Drought Research Initiative

First Annual Workshop

11-12 January 2006

Parktown Hotel (*Oak Room*)
Saskatoon, Saskatchewan
Canada

PROGRAM and ABSTRACTS

(for Science Presentations - Sessions II – IX)

For additional information, go to http://www.meteo.mcgill.ca/dri/

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AGENDA

Wednesday, 11 January:

08:15-09:00 – Registration and Refreshments (Oak Room, Parktown Hotel)

09:00-10:00 – Session I – Opening and Overview of DRI (Co-Chairs: Ron Stewart/John Pomeroy)

09:00-09:20 – Welcome Address – The Honourable *Peter Prebble, MLA*, Minister Responsible for Saskatchewan Water Corporation
09:20-09:30 – Canadian Foundation for Climate & Atmospheric Sciences (CFCAS) – *Tim Aston*, CFCAS Science Officer
09:30-09:40 – Management Perspective on Drought & DRI – *Jim Bruce*, Chair BoD
09:40-10:00 – Objectives, Overview, Current Status of DRI – Ron *Stewart & John Pomeroy*, Co-Chairs DRI Science Committee

10:00-10:30 – Health Break

NOTE: *The following presentations are assumed to be 10 minutes (including any discussion), except where noted.* Suggested questions for Investigators and Collaborators to address in their presentation:

- *What research will you carry out?*
- *What do you expect to achieve?*
- *How will this fit into the network?*

10:30-11:00 – Session II – Characterization and Implications of Drought (Chair: Harvey Hill)

10:30-10:45: Lawrence Martz, U. Saskatchewan, Saskatoon – *Applying Hydroclimatological Science to the Socio-Economic Dimensions of Water*
10:45-10:55 Elaine Wheaton, SRC/U. Saskatchewan, Saskatoon – *Characterization of Prairie Drought*
10:55-11:00: *5-minute open discussion*

11:00-14:45 – Session III – Atmospheric Processes and Teleconnections (Chair: Ron Stewart)

11:00-11:10: Barrie Bonsal, U. Saskatchewan, Saskatoon – *Hemispheric to Global-Scale Factors Associated with Canadian Prairie Droughts*
11:10-11:20: John Gyakum, McGill U., Montreal – *Blocking and its Relationship to Droughts*
11:20-11:30: Steven Quiring, Texas A & M University, College Station, Texas – *Characterizing and Understanding the Causes of Drought in the Northern Great Plains*
11:30-11:40: Charles Lin, McGill U., Montreal – *Seasonal Prediction and Land-Atmosphere Coupling*
11:40-11:45: *5-minute open discussion*

11:45-13:00 – Lunch

13:00-13:45 – Session IV – Surface Water/Atmospheric Moisture & Energy Budgets (Chair: John Pomeroy)

13:00-13:10: Kit Szeto, EC/MSC, Toronto – *Assessing Water and Energy Budgets for the Prairie Region*
13:10-13:20: Ron Stewart, McGill U., Montreal – *Prairie Drought, Storms and Water Budgets*
13:20-13:30: Geoff Strong, U. Alberta, Edmonton – *Atmospheric Moisture and Thunderstorm Drought*
13:30-13:40: Henry Leighton, McGill U., Montreal – *Use of Satellite for Regional Climate Studies*
13:40-13:45: *5-minute open discussion*

13:45-14:30 – Session V – Precipitation Processes and Assessment (Chair: John Pomeroy)

13:45-13:55: John Hanesiak, U. Manitoba, Winnipeg – *Surface-Atmosphere Feedbacks during Convective Events*

13:55-14:05: Craig Smith, EC/MSC/CRB, Saskatoon – *Systematic Errors in Precipitation Measurements and Implications for Monitoring Drought*

14:05-14:15: Susan Skone, U. Calgary Geomatics Eng., Calgary – *GNSS Remote Sensing of the Atmosphere: Potential Applications to Drought Research*

14:15-14:25: Chris Derksen, EC/MSC, Toronto – *Snow Cover Variability and Climate Interactions*

14:25-14:30: *5-minute open discussion*

14:30-15:00 – Health Break

15:00-15:30 – Session VI – Near-Surface Exchanges and Hydrology (Chair: Ron Stewart)

15:00-15:10: John Pomeroy, U. Saskatchewan, Saskatoon – *Land Surface Hydrological Processes and Modelling*

15:10-15:20: Paul Bullock, U. Manitoba, Winnipeg – *Moisture Stress: A Crop's Perspective*

15:20-15:30: Al Pietroniro, U. Saskatchewan, Saskatoon – *Water Cycle Prediction for the Drought Research Initiative*

15:30-15:40: Brenda Toth, NHRC/EC, Saskatoon – *Hydrological Modeling in the SSRB*

15:40-15:45: *5-minute open discussion*

15:45-15:55 – Session VII – Surface to Sub-Surface Hydrology (Chair: John Pomeroy)

15:45-15:55: Ken Snelgrove, Memorial U., St. John's – *Determining Moisture Distributions in the Saskatchewan River Basin*

15:55-16:05: Al Woodbury, U. Manitoba, Winnipeg – *Climate Change Assessment over the Assiniboine Delta Aquifer*

16:05-16:15: Masaki Hayashi, U. Calgary, Calgary – *Effects of Drought on Prairie Groundwater*

