2007 DRI Progress Report
Drought, Clouds and Precipitation
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This study will focus on the flow of water through clouds and precipitating systems to the surface within and adjacent to drought regions. In particular, it will focus episodic events that produced heavy, widespread precipitation and on thresholds that must be exceeded before precipitation can reach the surface and on. Key issues include the relative contributions of water vapour from external and local moisture sources, the efficiency through which cloud systems convert this water vapour to precipitation, the possible role of the drought environment in enhancing the strength and/or efficiency of some precipitating systems, and the production of scattered, partially drought-alleviating precipitation. The ensuing insight will be related to surface and sub-surface moisture conditions in collaboration with other DRI scientists. Throughout the effort, the degree to which current models are able to capture the flow of water through the system will be assessed.

In particular, the objectives are:

- To better understand the flow of water vapour into and through clouds and precipitating systems to the surface within and adjacent to drought regions
- To apply these advances to water issues and to prediction capabilities

This research will contribute to each of the funded themes of DRI through:

- Quantitative assessment of several branches of the water cycle in relation to drought
- Assessment of simulation and predictive models and recommendations for improvement

1.0 Progress in 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? List the key objectives and results achieved to date as well as any relevant application(s) of the results.

Theme 1:

Characterization of drought within this theme in 2007 was associated with cloud fields as well as precipitation.

Little is known about cloud climatology during drought. But, information on clouds is now readily available from satellite data as far back as the early 1980's. Surface Radiation Budget (SRB) satellite data has been acquired and applied to the Prairies. This currently covers the period 1984-2004. There are several parameters associated with this dataset. These include cloud cover, estimates of cloud amount by height, cloud base height, optical depth, and estimated shortwave surface radiation.

In addition, operational radar data from three sites over the Prairies have been 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 sits at Calgary, Edmonton and Saskatoon. This radar information has furthermore been analyzed to develop a dataset of processes producing precipitation (convective or stratiform) or virga at these locations.

Theme 2:

Over the past year, the main Theme 2 issues include cloud, precipitation anomalies, individual storms and virga. A brief summary of progress on these issues is listed below.

Showed that the majority of the water vapour flux in this storm was associated with a strong low level jet, one must handle this well to address such major moisture sources

The CanGrid precipitation was used to characterize aspects of the drought. One of the ways through which this was done was simply to count the number of months when each grid over the Prairies was in drought. For the period 1999-2004, the peak number of months was 35. This was located along the northern Alberta-Saskatchewan border near Ft. McMurray. This particular grid was surrounded by other grids with very high values and this pattern of high number of grid boxes carried on towards the north-east. In contrast, some grids in south-east Manitoba experienced less than 15 months within drought conditions.

On the opposite extreme, the June 2002 major rainstorm is still being examined. This mammoth storm changed extremely dry conditions over the southern Prairies to above average conditions. Research on this storm had started last year and this year the focus was on better understanding water vapour flux around and within the storm system.

Preliminary analyses of cloud cover throughout the Canadian Prairies were also examined. Cloud amounts differ only slightly from dry to wet conditions so cloud cover is only weakly correlated to the amount of precipitation. This is not surprising since precipitation can be generated by individual convective clouds as well as by widespread stratiform clouds and both types occur.

Instances of precipitation at Calgary, Edmonton and Saskatoon during the heart of the drought, 2001 and 2002, were examined in detail. It was found through the examination of radar information that both stratiform and convective processes were critical for the generation of this precipitation. The relative importance of these varied greatly at any location and between locations so that there was no overall pattern.

Instances of virga were also examined in detail. It was quite common for virga to occur at Calgary, Edmonton and Saskatoon during 2001 and 2002. This virga was linked with either convective or stratiform processes. Importantly, cloud base heights during instances of virga were normally at height above the freezing level. This means that the precipitation formed in these clouds descended initially at temperatures colder than 0°C. The precipitation would then begin to sublimate before evaporating. For the same precipitation arte and temperature, falling snow can sublimate faster that falling raindrops can evaporate. This means that the cold cloud bases act in a manner that effectively loses precipitation and therefore acts to enhance drought.

It is important to fully understand the role of the cold season in terms of the cycling of water during the drought. One initial issue being addressed is whether periods of above freezing temperatures and/or rain occurred during the cold season (November through March), in particular when snow was on the ground. Such events would act to cap the snow with ice, limiting the possibility that it will be lost in whole or part due to blowing snow. Twelve observing sites over the Canadian Prairies were used to characterize such periods during the cold seasons of 1999 - 2004 as well as over a longer period (1965 - 2006). On average, while snow was on the ground, there were significantly more hours (at a 95% confidence level) with temperatures greater than 0°C between 1999 and 2004 (34.5 h on average per year) than observed between 1965 and 2006 (31 h on average per year). However, little difference was noted in the occurrence of rain during the cold season from 1999 - 2004 and the average occurrence between 1965 and 2006. For example, across the Prairies, an average of 11 hours of rain was observed between 1999 and 2004 compared with an average of 10 hours between 1965 and 2006. Collectively, warm periods as well as rain occurred during the drought when snow was on the ground. These instances may have made a significant impact on the evolution of the drought but this still needs to be demonstrated.

