Climate Scenarios for Alberta

SUMMARY DOCUMENT

Elaine Barrow
Ge Yu

No. 06-02

The Whaleback
Photo credit: Suzan Lapp

This summary report provides an overview of the findings from the Prairie Adaptation Research Collaborative project, Climate Scenarios for Alberta. The full report is at the PARC website (www.parc.ca). Click on the link to "Research Publications" and "Scenarios".

General e-mail for PARC: info@parc.uregina.ca

Telephone: 306-337-2300

Fax: 306-337-2301

Website: www.parc.ca

PARC
PRAIRIE ADAPTATION RESEARCH COLLABORATIVE

Alberta
ENVIRONMENT

Storm over southern Alberta
Photo credit: Dave Sauchyn

INTRODUCTION

In the most recent assessment undertaken by the Intergovernmental Panel on Climate Change (IPCC) a number of conclusions concerning global climate change were reached, including the following: "that the increasing body of observations gives a collective picture of a warming world and other changes in the climate system" and that "there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC, 2001). These observed changes in climate are as a result of a global average surface air temperature increase over the 20th century of about 0.6°C. In contrast to these observed changes, global average surface air temperature is projected to increase between 1.4°C and 5.8°C by 2100, relative to 1990. What may these projected changes in global average climate mean for Alberta?

METHODOLOGY: CONSTRUCTION AND SELECTION OF CLIMATE CHANGE SCENARIOS

One way of translating climate changes at the global scale to climate changes at the local scale is to use global climate models (GCMs). These three-dimensional mathematical models represent the physical processes of, and the known feedbacks between, the atmosphere, ocean, cryosphere and land surface, and have been used successfully for simulating past, present and future climates. The most advanced GCMs are known as 'warm-start' transient GCMs and these simulate the effect of historical changes in atmospheric composition (beginning as early as the 18th century) on the radiation balance of the atmosphere and then, by using information about how atmospheric composition may change in the future (derived from a greenhouse gas emissions scenario), they are able to simulate future climate. Table 1 shows the GCMs and associated climate change simulations which were available for this study - a total of 29 climate change experiments. These climate change simulations use the most recent greenhouse gas emissions scenarios detailed in the Special Report on Emissions Scenarios (SRES; Nakicenovic *et al*., 2000).

Following recommendations outlined by the IPCC, we constructed scenarios of climate change using these GCM results to provide information about changes in average climate centred on the 2020s, 2050s and 2080s, relative to the current climate. Although advances in computing technology have enabled large increases in the spatial and temporal resolution of GCMs over the last few years, their model results are still not sufficiently accurate (in terms of absolute values) at regional scales to be used directly in impacts studies (Mearns *et al*., 1997). Instead, mean differences between the model's representation of current climate (this baseline period is currently 1961-1990) and some time period in the future are calculated (see Figure 1). Thirty-year periods are used to define the baseline and future time periods since averaging over this length of time gives a better indication of the longer-term trend in climate than does a shorter interval. The changes between the future and baseline periods are calculated on a grid-box by grid-box basis and are referred to as *change fields* or *climate change scenarios*. Conventionally, differences (future climate minus baseline climate) are used for temperature variables and ratios (future climate/baseline climate), often expressed in percent terms, are used for other variables such as precipitation and wind speed. In order to obtain a representation of the 'actual' average climate (a *climate scenario*) at some point in the future these change fields are combined with observed climate information for the baseline period. In this case, the climate change scenarios were combined with a high resolution (1 km) 1961-1990 baseline climatology constructed using the Alberta Climate Model.

Such a large number of climate change scenarios (29) makes for a very unwieldy analysis, so a sub-set of climate change scenarios, spanning the range of possible future climates projected by the large number of GCM results available, was selected for use. This selection was based on changes in summer mean temperature and precipitation for the 2050s since this season provided a large range in the scenario results, particularly for precipitation (see Figure 2). Five scenarios were selected to represent conditions which were cooler and wetter (NCARPCM A1B), cooler and drier (CGCM2 B2(3)), warmer and wetter (HadCM3 A2(a)) and warmer and drier (CCSRNIES A1FI) than median conditions (HadCM3 B2(b)). Climate change scenarios were constructed for minimum, mean and maximum temperature, precipitation, degree days > 5°C (indicative of general plant growth) and annual moisture index (an indication of moisture availability for plant growth). These climate change scenarios were then combined with the 1961-1990 high resolution baseline climate information to obtain realisations of 'actual' average climate (the *climate scenarios*) for Alberta for the 2020s, 2050s and 2080s.

Table 1: Details of the SRES simulations currently available on the IPCC Data Distribution Centre (after Parry, 2002).

Climate Modelling Centre	Country	Model	SRES simulations
Canadian Centre for Climate Modelling and Analysis	Canada	CGCM2	A2*, B2*
Hadley Centre for Climate Prediction and Research	UK	HadCM3	A1FI, A2*, B1, B2*
Max Planck Institute for Meteorology	Germany	ECHAM4/ OPYC3	A2, B2
Commonwealth Scientific and Industrial Research Organisation	Australia	CSIRO-Mk2	A1, A2, B1, B2
Geophysical Fluid Dynamics Laboratory	USA	GFDL-R30	A2, B2
National Centre for Atmospheric Research	USA	NCAR-PCM	A2, B2, A1B
Centre for Climate Research Studies/National Institute for Environmental Studies	Japan	CCSR/NIES AGCM + CCSR OGCM	A1FI, A1T, A1B, A2, B1, B2

*More than one experiment has been carried out for these emissions scenarios. These are known as ensemble experiments and it is common practice for the ensemble mean to be calculated from the individual experiments. This is simply the average of the individual experiments and since the averaging process reduces the 'noise' due to climate variability, the ensemble mean generally represents the climate response ('signal') to the imposed forcing change.

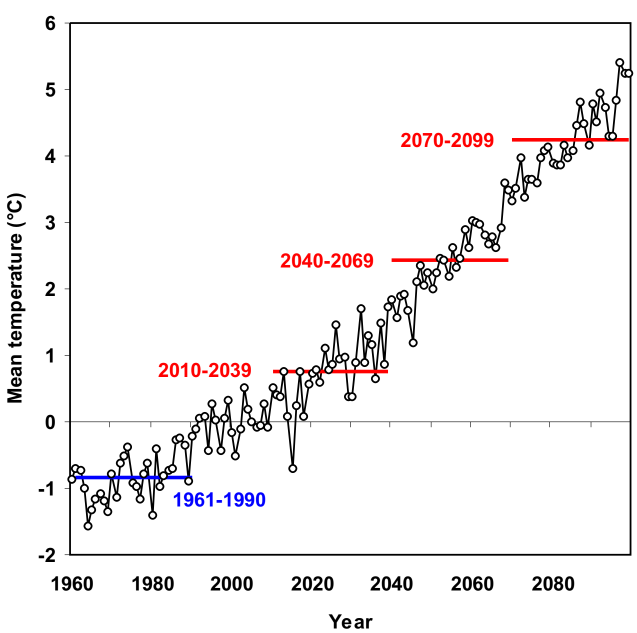


Figure 1: Schematic illustrating the construction of climate change scenarios from GCM output. The graphic shows the time series of mean surface air temperature for the Canadian land area from the CGCM2 simulation forced by the SRES A2 emissions scenario. The blue line indicates the 30-year mean for the 1961-1990 baseline period, whilst the red lines indicate the 30-year mean values for the 2020s (2010-2039), the 2050s (2040-2069) and the 2080s (2070-2099). Scenarios are constructed by calculating the difference, or ratio, between the time means of the future and baseline periods. To create a climate change scenario, this process is carried out for each grid box in the region of interest.