16:15-16:25: Garth van der Kamp, U. Saskatchewan, Saskatoon – *Groundwater and Lake Level Data*

16:25-16:30: *5-minute open discussion*

16:30-17:15 – Session VIII – Drought Initiatives & Concerns of Partners: Part I (Chair: Gary Burke)

Suggested questions for Partners to address in their presentation:

- *What are your issues and concerns with respect to drought?*
- *What activities are you presently carrying out in this regard?*
- *What do you hope that DRI can accomplish and how can we work together?*

16:30-16:40: Dave Sauchyn, PARC / U. Regina, Regina – *PARC / Long Drought Records*

16:40-16:50: Ross Herrington, MSC/EC for PPWB – *Droughts: Implications for the Prairie Provinces Water Board*

16:50-17:00: Bob Clark, Canadian Wildlife Service, Saskatoon – *CWS Perspective on Drought Impacts/Concerns*

17:00-17:10: Aston Chipanshi, Agriculture and Agri-Food Canada, Regina – *Exploring Research Opportunities Under the AAFC's Drought Monitoring Program*

17:10-17:15: *5-minute open discussion*

17:15-17:20: Next Day's Agenda and any Announcements

18:00-20:00 – DRI Icebreaker – *snack food and liquid refreshments, along with vigorous discussions.*

<u>Thursday, 12 January</u>:

***08:15-09:00* – Refreshments**

09:00-09:45 – Session IX – Drought Initiatives & Concerns of Partners: Part II (Chair: Gary Burke)

09:00-09:10: Ralph Wright, AAFRD, Edmonton – *A QA/QC and Data-Filling Decision Support System for Near Real-Time Climate Data*
09:10-09:20: Bill Girling, Manitoba Hydro, Winnipeg – *Drought Research Initiatives in Manitoba Hydro*
09:20-09:30: Bart Oegema, Sask Watershed Authority, Moose Jaw – *Saskatchewan Watershed Authority Perspective on Drought*
09:30-09:40: Kevin Shook, Alberta Environment, Edmonton – *Flood Forecasting Drought Concerns*
09:45-10:05: Daniel Caya, Ouranos, Montreal – *Regional Climate Model Results*
10:05-10:10: *5-minute open discussion*

10:10-10:40 – Health Break

10:40-11:50 – Session X – DRI Themes (Chair: Jim Bruce)

Themes: objectives, actions, challenges, participants
10:40-10:50: John Pomeroy/Ron Stewart – *Brief summary of DRI and its themes funded and proposed*
10:50-11:00: John Hanesiak - <u>Theme 1</u> – *Quantify physical features of the recent Canadian Prairie drought*
11:00-11:10: Masaki Hayashi - <u>Theme 2</u> – *Understanding processes and feedbacks of this recent drought*
11:10-11:20: Charles Lin - <u>Theme 3</u> – *Assess and reduce uncertainties in prediction of drought*
11:20-11:30: Barrie Bonsal - <u>Theme 4</u> – *Comparisons of the recent Canadian Prairie drought with others*
11:30-11:40: Elaine Wheaton - <u>Theme 5</u> – *Apply progress to address critical issues of importance to society*
11:40-11:50: *10-minute open discussion*

11:50-13:30 – Lunch

11:50-13:30 – Board of Directors Luncheon Meeting – Chair: Jim Bruce)

13:30-14:30 – Session XI – Break-out Groups on DRI Themes

Three **Break-out Groups** on the 1st 3 themes to address the questions:

How can we best move ahead with Themes 1-3, and what issues must be addressed?

Group 1 – *Quantify physical features of the recent Canadian Prairie drought*
Group 2 – *Understand processes and feedbacks of the recent drought*
Group 3 – *Assess and reduce uncertainties in prediction of drought*

Group 4 – Address the question, *"How can we move ahead with (unfunded) Themes 4/5?"*

14:30-14:45 – Health Break

14:45-15:45 – Session XII – Plenary (Summary, Plans and next Workshop)

14:45-15:05: Break-Out Summary Reports – Each group presents a 5-minute summary report
15:05-15:35: Discussion/feedback
15:35-15:45: Plans and Next Workshop

15:45-16:45 – DRI Science Committee Meeting

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Session II – Characterization and Implications of Drought

2.1 Applying Hydroclimatological Science to the Socio-Economic Dimensions of Water

Lawrence Martz *and Joel Bruneau*
University of Saskatchewan, Saskatoon, SK
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The focus of this presentation is a study of the impacts of climate change on the water resources of the South Saskatchewan River Basin (SSRB) that is nearing completion. Its aim is to enhance understanding how potential climate change will affect the availability of water and water use. It consists of two main modelling components: (1) a physical component simulating future availability of water in the SSRB under a range of possible climate change scenarios, and (2) a socio-economic component assessing the impacts of water resource availability on major water users and their vulnerabilities to changes in water supply under climate change. Methodologically, the study employs a disaggregated and distributed approach to estimating water resource demands and uses. Existing climate, hydrological and socio-economic models are calibrated and updated for the SSRB to address several key issues, namely: to document current water use patterns and estimate the value of water use by type of use; forecast the availability of water and water use for a time period in the foreseeable future; assess the vulnerability of regional withdrawal and in-stream water users to changes in water supply (under climate change); estimate the cost of such changes to users to evaluate potential costs and benefits; and, establish a framework for addressing policies and programs that govern water use and adaptation to potential change.

