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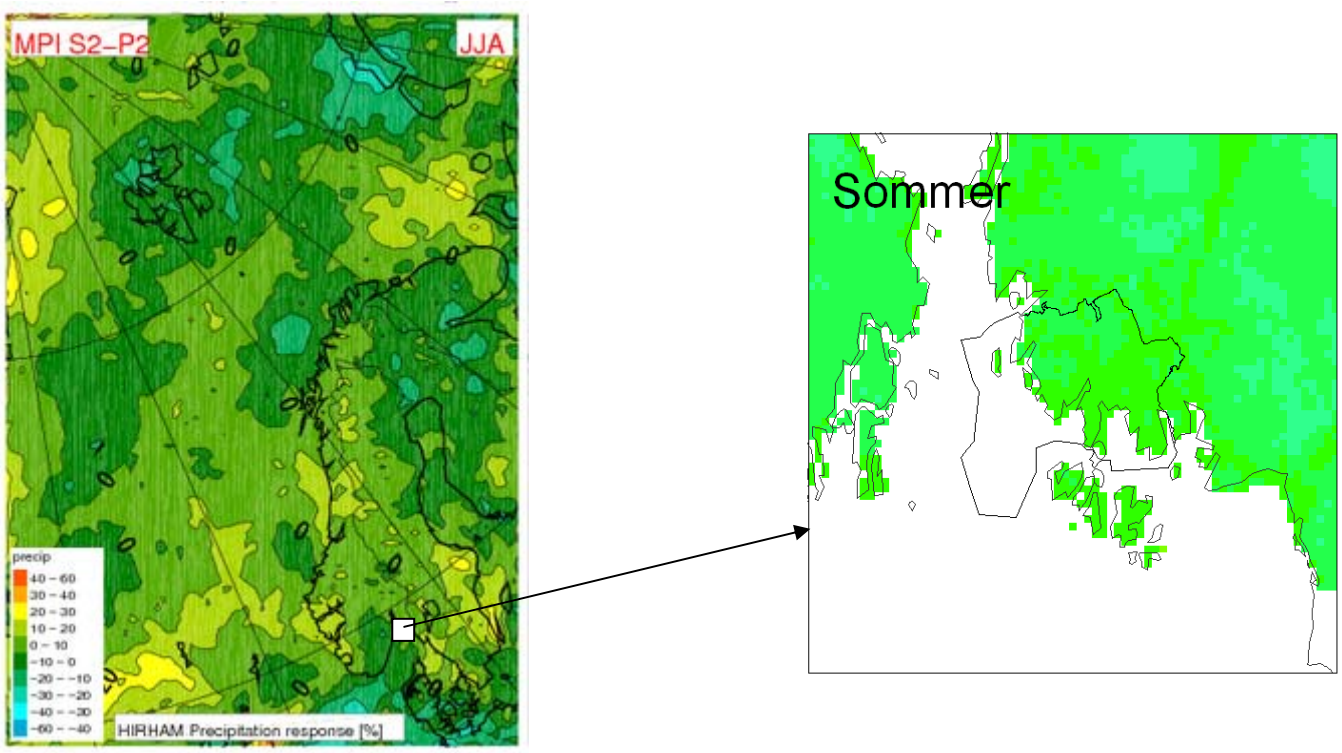
Climate

Dynamically downscaled climate scenarios available at the Norwegian Meteorological Institute

per December 2008

Torill Engen-Skaugen, Jan Erik Haugen and Inger Hanssen-Bauer



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Abstract

Dynamically downscaling of Global Climate Models (GCMs) provides high resolution climate projections regionally in time and space. The spatial resolution of the Regional Climate Models (RCMs) are typically ~25 x 25 km^2 with daily or 6 hourly time steps. RCMs do have problems when it comes to reproducing historical statistics as mean monthly temperature and mean monthly precipitation sums as well as mean monthly standard deviation based on daily values for temperature and precipitation respectively. And, for some analyses the spatial resolution of RCMs are still too coarse.

Daily temperature and precipitation projections from selected HIRHAM runs (HIRHAM is the RCM run at met.no) have therefore been interpolated to 1 x 1 km^2 covering the Norwegian mainland. The interpolated model runs have further been adjusted to be representative locally, meaning that the statistics listed above are corrected. The climate change signal obtained with HIRHAM is maintained. Thus, high spatial resolution projections of temperature and precipitation are now available for the Norwegian mainland. The present report gives an overview over available RCM-based climate projections at met.no, both directly from HIRHAM and post-processed 1 x 1 km^2 projections.