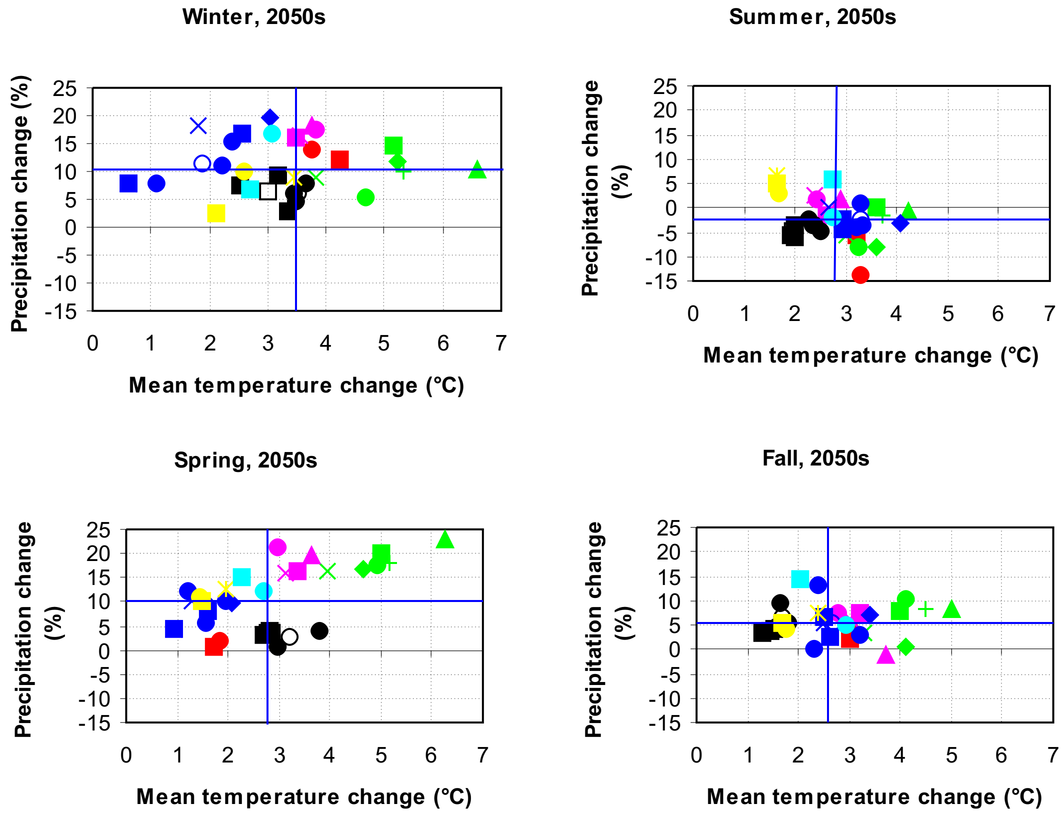


Figure 2: Scatter plots indicating seasonal changes in mean temperature (°C) and precipitation (%) for Alberta for the 2050s. Each symbol and colour represents a different GCM and SRES experiment: A1FI; A1T; A1; A2; B1; B2; CGCM2 - black; CCSR/NIES - green; CSIROMk2 - pink; ECHAM4 - red; NCAR-PCM - yellow; HadCM3 - blue; GFDL-R30 - cyan. Closed symbols indicate individual experiments, whilst open symbols represent ensemble-means (i.e., the average of a number of individual experiments using identical SRES forcing). Blue lines indicate the median changes in mean temperature and precipitation and may be used to determine which scenarios are warmer, wetter, cooler or drier than other scenarios in the suite illustrated. The results for the ECHAM4 and GFDL-R30 experiments are shown although they were not considered for selection since not all the required climate variables were available from these GCMs.

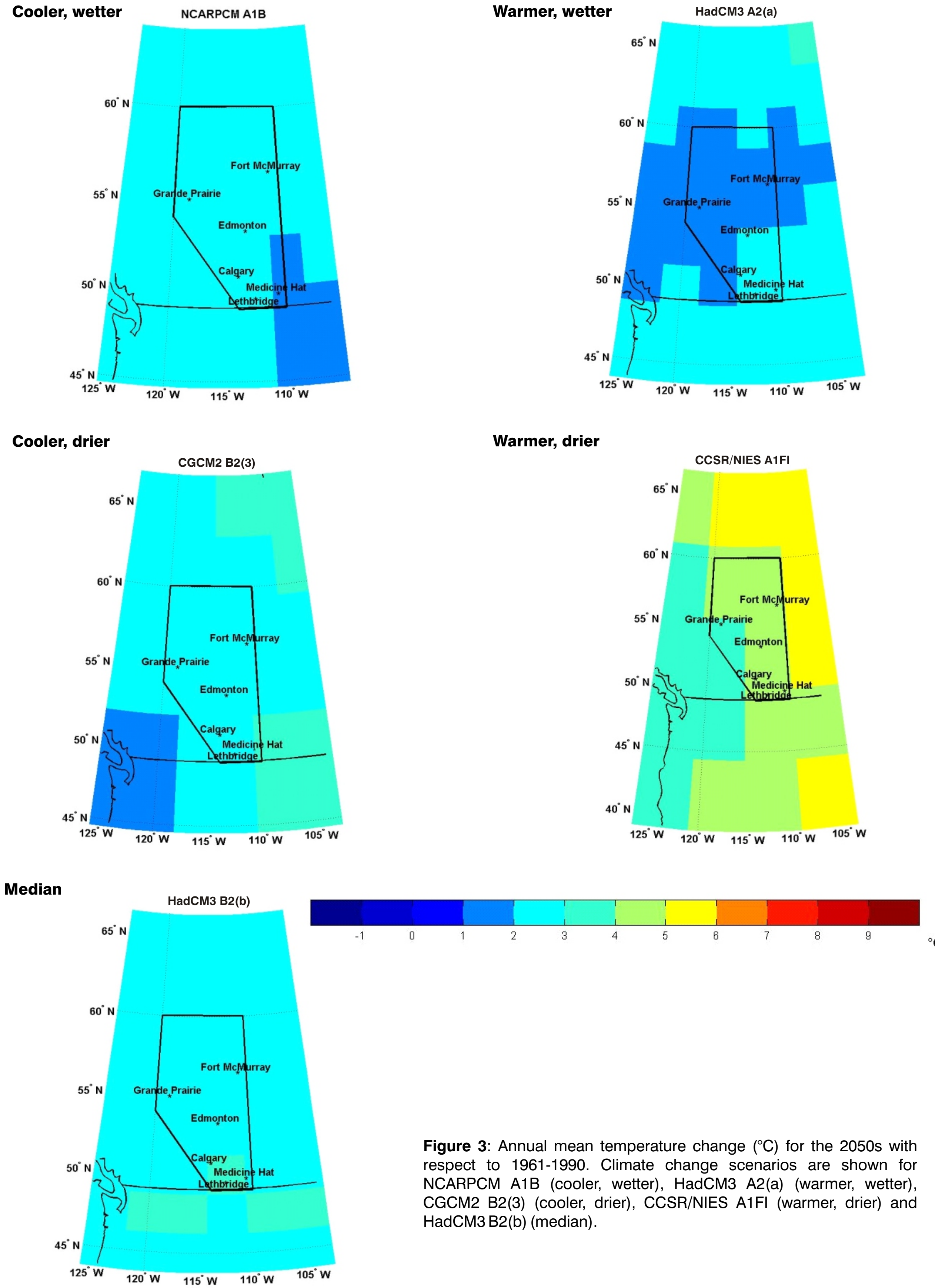


Figure 3: Annual mean temperature change (°C) for the 2050s with respect to 1961-1990. Climate change scenarios are shown for NCARPCM A1B (cooler, wetter), HadCM3 A2(a) (warmer, wetter), CGCM2 B2(3) (cooler, drier), CCSR/NIES A1FI (warmer, drier) and HadCM3 B2(b) (median).

