

Region 3

We observe a dramatic increase for the simulated scenario extremes. The increase occurs for both durations and for all seasons.

Region 4

We observe a nearly 15 % increase for the annual values of duration one day and a corresponding decrease for the 5 day duration. For both durations there is a shift in seasonality with increase in winter and summer and decrease in spring and autumn.

Region 5

For both durations there is an increase for annual values as well as for seasonality values, with autumn as the season with biggest changes. The increase is more pronounced for the one day than the 5 day duration.

Region 6

2 stations are considered in region 6. We observe a minor increase for the annual values for the one day duration combined with a shift in seasonality with decrease in spring and increase in summer/autumn. For the 5 day duration there is a significant increase for annual values. We also observe a shift in seasonality with increased extreme precipitation events in winter and decrease in spring.

Region 7

We have not been able to calibrate the precipitation simulation model for region 7, and further analysis is therefore not performed.

Region 8

We observe an increase for annual values and in the winter season. The changes are enhanced for the 5 day duration compared to the one day duration. We also observe a significant decrease in spring.

Region 9/10

The region is rather small, and the selected station may be representative for region 10 as well. We observe a major increase for the one day duration for annual values and a minor increase for the 5 day duration. There is a shift in seasonality with increase in summer and decrease in winter and spring for both durations.

Region 10

The results differs from all other regions as we here observe a considerable decrease for both annual and seasonal values. The decrease is most pronounced in spring.

Region 11

For both durations there is an increase for annual and most of the seasonal values. The increase is enhanced for the one day event compared to the 5 days event. We observe a shift in seasonality with the most pronounced increase in winter.

Region 12

The scenario values have an increase for the one day duration and a minor decrease for the 5 day duration. There is a shift in seasonality with an increasing tendency in spring and summer and decrease in winter and autumn.

Region 13

For both durations there is an increase for the annual values and for all seasons. The increase in summer and autumn is most pronounced.

The choice of extreme value distribution is, for each series, based on best fit according to visual assessment in frequency plots. Figures 2-5 show examples of such frequency plots, and we can observe that the choice of extreme value distributions is of little interest for return periods lower than $T = 200$ years. General extreme value distribution (GEV) and three parameter log normal distribution (LN3) give very similar results for all return periods for nearly all cases. For the cases where LN3 is chosen instead of GEV, the LN3 produced a closer fit to the data for the very high return periods.

An obvious topic for further research is to improve the downscaling methods. Under the (perhaps too optimistic) assumption that the atmospheric model is able to reproduce the current climate for the large scale, we need theoretical tools for describing the transformation of the statistical parameters going from one scale to another.

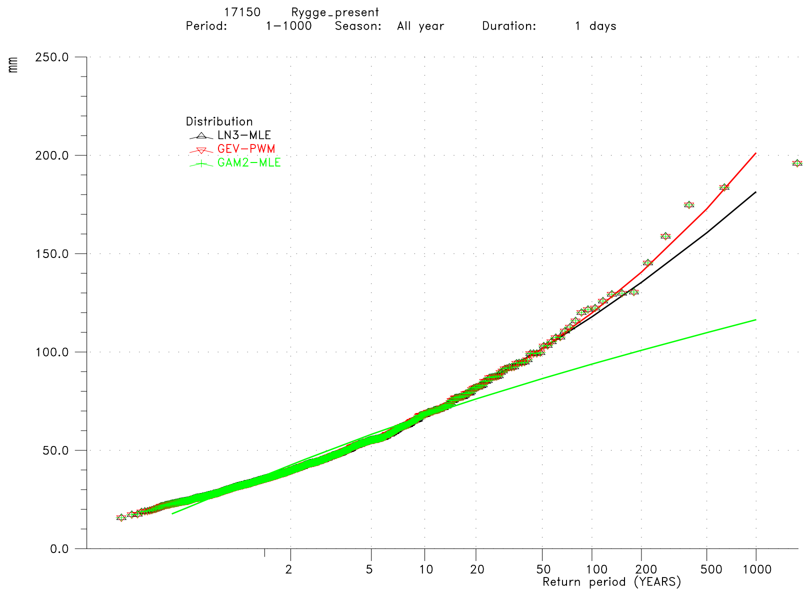

Figure 2. Fit of distribution functions for station 17150, control data. Duration, 1 day.

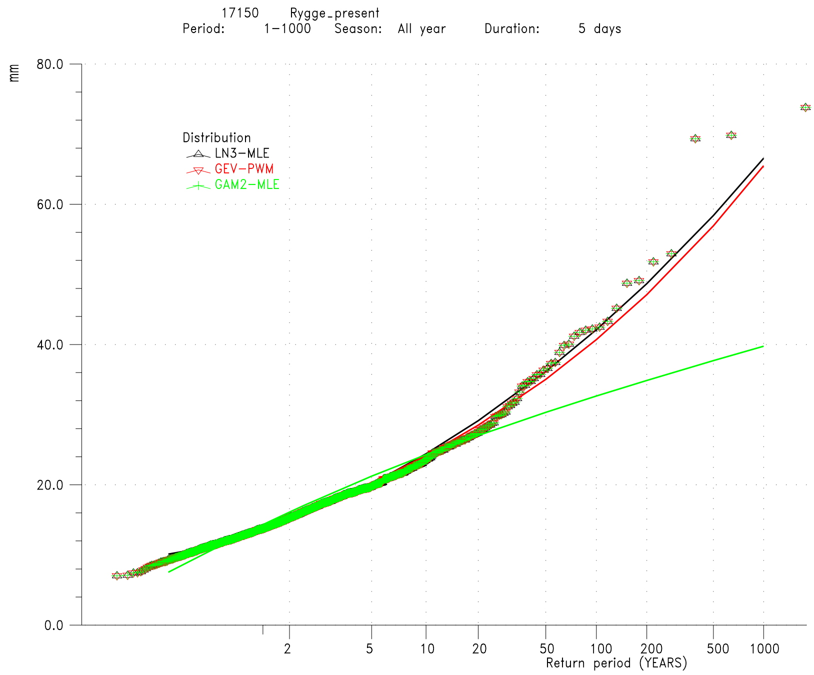

Figure 3. Fit of distribution functions for station 17150, control data. Duration, 5 days.

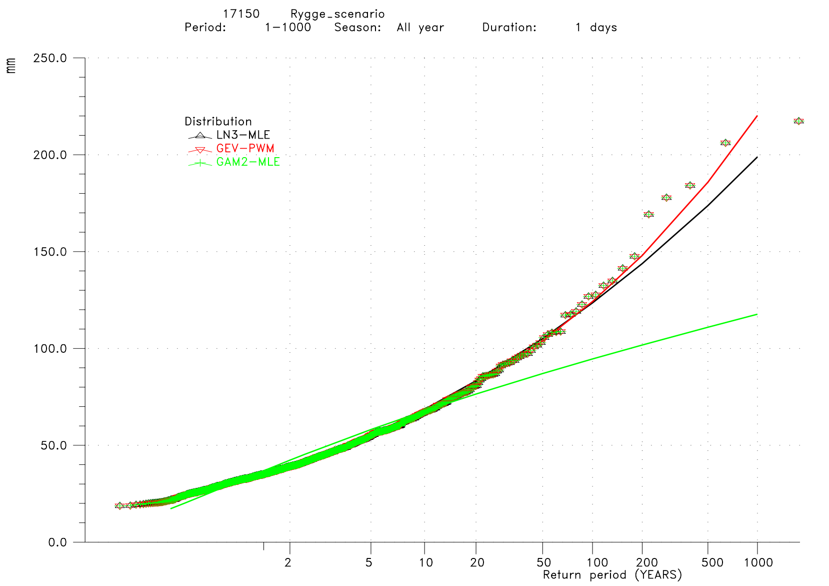

Figure 4. Fit of distribution functions for station 17150, scenario data. Duration 1 day.