Keywords

Climate scenarios

Disiplinary signature	Responsible signature
Inger Hanssen-Bauer	Eirik J. Førland

Postal address	Office	Telephone	Telefax	e-mail: met@met.no	Bank account	Swift code
P.O.Box 43, Blindern NO-0313 OSLO Norway	Niels Henrik Abelsvei 40	+47 22 96 30 00	+47 22 96 30 50	Internet: met.no	7694 05 00628	DNBANOKK

Postal address	Office	Telephone	Telefax	e-mail: met@met.no	Bank account	Swift code
P.O.Box 43, Blindern	Niels Henrik Abelsvei 40	+47 22 96 30 00	+47 22 96 30 50	Internet: met.no	7694 05 00628	DNBANOKK
NO-0313 OSLO						
Norway						

1 Background

Future climate projections for Norway and northern regions have been developed by the Norwegian Meteorological Institute (met.no) mainly as contributions to large national and international research activities, e.g. the RegClim project (http://regclim.met.no), the NorClim project (http://www.norclim.no), the NorACIA project (http://www.noracia.npolar.no/) and the ENSEMBLES project (http://ensembles-eu.metoffice.com/). Regional and local climate projections are in general produced by downscaling the output from global climate models (GCMs). Different downscaling methods are available. At met.no dynamical downscaling and empirical-statistical downscaling (ESD) methods are commonly used. The present report gives an overview over the dynamically downscaled climate projections available at met.no. These projections are produced with the regional climate model HIRHAM (Haugen and Iversen, 2008)

As the spatial resolution in regional climate models still is rather coarse (in HIRHAM: 25km x 25km at the best), and the output usually is flawed by biases, post processing of the regional climate projections is often necessary to make them useful when studying possible consequences of climate change. A method for post processing the temperature and precipitation fields from HIRHAM, by applying adjustment factors calculated from observationally based fields with resolution 1km x 1km, was developed at met.no (Engen-Skaugen 2007). The method has been applied on selected HIRHAM projections to make them usable in a number of studies of climate change impact/vulnerability (e.g. CAVIAR, Éalat, NorAdapt, PLAN, PodyClich). The present report gives an overview also of the available post processed climate projections.

The calculation of empirically based adjustment factors is performed by relating HIRHAM results from a "control period" to observationally based gridded datasets for a similar period. These observationally based datasets, which thus represent "present climate" are described in section 2 of this report. Short descriptions of the downscaling methods and available climate projections, both directly from HIRHAM and adjucted projections, are given in section 3. Examples of results, as well as a detailed list over available projections of different variables, are presented in section 4.

2 Observationally based datasets

Temperature and precipitation is measured at stations which register local values that in essence can be considered as point-measurement. Thus, the temperature and precipitation values measured in one or several points within a catchment may be unrepresentative for a region, especially for larger areas with complex terrain. Daily precipitation sum and mean daily temperature are therefore interpolated to grids with spatial resolution of 1 x 1 km^2 over the Norwegian mainland (Tveito et al., 2005; Jansson, et al., 2007). The daily 1 x 1 km^2 grids contain uncertainties due to low density of the available temperature and precipitation stations as well as the fact that the local measurement may not be representative of the 1km^2 area. In Norway the density of temperature and precipitation stations increased from the beginning of measurements (before 1900) until ~1970. The number of stations was stable within the twenty-year period 1970-1990, but it has decreased after 1990. The uncertainty of the estimates follows the number of stations (Tveito, 2007). Another aspect is that most of the stations are situated in low lying regions. High-elevation regions with complex terrain are therefore associated with larger uncertainty.

The interpolation method used is triangulation on precipitation and spline (topogrid in ArcInfo) on temperature (Jansson et al., 2007; Tveito et al., 2005). The precipitation values are further corrected for altitude and for under-catch. Daily grids have been derived for the period 1961-present, and an evaluation of the gridded results is given in Jansson et al. (2007). Time series in each 1 x 1 km^2 grid point of temperature and precipitation are thus available.

The adjustment method for regional climate model output suggested by Engen-Skaugen (2007) requires, for each calendar month, daily mean values and standard deviation based for the actual control period. These values are obtained from the historical gridded datasets. As an example, in the ECHAM4/OPYC3 GSDIO

integration following emission scenario IS92a projection the control period is 1981 – 2010 (model run P5 in Table 3.1). The control run represent the present climate although, in this case, the control run expands a few years into the future. Therefore the statistical values based on the historical grids are established for the period 1981 – 2007. Examples of mean monthly values and mean standard deviation based on daily values for January are presented for temperature and precipitation in the figures 2.1 and 2.2 respectively. Figure 2.2b shows the mean monthly standard deviation based on daily precipitation values. Both days with precipitation and without precipitation are included in the estimates.

Unfortunately there are some small regions in Norway where daily precipitation with high spatial resolution is not available, see Figure 2.3. This is due to the interpolation method used to obtain spatial distribution of daily precipitation (the triangulation method). The problem will be solved probably in 2009.