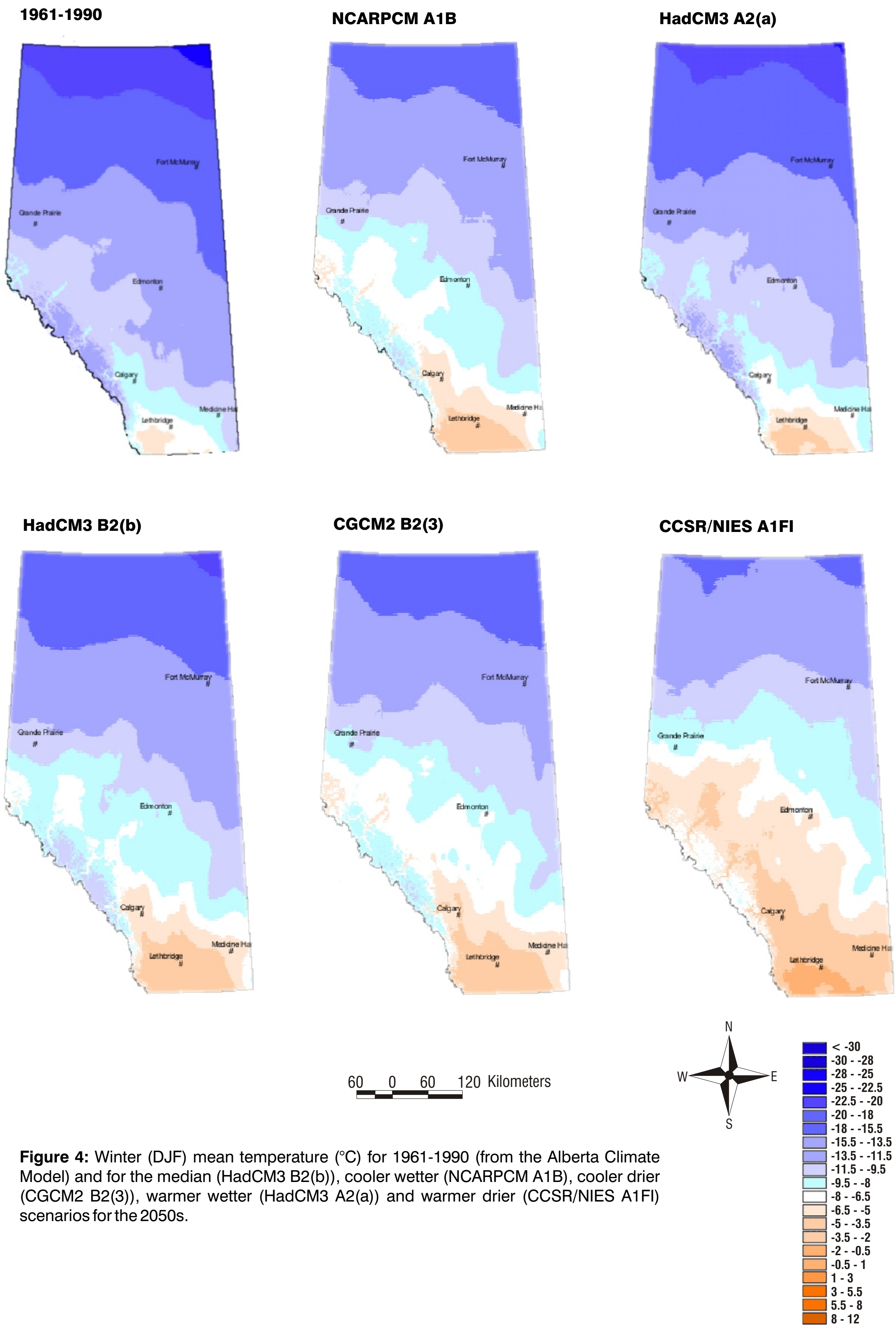
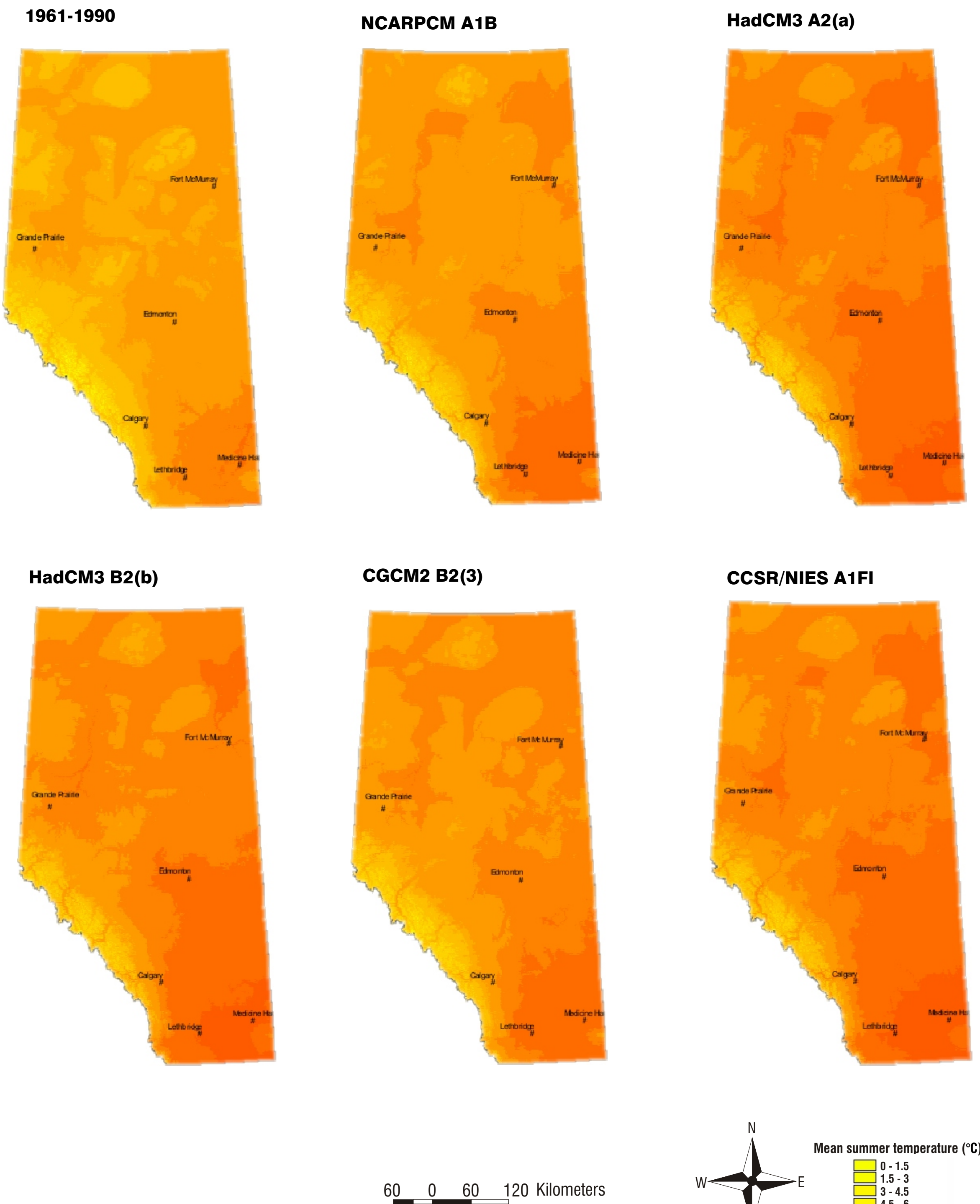


