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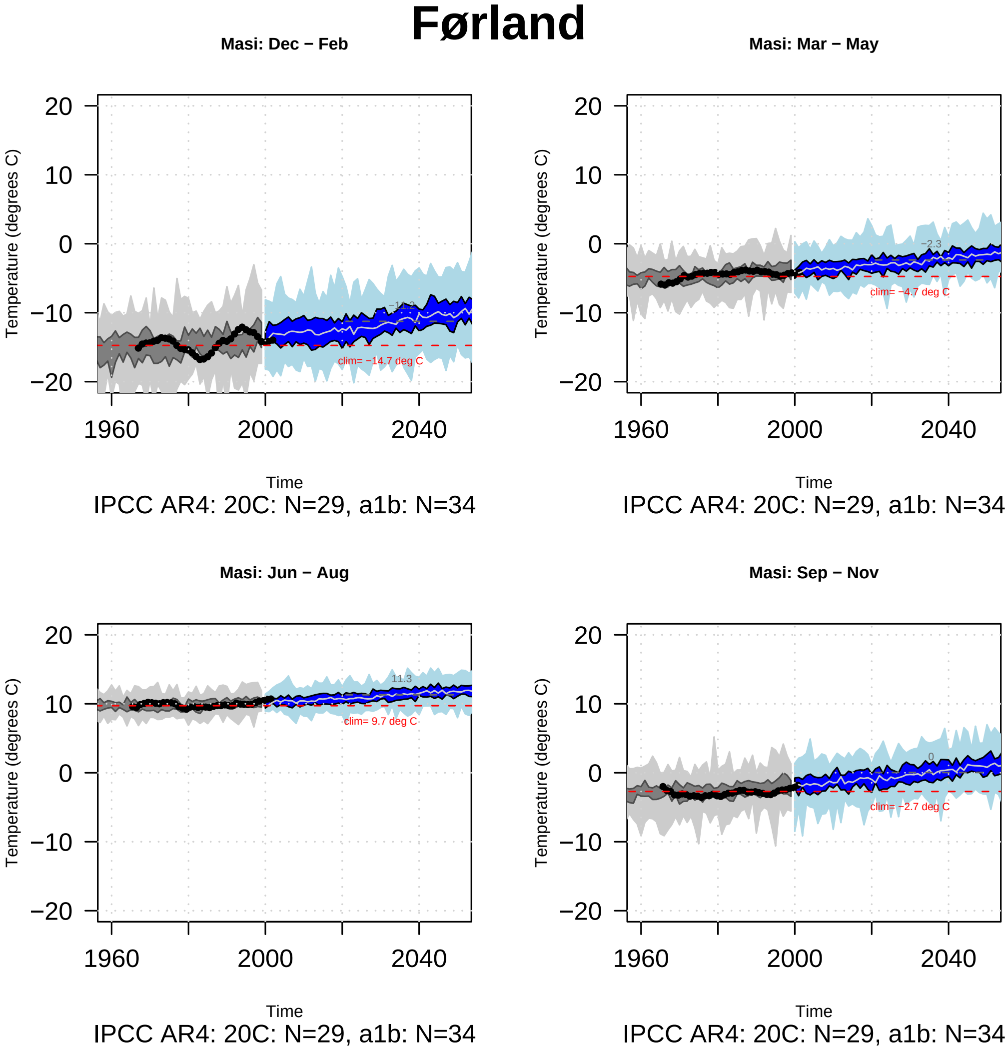
Climate

Appendix C

Results from ESD analyses on temperature representing twenty-five Norwegian catchments

Torill Engen-Skaugen, Rasmus Benestad and Eirik J. Førland



The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 30 GCMs used for the historic period 1958 -2000 and the 38 GCMs for the future period 2000-2050 following the SRES A1b emission scenario for Masi. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). The mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

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Abstract

This is an annex report presenting results from empirically downscaled mean monthly temperature representing twenty-five catchments in Norway. The background, temperature data used and location together with summary and concluding remarks are given in Engen-Skaugen et al. (2008). The projections derived for the catchments in the Norwegian RegClim project are given as well. Results from ESD analyses on precipitation for the catchments are given in Annex report B (Engen-Skauge et al., 2008b).

Keywords

Climate change, ESD, temperature

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Norway						

1 Background

Mean monthly temperature is downscaled using Empirical-Statistical Downscaling (ESD) methods for twenty-five Norwegian catchments. The work is documented in Engen-Skaugen et al (2008). The present report is an Annex report presenting resulting plots from empirically downscaled precipitation to the selected catchments.

Estimates from ~30 GCM runs for the 20^{th} century and ~30 GCM runs for the 21th century from the CMIP3 (IPCC WG1, 2007) are derived. The downscaling involved stepwise multiple regression and a common-EOF frame-work, and was performed on monthly mean/total values. Results with discussion from all twenty-five catchments are presented in the present annex report (Section 2). Summary and concluding remarks are given in Engen-Skaugen et al. (2008 a). Results from ESD analyses on precipitation for the catchments are given in Annex report B (Engen-Skauge et al., 2008b)

Results from ESD of temperature representing the twenty-five selected catchments in Norway (Section 2 in Engen-Skaugen et al., 2008 a) are presented in Section 2.Results on the respective catchments from earlier studies within the Norwegian RegClim project are given in Section 3.

2 Results from ESD on mean area temperature

The present study is based on 14 different GCMs following the SRES emission scenario A1b. It is based on ~60 global model runs for the 20th and 21st century, not all of these GCM results were used; a quality check was implemented that weeded out poorly performing models (See Section 4 in Engen-Skaugen et al, 2008) for more details.

The time period analysed is 1960-2050 where the time period 1960 – 1990 is used as the control period. The downscaling technique used is ESD (Engen-Skaugen et al, 2008). Figs. 2.1 - 2.25 shows the model runs; black is used for the period 1958 – 2000 and blue for the period 2000-2050. Dark colours are used for models within the 25 and 75 percentile, while light colours are used for the model runs outside these thresholds.

2.1 Masi

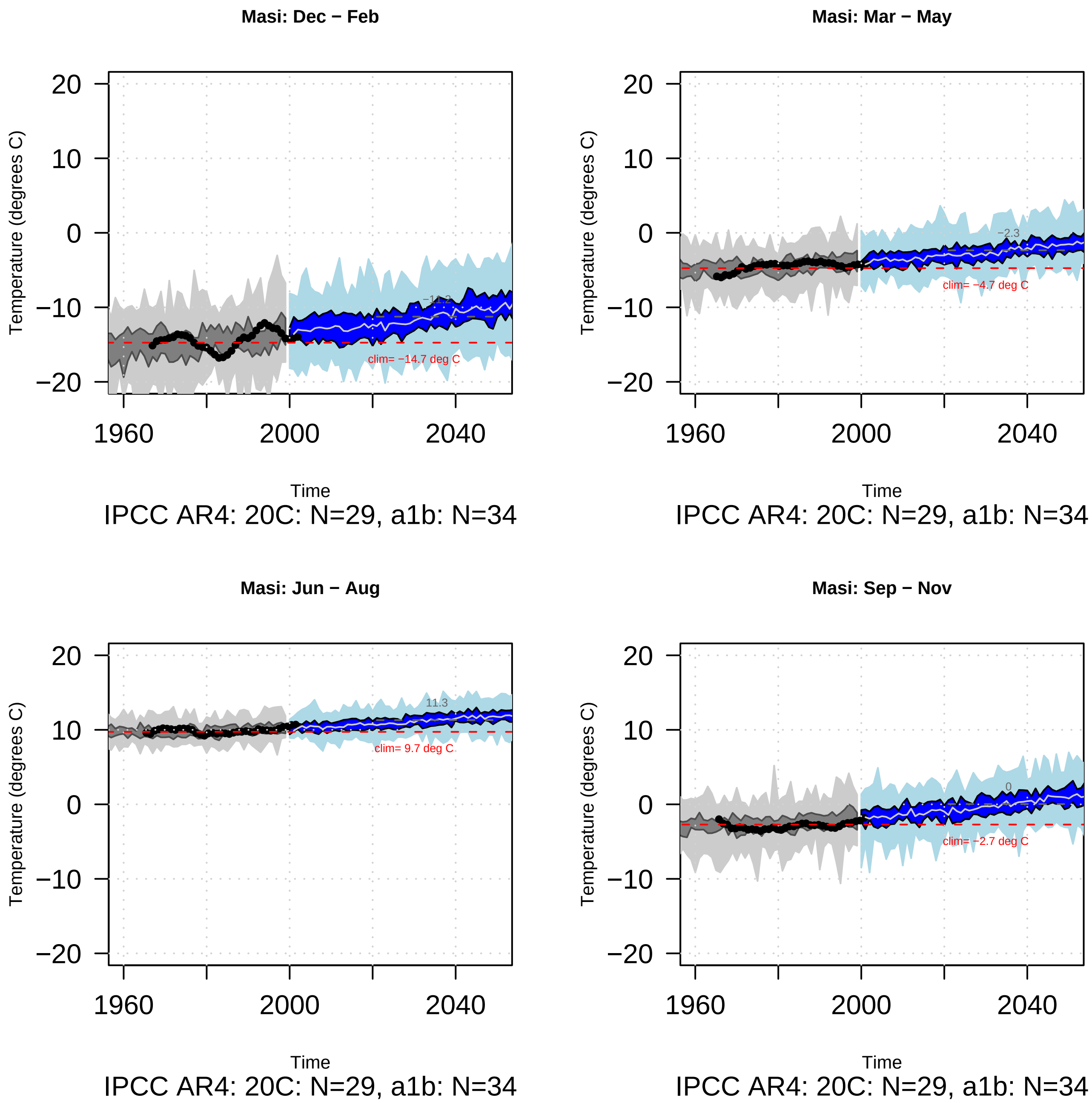


Figure 2.1 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 34 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.2 Kobbvatn

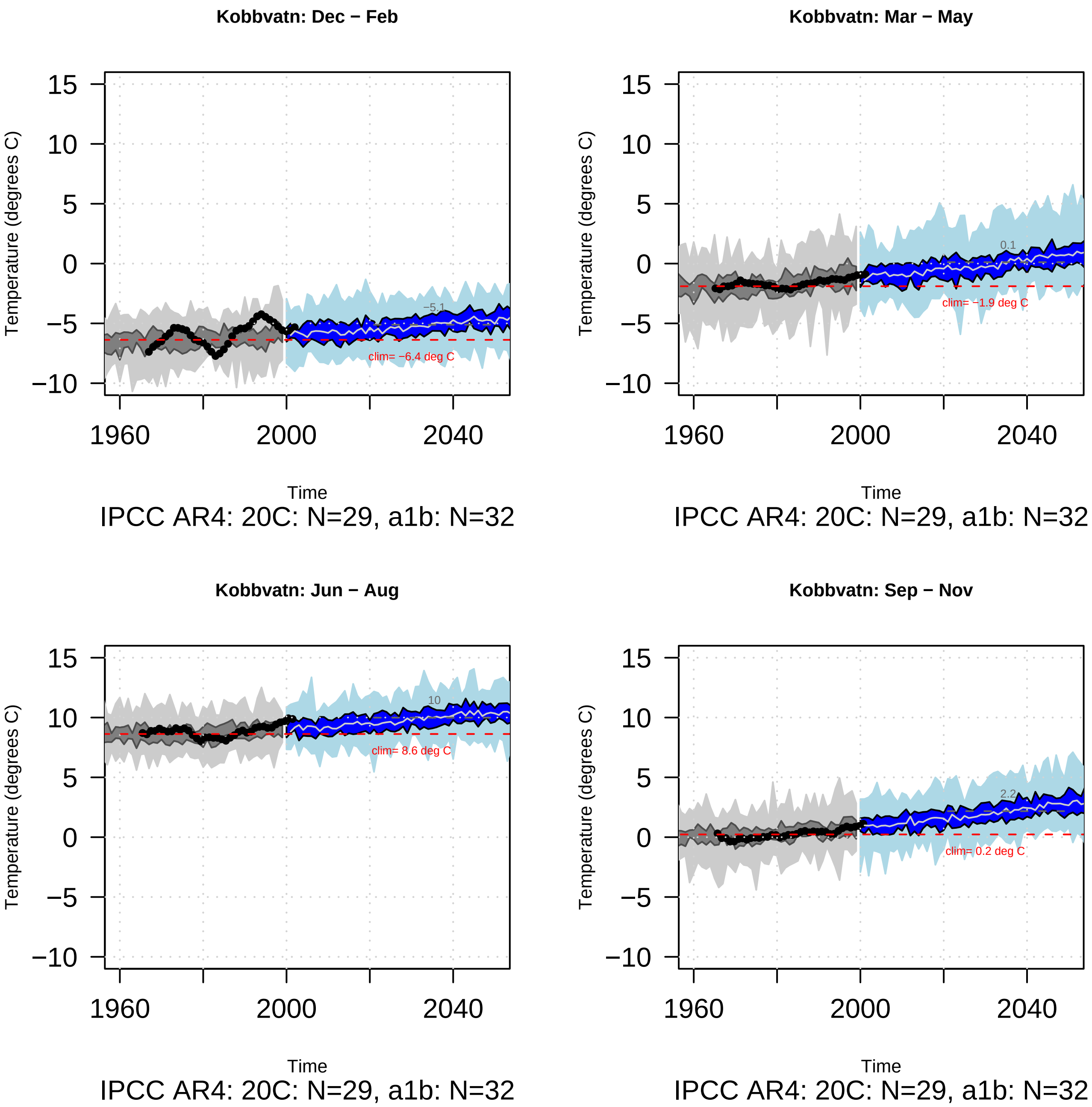
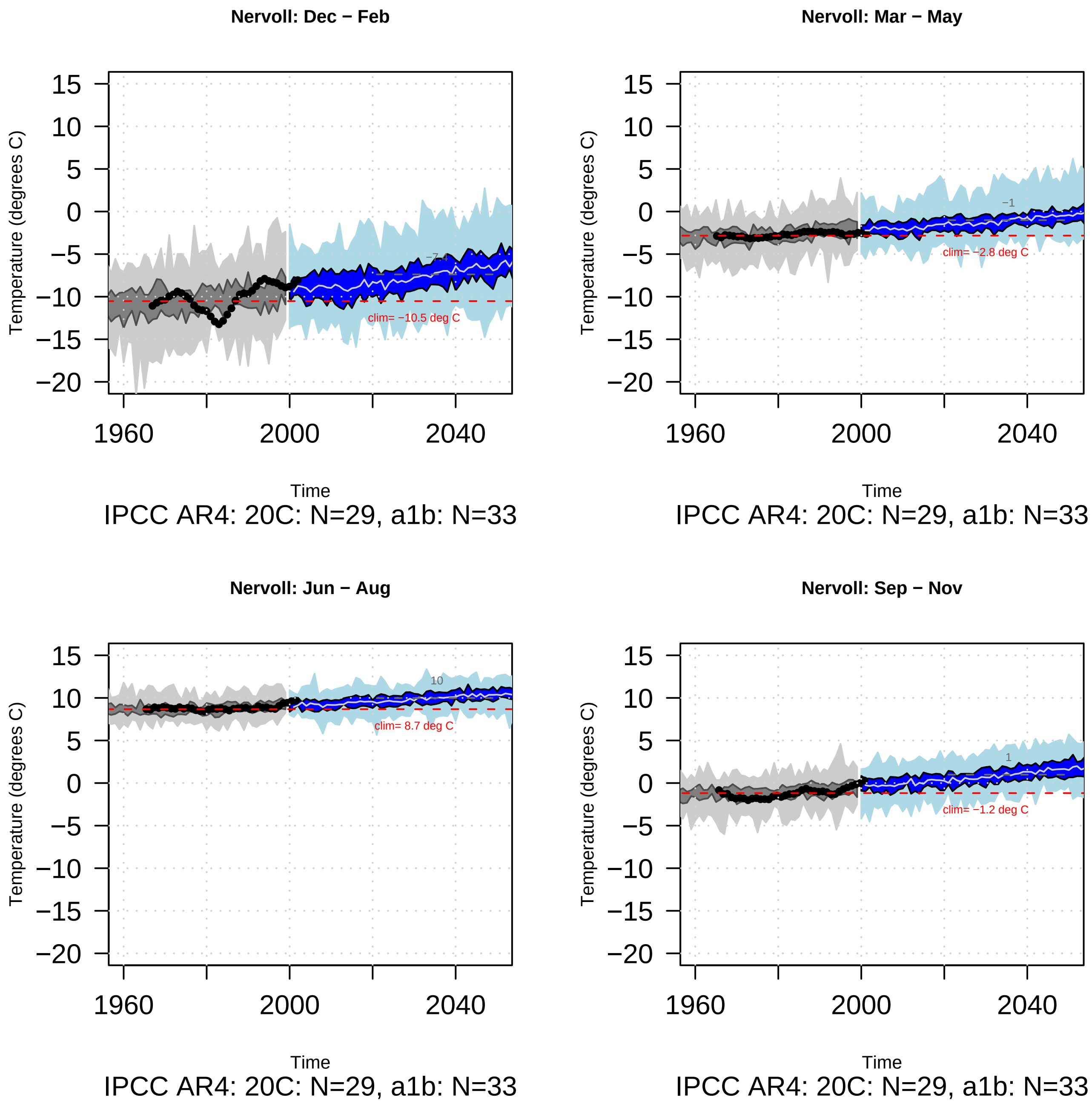


