The Third Annual Report of the Drought Research Initiative (DRI)

January 2007 to December 2007
(20/2/2008)

Grant Title: **DROUGHT RESEARCH INITIATIVE**

Grantees: ***Drs. Ronald Stewart*** **and** ***John Pomeroy***

CFCAS Grant No.: NW CC DRI

1.0 DRI Scientific Progress (January 2007 to December 2007)

1.1 Progress towards meeting the project objectives.

1.1.1 Review of DRI Objectives

The overall objective of the Drought Research Initiative (DRI) is *to better understand the physical characteristics of and processes influencing Canadian Prairie droughts, and to contribute to their better prediction, through a focus on the recent severe drought that began in* 1999.

To address this overall objective, the Network is focused on complementary and cross-cutting research objectives that correspond to the following themes:

1. Quantify the physical features of this recent drought:
   a)spatial and temporal features
   b)flows of atmospheric and terrestrial water and energy into and through the region, and their storage and redistribution within the region.
2. Improve the understanding of the processes and feedbacks governing the formation, evolution, cessation and structure of the drought.
3. Assess and reduce uncertainties in the prediction of drought and its structure.
4. *Compare the similarities and differences of the recent drought to previous droughts over this region and those in other regions, in the context of climate variability and change.*
5. *Apply our progress to address critical issues of importance to society.*

Note that CFCAS support is for Themes 1-3. Themes 4 & 5 are supported by in-kind contributions to network investigators and are briefly reported here.

The following sections are organized according to a synthesis and overview prepared by the DRI Principal Investigators and the Network Manager, and Theme reports and outlooks prepared by the Theme leads. The remainder of the report summarizes the Annual Reports of the 15 DRI investigators and one collaborator as well as the secretariat views relative to the questions posed in the CFCAS annual report template. Appendices are available that include the detailed investigator and collaborator reports. These individual reports are very important because they document the scientific results for DRI during the past year and they also outline the directions that each investigator plans to pursue in the coming year.

1.1.2 Results Achieved for the Period January 2007 to December 2007

Overview for 2007:

During the period from January 2007 to December 2007, the Drought Research Initiative (DRI) made significant progress on the goals and milestones described in its original plans. Highlights from this progress are given in the Theme summaries. Investigators have achieved research advances in each theme area although more work needs to be done to reach all of the milestones set for the themes. Themes 1 and 2 are proceeding as initially planned, while Theme 3 has focussed more on hydrological prediction in order to take advantage of new possibilities for developing coupled atmospheric-hydrological models.

Research Highlights and Theme Assessments:

Theme 1 continues to advance on two tracks: the first track on drought characterization led by Dr. John Hanesiak of the University of Manitoba, who has responsibility for the overall theme as well, and the second track led by Drs. Kit Szeto of Environment Canada (a DRI collaborator) and Ron Stewart of McGill University. During the past year the first track was advanced by the analysis of data sets related to the large scale atmospheric circulation, precipitation products, various drought indices, soil moisture and groundwater. The analysis has been carried out for the entire region affected by drought in some cases and for river basins or more localized regions for other variables. Comparative analyses are being carried out to assess the ability of different drought indices to represent drought conditions (e.g., Palmer Drought Severity Index <PDSI> versus Standardized Precipitation Index <SPI>) or to assess the ability of different analysis and reanalysis products to represent the distribution of precipitation over the prairies during the drought.

The characterization of the atmospheric circulation during the 1999-2004 drought has shown that storm tracks during this drought were frequently located either to the north or south of the Prairies. This is in marked contrast to most previous droughts where the mean storm tracks during drought were located primarily to the north of the region. Consequently, it was inferred that no single teleconnection index or flow regime could account for the severity or duration of the 1999-2004 drought, although additional analyses are being conducted to verify this.

The surface and near-surface characterization of the 1999-2004 drought is being addressed through prairie-wide and basin specific studies. In most cases the data are available and analyses are being or have been carried out. Table 1 provides a summary of the status of work completed to date. In the coming year basin wide cloud and surface hydrology assessments will receive more attention.

The GRACE satellite measurements from 2003 onwards have been used to assess groundwater variability over the region. The drought period is represented by a reduction in moisture of approximate 6 cm water equivalent during the fall of 2003 averaged over the entire Saskatchewan River Basin (SRB). Moisture in the basin recovered through 2004 with a cycle of drying and wetting and steadier moisture conditions prevailed in 2005. This period corresponds with the end of the drought period and wide spread flooding in the Canadian Prairies during the spring of 2005.

Table 1. Summary of studies carried out to date in Theme 1 low level drought characterization.

Variable	Prairie-wide	Region Specific
Drought indices	**	
Teleconnections	*	
Precipitation	**	Radar data analysis
Clouds	(2008)	
Soil Moisture	*(model)	
Groundwater	*	Assiniboine Delta, SSRB
Surface Hydrology	(2008)	SSRB, St Dennis
Water and Energy Budgets	**	SSRB

* - data sets assembled
** - data sets assembled and analysis completed
2008 – indicates that this variable will be a focus for data collection and analysis activities in 2008
SSRB – South Saskatchewan River Basin

A comprehensive baseline climatology of water and energy budgets for the Saskatchewan River Basin, including water and energy budgets for part of the 1999-04 drought period, was developed from different datasets and results have been published. The spatial and temporal variability of water and energy budgets for the Prairie region including budget anomalies during major drought episodes within the 1960-2005 period have also been quantified using reanalysis datasets. Efforts are underway to look at the relationship between cloud patterns and radiation budgets during drought periods.

In general work on this theme has been proceeding as planned although the lack of a replacement for Matt Regier of the Hydrometeorology and Arctic Laboratory (HAL) of Environment Canada in Saskatoon after his departure in the late summer has slowed the data preparation activities within this theme.

Work on the second track is also progressing. Analyses of the water budgets have been carried out and it is possible to see the migration of the drought over the region throughout its lifetime. The anomalies introduced by heavy rains in southern Saskatchewan in June 2002 are very dramatic when viewed in the context of the regional water and energy budgets under drought conditions. Another unique feature is the very wet conditions that brought the drought to an end (at least from a meteorological perspective) in Manitoba and in parts of Saskatchewan and Alberta in the spring of 2005.

Throughout the past year Theme 2 has progressed under the leadership of Dr. Masaki Hayashi from the University of Calgary aided by Dr. Barrie Bonsal of the University of Saskatchewan. Process understanding is being developed by the analysis of previously collected data and by simulations of different aspects of the drought using process models. In some cases special field data are being collected to understand processes that played an important role in the 1999-2005 drought. Moisture recycling in the boundary layer plays a key role in precipitation events during droughts. Examination of the archived data from the St. Denis site in Saskatchewan showed that the diurnal increase of mixing ratios in the boundary layer due to evapotranspiration can be as large as 4 g kg^{-1}. This study found that the diurnal evaporation cycle was interrupted well before the soil moisture decreased to the point where it caused wilting in plants. The diurnal cycle of evaporation may be critical to the early detection of drought initiation. In addition, Theme 2 investigators are testing and improving several different models of evaporation. The results were presented at the DRI Evaporation Workshop in May 2007 and will be published in a special issue of the Canadian Water Resources Journal in 2008.

On a smaller scale, the processes in a major storm event in June 2002 are being examined to understand water vapour fluxes around and within the storm system. Instances of virga (rain that falls from the base of a cloud but evaporates before it reaches the ground) were also examined in detail. Such instances often occur with cloud bases at temperatures below freezing. Falling snow can sublimate faster than falling raindrops can evaporate, implying that the cold cloud bases, which result in snow rather than rain, act to enhance drought.

There are interactions between Theme 1 and 2 in a number of areas. For example several atmospheric studies are contributing to both themes as they consider dominant circulation features and teleconnection patterns. Modelling studies are also being undertaken to gain a better understanding of both atmospheric and land surface processes. For example, Dr. Ron Stewart has been using a single column model to simulate clouds and found that virga is not simulated well in many forecast models. Dr. John Pomeroy has been using a distributed blowing snow model to find that winter meteorological drought suppresses blowing snow transport and sublimation, such that net winter snow sublimation losses, normally a substantive loss for prairie snow packs, are reduced during drought periods.

Hydrologic models and data are also being used to gain understanding of surface based drought processes. The analysis of archived data from the St. Denis site showed that once the soil dried during the drought, the normal amount of winter precipitation was not sufficient to produce significant spring runoff.

In addition, the amount of runoff was strongly affected by the connectivity of numerous small depressions. Soil moisture and groundwater fluxes are being modelled for four Fluxnet/BERMS jack pine sites near Prince Albert, Saskatchewan, where latent and sensible heat fluxes were continuously monitored during the drought. Preliminary analysis indicates that the plant-mediated feedback between groundwater and the atmosphere may be significant at least locally.

Theme 3, which is led by Dr. Charles Lin of McGill University, has progressed in terms of both atmospheric and hydrologic prediction systems through the examination of model simulations and modelling studies using hydrologic models. Progress in Theme 3 has come in the areas of precipitation and related atmospheric parameters, and in surface and groundwater hydrology. The research seasonal forecast (HFP) system (GCM3 coupled to CLASS) has been examined over the period 1969-2003 while the monthly forecasts for the 500 hPa geopotential height have some skill, the skill is much less for precipitation (Lin). Outputs for precipitation, temperature and snow cover from two versions of the CRCM (coupled respectively to the force restore land surface scheme and CLASS) have been compared to observations for the drought period (Hanesiak). In general, the CLASS version generally produces better results. The sensitivity of hydrologic predictions to different precipitation products over the South Saskatchewan River Basin (CaPA, GEM and gridded observations from Environment Canada archive) are being evaluated (Pietroniro). WATFLOOD was also run using the different precipitation products as forcing to examine the sensitivity of simulated hydrographs to the choice of the precipitation product.

Research focusing on hydrological modelling involves both large basin and small basin modelling efforts. The CRHM is being used at high resolution to examine the effects of blowing snow and snowmelt on spring runoff generation (Pomeroy). The model generally performed well when compared to observed snow accumulation and streamflow. CRHM was also used to model drought evaporation. The model correct estimation requires an accurate representative depth of the rooting zone and soil column in the model, and correct soil moisture initialization to provide reliable evaporation estimates. The statistical treatment of contributing areas and drainage connectivity is also being examined. A modelling strategy using VIC and CLASS that has been applied to simulate soil moisture in China, is being used for the Canadian prairies (Lin). Allowance for non-contributing areas is made by decoupling the interflow from runoff generation in these areas. A soil moisture anomaly percentage index over the Prairies has been calculated using VIC over the period 1950-2005 and made available to DRI researchers. Dr. Woodbury has benchmarked an improved version of CLASS which couples the flows in the saturated and unsaturated zones and is being tested over the Assiniboine Delta Aquifer. These results will be compared with the new estimates from a coupled land surface and groundwater scheme (ParFlow) (Dr. Snelgrove) as a first step in developing a “toolbox” of numerical simulators for hydrological drought studies over the Prairies.

Although there is no funding for Themes 4 and 5, DRI is influencing others to make progress on these research topics. DRI investigators have found that it is not possible to fully address themes 1 to 3 without having a better understanding of how the 1999-2004 drought compared to other droughts. This is particularly true for some of the stakeholders who are questioning the representativeness of the results of DRI research because it is based on one multi-year event. DRI has been developing collaborations with other projects and groups that have been addressing some of the goals of theme 5.

During the coming year Themes 1, 2 and 3 are expected to progress rapidly. Theme 1 has identified the gaps in its comprehensive characterization of the 1999-2004 drought and is taking steps to address those gaps. Theme 2 has identified areas where models need to be improved and can provide a more focused research program as it addresses those needs. In Theme 3 the model data sets have now been assembled and the investigators are poised to analyze these products. Integration also will be a focus of Year 4 of

the project. In 2007 small focused workshops advanced the topics of Evaporation and Drought Prediction. In 2008 a workshop is planned on characterizing droughts. Other strategies to increase integration between the themes are needed. Interactive projects between the atmospheric and hydrological scientists will be encouraged and facilitated during the coming year. In addition, an effort will be made to achieve better integration (budget permitting) through the development of an integrated data management system and archive that will bring together diverse data and information on drought.

Secretariat update:
DRI has experienced some administrative challenges during the past year. Shelly Rooney the McGill Financial Officer was sick for much of the year and resigned from her post. Rachael Reynen has been hired to carry out her duties. Also, Matt Regier who was committed by Environment Canada to work on DRI for 50% of his time has left DRI and Environment Canada in the late summer to join a consulting firm. In order to partially fill this gap, Peter Lawford, a student at the University of Manitoba, has been hired as the DRI Webmaster. Patrice Constanza continues to serve as an information manager and Rick Lawford continues as the DRI Network Manager. The Secretariat has supported monthly teleconference calls of the DRI Science Committee, supported BoD and PAC meetings and teleconference calls, promoted DRI through talks and participation in external workshops and working groups (e.g., Canadian GEO activities), interacted with Partners and stakeholders, prepared reports and organized workshops including the annual workshop, and developed and maintained the DRI web site. Two new features that will appear soon on the DRI web site are the Canadian GEO Soil moisture activities and the GEWEX Extremes web site.

