Canadian PUB planning and implementation

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Abstract The concept of the IAHS Predictions in Ungauged Basins (PUB) program has been widely embraced by the Canadian water resource community because its science plan is seen by many as a useful foundation from which Canadian water science and management issues can be addressed. Water managers are keen to update their predictive tools to those that encapsulate the recent advances in hydrological science; their interest is driven by the low density of streamflow gauges and the poor understanding of the hydrological and water quality processes and regimes. An initial Canadian PUB workshop held in Yellowknife, Northwest Territories in March 2004 developed a series of recommendations for PUB in Canada. The mechanism proposed to lead to reductions in predictive uncertainty will be a nested monitoring and research basin network (MRBN) across key regions of the country with involvement from academia, government and industry.

Key words Canada; hydrometric network; prediction; PUB

CANADA AND THE PREDICTIONS IN UNGAUGED BASINS (PUB) INITIATIVE

The Water Survey of Canada (WSC) and the Canadian Society for Hydrological Sciences (CSHS) hosted a workshop in Yellowknife, Northwest Territories on 8 and 9 March 2004 to develop a formal coordinated Canadian PUB effort. The focus was on Canada's cold regions because Northern Canada's current economic growth rate, its high proportion of ecologically sensitive landscapes, sparse monitoring network and poorly understood hydrological processes place high demands on infrastructure designers. The workshop's objectives were to:

(1) provide outreach to practitioners of the results of recent cold regions hydrology research in the context of predicting streamflow;
(2) assess "state of the art" techniques to predict streamflow in ungauged basins in northern landscapes; and
(3) define technical needs and recommend a research agenda that can deliver these over the next decade. The outcome of this objective is to define how Canada can contribute to the PUB initiative.

In regards to objective (3) above, recommendations mirrored recent reviews of Canada's water resource policy (Environment Canada, 2004; O'Neill, 2004; Thormann *et al.*, 2004; Whitfield *et al.*, 2004) that call for focused research on hydrological processes and their incorporation into predictive tools. There was consensus among the workshop participants that a research basin approach advocated and demonstrated by Pomeroy *et al*. (2005) will improve the understanding of hydrological processes and permit the incorporation of this knowledge into tools that will reduce predictive uncertainty. In summary, the workshop participants recommended that efforts encapsulate all of Canada's regions by:

(1) Establishing a nested monitoring sub-network of the Water Survey of Canada hydrometric network, with coordinated multi-scale research efforts that lead to improved understanding of hydrological processes and incorporation of this knowledge into predictive models.
(2) Developing multi-scale environmental data sets to facilitate the exchange of data between research and monitoring partnerships and comparative model testing.
(3) Organizing a Canadian PUB committee, tasked to carry forward these recommendations within the context of regional working groups (Spence *et al*., 2005).

A MONITORING AND RESEARCH BASIN NETWORK FOR CANADA

Few Canadian streamflow regimes are well defined or delimited, and that increases the uncertainty, and cost, of engineering design. It is therefore critical that Water Survey of Canada and its partners design an efficient programme that can support the development of tools that can be used to characterize streamflow regimes with a minimum of uncertainty. The foundation for these tools is a strong sustainable observational network that responds to current, immediate needs and anticipates future demands. New theories and modelled data cannot be tested if suitable data sets are not available. Furthermore, observed data is necessary to assess uncertainty. In order to meet PUB objectives of reducing uncertainty associating with prediction and in response to the first recommendation from the Yellowknife workshop, the Water Survey of Canada, its partners and clients have proposed a methodology. This methodology focuses on the identification and implementation of a Monitoring and Research Basin Network (MRBN) supported by the Water Survey of Canada hydrometric network, university and government research, and industry. Its purpose will be to advance research and develop predictive tools that can assist in the construction of water policy, the characterization of ungauged basins for design, water resource allocation and environmental assessment across Canada. Initial thoughts are that activities in candidate basins should at least:

(1) have definitive engineering design and/or environmental prediction goals;
(2) include high quality collaborative monitoring and research;
(3) operate at a relevant range of space and time scales;
(4) have high rationale;
(5) exhibit demonstrable return;
(6) be representative of Canada's hydrology.

Identifying this network is one piece of a broader effort. This sub-network of basins is meant to provide a foundation for coherent multi-scale research and monitoring programmes of the water and energy cycle, and possibly water quality and sediment processes, by university and government scientists. Regional workshops are planned across Canada following which nomination of MRBN basins by research consortiums can proceed. These partnerships of scientists, water managers, industry and stakeholders will define their own research and development objectives, but remain true to the focus of PUB—reducing predictive uncertainty. As MRBN groups develop, there is the potential for comparability of approaches, data, theories and models. The network of MRBN basins would supply databases necessary to test scale transferability and the influence of scale on hydrometeorological processes as suggested in the second workshop recommendation.