Figure 2.2 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 32GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.3 Nervoll



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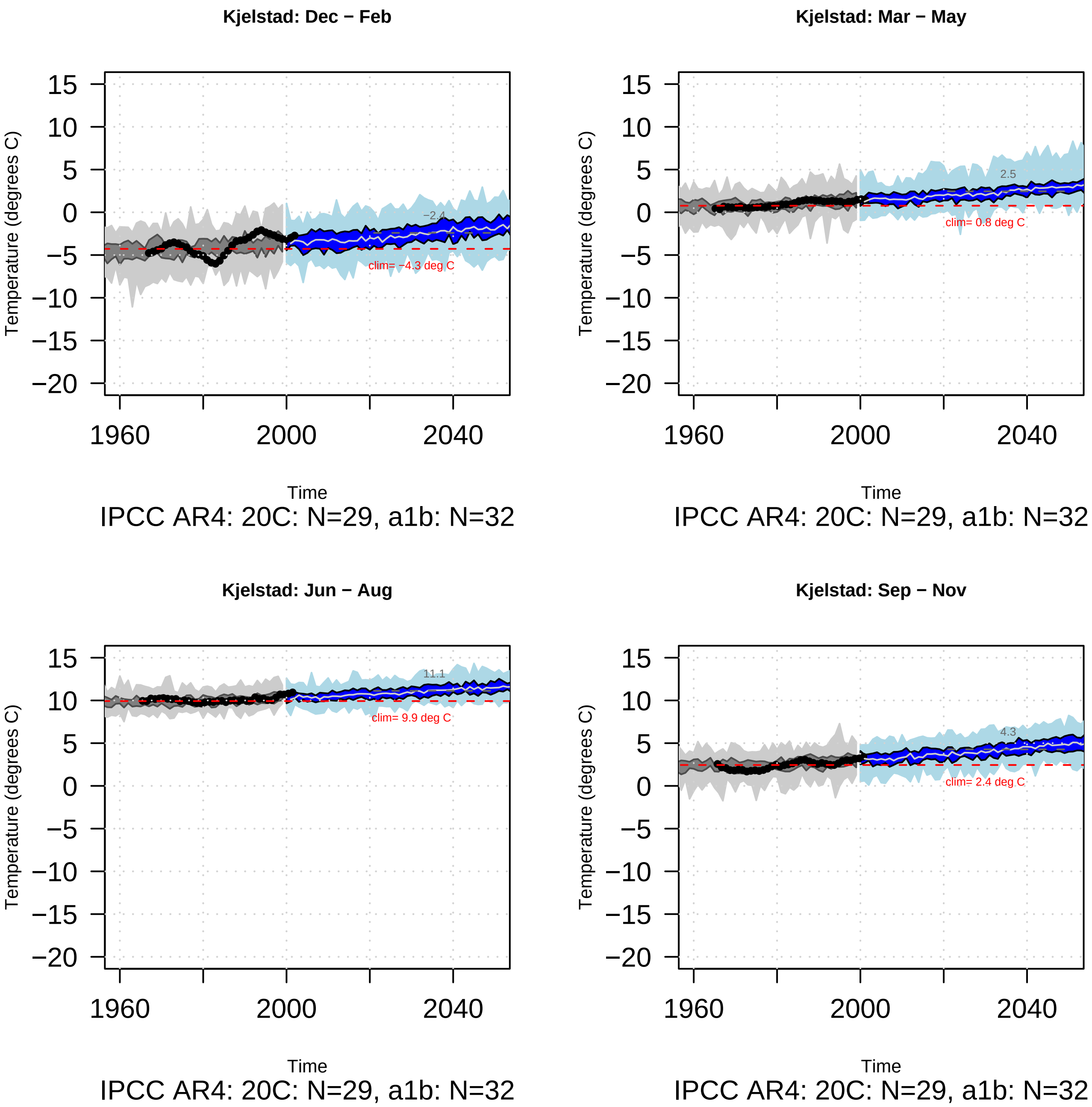
2.4 Kjelstad



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2.5 Rathe

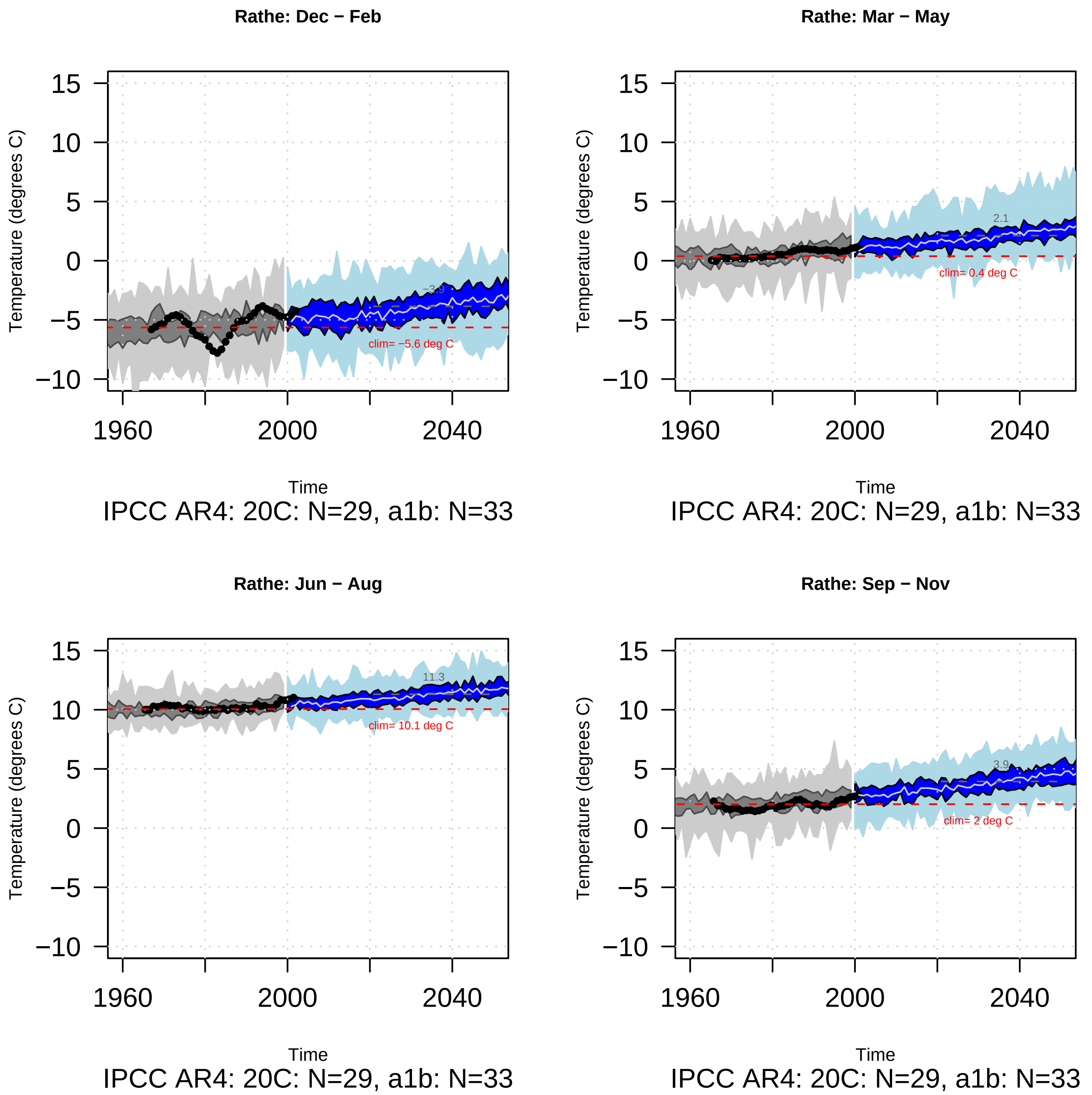


Figure 2.5 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 33 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.6 *Aursunden*

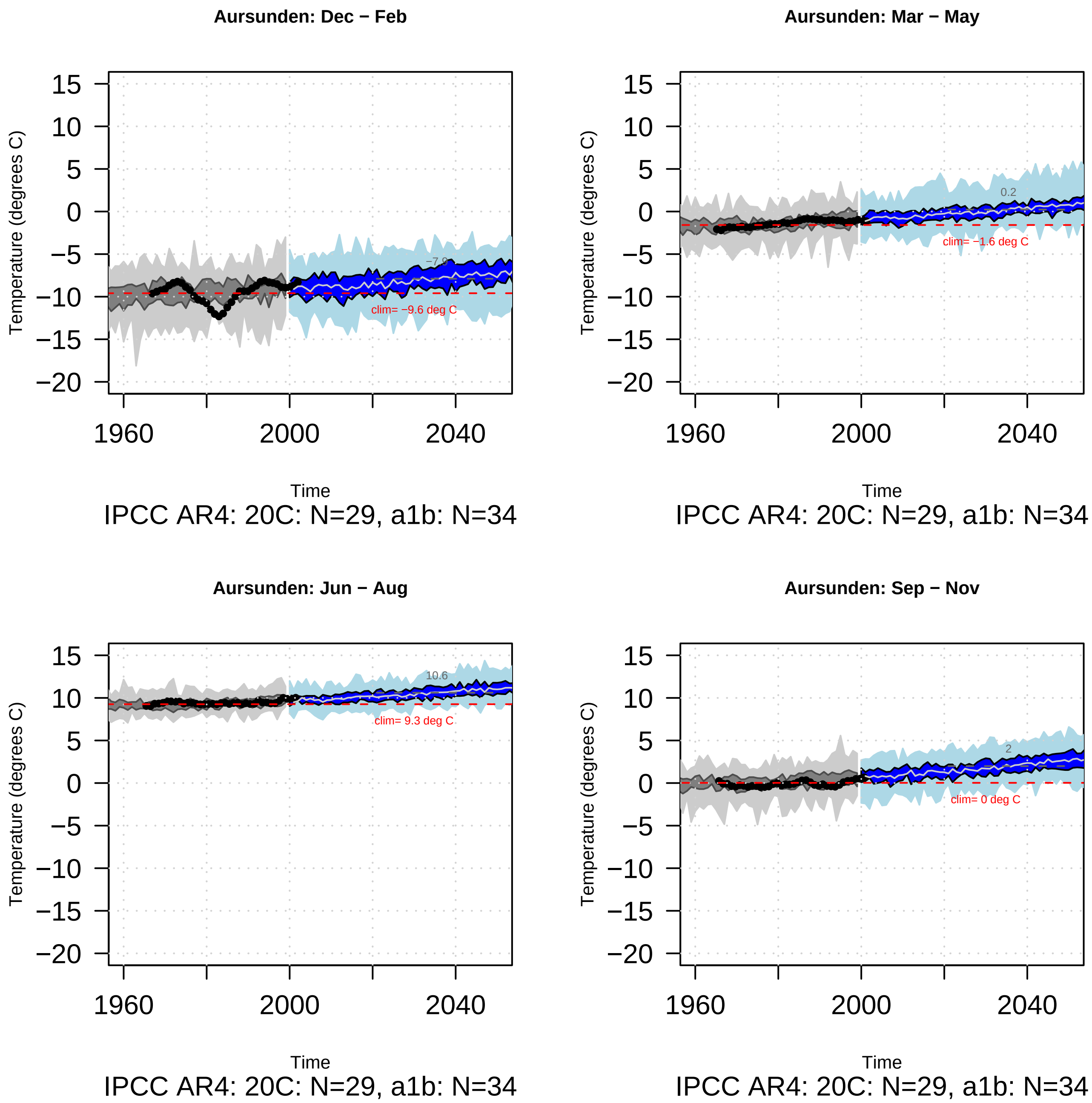


Figure 2.6 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 34 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.7 Nybergsund