Partners and Stakeholders:
During the past year Partners were given a more visible role in the Initiative through the formation of the Partners Advisory Committee (PAC). As outlined in the Terms of Reference for this Committee, given in Appendix A, this committee provides advice to the Board of Directors on how the project can more effectively address the needs of its stakeholders. To date, this committee has carried out a survey of user needs and is now discussing possible initiatives that it may bring forward to the DRI Board of Directors early in 2008.

Workshops:
DRI makes extensive use of workshops both as motivators for the investigators and as a tool for reporting and planning. In addition to the annual all-investigators meeting held in January 2007 in Winnipeg which was attended by approximately 75 scientists, two smaller workshops were held: one on Evaporation in May in Saskatoon and one on Predictability in Montreal in October at McGill University. The workshop in Saskatoon featured a number of talks on state-of-the-art techniques for estimating evaporation. These papers will be published a special issue of the CWRA journal. The Predictability workshop at McGill identified the progress that is being made in modelling, sensitivity and simulation studies for the 1999-2005 drought and clarified the DRI prediction theme strategy.

Visibility:
In terms of increasing visibility, the annual DRI workshop in January 2007 was a highlight with several newspaper articles and radio interviews related to drought occurring in and after this event. DRI was also displayed as a component of Canadian GEO efforts at the Global Earth Observation Summit in Capetown, South Africa in November 2007. The DRI web site continues to be a focal point for DRI communications both internally and externally. It has recently been expanded to include some International Extremes activities and is being developed as a focal point for drought-related activities.

Summary:

While significant advances have been made in each theme the progress in Themes 1 and 2 has been directed at the deliverables and milestones proposed in the original proposal while the progress in Theme 3 has incorporated more of the hydrologic prediction activities than envisioned in the original milestones. In addition the original proposal indicated that Theme 1 would be brought near to completion by the end of Year 3, however the reduced funds available to address the Themes has meant that Theme 1 must be maintained near the same level for Year 4 and possibly for Year 5. In addition, work will progress over the next 2 years on the overall synthesis article of our DRI progress. DRI also needs to finalize its decision to move ahead on a Phase 2 proposal and begin to work actively towards this goal.

(Principal Investigators: Ron Stewart, John Pomeroy)
(Network Manager: Rick Lawford)

1.1.3. Theme 1 Summary for Year 3

Objective: Quantify the physical features of the recent Canadian Prairie drought.

Milestones for Years 1 to 3:
- Begin collective Network effort on drought characterization
- Produce initial Network products on CDs and continue to update on a regular basis
- Provide presentations (and write-ups) on the characteristics of the drought in parallel with the developing datasets and results in other Themes

Progress Summary:
A summary of Theme 1 activities for Year 3 is provided below. A journal article on Theme 1 findings is planned for submission in spring 2008 in which many of the products and analysis highlighted here will be integrated more fully.

Various researchers in DRI have completed initial work to quantify the extent and severity of the 1999-2005 Canadian Prairie drought at a variety of spatial and temporal scales. The larger scale atmospheric circulation patterns have been analyzed using a variety of gridded reanalyses data such as NCEP and ERA40, focusing on monthly and seasonal circulation anomalies. As noted above, the primary characteristics of storm tracks during the drought were frequently located either to the north or south of the Prairies. This is in stark contrast to most previous droughts where the mean storm tracks during drought were located primarily to the north of the region. Consequently, it was discerned that no one teleconnection index or flow regime could account for the severity or duration of the drought. Rather, the drought was characterized by a series of differing patterns which each had the impact of limiting moisture transport into the region. When storm tracks were displaced to the north, moisture transport from the Gulf of Mexico was impeded by the presence of a strong anticyclone situated over the South Central United States. Instances where the storm track was displaced to the south of the Canadian Prairies resulted in moisture from the Gulf of Mexico being "shunted" to the east due to the strong westerly flow associated with the jet stream.

Several gridded datasets of temperature and precipitation for Canada (CANGRID) and North America (Climate Research Unit (CRU) TS 2.1) were acquired and are being analyzed to document near-surface meteorological characteristics of the drought. Recently a North American ANUSPLIN dataset was identified and is being acquired. The CRU and ANUSPLIN datasets are of particular interest because the data extend into the United States to provide a broader context of the Canadian Prairie drought. An in-depth evaluation of the CRU temperature dataset is underway to determine how these gridded temperature and precipitation values correspond with recorded station values. Regional analyses are also being undertaken for basins within the prairie region. For example, time series data of CMC temperature

and precipitation observations from 1990 to 2005 have been downloaded from CMC and gridded at 0.2º by 0.2º lat/long grids across the SSRB. These gridded products are available as hourly matrices for the domain.

Thus far, we have begun the process of summarizing the main spatial and temporal larger scale characteristics of the drought through mapping several drought indices (monthly PDSI and SPI), monthly precipitation and temperature anomalies using the CanGrid dataset (anomalies calculated using the standard 1971-2000 means), prairie wide daily crop root-zone soil moisture and evapotranspiration patterns using the PAM-II crop model as well as daily and monthly maps of lightning (as a surrogate for convective precipitation). Animations of these fields have been produced and will be used for comparison and consistency analysis and integrated into atmospheric dynamic results above.

Monthly gridded global sea-surface temperature (SST) data have been acquired from the Reynolds and Hadley data sets and will be correlated with various teleconnection indices (ENSO, PDO, PNA, AMO, AO, NAO, and QBO). Analysis of these data will be integrated with other datasets discussed above to better understand the linkages amongst the various data sources.

A comprehensive baseline climatology of water and energy budgets for the Saskatchewan River Basin, including water and energy budgets for part of the 1999-04 drought period, was developed from different datasets and results have been published. Completed quantification and analysis of spatial and temporal variability of water and energy budgets for the Prairie region including budget anomalies during major drought episodes within the 1960-2005 period by using reanalysis datasets. A paper summarizing these results is in preparation.

Little is known about cloud climatologies during drought. However, satellite based cloud and radiation data are available for the period 1980-2004. These data are now being acquired and analyzed. Parameters that will be analyzed include cloud cover, estimates of cloud amount by height, cloud base height, optical depth, and estimated shortwave surface radiation. There is a small but clear signal in the relationship between cloud amount anomaly and SPI, with increasingly more positive SPI (wetter than normal conditions) being associated with positive cloud anomalies and increasingly more negative values of SPI (drier conditions) being associated with negative cloud anomalies. This relationship is evident in all seasons except January and February but over snow-covered surfaces the cloud amount data must be considered less reliable. Interestingly, when the data are stratified by cloud type, the correlation between cloud amount anomaly and SPI was greatest for high cloud.

In addition, operational radar data from three sites over the Prairies were acquired for the summers of 2001 and 2002. From this information, vertical profiles of radar reflectivity as well as vertical cross-sections were generated. The vertical profiles were constructed over the surface observing sites at Calgary, Edmonton and Saskatoon. Furthermore, this radar information has been analyzed to produce a dataset for assessing precipitation processes (convective or stratiform) or virga at these locations.

Northern Hemisphere monthly soil moisture anomaly data have been acquired from the Climate Prediction Center, LDAS, and NARR. Regional scale PAM-II crop model root-zone soil moisture maps have also been generated for the agricultural zone. Monthly and annual CMI maps over the entire drought period have been produced showing the relevant aspen growth and die-back features over the boreal zone. In addition, CCRS satellite products of NDVI and NDVI anomalies have also been recently produced. Intercomparisons of all of these products will be undertaken in future work to examine similarities and differences and highlight the spatial and temporal patterns of the drought over large scales.

Regional drought studies are also being undertaken. A detailed description of the drought from the St Denis National Wildlife Area, in Saskatchewan is underway. Reliable datasets of incoming solar

radiation, temperature, humidity, wind speed, precipitation, soil moisture, snowpack water equivalent and pond level were assembled for St Denis from 1999 to 2006 to show the drought and post-drought recovery period. A number of other datasets, including station data and reanalyses products for use in the CRHM platform to characterize the drought over larger spatial scales is ongoing.

Some ground water observations and trends have also been found. A brief survey of the Alberta Environment Groundwater Observation Well Network (GOWN) indicated that the groundwater level was steadily going down in some regions, presumably due to over pumping, and the effects were particularly pronounced during the drought. A case study examining the relation among groundwater level, water usage, and meteorological forcing in southern Alberta is underway. This type of study is very important for understanding the impacts of drought on groundwater resources and its sustainability. Similar ground water observations are available for the Assiniboine Delta Aquifer (ADA) in Manitoba and have been analyzed during the drought, discussed below.

The remote sensing observations of gravity from the GRACE satellite system can be translated into monthly measurements of land surface moisture and are being used to assess changes in moisture stored within the Saskatchewan River Basin. The GRACE satellite measurements provide an integrated quantity of land surface moisture at continental scales and are compared with the monthly water balance developed from an atmospheric P-E analysis obtained from the four times daily global analysis from the Canadian GEM. Although this technique does not cover the entire drought it does show that both model estimates and observations of moisture during the drought period are represented by a reduction in moisture of approximate 6 cm water equivalent during the fall of 2003 averaged over the entire SRB. Beyond the fall of 2003, moisture in the basin recovers through 2004 with a cycle of drying and wetting and steadier conditions in 2005. This period corresponds with the end of the drought period and wide spread flooding in the Canadian Prairies during the spring of 2005. Similar GRACE measurements have been downscaled to the ADA region and results show that ground water observations and gravity anomalies correlated during a majority of the record. Not all wells show this behaviour indicating the local influences on the regional water balance are not all captured by GRACE. GRACE downscaling results are correlated with well observations to a high of R=0.8 to a low of R=0.5.

In general the milestones for Theme 1 have been achieved. Although the planned CD has not been produced, data sets continue to be added to the web site and the archive. Rather than finalizing this on a CD at this time it has been agreed that the collection process should continue and a comprehensive CD or DVD should be issued at the end of the project.

(Theme 1 Report by Theme Leader: John Hanesiak)

1.1.4. Theme 2 Summary for Year 3

Objective: To improve the understanding of the processes and feedbacks governing the formation, evolution, cessation and structure of the drought.

Milestones for Years 1-3

- Initiation and continuation of enhanced observation of atmospheric, surface and groundwater processes in research sites
- Data acquisition from collaborating agencies
- Data rescue from previous observations, selection of numerical models
- Initial model evaluations with simple scenarios
- Hypothesis testing and new hypothesis generation
- Journal papers submitted

Progress Summary

The following summary is organized according to the spatial scale from continental-scale atmospheric processes to plot-scale hydrological processes. To discover the atmospheric circulation regimes that are particularly pertinent to droughts in North America, we have conducted studies of blocking using the National Centers for Environmental Prediction (NCEP) global reanalysis data. These studies have shown that three different flow regimes contributed to the length and severity of the recent Prairies drought: 1) an enhanced zonal jet stream located across Alaska as well as the Northwest Territories, 2) strongly meridional ridge/trough couplet centered over western British Columbia, and 3) positive phase of the Pacific North American (PNA) pattern index. Progress was also made in the water and energy cycling in the Prairie region using reanalysis datasets, particularly in relation to the dynamics of extreme precipitation events during the drought. We also used CanGrid precipitation data to examine the spatial distribution of the severity of drought.

On a smaller scale, we are carefully examining the June 2002 major storm event to understand water vapour flux around and within the storm system during the drought. Instances of virga were also examined in detail. We found that falling snow can sublimate faster than falling raindrops can evaporate, implying that the cold cloud bases often found during drought, which result in snow rather than rain, act to enhance drought. The impact of drought is most strongly felt during the warm season, but it is important to understand the role of the cold season in terms of the cycling of water. During the drought, warm periods (as well as rain) in winter occurred when snow was on the ground, which may have implications for drought processes but this still needs to be investigated. We have published results documenting the impact of aerosol from forest fires on the radiative forcing in areas where forest fires are more frequent during dry periods. The implication of these fires for droughts is still being examined, but the feedback of aerosols on cloud amount and precipitation is of particular interest.

Moisture recycling in the boundary layer plays a key role in precipitation events during droughts. Examination of the archived data from the St. Denis site in Saskatchewan showed that the diurnal increase of moisture inputs to the boundary layer by evapotranspiration was very significant, as much as 4 g kg^{-1} in terms of mixing ratio. We found that the diurnal evaporation cycle was interrupted well before the soil moisture decreased to the point where it caused wilting in the plants. The diurnal cycle of evaporation may be critical to the early detection of drought initiation. Convective storm processes were examined as they are related to initiation and cessation of droughts. These processes are also important in relation to severe thunderstorms that occur on the periphery of a region under severe drought conditions. We are using Global Positioning System (GPS) signals to estimate the amount of precipitable moisture in the atmosphere. These data, along with mobile transects of temperature and humidity, will be used to understand the dynamics of storm events.