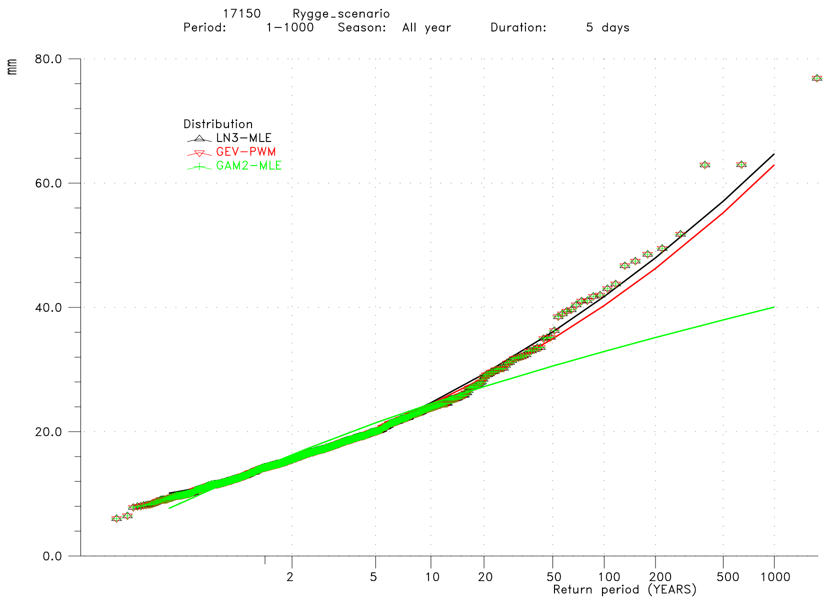

Figure 5. Fit of distribution functions for station 17150, scenario data. Duration, 5 days.

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Annexe A

Presentation of relative differences of extreme precipitation values for control - and scenario climate on maps

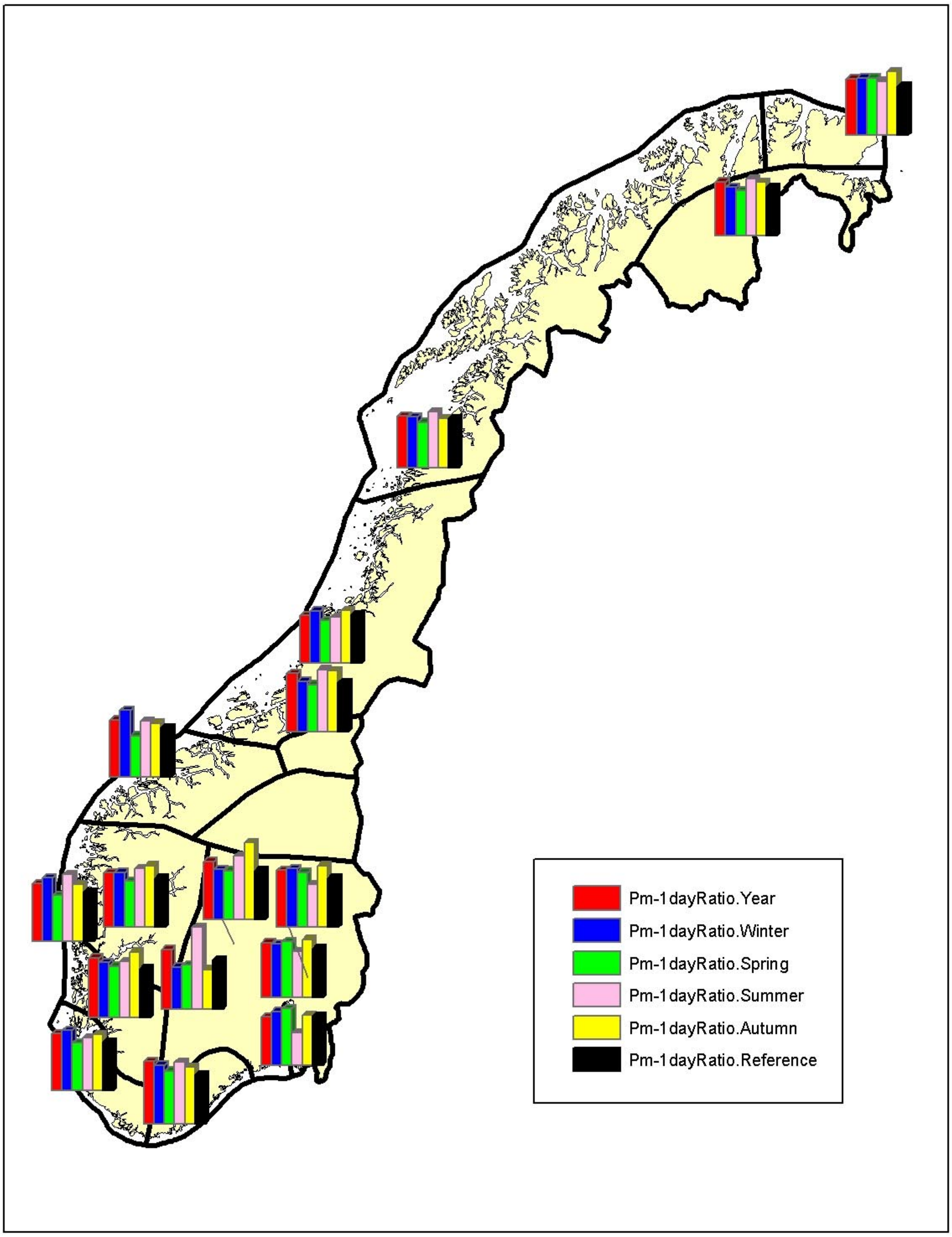

Figure A 1 Regional distribution of the relative change in mean of extreme values (Pm), duration one day. The black column is for reference with height implying no change.