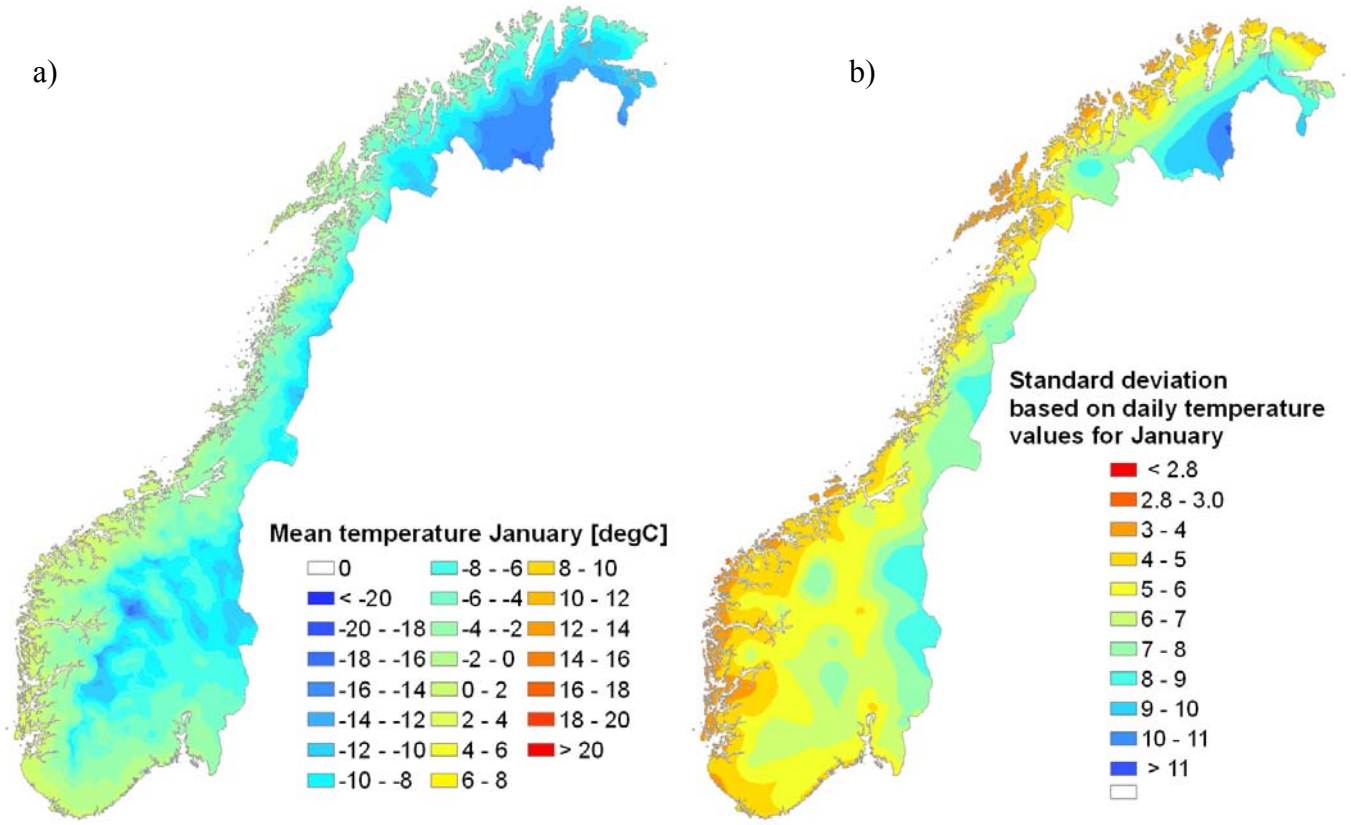

Figure 2.1. a) Mean temperature and b) standard deviation of daily mean temperature for January for the time period 1981 – 2007.