Evaporation is a key process for the atmosphere-land feedback during droughts. We are testing and improving several different models of evaporation. The results were presented at the DRI Evaporation Workshop in May 2007 and will be published in a special issue of the Canadian Water Resources Journal in 2008. We examined the ability of PAM-II (2^{nd} Generation Prairie Agrometeorology Model) crop model in simulating evaporation and soil moisture, and found that an ensemble approach was necessary to incorporate the variability of soil water retention characteristics. The ensemble mean agreed with the observations remarkably well with coefficient of determination values of 0.8 or higher, providing confidence in the crop model's ability to represent the spatial distribution and temporal variability of soil moisture and evaporation. A similar crop model, the Versatile Soil Moisture Budget (VSMB), was also examined and the results showed that the use of actual radiative forcing, rather than the values computed from latitude and day of the year, greatly improved the model performance. We also examined two other radiation-driven methods, the Penman-Monteith (P-M) method and the Granger-Gray method, and found that the P-M performed best. However, the Granger-Gray method provided results that were close to the

P-M and did so without requiring soil moisture information. A field study of evaporation from a small pond and adjacent dry prairie soil showed that evaporation from the pond was enhanced by the drying of the surrounding land, suggesting the importance of the horizontal advection between wet and dry surfaces.

As noted in the project overview, DRI has started modelling soil moisture and groundwater fluxes at the four Fluxnet/BERMS jackpine sites near Prince Albert, Saskatchewan, where latent and sensible heat fluxes were continuously monitored during the drought. Preliminary analysis indicates that the plant-mediated feedback between groundwater and the atmosphere may be significant at least locally. We are also refining the "geological weighing lysimeter" technique to quantify the soil water balance very accurately from the stress-strain response of groundwater aquifers to moisture loading, which can potentially provide an effective method for large-scale water balance characterization. Comparison of weighing lysimeter data at Duck Lake, Saskatchewan with the water balance modelled by WATFLOOD showed promising results, but the model did not simulate very well the use of deep soil moisture by vegetation during the drought.

Spring melt provides a large portion of runoff and fills up wetlands and dugouts in the prairies. Therefore, it is important to understand the role of spring snowmelt in hydrological droughts. The analysis of archived data from the St. Denis site showed that once the soil dried during the drought, the normal amount of winter precipitation was not sufficient to produce significant spring runoff. In addition, the amount of runoff was strongly affected by the connectivity of the numerous small depressions. These depression need to be filled up to cause the sequential "fill and spill", which eventually generates runoff. The runoff contributing area, therefore, is variable depending on the wetness of the soil and wetlands. The importance of variable contributing area was also noted in the modelling study of the Assiniboine River Delta in Manitoba, where Variable Infiltration Capacity (VIC) model was used simulate stream flow during the drought.

Overall, significant progresses is being made in understanding the atmospheric and hydrological processes and feedbacks at various scales, process models were selected and tested, and new hypotheses were generated. Some results have already been published or submitted to journals. Therefore, all milestones for Theme 2 have been achieved.

Plans for Coming Years

We will establish relationships between the observed surface conditions (such as Palmer Drought Severity Index) and various atmospheric, oceanic and soil moisture parameters over the Canadian prairies during the 1999-2005 period; and conduct further analyses on the processes that govern water and energy cycling and the development of drought over the prairies. This analysis will include studies of the generation, maintenance, and decay of the relevant circulation regimes associated with the various phases of the drought. We will look for anomalies in surface radiation budgets that may correlate with drought and examine possible links between concentrations of large aerosol and drought.

Regarding the storms during the drought, we will continue studying the June 2002 storm with a focus on the effects of this storm on regional water cycling, and extend the analysis to other major storms during the drought. We will also investigate the role of marginal precipitation that provides much needed moisture during droughts, and the role of thunderstorms during drought and non-drought situations, including initiation and cessation of drought.

To investigate the atmosphere-land surface interaction, the VIC model for the Assiniboine River Delta study will be refined to improve the representation of depression storage and variable contributing area. At the same time, the PAM-II crop model will be run over the Prairie-wide region to identify the areas of wet/dry soil moisture and link these areas to convective cloud initiation, lightning and storm

development. Field work will take place in summer 2008 during the UNSTABLE field campaign to quantify boundary layer thermodynamic structure and its impact on convective cloud development.

Land surface processes pertinent to droughts will be examined using the data from on-going and archived field studies. In particular, wetland water storage and its effects on snowmelt runoff retention and groundwater recharge will be characterized using frequency distributions so that small streams and internally drained areas can be modelled at a moderate (i.e. km to 10 km) resolution. The improved understanding of these processes will be incorporated into the further development of the Cold Region Hydrology Model (CRHM) with respect to snow redistribution, melt over frozen soils, wetland filling and spilling, stream flow generation, evaporation and soil moisture evolution. The relation between soil moisture and groundwater recharge processes will be examined using the archived groundwater level data from the three Prairie Provinces, as well as detailed data from the three enhanced study sites (West Nose Creek in Alberta, St. Denis in Saskatchewan, and the Assiniboine River Delta in Manitoba).

(Theme 2 Report by Theme Leader: Masaki Hayashi)

1.1.5. Theme 3 Summary for Year 3

Objective: Assess and reduce uncertainties in the prediction of drought.

Milestones for Years 1 to 3:

- Analysis of CGCM3 for droughts; complete HFP runs with AGCM3; long control run of CRCM4/CLASS driven by NCEP; SSRB flow assessment; CRHM redevelopment; testing of process algorithms.
- Analysis of AGCM3 to assess role of sea surface temperature in forcing droughts; complete HFP runs with AGCM3 including initial soil moisture anomalies; preliminary analysis of HFP runs; start sensitivity runs to examine relative roles of SST and soil moisture in forcing drought; CRHM modelling of small basins; Improvements to coupled land surface-hydrological model.
- Analysis; predictive skill assessment; CRCM4 sensitivity runs; comparison with other droughts; development of CRHM 'drought model' version for general use.

Progress Summary:

We have made significant progress in Theme 3 with the most noticeable progress coming in hydrologic prediction. In this report, Theme III progress is summarized for three areas: i) precipitation and other atmospheric parameters, ii) soil moisture and runoff generation, and iii) groundwater. We conclude with an outlook for 2008.

<u>i) Precipitation and other atmospheric parameters</u>

- Hanesiak has acquired output from two versions of the CRCM (coupled respectively to force restore land surface scheme and CLASS). He has compared the modelled precipitation, temperature and snow cover to observations. The CLASS version generally produces better results.

- Stewart found the operational seasonal prediction were poor with regard to prediction of summer precipitation. In some cases, this is due to the incorrect treatment of individual storm events.

- Pietroniro compared different precipitation products over the South Saskatchewan River Basin (CaPA, GEM and gridded observations from Environment Canada archive). WATFLOOD was also run using the different precipitation products as forcing to examine the sensitivity of the simulated hydrographs to these products.

- Szeto has used different regional climate models (CRCM and other RCMs from US and Germany) and data assimilation systems (NCEP, ERA40, NARR and GEM) to assess the extent to which the 1999-2004 drought was simulated.

- Strong has quantified the atmospheric moisture gradients across different land cover types.

- Lin examined the research seasonal forecast (HFP) system (GCM3 coupled to CLASS) over the period 1969-2003 and found the monthly forecast for the 500 hPa geopotential height to have skill, but the skill is much less for precipitation.

ii) Soil moisture and runoff generation

- Pomeroy has used the CRHM at high resolution to examine the effects of blowing snow and snowmelt on spring runoff generation. The model generally performed well when compared to observed snow accumulation and streamflow. CRHM was also used to model drought evaporation during drought; its correct estimation requires an accurate representative depth of the rooting zone and soil column in the model, and correct soil moisture initial conditions. The statistical treatment of contributing areas and drainage connectivity is also being examined.

- Lin has tested a modelling strategy using VIC and CLASS in a standalone mode over China to simulate soil moisture, where forcing and verification data are readily available. This methodology has been applied to the Liard Basin in the Mackenzie River Basin as well as the Prairie provinces. Allowance for non-contributing areas is made by decoupling the interflow from runoff generation in these areas. A soil moisture anomaly percentage index over the Prairies has been calculated using VIC over the period 1950-2005 and made available to DRI researchers.

iii) Groundwater

- Hayashi is developing a groundwater recharge model for coupling to existing groundwater flow models. The VSMB was selected as a model prototype, and improvements in potential evaporation and snowmelt modules of the model have been made.

- Woodbury has benchmarked an improved version of CLASS which couples the flows in the saturated and unsaturated zones. The model is being tested over the Assinboine Delta Aquifer. A goal is to develop a "toolbox" of numerical simulators for drought studies over the Prairies.

- Snelgrove is a collaborator in the Woodbury project. He is also working with US colleagues to test a coupled land surface and groundwater scheme (ParFlow). Pietroniro has developed a hydrological modelling tool (MEC, MESH) and is testing it over the South Saskatchewan River Basin focusing on the prediction of soil moisture, runoff, groundwater, evapotranspiration and snow processes.

Outlook for 2008

All investigators will continue their projects in 2008. Focal points for integrating activities include the following.

- An examination of the Canadian operational and research seasonal forecasts for the 1999-2004 drought over the Prairies will be undertaken. Some work in this direction has already started in 2007. DRI is producing the first results from an assessment of the skill of the forecasts.

- There will be an ongoing effort to incorporate progress made in improving the different modelling modules for soil moisture, runoff and groundwater into Canadian (MEC, MESH, CLASS) and US (VIC) hydrological modelling systems.

- The role of non-contributing areas will be examined using different modelling approaches covering a range of spatial scales.

(Report by Theme Leader: Charles Lin)

1.1.6. Progress Summary for Themes 4 and 5 for Year 3

There has been some progress made with respect to the unfunded Theme 4 of DRI which strives to: "compare the similarities and differences of the recent drought to previous droughts over this region and those in other regions, in the context of climate variability and change." In particular, while contributing to research directed to Themes 1 to 3, several DRI investigators have begun to characterize this recent drought in terms of its historical variability. This has included:

1) Comparing the 2001/2002 Canadian Prairie drought (in terms of extent and severity) to those that occurred during the instrumental period of record as measured by the PDSI and SPI indices.
2) Examining changes in Prairie drought-related atmospheric circulation regimes during the past 60 years.
3) Assessing and comparing water and energy budget anomalies for different drought periods over the Prairies.
4) Comparing boundary layer moisture cycling and the diurnal cycle of moisture from varying land cover during the 1999-2004 drought to the drought that occurred in 1988.
5) Beginning to address drought in other regions of the world through international GEWEX and, in particular, examining whether major precipitation events mark the end of meteorological drought.
6) Producing and analyzing a long-term soil moisture percentage index from the VIC model for the Canadian Prairies to assess drought predictions for the period 1969-2003 over all of Canada.
7) Planning is underway for a newly funded project that will a) identify the timing, frequency and causes of annual to multi-decadal hydrologic cycles, b) examine the influence of climate change on the magnitude and duration of hydrologic cycles in the Prairie region, and c) apply scenarios of future hydrologic variability, and a time series of summer and annual water balances that spans AD 1400 to 2100, to assess their implications for water resource management practices and policies.
8) Analysis of daily observations up to 2004, from prairie climate stations with at least one century of record in one location showed that the probability distributions of daily mean, maximum and minimum temperatures, and daily totals of rainfall, snowfall and precipitation could be assumed to be stationary about a mean value. The implications are that, despite the drought of 1999-2004, the existing extreme value frequency distributions used by many DRI partners are still functional when considered in terms of the whole period of instrumental record. Further work will examine trends in skewness, kurtosis and whether trends have been imposed on the last quarter of this record by anthropogenic climate change.

(*Summary by Barrie Bonsal*)

The objective of Theme 5 is to apply our progress to address critical issues of importance to society. Some DRI Investigators work collaboratively with the Canadian Water Network (CWN). This Network is focusing on economic and environmental sustainability in agriculture through the implementation of

combined beneficial management practices and remedial approaches designed to minimize impacts to water quality. It is anticipated that DRI research results will make a larger contribution to CWN objectives over the next two years.

In-kind research from Saskatchewan Research Council (SRC) and Environment Canada (EC) has resulted in a number of activities that contribute directly to Theme 5. These talks and publications, which are listed in Section 4.1.2, dealt with topics such as impacts and adaptations during the 2001-2002 drought, historic drought and institutional adaptation in the Great Plains of Alberta and Saskatchewan, dust storms, Agricultural Adaptation to Drought (ADA) in Canada, use of decision support tools to enhance sustainable agricultural water use, drought as a factor in the vulnerability of prairie communities', water supply, among others.