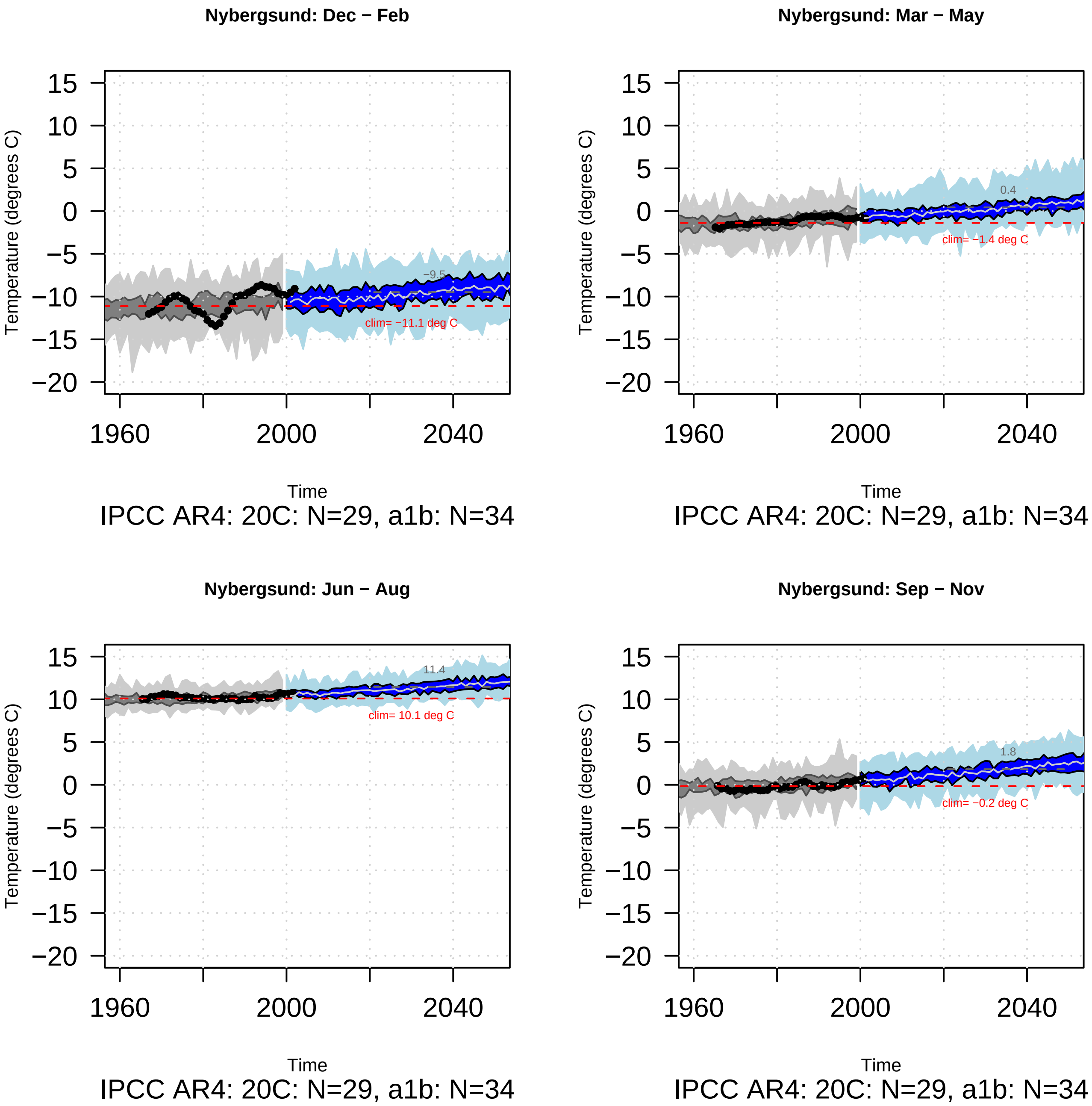


Figure 2.7 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 34 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.8 Knappom

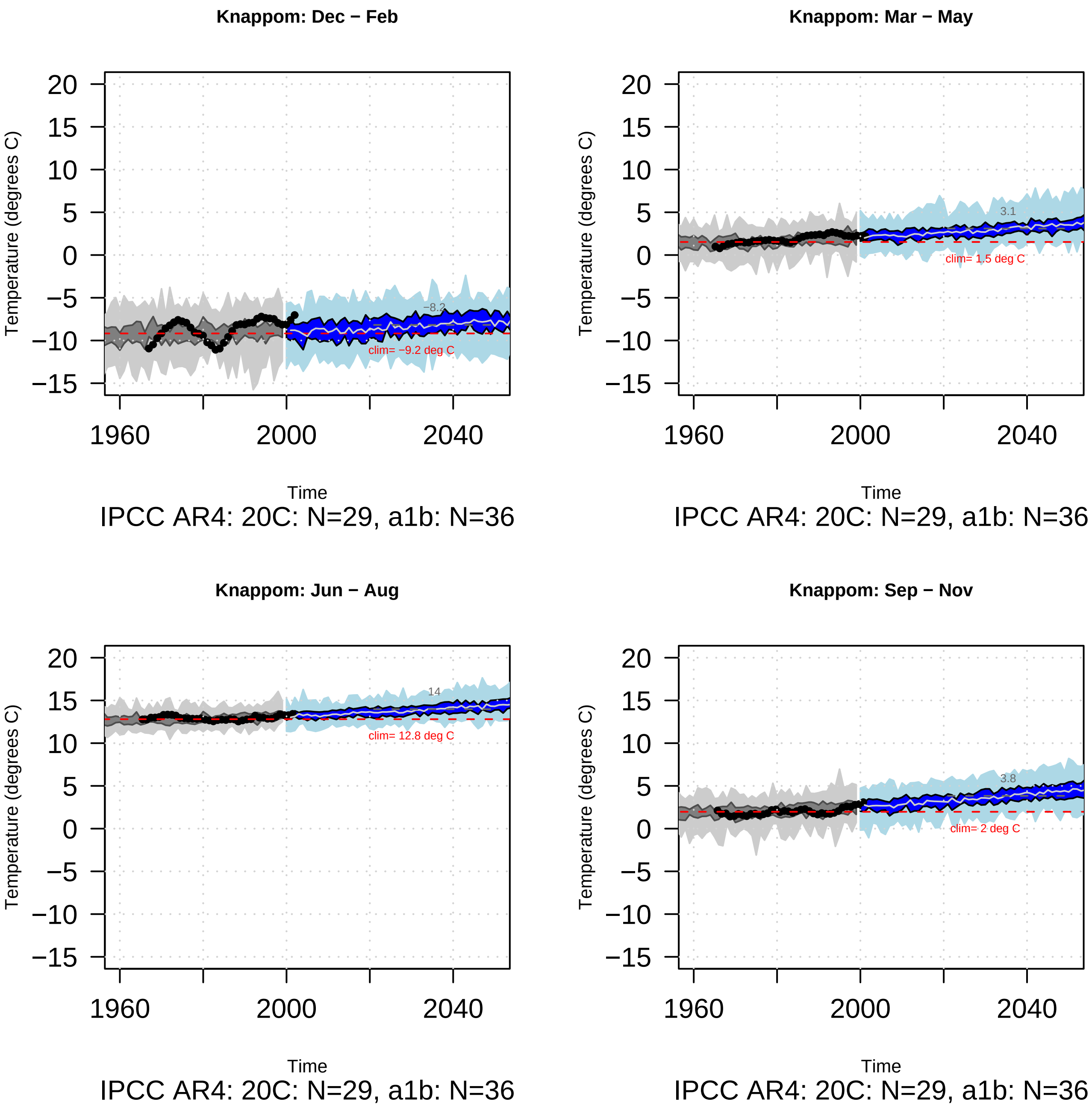


Figure 2.8 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 36 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve..

2.9 Risefoss

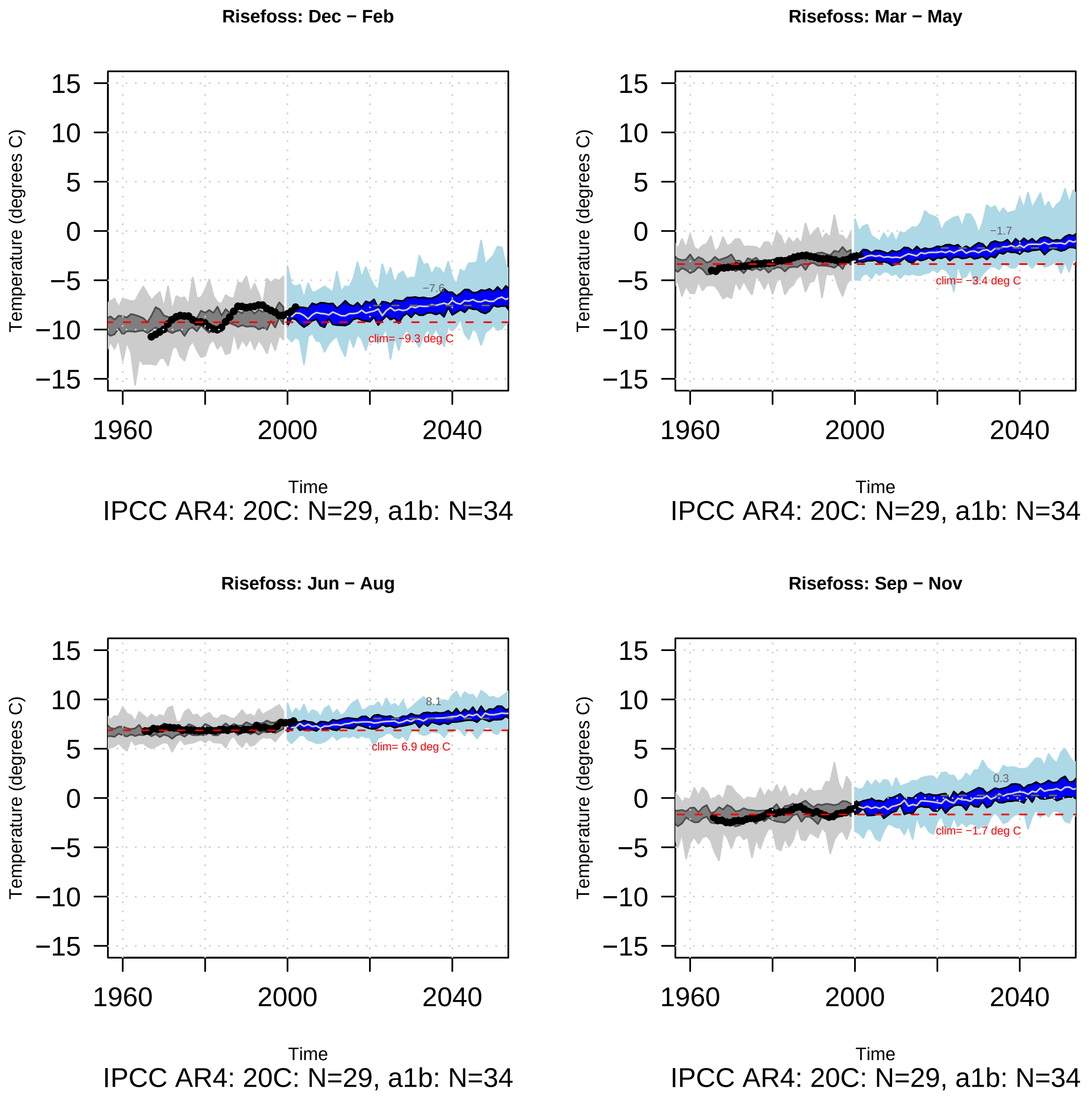


Figure 2.9 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 34 GCMs used for the historic period 1958 -2000 and the 29 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.10 Farstad

