Supplementary Material for: Coordinated Global and Regional Climate Modelling

a. CanRCM4 NARCCAP Analysis

As CanRCM4 is a new regional model that employs a physics package from a global model, it is important to provide an evaluation of its performance. The most straightforward way to do this is to compare its performance against the performance of RCMs documented in an established intercomparison project. Here we consider the performance of CanRCM4 against RCMs that participated in the North American Regional Climate Change Assessment Program (NARCCAP) (Mearns et al. 2009). Specifically, a CanRCM4 evaluation run is performed for the North America domain at 0.44 degree resolution for the period 1980–2000 driven by the NCEP reanalysis R-2 (Kanamitsu et al. 2002). Following the study of Mearns et al. (2012), the modelled near surface (2 m) temperature (T_{as}) and total precipitation rate (Pr) in CanRCM4 is validated against the version 2.10 Climatic Research Unit (CRU2) monthly time series of temperature and precipitation (Mitchell 2008; Mitchell and Jones 2005), which includes elevation correction for temperature and precipitation (New et al. 2000).

Figures S1 and S2 present June-July-August (JJA) and December-January-February (DJF) mean T_{as} biases relative to the CRU2 dataset for spectrally nudged CanRCM4 (panel a), spectrally unnudged CanRCM4 (panel b), and six other regional climate models (panels c–h). Details related to the six additional RCMs, as well as a more in-depth analysis of their performance, is provided by Mearns et al. (2012). From Figs. S1 and S2 it can be seen that CanRCM4 displays a warm bias in the south central U.S. in JJA and in the continent interior in DJF, and a cold bias along the west coast in both seasons. The impact of spectral nudging in CanRCM4 causes a slight reduction in the amplitude of biases (particularly in DJF) but has little impact on their structure and distribution.

This T_{as} bias is consistent with bias present in CanRCM4’s parent model CanAM4 when run in
the AMIP-type mode (i.e. with prescribed observed SSTs and sea ice distribution). It is apparent
that CanRCM4 temperature biases displayed in Figs. S1 and S2 are reasonable relative to the other
six RCMs considered.

CanRCM4 temperature biases are further evaluated for a number of North America sub-regions,
which are displayed in Fig. S3. Figure S4 presents a graphical summary of spatially averaged
seasonal and annual mean Tas biases for each of these sub-regions for the considered RCMs to-
gether with the overall North America bias (labelled as “All Regions”). The results indicate that
CanRCM4 regional temperature biases generally fall within the inter-model spread of other NAR-
CCAP RCMs and are not strongly influenced by spectral nudging.

Figures S5 and S6 present JJA and DJF mean precipitation rate (Pr) biases relative to the CRU2
dataset for spectrally nudged CanRCM4 (panel a), spectrally unnudged CanRCM4 (panel b), and
the six other RCMs (panels c–h). CanRCM4 displays a dry bias in south central U.S. in JJA
and near the Gulf of Mexico in DJF, and a wet bias along the west coast in both seasons and the
east coast in JJA, which display little sensitivity to spectral nudging. The CanRCM4 precipitation
biases displayed in Figs. S5 and S6 are reasonable relative to the six other RCMs considered.

The precipitation biases in CanRCM4 are also evaluated for the same sub-regions presented in
Fig. S3. Their graphical summary is presented in Fig. S7 in the same format as for Tas regional
biases in Fig. S4. Again, it is apparent that CanRCM4 regional precipitation biases generally fall
within the range of those for the other six models. CanRCM4 suffers from the same systematic
wet bias in the North-West and dry bias in the South-East as is displayed by the other NARCCAP
RCMs. Overall, the analysis of Tas and Pr biases indicates that the performance of CanRCM4
generally falls within the range of the RCMs that participated in the NARCCAP.

As an initial test of the potential influence of spectral nudging in CanRCM4 future projections, an additional 5 historical simulations and 5 future RCP4.5 simulations were performed in the North American CORDEX domain with a version of CanRCM4 in which interior spectral nudging was turned off. The appreciable difference analysis presented in Section 5c was then repeated with these new simulations. Figs. 5–7 of that section are reproduced here in Figs. S8–S10, respectively. In general, the area covered by statistically significant differences in the RCM and GCM response means is marginally reduced when spectral nudging is turned off. This is expected as internal variability of the large scales in the RCM relative to the driving GCM should generally increase due to chaotic divergence and enhanced upscale influence.

For the lower order diagnostics of total precipitation, $P$, and near-surface temperature, $T$, a comparison of Figs. 5 and 6 to S8 and S9 reveal striking similarities. With respect to total precipitation, the precipitation enhancement in the RCM response along the west coast of North America remains statistically robust. Larger differences in the RCM and GCM responses occur at the Eastern boundary of the domain in the unnudge experiments. These are likely associated with artifacts at the outflow boundary, which are expected to be exacerbated in the spectrally unnuged configuration but further analysis would be required to verify this.

For the higher-order diagnostic of 10-year return values of annual extremes of 24-hr precipitation amounts, $P_{10}$, there occur significant differences in panels c and d between Fig. 7 and S10. The higher internal variability of the spectrally unnuged RCM configuration results in a domain fraction of statistical significance that is reduced from 7% to 6%. As this is essentially equal to the average areal fraction expected to be labelled significant simply by chance, it provides additional
evidence that much larger ensemble sizes are required to discern appreciable differences in such higher order statistics.

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DJF 2m Temperature Biases

a) CanRCM4
b) CanRCM4 (not nudged)
c) ECP2
d) HRM3
e) RCM3
f) CRCM4
g) WRFG
h) MM5I

Fig. S2. Same as Fig. S1 but for December-January-February mean 2 m temperature biases.
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DJF Precipitation Biases

- a) CanRCM4
- b) CanRCM4 (not nudged)
- c) ECP2
- d) HRM3
- e) RCM3
- f) CRCM4
- g) WRFG
- h) MM5I

Figure S6. Same as Fig. S5 but for December-January-February mean precipitation rate biases.
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FIG. S7. Annual and seasonal average precipitation biases relative to the CRU2 observations over the period 1980–2000 in the various subregions defined in Fig. S3.
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FIG. S9. As in Fig. S8 except for near surface temperature response \( T \). The domain/land fraction of statistically significant differences is 44%/55%
**10yr Return Values of Annual Extreme P**

![Maps of Percentage Change and Standard Deviations](image)

**Percentage Change**

- **P10\textsubscript{GCM}**
- **P10\textsubscript{RCM}**

**Standard Deviations**

- **(P10\textsubscript{RCM} - P10\textsubscript{GCM}) / P10\textsubscript{GCM}**

**Statistically Significant Differences**

- **(P10\textsubscript{RCM} - P10\textsubscript{GCM}) / P10\textsubscript{GCM}\textsubscript{SIG}**

**Figure S10.** As in Fig. S8 except for the response of 10-year return values of annual extremes of 24-hr precipitation amounts shown only over land. The land fraction of statistically significant differences is 6%