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

2007 DRI Progress Report

Project Title: Seasonal forecast of drought and the role of soil moisture

Investigator: Charles Lin

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

Theme 1 (0%):
Not applicable

Theme 2 (0%):
For 2007, we have not participated in Theme 2 activities. This is a change from 2006, where we participated in Theme 2 at the 20% level. The change is due to the focusing of our activities on prediction, using different land surface schemes and seasonal forecasts from the Historical Forecasting Project (HFP). More details are given below.

Theme 3 (100%):
We have made progress on using two land surface models (VIC, CLASS) in stand alone mode to simulate land surface properties, including soil moisture. The studies are first conducted over China, where data for forcing the model and verification of results are available. Having verified the modelling methodology and simulation results, the models are applied to Canadian sites, including the Prairies.

In Wu et al. (2007: *Atmosphere-Ocean* 45(1), 37-45), we drive VIC in the water balance mode using observed maximum and minimum air temperatures and precipitation to map daily soil moisture values over China for the period January 1971 to July 2005. The model is applied over a grid of 10,458 points with a resolution of 30 km. The model is first calibrated using observed hydrographs from 35 catchments with drainage areas ranging from 190 to 351,530 km^2. The model is then validated over these catchments over different time periods, and over an additional 8 catchments. An estimation procedure to determine model parameters is developed and applied to catchments where hydrographs are not available for the standard calibration process. VIC performs well over both calibration and validation catchments, especially in humid and semi-humid regions. The 35-year soil moisture climatology for the top 1 m from the model is consistent with known soil moisture conditions in China.

Wen et al. (2007: *Journal of Hydrology* 345, 1-15) evaluated two versions of CLASS using site-specific data and observed hydrographs from the monsoon regions of China. The first is CLASS version 2.7, which we refer to as the standard version. The second is a modified version of CLASS, where we use a field capacity threshold together with a spatial probability distribution function to represent sub-grid scale variability in soil field capacity. We also introduce a linear reservoir at the bottom of the third CLASS soil layer to model the baseflow. The 1998-99 HUBEX/GAME IOP data set is used for model verification. Both CLASS versions are evaluated for their ability to simulate net radiation, sensible and latent heat fluxes, ground heat flux, and soil temperature and moisture over four measurement sites with different land covers in the Huaihe River Basin. The total runoff in the Shiguanhe sub-basin simulated by the two versions is similar, and close to the observed value. The main difference is the partitioning of runoff components among the surface runoff, interflow and baseflow. Modified CLASS simulates better both the intensity and timing of peak flows. Both versions also simulate well the net radiation, heat fluxes and soil moisture and temperature. Our modification thus leads to an improvement in runoff and hydrograph simulation, while preserving its existing positive features.