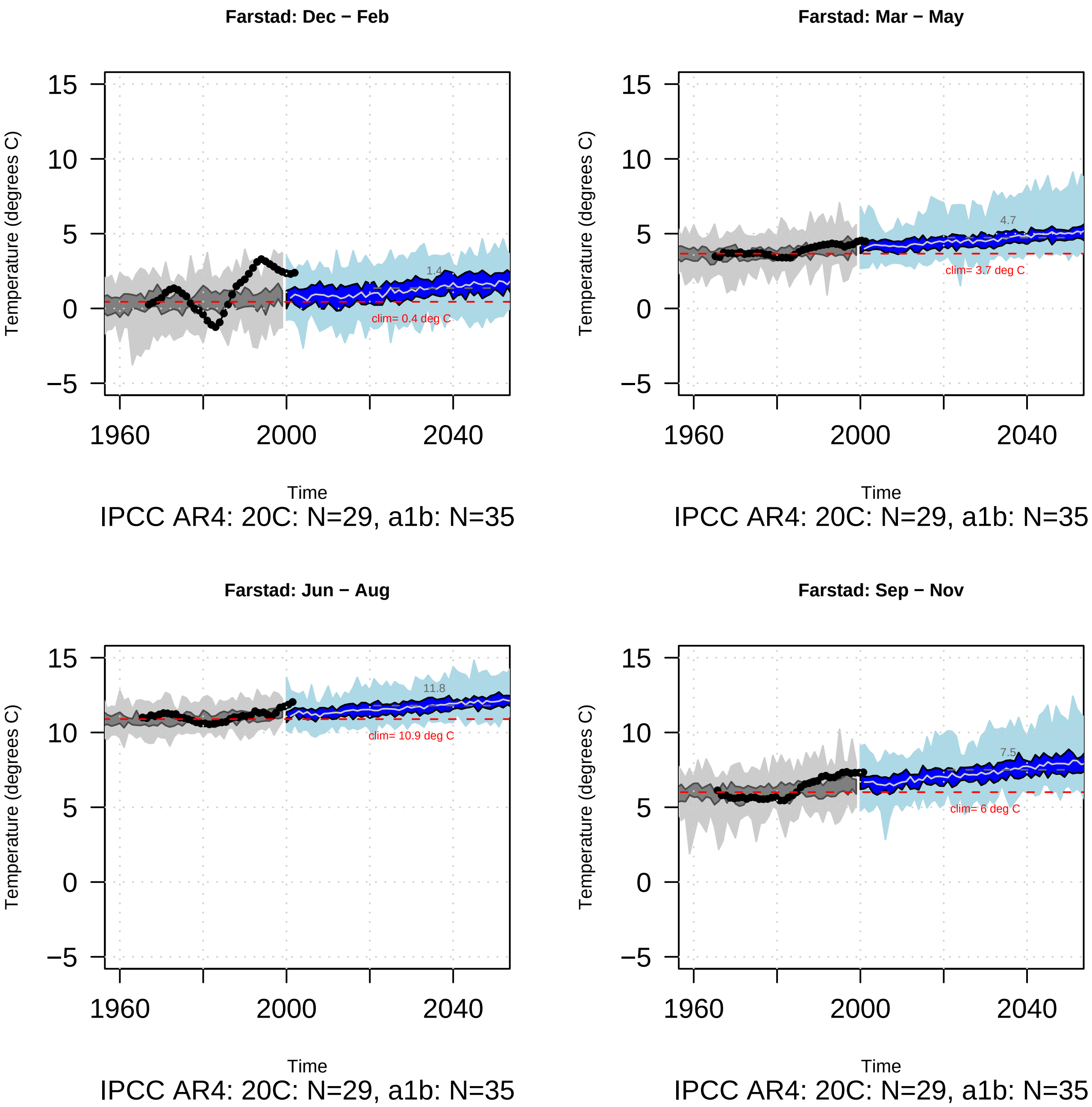
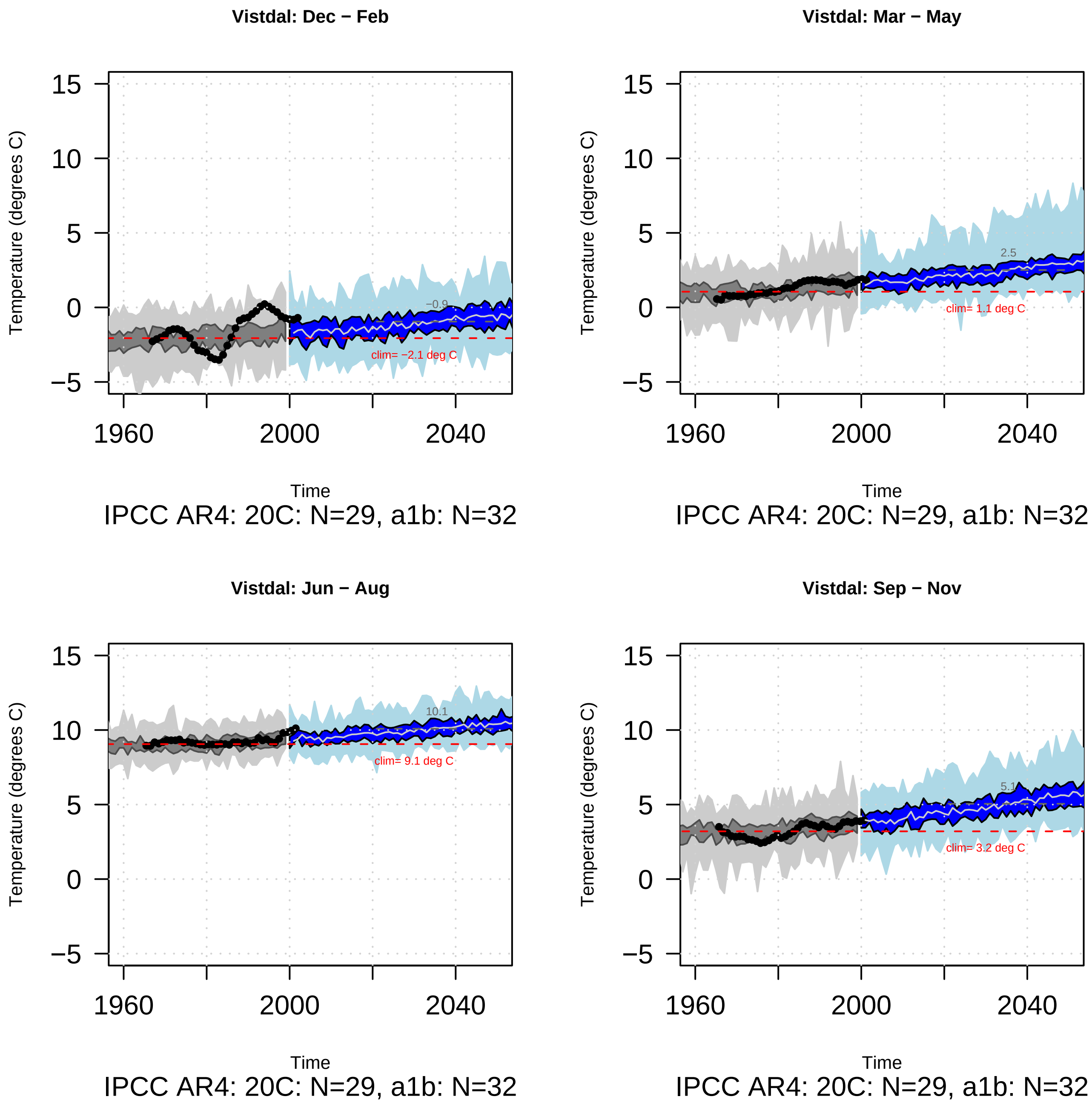


Figure 2.10 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 35 CMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.11 Vistdal



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2.12 Viksvatn

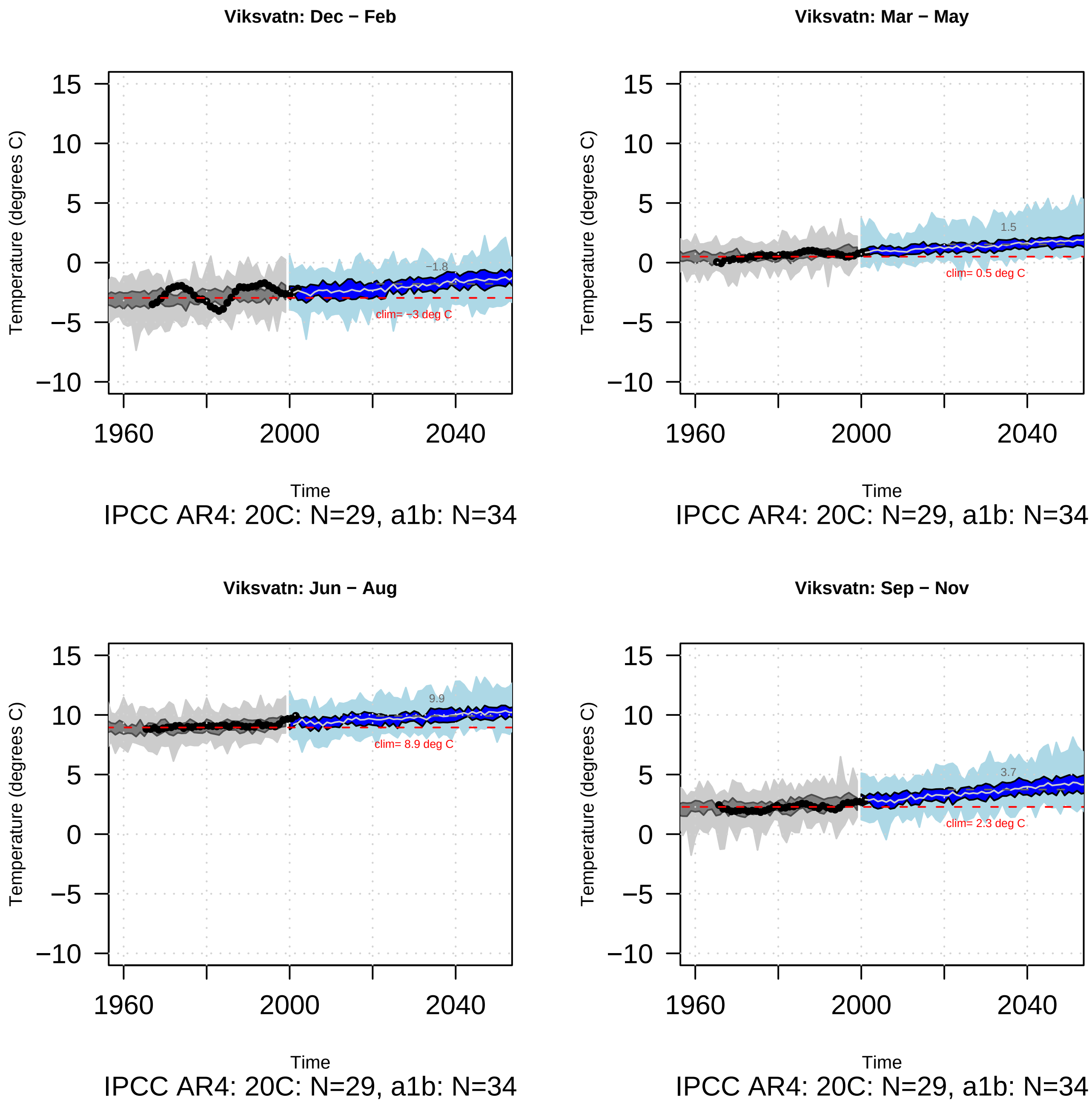
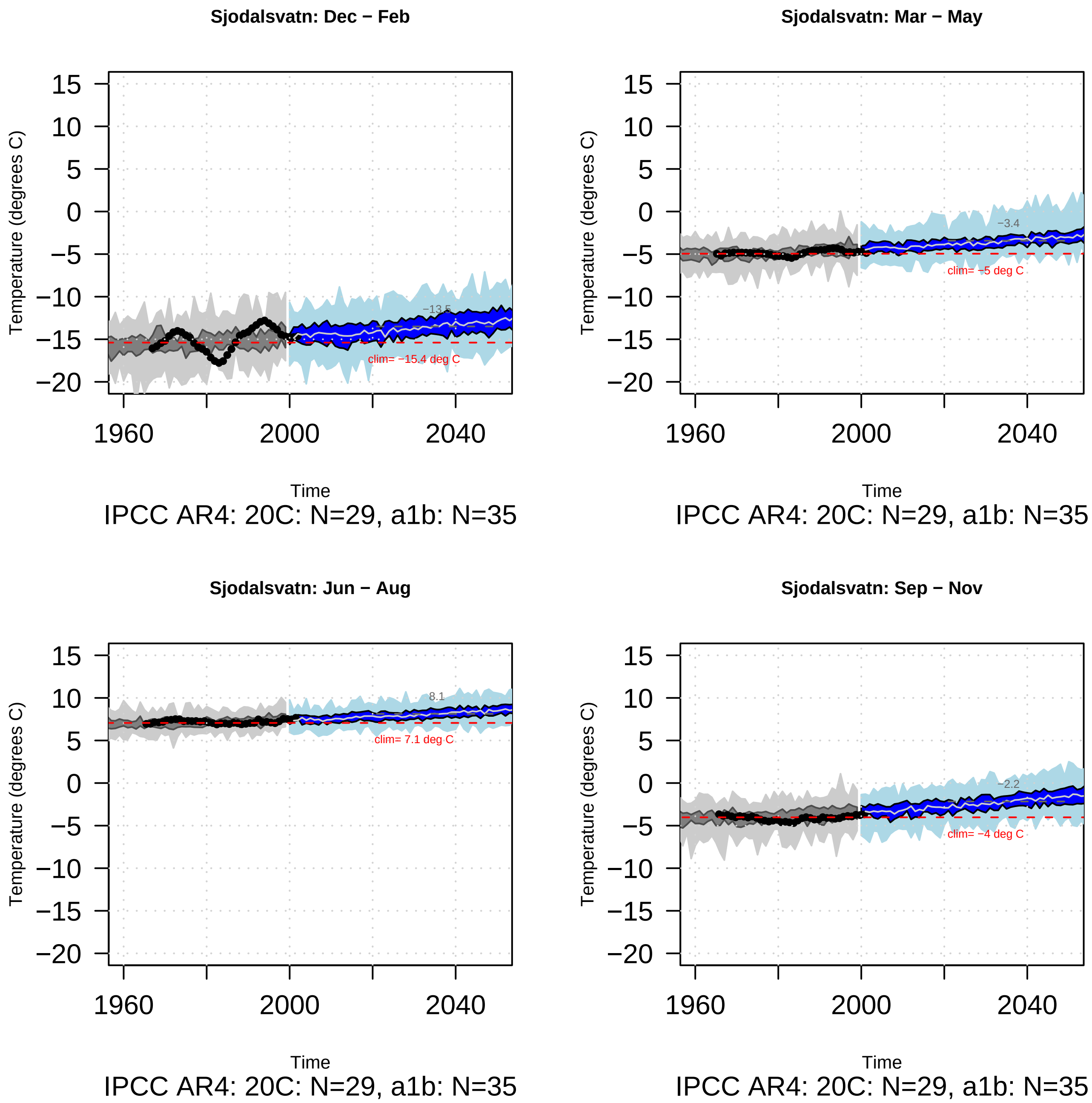


Figure 2.12 The figure shows the spread of empirically downscaled temperature with temperature as predictor from the 29 GCMs used for the historic period 1958 -2000 and the 34 GCMs for the future period 2000-2050 following the SRES A1b emission scenario. The projections are derived for four seasons; winter (upper left), spring (upper right), summer (lower left) and autumn (lower right). Mean temperature for the catchment as a whole, estimated from observations, is drawn as a dotted black curve.