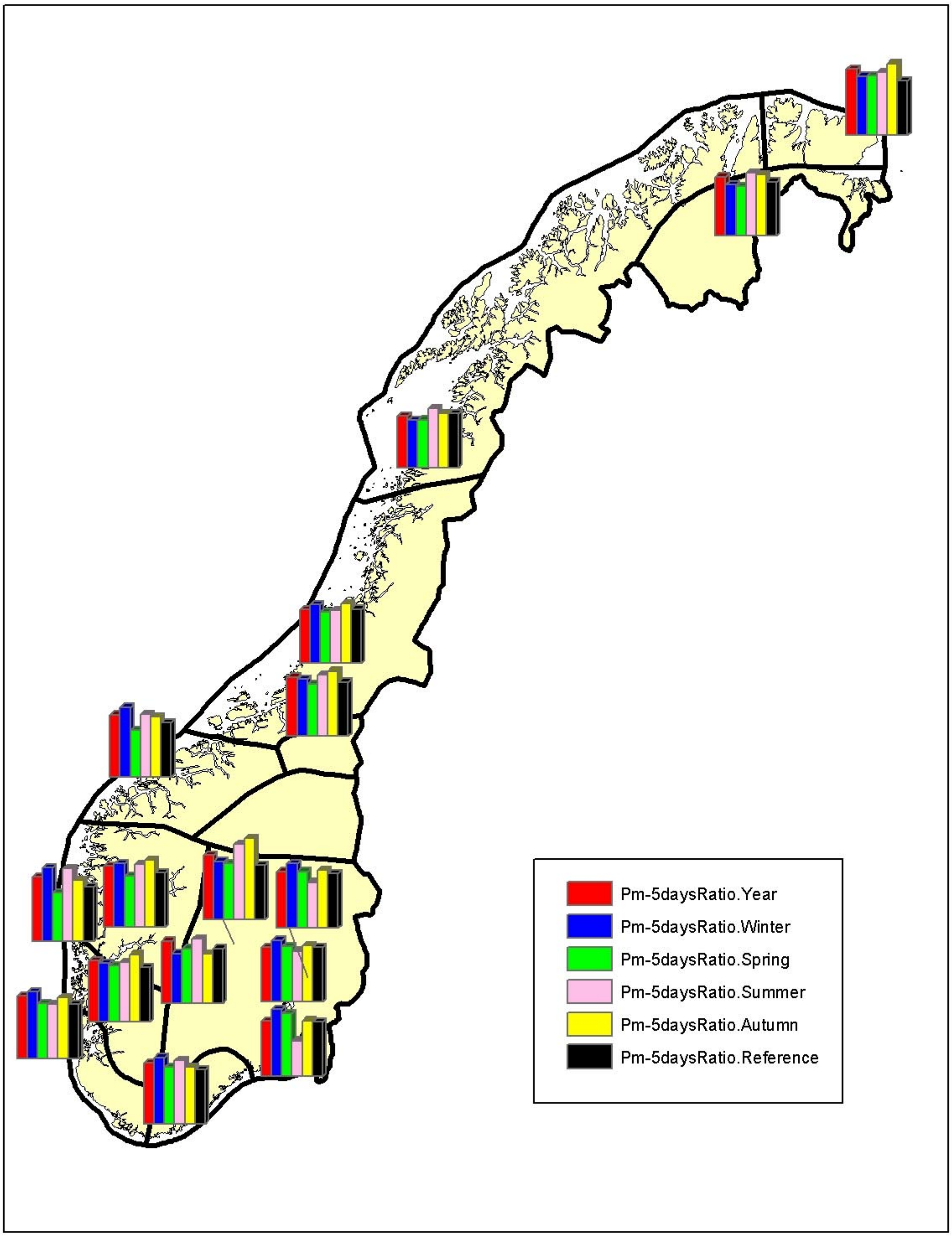

Figure A 2 Regional distribution of the relative change in mean of extreme values (Pm), duration 5 days. The black column is for reference with height implying no change.

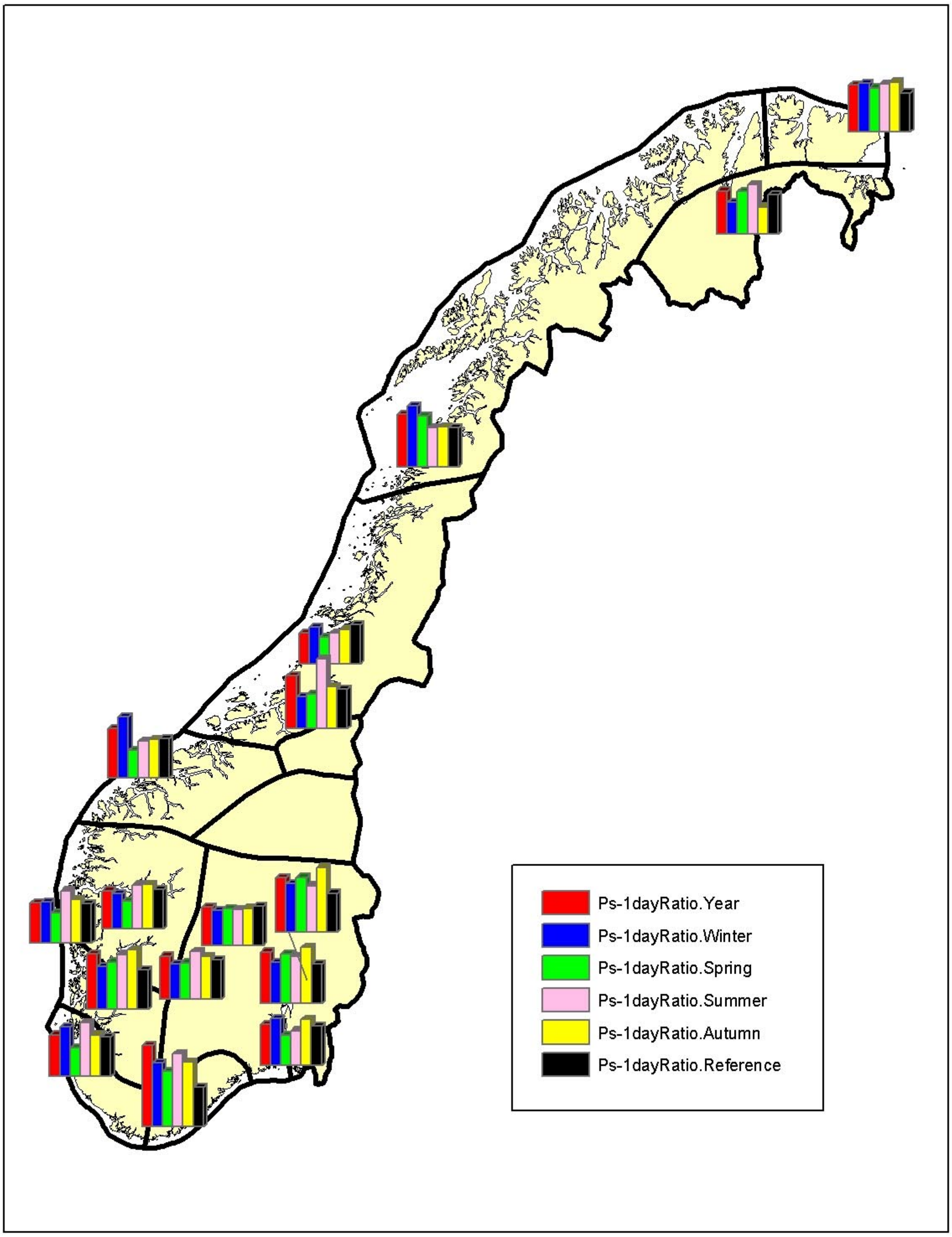

Figure A 3 Regional distribution of the relative change in standard deviation of extreme values (Ps), duration one day. The black column is for reference with height implying no change.