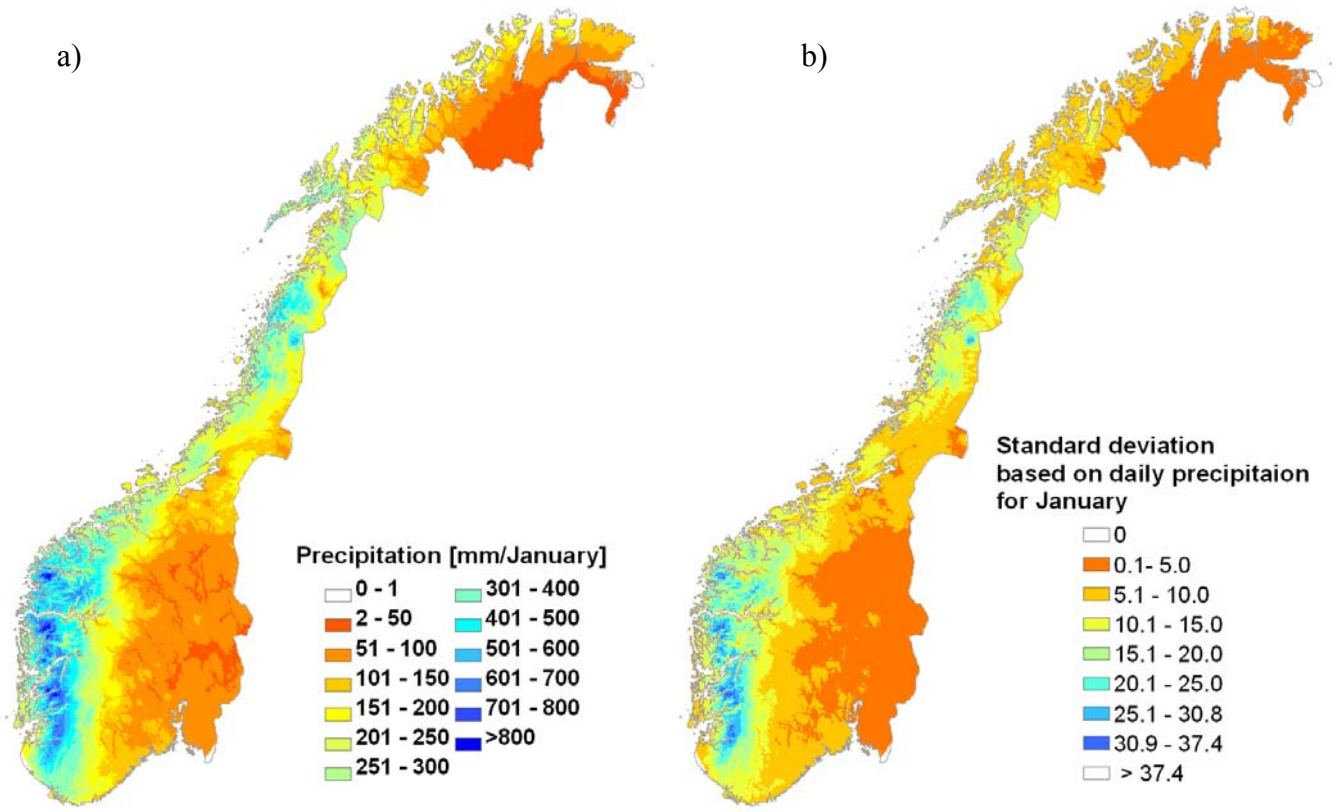

Figure 2.2. a) Mean precipitation sum and b) standard deviation of daily precipitation (wet and dry days are included) for January for the time period 1981 – 2007.

Figure 2.3 The high resolution (1 x 1 km^2) daily precipitation data are available for the mainland of Norway (the grey part), except a few areas near the coast or the country border (the black regions))

3 Downscaling procedure

A number of different global climate projections made with a range of different GCMs, reported in IPCC AR4 (Meehl et al., 2007), are freely available from Program for Climate Model Diagnosis and Intercomparison (PCMDI; https://esg.llnl.gov:8443/index.jsp). The GCM runs are used as boundary conditions in Regional Climate Models (RCMs) to obtain regional projections of future climate. RCM runs are highly computer demanding, thus only a selection of the available GCM projections are downscaled with RCMs.

The RCM used at Norwegian Meteorological Institute (met.no) is the HIRHAM model (Haugen and Iversen, 2008, Haugen and Haakenstad, 2006). The present version of the model has 31 levels in the vertical and a spatial resolution of ~25 x 25 km^2. Earlier HIRHAM runs have a resolution of ~55 x 55 km^2 and 16 levels. The model has been run at three different domains within different projects; RegClim domain for the RegClim project, NorACIA domain for the NorACIA and NorClim projects and the ENSEMBLES domain for the ENSEMBLES project (Figure 3.1). The different domains where chosen according to the regions of interest in the projects. The regional climate projections available at met.no (status per December 2008), run with the HIRHAM model, are listed in table 3.1.

For selected HIRHAM runs, daily temperature and precipitation projections were interpolated to the 1 x 1 km^2 grid covering the Norwegian mainland. The interpolated model runs were then adjusted to be locally representative, applying the method described in Engen-Skaugen (2007). The climate change signal from the HIRHAM runs was maintained. The adjusted high resolution scenarios available for the Norwegian mainland are listed in table 3.1. The same limitations in coverage are present in the projections as in the historical gridded precipitation data (see Section 2).