2.13 Sjodalsvatn



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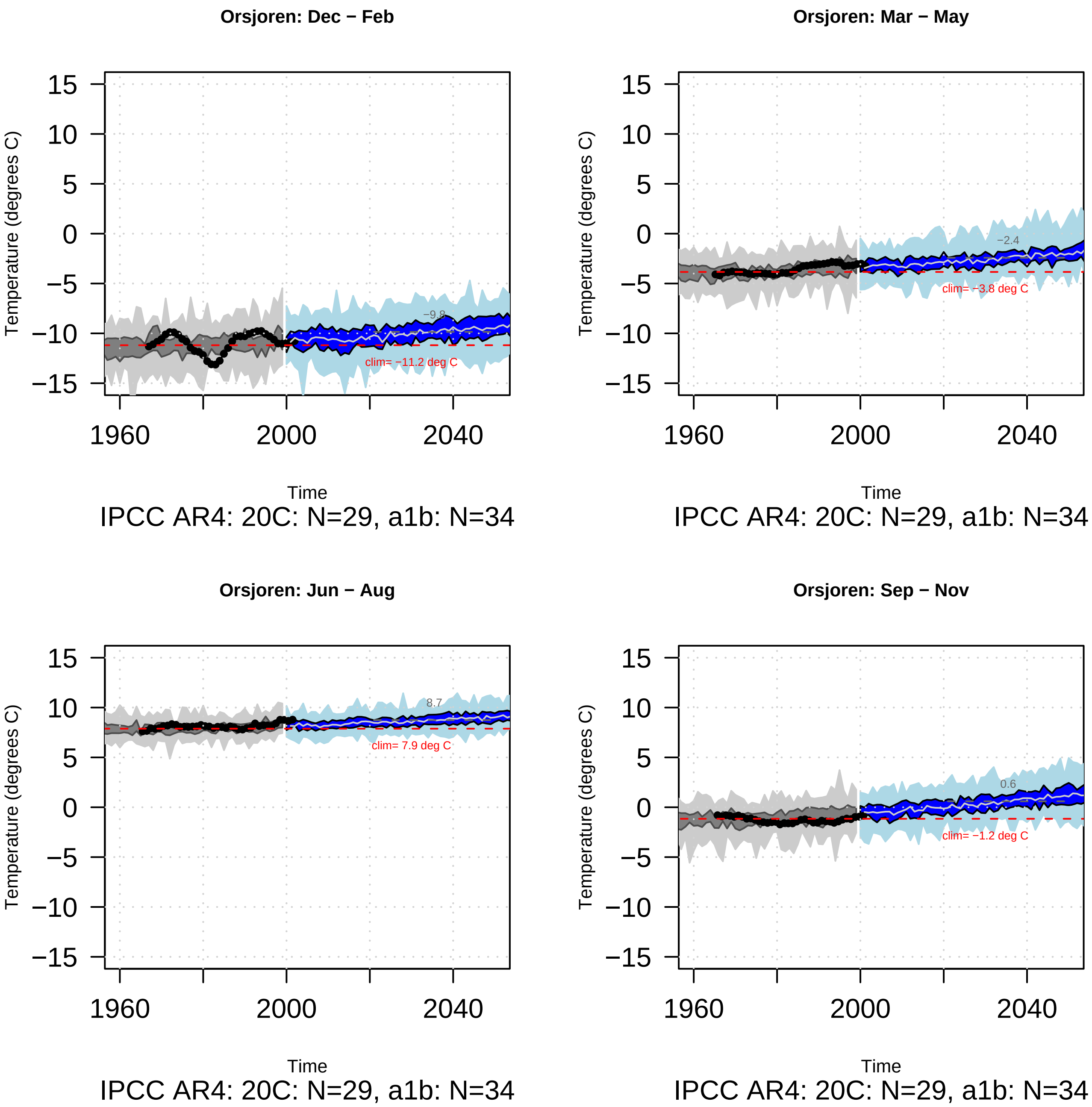
2.14 Orsjoren



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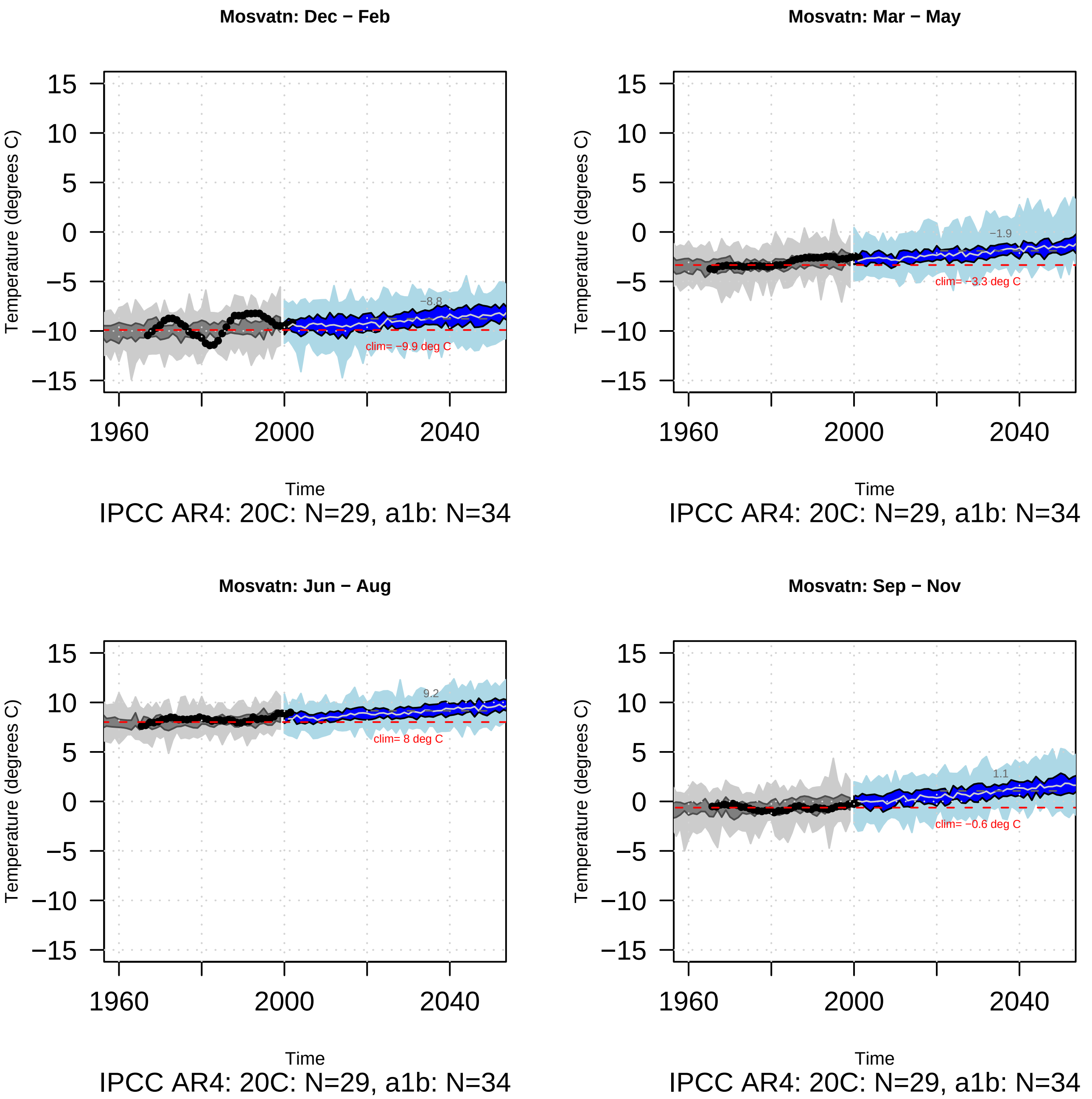
2.15 Møsvatn



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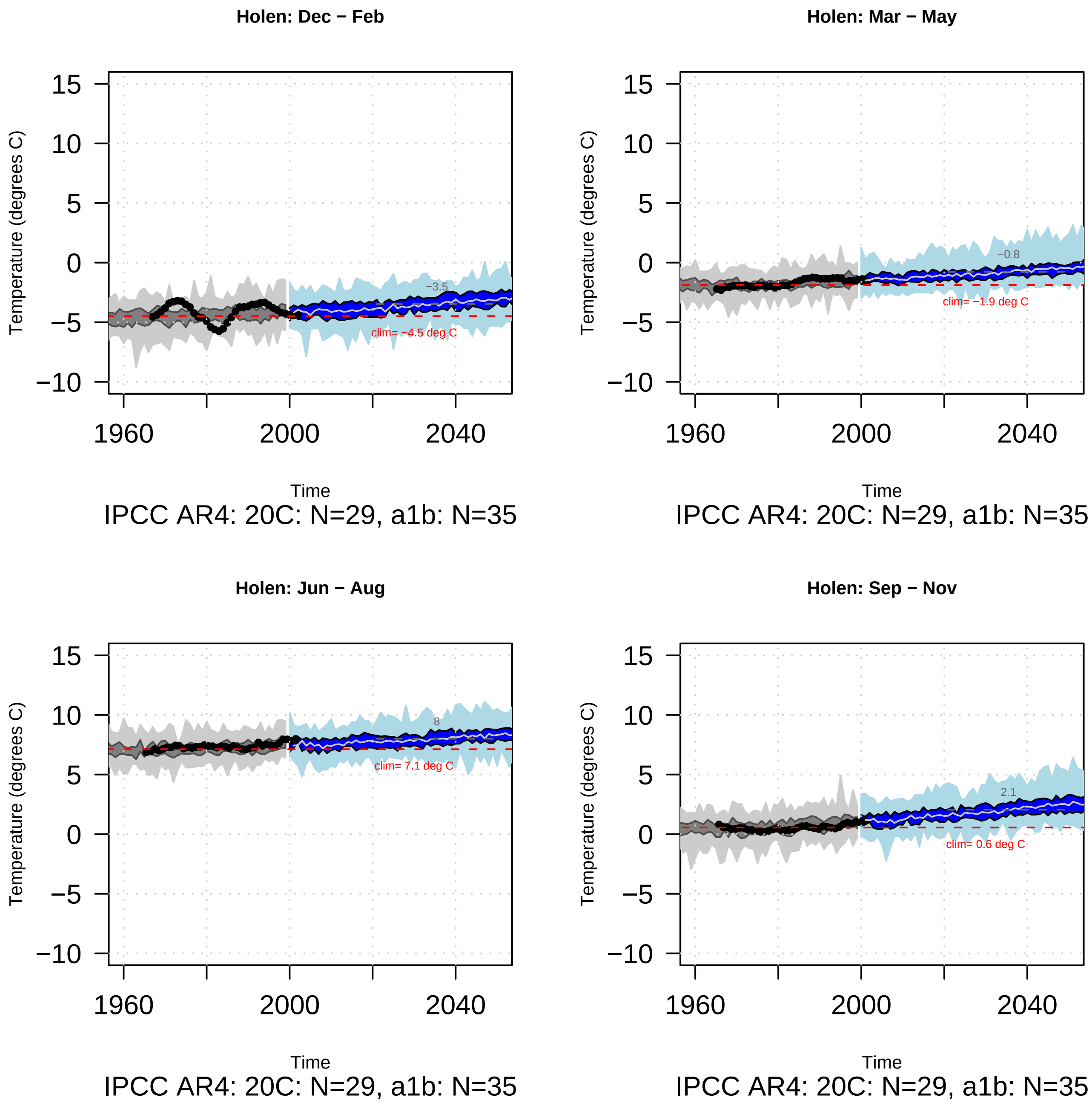
2.16 Hølen



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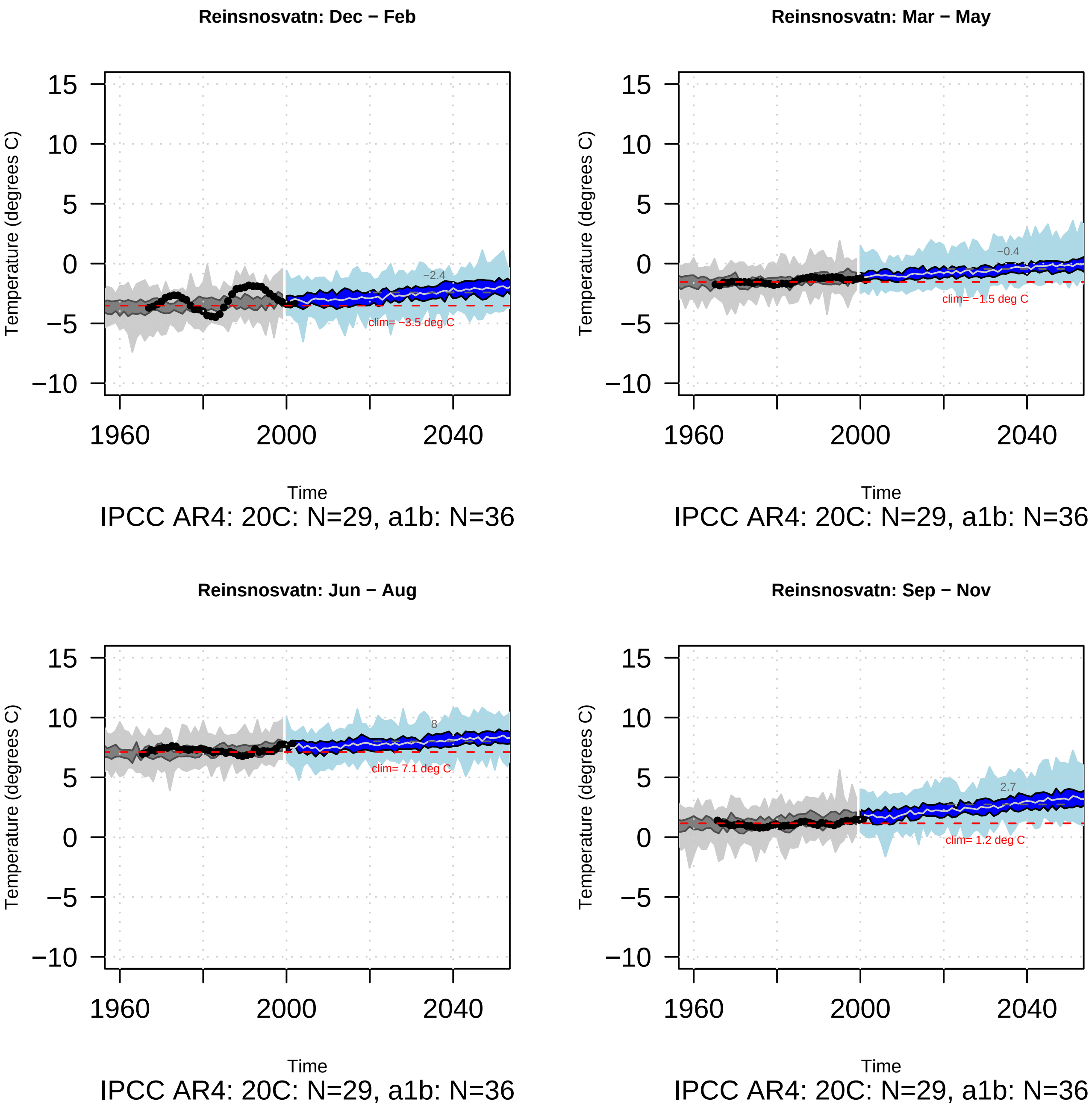
2.17 Reinsnosvatn