1.2 Delays or departures from the research plan and how they were addressed.

There have been no significant departures from the revised research plan, apart from the enhanced efforts in hydrologic prediction that were not fully articulated in the milestones for the project. To a large extent last year's delays in the recruitment of student assistants have been overcome, although two investigators still reported some difficulties in finding appropriate assistants. Several projects are still accumulating data sets, developing computational schemes, and testing and modifying numerical modelling approaches. The DRI team feels that research is on schedule. Two investigators have experienced delays in getting access to specialized data sets (e.g. radar data) and in resolving data format problems. These problems have been exacerbated by the inability of Environment Canada to maintain its in-kind contribution with the data manager position from the HAL lab after Mr. Matt Regier left in August 2007. Mr. Regier had been working half time for DRI as an information manager and webmaster. One investigator experienced delays because of changes in personnel in the financial group at his home institution's financial department. Individual sources of delays were encountered in processing data due to the health problems of a student assistant, Difficulties and delays were also experienced in the Secretariat due to the sickness of the person assigned to monitoring project expenditures and budgets.

1.3 Significant deviations from the budget.

There have been no significant deviations from the revised budget apart from some carry-over due to delays in spending arising from difficulty in finding suitable students in Year 2.

1.4 Integration and Coordination of co-investigators.

DRI has promoted integration through its three themes. These themes have provided investigators with a framework for relating their contributions and efforts to the contributions of others, Workshops dealing with cross-cutting activities have proven to be a very successful means for coordinating and integrating the work of different investigators. Workshops were held on Evaporation and Drought Predictability during the past year. Synthesis articles are being developed related to drought characterization and water and energy budgets. During the coming year a workshop is planned on drought characterization. This workshop will address issues related to scale interactions, precipitation, and soil moisture.

Collaborations arise in different ways. In some cases it results in the co-supervision of graduate students, in other cases it results in collaborative projects that have periodic teleconference calls or meetings, and in other cases it involves investigators using common data bases and models and comparing their results as they proceed with their analysis. Examples of enhanced collaboration are occurring in the scale

interactions of drought processes (Bonsal and others), the use of CRCM data (Lin, Hanesiak, others), hydrologic modelling (Hanesiak, Lin/Wei, Pietroniro, Pomeroy), cloud studies (Leighton, Stewart), development of CLASS groundwater components (Woodbury, Snelgrove), water and energy budget studies (Szeto, Snelgrove), vegetation cover and convection studies (Hanesiak, Strong, Raddatz), and groundwater studies (Woodbury, Hayashi, Pomeroy, Snelgrove van der Kamp).

1.5 Participation of government (federal, provincial or municipal), university, industry, foreign or private sector researchers (and/or other staff) in the project.

Various teams of DRI investigators continue to work with collaborators in the federal government (e.g., through the Meteorological Service of Canada (including CMC, Canadian Centre for Climate modelling and analysis (CCCma), and Ouranos modelling groups), the National Water Research Institute and the Hydrometeorology and Arctic Laboratory (HAL), the Canadian Wildlife Service (St. Denis) and the Geological Survey of Canada), provincial agencies (e.g., Alberta Environment, Alberta Agriculture, Saskatchewan Research Council, Saskatchewan Watershed Authority, Manitoba Water Stewardship, and others), universities (regionally), private sector (e.g., Manitoba Hydro), and foreign agencies (e.g., NCAR/Boulder, National Oceanic and Atmospheric Administration (NOAA)/NWS (National Weather Service) and international programs (GEWEX, CEOP, CLIVAR). DRI has forged links with the WCRP Extremes activity, the GEWEX Hydrological Applications Project (HAP), the North American Drought Monitor (NADM) and the US National Integrated Drought Information System (NIDIS). During the past year, DRI investigators and collaborations participated with Berkhardt Rockel in a model intercomparison study for the Canadian drought case. Data from the Canadian Ameriflux sites are being used in the analysis of fluxes and the evaluation of models for the DRI period. Collaborations with the USA have also involved the Lawrence Livermore Laboratory and their PAR model. DRI predictability studies are also coordinated with HFP and GOAP, another CFCAS Network.

During the past year we have developed closer links with the Canadian GEO activity through participation in their Soil Moisture workshop held in Saskatoon in June 2007, through discussions about having the Soil moisture group use the DRI web site for getting its information out to the world more effectively and through contributions to the Agriculture Canada/ GEO presentation on Drought made at the GEO Summit in South Africa on November 30, 2007. During the coming year we plan to expand the US linkages particularly with the growing US effort on drought through the NIDIS program.

During 2007, the Partners Advisory Committee (PAC) was formed and held its first meeting. The Terms of Reference for this committee are given in Appendix A. The membership on this Committee consists of representatives from Alberta Environment, Saskatchewan Agriculture, Saskatchewan Research Council, Saskatchewan Watershed Authority, Manitoba Water Stewardship, Manitoba Hydro, Manitoba Agriculture, Prairie Farm Rehabilitation Administration and the Canadian Group on Earth Observations.
The Committee is chaired by Dr. Harvey Hill of the Prairie Farm Rehabilitation Administration.
During the coming year this committee is expected to bring forward proposals regarding ways in which DRI investigators can work more closely with partners and stakeholders.

2.0 <u>Impact</u>

2.1 Short and medium term objectives achieved or anticipated in 2007;

This section outlines the Theme goals and objectives that have been achieved or will be in the near future.

Theme 1 Objectives:

DRI has made significant progress towards the objectives for Themes 1. Relevant data sets have been acquired and a research plan for statistical analyses of these data has been formulated. Relevant precipitation data sets are being evaluated against station observations before being used in drought indices and analyses. Agrometeorological drought indices produced by the PAM model have been tested against an observational datasets. Graphics and animations of precipitation, temperature, soil moisture and evapotranspiration fields over the drought period have been developed to characterize the drought. The spatial and temporal variability of the SPI and cloud anomalies have been analyzed and the relationships between SPI and cloud type and amount are being investigated. New technologies are also being examined in terms of drought monitoring. It is anticipated that progress will be made in assessing the potential value of the Alberta GPS network in drought monitoring.

GRACE satellite data have been downscaled to provide a data-driven approach to determine month-to-month changes in individual water well observation for the Assiniboine Delta Aquifer. Other hydrological aspects of drought are being examined.

Soil moisture and evaporation datasets will be used in the calculation of additional drought indices to assess the 1999-2005 drought. These indices will be related to observed drought impacts including but not limited to crop yields, pasture growth, water levels (dugouts) and aerosols (dust storms). As part of the DRI outreach to stakeholders, DRI datasets are being made available through the DRI and Ouranos websites.

Theme 2 Objectives:

The short term objectives of this theme in 2007 were to characterize and to interpret some of the key internal features of drought. This includes understanding the importance of marginal precipitation, the instances of virga and the role of major storm systems. The importance of all these processes has now been demonstrated and the next steps are to more fully understand their role in drought structure and evolution. In addition, results of a study of the forcing mechanisms associated with significant rainfall have been published. A study of the role of drought in modulating short-term cycles and long-term trends in atmospheric temperature and moisture is underway.

Better understanding of spring snowmelt runoff sensitivity to drought and evaporation sensitivity to soil moisture during drought has been achieved. Surface processes during the drought are being examined through a field study of the effect of infiltration on spring-melt surface runoff (using variable infiltration rates) for a small-scale prairie basin using input snow water equivalent (SWE) values from snow surveys and validated using wetland water levels.

In order to improve the models used in simulating the 1999-2004 drought a SWE/soil moisture mesonetwork, co-located with flux towers and a deep observation well, have been established.

Theme 3 Objectives:

For the first time the skill of seasonal forecasts of drought by the Canadian operational or research models is being undertaken through the McGill-based HFP project. A study is underway to investigate how well the CRCM is able to simulate drought. Work on soil moisture simulation and analysis, and the degree to which soil moisture initialization can increase seasonal predictability will be assessed.

A number of improvements have been made to hydrologic models as a result of DRI studies. CRHM model basics have been developed so that prairie hydrology can be accurately modelled. A set of PAM2nd base runs and their initial assessment have been completed and used to identify a series of modifications that can help improve model accuracy. The CLASS code for vertical fluxes (snowmelt infiltration) and sloped CLASS routing (overland flow, interflow and baseflow) has been reviewed. Significant progress has been made in coupling the MEC/MESH code to the Numerical Weather Prediction model through collaborations with RPN in Dorval.

Conditions in the South Saskatchewan River Basin during the drought have been modelled at a 15 km resolution on an hourly basis with daily streamflow output. Comparisons between model simulations and observations have been undertaken to assess the ability of the WATFLOOD model to simulate lower zone storage and yearly and longer term groundwater trends. A thesis and journal papers describing an improved contributing area change and an improved 'fill and spill' algorithm for runoff simulation will be completed in early 2008.

Model simulations using the VIC land surface scheme and parameter sensitivity studies are underway in the Upper Assiniboine River basin for the drought period. The results of SABAE-HW runs on soil columns from the ADA, Carman and West Nose Creek are being compared using actual weather and soil data, and results from the SHAW and CLASS runs in the case of ADA sites. The SABAE-HW column model has been coupled with a 2D horizontal saturated flow model and shows promising results. In the future this modified hydrologic model will be coupled with the MM5 model and the Canadian GCM. The SABAE groundwater model also will be supported by the concurrent evaluation of the Assiniboine Delta Aquifer area using the ParFlow simulation tool.

2.2 Significance / impact of the results achieved to date and their contributions to research policy, enhanced research collaboration or competitiveness, or training of skilled personnel.

To date, DRI has been addressing fundamental issues related to drought. As this research matures, its impacts will increase. Anomalies related to the hydrological cycle are an enormous problem. DRI itself and those individual researchers addressing such issues will eventually contribute to methods for coping with such features.

1) **DRI Impacts on government policy development (federal, provincial or municipal);**

As part of the DRI project, the methodology for implementing locally-based groundwater monitoring network in the West Nose Creek pilot study has been developed. The methodology has been adopted by the Municipal District of Rocky View, which is in the process of implementing a district-scale groundwater monitoring network.

Models of land surface, surface hydrology and groundwater are of specific interest to provincial agencies. Development of these tools has been received positively by the Saskatchewan Watershed Authority and Manitoba Water Stewardship. For example, the Prairie Province water resource departments are interested in applying the CRHM model in hydrological prediction for small prairie streams. DRI research has demonstrated the importance of blowing snow to drought runoff generation and subsequently the MESH of Environment Canada has been modified for inclusion in this process.

2) **DRI contributions to contacts in partner organizations, or increased cross-disciplinary cooperation.**

As a result of the developments with DRI, a number of contacts have been developed between DRI Investigators and users. These are described below.

1) The Canadian Wheat Board has expressed an interest in utilizing a DRI model as a tool to generate soil moisture estimates for the prairies using their real-time weather network for input.
2) MAFRI has expressed an interest in using a DRI model to generate soil moisture estimates in potato fields as well as input for a disease risk estimate of sclerotinia in canola.
3) DRI scientists are working with AAF and PFRA, both DRI partners, to improve the VSMB model.
4) Dr. Berg with the University of Guelph has been undertaking remote sensing and satellite verification links to the NAESI field study.
5) The DRI seasonal forecast project is expanding links with CLIVAR and Environment Canada.
6) Charles Lin and colleagues organised a Theme #3 Prediction Workshop held at McGill University on September 20, 2007. There were 29 participants from McGill, University of Manitoba, University of Saskatchewan, Environment Canada and Ouranos. This workshop reviewed the progress made to date and proposed specific next steps to advance the prediction theme. A report is available on the DRI web site.
7) Through Rick Lawford, Harvey Hill and others, DRI has been actively working with a PFRA (Prairie Farm Rehabilitation Administration) Senior Policy Analyst and Climate Specialist to connect DRI activities to the development of a drought strategy for PFRA. DRI plans to provide data, experience and analysis tools from its period of study to support policy research to facilitate the development of this strategy. A small workshop was held on January 10, 2007 to clarify these linkages and to identify areas of agricultural policy that could benefit from a better understanding of drought phenomena.

In terms of cross-discipline activities Dr. Ken Snelgrove has collaborations with atmospheric scientists (Szeto, Caya) that are reinforcing the important linkages between the land surface and atmosphere in closing the water balance. A number of other DRI scientists are also contributing to interdisciplinary and cross-disciplinary science.

3) DRI contributions to the reliability of predictive and monitoring methods.

Providing integrated assessments of model products, including the GEM products by DRI provide greater confidence in these forecast tools. Considerable work has been directed toward the improvement of hydrologic models. Some of this work has been directed to improving the reliability of models and the representation of physical processes in the models such as the VSMB model. The codes for the CLASS and MEC/MESH are undergoing review and improvement which will lead to better links to Numerical Weather Prediction through RPN.