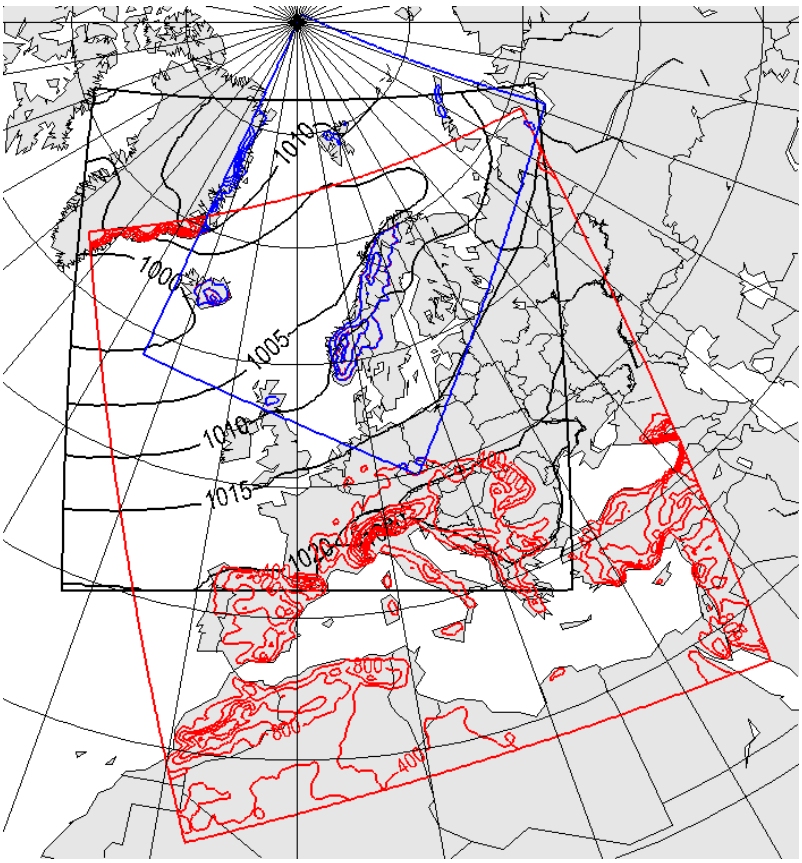

Figure 3.1 Three different HIRHAM domains; the ENSEMBLES domain (red), the RegClim domain (black) and the NorACIA/NorClim domain (blue).

Table 3.1 Regional climate projections run with the HIRHAM model available at met.no (status per December 2008). Last column indicates if/when the projection has been/ will be adjusted.

Projection No.	GCM	emission sc	domain	Time period *(ctr + proj)*	Spatial resolution	High spatial resolution (1 x 1 km^2)
P1	ECHAM4	Ctr + IS92a	RegClim	1980 - 2049	55 x 55 km^2	Not planned
P2	HadAm3H	Ctr + A2	RegClim	(1961 – 1990) + (2071 – 2100)	55 x 55 km^2	2008
P3	HadAm3H	Ctr + B2	RegClim	(1961 – 1990) + (2071 – 2100)	55 x 55 km^2	2008
P4	ECHAM4	Ctr + B2	RegClim	(1961 – 1990) + (2071 – 2100)	55 x 55 km^2	2008
P5	BCCR BCM v1	Ctr + CMIP2	RegClim	30 y high AMOC + CMIP2 year 51-80	55 x 55 km^2	Not planned
P6	BCCR BCM v1	Ctr + CMIP2	RegClim	30 y low AMOC + CMIP2 year 36-65	55 x 55 km^2	Not planned
P7	BCCR BCM v2	Ctr + A1B	RegClim	(1961-1990) + (2071-2100)	55 x 55 km^2	Not planned
P8	UiO CAMS-Oslo	1xCO2 + 1.63xCO2	RegClim	2x30years	55 x 55 km^2	Not planned
P9	ECHAM4	Ctr + B2	NorAcia/NorClim	(1961 – 1990) + (2071 – 2100)	25 x 25 km^2	2009
P10	ECHAM4	Ctr + IS92a	NorAcia/NorClim	(1981 – 2010) + (2021 – 2050)	25 x 25 km^2	2008
P11	ERA40	re-analyses	NorAcia/NorClim	1961-2000	25 x 25 km^2	Not planned
P12	ERA40	re-analyses	ENSEMBLES	1961-2000	25 x 25 km^2	Not planned
P13	Hadley	Ctr + A1b	ENSEMBLES	(1950– 2000) + (2000-2050)	25 x 25 km^2	2009
P14	BCM	Ctr + A1b	ENSEMBLES	(1950– 2000) + (2000-2050)	25 x 25 km^2	Not planed

4 Results

Met.no can offer regional climate projections in two different forms: 1) direct output from the HIRHAM model, or 2) adjusted climate projections (Section 3). The projected climate change is the same in 1) and 2), but the local climate is more realistic in the adjusted projections, and the spatial resolution is better. On the other hand, only temperature and precipitation have been adjusted so far, while several variables are available directly from HIRHAM. Further, the adjusted values have only daily resolution, while many variables are available with better time resolution in HIRHAM.

