Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Final Progress Report

Project Title: Large-Scale Circulation Patterns and Teleconnections Associated with the 1999-2005 Canadian Prairie Drought

DRI Investigator: Barrie Bonsal

1.0 Project Work

1.1 **Provide a summary description of a) the objectives of the study, b) the scientific findings and c) the project work undertaken.**

a) The main objective of this study was to describe and quantify the large-scale (hemispheric/synoptic) physical factors associated with the 1999-2005 Canadian Prairie drought and compare them to factors that have been attributed to past drought occurrences in the region. For comparison, extreme wet periods or pluvials were also analyzed.

b) & c) Project work and main scientific findings were as follows:

- Analyses of circulation features over the Pacific North American sector revealed mid-tropospheric circulation patterns that were dominated by anomalous ridging over North America during the warm seasons from 1999-2002. A coupled mode of variability, which relates the SSTs to 500 hPa heights in the North Pacific, has been identified as an important factor in controlling these circulation features over North America.
- The central and western Prairie soil moisture deficit for the 1999-2003 drought period could be linked to the northward extension of wider dry conditions in the western U.S. During 2002, the soil moisture deficit worsened and spread eastward to cover the entire southern Prairie Provinces.
- Large-scale SST anomaly patterns associated with the 1999-2004 Canadian Prairie drought revealed a moderate to strong La Niña during the first part of the drought (1999-2002) that switched to weak El Niño conditions in 2003-2004. In terms of teleconnections, the PDO and PNA were predominately negative during the most extreme part of the drought (2001 and 2002) and positive thereafter, while the AMO was in a positive phase throughout the entire period. The lack of both a consistent positive PNA pattern (indicative of ridging over western Canada) and a persistent positive PDO during the most extreme drought conditions in 2001 and 2002 differs from the large-scale teleconnections associated with previous extended dry periods on the Canadian Prairies (e.g., 1961 and 1988). Furthermore, the mid-tropospheric atmospheric circulation patterns during 2001 and 2002 lacked the distinct meridional flow over the North Pacific and North America normally characteristic of drought in western Canada. Results suggested that the 1999-2004 drought was related to a

northward extension of persistent drought producing circulation anomalies that impacted the continental U.S. where severe drought encompassed much of the country from 1998 through at least 2005.

- A detailed examination of the atmospheric and oceanic variability associated with growing season (May to August) droughts and pluvials over the Canadian Prairies showed that moisture from the Gulf of Mexico was notably decreased during the identified drought seasons. Stronger than normal subsidence associated with anomalously high pressure over north-western North America also led to weakened moisture transport from the Pacific Ocean. Conversely, during pluvial seasons, low-level flow aided by the circulation associated with increased cyclone frequency over western North America brought abundant moisture northward into the southern Prairie region. These circulation patterns over western North America and their associated moisture transport anomalies into the Prairies showed some linkages to previous winter SST patterns both globally, and in the Pacific Ocean where the SSTs were similar to those associated with inter-annual El Niño/Southern Oscillation (ENSO) events and ENSO-like inter-decadal North Pacific variability.

1.3 **Describe the tangible results or the measurable outputs generated by the project and how these results have been taken up by user groups for policy development or operational improvements.**

Results from this study have advanced the understanding of drought occurrence on the Canadian Prairies. This information is available to user groups through various publications (DRI Professional Document; journal papers) and from various DRI meetings. However, it is unknown as to how these groups are using this information for policy development or operational improvements.

2.0 Impact

2.1 Describe in broad terms how your work has contributed to the overall objectives of DRI and to our scientific understanding of drought.

This research contributed to the following objectives of DRI:
Firstly, it helped quantify the physical features of this recent drought in terms of the large-scale atmospheric circulation patterns and teleconnections. Next, it helped improve the understanding of the processes and feedbacks governing the formation, evolution, cessation and structure of the drought by identifying changes to these large-scale atmospheric circulation patterns and teleconnections during various drought phases. The research also has implications for assessing and reducing uncertainties in the prediction of drought through a better understanding of the large-scale causes of the 1999-2005 episode. Finally, it directly contributed to the comparison of similarities and differences of the recent drought to previous droughts over this region by examining similar large-scale patterns associated with previous major droughts (and even pluvials) over the Canadian Prairies during the instrumental record.

