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

2007 DRI Progress Report

December 3, 2007:

Project Title:

Diagnostic Analyses of the Prairies Drought

Investigator:

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1.0 Progress (beginning January 2007 to end December 2007)

1.1 **Describe progress towards meeting the project objectives for those theme areas where you have received funding for 2006-2007. How are the original milestones being met (be specific)? List the key objectives and results achieved to date as well as any relevant application(s) of the results.**

1.1.1 Objectives

The overall objective of the Drought Network 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 focussed on complementary and cross-cutting research objectives that correspond to the following themes:

1. **Theme 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.

We address the first DRI objective of understanding of the spatial and temporal features of the recent Canadian Prairie Drought, with a study of how atmospheric dynamics act to modulate

both the severity and length of the drought on the synoptic and sub-synoptic scales. This includes:

1) Studying systematic changes in the location and frequency of storm tracks.
2) Documenting source regions and impacts of atmospheric moisture.

Results achieved include:

1. We have documented that there were strong oscillations in the position of the mean storm track, especially during the growing season. The primary characteristic is that these storm tracks 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.
2. 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. This is especially important during the warm season, as this moisture strongly impacts the atmospheric stability and consequently the presence and severity of convection, which can account for upwards of 60-80% of warm-season precipitation accumulations in the region.
3. Moisture transport is found to also be important even when the transport does not directly impact the region. "Pineapple Express" events (events when moisture from the tropical Pacific is transported to high latitudes) have been found to have a significant impact on the flow regimes over the Prairies. When these events occur, strong latent heat release associated with the deep tropical moisture over the western Canadian Rockies results in diabatic ridging over British Columbia. This has the impact of both displacing the mean jet to the north of the Prairies and enhancing warm temperature anomalies in the region.
4. On the sub-synoptic scale, the presence of lower-tropospheric moisture can be monitored through the implementation of a network of GPS receivers currently in place near Calgary, Alberta. Recent research has demonstrated the utility of these GPS receivers in quantifying the atmospheric moisture available on considerably finer time and space scales than conventional meteorological data provide. In fact, GPS receivers can be instrumental in assessing how quickly atmospheric moisture can fluctuate, providing insight into mesoscale flow regimes associated with severe convection. This can has also been shown to be useful in helping to quantifying the impact of evapotranspiration (ET) on available atmospheric moisture/stability as numerical predictions of ET in operational models are somewhat problematic.

2. Theme 2: Improve the understanding of the processes and feedbacks governing the formation, evolution, cessation and structure of the drought.

Current research associated with Theme 2 of DRI emphasizes the understanding of synoptic-scale settings responsible for the initiation, maintenance, and cessation of the current drought as well as understanding the mechanisms by which precipitation and storms are modulated and their influence on drought. Our goal is to discover the atmospheric circulation regimes (if any) that are particularly pertinent droughts in North America. We have done so with the aid of theoretical studies of blocking, and with the National Centers for Environmental Prediction (NCEP) global reanalyses.

In an attempt to understand the large-scale settings of drought, a careful examination of the synoptic-scale flow regimes responsible for the modulation and intensity of the drought has been undertaken on weekly, monthly, and seasonal time scales. This work is designed to provide a dynamical framework for understanding the mechanisms of drought.

Results achieved include:

1. Work on previous droughts in central and western Canada have often been related to a positive phase of the Pacific North American Pattern (PNA) index which is associated with anomalous mid and upper-tropospheric ridging in western Canada. The subsidence accompanying this anomalous ridging generally produces fair and warm conditions over Canada west of Manitoba. Consequently, we have undertaken a study of trends in the phase and intensity of the PNA. Results indicate a significant trend in the PNA index towards positive values over the past 50 years. This is not to say that there are more extreme events of positive PNA, but rather that there is simply more frequently flow regimes which are characterized by a positive phase of the PNA. If these changes are related to anthropogenically forced climate change, then it might be surmised that droughts in the Prairies may indeed become more frequent over the next several decades.
2. However, precipitation deficits at several locations, including Calgary, Edmonton and Saskatoon could not be correlated with any of the established teleconnection indices such as the Pacific North American pattern (PNA) and the El Nino Southern Oscillation (ENSO). In fact, when examined on a seasonal basis, it appears that only the spring and summer of 2004 are consistently characterized by a positive phase of the PNA. Interestingly, it was found that several 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 Northern Territories.**

This represents a mean displacement of the storm track to the north resulting in fewer synoptic-scale disturbances, and consequently fewer triggers for precipitation, traversing the Prairies. Also, this flow configuration places the Prairies in a region of enhanced anticyclonic shear and subsidence on the equatorward side of this jet stream.