Figure 4: Winter (DJF) mean temperature (°C) for 1961-1990 (from the Alberta Climate Model) and for the median (HadCM3 B2(b)), cooler wetter (NCARPCM A1B), cooler drier (CGCM2 B2(3)), warmer wetter (HadCM3 A2(a)) and warmer drier (CCSR/NIES A1FI) scenarios for the 2050s.



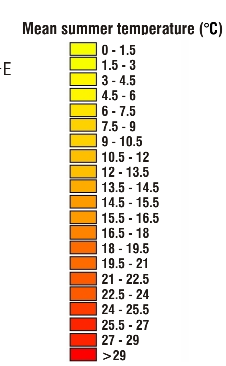


Figure 5: Summer (JJA) mean temperature (°C) for 1961-1990 (from the Alberta Climate Model) and for the median (HadCM3 B2(b)), cooler wetter (NCARPCM A1B), cooler drier (CGCM2 B2(3)), warmer wetter (HadCM3 A2(a)) and warmer drier (CCSR/NIES A1FI) scenarios for the 2050s.

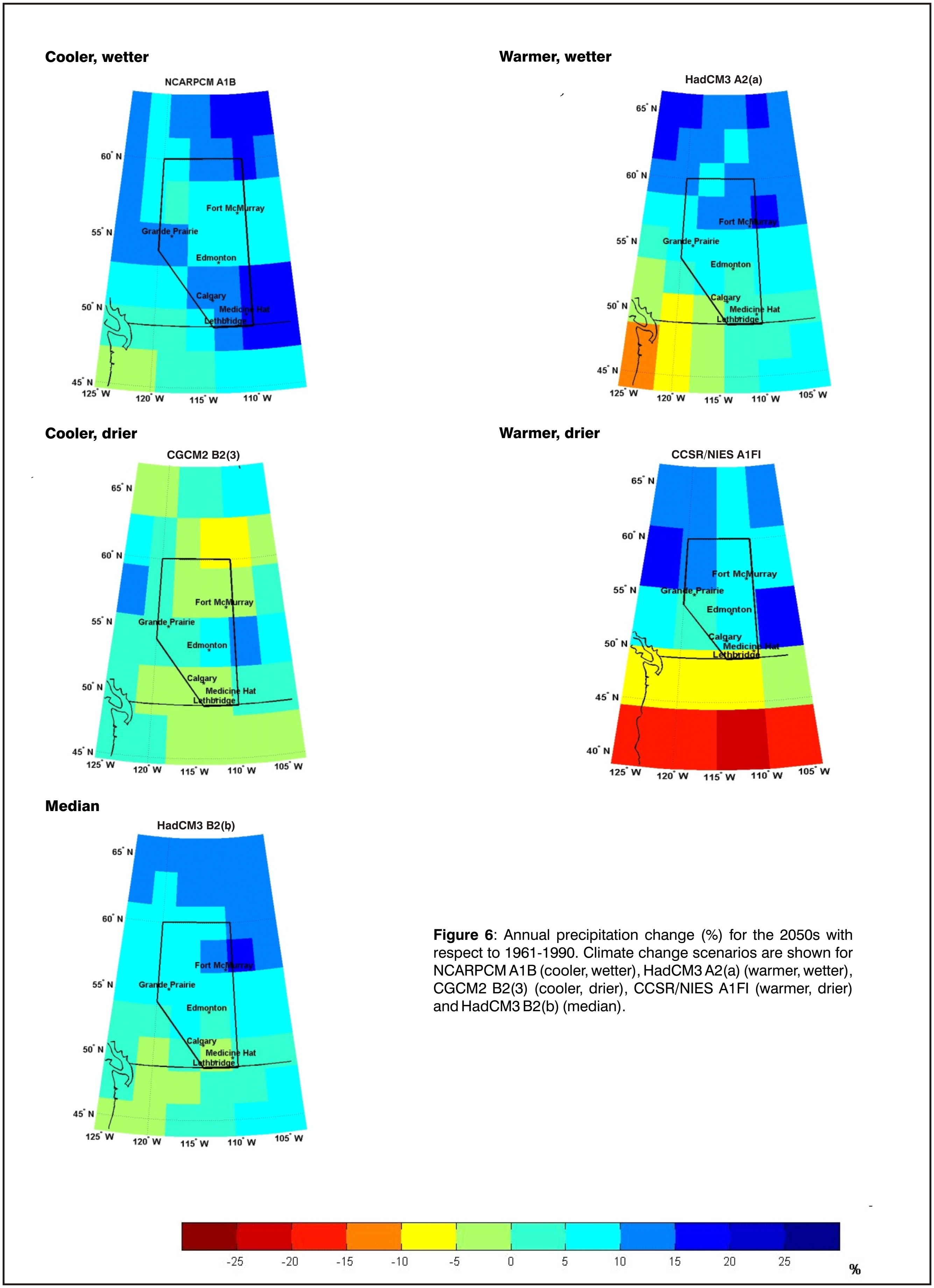
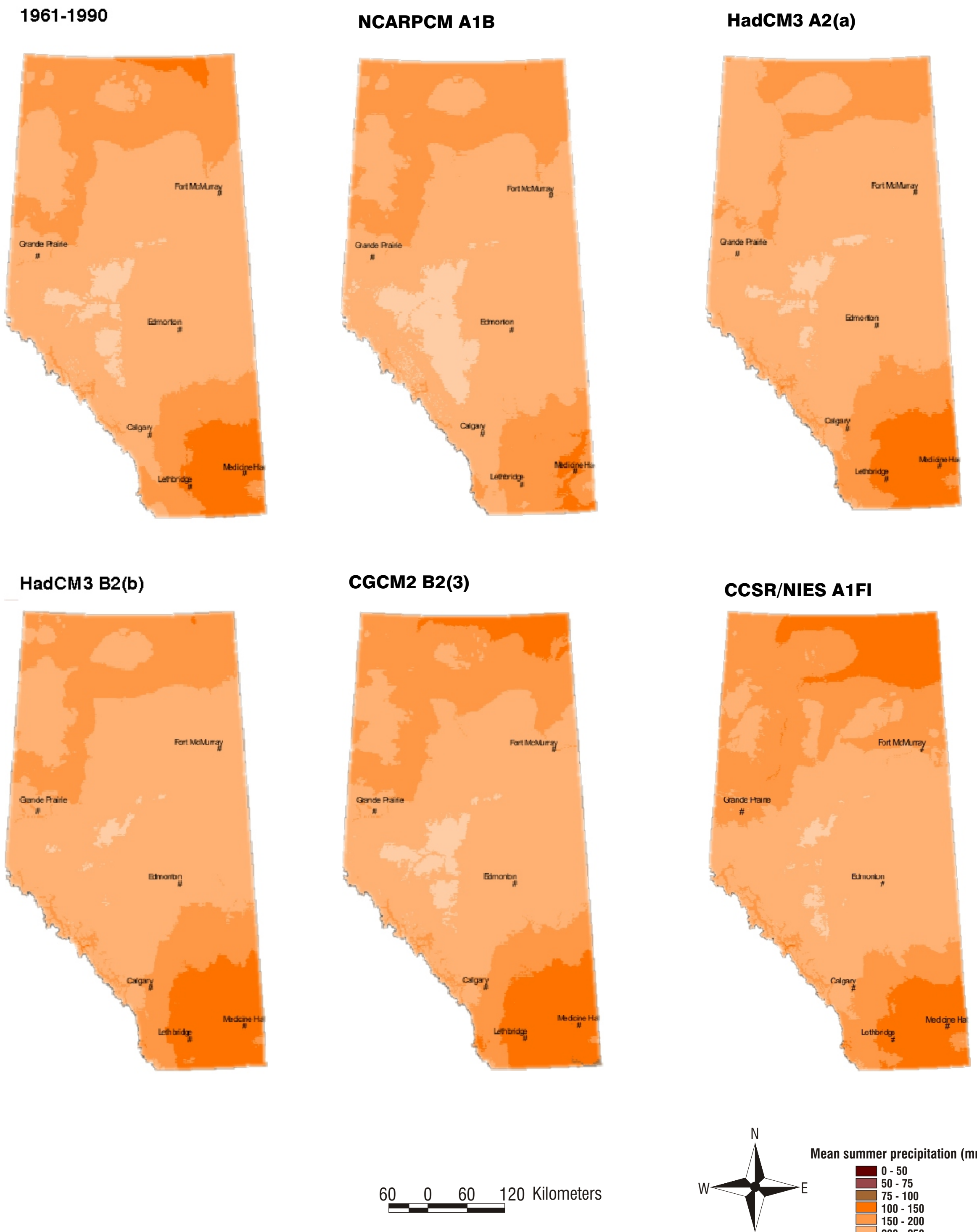


