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: Prairie Water and Energy Cycling: Budgets, Processes and Modeling

DRI Collaborator: Kit Szeto

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. Objectives:

(i) To Assess water and energy budgets for the Canadian Prairies;
(ii) to better understand the processes that govern water and energy cycling and drought development in the Prairies;
(iii) to assess how well water and energy cycling processes are represented in regional climate models and their impacts on Prairie drought prediction; and
(iv) to assess trends of Prairie droughts by using various datasets.

b. Scientific Findings:

(i) While some of the assessed component budgets for the Prairie water and energy cycle compared quite well with observations, magnitudes of the residuals in balancing the budgets were often comparable to the budget terms themselves in all (re-)analysis datasets, suggesting that substantial improvements to models and observations are needed before we can accurately close the budgets for the region.
(ii) The commonly used NCEP-reanalysis dataset was found to be severely over-predicting the Prairie water cycle while the basin-scale water cycle was found to be quite well-represented in the newer ERA-40 dataset.
(iii) Although the evapotranspiration (E) and precipitation (P) dominate the mean warm-season water budgets, the temporal variation of P is strongly correlated with that for the moisture flux convergence (MC) and poorly correlated with E, suggesting that the interannual variability of P is strongly governed by moisture transport processes rather than local evaporation.
(iv) Warm-season moisture transport and precipitation in the Prairies is strongly affected by synoptic storms activities, particularly those occur in its southern vicinity, and their interactions with topographic features of the region.
(v) Results from examination of past Prairie drought and pluvial events suggest that extreme drought would occur when both low soil moisture and evapotranspiration from low winter precipitation occurs in conjunction with lower than normal frequency of favourable synoptic systems during the spring and summer whereas extremely wet growing seasons are largely a result of anomalously high occurrence of these systems.

(vi) Both the structure of Prairie extreme rain storms and the dynamic processes that are responsible for their development have been elucidated. These extreme events, such as the one that occurred in June of 2002, often alleviate, and sometimes initiate the termination of, multi-year drought in the region. There are also evidences that conditions during the severe drought had contributed to the development of the extreme system.

(vii) Warm-season synoptic systems provide the critical dynamical link between Prairie precipitation response and large-scale forcings and hence the accurate modeling of these systems and their interactions with regional processes and topographic features in the Prairies in models are critical for the improved dynamical prediction of Prairie droughts over different scales.

(viii) Model biases exhibited in the simulation of the 1999-2005 Prairie drought by using several different regional climate models were quantified and model deficiencies (e.g., the over- and under- predictions of air-land interactions) that caused these biases were identified.

(ix) The enhanced increasing trends of droughts detected over the western Prairies during the later half of the 20th century by using PDSI data were not substantiated by trends that were detected by using other datasets (e.g., SPI and assimilated soil moisture).

c. Project Work:

(i) Different observed, remotely-sensed, (re-)analysis and modeled datasets were used to obtain independent estimates of Prairie water and energy budgets.

(ii) Results from correlation analysis conducted with the regional budgets were used in a process diagnostic study to identify the interplay between various water and energy cycling processes in governing the interannual variability of precipitation and development of drought in the Prairies.

(iii) An objective storm track analysis was performed with NCEP and ERA40 data and the results are used in conjunction with those from the budget study to identify dynamical linkages between moisture transport and storm activities that affect precipitation in the Prairies.

(iv) A detailed case study of the June 2002 Prairie extreme rain event was conducted.

(v) Results from the storm track analysis were used along with other datasets in a teleconnection study that attempted to elucidate the causal mechanisms that link Prairie precipitation to large-scale forcings.

(vi) Results from simulations of the 1999-2005 Prairie drought with different regional climate models performed under the auspice of the GEWEX CEOP Model Transferability Study were analyzed to assess how well aspects of the drought could be captured by the models and to identify model deficiencies that were responsible for the exhibited model biases.

(vii) Sensitivity experiments were performed with the Canadian Regional Climate Model (CRCM) to examine the sensitivity of predicted Prairie warm-season precipitation to the specification of initial soil moisture. This work constitutes part of the CFCAS-supported project led by Prof. A. Berg.

(viii) Assessments of trends of drought frequency and intensity in the Prairies by using various drought indices (PDSI, SPI and assimilated soil moisture).

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.**

A climatology of Prairie water and energy budgets was compiled that could be used for the purposes of model validation, the development of statistical prediction schemes and climate change studies. Results from the Prairie drought trends studies also have potential applications for policy development.