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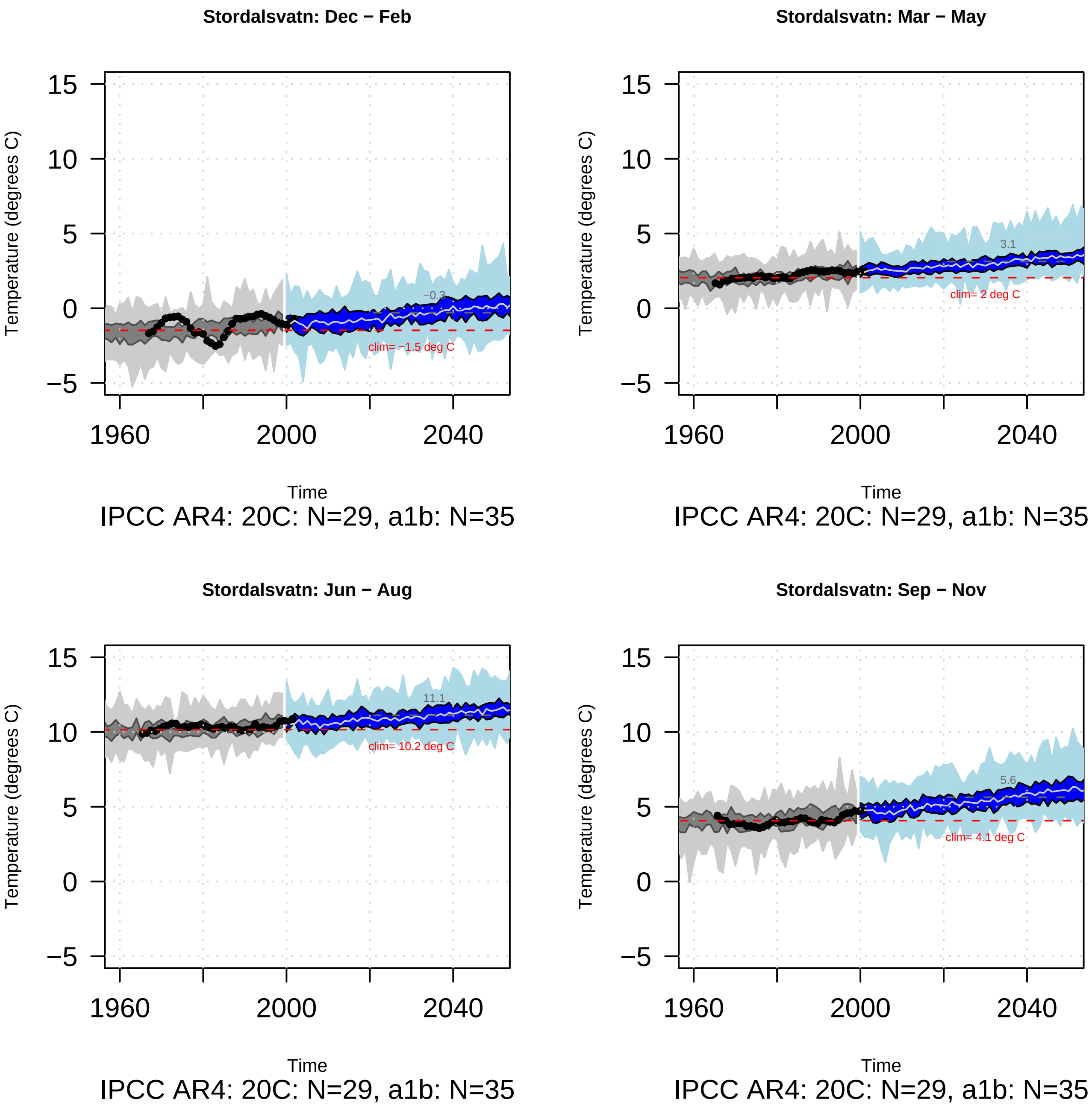
2.18 Stordalsvatn



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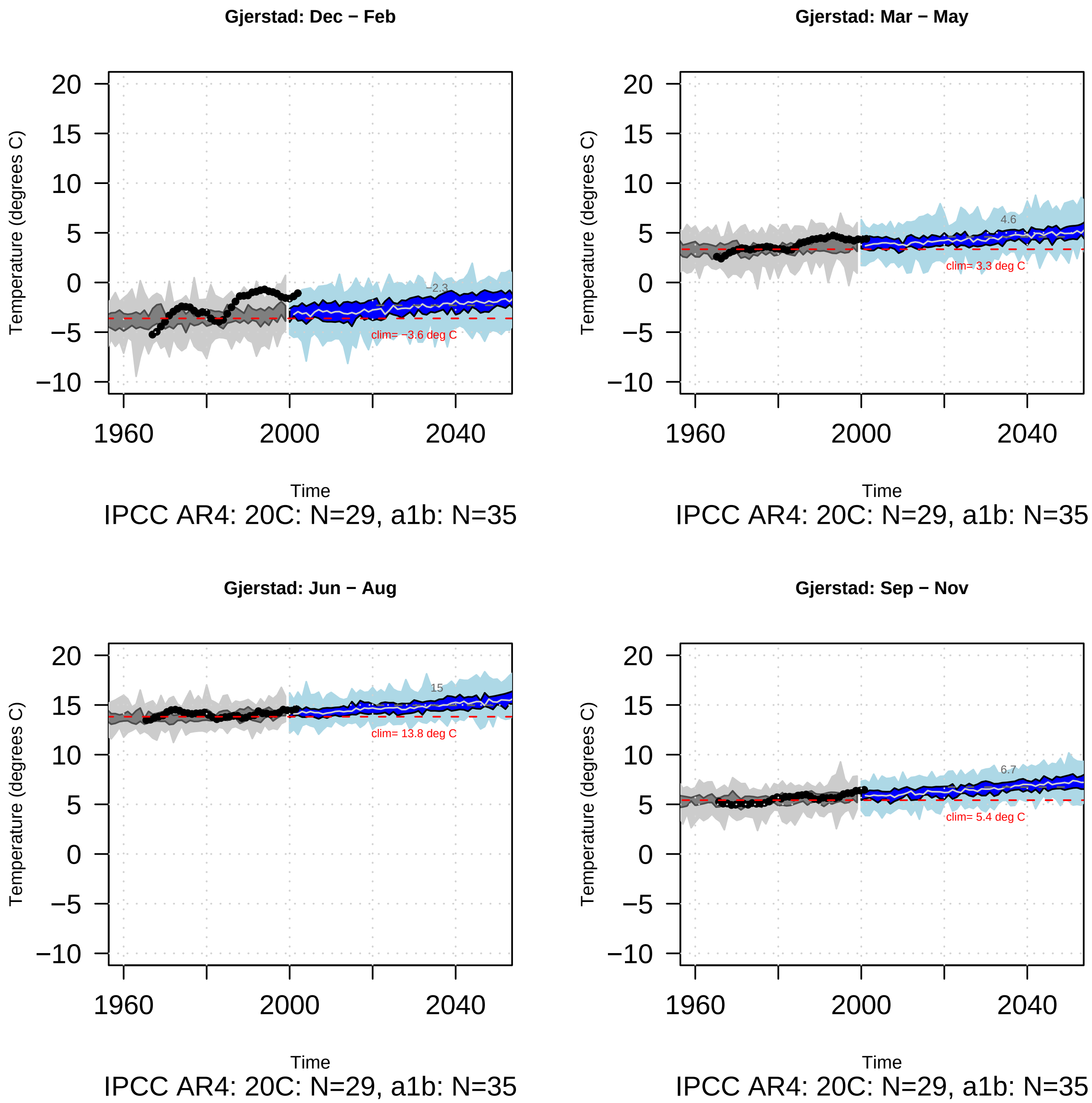
2.19 Gjerstad



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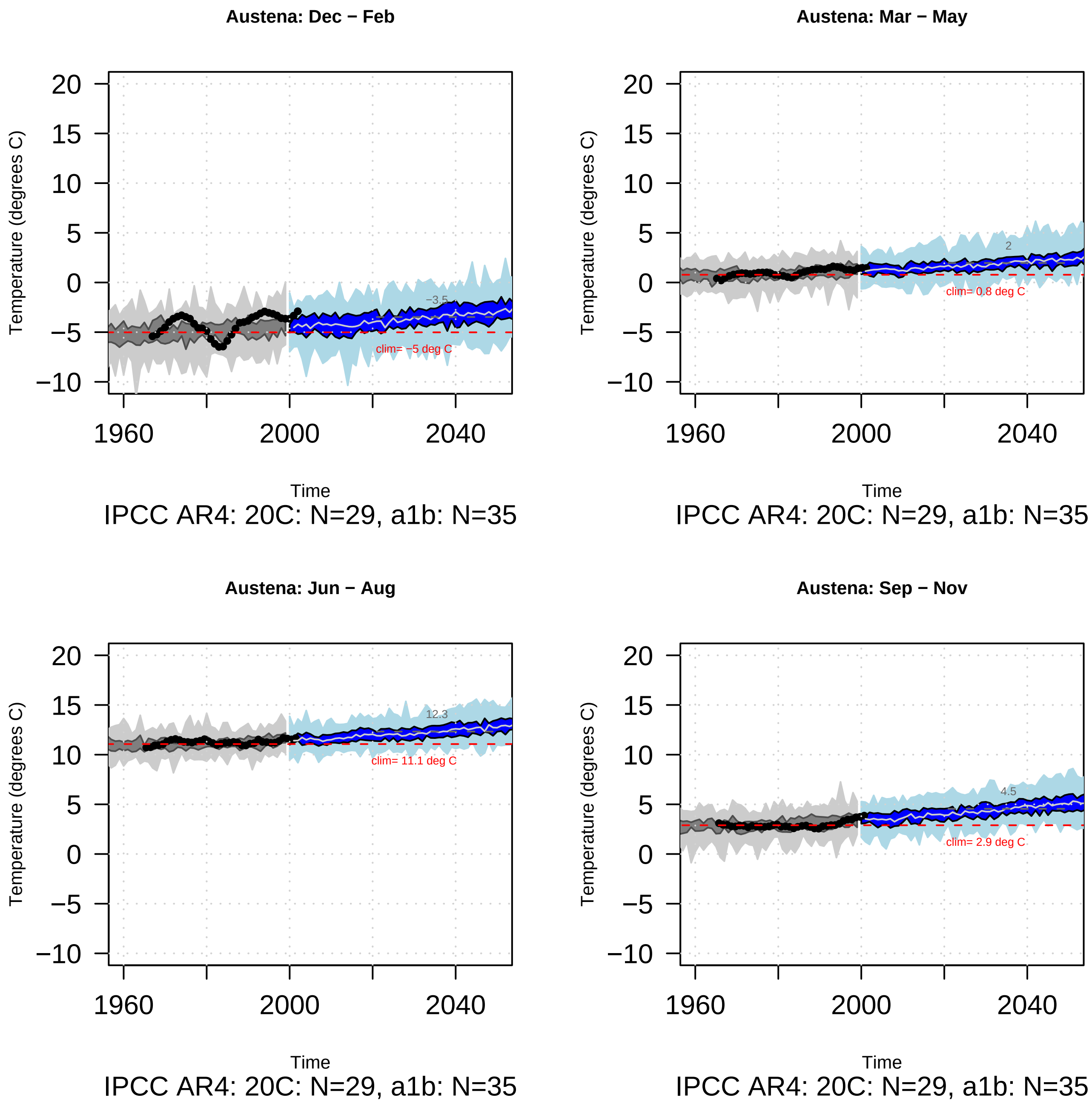
2.20 Austenå



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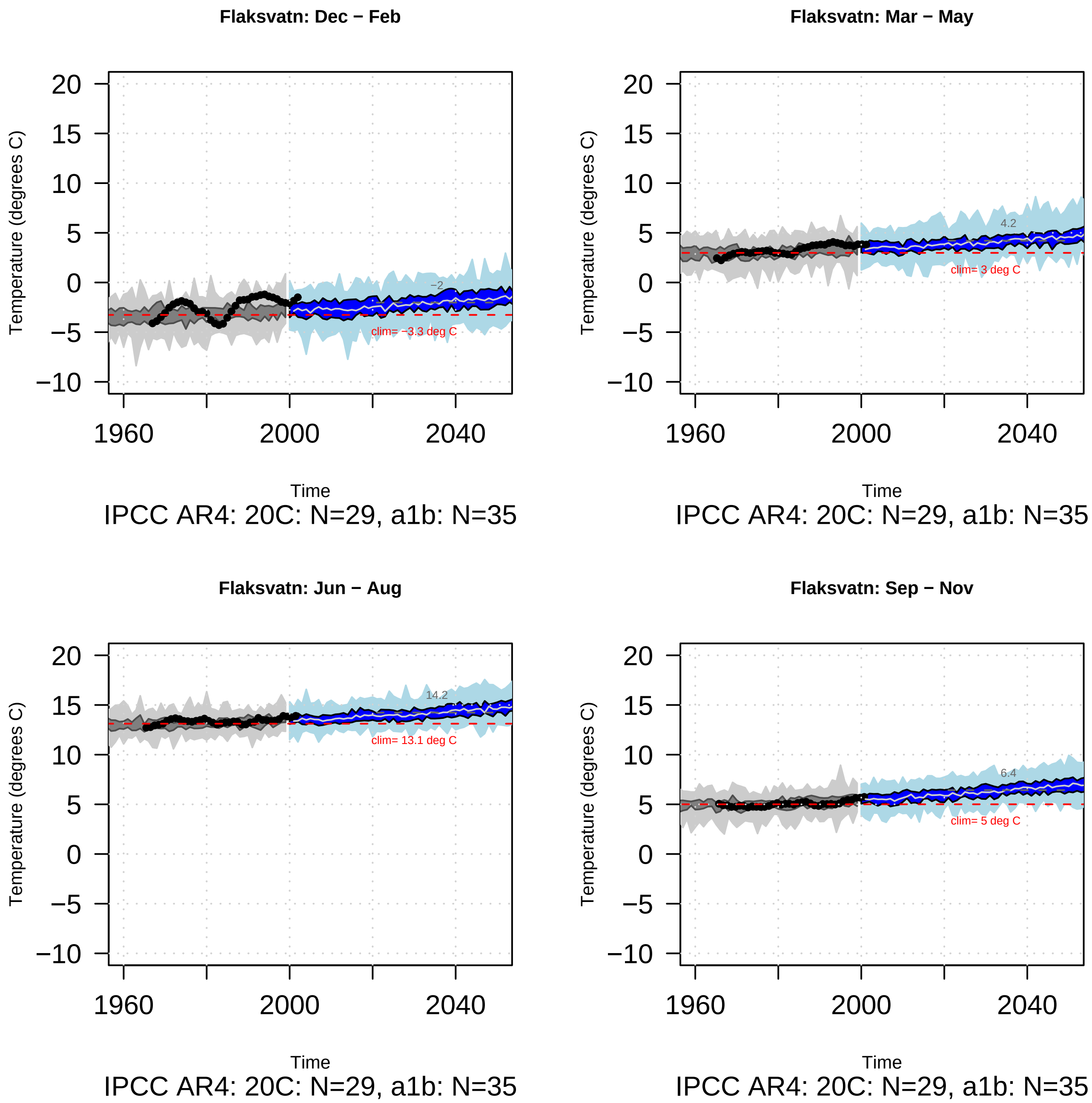
2.21 Flaksvatn