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2.2 Characterization of Prairie Drought

Elaine Wheaton
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Droughts are one of the world's and Canada's most significant hazards. Droughts have major impacts on the economy, environment and society. Drought is a recurrent and complex phenomenon. Most regions of Canada have experienced drought, but the Canadian prairies is preferred by the worst droughts. Four main characteristics distinguish droughts: intensity, duration, spatial coverage and frequency. Each drought is unique in terms of one or more of these characteristics. However, the great droughts tend to be intensive, extensive, and long lasting. Considerable decadal variation exists in drought trends and some evidence of increasing droughts exists. Abrupt switches from droughts to wet events also occur. Planning to adapt to droughts urgently requires much improved knowledge of the characteristics and causes of droughts.

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Session III – Atmospheric Processes and Teleconnections

3.1 Hemispheric to Global-Scale Factors Associated with Canadian Prairie Droughts

Barrie Bonsal[1] *& Amir Shabbar*[2]
[1]University of Saskatchewan/Environment Canada, Saskatoon, SK
[2]Environment Canada, Downsview, ON
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Several studies have determined significant relationships between hemispheric to global-scale atmospheric and oceanic oscillations and climate anomalies over the Canadian Prairies particularly, during the cold season. Linkages between North Pacific sea-surface temperature (SST) anomalies, El Niño/Southern Oscillation (ENSO), and the Pacific Decadal Oscillation (PDO) and summer moisture availability across western Canada have also been identified. Preliminary analyses of the large-scale atmospheric circulation patterns associated with the recent 2001 to 2002 Canadian Prairie drought revealed significant differences when compared to previous severe droughts over western Canada. In addition, the recent 1998 to 2002 extreme drought over most of the United States was attributed in part, to La Niña-like conditions in the tropical Pacific. The objectives of this current study are to build upon this previous research by determining the global/hemispheric-scale physical factors responsible for the initiation, persistence, and termination of the recent Canadian Prairie drought. This will include examination of relevant teleconnection indices (ENSO, PDO, AO, PNA, NAO, AMO, EPO), global SSTs at various lead and lag times, and large-scale soil moisture anomalies and associated feedbacks to atmospheric circulation patterns. The proposed research will also compare these identified factors to those associated with previous Prairie droughts as well as, droughts in other regions of Canada/North America including the Great Plains of the United States. The results of this study will characterize the global/hemispheric-scale factors associated with the recent Canadian Prairie drought and in collaboration with other Network studies, improve the understanding of processes and feedbacks governing the drought's formation, evolution, cessation, and structure. In addition, the findings will aid in determining similarities/differences in large-scale factors associated with droughts at different times and in different regions (in part, through collaborations with other drought researchers including those in the United States). As a result, this investigation contributes to all five themes identified in the DRI Network proposal.

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3.2 Blocking and its Relationship to Droughts

John Gyakum, *Eyad Atallah, and Florian von Appen*
McGill University, Montreal, QC
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The purpose of this research is to understand the concept of atmospheric circulation regimes during the North American warm season. These circulation regimes are typically manifested during the winter season as the PNA, AO, NAO, etc. Despite the fact that these well-known circulation indices are not so prominent during the warm season, manifestations of regimes do occur in the form of long-lived droughts.

Our goal is to discover the atmospheric circulation regimes that are particularly pertinent to the development, maintenance, and decay of droughts in North America. We will do so with the aid of theoretical studies of blocking, and with the high-resolution ECMWF ERA-40 global reanalyses.

This work links well with the DRI network, through the offering of a dynamical understanding of droughts. This larger-scale perspective may be used as a background for fellow researchers studying soil moisture, and other relevant factors germane to the drought problem.

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3.3 Characterizing and Understanding the Causes of Drought in the Northern Great Plains

Steven Quiring
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Canada DRI provides an excellent opportunity to develop synergistic partnerships with Canadian scientists who are pursuing closely related research agendas. I am involved in a number of ongoing research projects that are related to the major themes of DRI. Specifically, I am reviewing and evaluating existing drought (moisture) indices to determine which are the most appropriate for characterizing drought conditions. A second research project involves examining the role that land surface conditions play in the formation and persistence of drought events. This research involves both observational and modeling approaches to quantify the role that snow cover and soil moisture play in creating and sustaining droughts in the Northern Great Plains. Finally, I am also working on updating and expanding a recent paper that examined the main spatial and temporal patterns of growing-season moisture variability in the Canadian prairies. I believe that my on-going research could directly contribute to the DRI and it also provides an opportunity to explore the nature and causes of drought in the entire Northern Great Plains study region, and to eliminate the artificial (non-climatic) boundary imposed by the Canada–United States border.

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3.4 Seasonal Prediction and Land-Atmosphere Coupling

Charles Lin
McGill University, Montreal, QC
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We examine how well was the current prairie drought predicted on the seasonal time scale by GCM3 of the Canadian Centre for Climate Modelling and Analysis (CCCma); this version of the model is coupled to the Canadian Land Surface Scheme (CLASS) and is used in the Historical Seasonal Forecast Project of the Canadian CLIVAR study. We will also study the effect of soil moisture and snow cover anomalies on predictability of the drought, in comparison with sea surface temperature anomalies. The CRCM (Canadian Regional Climate Model) will also be used. We will also examine the influence of soil moisture on atmospheric convection using a column model from GCM3.