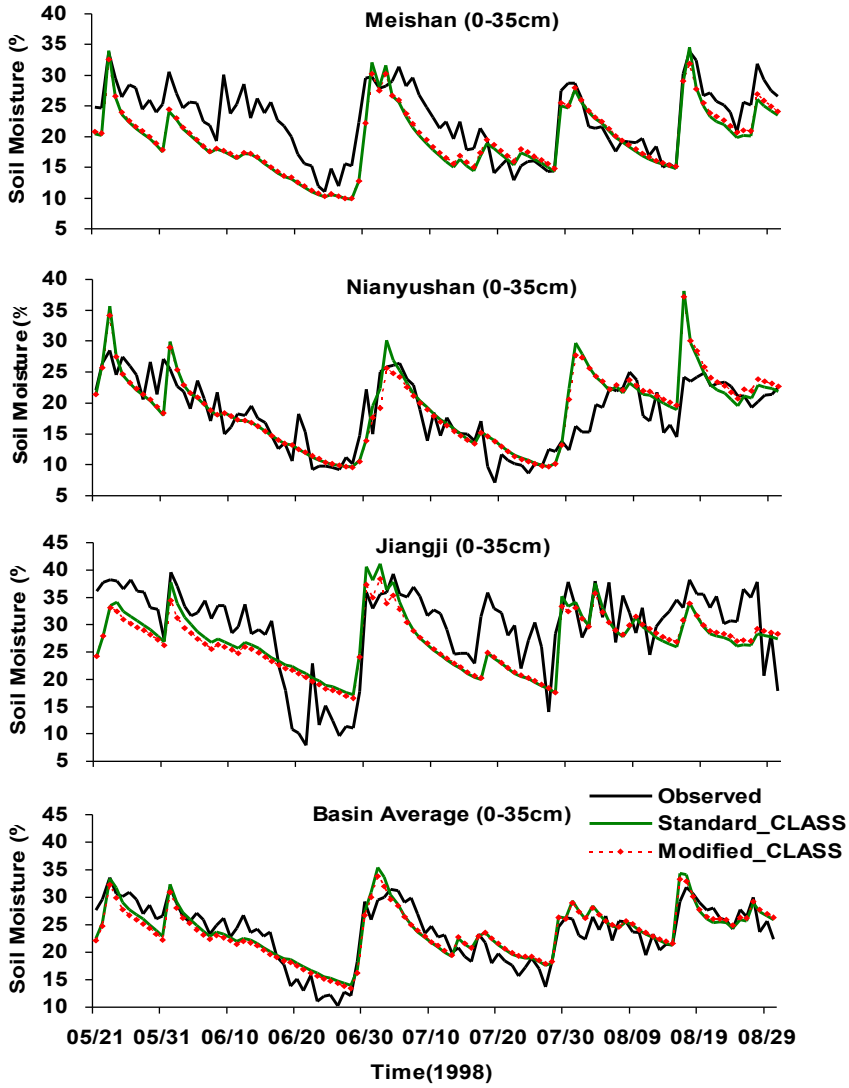

Figure 1: A comparison of soil moisture content simulated by standard (green) and modified (dashed red with diamonds) CLASS with observed values (black) over the period May to August 1998 at three measurement sites (Meishan, Nianyushan, Jiangji) in the Huaihe River Basin and the sub-basin average.

Having tested the modelling methodology, we have applied VIC in a stand-alone mode over two regions in Canada: the Liard Basin in the Mackenzie River Basin, and the three Canadian Prairie provinces. Over the Liard Basin, VIC calibration (1994-99) and validation (1975-2001) are performed using observed hydrographs at Fort Simpson. Nash scores are of order 0.87 and 0.78 for the calibration and validation periods respectively. We have also set up VIC over the Prairie provinces, at a resolution of 0.25° by 0.25° latitude/longitude. Observed values from 1,167 meteorological stations are used for the forcing data. Allowance for non-contributing areas is made by stopping the simulated interflow from contributing to runoff in these regions. Calibration and validation are done over 11 catchments. The Nash scores range from 0.40 to 0.80 (average 0.60) for daily flows, and 0.58 to 0.87 (average 0.72) for monthly flows. A Soil Moisture Anomaly Percentage Index (SMAPI) has been calculated over the Prairies for the period January 1950 to December 2005, and the results are available on the DRI website (www.meteo.mcgill.ca/~leiwen/vic/prairie). We have started to use SMAPI to reconstruct the history of prairie droughts over this period, and the preliminary results are encouraging. Papers are now being written reporting on these results.