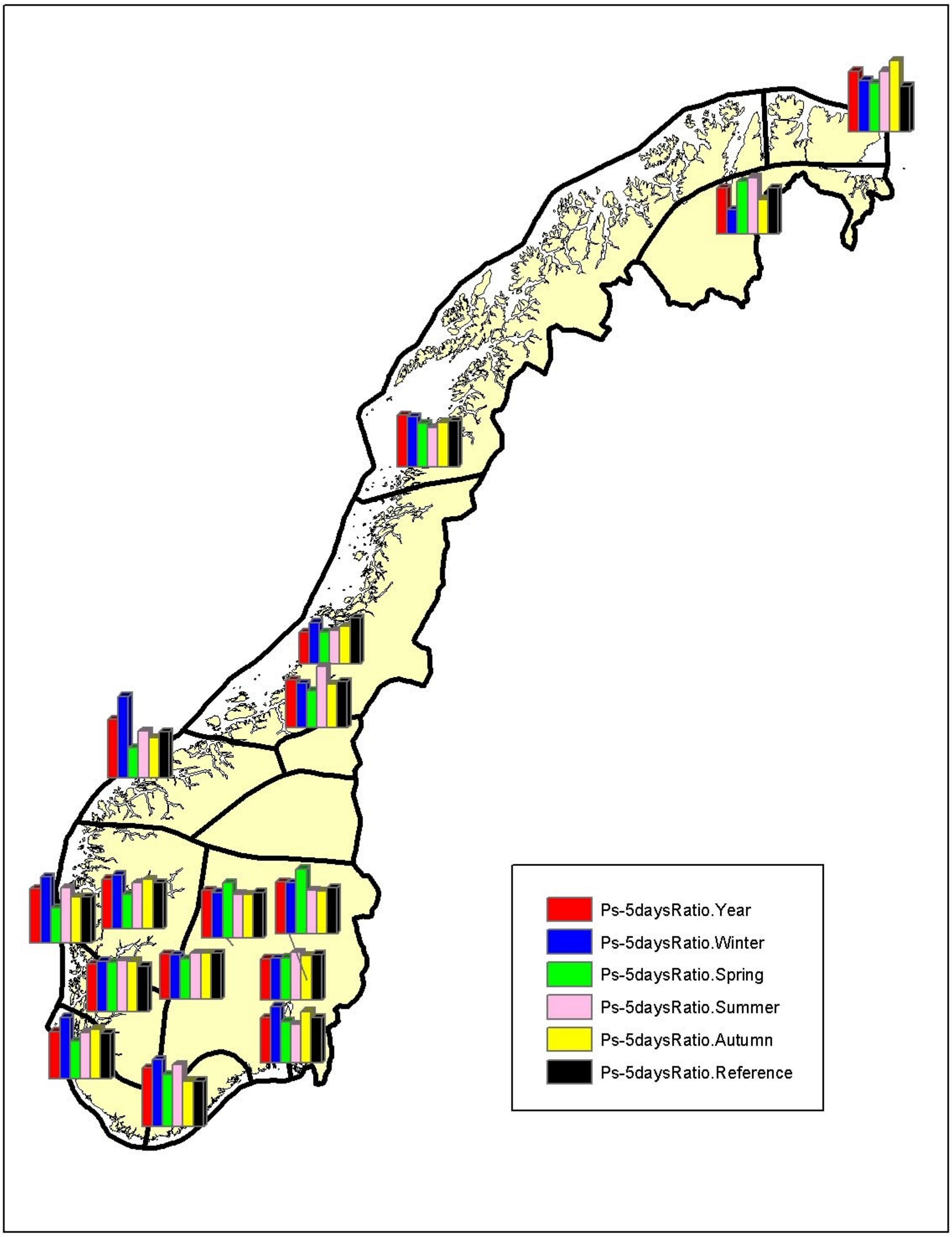

Figure A 4 Regional distribution of the relative change in standard deviation of extreme values (Ps), duration 5 days. The black column is for reference with height implying no change.

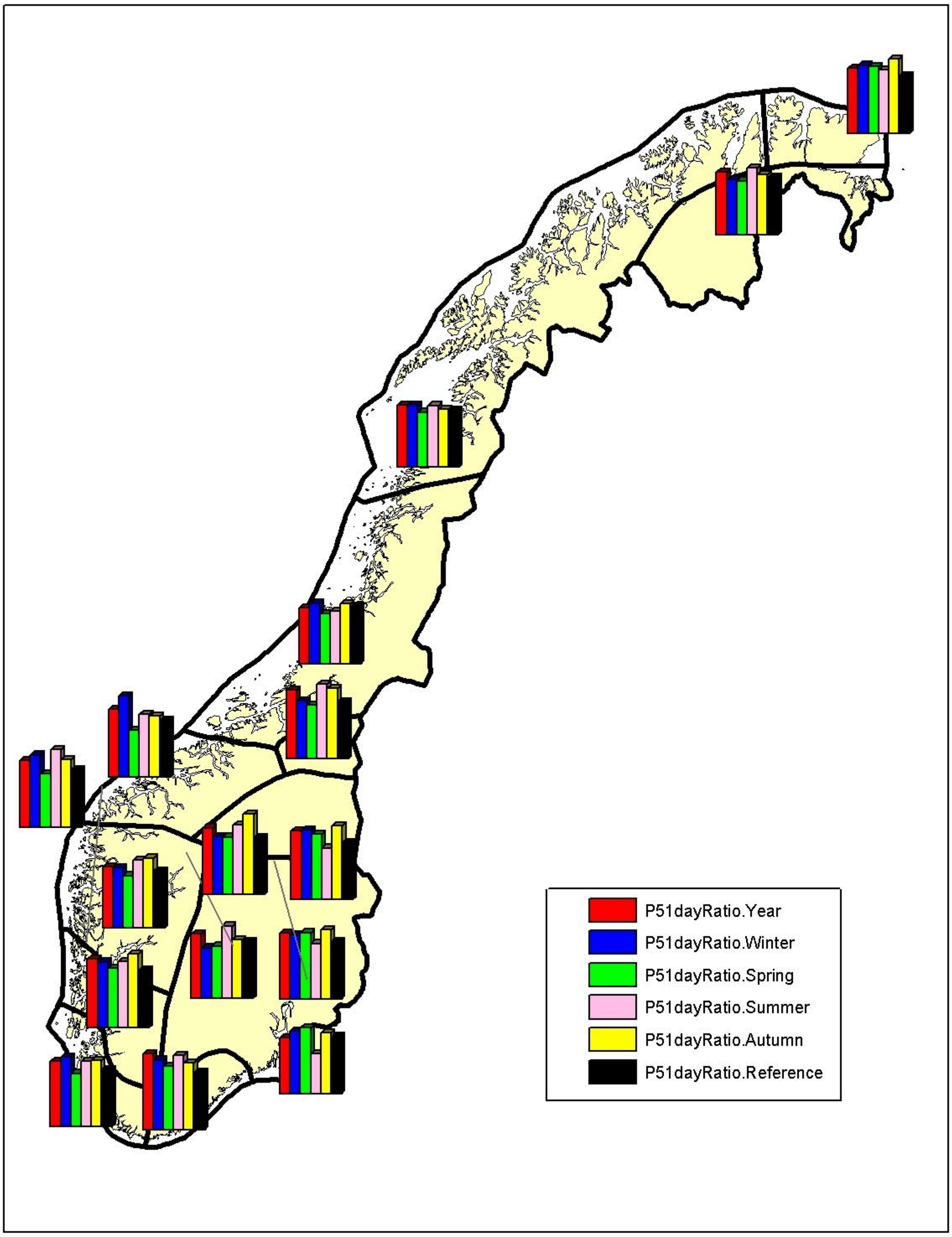

Figure A 5 Regional distribution of the relative change in extreme value, T= 5 years (P5), duration one day. The black column is for reference with height implying no change.