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Session IV – Surface Water/Atmospheric Moisture & Energy Budgets

4.1 Assessing Water and Energy Budgets for the Prairie Region

Kit Szeto
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The regional climate system is operated largely through the exchange of water and energy between the region and its environment, as well as the conversion and cycling of these quantities within the region. Thus, to better understanding the dynamics of drought in a region, it is essential for us to improve the quantitative characterizations of water and energy cycling in the region and to examine how they deviate from their normal states during drought episodes. In this study, the atmospheric and surface water and energy budgets of the Prairie region are evaluated by using several global and regional observational, (re-)analysis, and model datasets. The relative merits of how well the regional water and energy budgets are represented in the different datasets will be assessed. Diagnostics of hydrometeorological processes such as storm processes and precipitation recycling will be performed to interpret some of the budget results. The implications of the results to drought studies in the region, and in particular, the use of global climate datasets (e.g. the widely available NCEP and ECMWF reanalysis datasets) for drought studies in the region will also be discussed.

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4.2 Storms, Clouds and Drought

Ron Stewart
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This study will focus on the flow of water through clouds and precipitating systems to the surface within and adjacent to drought regions. In particular, it will focus on thresholds that must be exceeded before precipitation can reach the surface and on episodic events that produced heavy, widespread precipitation. Key issues include the relative contributions of water vapour from external and local moisture sources, the efficiency through which cloud systems convert this water vapour to precipitation, the possible role of the drought environment in enhancing the strength and/or efficiency of some precipitating systems, and the production of scattered, partially drought-alleviating precipitation. The ensuing insight will be related to surface and sub-surface moisture conditions in collaboration with other DRI scientists. Throughout the effort, the degree to which current models are able to capture the flow of water through the system will be assessed. To accomplish this activity, a wide variety of observational and model information will be utilized.

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4.3 Atmospheric Moisture and Thunderstorm Drought

Geoff Strong
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Convective thunderstorms occur in response to diurnal increases in temperature (sensible heat) and moisture (latent heat), the latter being the most variable quantity, and is also the most critical meteorological factor in the initiation and cessation of drought. Summer convective processes on the prairies contribute 50% or more of annual precipitation, the role of such storms being to recycle and redistribute water downstream across the prairies. This critical component of the water balance is interrupted or missing during drought periods with low soil moisture and evapotranspiration. Convective storms often herald both the beginning and the cessation of drought, but are also known to occur in the middle of such prolonged dry periods, albeit with less frequency. This presentation introduces the topic of *thunderstorm drought*, emphasizing the equal, if not more importance of atmospheric moisture over temperature in studies of climate change and drought, and the role that convective storms play. The study will investigate both short-term cycles and longer-term climate trends in atmospheric temperature, moisture, and precipitation, utilizing traditional surface and radiosonde data, satellite and radar images, as well as new remote sensing techniques such as moisture retrieval from GPS signals.

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4.4 Use of Satellite for Regional Climate Studies

Henry Leighton
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Clouds have major impacts on energy and moisture budgets. One important contribution of satellite data to the understanding of the prairie drought will be to characterize cloud properties during the drought and to compare those properties with those from periods of normal precipitation. The International Satellite Cloud Climatology Project provides data that are convenient for such comparisons. Another important use of satellite data will be for the evaluation of the models that will be used to simulate the drought. We will want to determine how well the models are able to reproduce the observed cloud and radiation fields. To accomplish this we will generate cloud, aerosol and radiation fields from CERES, AVHRR, MODIS and GOES data and compare those fields with the model generated fields. This work is a natural extension of similar work for the MAGS project.

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Session V – Precipitation Processes and Assessment

5.1 Surface-Atmosphere Feedbacks during Convective Events

John Hanesiak
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An average of 75% of all significant rainfall (>= 10 mm) is due to convective processes during the summer (June - August) on the Prairies, and most of these events are driven by mesoscale mechanisms. It has been shown that the surface plays a critical role in summer convective events by contributing to and regulating heat and moisture supplies in the boundary layer. This can affect mesoscale dynamics, boundary layer thermodynamics and the likelihood and severity of convection, especially across transition zones between wet and dry regions. Drought periods may accentuate the mesoscale processes and thermodynamics since dry areas tend to be very dry which can be in close proximity to relatively wet areas. This study will investigate the nature of convective events (and associated significant rainfall) in relation to dry and wet areas during drought years with particular focus on mesoscale forcing mechanisms. This includes studies that will attempt to determine whether drought perpetuates drought.

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5.2 Systematic Errors in Precipitation Measurements and Implications for Monitoring Drought

Craig D. Smith
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The most significant measurement error for precipitation is the systematic under-estimation due to wind. This error is exacerbated for solid precipitation and can be as large as 100%. As meteorological services incorporate Geonor all-weather accumulating precipitation gauges into national networks, it is important to quantify the potentially large systematic errors associated with wind. In response to this, an intercomparison program, located at Bratt's Lake Saskatchewan, was re-initiated in 2003. The objective of this program is to examine wind induced bias in solid precipitation as measured by the Geonor T-200B gauge in a relatively dry, cold and windy environment. Geonor measurements using a standard Alter-type wind shield and an octagonal vertical double fence wind shield have been compared to the manually observed Dual Fence Intercomparison Reference (DFIR). Preliminary results suggest that the catch efficiency of the Alter-shielded Geonor gauge can be as low as 40% at wind speeds of 5 m/s. Since precipitation observations are typically archived without a wind correction, it is crucial that users of this data are aware of the potentially large bias.