Figure 6: Annual precipitation change (%) for the 2050s with respect to 1961-1990. Climate change scenarios are shown for NCARPCM A1B (cooler, wetter), HadCM3 A2(a) (warmer, wetter), CGCM2 B2(3) (cooler, drier), CCSR/NIES A1FI (warmer, drier) and HadCM3 B2(b) (median).



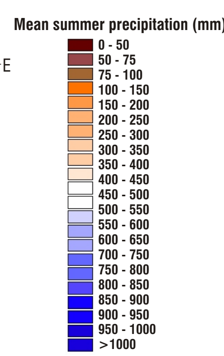


Figure 7: Summer (JJA) precipitation (mm) for 1961-1990 (from the Alberta Climate Model) and for the median (HadCM3 B2(b)), cooler wetter (NCARPCM A1B), cooler drier (CGCM2 B2(3)), warmer wetter (HadCM3 A2(a)) and warmer drier (CCSR/NIES A1FI) scenarios for the 2050s.

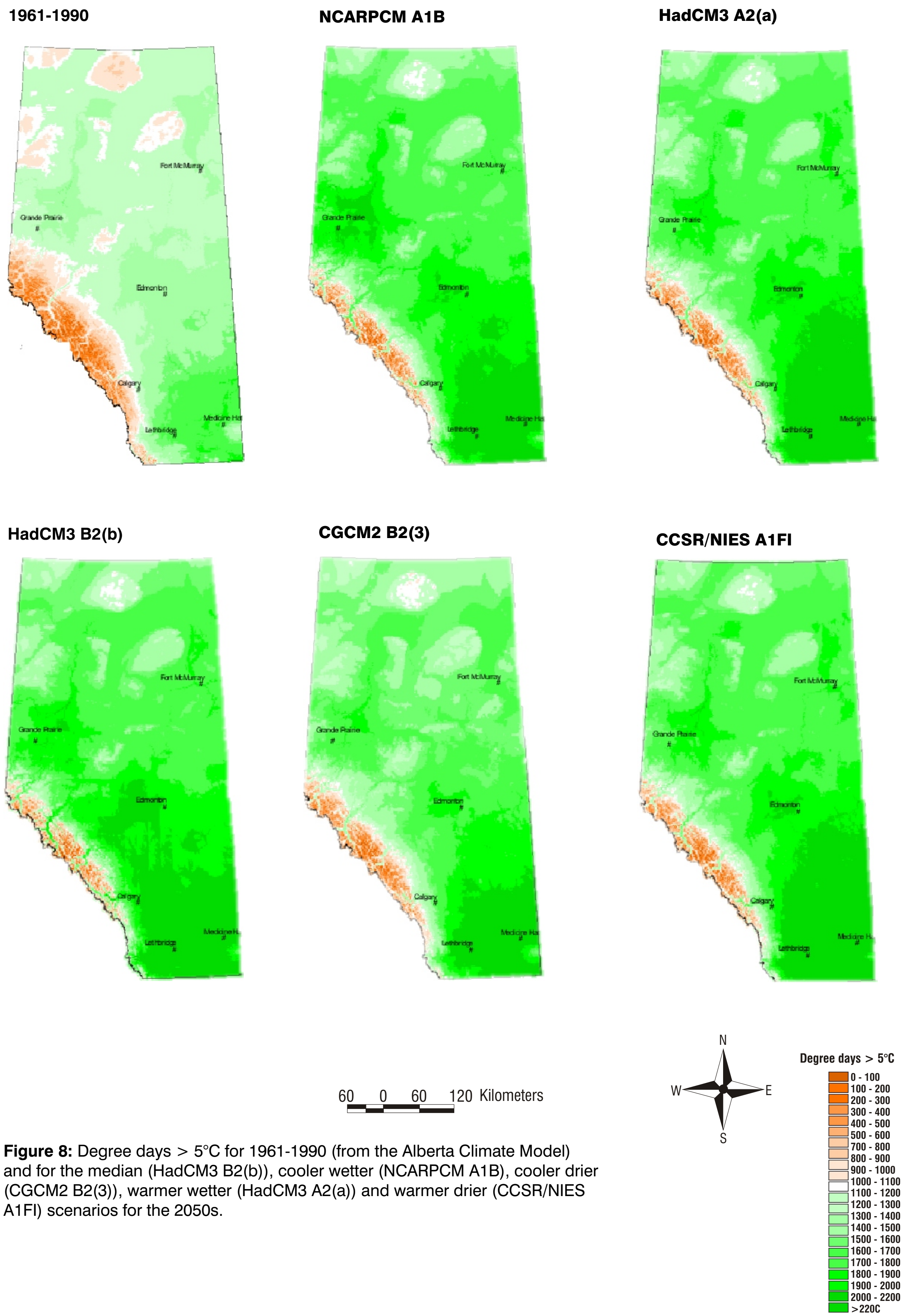


Figure 8: Degree days > 5°C for 1961-1990 (from the Alberta Climate Model) and for the median (HadCM3 B2(b)), cooler wetter (NCARPCM A1B), cooler drier (CGCM2 B2(3)), warmer wetter (HadCM3 A2(a)) and warmer drier (CCSR/NIES A1FI) scenarios for the 2050s.