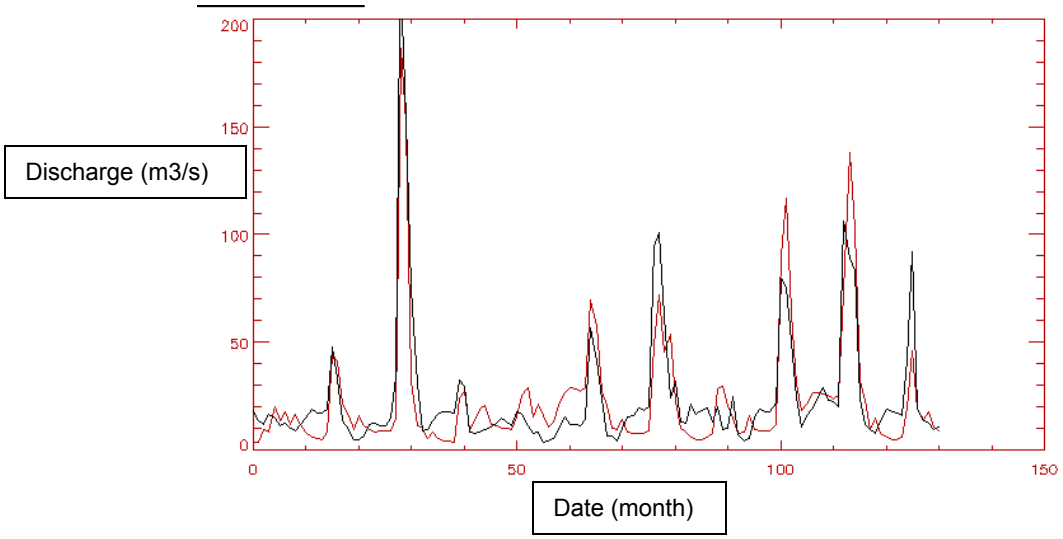

Figure 2: The validation results over the Assiniboine Basin for monthly flows over the period 1977-87, with observed values in black and simulated values in red. The Nash scores are 0.77 and 0.62 for monthly and daily flows respectively.

We have started to examine the seasonal forecasts from the Historical Forecast Project (HFP) over North America; HFP is a CLIVAR project and is led by Jacques Derome of McGill University and George Boer of CCCma. They are both collaborators of DRI. We investigate the skill in mean monthly forecasts of GCM3 (coupled to CLASS) of HFP2 (phase 2 of HFP) for the period 1969-2003 over North America. We focus on the 500 hpa geopotential height (Z500), precipitation and soil moisture. Temporal correlations are calculated for each month's forecast, with observational values taken from the NCEP global reanalyses for verification. The highest skill is found for Z500, with correlations reaching 60% and higher in February and March over North America and the Prairies (Figure 3). The minimum skill for North America is found for October with only 39% correlation. In the warm season, June is the month with the highest skill (55%), whereas July and August also show statistically significant scores of 44% and 49% respectively. The skill is no longer significant when the lead time of the monthly forecasts is increased to one month. For the summer seasonal forecasts, the skill for the June-July-August forecast is 45% and 39% for lead times of zero and one month respectively. It is not surprising the skill is highest for the 1-

month forecast at zero lag, due to the dominant role of the initial conditions. Preliminary results show the skill scores of the forecasts for precipitation and soil moisture are low.

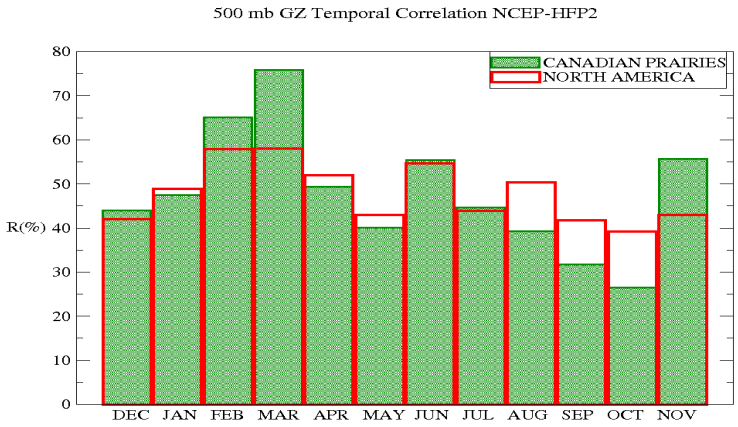

Figure 3: The skill of the mean monthly forecast from GCM3 (coupled to CLASS) throughout the year from December to November. The statistics are compiled based on the period 1969-2003. Results for both North America and the Canadian Prairies are shown.

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 seasonal forecast project involves the participation of Jacques Derome, Hai Lin and George Boer, principal scientists of the HFP project. There are thus links to CLIVAR and Environment Canada. We have also 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 was prepared and submitted to DRI after the workshop.

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.

Research results are published in refereed journals as they become available.