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5.3 GNSS Remote Sensing of the Atmosphere: Potential Applications to Drought Research

Susan Skone
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Global Navigation Satellite Systems (GNSS) include the current Global Positioning System (GPS) and the upcoming European Galileo. These systems provide continuous positioning and navigation capabilities, with thousands of GPS/GNSS reference stations deployed worldwide. GNSS signals experience delays in the neutral atmosphere, with the resulting range errors being dependent on the atmospheric water vapour. GNSS can therefore be used for atmospheric remote sensing. With current ground-based infrastructure, potential exists to exploit GNSS for both local and global climate applications, in support of drought studies and modelling efforts.

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5.4 Canadian Snow Cover Variability and Climate Interactions

Chris Derksen
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Winter season snow cover is an important variable to consider in the context of Canadian droughts because of its insulating properties above the top soil layer, and through spring melt water release for surface, soil, and groundwater recharge. In an era of sparse conventional observations, satellite remote sensing plays an important role in monitoring snow extent (through the NOAA snow chart record) and snow water equivalent (SWE – via passive microwave sensors). The NOAA dataset can be used to identify continental and regional trends in snow cover duration from 1966 to the present, while passive microwave technology provides a capability to monitor SWE in near real time across the prairie and boreal forest regions of western Canada. An overview will be provided on historical snow cover duration variability across the Canadian prairies, and the existing operational SWE products produced by the Climate Research Division of Environment Canada. Ongoing field studies have reduced the uncertainty in SWE retrievals through algorithm evaluation and the development of enhanced retrieval techniques. The microwave time series (1978 to the present) has been successfully merged with the conventional historical data record (1915-1992) to provide a long term perspective on SWE variability, and allow the satellite era to be viewed in the longer climatic context.

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Session VI – Near-Surface Exchanges and Hydrology

6.1 Land Surface Hydrological Processes and Modelling

John Pomeroy, *Raoul Granger, Newell Hedstrom, Tom Brown, Alain Pietroniro, Lawrence Martz, Robert Armstrong and Logan Fang*
Centre for Hydrology, University of Saskatchewan and NWRI/Environment Canada
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This study will focus on three topics relating to the hydrological manifestation of prairie drought and its interaction with the atmosphere, specifically:
i) Snowmelt runoff: controls on the rate and amount of runoff to streams and sloughs under conditions of low snowfall, low soil moisture and a short snow-covered season. Particular reference will be paid to infiltration into frozen soils, snowmelt and redistribution of blowing snow and determining the appropriate scales for calculating these terms and aggregating runoff from process to larger scales.
ii) Areal evaporation: the effect of changing moisture content in soils on the spatial distribution of evaporation from prairie terrain of mixed land use and mild topography. Particular reference will be paid to the feedbacks between soil moisture, plant response and atmospheric water vapour deficit near the surface.
iii) Process based modelling of prairie hydrology in small catchments. Physically based small scale models of the hydrological cycle will be developed and evaluated under varying drought conditions across the prairies using the Cold Regions Hydrological Modelling Platform (CRHM). The runoff and soil moisture response of an 'ideal' small catchment to drought will be developed as a hydrological drought index for Canada.

All topics will use experimental archives to describe processes and support modelling of both cold and warm season hydrological processes to examine how they influence the development, persistence and cessation of water resource drought in the Canadian prairies. Observations and model results from the St Denis National Wildlife Area in the central prairies will be compared to those from the Bad Lake Research Basin in the southern prairies. Results from snowmelt and evaporation studies will support the development of the hydrological model. Process-based modelling will be at the resolution that defines the dynamics within small 'headwater' prairie basins and will permit a detailed examination of drought hydrology processes and the scale of their interaction. This will be upscaled to inform the parameterization of larger scale modelling efforts for both hydrology and land surface schemes coupled to atmospheric models.

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6.2 Moisture Stress: A Crop's Perspective

Paul Bullock
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In western Canada, fluctuations in moisture availability and heat stress have a significant impact on crop yields and quality.

Detailed weather and soil conditions were monitored starting in 2002 and continuing through 2006 throughout the growing season at several locations where multiple crop cultivars were grown in replicated crop variety trials. From 2003 through 2005, more than 300 grain samples were collected from producer fields right across western Canada with documented information on genotype and weather conditions. A series of yield and technical quality characteristics were measured on each individual replicate and each producer field sample. A range of environmental indices calculated from the meteorological data at each site are being statistically analyzed against yield and quality characteristics of the various cultivars. The indices range from simple precipitation totals, useful heat and stress heat for the growing season to more complex indices that include evapotranspiration, water demand, water deficit and crop water use defined by the physiological growing season of each cultivar and progressively more sophisticated models to estimate evapotranspiration and crop water use. Initial evidence suggests that the more sophisticated characterizations of the growing season weather conditions, improve the ability to explain the variation in crop yield and quality. The data collected spans the time period from the drought to the pluvial cycle. The more accurately that a weather index reflects the actual response of a particular element of the environment, the better the index will portray that particular reality and the higher the potential for sound decisions.