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.

Results from the budget study contribute directly to the DRI objective of quantifying the physical features of the 1999-2005 drought. Results from the studies that examined the interplay of different processes in governing the variability and extremes of Prairie precipitation contribute to the DRI objective of improving the understanding of the recent drought as well as to the objective of comparing the recent drought to previous droughts. Results from the inter-model comparison study and CRCM sensitivity study and also the enhanced understanding of processes that govern drought development in the region contribute to the DRI objective of assessing and reducing the uncertainties in drought prediction.

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);**

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

Research collaborations between government (e.g. EC) and university scientists and also the transfer of technology between the institutes (e.g., the enhanced awareness of EC-developed datasets and their utilizations by university scientists in drought research) have been enhanced substantially through works performed in this project.

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

While results from the current project could not be applied immediately to improve drought prediction, the identification and enhanced understanding of the processes that are critical in the development of Prairie drought are essential for future improvements of the operational models.

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

The project had facilitated or strengthened research collaborations among scientists from different Divisions within EC to work on a focused subject that is relevant to the Departmental mandates.

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

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

Some of the work have been contributed to international GEWEX initiatives (Extremes, CEOP, etc.)

- **Any commercial or social application the results may have had or could have;**
- **The anticipated impact of the work on Canadians and their well-being;**

Results from this work will lead to the improved understanding and prediction of drought and other hydrometeorological extremes in the Prairies which are important for agricultural activities, sustained economic and societal developments and planning and the general well-being of Canadians living in the region and beyond.

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.

Prairie water and energy budgets and their closure need to be re-assessed on an on-going basis when new reanalysis, observations and improved models become available.

The relative roles of soil moisture, evapotranspiration and atmospheric circulations and associated moisture transport in affecting Prairie precipitation, and how they might change over the growing season, need to be better quantified and clarified.

The development of regional circulations, particularly those that are orographically-induced, and their roles in affecting warm season convective precipitation need to be better understood and modeled.

Both the statistical and physical connections between severe droughts and extreme precipitation events in the Prairies need to be better studied.

Both large-scale and regional factors that affect the variability of warm-season continental synoptic storm activities need to be identified and better understood. How well these processes are captured in current models also need to be assessed.

How the regional feedback processes and warm-season synoptic storm activities might change in a warmed Prairie environment, and their subsequent effects on future precipitation in the region, need to be examined.

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 papers (Atmos.-Ocean, J. of Met Soc. Jap., JGR, J. Hydrometeorl.)

Conference contributions: CMOS Congress, CGU Annual Meeting, AGU meeting, International Precipitation Conference, GEWEX Conferences

Workshops: DRI Annual Meeting and various DRI Workshops

Seminars: EC ASTD seminars, EC-CRD seminars

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?

The climatology of Prairie water and energy budget and CRCM model results are available upon request or through research collaborations.

6.3 Comment on any outreach or public information activities, including press interviews or other media interest or reports. Has the project helped to popularize science or increase public awareness?

I have contributed to the development of the DRI entries in the Wikipedia.

6.5 Provide a reference list for all publications produced as a result of this project.

Szeto, K., 2007: Accessing water and energy budgets for the Saskatchewan River Basin. J. Met. Soc. Jap., 85A, 167-186.

Shabbar, A., B. Bonsal, K. Szeto 2010: Atmospheric and oceanic variability associated with growing season droughts and pluvials on the Canadian Prairies. Atmos.Ocean (In press).

Szeto, K.K., W. Henson, and R.E. Stewart: The June 8-12 2002 extreme Prairie rain event. J. Geophys. Res. (submitted).

Szeto, K., 2010: Water cycling and hydroclimate extremes in the Canadian Prairies. J. Hydrometeorol. (submitted).

Szeto, K., 2011: Water cycling and hydroclimate extremes in the Canadian Prairies. The 1999-2005 Canadian Prairies Drought: Science, Impacts, and Lessons. R. Stewart and R. Lawford (Eds.) 35-40.

Ronald Stewart, William Henson, Hannah Carmichael, John Hanesiak, and Kit Szeto, 2011: Precipitation events during the recent drought. 43-46.

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.

Supervised 5 under-grad co-op students who had worked directly on the project.

Co-supervised 1 PhD student who had applied budget assessment and processes diagnostic techniques developed in this project to study droughts in Central South Asia (now employed by Government of Pakistan).