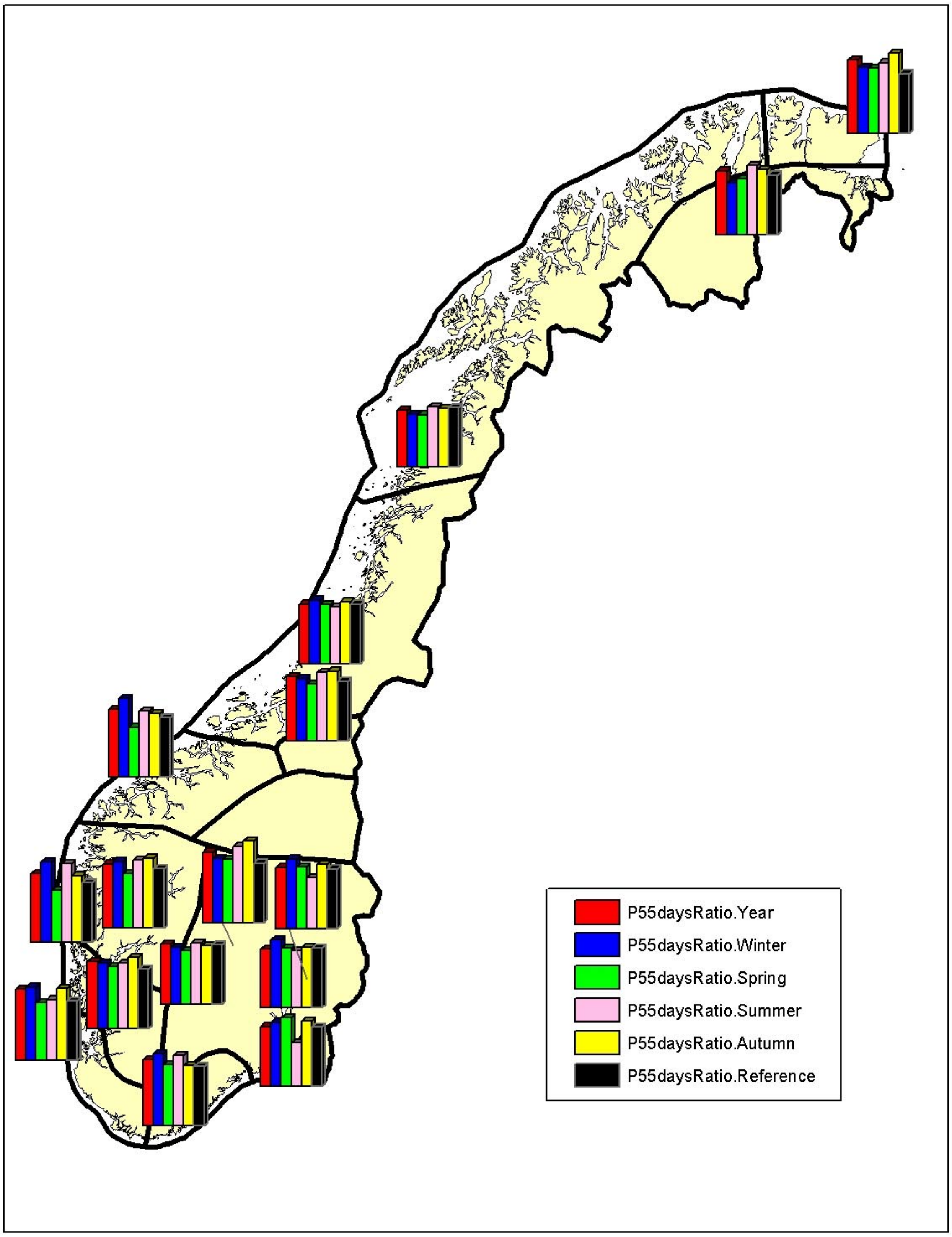

Figure A 6 Regional distribution of the relative change in extreme value, T= 5 years (P5), duration 5 days. The black column is for reference with height implying no change.