The data collected in the field studies will provide a means to link meteorological drought measures to accurate estimates of agricultural drought. This information will help to determine how the extent and frequency of weather-induced crop impacts has changed historically and how climate change may affect it in the future.

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6.3 Water Cycle Prediction for the Drought Research Initiative

***Al Pietroniro*[1], B. Davison, G. Burke, P. Pellerin, V. Fortin, and S. Belaire
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There is a strong research effort within Evironment Canada in coupling atmospheric and hydrologic models for improved hydrological flow modelling and improved atmospheric simulation. The land-surface is an important hydrologic control as it is the primary influence in the surface water budget and it is almost always a requirement in the implementation of either hydrological or atmospheric models. Sophisticated soil-vegetation atmospheric transfer schemes also know as land-surface schemes (LSS) are currently being implemented in global climate models, regional climate models and day-to-day operational forecasting numerical weather prediction models. Over the last 10 years, there has been a systematic attempt, through collaborative research in Canada and under a variety of research programs to couple atmospheric and hydrological models using the LSS as the common link. Our approach has been to combine LSS with hydrological streamflow models to provide stand-alone hydrology-land-surface schemes. When these stand alone models are also incorporated as the LSS in the atmospheric models creating a fully coupled system. We propose to use the MEC/MESH modelling system (Fortin et al., 2005) to drive the CLASS land-surface model (Verseghy, 2000), forced by observed and atmospheric model outputs and analyses, and coupled to a hydrological model, based on the framework proposed by Soulis et al. (2005). Using the OASIS/Gossip coupler (Valcke et al., 2004), we propose to assess the impact of one-way vs two-way coupling of the surface model with the atmospheric model both for hydrological and atmospheric prediction in this region. Using parameterization results, we anticipate improved prediction capabilities through the use of some of the proposed observational networks (both atmospheric and hydrological) to validate and calibrate some of the processes in the land-surface model and in the hydrological model.

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6.4 Hydrological Modeling in the SSRB

Brenda Toth
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The semi-arid South Saskatchewan River Basin (SSRB) will potentially face increased stressors due to climate change. Key to the multi-disciplinary study of mitigation and adaptation is an understanding of the physical hydrologic response to atmospheric perturbations. This resulting quantification of streamflow changes will assist socio-economists re-examining changing water-use patterns when multiple sectors share a possibly shrinking resource. To predict water availability in the SSRB under potential climate change, the fully distributed hydrologic model WATFLOOD was employed. Forcing data for future climate was selected after a rigorous evaluation of the currently available Global Circulation Models (GCMs); future climate scenario data was assessed by comparing baseline climatology (observed data) with the 1961-1990 climatology for selected climate models. To provide forcing of WATFLOOD the future climate scenarios were downscaled to an hourly temperature and precipitation product gridded across the SSRB for 2040-2069 for the selected GCMs. Current climate runs tested the performance of the hydrologic model against 1961-1990 observed streamflow; while future climate data runs were used to predict 2040-2069 monthly stream flows. This physical study employed cross validation with an ensemble of modelling efforts. The results of the climate scenario modelling were then offered as a first attempt to help examine surface water management strategies on the prairies in an integrated watershed management framework under varying climate scenarios.

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Session VII – Surface to Sub-Surface Hydrology

7.1 Determining Moisture Distributions in the Saskatchewan River Basin

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It is believed that prairie drought begins, is sustained and terminates as a result of a wide variety of processes ranging in "memory" time scales from decadal to diurnal. Many droughts, particularly those in the US mid-west, have been correlated with long period variations in sea surface temperatures (SSTs). However, SSTs alone have not been sufficient to explain all drought occurrence. This points to other, perhaps shorter memory, requirements for effective drought prediction. Surface soil moisture has an important influence in moisture recycling within the Canadian prairies and is known to be influential in triggering local convection. But variability in surface soil moisture can change rapidly and as a result should not be capable, alone, of explaining multi-year drought. As a result, it is hypothesized that near surface groundwater storage may play an important role in the delivery of moisture to the surface and thus influence the distribution of rainfall and hence drought producing phenomena.

Groundwater storage is known to evolve slowly and thus may contribute to earth-atmosphere system memory required to trigger and sustain multi-year drought. Currently, groundwater as a saturated flow process is poorly represented in atmospheric models and is most often neglected. It is proposed to test the influence of groundwater, within a regional atmospheric simulation, on drought evolution. Groundwater simulation will be added to existing models using model coupling toolkits which are fast becoming the standard for mixing and matching modelling components. Model coupling, initially using a land surface scheme and a saturated flow groundwater model, will be tested over the Assiniboine Delta Aquifer (ADA), a 4000 km2 area in southwestern Manitoba with a considerable data history. Once constructed and tested, it will be necessary to test the coupled model beyond the ADA and methods for initializing soil moisture and groundwater storage will be required to support this effort. Additionally, addressing scale related issues necessary to capture the essence of the spatial complexity of near surface geology, important for atmospheric simulation, will be necessary.