    2. **Strongly meridional ridge/trough couplet centered over western British Columbia.**

This flow configuration is perhaps the least intuitive of the three as most of the Prairies are characterized by anomalously low heights and temperatures. In fact, temperature anomalies at 850 hPa over Saskatchewan were generally 4 to 6°C below normal. The prevalence of this flow regime resulted in temperatures over the duration of the drought that were very close to the climatological average. This flow regime contributed to drought in the

Prairies in two ways. Firstly, the air over the Prairies was relatively cool and stable, with significantly lower precipitable water values than the climatological average, which precluded the development of deep convection in the region. Secondly, synoptic-scale low pressure systems often developed well to the south of the Canadian Rockies, leading to a majority of the associated precipitation falling to the south and east of the Prairies.

3. **Positive phase of the Pacific North American pattern**.

This flow configuration has been historically associated with major droughts over the Canadian Prairies. Strong ridging over British Columbia places the Prairies in a region of enhanced differential anticyclonic vorticity advection and subsequently synoptic-scale forcing for descent. The impact of this on the sensible weather is to produce sunny and warm conditions over large parts of Alberta and Saskatchewan. This is also the pattern most likely to produce a positive feedback with respect to the drought, as the warm and dry conditions will deplete any ground moisture, which may be available.

1.2. **What contributions have you made, if any, to the unfunded themes of DRI through support in kind.**

Theme 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.

We have been studying the details of secular changes in atmospheric circulation regimes during the past 60 years. This is a first step towards a deeper understanding of the associated drought structures.

Theme 5: Apply our progress to address critical issues of importance to society.

1.3 **Describe your plans for research during the coming year and the following year and outline how the expected results will support the deliverables and goals of DRI.**

We have established the essential foundation for a significantly-improved understanding of the 1999-2004 Prairie Drought. Our plans for the next two years include the analysis of generation, maintenance, and decay of the relevant circulation regimes associated with the various components of the drought.

Our research on moisture transports, particularly the “Pineapple Express” will focus on the details of how strong latent heat release effects diabatic ridging, and the displacement of the mean jet to the north of the drought region.

We intend to continue our research on the relationship of the secular changes in atmospheric circulation regimes to global climate change.

We will continue to monitor the details of GPS-derived precipitable water to provided crucial sub-synoptic-scale information to enhance our understanding of the impact of evapotranspiration

(ET) on available atmospheric moisture/stability as numerical predictions of ET in operational models are somewhat problematic.

All of the above projects address the goals and objectives set out in DRI Themes 1 and 2.

2.0 Impact

2.1 Describe the significance / impact of the results achieved to date and how this new knowledge has influenced research policy, enhanced research collaboration or competitiveness, or helped attract or train skilled personnel.

Address the following items, as appropriate:

- **The impact of the project on government policy development (federal, provincial or municipal);**
- **How the project has expanded contacts in partner organizations, or increased cross-disciplinary cooperation;**
- **Whether and how it has improved the reliability of predictive methods;**
- **The impact of the project on your own institution;**
- **Whether and how the project has helped increase funding from other agencies, or led to new partnerships;**
- **Any current (or potential) commercial or social applications, which the results may have;**
- **Links with international initiatives and the potential impact of these;**
- **Anticipated benefits of the work for Canadians.**

Our project has continuing relevance for Dr. Gyakum's participation with the GEOIDE network project of Dr. Susan Skone of the University of Calgary. Our research using the GPS data, promises to enhance our understanding of sub-synoptic evapotranspiration processes in regions prone to droughts.

The Pineapple Express research described above is primarily funded by Dr. Gyakum's NSERC Discovery Grant.

The research on secular changes in atmospheric circulation regimes has been funded in part by and NSERC summer grant for an Honours Undergraduate student, Ms. Véronique Dansereau.

3.0 Dissemination

3.1 Provide information on 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.

Presentations:

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

2. **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.
3. **Atallah, E**., CMOS, oral presentation, entitled 'A series of unfortunate events'. St. John's, NF, May 31, 2007.
4. **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.
5. **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.
6. **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.