Evaluation of CRCM output during the 1999-2004 drought over the Canadian Prairies

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1. Introduction

From 1999 to 2004, the Canadian Prairies experienced a drought with repercussions that were so far-reaching and severe that the Gross Domestic Product fell some $5.8 billion for 2001 and 2002 combined. Given the continental location and surrounding orography of the Canadian Prairies, it is likely that in the future this region will experience long droughts again. Every effort should therefore be taken to fill in the many gaps in our knowledge that limit our ability to predict droughts and reduce their potentially enormous and widespread impacts.

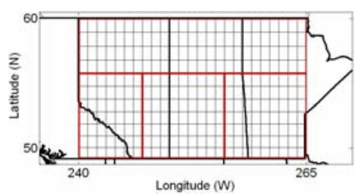
As an extension of previous studies [1,2] that were focused on characterizing the cloud fields associated with the recent and devastating Canadian Prairie drought of 1999 to 2004, the objective of this study is to determine how well the Canadian Regional Climate Model (CRCM) [3] is able to reproduce associated data fields and the correlations between those fields with those determined from observational data. This will ultimately contribute to the better prediction of drought by improving the understanding the strengths and weakness of the CRCM output.

2. Data & methodology

This study utilizes three datasets:

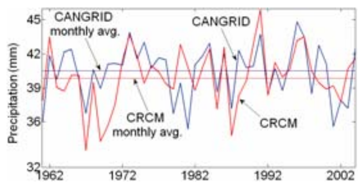
1. CRCM – version 4.1.1, experiment ade. Variables analyzed in this study include precipitation, cloud amount, and outgoing shortwave radiation at the top of the atmosphere (TOA) from which TOA albedo was calculated.
2. CANGRID – a gridded precipitation dataset using surface observations. Used in calculating the Standardized Precipitation Index (SPI).
3. Surface Radiation Budget (SRB) – a dataset utilizing International Satellite Cloud Climatology observations to obtain cloud and radiative properties of the atmosphere.

The study area focuses on the Canadian Prairie Provinces and consists of a 1°x1° square grid from 49-60°N and 240-265°W. Four sections within the study area were created to determine if differences between the model and observations varied with topography ('Rockies': 49-56°N, 240 -247°W) or areas with a low density of CANGRID stations ('North': 56-60°N, 240 -265°W). The rest of the study area is split in half ('West': 49-56°N, 247-256°W; 'East': 49-56°N, 256-265°W).



3. Results

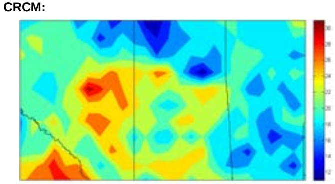
3.1 Monthly average precipitation per year



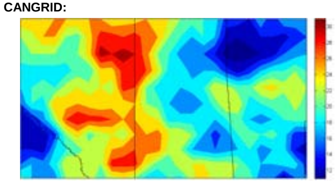
The values of the spatially-averaged monthly accumulated precipitation from the CRCM and CANGRID agree well. Over the entire study area and study period (1961-2004), the average monthly precipitation was 39.9mm using the model and 40.5mm using CANGRID. Differences on smaller spatial scales and for individual months can be greater. For example, the North tends to underestimate precipitation while the West and East consistently overestimate. The Rockies tend to overestimate in the summer months and strongly underestimate in the winter months.

3.2 Frequency of drought months

CRCM:

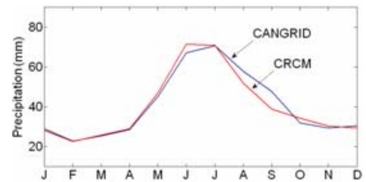


CANGRID:



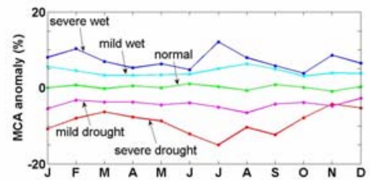
Spatial distributions of the frequency of drought (SPI<-0.5) months over the Prairie Provinces during the recent drought period reveal that both datasets show significant drought in particular areas such as the west-central Prairie region. The Rockies appear to be an area of disagreement, which is not surprising since the Rockies have fewer observational sites and modeling can be difficult due to the complex topography.

3.3 Annual cycle of precipitation



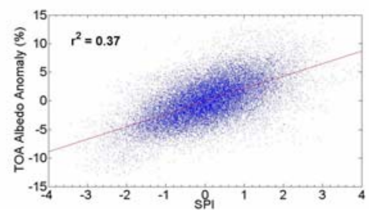
In the annual cycle of precipitation, the modeled monthly average precipitation reaches its summer peak about one month earlier than the time of the observed maximum.

3.4 Mean cloud amount



Cloud amounts differ slightly from dry to wet conditions and are only weakly correlated with the SPI in both the model and observations (r^2 = 0.28 and r^2 = 0.16, respectively). The model exhibits lower cloud amounts overall (59.8% versus 69.1%).

3.5 Top of atmosphere (TOA) albedo



Modeled TOA albedos are more strongly correlated with SPI than those observed (r^2 = 0.37 and r^2 = 0.29, respectively) and the model exhibits higher TOA albedos overall (40.7% versus 33.2%).

4. Conclusions

While many studies have utilized this model [4,5], until now, there have been no known analyses determining how well the model resolves these variables during extreme conditions such as drought in Canada. Precipitation, cloud amount, and TOA albedo were evaluated out of the 58 available products generated by the CRCM, as these variables are vital in resolving properly when studying meteorological drought.

The precipitation analysis suggests that the model would be preferred for predicting large-scale drought. The underestimates of cloud amount combined with the overestimates of TOA albedo suggest that the model may simulate thicker clouds than the observations show.

Given that the model is forced at the boundary by the analysis, it is encouraging that given the correct forcing, the model simulates precipitation, cloud-SPI correlations, and TOA albedo-SPI correlations that are in good agreement with the observations. This study creates confidence in the usefulness of the CRCM as a tool to understand and perhaps predict Prairie drought.

5. Literature cited

1 Greene, H. 2008: Drought and associated cloud fields over the Canadian Prairies. Master's Thesis, McGill University, Montreal, Quebec.

2 Roberts, E., R.E. Stewart, and C.A. Lin, 2006: A study of drought characteristics over the Canadian Prairies. *Atmos.-Ocean*, 44, 331-345.

3 Caya, D., R. Laprise, M. Giguere, G. Bergeron, J.P. Blanchet, B.J. Stocks, G.J. Boer, and N.A. McFarlane, 1995: Description of the Canadian Regional Climate Model. *Water, Air and Soil Pollution*, 82, 477-482.

4 Caya, D., and S. Biner, 2004: Internal variability of the RCM simulations over an annual cycle. *Clim. Dyn.*, 22, 33-46.

5 Dimitrijevic, M., and R. Laprise, 2005: Validation of the nesting technique in a regional climate model and sensitivity tests to the resolution of the lateral boundary conditions during summer. *Clim. Dyn.*,25, 555-580.

6. Acknowledgments

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7. For further information

Please contact trudy.mccormack@mail.mcgill.ca. This poster can be viewed online at: www.meteo.mcgill.ca/caos/posters/crcm_drought_evaluation.pdf