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7.2 Climate Change Assessment over the Assiniboine Delta Aquifer

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To assess how major atmospheric changes, such as a drought, will have on groundwater resources (and how we might adapt to them) a multi-disciplinary study based on large sand and gravel aquifer system known as the Assiniboine Delta Aquifer (ADA) is being conducted. The generalized approach will be to use physically based mathematical models of both the land surface and groundwater systems to predict changes in water quantity given drivers of future atmospheric climate. Research efforts intended to understand the interaction between General Circulation Models (GCM) are progressing with computational methods, and hydrologic models are components of paramount importance in water resources management as well as in climate change assessment. Here the groundwater model MODFLOW that simulates the 3D groundwater flow by using a finite difference method is coupled together with the Canadian Land Surface Scheme CLASS for representing the water flow in the saturated and unsaturated zones of the porous medium respectively. CLASS follows Darcy's law of moisture fluxes and simulates the mean temperature, liquid water and ice contents in three soil layers. The two models are linked and run within the parallelized world of a componentized coupler. The complete set of linked codes is used to simulate a number of synthetic examples in both sequential and concurrent modes. Finally, it is used to model the hydrological water cycle in the Assiniboine Delta Aquifer, dealing with field data processed by Geographic Information Systems. Another purpose of our work and code development is to provide accurate planetary boundary layer conditions for the atmospheric model, in order to improve the short and long term climate forecasts over the Prairies.

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7.3 Effects of Drought on Prairie Groundwater

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Groundwater level in aquifers tends to decrease during prolonged droughts, but very few studies have been conducted in the Canadian Prairies to investigate the mechanistic linkage between atmospheric drought and groundwater. Working with other DRI investigators, we plan to analyze groundwater data along with soil moisture, stream flow, and climate; understand the feedback relations among them; and eventually construct a coupled model of surface water and groundwater. The primary emphasis of our work is on the Paskapoo Fomation aquifer system using the West Nose Creek watershed, near Calgary, as a pilot site.

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7.4 Groundwater and Lake Level Data

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Session VIII – Drought Initiatives & Concerns of Partners: Part I

8.1 PARC / Long Drought Records

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The Prairie Adaptation Research Collaborative was established in 2000 to facilitate research on the impacts of climate change in the Prairie Provinces and the adaptation that will be required to alleviate adverse impacts and take advantage of new opportunities presented by a warmer climate. In the past five years PARC has supported more than 40 research projects and sponsored numerous meetings and workshops to facilitate collaborations among researchers and decision makers. Prairie ecosystems, economies and communities are sensitive to climate variability, and specifically drought, probably more so than to climate change. Much of the current capacity to adapt to climate change is a function of past adaptation to drought. Research based at PARC includes the study of prairie drought over the past 500 years. Instrumental weather records provide a limited perspective on the long-term frequency, magnitude and causes of drought. Tree-rings from dry sites are a good proxy of timing and duration of drought. Our tree-ring records from more than 60 sites show that prolonged drought is more frequent than indicated by instrumental weather records. At PARC, we hope that the DRI can improve our understanding of the climatology of prairie drought. Collaboration between DRI and PARC would link the DRI to various PARC initiatives and a broader perspective on climate change and variability.

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8.2 Droughts: Implications for the Prairie Provinces Water Board

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Manitoba, Saskatchewan, Alberta and Canada entered into a Master Agreement in 1969: to provide an apportionment formula for eastward flowing interprovincial streams; to address water quality issues; and, to reconstitute the Prairie Provinces Water Board, which was established in 1948. The Master Agreement facilitates a cooperative approach to the integrated development and management of interprovincial streams and aquifers to ensure their sustainability for the benefit of the people of the Prairie Provinces.

The Master Agreement is based on the principle of equitable sharing of available water in the Prairies. The formula generally states that each province may use one-half of the natural flow of water originating within its boundaries and one-half of any flow entering from an upstream province. In addition, Alberta is entitled to consume a minimum of 2.1 million acre-feet from the South Saskatchewan River as long as the actual flow at the Saskatchewan is not less than1500cfs. Natural flow is broadly defined as the volume of flow that would occur if a river had not been affected by human activity.

One potentially significant human intervention is the creation of reservoirs which greatly increase the surface area of the natural water course and increase evaporative losses. While evaporation is countered to some extent by precipitation onto the reservoir, this difference between these two parameters, net evaporation, has been adopted as the net impact of that project on natural flow. Evaporation from reservoirs is considered to be a water use in the determination of natural flow and, hence, apportionment at the interprovincial boundaries.

Commencing in the early 1970s with Lake Diefenbaker on the South Saskatchewan River, explicit evaporation calculations have been implemented for a number of reservoirs where annual evaporative losses exceed the normal annual precipitation. Some reservoirs in the mountain headwaters have not been considered since it has been assumed that the average net evaporation is approximately zero.

The PPWB has three permanent committees to assist in technical work and to advise the Board. In the 1990s, the Committee on Hydrology (COH) participated in a study of evaporation on the Prairies. In 2002, the COH completed an assessment of current evaporation methodologies and the sensitivity of apportionment monitoring to these evaporation calculations and errors in evaporation estimates. The general conclusions are that for reservoirs on the major rivers, simple, existing methods for estimating net evaporation are applicable. For smaller river systems, errors in evaporation have the potential to significantly affect natural flow calculations and apportionment in low flow years. Improved methods to estimating evaporation estimates may be required. In general, improving our understanding of water and energy budgets should be of value to operational institutions such as the PPWB.