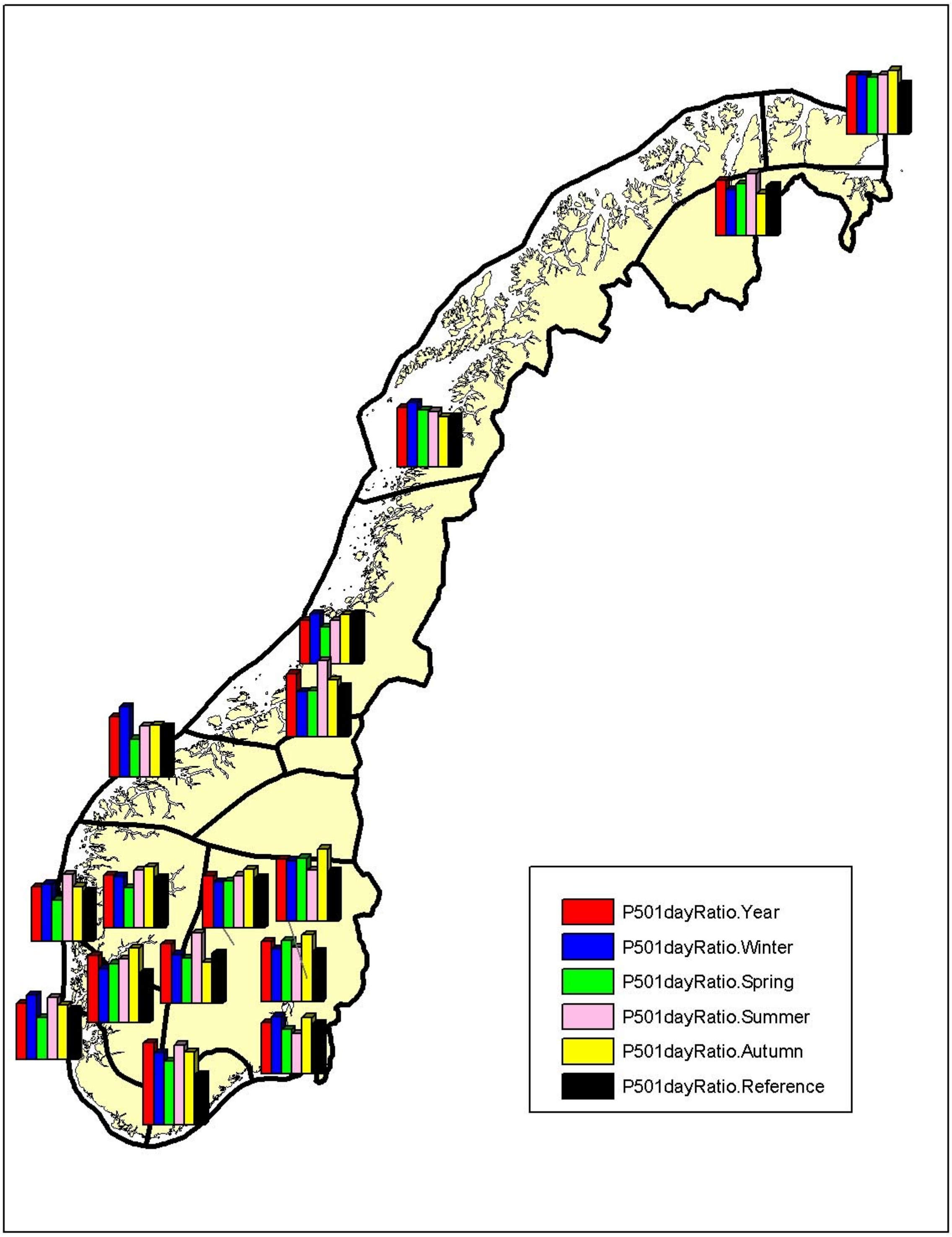

Figure A 7 Regional distribution of the relative change in extreme value, T= 50 years (P50), duration one day. The black column is for reference with height implying no change.

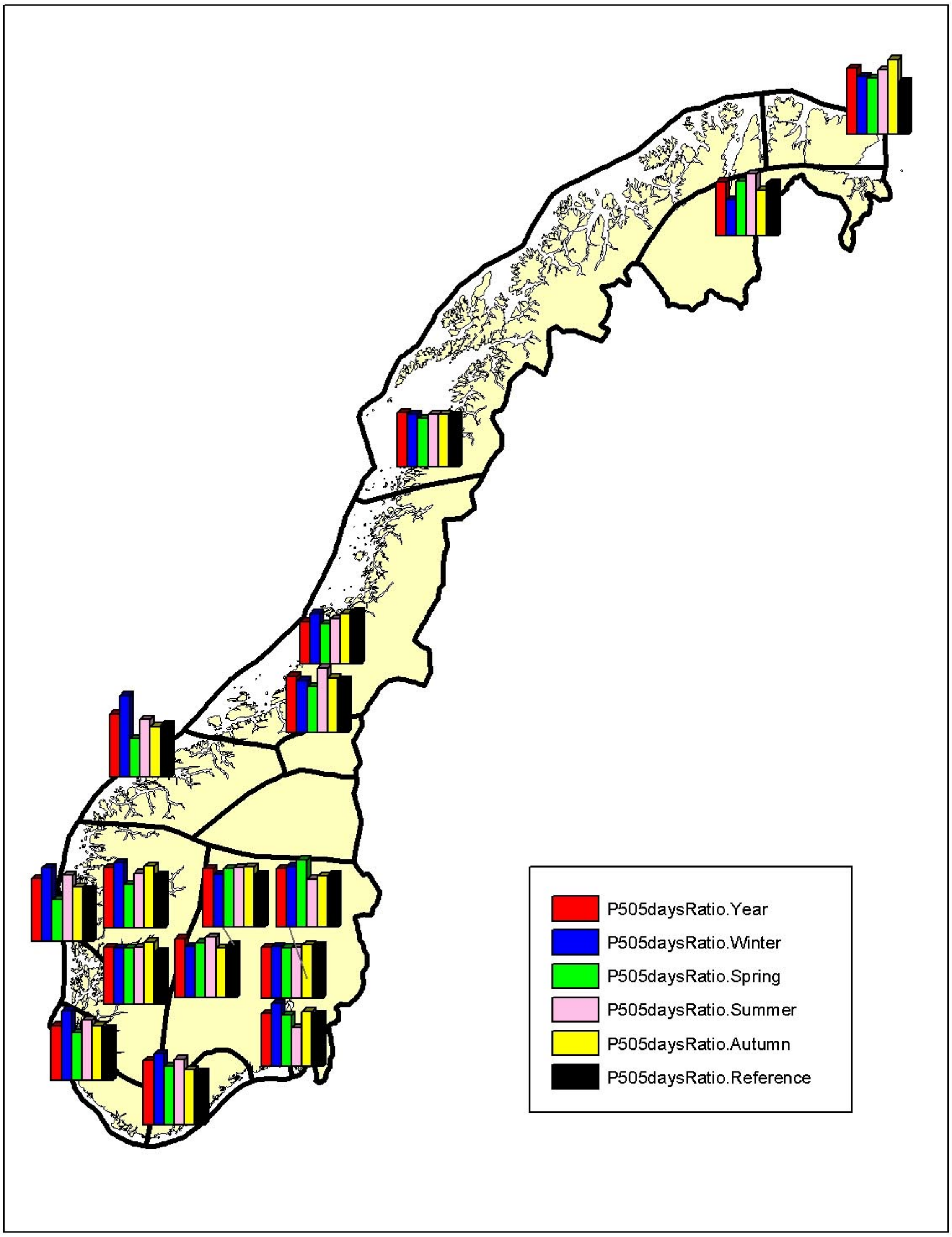

Figure A 8 Regional distribution of the relative change in extreme value, T = 50 years (P50), duration 5 days. The black column is for reference with height implying no change.