Theme 3:

Theme 3 issues mainly focused on an examination of predictions during the drought as well as inferences of marginal precipitation and virga.

On a large scale perspective, operational seasonal predictions were examined in order to assess in general terms their ability to predict precipitation anomalies during the recent drought. These predictions generally were poor with regard to predictions of summer precipitation in particular. A good example of this is the summer of 2002. A persistence of dry conditions was predicted for the southern Prairies but a major June storm changed that. This also suggests that, in at least in some instances, seasonal predictions can be erroneous due to the effects of individual events.

The focus of so far has largely been on the internal features of drought. Within a drought, prediction of some precipitation can be quite important. To begin to address this, initial assessments of the synoptic and mesoscale conditions associated with marginal precipitation and virga were carried out for Calgary, Edmonton and Saskatoon. The synoptic and mesoscale conditions showed considerable differences for these parameters beteen the three locations, due at least in part to differences in topograohic forcing. These are preliminary findings and more research will be carried out on this issue in the future.

1.2 Next Year:

Over the next year, research focal points will be:

June 2002 storm: The major June 2002 storm will continue to be a focal point. The analysis of the structure of the event will be completed but the focus will then shift towards determining the effects of this storm on regional water cycling and assessing to what extent this was captured within regional climate simulations as well as in seasonal predictions. If poorly handled, the focus will be on explanations for differences.

Other major precipitating storms: Similar analyses of other major storms during the drought will be carried out. To what extent were the features of the June 2002 seen in other events and to what extent were these other storms captured in models?

Particular dry regions: One issue to examine over the next year is better understanding the factors that led to sustained dry conditions in particular parts of the Prairies during the recent drought. It may well be a coincidence but one issue to be considered is the impact of enhanced aerosol concentrations on the reduction of precipitation.

Optical thickness: The SRB information will be exploited to better assess whether cloud optical thickness information can be used to distinguish between precipitating and non-precipitating clouds. Cloud top information can be erroneous in a drought situation since a significant amount of the precipitation may sublimate/evaporate before reaching the surface.

Marginal precipitation: In a drought, marginal precipitation can be critical. Further work will be carried out on this issue by examining other sites beyond the three already started and a particular focus will be on better understanding the key factors delineating whether any precipitation will actually reach the surface.

From a Network perspective, a critical new initiative will be starting to synthesize the entire findings of the Network into a succinct article. This process will take three years to complete so that the end of DRI will coincide with the completion of this multi-authored article.

1.2 Contributions to Themes 4 and 5:

Theme 4:

One contribution to this theme is beginning to address drought in other regions of the world through international GEWEX. One issue that appears to be relatively common is that major precipitation events mark the end of drought, at least meteorological drought.

This is similar to what occurred during the 1999-2004/05 event over the Prairies. This, as well as other similar and different features of drought will be examined in more detail over the next few years.

Theme 5:

Over the past year some work was devoted towards Theme 5. For example, I participated in some of the activities of the Partners Advisory Panel for DRI and I have also contributed to a potential new collaboration with Manitoba Hydro.

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.

This project so far has been addressing fundamental issues in association with drought. Issues such as marginal precipitation occurrence don't seem to have been examined in any detail before yet they can be very important. As the research proceeds, its impacts will increase. This research is of considerable interest to students because it is addressing key aspects of a type of hazardous weather that has not been addressed before. There is tremendous opportunity for discovery.

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

At this point, my personal work probably does not have an impact on government policy.

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

It will in the future

2.5 Whether and how it has improved the reliability of predictive methods

This work has not yet led to improvements in predictive methods. Some model deficiencies are beginning to be identified though.

2.6 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. It may lead to such increases but not yet.

2.7 Any current (or potential) commercial or social applications, which the results may have;

2.8 Links with international initiatives and the potential impact of these;

The whole DRI effort is linked closely with international GEWEX activities on extremes.

2.9 Anticipated benefits of the work for Canadians.

Anomalies related to the hydrological cycle are an enormous problem. DRI itself and its individual researchers addressing such issues will eventually contribute to being better able to cope with such features.

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:

April 2007: The water cycle and soil moisture. Canadian Global Earth Observation Workshop Saskatoon (opening presentation)
February 2007: Waiting for rain: the science of drought. Canadian Meteorological and Oceanographic Society, Alberta Chapter, Edmonton.
February 2007: Waiting for rain: the science of drought. Canadian Meteorological and Oceanographic Society, Ottawa Chapter, Ottawa

Conference Presentations:

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.
Gascon, G. and R.E. Stewart, 2007: Major precipitation events in the Eastern Canadian Arctic. CMOS Congress, St. John's.
Greene, H., H. Leighton and R.E. Stewart, 2007: Clouds, precipitation and radiation over the Canadian Prairies. CMOS Congress, St. John's.
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.

Conference Organization:

Co-Chair of Canadian Drought Session at 2007 CMOS Conference in St. John's
Chair of Water Cycle Symposium at IUGG 2007, Perugia, Italy (drought was a prominent focal point)