4.1 Available RCM output

Regional climate projections with spatial resolution of ~55 x 55 km^2 or ~25 x 25 km^2 for selected time windows are available for the respective domains (see Table 3.1 and Figure 3.1). An example of projected seasonal changes in 2 m temperature for the P3 run (Table 3.1) is displayed in Figure 4.1.

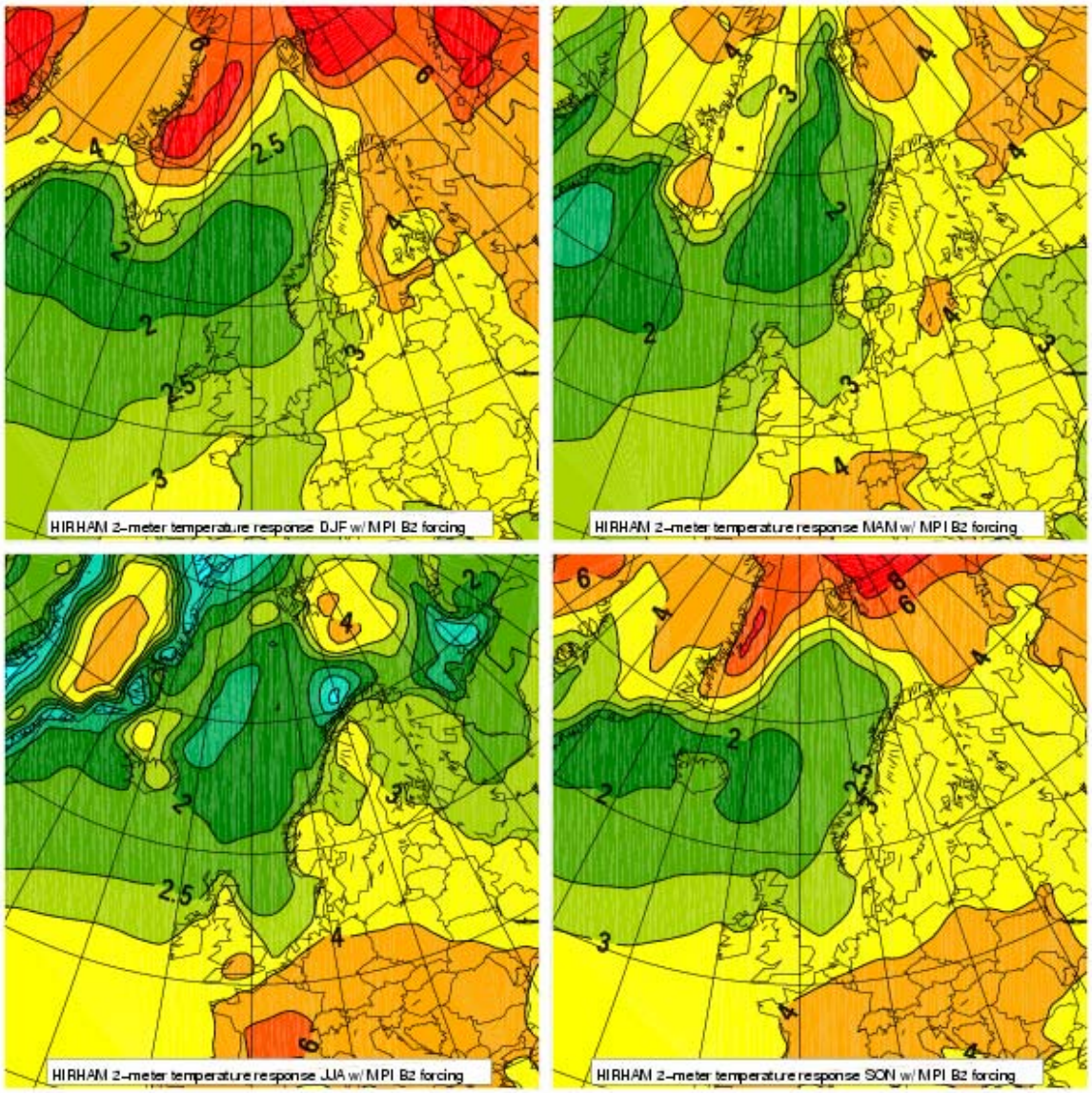

Figure 4.1 Projected 2 m temperature for the time period 2071- 2100 compared to 1961 – 1990 dynamically downscaled with the HIRHAM model run at met.no for the RegClim domain (see Figure 3.1). The GCM downscaled is ECHAM4 from the Max Plank Institute in Hamburg (Roeckner, 1999) following the SRES emission scenario B2 (Model run P3 in Table 3.1).

Table 4.1 gives a survey of available variables and time resolutions from the individual runs. Be aware that these elements are not adjusted to be representative locally, and that the spatial resolution is coarse. The best way to receive the data will depend on the use of the data.