2.2 Describe the significance / impact of the results in terms of some or all of the following areas:

- **The impact of the project on government policy development (federal, provincial or municipal);**

No immediate impacts on government policy are evident, however, it is hoped that the results of this research and of DRI in general will contribute to future government policy development regarding the occurrence and causes of hydro-climatological extremes both in the Prairies and all of Canada.

- **How the project has expanded contacts in partner organizations, or increased cross-disciplinary cooperation;**

DRI in general has aided the research community in expanding contacts with partner organizations.

- **Whether and how it has enhanced or improved the reliability of predictive methods related to the science;**

The better understanding of drought occurrence and causes attained from this project should aid in the better prediction of these events, however, much more research is required.

- **The impact of the project on your own institution (e.g. helped attract new students or personnel);**

It has enabled the University of Saskatchewan to partially fund a Masters student.

- **Whether it has improved or increased the acquisition of funds from other agencies, or led to new partnerships;**

It did not improve or increase the acquisition of funds from other agencies.

- **Any links with international initiatives and the potential impact of these (e.g. profile of Canadian science, influence on international programs);**

None directly related to this project.

- **Any commercial or social application the results may have had or could have;**

None.

- **The anticipated impact of the work on Canadians and their well-being;**

Although not in a direct manner, this work will advance our understanding of extreme events such as droughts that impacts Canadians and their well being.

4.0 Reverse Impact Statement

4.1 Provide a reverse impact statement, describing what would have happened in terms of the project, the resulting science and the impacts on users/stakeholders, if the work had not been funded by CFCAS.

It is envisioned that “large-scale factors associated with drought” research similar to this project would have been undertaken even without CFCAS funds. However, without

CFCAS funding, there would have not been an integration of this research into a larger project (i.e., DRI). This integration was integral to obtain a better understanding of critical hydro-climatic extreme events such as droughts from numerous research, operational, and stakeholder perspectives.

5.0 Follow-on Science

5.1. Based on the findings of your research identify any outstanding scientific questions that need to be addressed in future drought studies.

The main scientific question that still needs to be answered is why the large-scale factors and teleconnections associated with the 1999-205 Canadian Prairie drought differed from those associated with previous Prairie droughts and what implications these differences have for understanding and predicting future drought occurrence in this region and other regions of Canada and North America.

6.0 Dissemination

6.1 Provide information on the dissemination of the research results (publications, including journal names and whether refereed), conference contributions, seminars, workshops or videos, websites or other methods of transferring the results.

Refereed journal articles:

Bonsal, B.R., E.E. Wheaton, A. Chipanshi, C. Lin, D.J. Sauchyn, and L. Wen. 2010. Drought research in Canada: A Review. *Atmosphere-Ocean*, in press.

Bonsal, B.R., E.E. Wheaton, A. Meinert and E. Siemens. 2010. Characterizing the surface dynamics of the 1999-2005 Canadian Prairie drought in relation to previous severe 20th century events. *Atmosphere-Ocean*, submitted.

Shabbar, A., B.R. Bonsal and K. Szeto. 2010. Atmospheric and oceanic variability associated with growing season droughts and pluvials on the Canadian Prairies. *Atmosphere-Ocean*, in press.

Bonsal, B.R. and A. Shabbar. 2008. Impacts of large-scale circulation variability on low streamflows over Canada: A review. *Canadian Water Resources Journal*, **33**, 137-154.

Bonsal, B.R. and M. Regier. 2007. Historical comparison of the 2001/2002 drought in the Canadian Prairies. *Climate Research*, **33**, 229-242.

Bonsal, B.R. and E.E. Wheaton. 2005. Atmospheric circulation comparisons between the 2001 and 2002 and the 1961 and 1988 Canadian Prairie droughts *Atmosphere-Ocean*, **43**, 163-172.

