HEPEX Project
Great Lakes testbed progress report #1

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1 Project purpose

The purpose of this test bed is twofold:

- first, we want to propose to the scientific community a hydrological modelling environment and an ensemble hydrological forecasting system which can be used to experiment, on a basin large enough to be resolved by currently available meteorological ensemble forecasting systems, with the spatial resolution and parameterization of atmospheric, land-surface and hydrologic models;
- then, together with end users responsible for water management on the basin, to evaluate the impact of these modelling choices on the accuracy and reliability of ensemble streamflow forecasts, with the final objective of convincing them to move towards using outputs from ensemble forecasting systems in their decision-making processes.

The goals of the Great Lakes testbed project are therefore:

- to evaluate the impact of the spatial resolution and parameterization of the atmospheric, land-surface and hydrologic models on hydrologic forecasts for the Great Lakes and St. Lawrence basin;
- to evaluate the impact of using a multi-model ensemble forecasting system, such as the North American Ensemble Forecasting System (NAEFS) instead of a single model ensemble forecasting system;
- to measure the value for end users of using ensemble weather predictions instead of climatology for lead times of up to two weeks.

To reach these goals, we have identified five objectives:

- We aim to provide the scientific and user communities with a community hydrologic prediction system named MESH[1] which will simplify the process of making and comparing hydrologic predictions on the Great Lakes and St. Lawrence basin using different atmospheric, land-surface and hydrologic models running at different spatial resolutions. In particular, participants in the project should be able to use MESH to set up a hydrological model on any subbasin of the Great Lakes and St. Lawrence basin at a spatial resolution of their choice (up to 1 km), and then to generate hydrological predictions by forcing the hydrological model with an ensemble of meteorological forecasts.
- Using MESH, we want to set up and verify a reference distributed hydrological model at a resolution of one sixth of a degree on the basin which takes into account the sub-grid heterogeneity in the land cover using a tile approach. This reference model will comprise of a land-surface scheme coupled with a routing model which will deal with drainage, surface and sub-surface runoff. Participants should be able to use this MESH setup to run hydrological simulation and forecasting experiments on the whole basin if they so choose.

[1] In French, MESH stands for Modélisation Environnementale communautaire - Surface et Hydrologie, which means community environmental modelling focused on surface and hydrology.

- Using this reference hydrological model, we will then provide interested parties with ensemble predictions (based on various meteorological ensemble prediction systems) of surface variables (runoff and snow water equivalent) as well as hydrological variables (streamflow and lake inflows).

- Together with the scientific and user community, we also wish to produce calibrated probabilistic forecasts from the raw ensemble forecasts, testing for that purpose various ensemble-MOS techniques.

- Finally, together with the user community, we shall verify the ensemble and the probabilistic forecasts and assess their value. In particular, we want to compare the forecasts obtained using the reference hydrological model using different ensemble prediction systems to the forecasts using either existing, operational, forecasting systems on the Great Lakes and St. Lawrence basin or to results from experimental forecasting systems, obtained for example by running MESH at a higher resolution on specific subbasins.

2 Accomplishments during the past year

Most of the past year was dedicated to planning, building support for the project and linking with other organizations having shown interest in the project. The testbed project was presented at a workshop entitled "Surface and Subsurface Water Quantity Modeling/Prediction Activities within the Great Lakes - St. Lawrence - Gulf Region" held in Burlington, Ontario in January 2006 (Pietroniro et al., 2006b), during which it was decided to focus on the verification of the reference distributed hydrological model, and in particular of its ability (1) to simulate snow accumulation and ablation, and (2) to simulate streamflow and lake levels.

2.1 Hydrological modelling using MESH

The result of this study, together with a complete description of the hydrological modelling system, has been submitted for publication in a special issue on hydrological uncertainty of the journal Hydrology and Earth System Sciences (Pietroniro et al., 2006a). In this paper, the authors show that MESH can indeed be used to model the hydrological cycle on the Great

Lakes and St. Lawrence at a regional scale. While interesting results have been obtained regarding streamflow simulation, the simulation of lake level is still difficult. Errors in lake levels can be attributed to a number of factors including poor estimates of evapotranspiration, limited lake routing model, lack of regulation effects in the lake routing, and no reservoir routing in the tributary catchments. Given all of the potential errors, the results are still quite acceptable and encouraging.