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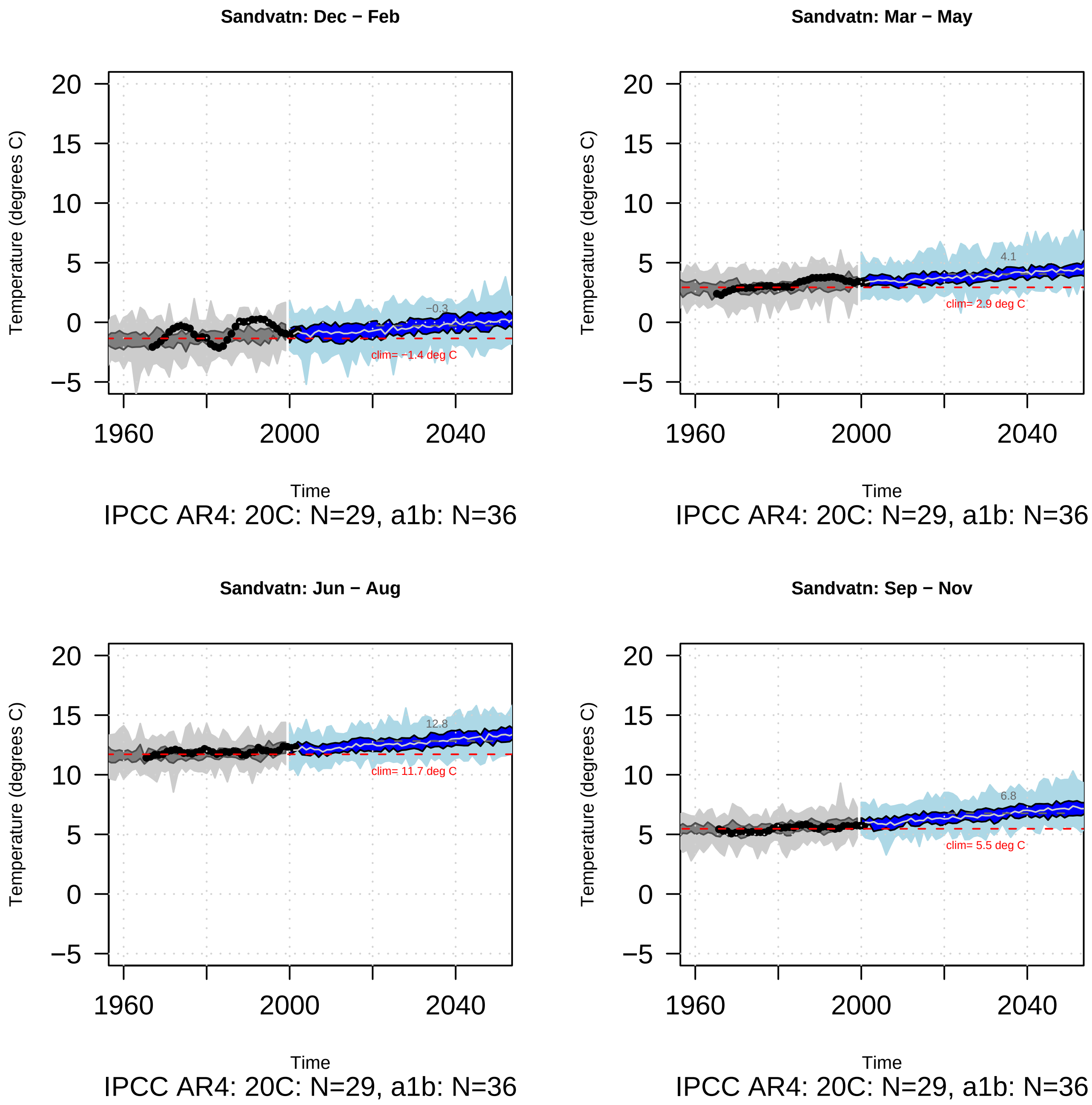
2.22 Sandvatn



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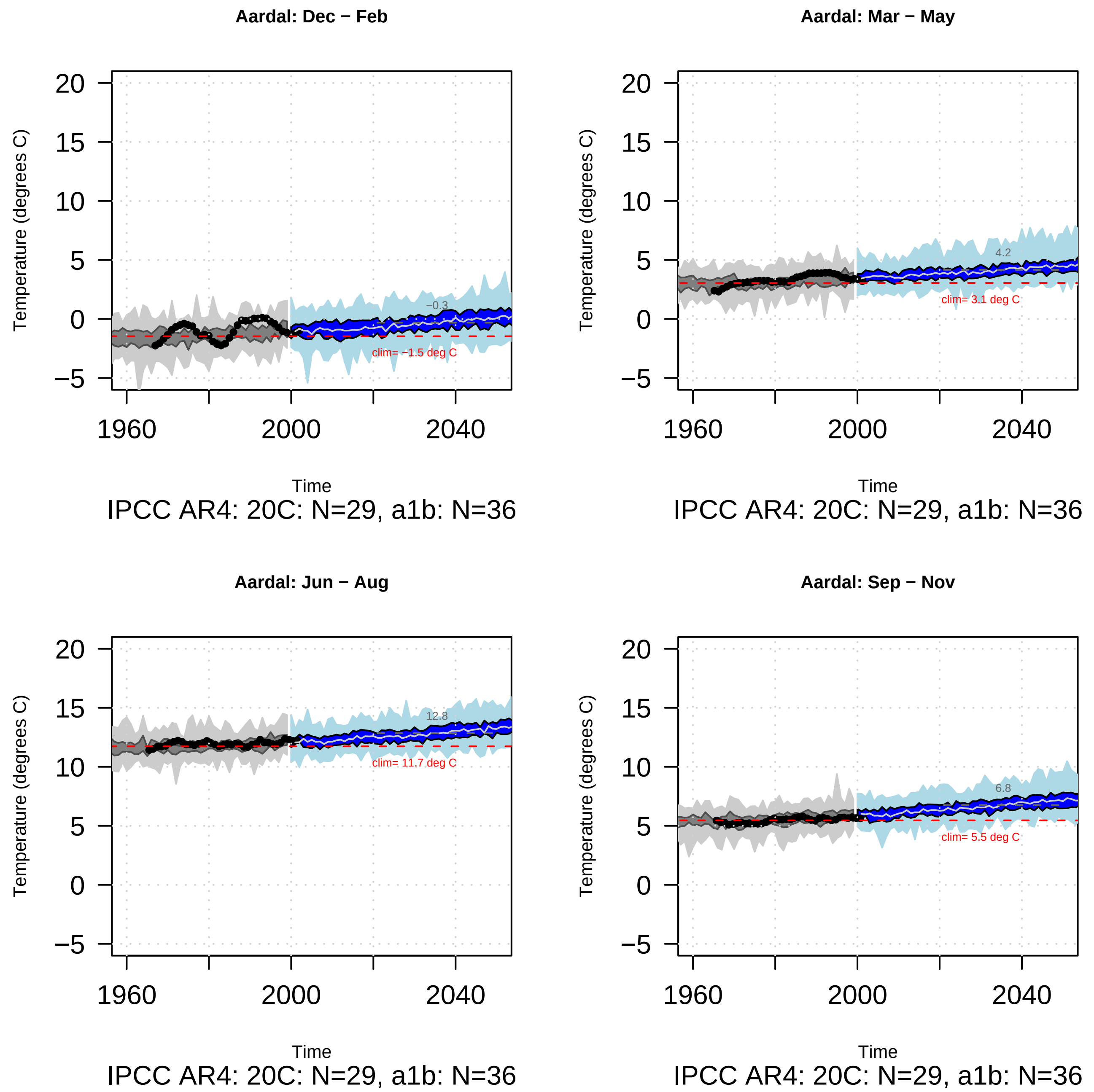
2.23 Årdal



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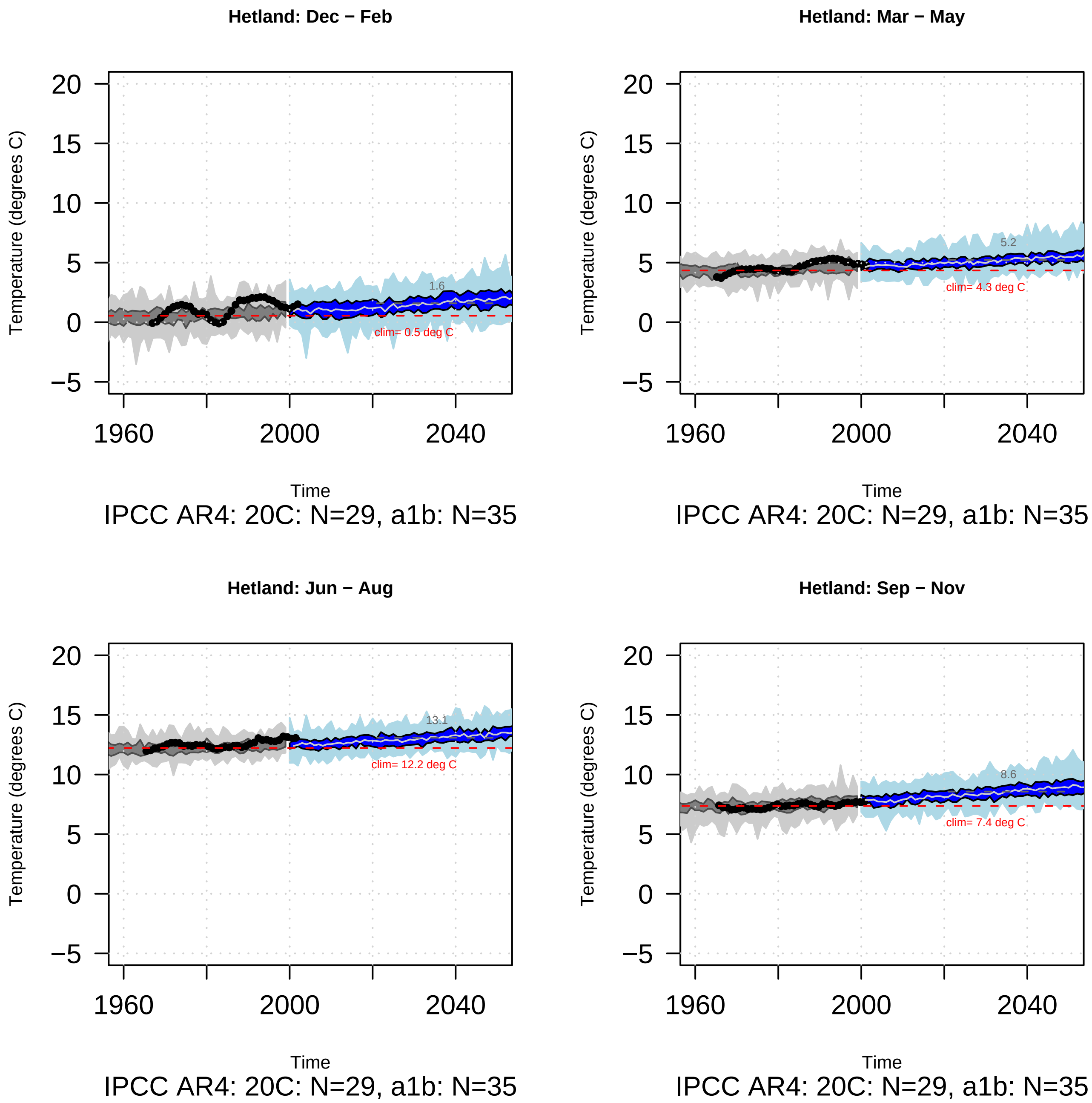
2.24 Hetland



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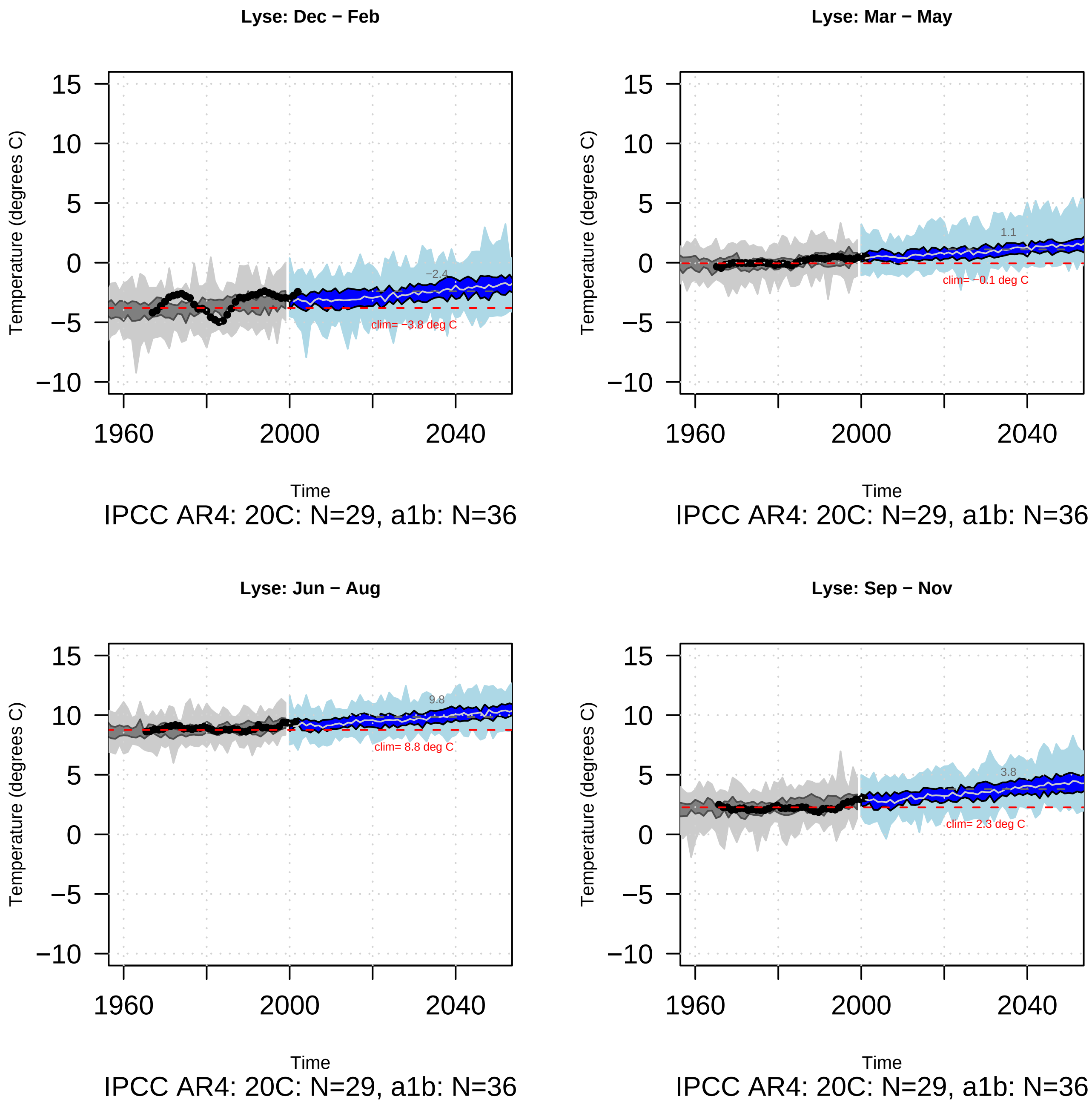
2.25 Lyse