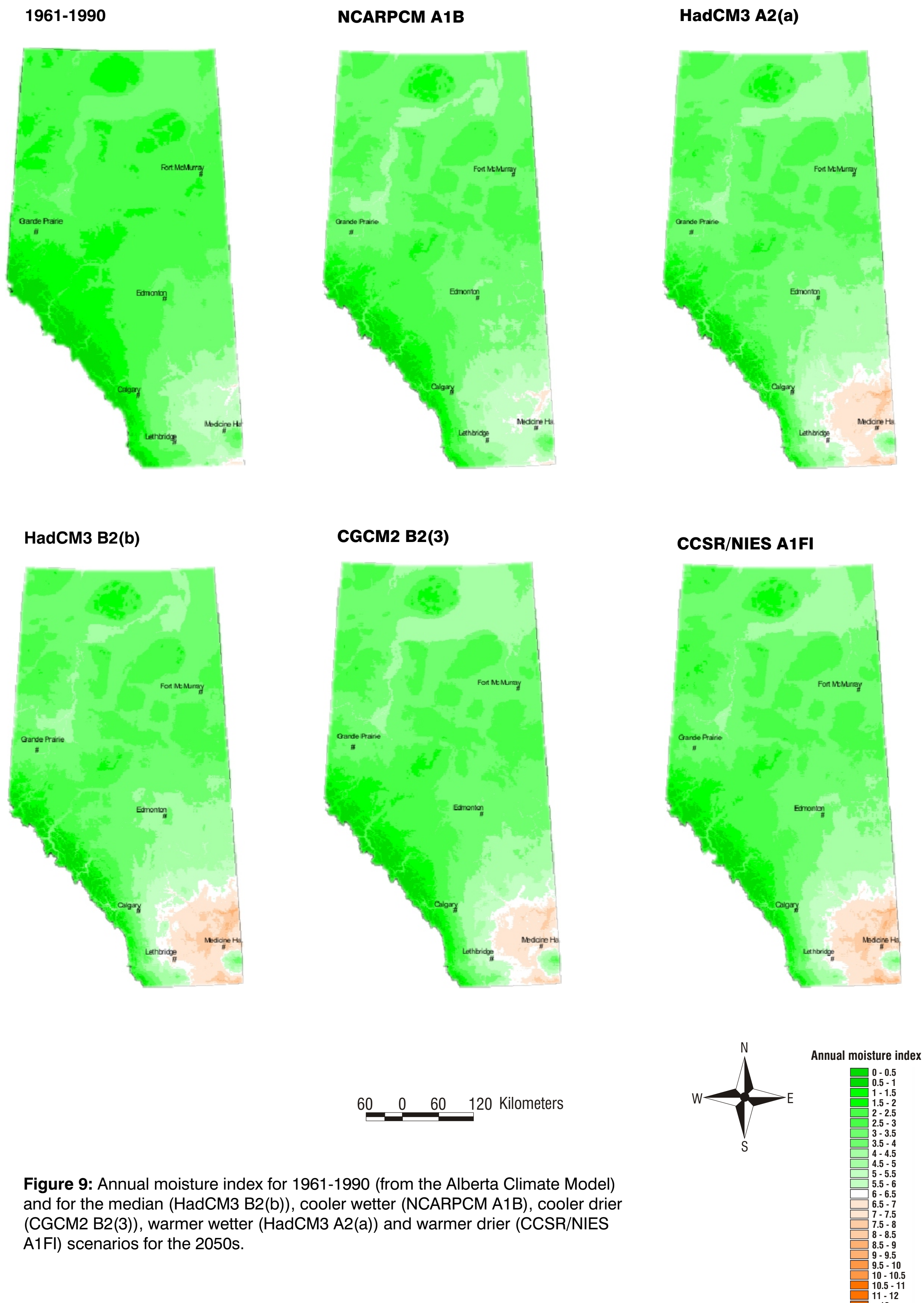


Figure 9: Annual moisture index for 1961-1990 (from the Alberta Climate Model) and for the median (HadCM3 B2(b)), cooler wetter (NCARPCM A1B), cooler drier (CGCM2 B2(3)), warmer wetter (HadCM3 A2(a)) and warmer drier (CCSR/NIES A1FI) scenarios for the 2050s.

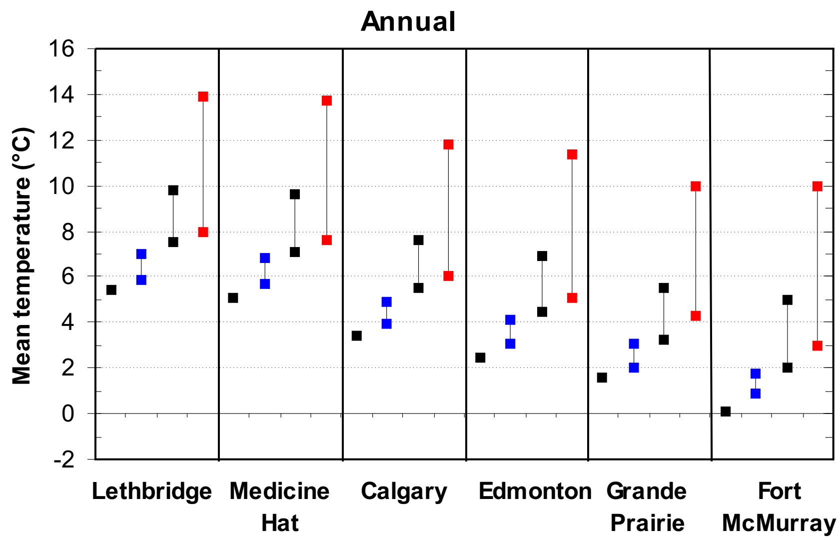


Figure 10: Annual mean temperature (°C) for six selected sites in Alberta. At each site baseline (1961-1990) conditions (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines) are illustrated. The scenario range has been calculated from the results for the five selected scenarios

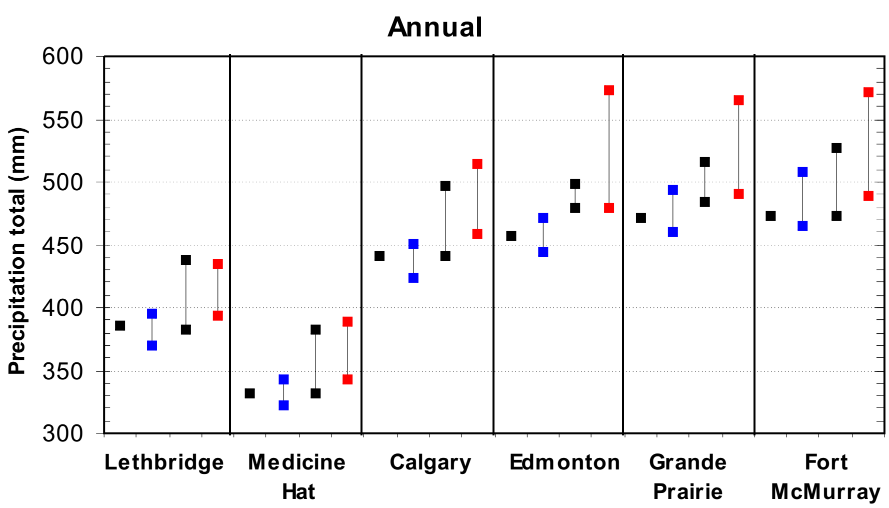


Figure 11: Annual precipitation total (mm) for six selected sites in Alberta. At each site baseline (1961-1990) conditions (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines) are illustrated. The scenario range has been calculated from the results for the five selected scenarios