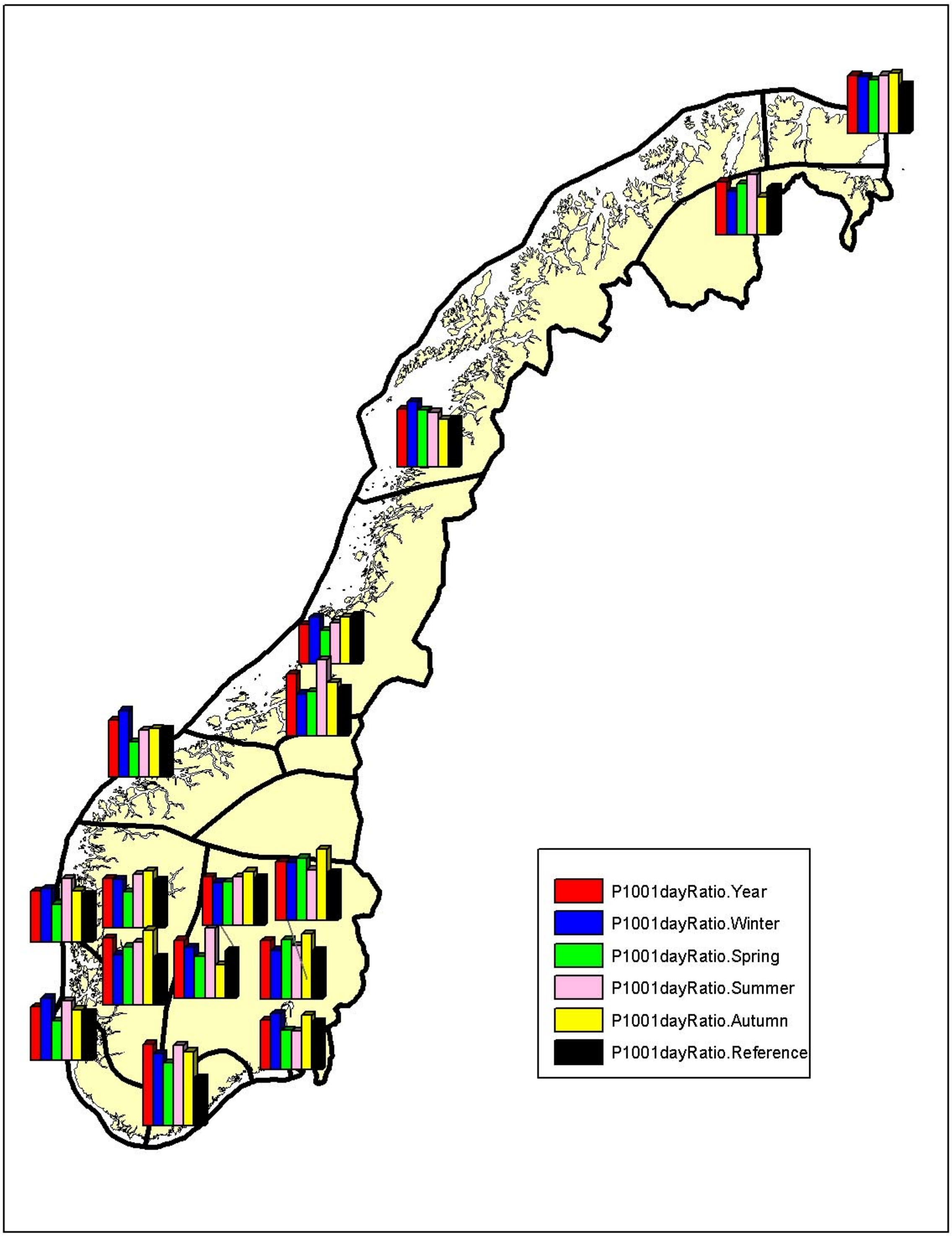

Figure A 9 Regional distribution of the relative change in extreme value, T= 100 years (P100), duration one day. The black column is for reference with height implying no change.

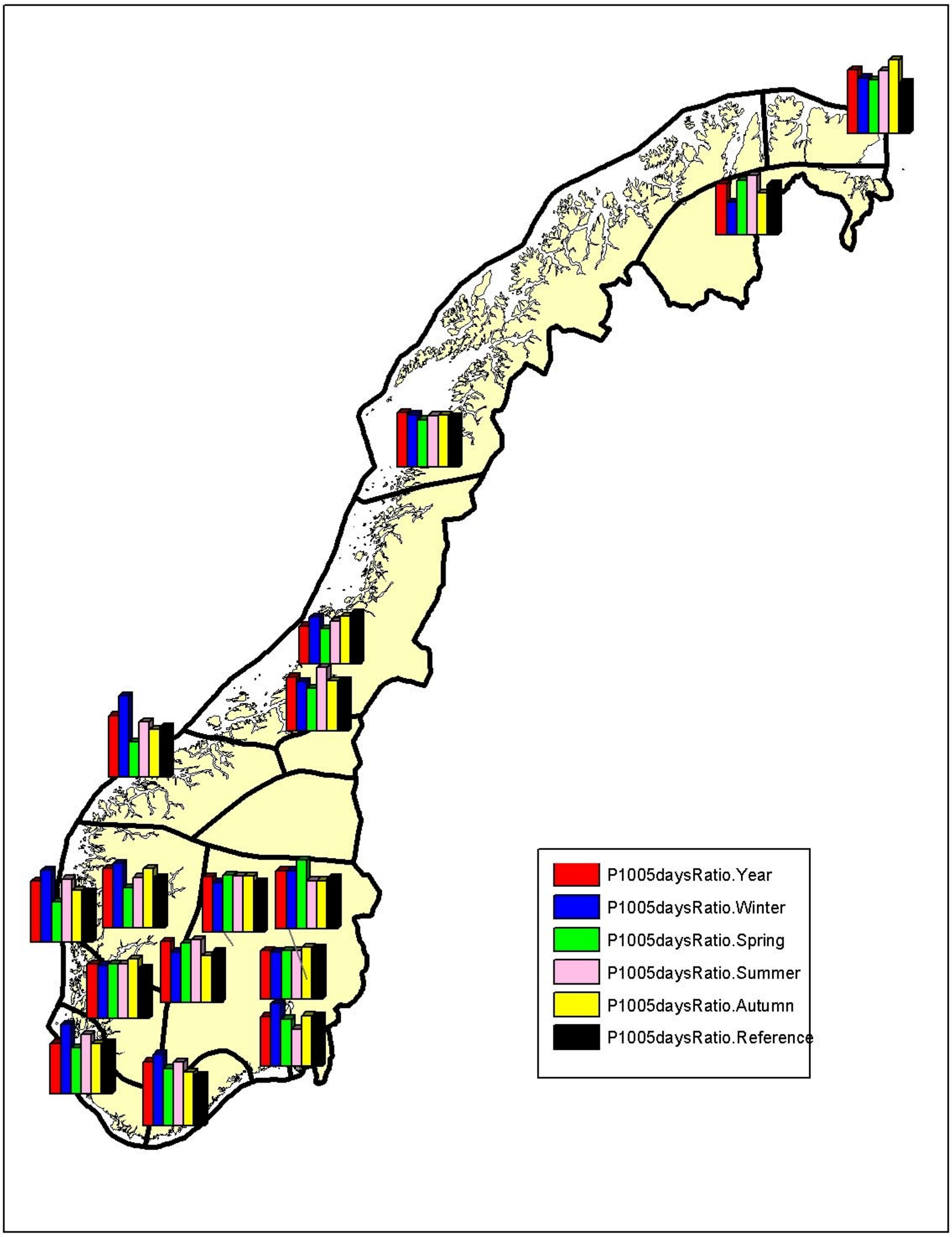

Figure A 10 Regional distribution of the relative change in extreme value, T= 100 years (P100), duration 5 days. The black column is for reference with height implying no change.