2.2 Snow modelling using MESH

Excellent results have been obtained for snow water equivalent prediction using a combination of two energy-balance models embedded within the CLASS 3.0 and ISBA land-surface schemes available within MESH, which has given us the idea to use the prediction of snow water equivalent provided by MESH as a first guess for a snow water equivalent analysis. The objective is here not only to provide the best initial conditions to the hydrological model but also to assess and take into account the uncertainty on these initial conditions, by providing the hydrological model with an ensemble of initial conditions for the state of the snowpack. This idea is discussed in a paper by Seidou et al. (2006), has been presented in a poster presented at the 2nd symposium on Quantitative Precipitation Forecast and Hydrology (Fortin et al., 2006c) and in a paper submitted for oral presentation at the annual conference of the Canadian Dam Association (Fortin and Turcotte, 2006). The impact of using a tile approach to take into account the sub-grid heterogeneity in the land cover on the prediction of snow accumulation and melt has also been studied by Larocque (2006).

The ability of the Canadian ensemble prediction system to forecast snow accumulation on the basin has also been investigated. Results, which have been presented at the April workshop of the NAEFS project (Fortin et al., 2006b), show that (1) it is possible to diagnose the precipitation bias from this analysis, (2) members which perform better use a combination of the GEM atmospheric model with the ISBA land-surface scheme, and (3) these members can be used to obtain quite accurate estimations of snow water equivalent on such a large basin. This illustrates that hydrological modelling experiments can be used to evaluate the quality of an ensemble prediction system, and provide feedback to the atmospheric modelling community, thus helping to improve the quality of the meteorological forecasts.

2.3 Calibration of ensemble meteorological and hydrological forecasts

Some thought has also been given to the problem of obtaining calibrated probabilistic forecasts from ensemble forecasts. Fortin et al. (2006a) as well as Fortin and Favre (2006) have experimented with the best member method for post-processing ensemble precipitation forecasts used as inputs for MESH and Fortin (2006a,b) has tested the Bayesian processor of output (BPO) for obtaining probabilistic forecasts of snow accumulation from MESH outputs. A research proposal is in preparation to address this issue more thoroughly.

2.4 Linking with the scientific and user communities

End users which have shown interest in this project include Hydro-Québec, the largest hydropower utility in North-America, the Centre d'Expertise Hydrique du Québec (CEHQ), which issues hydrological forecasts for public dams in Québec, and the International St. Lawrence River Board of Control (ISLRBC), which oversees the implementation of some of the decisions of the International Joint Commission (IJC), responsible for managing the water in the Great Lakes.

Contact has been established with Dingchen Hou and Zoltan Toth at NCEP with the objective of extending the hydrological model that they have set up on the conterminous United States so that it covers the Great Lakes Basin. As this model will also be used to obtain ensemble forecasts based on the NAEFS products, it should enable us to compare two hydrological models on the Great Lakes for the purpose of ensemble hydrological forecasting and eventually obtain multi-model hydrological ensemble forecasts on the Great Lakes.

Contact has also been established with Roberto Buizza at ECMWF to see if we could obtain ensemble forecasts from ECMWF and compare them to NAEFS forecasts for the purpose of hydrological forecasting. While it seems that we could indeed obtain such forecasts for research purposes, lack of resources has prevented us for now from taking advantage of this opportunity.

We have also met with forecasters and developers at the Northeast River Forecast Center (NERFC) of the U.S. National Weather Service (NWS) which is responsible for issuing hydrological forecasts for some of the basins (located in the Adirondacks) which flow into the St. Lawrence basin. We expect to be able to compare the deterministic forecasts and the probabilistic

volume forecasts that they issue for these rivers with probabilistic hydrological forecasts based on ensemble meteorological forecasts.

Finally, we have discussed with Hydro-Québec and BC Hydro the problem of assessing the economic value of ensemble forecasts for hydrological prediction. In particular, we have worked jointly to assess the quality of existing ensemble forecasting systems, which do not use ensemble meteorological forecasts, in use both at Hydro-Québec and at BC Hydro (Weber et al., 2006a,b). A verification software in development at Hydro-Québec's research institute has been used to that effect on both Hydro-Québec's and BC Hydro's forecasts. We are therefore hoping that the same techniques will be used to verify the ensemble forecasts obtained for the Great Lakes testbed and for the testbed focusing Western US and BC basins.