Significant changes in future climate or water use within a basin may require improvements in estimates of evaporation for apportionment purposes. However, in the broadest sense, interprovincial apportionment of flows should not be affected by more frequent and longer droughts. The fifty-percent apportionment formula ensures that each province will retain an equitable share of the waters although the overall natural flow may be reduced in volumes and flow rates.

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8.3 Perspectives about Prairie Drought Impacts on Wildlife

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Most prairie biota evolved in a dynamic environment characterised by wet-dry cycles of varying severity and duration. Many species are able to withstand (e.g., plants, invertebrates, some mammals) or escape (e.g., many aquatic birds) dry conditions. The drought from 1998-2004 was severe relative to conditions recorded over the past century, and it affected much of the Canadian prairies. From a wildlife perspective, drought impacts may be organised into four main areas of concern. First, wetlands are a dominant characteristic of the prairie landscape and many small, ephemeral or seasonal wetlands may be permanently destroyed by agricultural activities when accessible during dry periods. Second, scarce supply intensifies competition among agricultural, urban/domestic and wildlife uses for high-quality water sources. Third, rapidly changing or progressively drying conditions can favour invasive species that affect abundance, distribution and persistence of endemic species. Finally, future projections about the frequency, intensity and duration of drought conditions will help to guide the allocation of limited conservation program funds to regions where returns on investments can be optimized. Here, I provide *a few* examples of these issues, by focusing principally on problems confronted by migratory birds, a wildlife group for which a well-defined legal mandate exists for conservation.

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8.4 Exploring Research Opportunities Under the AAFC's Drought Monitoring Program

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AAFC has the mandate to monitor climatic conditions in agricultural landscapes of Canada, including drought and water resources, on an ongoing basis. Due to the complexity of drought, it is monitored using a variety of indices such as rainfall statistics, Palmer Drought and Standardized Precipitation Index. The poor density of climate stations and the complexity of terrain in some parts of Canada makes the mapping of drought indices temporally and spatially challenging. The potential to use remote sensing to quantify aspects of drought or flooding over large areas, remains largely unexplored. As well, the existing drought monitoring methods are not used for forecasting drought because of the low confidence in climate prediction. Low confidence is ascribed to insufficient understanding of what forces the climate at timescales that are useful to the agricultural industry. Research efforts to these issues will contribute towards finding a solution to problems of drought in the agricultural industry.

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Session IX – Drought Initiatives & Concerns of Partners: Part II

9.1 A QA/QC and Data-Filling Decision Support System for Near Real-Time Climate Data

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Modeling and reporting in near real-time on weather related phenomenon requires reliable, readily available, climate data. Incoming raw weather data needs to be screened, quality assured and quality controlled (QA/QC). Often for modeling and reporting purposes where data are invalid or missing, it must be filled. To meet these needs, a state of the art, computer-assisted QA/QC and data-filling decision support system was developed. Each day, climate elements are screened against a variety of tests, including range, step, persistence, like sensors and neighbors. The computer flags data as valid, suspect or invalid. A human rarely checks valid data. Suspect data are checked by a human and through a variety of decision support tools is rated as either valid or invalid. Invalid data are automatically filled using either temporal or spatial filling algorithms. The end result is a simple to run process that requires minimal labor, yielding clean, continuous weather data that can be used for a variety of modeling and reporting purposes.

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9.2 Drought Research Initiatives in Manitoba Hydro

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Since Manitoba Hydro's system is comprised mainly of hydro-electric generating facilities, major system-wide drought events have a very significant impact on the operations of its integrated system. Manitoba Hydro has funded research programs for over 15 years, with emphasis on understanding the probability of a drought greater in magnitude than the current drought-of-record. A number of research projects are underway using statistical techniques as well as investigating past drought events inferred from paleo-environmental records such as tree-rings and lake sediments in various regions of the Nelson-Churchill basin.

To that end, Manitoba Hydro has an interest in the Drought Research Initiative from several perspectives:

- Enhanced statistical predictions of frequency & severity of drought
- Identification of more severe droughts before historical record for Nelson basin
- Climate Drivers of major system-wide droughts in Nelson-Churchill basin
- Cyclic patterns of major Prairie drought and linkages to climate change

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9.3 Saskatchewan Watershed Authority Perspective on Drought

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Abstract

The Saskatchewan Watershed Authority was formed in October 2002 with a mandate to manage and protect source water quantity and quality in the province. The Authority owns and operates 45 dams and over 130 kilomeu.es of conveyance chamlels. We are the provincial agency responsible for licensing all surface ~nd groundwater use in the province and for leading the development of watershed and aquifer management plans. One of the Authorities Objectives is that "Water supply is reliable". Drought impacts water supplies for municipal, industrial, and irrigation use, and for recreation, power generation, It can also impact water quality, in-stream uses, and the health of aquatic ecosystems.

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9.4 Flood Forecasting Drought Concerns

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Alberta Environment's River Forecast centre is responisble for providing real-time flood forecasts and for estimating seasonal river flows, for Alberta rivers. As most of the water supplies for irrigation, municipal and indistrial uses originates in the mountains and foothills, we are primarily interested in understanding droughts in these regions. Because the water supply forecasts influence the operation of Alberta's water infrastructure, improvements in water supply forecasts can also lead to improvements in flood attenuation by dams.

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9.5 Regional Climate Model Results

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