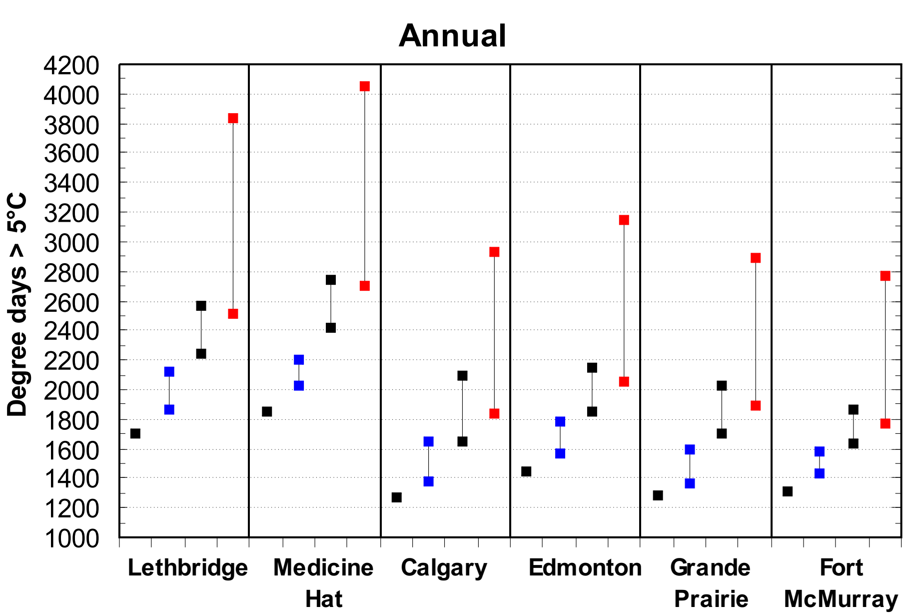


Figure 12: Degree days > 5°C for six selected sites in Alberta. At each site baseline (1961-1990) conditions (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines) are illustrated. The scenario range has been calculated from the results for the five selected scenarios

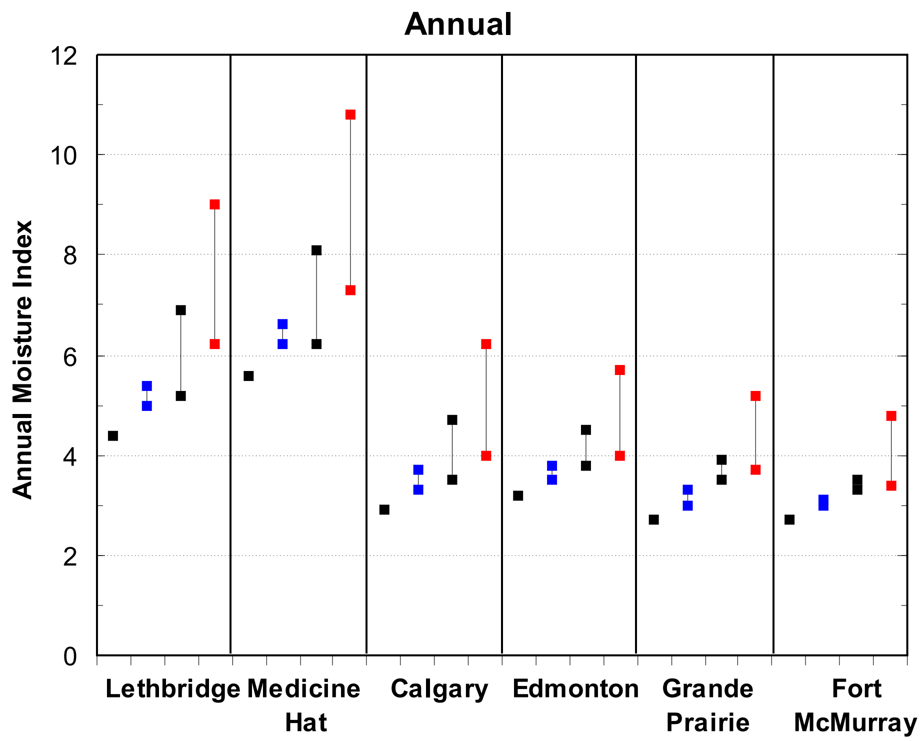


Figure 13: Annual moisture index for six selected sites in Alberta. At each site baseline (1961-1990) conditions (black square), and the scenario ranges for the 2020s (blue high-low lines), the 2050s (black high-low lines) and the 2080s (red high-low lines) are illustrated. The scenario range has been calculated from the results for the five selected scenarios

FUTURE CLIMATES FOR ALBERTA

For Alberta, changes in annual mean temperature by the 2050s are typically between 3°C and 5°C, although the CCSRNIES A1FI (warmer, drier) scenario is consistently warmer than the other scenarios by about 2°C (see Figure 3). Changes in maximum and minimum temperature are similar to those for mean temperature, although the changes in minimum temperature tend to be slightly greater than those for maximum temperature, thus implying a general decrease in the diurnal temperature range. Figures 4 and 5 illustrate winter and summer mean temperature (°C) for the 2050s for the five selected scenarios, respectively.

Annual precipitation changes for the 2050s (Figure 6) are generally within the range -10% to +15%, and any decreases in annual precipitation are generally driven by decreases in summer precipitation. By the 2080s, however, all five climate change scenarios indicate increases in annual precipitation of up to 15% in general. Figure 7 illustrates summer precipitation totals (mm) for the 2050s for the five selected scenarios, respectively.

Degree days > 5°C[1] and annual moisture index[2] scenarios indicate increases of between 30-50% and 20-30% by the 2050s, respectively. Increases in the number of degree days > 5°C imply a lengthening of the growing season and/or the availability of more heat units for plant growth during the growing season. Increases in annual moisture index indicate increases in the degree day total, or decreases in annual precipitation, and larger index values generally indicate drier conditions. In this case, the projected increases in annual moisture index are generally driven by the large increases in degree days above 5°C, rather than by decreases in precipitation. Figures 8 and 9 indicate annual degree day totals > 5°C and annual moisture index values for the 2050s for the five selected scenarios, respectively.

In order to further interpret this analysis, the climate scenario results for six sites in Alberta Lethbridge, Medicine Hat, Calgary, Edmonton, Grande Prairie and Fort McMurray were compared.

Future minimum, mean and maximum temperatures indicate a similar pattern, with the gradual march north of warmer temperatures. By the 2050s, annual mean temperature at Calgary is projected to be similar to, or warmer than, that currently observed at Lethbridge and Medicine Hat. For this to be the case at Grande Prairie and Fort McMurray we must wait until the 2080s (see Figure 10).