DRI water and energy budget studies have provided assessments of the reliability of different major climate datasets in representing the Prairie water and energy budgets. The baseline water and energy budgets can be used for validations of model simulations of Prairie droughts. The high resolution soil datasets developed in association with the water and energy budget study have been utilized to specify model soils data by several investigators from both inside and outside of DRI. Results from the project contribute directly to the EC Drought OPP. The intercomparison of RCM drought simulations, which made use of results from GEWEX model intercomparison studies and its results will contribute to the international CEOP Extreme initiative.

The ability to monitor change in surface wetness conditions is becoming increasingly critical during this time when climate change impacts are becoming more evident. While agrometeorological indices have limitations for monitoring droughts (e.g., precipitation-based indices are not strongly correlated to spring wheat yield or quality) some indices based on moisture demand are strongly related to wheat yield and quality. Therefore, testing and improvement of the PAM2nd model which produces these indices is on-

going in support of agricultural drought characterization. Lake level data, compiled for the first time across the prairie region, serves to provide a regional perspective on the effects of drought and provides an improved understanding of driving mechanisms such as land-use changes, increased length of ice-free periods and diversions/drainage. The use of remote sensing as a monitoring tool is also being examined. The prediction of mass changes in the land surface due to moisture changes, as measured by the GRACE satellite system, has shown a surprisingly good agreement with the GEM analysis data and groundwater well observations.

4) **DRI Impacts on the participants' institutions.**

Drought research is of considerable interest to students because it is addressing key aspects of a type of hazardous weather that has not been addressed extensively before. This provides great opportunities for discovery, research and training in academic environments. For example, DRI has supported graduate level students in physical science programs in smaller universities such as the Memorial University.

The National Water Research Institute benefits from the synergy of activity in arid region research that results from its involvement in DRI and NAESI.

5) **DRI impacts on funding from other agencies, and new partnerships.**

Involvement by investigators in DRI has facilitated their success in other areas. A number of examples from 2007 are given below.

1) Dr. Masaki Hayashi was granted Canada Research Chair in Physical Hydrology in November 2007, partly in recognition of his work conducted as part of the DRI project.
2) A grant from the Canada Foundation for Innovation was approved in November 2007 for establishing a hydrological observatory at Dr. Hayashi's DRI site the West Nose Creek.
3) Dr. Al Woodbury received additional funding from the Canadian Waters Network based on an application related to his DRI research on the Assiniboine Delta Aquifer (ADA).
4) Dr. Gyakum's DRI project on secular changes in atmospheric circulation regimes is receiving partial support through an NSERC summer grant for an Honours Undergraduate student,
5) DRI research enables Dr. Gyakum's participation with the GEOIDE network project of Dr. Susan Skone of the University of Calgary.
6) Dr. John Hanesiak has developed direct collaborations with Civil Engineering (Manitoba) who are working on a water and climate change NSERC project with Manitoba Hydro and Ouranos. Together with the DRI Network Manager and DRI Investigators they are in the process of developing a research proposal centred around DRI science focused on Manitoba Hydro water issues with major funding potentially coming from MB Hydro and NSERC.
7) Dr. Al Pietroniro has developed new partnerships with University of Guelph and now has increased involvement with RPN of Environment Canada in Dorval
8) Currently, a new proposal by Dr. Paul Bullock is being evaluated by the Canadian Grain Commission and the Canola Council of Canada, to do an assessment of weather impacts (including drought impacts) on canola quality.

6) **DRI contributions to current (or potential) commercial or social applications.**

Due to their large market for hydropower, Manitoba Hydro has a vested interest in understanding drought processes and the probability of drought reoccurrence. Outcomes from DRI, while not directed toward assessing the probability of droughts could be important for short term planning associated with their reservoir operations.

The potato growing industry in the Assiniboine Delta Aquifer is very interested in knowing the quantity of groundwater that is available on a sustainable basis. This water has considerable value and the research to understand the impacts of drought on this resource is critical for their planning.

Some provincial and federal agencies may consider drought indices as a basis for implementing drought contingency plans and financial support programs, if they are available. More accurate characterizations of agricultural drought will improve their response to drought and facilitate a more appropriate level of support and help to drought affected areas to ensure that program payments are targeted most effectively to assist those most in need.

7) **DRI links with international initiatives and their potential impacts.**

DRI efforts are linked closely with international GEWEX activities on extremes. In fact, DRI is the pilot project for the Extremes activities within the Coordinated Energy and water Cycle Observations Project (CEOP). The GEWEX Extremes web site will be co-hosted with the DRI web site and supported by the DRI webmaster. Also Dr. Ron Stewart, the GEWEX lead for Extremes, serves on the US CLIVAR drought committee. There will be participation by US CLIVAR and the NIDIS project in the upcoming 2008 DRI Annual Workshop in Calgary.

Several DRI scientists and support people participated in a University of Melbourne project (NAFE'06) to test equipment for soil roughness, soil moisture and GPS data collection. DRI scientists shared details of DRI and Canadian soil moisture data collection programs with the international colleagues.

International linkages also are developing through collaboration between Drs. Ken Snelgrove and Reed Maxwell at the Lawrence Livermore National Laboratory to foster the incorporation of groundwater resources within atmospheric simulations.

8) **Anticipated benefits of DRI for Canadians.**

Anomalies related to the hydrological cycle are a major economic risk for western Canadians. Understanding drought processes and improving prediction and monitoring of drought would directly benefit Canadians. Better forecasts will lead to improved planning and drought response programs, and in turn contribute to improved economic efficiency. Better forecasts will only be realized if we have better models which in turn are dependent on understanding of the physical processes causing drought. DRI is making gains on all these fronts although in many cases the progress will appear to be incremental and will only benefit Canadians through better services that will be provided to them by agencies that use this information,

In addition, DRI benefits Canadians because it promotes dialogue among universities and between the academic and public sectors. It also provides opportunities for young people to obtain an advanced degree while learning the basics of a phenomenon which has critical impacts on Canada.

3.0 Level of Support

3.1 Proportion of the total DRI budget provided by CFCAS

Although only very rough estimates are available, it is estimated that CFCAS is providing 47$\% of the total support for this project. Other support comes from organizations like Environment Canada which, in the past, has provided support for a DRI Information manager, and together with the Global Environmental and Climate Change Centre, provides computing infrastructure and data services. Direct financial support for the research also comes from investigators drawing from other federal and provincial grants. Table 2 lists some of the direct and in-kind resources that DRI has leveraged. Given that only 47% of DRI's budget came from CFCAS the total budget being spent on DRI comes from CFCAS. This result indicates that we enjoyed a larger investment in DRI from outside agencies in Year 3 of the project than in Year 2 when 51% of the total DRI budget came from CFCAS.

3.2 Additional or 'matching' resources secured or committed to the project.

Some of the more direct estimated in-kind contributions are included in Table 1. In some cases these resources are committed to DRI until the project ends in 2010 (provided the funders continue to be happy with DRI) or until the grants providing the funds expire. Significant shifts have occurred between this report and last year's report due to the completion of some grants which have made investigators more dependent on DRI funds and the initiation of new agreements that have provided new opportunities for cost sharing.

Discussions are being held with Manitoba Hydro to develop a supplementary grant/contract for drought studies that more directly address their needs in the areas of regionalization of drought analysis and comparative analysis of different drought events (DRI Objective #4 that was not funded by CFCAS).

Specific support by University that benefits DRI includes:

University of Saskatchewan:

1) MITACS (The Mathematics of Information Technology and Complex systems) provided $15 000 in matching funds for a University of Saskatchewan student to assist in data analysis for the period May to December 2007.
2) Environment Canada's NWRI is providing $75K support for field work through the NAESI field budget.
3) SGI Canada provided support for the SGI Canada Hydrometeorology Programme which is supporting DRI research into the historical trends associated with drought extreme meteorology and hydrology (Theme 4) amounting to $50k/year for 5 years.
4) The Prairie Hydrological Model Study is supported by PFRA-AAFC, Prairie Habitat Joint Venture Policy Committee and Prairie Provinces Water Board for $120k/year for 2 years. This partially contributes to DRI through collaborative development of CRHM for prairie hydrology and through outreach in Theme 5.
5) Canada Research Chair in Water Resources and Climate Change provides basic support for operation of the Centre for Hydrology and salary for research officer, Mr. Michael Solohub in data archiving and summer experiments; Ms. Joni Onclin in data archiving and meeting organisation (evaporation workshop), and for Mr. Tom Brown, CHRM model programmer. $40k/year for the duration of DRI.
6) Additional support was received from the Prince Albert Model Forest Association to carry out data compilation and assessment for the forest sites including the Fluxnet sites.
7) The Climate Change Impacts and Adaptation Program (CCIAP) has funded a project entitled "Enhancing Capacity for the Adaptive Management of Prairie Water Resources" that involves a DRI Investigator based at the University of Saskatchewan.

Table 2. Listing of non-CFCAS contributions to individual DRI projects.

Investigator/component	2007-08 DRI funding	Third Party (including in-kind)	% from DRI
Bonsal, B.R.	20,000	MITACS matched DRI funds for a student	65%
Bullock, P.	29,000	Manitoba Corn Growers Assn/ NSERC grant. Data support	~75%
Gyakum, J.	29,000	NSERC Discovery Grant Tri-Council GEODIDE network	35%
Hanesiak, J	51,000	NSERC industrial scholarship	75%
Hayashi, M.	29,000	Support from Provincial Govt grants and an Env. Canada grant	40%
Leighton, H.	29,000	None	100%
Lin, C.	51,000	Extensive support in kind	33%
Pietroniro, A.	51,000	Extensive salary support for Environment Canada employees who work on the project	~50%
Pomeroy, J.	59,000	Canada Research Chair and Saskatchewan government. pus field support	20%
Snelgrove, K.	29,000	NSERC Discovery Grant and U of Manitoba scholarship account	50%
Stewart, R.	51,000	25% from NSERC/ICLR/EC Industrial Research Chair supplies	75%
Strong, G.	20,000	Rest from his personal budget	75%
Szeto, K.	0	Environment Canada salary ($60K)	0%
Van der Kamp, G.	29,000	Environment Canada	40%
Wheaton, E.	20,000	None	66%
Woodbury, A.	51,000	Canadian Water Resources Network	66%
Secretariat (Sal./Travel)	135,000	Support for the Information Manager	80%
Total	676,000	Outside support estimated at $758,473	47%

McGill University:

1) Tri-Council GEOIDE network Grant for the GPS water vapour data and analysis, and by NSERC Discovery Grant being used to support research.
2) NSERC Industrial Chair for Extreme Events studies.

University of Manitoba:

1) NSERC Industrial Scholarship and Manitoba Hydro funds being used to partially support one PhD student.
2) Support for DRI of an estimated $30,000 per year will come through the recently renewed Canadian Water Network grant. The grant entitled "Towards economic and environmental sustainability in agriculture through the implementation of combined beneficial management practices and remedial approaches designed to minimize impacts to water quality" will facilitate links between DRI and the water quality community.

Memorial University:

1) A Ph.D. student with full scholarship support from the University of Manitoba is engaged in the project. This amount is topped up by $7K per year from a NSERC Discovery Grant to fund travel, student computing and stipend. In addition another PhD student engaged in the project receives a $8K per year from Memorial University.

University of Calgary:

1) Canada-Alberta Water Supply Expansion Program ($35,000),
2) Alberta Ingenuity Centre for Water Research ($27,000),
3) Environment Canada Science Horizons Program ($6,000).

3.3 In-kind contributions received from collaborators or sponsors.

There are numerous in-kind contributions being made to DRI but it is difficult to estimate value in terms of the cost to the contributors although DRI may estimate these contributions as invaluable. There are a number of government scientists contributing to DRI and use is made of the computing and field facilities of Environment Canada, Agriculture and Agri-Food Canada (AAFC) and the Global Environmental and Climate Change Centre (GEC3). Ouranos model datasets are also being made available to DRI investigators. Many DRI scientists have consulted and collaborated with federal government scientists. As noted earlier, Environment Canada covered the salary costs for our half-time Saskatoon information manager until August 2007, while GEC3 is sharing its data manager half-time at a small cost to DRI. In addition, Environment Canada is making specialized datasets available to DRI that are not normally accessible to the university community. The following tabulations provide a sense of the extent of support being provided to DRI from outside agencies and institutions.