A CANADIAN PUB FRAMEWORK

Two levels comprise the Canadian PUB framework—a Canadian National Committee for PUB (CNC-PUB) and participation in PUB working groups. The committee recommended at the Yellowknife workshop is taking the form of CNC-PUB. CNC-PUB has been endorsed by the Canadian National IAHS Committee and (CNC-IAHS) will be a joint committee of the Canadian Geophysical Union—Hydrology Section (CGU-HS) and the Canadian Society for Hydrological Sciences (CSHS). CNC-PUB is Canada's national working group and has six key responsibilities. These are:

(1) liasing with water resource managers and government agencies in the development of programmes supportive of the PUB initiative;
(2) supporting PUB working group implementation and funding;
(3) supporting outreach of working group scientific progress;
(4) encouraging technology transfer from the working groups;
(5) encouraging linkage between Canadian PUB research and international PUB thematic working groups;
(6) reporting to IAHS on Canadian PUB activities.

The regional MRBN workshops are meant to act as major catalysts for Canadian researchers to lead or participate PUB working groups. CNC-PUB provides front and back end support to these groups by providing logistical and scientific direction during working group development and a means of outreach and technology transfer once scientific results and tools have been developed. The linkage between CNC-PUB and Canadian scientific and professional societies will aid in disseminating working group results.

CANADIAN SCIENCE CONTRIBUTIONS TO PUB

The hydrological research and tool development priorities for Canada are diverse. Snowfall, rainfall, evapotranspiration, runoff, infiltration and storage are key water cycle terms for which better understanding is necessary for sound water resource management and infrastructure design. Information is needed of the full range of streamflow regimes, including low and high flows. Space and time scales of less than 1000 km^2 and no longer than a month are priorities because they are presently the most problematic in terms of prediction and design. In addition, we understand very little about how smaller basins are influenced by rare processes and how to design for them (Spence *et al*., 2005). The influence of variable contributing areas is a distinct problem for streamflow prediction on typical Canadian landscapes (Richards & Brenner, 2004; Quinton & Hayashi, 2005; Spence & Woo, 2006). Not only does the Canadian water resource community need to better understand temperate zone hydrological processes predominant in other countries, but also cold zone processes such as those associated with snow, frozen ground and glaciers. Tools to account for non stationarity in time series need to be developed for the Canadian situation because the region is subject to both climate change (Zhang *et al*., 2001) and cyclical variability (Spence, 2002).

PUB encourages the development of techniques that can be tested and compared among landscapes (Sivapalan *et al*., 2003). Soulis *et al.* (2005) proposed a modelling framework that lends itself well to the goals of Canadian PUB science. The Modelling the Environment Community modelling system (MEC) has been developed by the Meteorological Service of Canada (MSC) in collaboration with many Canadian groups including universities and the private sector. The main objective of this system is to optimize research and development in environmental modelling by sharing a unified modelling environment for the atmosphere and Earth surface. The land surface portion, known as MESH, allows hydrology-land surface schemes (H-LSS) to run independently or embedded within atmospheric models over a local domain. The former application allows for off-line testing using observed forcing data at the small research basin scale where the energy and water budget can be closed experimentally, thus reducing both parameter and model uncertainty. This provides a possible scaling or transfer mechanism as findings at the experimental basin scale could be translated to other domains.

CONCLUDING REMARKS

The most significant gap between understanding and pragmatic need is at the smaller space and time scales, particularly those less than 1000 km^2 and shorter than a month. There are particularly large gaps in understanding the role of variable contributing area, storage and phase change on water resources. The cold nature of the Canadian climate means Canadian hydrology encompasses all the temperate zone processes experienced in other countries as well as cold zone processes such as frozen ground, river ice, snow redistribution and glaciers, that must be understood to predict the water cycle in ungauged basins.

New process understanding needs to be incorporated into predictive tools that can extrapolate long-term data from short records and fill spatial gaps. These tools need to be tested in a comprehensive manner over a range of landscapes in order to discern their usefulness and the degree of uncertainty associated with using them. A practical framework to do so has been forwarded by the Meteorological Service of Canada that allows for the coupling of atmospheric, land surface schemes and hydrological models. While a research tool today, such a framework in the future may provide practioners with improved water cycle prediction with an acceptable level of uncertainty.

Water Survey of Canada is supporting PUB initiatives in Canada with their proposed MRBN programme. This programme can be a catalyst for Canadian involvement in PUB working groups addressing the science gaps noted above. These working groups could be focused on geographically specific issues in individual MRBN basins, or may choose to conduct thematic research in several basins.

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