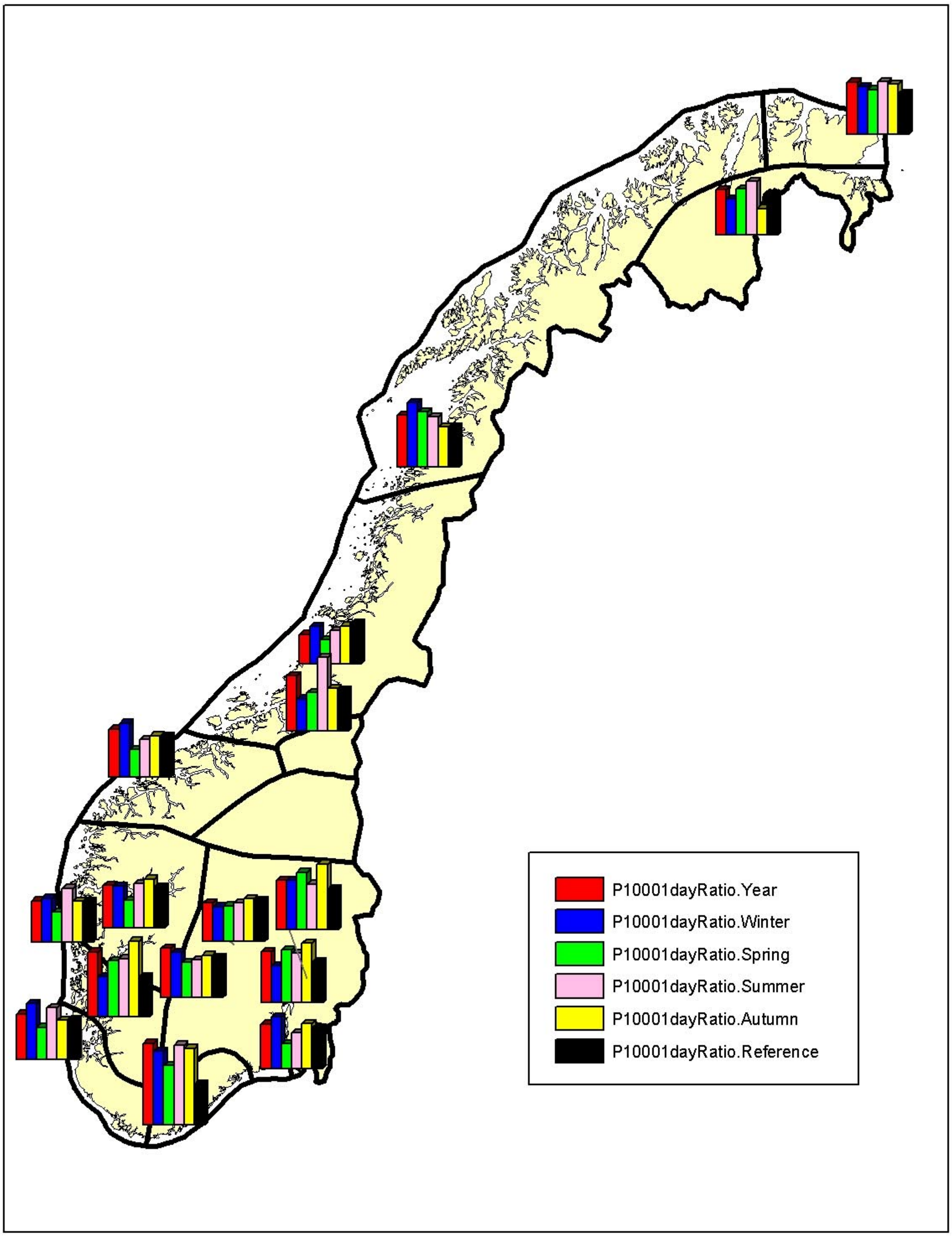

Figure A 11 Regional distribution of the relative change in extreme value, T= 1000 years (P1000), duration one day. The black column is for reference with height implying no change.

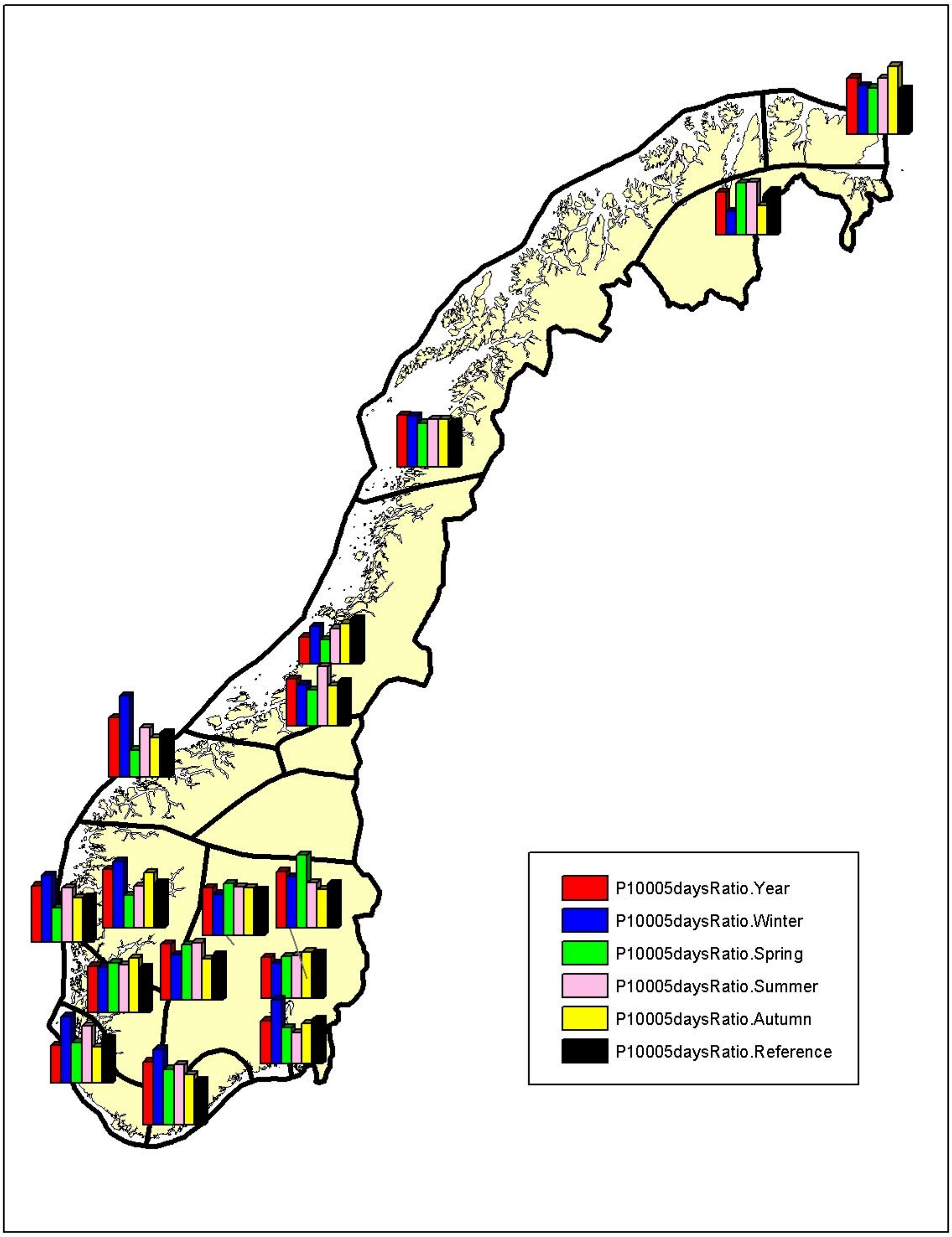

Figure A 12 Regional distribution of the relative change in extreme value, T= 1000 years (P1000), duration 5 days. The black column is for reference with height implying no change.

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