Feature articles:

Bonsal, B.R. 2010. Large-Scale Atmospheric Circulation Patterns and Severe Droughts on the Canadian Prairies, in: *The 1999-2005 Canadian Prairies Drought: Science, Impacts and Lessons.*

Bonsal, B.R. 2008. Droughts in Canada: An Overview. *CMOS Bulletin* **36 (3)**, 79-86.

Wheaton, E., V. Wittrock, S. Kulshreshtha, B. Bonsal, G. Koshida, C, Grant, P. Adkins, A. Chipanshi, G. Bell, A. Howard, B. MacGregor, and G. Brown. 2006. Impacts of the 2001 and 2002 droughts in Canada: Some highlights, *Prairie Water News*, **16 (1)**, pp. 6-7.

Conference presentations:

Bonsal, B.R., A. Shabbar, and K. Szeto. 2010. Atmospheric and oceanic variability associated with growing season droughts and pluvials on the Canadian Prairies. CMOS Annual Workshop, June 1-4, 2010, Ottawa, ON.
Bonsal, B.R. 2010. Droughts in Canada: A Review. AMS Annual Meeting, January 20-21, 2010, Atlanta, GA.
Meinert, A., B.R. Bonsal, and E. Wheaton. 2009. Capturing the Dynamics of the 1999-2005 Canadian Prairie Drought using the SPI and PDSI**.** DRI Precipitation and Drought Indices Workshop, April 30, 2009, Toronto, ON.
Bonsal, B.R. Droughts in Canada. 2009. Research for Disaster-reduction from Extremes (REDE) Workshop, May 20-21, 2009, Winnipeg, MB.
Siemens, E., B.R Bonsal, E. Wheaton, and N. Nicolichuk. 2009. Drought Characterizations. Climate Hazards Workshop, November 25, 2009, Saskatoon, SK.
Bonsal, B.R. and C. Cuell. 2009. An Assessment of the 500mb Synoptic Types Associated with the 1999-2004 Canadian Prairie Drought. Drought Research Initiative Annual Workshop, January 26-28, 2009, Regina, SK.
Bonsal, B.R. and C. Cuell. 2009. An Assessment of Mid-Tropospheric Circulation Patterns Associated with Canadian Prairie Droughts. CMOS Annual Workshop, June 1-4, 2009, Halifax, NS.
Bonsal, B.R., 2008. *The Drivers of Hydro-Climate Variability in Western Canada.* Past and Future Hydroclimatic Variability: Applications to Water Resource Management in the Prairie Provinces, March 17-18, 2008, Canmore, AB.
Bonsal, B.R. and A. Shabbar, 2008. Large-Scale SST Patterns and Teleconnections Associated with the 1999 to 2005 Canadian Prairie Drought. Drought Research Initiative Annual Workshop, January 17-19, 2008, Calgary, AB.
Bonsal B.R., *Droughts in Canada: An Overview*. Annual CMOS/CGU Meeting, May 28 – Jun 1, 2007, St. John's, NL.
Bonsal B.R., *Droughts in Canada: An Overview*. Annual American Geophysical Union Meeting, December 11-15, 2006, San Francisco, CA.

6.2 Describe data management/sharing activities including organization of the metadata. Also, are the data being archived, and how will they be made available to other researchers?

Data are being managed by the DRI Data Manager.

7.0 Training

7.1 Quantify student and PDF involvement (indicate the level of each: undergraduate, masters, doctorate or PDF). If possible and within the Federal Privacy Act rules governing the collection of personal information, provide a general indication of their subsequent employment (i.e., university, industry, government, other, etc.), and indicate whether the employment was foreign or domestic.

A Masters' student from the University of Saskatchewan (under my co-supervision) is focusing his Thesis on analyzing the large-scale features associated with drought on the Canadian Prairies. Unfortunately, the student had to take medical leave and was unable to finish his degree prior to the end of DRI. He does plan on continuing his Masters in the next year.