Hydrology of Northern Quebec as seen by the Canadian Regional Climate Model.

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Results from five simulations performed with the Canadian Regional Climate Model (CRCM; Caya and Laprise 1999) are used to compare simulated hydrologic regimes with observations over 21 basins over the Québec/Labrador peninsula. Basins of interest cover areas ranging from 13 000 to 177 000 km^2, for a total area of 1 000 000 km^2.

Four of these simulations were driven by NCEP/NCAR global atmospheric reanalyses (NRA1; Kalnay et al. 1996) and the other was driven by ERA40 (European Center for Medium-Range Weather Forecasts reanalyses; Gibson et al. 1997); both reanalyses used are freely available at a 2.5x2.5 degree resolution. One simulation, NRA1 driven, was performed over a large domain covering North America (AMNO; 201x193 grid points) while the four others were done over a smaller domain centered over Québec (QC; 112x88). One simulation over the QC domain used a simple one-layer surface scheme, while the four others were run with the CLASS multi-layer surface scheme (Canadian LAnd Surface Scheme; Verseghy 2000). Spectral nudging of large-scale winds (Riette and Caya 2002) keeps CRCM's large-scale flow close to its driving data and was applied to the run over the large AMNO domain and to two simulations performed over the smaller QC domain (driven by NRA1 and ERA40). All simulations were driven by 6-hourly reanalyses over the 1959–99 period (linearly interpolated to the model's 15-minute time steps) with a horizontal grid-size mesh of 45 km (true at 60^{o}N) and 29 vertical levels, unequally spaced from the surface to the model top (29 km). Over ocean grid points, values of sea surface temperature and sea-ice cover from AMIP II monthly observations were used.

A subset of ten basins, covering a total area of 406 000 km^2 (Rivière à la Baleine, Bell, Réservoir Caniapiscau, Réservoir Churchill Falls, Georges, Réservoir Manic5, Caniapiscau-Pyrite, Rupert, Lac Saint-Jean, Waswanipi), were chosen to perform comparative analyses on the influence of (1) domain characteristics, (2) the surface scheme and (3) driving data, on surface hydrologic budget components. The choice of basins was motivated by the availability of reliable and long series of runoff observational data. Over this 10-basin composite, we compare climatologic means (over the 1961–90 period) simulated by the CRCM with annual runoff and precipitation observed during the same period. When required, observed annual runoffs were corrected for variability introduced by anthropogenic water storage. Monthly precipitation series from the Climatic Research Unit (CRU TS2.02; Mitchell and Jones 2005) and from University of Delaware (WM 1.02; Willmott and Matsuura 2001) were interpolated from their global grid to the CRCM's polar stereographic grid. Finally, composite results over the 10 or 21 basins were computed by weighing each basin value according to the number of grid points located within the basin.

We find that domain size has an influence on simulated annual precipitation and runoff. In the 1961–90 period, over the 10-basin composite, the large domain CRCM simulation generates 0.27 mm/day less precipitation and runoff than the small domain run, which represents –13% for precipitation and –19% for runoff (both runs with CLASS and NRA1 driven).

The choice of the surface scheme seems to have less influence than domain size on simulated annual runoff. However, it is not negligible, since the CRCM simulation with CLASS shows a difference of –0.08 mm/day (–6%) when compared to the simulation using the one-layer surface scheme (both runs on QC domain and NRA1 driven).

Different reanalyses used as driving data have an influence comparable to that of the surface scheme. With respect to the NRA1 driven CRCM simulation, the ERA40 driven run has values larger by about 5% over the 10-basin composite for the 1961–90 period, giving absolute differences of +0.13 mm/day for precipitation and +0.08 mm/day for runoff (both runs with CLASS on QC domain).

Over the 10 basins, the CLASS/QC/ERA40 simulation is found to be the best of the five CRCM runs. With respect to observations, it shows simulated annual biases of only –2% for precipitation and –10% for runoff, which is considered to be within the observational error associated to water related variables.

Fig. 1 shows that CRCM's mean annual runoffs differ for the 10-basin composite when the simulation is driven by NRA1 and by ERA40 (both runs with CLASS on QC domain). This is the case, even though standard deviations are quite comparable for both simulations in the 1961–99 period (0.17 mm/day for

NRA1 driven run and 0.18 mm/day for ERA40 driven run). Correlations with annual 1961–99 observations also remain comparable for both runs (R=0.82 vs 0.81). These differences become more important when we examine individual basin behavior.

Finally, Table 1 summarizes CRCM simulation results over the 21-basin composite in the 1961–99 period. We find that the best run in regards to simulated mean annual runoff (CLASS/QC/ERA40) gives a root mean square difference (RMSD) value of 13% with a mean bias of only –3%. Considering each of the 21 basins, RMSD values range from 8 to 18%, without any apparent relation with the size of the basins or with their regional location (north vs south and east vs west).

Globally, over each of the 21 basins studied, in the 1961–99 period, simulated annual runoffs show biases with observations that vary from –15% to +10%, while coefficients of determination span from near zero over some basins, to values reaching almost 0.7. There does not seem to be any relation between these two variables and their distribution appears random over the territory.

In conclusion, we find that, when driven by atmospheric reanalyses, the CRCM is capable of reproducing annual runoff within 15% over the study basins in regards to mean climatology as well as interannual variability. Domain size plays an important role on the bias as well as on correlation of annual runoff simulated by the CRCM; the choice of the surface scheme seems to have a weak but not negligible influence on the simulated annual runoff; the choice of atmospheric reanalyses (driving data) has an effect similar to that of the surface scheme.

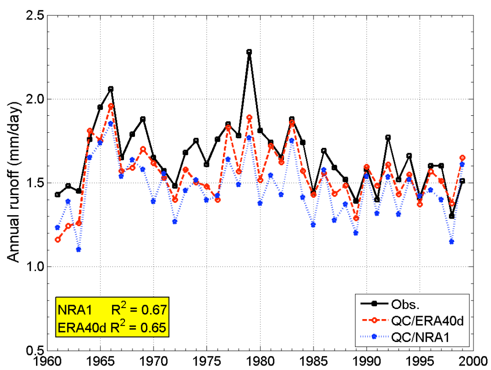

Fig. 1. Mean annual runoff over the 10-basin composite from two CRCM/CLASS simulations performed over the small QC domain, one being driven by NRA1 (dots) and the other by ERA40 (dash); continuous line shows observations.

	AMNO/ NRA1	QC/ NRA1	QC/ ERA40d
Obs. (mm/day)	1.57	1.57	1.57
CRCM (mm/day)	1.12	1.41	1.51
Bias (mm/day)	-0.46	-0.16	-0.06
Bias (%)	-29%	-10%	-3%
RMSD (mm/day)	0.51	0.26	0.21
RMSD (%)	32%	16%	13%

Table 1. Simulated 21-basin composite 1961–99 mean annual runoff from CRCM/CLASS, with different domains and driving data, compared with observations (Obs.).

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