1. netcdf covering the full HIRHAM domain in the model grid with resolution 55x55 km^2 or 25x25 km^2. The netcdf format was adopted for exchange of data between regional climate research senters in Europe, including impact modellers The model output parameters are stored in separate netcdf files.
2. Ascii tables (csv) with timeseries in selected geographical positions, obtained by interpolation between the nodes of the model grid.

Table 4.1. Lists output surface elements available from the different HIRHAM runs at met.no. For distribution most elements are stored as daily data, with a few exceptions (see notes).

No	*Parameter*	*Name*	*Unit*	*Type*	*Note*
1	2m temperature	t2	K	Average	[1]
2	2m min. temperature	t2min	K	Min. value	
3	2m max. temperature	t2max	K	Max. value	
4	2m dewpoint temperature	dew2	K	Average	[1]
5	Surface temperature	tsurf	K	Average	
6	Total precipitation	prt	mm (kg/m^2)	Accumulated	[1]
7	Snowfall	aprs	mm (kg/m^2)	Accumulated	
8	10m wind speed	wind10	m/s	Average	[2]
9	10m max. wind speed	wimax	m/s	Max. value	[2]
10	10m u-velocity	u10	m/s	Average	[2]
11	10m v-velocity	v10	m/s	Average	[2]
12	Cloud cover	aclcov	%	Average	
13	Surface pressure	ps	hPa	Instantaneous	[1]
14	Mean sea level pressure	mslp	hPa	Instantaneous	[2]
15	Net surface short wave radiation	srads	W/m^2	Average	
16	Downward surface short wave radiation	sradsd	W/m^2	Average	
17	Net surface long wave radiation	trads	W/m^2	Average	
18	Downward surface long wave radiation	tradsd	W/m^2	Average	

[1] one-hourly output from P9, P10, P12-P14 (see table 3.1)

[2] three-hourly output from P9, P10, P12-P14 (see table 3.1)

4.2 Available adjusted RCM output

The high spatial resolution projections of daily temperature and precipitation covering the Norwegian mainland listed in table 3.1 are available (see column 6). An example of an arbitrary one-day estimate of temperature and precipitation is given in Figure 4.2. The data are stored on binary files in a file structure defined by met.no. An example showing the density of the grid points are presented in Figure 4.3. How to receive the data will therefore depend on the use of the data. Some possibilities are listed below.

1. The whole dataset may be received by the user. The data is stored in 324567 grid points on daily binary files in an appropriate file hierarchy defined at met.no.
2. Time series (ascii format) of daily mean values at selected grid points may be derived and received by the user.
3. Time series of daily mean values (ascii format) of pixels within an area may be derived by the user. E.g. within a county or below a specific altitude etc.

Estimates derived from the high resolution temperature or/and precipitation projections, e.g. heating degree-days and growing degree-days, may be obtained from the dataset.