For precipitation, the scenario results are not as clear-cut as for temperature and in the earlier time periods in particular

---

[1]Degree days are summed over the year on days when the threshold temperature (in this case 5°C) is exceeded. So, for example, 5 degree days are accrued on a day when the mean temperature is 10°C (mean temperature value minus threshold temperature value).
[2]Annual moisture index is defined as the ratio of the annual degree day total (using a threshold temperature of 5°C) to annual total precipitation

the changes are generally quite small. There is some overlap with baseline conditions especially in the 2020s and 2050s, with any decreases in annual precipitation generally being driven by decreases in summer precipitation. By the 2080s, precipitation is projected to increase at all sites (Figure 11).

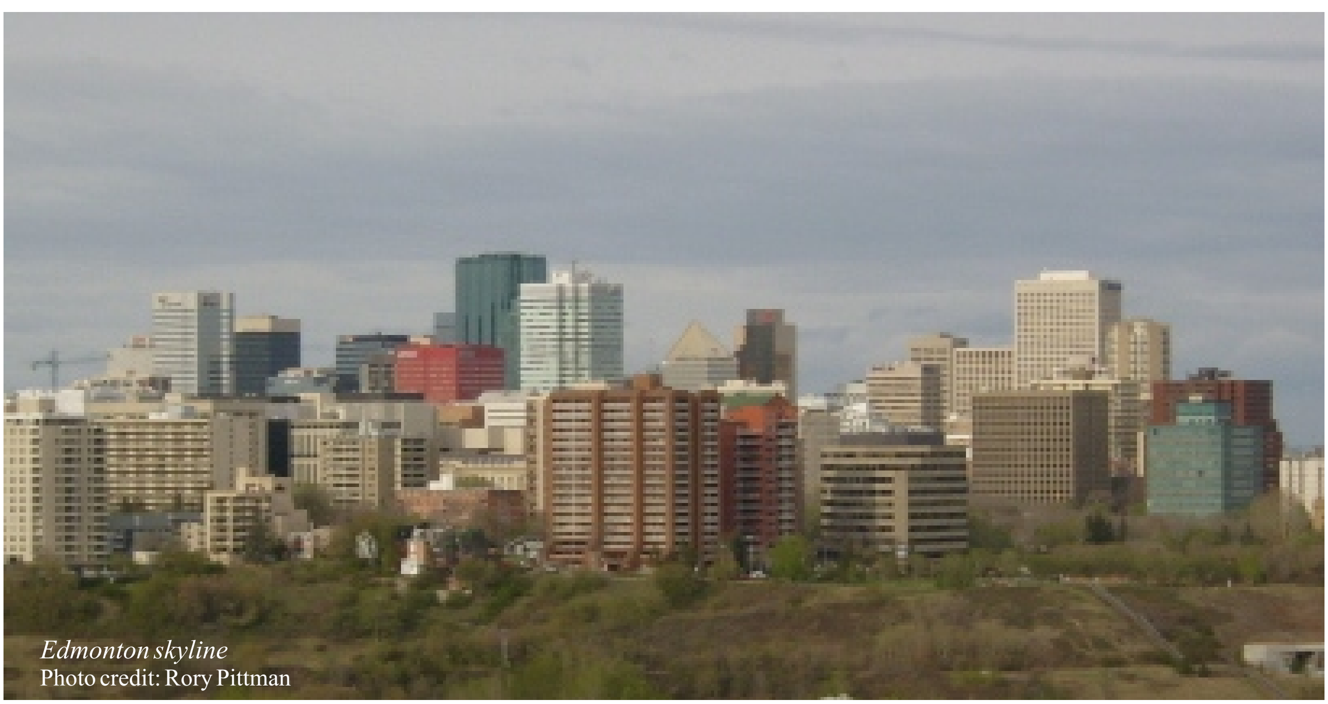
The projected increases in degree days > 5°C imply a lengthening of the growing season and/or the availability of more heat units during the growing season. For this variable, Calgary, Edmonton, Grande Prairie and Fort McMurray are projected to approach degree day totals similar to those currently observed at Lethbridge and Medicine Hat by the 2050s (Figure 12).

The annual moisture index is projected to increase province-wide, most noticeably in the south around Lethbridge, Medicine Hat and Calgary, with less pronounced increases in central and northern Alberta. These increases are driven by the large increases in degree day totals rather than by large decreases in precipitation. However, the selected scenarios indicate that the largest decreases in precipitation occur during the summer season, which is also the season when most degree-day units are accrued and so moisture stress is likely to occur. For this variable, Calgary, Edmonton, Grande Prairie and Fort McMurray are projected to experience conditions similar to those currently observed at Lethbridge and Medicine Hat by the 2080s (Figure 13).

For more details of Alberta's climate future the reader is referred to Barrow and Yu (2005).

ACKNOWLEDGEMENTS

This work was funded by the Prairie Adaptation Research Collaborative in co-operation with Alberta Environment. The authors thank Alberta Sustainable Resource Development for supplying the baseline data from the Alberta Climate Model which was used in the construction of the climate scenarios. The authors also thank Tammy Kobliuk of Alberta Sustainable Resource Development for technical assistance in obtaining these baseline data.



Edmonton skyline
Photo credit: Rory Pittman

REFERENCES

Barrow, E.M. & Yu, G. (2005): *Climate Scenarios for Alberta*. A report prepared for the Prairie Adaptation Research Collaborative (PARC) in co-operation with Alberta Environment. Available at www.parc.ca.

IPCC (2001): *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. (Eds.)]. Cambridge University Press, Cambridge, U.K. and New York, N.Y., U.S.A., 881pp.

Mearns, L.O., Rosenzweig, C. and Goldberg, R. (1997): Mean and variance change in climate scenarios: methods, agricultural applications, and measures of uncertainty. *Climatic Change* **35**, 367-396.

Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., Jung, T.Y., Kram, T., La Rovere, E.L., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Raihi, K., Roehrl, A., Rogner, H-H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooijen, S., Victor, N. and Dadi, Z. (2000): *Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, U.K. and New York, N.Y., U.S.A., 599 pp.

Parry, M. (2002): Scenarios for climate impact and adaptation assessment. *Global Environmental Change* **12**, 149-153.

Other publications in the PARC Summary Series:

- Climate Change Impacts on the Island Forests of the Great Plains and the Implications for Nature Conservation Policy
- Aridity on the Canadian Plains: Future Trends and Past Variability
- Socio-Economic Vulnerability of Prairie Communities to Climate Change
- Political Climate Modeling: Predicting socio-political responses to climate change in the Prairie Provinces
- Assessment of Climate Change on the Agricultural Resource of the Canadian Prairies
- Fire Behavior Potential in Central Saskatchewan under predicted climate change
- Exploring the Impacts of Climate Change and Adaptation Options for Boreal Forest Ecosystems
- How Adaptable are Prairie Cities to Climate Change? Current and Future Impacts and Adaptation Strategies
- Isi Askiwan - The State of the Land: Prince Albert Grand Council Elders' Forum on Climate Change
- Assessing Future Landscape Fire Behavior Potential in the Duck Mountains of Manitoba


Wind turbines near Pincher Creek
Photo credit: Jeremy Pittman