Hydrological modelling using convective scale rainfall modelling – phase 3

Project Summary SC060087/S2

Flood forecasting could benefit from the latest computer modelling and forecasting technology available from the UK Met Office, particularly to predict floods following severe storms, according to a new report by Environment Agency.

This report explores hydrological model concepts and computer modelling methods that make best use of the latest Met Office technology in high resolution and probabilistic rainfall forecasting. Regional case studies in the South West and the Midlands were used to evaluate the hydrological models, and these were subsequently extended to include a nationwide test of the G2G (Grid-to-Grid) distributed hydrological model. The potential for flood forecasters to use ensemble rainfall forecast products such as MOGREPS (Met Office Global and Regional Ensemble Prediction System), STEPS (Short-Term Ensemble Prediction System) and NWP (Numerical Weather Prediction) were also investigated.

Two test cases were examined: the Boscastle flood of August 2004 in the South West and the June/July 2007 floods in the Midlands. For these case studies, existing or newly calibrated lumped hydrological models were used as benchmarks against which to assess the potential value of a distributed hydrological modelling approach to flood forecasting. For the Boscastle study, a split sample method was used where distinct calibration and verification periods were identified. For the Midlands test case (which was modelled as part of the nationwide study), paired benchmark catchments were identified, one of each pair being treated as gauged (monitored) and the other as ungauged (not monitored). The hydrological modelling included two lumped rainfall-runoff models of the type used currently - the PDM (Probability Distributed Model) and MCRM (Midlands Catchment Runoff Model) – together with two distributed hydrological models: the physics-based REW (Representative Elementary Watershed) model and the physical-conceptual G2G model.

For the Boscastle test case, model performance ranged from good to excellent for catchments across the Tamar and Camel river basins.

The lumped PDM model performed best, followed by the G2G model and then the REW model. For both the distributed models, the performance for ungauged sites was similar to the performance for gauged sites, indicating the potential usefulness of these models to forecast floods at ungauged river locations. When used in combination with different resolution (12, four and one km) NWP model rainfall forecasts, hydrological models performed best using the higher resolution forecasts, with the greatest performance moving from 12 to four km. When driven with a pseudo-ensemble of high resolution NWP rainfall forecasts (produced by random position displacements within a defined radius) the distributed model was better able to capture differences between the ensemble members. The generated hydrographs showed a spread in size and shape that sensibly reflected the changing position of the storm pattern over the catchments assessed.

The test case over the Midlands considered rural and urban catchments of low relief in the Avon and Tame river basins respectively, providing a more challenging modelling problem than the higher relief Tamar and Camel catchments of the Boscastle test case. The G2G model was assessed with reference to the summer 2007 floods, using the lumped MCRM as a benchmark model reflecting operational practice in the Midlands. Whilst the site-specific lumped models, as expected, proved hard to improve, the G2G model performed well across a range of catchment types. However, problems arose where the natural flow regime was affected by water imports/exports in urban catchments. Floods in summer 2007 were examined in detail using ensemble rainfall forecasts from NWP and STEPS. The sensitivity of the G2G model to the spatio-temporal structure of storms makes it particularly suitable for ensemble rainfall forecasts for probabilistic flood forecasting of convective-scale events such as storms .

The success of the G2G model in the Boscastle test case resulted in a project extension to consider a nationwide study of the G2G model across England and Wales.

Performance proved to be mixed. Model calibration and assessment was affected by problems with rainfall data obtained from the National Flood Forecasting System (NFFS) archive and by unaccounted for catchment abstractions and returns. Assessment using benchmark pairs of gauged/ungauged catchments showed that the G2G model gives comparable performance for both, confirming its utility for forecasting at ungauged catchments.

The report concludes that the G2G model offers a practical approach to nationwide flood forecasting that complements more detailed regional flood forecasting. It is able to represent a wide range of hydrological behaviours through its link with terrain and soil properties. The distributed model forecasts, however, are best used alongside, and not instead of, those from lumped catchment models in typical rainfall conditions.

The possibilities for using MOGREPS and STEPS ensemble rainfall forecast products were investigated within the current NFFS configurations for North East and Thames regions. Evaluation included configuration issues, data volumes, run times and options for displaying probabilistic forecasts within NFFS. A nationwide calibration of the G2G model was also tested in an operational NFFS environment and a trial system has been running for about six months. Although available, ensemble rainfall forecasts from MOGREPS were not extensive enough to verify its performance.

The report concludes that the use of MOGREPS in current Environment Agency regional forecasting can provide better information to the forecaster than deterministic forecasts alone. In addition, with careful configuration in NFFS, MOGREPS can be used in existing systems without a major increase in system load. Configuration of STEPS ensemble rainfall forecasts for hydrological models required relatively little effort to implement. However, no verification of the actual performance was possible in this study.

This summary relates to information from project SC060087, reported in detail in the following output(s):

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