Some of the individuals who have contributed expertise:
Dr. George Boer, Environment Canada
Dr. Jacques Derome, McGill University
Dr. Raoul Granger, National Water Research Institute, Environment Canada
Dr. Ted Hogg, Canadian Forestry Service
Dr. Hai Lin, Environment Canada
Mr. Amir Shabbar, Environment Canada
Dr. Kit Szeto, Environment Canada

Specialized data sets that have been used by DRI include:

- Lightning data from HAL
- SWE data from CRB
- Micrometeorological data from Alberta Agriculture
- CanGrid data from MSC
- Hydrometric data from Manitoba Hydro
- seasonal forecast model data from the HFP project
- CRCM data from Ouranos
- St Denis and Lethbridge surface data sets
- Radar data from the Winnipeg Office of MSC, Environment Canada
- International Satellite Cloud Climatology Product (ISCCP) data and Baseline Surface Radiation Budget data from GEWEX

Through the HAL Laboratory component at the National Water Research Institute, Environment Canada provided the following personnel support to DRI during the past year: Bruce Davidson and Brenda Toth, physical scientists at the Hydrology and Arctic Laboratory (HAL) and Jessika Toyra, a physical scientist with NWRI.

3.4 Transfers of funds to co-investigators.

McGill has established inter-institutional agreements with CFCAS and with each of the universities in the DRI network which outline procedures for transferring funds and reporting on expenditures. When available, a McGill DRI financial manager has gathered periodic reports on expenditures and surpluses which are then reviewed by the Principal Investigators and Network Manager and by others on an as-needed basis.

During the year, the DRI Science Committee held a competition for some of the DRI-wide funds that had been set aside for field work and new collaborations. As a result of that competition seven DRI investigators received funding.

3.5 Outside facilities used during the project (e.g. meteorological instruments, research laboratories, ship time, etc.).

Most DRI Co-Is are making use of external datasets, and borrowed equipment and facilities. For example, most are employing the Environment Canada climate data archive directly in their research. Other datasets in use include data output from the GEM (CMC), HFP (CCC), Ouranos, and MESH (HAL) models, radar images from Weather Modification Incorporated, and GPS (Global Positioning Systems) moisture retrievals from Geomatics Engineering at University of Calgary. Field facilities and experimental data archives have been provided by the Canadian Wildlife Service and National Water Research Institute (Environment Canada) in Saskatoon and the University of Saskatchewan including the NWRI Geomatics Laboratory. DRI also benefits from and receives data sets from field projects such NAESI.

Through Ouranos, DRI investigators and collaborators can access model and reanalysis data through the Data Access Interface (DAI; http://quebec.ccsn.ca/local/data/intro-e.html). This system is also being used to provide the DRI community with access to other Environment Canada and UQAM data sets. DRI contributes a part of the salary of GEC3 data professional, Patrice Constanza.

The Center for Earth Observations Science at the University of Manitoba is making office space available for the DRI Network Manager, at no cost to CFCAS or DRI.

Other specific Equipment and Software Loans include:

- Tethered sonding system for measurements (Environment Canada),
- Data logger and instrumentation. (Environment Canada),
- Computer software for the calculation of drought indices (PFRA), and
- High Performance Computing Resources **(**Atlantic Computational Excellence Network (ACEnet)).

4.0 Dissemination

4.1 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.

The primary method of distributing results is through the refereed literature, publications, and presentations. The following list applies to publications and presentations only in 2007. For a complete listing of DRI publications and presentations, the reader is referred to the DRI website.

4.1.1 DRI Publications and Presentations for 2007

Publications:

Armstrong, R.N., Pomeroy, J.W., and Martz, L.W., 2007: Evaluation of three evaporation estimation methods in a Canadian prairie landscape. *Hydrological Processes*, Accepted.

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

Bullock, P.R., Finlay, G.J. and Sapirstein, H.D., 2008(?): A preliminary assessment of evaporation as an agricultural drought index for spring wheat yield and breadmaking quality in western Canada. *Canadian Water Resources Journal* (submitted 23 November 2007).

Fang, X. and Pomeroy, J.W. 2007: Snowmelt runoff sensitivity analysis to drought on the Canadian prairies. *Hydrological Processes* 21: 2594-2609.

Fang, X. and Pomeroy, J.W., 2008 (?): Impacts of 1999-2004/05 drought on Canadian prairie wetland snowmelt hydrology. *Hydrological Processes*: Submitted.

Finlay, G.J., Bullock, P.R., Sapirstein, H.D., Naeem, H.A., Hussain, A., Angadi, S.V and DePauw, R.M. 2007. Genotypic and environmental variation in grain, flour, dough and bread making characteristics of western Canadian spring wheat. *Canadian Journal of Plant Science* 87: 679-690.

Pomeroy, J.W., Gray, DM, Brown, T., Hedstrom, N.H., Quinton, W.L., Granger, R.J. and S.K. Carey, 2007. The cold regions hydrological model: a platform for basing process representation and model structure on physical evidence. *Hydrological Processes*, 21, 2650-2667.

Pomeroy, J.W., de Boer, D. and L. Martz, 2007. Hydrology and water resources. In, (eds. B. Thraves, M. Lewry, J Dale, H. Schlichtmann) *Saskatchewan: Geographic Perspectives*. Canadian Plains Research Centre, Regina, SK. 63-80.

Raddatz, R.L. and J.M. Hanesiak, 2007: Significant Summer Rainfall in the Canadian Prairie Provinces: Modes and Mechanisms 2000 – 2004, accepted Intl. J. Climatology.

Saiyed, I., Bullock, P.R., Sapirstein, H.D., Finlay, G.J., and Jarvis, C.K., 2008 (?): Heat unit models for estimating wheat phonological development and weather-based relationships to wheat quality. *Canadian Journal of Plant Science* (submitted 29 June 2007).

Smith, C.D., N. Nicholson and S. Skone, and G.S. Strong, 2008: Evaluating regional atmospheric water vapour estimates derived from GPS and GEM in southern Alberta, accepted for *Atmosphere-Ocean*.

Song Guo and H.G. Leighton. Satellite-Derived Aerosol Radiative Forcing from the 2004 British Columbia Wildfires. Accepted for publication in *Atmosphere – Ocean,* 2007.

Strong, G.S., L. Hill1, R. Goodson, T. Krauss, V. Hoyle, N. Nicholson, S. Skone, C.D. Smith, P. King, and L. deGroot, 2008: A-GAME: Part II. Evaluation of Revised Multi-Scale Alberta Thunderstorm Model. Paper in prep. for submission to *Atmosphere-Ocean*.

Szeto, K.K., 2007: Assessing Water and Energy Budgets for the Saskatchewan River Basin. J. Met. Soc. Jap., 85A, 167-186.

Szeto, K.K., 2008: On the extreme variability and change of cold-season temperatures in northwest Canada. J. Climate, 21, 94-113.

Wen, L., Wu, Z., Lu, G., Lin, C.A., Zhang, J. and Y. Yang, 2007: Analysis and Improvement of Runoff Generation in the Land Surface Scheme CLASS and Comparison with Field Measurements from China. J. Hydrology 345, 1-15.

Wheaton, E.E. 2007. Focus Study 3.1 Drought. *In:* Thraves, B.D., M.L. Lewry, J.E. Dale, and H. Schlichtmann (eds), *Saskatchewan: Geographic Perspectives*. University of Regina, Regina.

Wu, Z., Lu, G., Wen, L., Lin, C.A., Zhang, J. and Y. Yang, 2007: Thirty-five years (1971-2005) of daily soil moisture simulation using the Variable Infiltration Capacity model over China. Atmosphere-Ocean 45(1), 37-45.

Yirdaw, S. Z., K. R. Snelgrove, and E. D. Soulis (2006) GRACE Satellite Observations of Terrestrial Moisture Changes and Drought Measurement in Western Canada. *J. Hydrometeorology*, 21 pages. (IN REVIEW)

Thesis:

Fang, X. 2007. Snow Hydrology of Canadian Prairie Droughts: Model Development and Application. M.Sc. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan. 172pp.

Conference Presentations:

Agboma, C. O., K. R. Snelgrove (2006) Non-Parametric Approach for Trend Delineation in the Canadian Prairie, *Eos Trans. AGU*, 87(52), Fall Meet. Suppl., Abstract GC41A-1034.

Armstrong, R.N., Pomeroy, J.W., and Martz, L.W. 2007. "Evaluation of evaporation estimation methods during a summer drying period." Canadian Geophysical Union 41st Congress, St. John's, NL, May 29 - June 1, 2007.

Armstrong, R.N. and Pomeroy, J.W.. 2007. Problems in Estimating Evaporation in a Complex Prairie Environment. DRI Evaporation Workshop, Saskatoon, Sask, Canada, May 17, 2007.

Atallah, E., Drought Research Initiative presentation, entitled "Prairie Droughts: A series of unfortunate events". Drought Research Initiative (DRI) Workshop #2; Winnipeg, Manitoba, 11-12 January 2007.

Atallah, E., CMOS, oral presentation, entitled 'A series of unfortunate events'. St. John's, NF, May 31, 2007.

Bhuiyan, H. and J. Hanesiak, "Regional Climate Model Simulations of the 1999-2004 Canadian Prairie Drought", DRI Theme 3 (Prediction) Workshop, Montreal, QC, Sept 20, 2007.

Bonsal B.R., *Droughts in Canada: An Overview*. Paper presentation at the Annual CMOS/CGU Meeting, May 28 – Jun 1, 2007, St. John's, NL.

Bullock, P.R. Agricultural drought indices. *Drought Research Initiative Evaporation Workshop*, Saskatoon, Saskatchewan, May 2007.

Bullock, P.R., Finlay, G.J., Jarvis, C.K., Sapirstein,H.D., Naeem, H. and Saiyed, I. Quantifying Agricultural Drought: An assessment using western Canadian spring wheat. *2nd Annual Drought Research Initiative Workshop*, Winnipeg, Manitoba, January 2007.

Dansereau, V., poster presentation at the McGill University Undergraduate research Conference, on 'Contribution of Atmospheric Circulation Regimes to the regional climate warming in the Mackenzie River Basin', October 19, 2007.

Evans, E., R. Stewart and W. Henson, 2007: Marginal precipitation and drought during 2001 and 2002 over the Canadian Prairies.CMOS Congress, St. John's.

Fang, X. and J.W. Pomeroy, 2007: Snow Accumulation, Snowmelt and Snowmelt Runoff to Prairie Ponds. St. Denis NWA Science and Planning Workshop. National Hydrology Research Centre, Saskatoon, SK. April 3, 2007.

Fang, X. and Pomeroy, J.W., 2007: Effects of Drought on Canadian Prairie Wetland. Snowmelt Hydrology. CMOS-CGU-AMS Congress 2007: Air Ocean, Earth and Ice on the Rock, Canadian Geophysical Union 33rd Annual Meeting, St. John's, NL, May 28 – June 1, 2007.

Fang, X. and J.W. Pomeroy,(2007) Snowmelt runoff sensitivity analysis to drought on the Canadian Prairies. *Hydrological Processes*, in press.

Fang, X. and J.W. Pomeroy,, 2007: Sublimation of blowing snow in the prairies. Drought Research Initiative Evaporation Workshop, Saskatoon. May 2007.

Fang, X. and J.W. Pomeroy, 2007: Model Scale Comparison for Wind Redistribution of Snow in the Canadian Prairies. Canadian Geophysical Union – Hydrology Section 6th Annual Student Meeting Prairie Regions, Calgary, AB, January 27, 2007.

Gascon, G. and R.E. Stewart, 2007: Major precipitation events in the Eastern Canadian Arctic. CMOS Congress, St. John's.

Grieef, L.A. and Hayashi, M. Establishing a rural groundwater monitoring network using existing wells: West Nose Creek pilot study, Alberta. Canadian Water Resources Journal (in press, December 2007 issue).

Gervais, M., P.R. Bullock, and R. Raddatz, 2007: A soil water budget approach to improving evapotranspiration estimates from the 2nd generation prairie agrometeorological model. *Drought Research Initiative Evaporation Workshop*, Saskatoon, Saskatchewan, May 2007.

Greene, H., H. Leighton and R.E. Stewart, 2007: Clouds, precipitation and radiation over the Canadian Prairies. CMOS Congress, St. John's.

Gyakum, J., Drought Research Initiative presentation, entitled "Warm-season blocking over North America and its relationship to Canadian Prairie droughts". Drought Research Initiative (DRI) Workshop #2; Winnipeg, Manitoba, 11-12 January 2007.

Hayashi, M. Effects of wet-dry cycles on groundwater sustainability in the prairies. Drought Research Initiative Workshop, Winnipeg, January 11-13, 2007.

Hayashi, M. Rural water well monitoring program for sustainable groundwater development: West Nose Creek study. Bow River Watershed Science Forum, University of Calgary, May 1, 2007. [invited]

Hayashi, M. Evaluation of ET modules in the Versatile Soil Moisture Budget in the West Nose Creek Watershed. Evaporation Workshop for Drought Research Initiative, University of Saskatchewan, May 17, 2007.

Hayashi, M. and van der Kamp, G., 2007: Using prairie pothole analogues to understand the hydrological response of closed lake systems. Annual Meeting of the Geological Society of America, Denver, Colorado, October 28-31, 2007.