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3 Projections of temperature for twenty-five Norwegian catchments; results from the Norwegian RegClim project

3.1 Masi

Masi is situated in Northern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~5600 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~1090 to ~270 m a. s. l. (Fig. 2.2 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-3.2 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -16°C in January to ~11 °C in July (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~3 - 3.5 °C in the area. Largest mean seasonal temperature is projected in winter (4-5) and autumn (3.5 – 4 °C), lower temperature change is projected for other seasons (spring: 3.5-4 °C and summer: 2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (~1-1.4 °C), largest increase in winter (2.2 - 2.4 °C). Spring and autumn 1.4 - 1.8 and 1 - 1.4°C respectively. Mean annual temperature increase is projected to 1.6-1.8 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.2 Kobbvatn

Kobbvatn is situated in northern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The catchment size is ~390 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a), it drains towards southwest. The catchments altitude rang from ~1520 to ~ 8 m a. s. l. (Fig. 2.2 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~0.1 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -6- -7°C in December - March to below 10 °C in July (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~3 - 3.5 °C in the area. Largest mean seasonal temperature is projected in autumn (3.5 - 4 °C), lower temperature change is projected for other seasons (winter and spring: 3-3.5 °C, summer: ~2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in summer (0.8 - 1 °C), spring (1.2 – 1.4°C) compared to autumn and winter (1.4 – 1.6 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.3 Nervoll

Nervoll is situated in northern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The catchment size is ~650 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a), it drains northwords. It is a high mountain catchment ranging from ~1700 to ~ 360 m a. s. l. (Fig. 2.2 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-1.6 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -12- -10°C in December-February to ~8-10 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~ 3 °C in the area. Largest mean seasonal temperature is projected in winter, spring and autumn (3-3.5 °C), lower temperature change is projected for summer (~2 - 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, is lower in summer (0.8 - 1°C), but also in spring (1 - 1.2°C) compared to winter (1.4 – 1.6°C) and autumn(1.2 - 1.4°C). Mean annual temperature increase is projected to 1.2 - 1.4 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.4 Kjelstad

Kjelstad is situated in the middle of Norway on the eastern side (Fig. 2.1 in Engen-Skaugen et al, 2008a). It is a small catchment ~142 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a), it drains towards northwest. It is a high mountain catchment ranging from ~1170 to ~ 280 m a. s. l. (Fig. 2.3). Mean annual temperature in the region is ~2.1 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -5°C in December-February to ~10 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in winter (1-1.2 °C), spring (0.8 - 1°C) and summer (0.8 - 1 °C) compared to autumn (1.2-1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.5 Rathe

Rathe is situated in the middle of Norway on the eastern side (Fig. 2.1 in Engen-Skaugen et al, 2008a). It is a large catchment ~3050 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a), it drains towards northwest. It is a high mountain catchment ranging from ~1762 to ~ 44 m a. s. l. (Fig. 2.3 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~1.6 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -6-7°C in January-February to ~10 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in winter (1-1.2 °C), spring (0.8 - 1°C) and summer (0.8 - 1 °C) compared to autumn (1.2-1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.6 Aursunden

Aursunden is situated in the eastern part of Norway near the Swedish boarder (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~850 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1525 to ~700 m a. s. l. (Fig. 2.3 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-0.6 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -11°C in January to ~10 °C in July (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (~3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in autumn and winter (1.2 – 1.4°C), less increase in spring (0.8 - 1°C), summer (0.4 – 0.6 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.7 Nybergsund

Nybergsund is situated in the eastern part of Norway with parts of the catchment in Sweden (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~4420 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1755 to ~355 m a. s. l. (Fig. 2.3 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~0.1 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~-12.5°C in January to ~11 °C in July (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3.5 - 4 °C), lower temperature change is projected for other seasons (winter: 3-3.5 °C, spring and summer: ~2.5 – 3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in summer (0.4 – 0.8 °C), spring (0.8 – 1 °C) compared to autumn and winter (1.2 – 1.4 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.8 Knappom

Knappom is situated eastern Norway on the Swedish boarder (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~1650 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~800 to ~180 m a. s. l. (Fig. 2.3 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-1.7 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -10°C in December - February to ~12-13.5 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~3-3.5 °C in the area. Largest mean seasonal temperature is projected in autumn and winter (~3 - 3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in autumn and winter (1.4 – 1.6°C), less increase in spring (0.8 - 1°C), summer (0.6 – 0.8 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.9 Risefoss

Risefoss is situated in the north-western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~743 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a), it drains northwards. It is a high mountain catchment ranging from ~2286 to ~ 580 m a. s. l. (Fig. 2.3 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-1.9 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -10°C in January-February to ~6-7 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (winter: ~2-2.5 °C, spring ans summer: ~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in spring (0.8 - 1°C) and summer (0.8 - 1 °C) compared to autumn (1-1.2 °C). Temperature change in winter is here of the same magnitude as in autumn though (1 - 1.2 °C). Mean annual temperature increase is projected to 1 - 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.10 Farstad

Farstad is situated in the coastal part of north-western Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~23 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) ranging from ~667 to ~ 19 m a. s. l. (Fig. 2.4 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~5.2 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ 0°C in January-February to ~10-11 °C in June to September (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2 – 2.5 °C in the area. Largest mean seasonal temperature is projected in autumn (2.5-3 °C), lower temperature change is projected for other seasons (~2-2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in spring (0.8 - 1°C) and summer (0.6-0.8 °C) compared to autumn (1-1.2 °C). Temperature change in winter is here of the same magnitude as in autumn though (1-1.2 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.11 Vistdaln

Vistdal is situated near the coastal part of north-western Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~66 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1550 to ~60 m a. s. l. (Fig. 2.4 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~2.8 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~-2.6 °C in January-February to ~10 °C in July an August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (spring: ~2.5-3 °C, winter and summer: ~2-2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, less increase in spring (0.8 - 1°C) and summer (0.6-0.8 °C) compared to autumn (1-1.2 °C). Temperature change in winter is here of the same magnitude as in autumn though (1-1.2 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.12 Viksvatn

Viksvatn is situated the western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~500 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~1640 to ~150 m a. s. l. (Fig. 2.4 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~2.2 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -3.5°C in January - February to 8.5-9.5 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (winter and summer: 2 – 2.5 °C, spring: 2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (~0.6 °C), largest increase in winter, spring and autumn (1 - 1.2°C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.13 Sjodalsvatn

Sjodalsvatn is situated in the high mountain region in the middle of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is 480 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) and the altitude ranges from ~2300 to ~940 m a. s. l. (Fig. 2.4 in Engen-Skaugen et al, 2008a), it drains towards east. Mean annual temperature in the region is ~4.3 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from -16.5 in January to 8.0 in July (Fig. 3.1 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5-3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, although less increase in spring (0.8-1 °C) and summer (0.6-0.8 °C) compared to autumn (1.2-1.4 °C) and winter (1.2-1.4 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

Mean monthly temperature representing Sjodalsvatn catchment (Section 3.1 in Engen-Skaugen et al, 2008 a) are drawn as a black dotted curve in Figure 2.1.1. The historical model runs are downscaled based on the ERA 40 reanalyses. The precipitation based on observations (black dotted curve) should therefore lie within the spread of the historical model runs. This is the case for all seasons.

3.14 Orsjoren

Orsjoren is situated in the high mountain region in southern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is 1177 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) it is a rather flat catchment ranging from ~1540 to ~950 m a. s. l. (Fig. 2.5), it drains towards east. Mean annual temperature in the region is ~-2.1 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from below -10 °C in January-February to 8-9 °C in summer (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~3°C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, although less increase in spring (1 – 1.2 °C) and summer (0.6-0.8 °C) compared to autumn (1.2-1.4 °C) and winter (1.2-1.4 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.15 Møsvatn

Møsvatn is situated in the high mountain regions of southern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~1500 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1630 to ~920 m a. s. l. (Fig. 2.5 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~-1.5 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -

10°C in January - February to ~7-8 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5-3 °C in the area. Largest mean seasonal temperature is projected in autumn (~3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in autumn and winter (1.2 – 1.4°C), less increase in spring (1 - 1.2°C), summer (0.6 – 0.8 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.16 Hølen

Hølen is situated in the western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~230 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~1700 to ~120 m a. s. l. (Fig. 2.5 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~0.3 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -5°C in January - March to 6-8 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (2.5 - 3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.6 – 0.8 °C), winter and spring (1 - 1.2°C) compared to autumn (1.2 - 1.4 °C). Mean annual temperature increase is projected to 1 - 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.17 Reinsnosvatn

Reinsnosvatn is situated in the western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~120 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~1600 to ~600 m a. s. l. (Fig. 2.5 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~0.8 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ 0°C in January - February to 11 - 13 °C in June to September (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in spring and autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (winter: 2.5 - 3 °C, summer: ~2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.6 – 0.8 °C), winter and spring (1 - 1.2°C) compared to autumn (1.2 - 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.18 Stordalsvatn

Stordalsvatn is situated in the western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~130 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~1250 to ~50 m a. s. l. (Fig. 2.5 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~3.7 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -2°C in January - February to ~10 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project

Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (winter and spring: 2.5 - 3 °C, summer: ~2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.4 – 0.6 °C), spring (0.8 - 1°C) compared to autumn (1 - 1.2 °C) and winter (1.2 – 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.19 Gjerstad

Gjerstad is situated in near the coast in south-eastern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is 236 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) it is a low laying catchment ~660 to ~80 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a), it drains southwards. Mean annual temperature in the region is ~4.7 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~-5 °C in January-February to 15 °C in July (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~3°C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show similar pattern, although less increase in spring (0.8 - 1°C) and summer (0.6-0.8 °C) compared to autumn (1.2-1.4 °C) and winter (1.2-1.4 °C). Mean annual temperature increase is projected to 1 – 1.2 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.20 Austenå

Austenå is situated in southern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~280 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1000 to ~270 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~2.4 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -6°C in January - February to ~11 - 12 °C in July to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5-3 °C in the area. Largest mean seasonal temperature is projected in autumn (~3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in winter (1.2 – 1.4°C), less increase in spring (0.8 – 1 °C), summer (0.4 – 0.6 °C) and autumn (1 - 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.21 Flaksvatn

Flaksvatn is situated in southern Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~1780 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1000 to ~35 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~4.4 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -4°C in January - February to

~13-14 °C in July to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5-3 °C in the area. Largest mean seasonal temperature is projected in autumn (~3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in winter (1.2 – 1.4°C), less increase in spring (0.8 – 1 °C), summer (0.4 – 0.6 °C) and autumn (1 - 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.22 Sandvatn

Sandvatn is situated in the south-western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~ 27 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment altitude rang from ~ 630 to ~320 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~4.7 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -2°C in January - February to 11 - 12 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (spring and summer: 2.5 - 3 °C, summer: ~2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.4 – 0.6 °C), spring (0.8 - 1°C) compared to autumn (1-1.2) and winter (1.2 – 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.23 Årdal

Årdal is situated in the south-western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The catchment size is ~77 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchments altitude rang from ~731 to ~ 110 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~4.7 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -2°C in January - February to 11 - 12 °C in June to August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (spring and summer: 2.5 - 3 °C, summer: ~2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.4 – 0.6 °C), spring (0.8 - 1°C) compared to autumn (1-1.2) and winter (1.2 – 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.24 Hetland

Hetland is situated in the south-western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~ 70 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a). The catchment rang from ~530 to ~60 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~6.1 °C

(Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ 0°C in January - February to 11 - 13 °C in June to September (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 - 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3 – 3.5 °C), lower temperature change is projected for other seasons (spring and summer: 2.5 - 3 °C, summer: ~2 – 2.5 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, show less increase in summer (0.4 – 0.6 °C), spring (0.8 - 1°C) compared to autumn (1-1.2) and winter (1.2 – 1.4 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

3.25 Lyse

Lyse is situated south-western part of Norway (Fig. 2.1 in Engen-Skaugen et al, 2008a). The size of the catchment is ~320 km^2 (Table 2.1 in Engen-Skaugen et al, 2008a) the catchment rang from ~1300 to ~500 m a. s. l. (Fig. 2.6 in Engen-Skaugen et al, 2008a). Mean annual temperature in the region is ~1.8 °C (Table 2.1 in Engen-Skaugen et al, 2008a). Mean monthly temperature rang from ~ -4.5°C in January-February to ~9 °C in July and August (Fig. 3.2 in Engen-Skaugen et al, 2008a). In the Norwegian project Regional Climate development under global warming (RegClim http://regclim.met.no), annual increase in temperature for the time period 2071-2100 compared to the time period 1961-1990 is projected to ~2.5 – 3 °C in the area. Largest mean seasonal temperature is projected in autumn (3-3.5 °C), lower temperature change is projected for other seasons (~2.5-3 °C) (Iversen et al., 2005). These estimates are based on dynamically downscaling of two global climate model runs following the emission scenario B2. Projections for the period 2020-2049 compared to 1980-1999 following the ECHAM4 GSDIO model and IS92a emission scenario, the largest increase is projected in winter (1.2 – 1.4°C), less increase in spring (0.8 - 1°C), summer (0.4 – 0.6 °C) and autumn (1 - 1.2 °C). Mean annual temperature increase is projected to 0.8 - 1 °C (Førland et al., 2000; Bjørge et al., 2000). The estimates of the latter projection are more moderate due to the use of a time window closer to present.

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