3 Plans for the coming year

During the coming year, we plan to setup an ensemble hydrological forecasting system based on our reference distributed hydrological model which will be used to issue ensemble hydrological forecasts based on the NAEFS system on a weekly basis. These experimental forecasts will be provided to interested parties for evaluation.

Once this system is set up, we will then proceed to set up parallel forecasting systems which will aim at improving some elements of the forecasting system, including the calibration of the ensemble forecasts (both meteorological and hydrological) and the spatial resolution of the hydrological model.

We then aim to verify the different forecasting systems by scoring them against existing forecasting systems on the basin in use at Hydro-Québec, the NWS and the ISLRBC, none of which make use of ensemble meteorological forecasts.

4 List of publications and presentations

- Fortin, V. (2006a). Anticipation probabiliste du stock de neige au sol partir de prvisions d'ensemble. Invited conference presented at the annual conference of the French Statistical Society (SFdS), Clamart, France, May 29 – June 2, 2006.

- Fortin, V. (2006b). Ensemble prediction of snow water equivalent using the Bayesian Processor of Output. Working paper, June 14, 2006.

- Fortin, V. and A.-C. Favre (2006). Taking into account the rank of a member within the ensemble for probabilistic forecasting based on the best member method. Proc. of the 18th Conference on Probability and Statistics in the Atmospheric Sciences, American Meteorological Society, Atlanta, 30 January – 2 February 2006.

- Fortin, V., A.-C. Favre and M. Saïd (2006a). Probabilistic forecasting from ensemble prediction systems: improving upon the best member method by using a different weight and dressing kernel for each member, Quarterly Journal of the Royal Meteorological Society, to appear.

- Fortin, V., A. Pietroniro, N. Kouwen, C. Neal, R. Turcotte and P. Pellerin (2006b). A Canadian contribution to HEPEX: The Great Lakes Testbed project. Presentation made at the NAEFS workshop, May 25, 2006.

- Fortin, V., R. Turcotte, P. Pellerin, O. Seidou and D. Tapsoba (2006c). Taking into account the uncertainty on the state of the snowpack in hydrological forecasts. Poster presented at the second "QPF and Hydrology" symposium held in Boulder, June 4-8, 2006.

- Larocque, R. (2006). Analysis of a system for resolving sub-grid heterogeneity in CLASS. Internal report, Numerical weather prediction research, Environment Canada.

- Pietroniro, A., V. Fortin, N. Kouwen, C. Neal, R. Turcotte, B. Davison, D. Verseghy, E.D. Soulis, R. Caldwell, N. Evora and P. Pellerin (2006a). Using the MESH modelling system for hydrological ensemble forecasting of the Laurentian Great Lakes at the regional scale. Hydrology and Earth System Sciences, submitted for publication.

- Pietroniro, A., V. Fortin, P. Pellerin and B. Davison (2006b). Towards a Canadian hydrological ensemble prediction system. Poster presented at the workshop "Surface and Subsurface Water Quantity Modeling/Prediction Activities within the Great Lakes - St. Lawrence - Gulf Region" held in Burlington, Ontario in January 2006.

- Seidou, O., V. Fortin, A. St-Hilaire, A.-C. Favre, S. El-Adlouni and B. Bobée (2006). Estimating the snow water equivalent on the Gatineau catchment using hierarchical Bayesian modelling, Hydrological Processes, to appear.

- Weber, F., L. Perreault and V. Fortin (2006a). Measuring the performance of hydrological forecasts for hydropower production at BC Hydro and Hydro-Qubec. Proc. of the 18th Conference on Climate Variability and Change, American Meteorological Society, Atlanta, 30 January – 2 February 2006.

- Weber, F., L. Perreault, V. Fortin and J. Gaudet (2006b). Performance measures for probabilistic hydrologic forecasts used at BC Hydro and Hydro-Qubec. Presentation made at the EGU General Assembly, Vienna, 2-7 April 2006.