Hanesiak, J., 2007: "An overview of Theme 1 activities", 2nd annual Drought Research Initiative (DRI) workshop, Winnipeg, MB, Jan 11-13, 2007.

Helgason, WD, Pomeroy JW. 2007: Observations of turbulent energy fluxes over an open prairie snow field. Drought Research Initiative Evaporation Workshop, Saskatoon, SK. May 9, 2007. *(Oral presentation).*

Helgason, WD, Pomeroy JW. 2007. Energy partitioning over snow surfaces. Canadian Geophysical Union Annual Meeting, St, Johns, NF, May 29 - Jun. 1. *(Oral presentation)*

Jackson, J., Chen, R. and Hayashi, M. Testing the Versatile Soil Moisture Budget model for groundwater recharge estimation in a northwest Canadian Prairie setting. Joint Annual Meeting of the Canadian Meteorological and Oceanographic Society, Canadian Geophysical Union, and American Meteorological Society, St. John's, Newfoundland, May 28 - June 1, 2007.

Johnstone, J.: GEOIDE workshop, June 2007, Halifax, NS, 'Utilization of GPS data in the analysis and understanding of severe weather'.

Lawford, R., I. Hanuta, H. Hill, A. Warkentin, E. Wheaton, R. Stewart, and B. Girling. 2007 May. *A Review of Some Requirements for Drought Information on the Canadian Prairies*. CMOS/CGU Congress, May 2007, St. John's Newfoundland. SRC Publication No. 11602-3D07. 20 pp.

Loukili, Y., Woodbury, A. D. and K. R. Snelgrove (2006) AccuCLASS - an Enhancement of the Canadian Land Surface Scheme for Climate Assessment Over the Prairies, *Eos Trans. AGU*, 87(52), Fall Meet. Suppl., Abstract GC41A-1030.

Marchildon, G.P., Kulshreshtha, S., Wheaton, E., Sauchyn, D. 2007. Drought and institutional adaptation in the Great Plains of Alberta and Saskatchewan, 1914 – 1939. *Nat Hazards.* DOI 10.1007/s11069-007-9175-5.

Pomeroy, J.W. 2007. Improving our Understanding and Prediction of Hydrology and Water Resources in Western Canada. *Plenary* to Canadian Water Resources Association Annual Meeting. Saskatoon, June 2007.

Pomeroy, J.W. 2007. Snow Processes and Modelling. Invited talk to NASA/Environment Canada Snowfall Hydrology Workshop, Montreal. June 2007.

Pomeroy, J.W. 2007. Soil Moisture and Evaporation in DRI. Invited talk to C-GEO Soil Moisture Workshop, Saskatoon, June 2007.

Pomeroy, J.W. 2007. Evaporation in hydrological land surface models. Talk to DRI Evaporation Workshop, Saskatoon, May 2007.

Pomeroy, J.W. 2007. Evaporation from Saline Lakes. Invited talk to International Workshop on Connecting the Gulf of Sirte Depressions with the Mediterranean Sea. Tripoli, Libya, Feb. 2007.

Pomeroy, J.W., Ellis, C.R., Brown, T. Gray, D., Hedstrom, N. The Cold Regions Hydrological Model: a simulation platform for physically based hydrology. *International Union of Geophysics and Geodesy (IUGG).* Perugia, Italy. July 2007.

Pomeroy, J.W. and X. Fang 2007. Spatial scale of blowing snow modelling on the Canadian Prairies *Eos Trans. AGU, 88*(52), Fall Meet. Suppl., Abstract C21B-0468.

Pomeroy, J.W. and Shook, K. 2007. *Prairie and Mountain National Network Research at the Centre for Hydrology, University of Saskatchewan.* CWRA Saskatchewan Branch Board of Directors Meeting. Saskatoon, November 28, 2007

Pomeroy, J.W., Fang, X., Armstrong, R., and Shook, K. 2007. Prairie drought hydrology prediction using the cold regions hydrological model. DRI Prediction Workshop, McGill University, Montreal, Sept 20, 2007.

Roberge, A., CMOS, oral presentation, entitled 'Atmospheric rivers affecting western Canada: Synoptic climatology and trajectory analysis'. St. John's, NF, May 31, 2007. May 31, 2007.

Shook, K and Pomeroy, J.W. 2007. *Prairie Flood and Drought Mitigation*. National Workshop on Watershed Conservation. Winnipeg, November 8-9, 2007.

Shook, K. and Pomeroy, J.W. 2007. *Water on the prairies*. 2007 Crop Advisors Workshop. Saskatoon, December 6, 2007.

Stewart, R.E. and J. Pomeroy, 2007: Canadian Prairie Drought and DRI. CMOS Congress, St. John's.

Stewart, R.E., 2007: A recent Canadian Prairie drought and its storms. IUGG, Perugia, Italy.

Stewart, R.E., 2007: The Water cycle, DRI and evaporation. DRI evaporation workshop, Saskatoon.

Stewart, R.E., 2007: Extremes and CEOP. International CEOP Workshop, Bali, Indonesia.

Strong, G.S., (2007): *Atmospheric Moisture and Thunderstorm Drought*. Presented at DRI Workshop #2, Jan. 2007, Winnipeg.

Strong, G., 2007: *Atmospheric Moisture and Thunderstorm Drought* CMOS Congress, St. John's, May 2007.

Szeto, K.K.: Assessing water and energy budgets for the Canadian Prairies. 2nd DRI Annual Meeting, Winnipeg, Jan, 2007.

Szeto, K.K.: Water cycling and drought development in three major NA river basins. CMOS Congress, St. John's, Newfoundland, Jun, 2007.

Szeto, K.K. et al.: RCM simulations of the 1999-2004 Prairie drought: A model intercomparison study. DRI Modelling Workshop. McGill, Sep, 2007.

Szeto, K.K.: Water cycling and the development of hydrometeorological extremes in three major NA river basins. EC Climate Research Division Seminar, Apr, 2007.

van der Kamp, G., S. Marin B. Davison, B. Toth, A. Pietroniro, H. Maathuis and N. Kouwen, 2007. Use of deep groundwater observation wells for continuous monitoring of kilometre-scale vertical water balance. CMOS-CGU Congress, St. John's NL, May 28-June 1, 2007.

van der Kamp, G., I. Judd-Henrey, A. Barr, R. Granger, 2007. Surface and subsurface hydrology of the Prince Albert Model Forest and the surrounding area. Invited presentation at workshop on "Wetlands and watersheds in forested ecosystems. Prince Albert SK, Feb 20, 2007.

Wen, L., and C.A. Lin, 2007: Calibration and validation of the VIC model over the Liard Basin in Canada. Evaporation Workshop, Saskatoon, SK. May 16-17.

Wen, L., C.A. Lin, Z. Wu and G. Lu, 2007: Towards the establishment of a drought monitoring and seasonal prediction system over Canada using the Variable Infiltration Capacity (VIC) hydrological model. Asia Oceania Geosciences Society 4th Annual meeting, Bangkok, Thailand, July 30- Aug. 4.

Wen, L., C.A. Lin, Z. Wu and G. Lu, 2007: Reconstructing Canadian Prairie droughts for the period from 1950 through 2005 using the Variable Infiltration Capacity (VIC) Hydrological Model. DRI Prediction Workshop, McGill University.

Wheaton, E. 2007 January. *Theme 5 Update: Droughts-Addressing Critical Issues Important to Society*. Presentation to the *Canada DRI Workshop*, Winnipeg, MB. Saskatchewan Research Council (SRC) Publication No. 11602-2D07.

Wheaton, E. and B. Bonsal. 2007 January. *Exploring the Surface Characteristics of the 1999-2005 Drought in the Canadian Prairies*. Presentation to the *Canada DRI Workshop,* Winnipeg, MB. Saskatchewan Research Council (SRC) Publication No. 11602-1D07.

Yirdaw-Zeleke, S and K Snelgrove (2007) Modelling of the Assiniboine Delta Aquifer (ADA) of Manitoba using the Groundwater Storage from GRACE, Eos Trans. AGU, 88(52), Fall Meet. Suppl., Abstract H33D-1615/

Presentations:

Stewart, R., 2007: The water cycle and soil moisture. Canadian Global Earth Observation Workshop Saskatoon (opening presentation), April 2007.

Stewart, R., 2007: Waiting for rain: the science of drought. Canadian Meteorological and Oceanographic Society, Alberta Chapter, Edmonton, February 2007.

Stewart, R., 2007: Waiting for rain: the science of drought. Canadian Meteorological and Oceanographic Society, Ottawa Chapter, Ottawa, February 2007.

PDFs of a number of these papers and presentations are available on the DRI website.

4.1.2. Related Reports and Presentations not funded by DRI Research Funds (for Themes 4 and 5):

*Wheaton, E., S. Kulshreshtha, V. Wittrock, G. Koshida. 2007 Accepted. Dry times: lessons from the Canadian drought of 2001 and 2002. *The Canadian Geographer.*

*Wheaton, E.E. 2007. Focus Study 3.1 Drought. *In:* Thraves, B.D., M.L. Lewry, J.E. Dale, and H. Schlichtmann (eds), *Saskatchewan: Geographic Perspectives*. University of Regina, Regina.

*Wheaton, E.E. 2007. Focus Study 3.2 Dust Storms. *In:* Thraves, B.D., M.L. Lewry, J.E. Dale, and H. Schlichtmann (eds), *Saskatchewan: Geographic Perspectives*. University of Regina, Regina.

Research Reports

*Wheaton, E., G. Koshida, B. Bonsal, T. Johnston, W. Richards, V. Wittrock. 2007 May. *Agricultural Adaptation to Drought (ADA) in Canada: The Case of 2001 to 2002. Synthesis Report.* Prepared for Government of Canada's Climate Change Impacts and Adaptation Program. Saskatchewan Research Council (SRC) Publication No. 11927-1E07. 35 pp.

Wittrock V., and Wheaton, E. 2007 May. *Towards Understanding the Adaptation Process for Drought in the Canadian Prairie Provinces: The Case of the 2001 to 2002 Drought and Agriculture.* Prepared for Government of Canada's Climate Change Impacts and Adaptation Program. Saskatchewan Research Council (SRC) Publication No. 11927-2E07, 154 pp.

Presentations/ Conference Proceedings

Wheaton, E., C. Beaulieu, M. Johnston, J. Thorpe, and V. Wittrock. 2007 November. *Risks and Opportunities of a Warming Climate: Views from the Prairies.* Invited Presentation to Environment Integrated Systems – Putting Policy into Action, November 22, 2007, Regina, SK. Saskatchewan Research Council (SRC) Publication No. 11225-20D07.

Wheaton, E., G. Koshida, V. Wittrock. 2007 September. *What does Current Agricultural Adaptation to Drought mean for Future Vulnerability? In:* Heinonen, M. Proceedings, Third International Conference on Climate and Water, Marina Congress Center, Helsinki Finland, 3 to 6 September 2007.Finnish Environment Institute, Helsinki. Saskatchewan Research Council (SRC) Publication No. 11927-10A07.

Wheaton, E., G. Koshida, and V. Wittrock. 2007 July. *What Does Current Adaptive Capacity Mean for Future Drought Management*? Abstract in Proceedings, Canadian Water Resource Association 60th Annual National Conference, July 25-28, 2007.

Koshida, G. E. Wheaton, E. Stratton and V. Wittrock. 2007 June. *Using Decision Support Tools to Enhance Sustainable Agricultural Water Use in the Prairie Provinces.* Abstract in CWRA June 2007Annual National Conference.

Sauchyn, D., M. Fiebig, E. Wheaton, J. Barichivich, S. Lapp and V. Wittrock. 2007 June. *Variability in the Hydroclimate of the Elqui and South Saskatchewan River Basins.* Abstract in CWRA June 2007 60th Annual National Conference Proceedings.

Wheaton, E., G. Koshida, V. Wittrock. 2007 June. *Current Agricultural Adaptation to Drought: Implications for Future Water and Resource Management Capacity Building.* Abstract in CWRA June 2007 60th Annual National Conference Proceedings.

Wittrock, V., E. Wheaton and S. Kulshreshtha. 2007 June. *Assessing the Vulnerability of Prairie Communities' Water Supply.* Abstract in Proceedings CWRA June 2007 60th Annual National Conference Proceedings.

Wittrock, V., S. Kulshreshtha and E. Wheaton. 2007 June. How Vulnerable are Prairie Communities' Water Supply? Presentation to *CWRA 60th Annual National Conference of the Canadian Water Resources Association*, Saskatoon, Saskatchewan, June 26 to 28, 2007. Saskatchewan Research Council (SRC) Publication No. 11899-4D07.