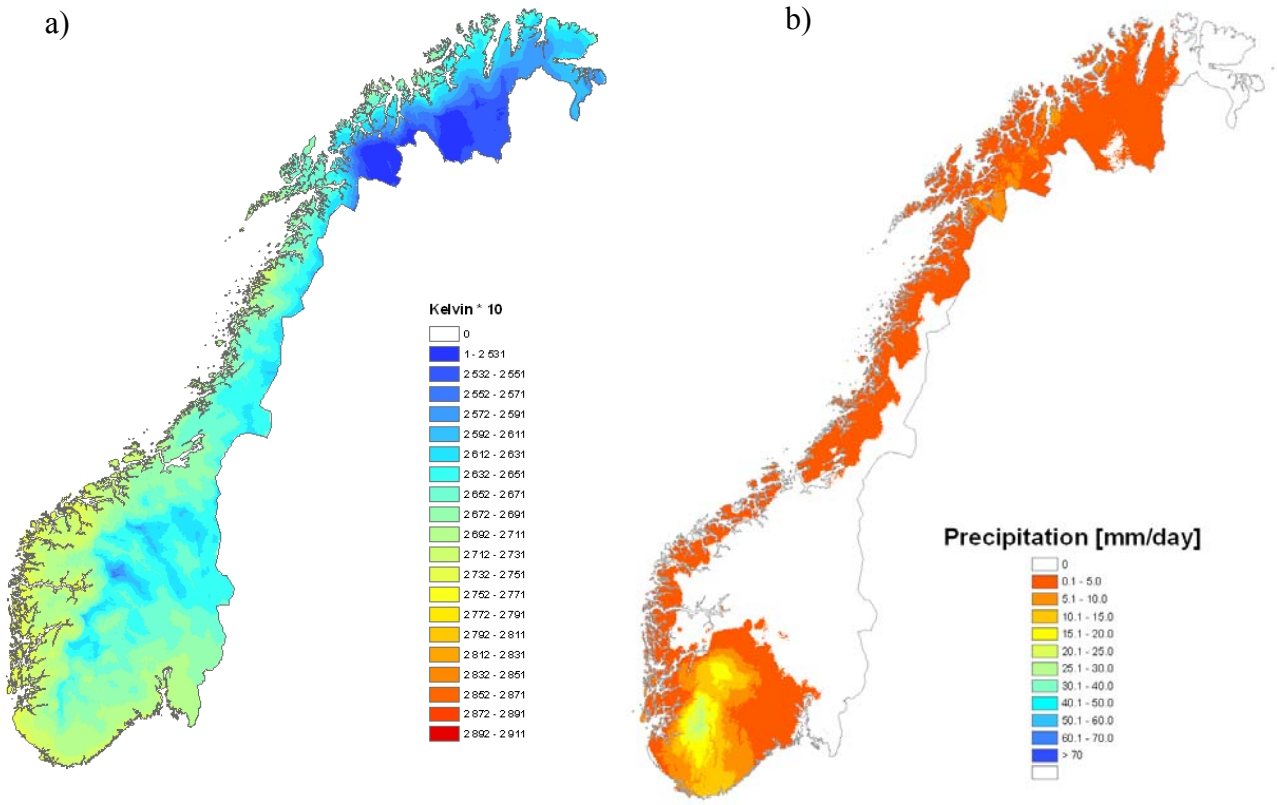

Figure 4.2 An example of temperature (a) and precipitation (b) from an arbitrary day in one of the control runs.

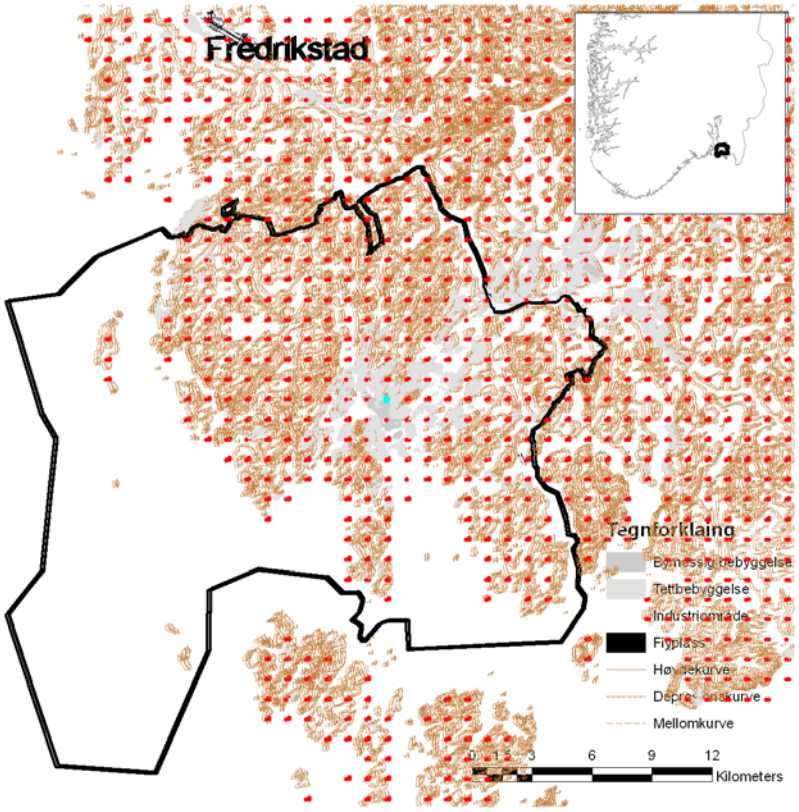

Figure 4.3 Example of the density (1 x 1 km^2) of the high resolution climate change projections available at met.no. The region defines the Fredrikstad municipality in the south-eastern part of Norway.

5 Concluding remarks

Climate projections for the future obtained with dynamically downscaling of global climate scenarios available at met.no are presented in the present report. The global models involved, as well as emission scenarios and domains used, are here documented. Projections of temperature and precipitation from HIRHAM are further interpolated to 1x1 km^2 and adjusted to be representative locally. It should be noted that met.no also offers climate projections developed with Empirical-Statistical Downscaling methods (e.g. Benestad et al., 2008). These are not included here.

The present report is meant as information in the dialog between the user and the provider of climate projections. Hopefully it will help the user to choose between the available climate projections. This involve being aware of which climate elements are available and useful for the respective analyses, as well as the resolution in time and space etc. The experience of the authors is that impact researchers have a range of different interest and needs. The information given in the present report is meant as a basis for a dialog; not as the sole basis for a conclusion concerning choice of climate projection data.

Acknowledgement

The present report is a result of met.no taking part in climate change impact/vulnerability studies within the projects PLAN, CAVIAR, CELECT, NorAdapt, EALÁT, CES, GeoExtreme, PodyClich, TerraC and "Klimaprediktabilitet på skala fra 0 til 100 år", ACTOR, PredClim, FECIMOD and NorClim.

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