Wittrock, V., M. Khakpour, S. Kulshreshthra and E. Wheaton. 2007 April. *Impacts and Adaptation Strategies: A Case Study of Outlook, Taber and Hanna and the 2001 and 2002 Drought Progress Report.* Invited presentation to the *Institutional Adaptation to Climate Change Annual Meeting.* April 23-27, 2007, La Serena, Chile. Saskatchewan Research Council (SRC) Publication No. 11899-2D07.

Wittrock, V. and E. Wheaton. 2007 February. *Impacts and Adaptations: The Case of the 2001-2002 Drought.* Invited presentation to the *Water Management Workshop in Alberta's Special Area #2.* February, 26, 2007, Hanna, AB. Saskatchewan Research Council (SRC) Publication No. 11899-1D07, 24 pp.

4.2 Data management/sharing activities including organization of the metadata.

Data management has been handled by Patrice Constanza at McGill in Montreal and was formerly handled by a half-time information manager, Matt Regier in Saskatoon (who was paid by paid by Environment Canada). Since Matt's departure in August 2007, Peter Lawford has been hired to manage the DRI web site but no one has taken on the challenge of data management. Data are being made available to collaborators and partner agencies as requested. These data will also be available to the general research community in accordance with the DRI Data Access Policy. A listing of the DRI data sets can be found at: http://www.drinetwork.ca/data.php. Small data sets are maintained on the web site while larger data sets are being maintained on the Ouranos data system at McGill. Some hydrologic data are also being archived at the National Water Research Institute of Environment Canada. Table 3 summarizes the status of the various DRI data holdings.

A MEC Workshop was held in Saskatoon on January 25th and 26th 2007. The workshop helped familiarize DRI researchers and other collaborators with the MEC modelling system and the types of data it produces. The workshop included a discussion of the concept of community-based modelling, information about modelling theory, and exercises to help the participants initiate their modelling work.

Table 3. Summary of DRI data holdings.

Data Set	Ouranos (DAI)	Self-archived	Link from DRI website
NCEP Gl Reanalysis	Yes		Yes
NARR	Yes		Yes
Atm Model Data	Yes		Yes
VIC Simulations	Yes		Yes
Hydrologic Field Data		Yes	Through co-I
NAESI field data		Yes	Yes
Hydro model data		Yes	Yes
Agromet data		Yes	Through co-I
SSRB data sets		Yes	Yes
Radar data		Yes	Will be
SRB		Yes	Will be

Thunderstorm data		Yes	Through co-I
Water/En Budget		Yes	Through co-I
West Nose Watershed		Yes	Through co-I

4.3 Outreach and public information activities, including press interviews or other media interest or reports.

During and after the 2007 DRI workshop in Winnipeg a number of interviews (Lin, Bruce, Hanesiak, Lawford and others) were held including:
- CBC French Radio,
- CBC English Radio,
- The Headliner newspaper,
- the Winnipeg Free Press (on-line article only),
- the Manitoban (University of Manitoba).

Similar media activities are planned for future workshops.

Interviews with the CBC radio in Alberta by Masaki Hayashi in February 2007 and April 2007 discussed dealt with water resources in southern Alberta.

The Memorial University Student Newspaper (MUSE) published an article on Ken Snelgrove and his DRI research. The article can be viewed at: http://www.themuse.ca/view.php?aid=40072.

A number of presentations to community groups such as the Saskatchewan Nature Society annual meeting on climate change and water; U of Victoria Geography Dept included discussions of DRI research.

Outreach IPY workshops planned for northern communities in association with John Gyakum's IPY research projects. It is expected that drought research will be discussed at these workshops.

In addition, the DRI website, http://www.drinetwork.ca/ , is continually being updated. Based on feedback received it is clear that a number of people access this site regularly.

4.4 Acknowledgements of CFCAS support.

Most DRI presentations and publications and journal articles formally acknowledge CFCAS as the primary funding agency. The CFCAS logo is often displayed on the first pages of power point presentations, on posters and in other appropriate locations. The CFCAS logo is also prominently displayed on the DRI website and interested people can follow a link to the CFCAS website. Available CFCAS documents are distributed at DRI meetings.

4.5 Attach copies of any papers published or accepted for publication.

Copies of many of the publications referred to in this report will be made available on the DRI website in pdf format.

5.0 Training

5.1 Quantify student and postdoctoral involvement in the project, indicating the number of: undergraduate, masters, doctoral or PDF's.

Table 4. Listing of Students and young graduates in DRI for 2007 and projected for 2008-09.

	Current (Dec 2007)	Planned (08-09 budget)
Post Doctorate Fellow	8	7
PhD	9	7
Masters	12	10
Undergraduate	10	8

The number of students or recent graduates employed by DRI in 2007-2008 was much higher than projected in the budget. This is interpreted as a positive sign because it suggests that the broader funding base that DRI is attracting is being used to provide education and training opportunities for young Canadians.

The following paragraph lists students and Post Doctorate Fellows by supervisor.

Bullock, University of Manitoba:

- Mark Gervais, MSc student (Jan 2007 to Dec 2008). He will be conducting the PAM2nd model testing.

Bonsal, Barrie, University of Saskatchewan:

- Jerry Kermack, Undergraduate student. He will be carrying our drought teleconnection analysis.

John Gyakum, McGill University:

- Graduate student – Alain Roberge; Master's Thesis on the Pineapple Express. Post-doctoral Fellow – Dr. Eyad Atallah: Extreme droughts and associated global teleconnections.
- Two undergraduates: Véronique Dansereau and Jackie Johnstone. Their respective roles have been in documenting secular changes in atmospheric circulation regimes and in the study of GPS-derived water vapour data.

John Hanesiak, University of Manitoba:

- Julian Brimelow, Ph.D. student: Linkages between surface characteristics and convective activity (initiation and rainfall) during the drought period.
- Hassan Bhuiyan, Ph.D. student: Regional climate model validation, dynamic downscaling.
- Daniel Battancourt and Justin Hobson (undergrad students) with PDSI and SPI analysis and mapping

Masaki Hayashi, University of Calgary:

- M.Sc.: John Jackson. Modelling the effects of land use and climate change on depression-focused groundwater recharge.
- M.GIS: Sangeeta Guha. Depression storage of snowmelt water and its relation to landform and vegetation.
- MSc: Rui Chen. Development of GIS-based ground data recharge model.
- B.Sc.: Nathan Green. Distribution of springs in the West Nose Creek watershed and their relation to bedrock topography.
- Dr. Ligang Xu (PDF, improving the VSMB model);
- Sangeeta Guha (Masters, estimation of depression storage from aerial photographs);
- Rui Chen (Masters, development of GIS-based groundwater recharge model); Paul Wozniak (Masters, hydrogeology of the Paskapoo aquifer system),

- Matthew Eckfeldt (Undergrad, case study of groundwater level change).

Henry Leighton, McGill University:

- Dr. Song Guo, PDF. Impact of aerosols from wild-fires upwind of the prairies on the properties of clouds over the prairies.
- Heather Greene, MSc., Collaborative with R.E. Stewart: Clouds and drought

Charles Lin, McGill University:

- Lei Wen, research associate. Assess the skill of the seasonal forecasts of the recent prairie drought by Canadian global models in the HFP (Historical Forecast Project) project
- . Rabah Aider is a M.Sc. student under the joint supervision of J. Derome and C. Lin.

Al Pietroniro, University of Saskatchewan:

- Pablo Dornes (Ph.D. Candidate - Department of Geography - Centre for Hydrology – University of Saskatchewan. – co-supervision with Dr. John Pomeroy
- Dean Shaw (Ph.D. Candidate) – Department of Geography - Centre for Hydrology – University of Saskatchewan. – co-supervision with Dr. Lawrence Martz
- Dr. Saul Marin (PDF - Department of Geography - Centre for Hydrology – University of Saskatchewan) – co-supervision with John Pomeroy

John Pomeroy, University of Saskatchewan:

- Xing Fang, MSc student: *Snow Accumulation, Infiltration and Melt during Drought*.
- Robert Armstrong, PhD student: *Spatial Variability of Prairie Evaporation during Drought*
- Jimmy Macdonald, undergraduate student: *Precipitation Gauge Undercatch during Winter Drought*
- Warren Helgason, PhD student, study of snow evaporation in drought
- Dr. Kevin Shook – Research Scientist, CHRM modelling, drought characterization, wetland characterization
- Mr. Tom Brown, Programmer, CRHM model development
- Mr. Michael Solohub, Research Officer – data archiving, instrumental deployment in summer
- Ms. Joni Onclin – Research Assistant, data archiving, evaporation workshop organisation

Ken Snelgrove, Memorial University of Newfoundland & Labrador:

- Sitotaw Yirdaw, Ph.D. student, Climate Change Implications for Assiniboine Delta Aquifer Water Resources
- Clement Agboma, Ph.D. student, Drought Implications for Water Resources of the Upper Assiniboine Basin

Ron Stewart, McGill University:

- Erin Evans, MSc student, Water vapour transport and precipitation production
- William Henson, PDF, Heavy precipitation events during the 1999-2005 drought
- Heather Greene, MSc, Clouds and drought

Geoff Strong, University of Alberta:

- Julian Brimelow, University of Manitoba: assisting Hanesiak with supervision.
- Undergraduate starting in early 2007.

Garth van der Kamp:

- Collins Anochikwa, Master student (modelling and analysis of geological weighing lysimeters)
- Dushmantha Jayawickreme, doctoral student (modelling of soil moisture regimes at forest sites)

Al Woodbury, University of Manitoba:

- Dr. Youssef Loukili is working full time on the modifications and parallel programming, and is interacting with Dr. Ken Snelgrove (Memorial) and his students.

- Smrita Joshi, PhD student (partial DRI funding)
- Alireza Hezazi, PhD student (CWN funding)

6.0 Other

6.1 Other potential CFCAS support for university-based research in climate and atmospheric sciences.

The information manager issue is becoming critical for DRI. The arrangement with Environment Canada was helpful while it lasted. However, since DRI did not budget for an information manager it now finds itself in a difficult situation to find someone with the required talents who can step in at short notice to take on this task with the very limited support that DRI currently can offer. Additional funds from CFCAS to support this need would be very helpful.

Reporting requirements may also merit consideration. One Co-I was concerned about the level of detail requested in the annual report template and was sceptical that this information would be used. While this view is not shared by all investigators in DRI it does suggest that some thought could be given to reviewing the template with a view to streamlining the request for information and eliminating any perceived duplication in the questions.

Appendix A

TERMS OF REFERENCE FOR A DRI PARTNERS ADVISORY COMMITTEE (March 5, 2007)

The Drought Research Initiative (DRI) is a major research effort funded by the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) that seeks to provide a better understanding of droughts on the Canadian prairies in order to provide advice to Canadians and the rest of the world on the nature, causes and prediction of drought events. The project has been funded for a 5-year period (2005-2010) and focuses its efforts especially on the prairie drought of 1999-2005. The DRI Board of Directors and the DRI Science team wish to ensure that at the end of the project there are significant benefits that accrue to those who are affected by drought on the Canadian prairies and to those who are affected world-wide.

Accordingly, the DRI team is determined to connect their research to practical applications wherever appropriate. Three areas of focus have been identified: data products, analytical tools and models, improved forecasts, and syntheses that can be used for policy development. In order to help focus the applications aspects of DRI, it is proposed that a small advisory committee made up of some of the DRI Partners be established to provide advice to the DRI Board of Directors. With this level of reporting it is believed that the advice will influence DRI research at its most fundamental levels.

Terms of Reference:
As the Board of Directors and the members of the Advisory Committee gain experience with this mechanism it is anticipated that the Terms of Reference will evolve. However, initially the Terms of reference for this group will be as follows:

1) To provide advice and assessments to the BoD on the status of DRI interactions with stakeholders.
2) To identify linkages and propose working groups and recommend actions that could be taken to develop specific proposals.
3) To develop an outreach strategy to ensure DRI results are used effectively.

Membership:
It is proposed that the DRI Partners Advisory Committee be made up of representatives from the following organizations:

Agriculture: PFRA (Harvey Hill and Irene Hanuta (drought policy))
Alberta Agriculture
Saskatchewan Agriculture
Energy: Manitoba Hydro (Bill Girling)
Water Resources: Alberta Environment (Ray Keller)
Manitoba Water Stewardship (Suggested: Alf Warkentin)
Saskatchewan Watershed Corporation (Bart Ogema)

GEO SEC: Ken Korporal
Saskatchewan Research Council: (Elaine Wheaton)

Members will be added or rotated off the committee as the need arises. Dr. Harvey Hill of PFRA will serve as the first chair of the committee.

Meeting and Reporting:
This advisory committee will conduct much of its business via email and teleconference calls. An annual meeting will be held either just before or just after the annual DRI workshop. The committee chair will report to the BoD at least semi-annually on its activities and recommendations for DRI Principal Investigators on the steps that should be taken to ensure DRI research becomes effectively linked to potential applications.