Joint Centre for Hydro-Meteorological Research

Report on Research Activities 22 March to 1 October 2004

1. Precipitation Nowcasting R&D

1.1 Nimrod and Gandolf

The Gandolf R&D programme in 2004-2005 remains focused on two areas: (i) quantifying errors in quantitative precipitation nowcasts in ways suitable for customer use through the development of the Short-Term Ensemble Prediction System (STEPS), and (ii) improving STEPS' predictions of locally-forced precipitation unresolved or partly resolved by mesoscale, operational Numerical Weather Prediction (NWP) models. A recent off-line verification study of STEPS performance (Met Office Forecasting Research Technical Report 433) demonstrated the need to account for two additional sources of uncertainty before an operational trial of the scheme could be justitifed: uncertainty in the radar observations, and errors arising from the mesoscale model's inability to resolve and predict localised orographic enhancement.

Work on incorporating an observation uncertainty algorithm into STEPS is being undertaken by collaborators at the Bureau of Meteorology in Melbourne. This work seeks to represent the uncertainty in radar-inferred surface rain rate by adding stochastic perturbations to the best guess analysis of surface rain rate. The principle challenge lies in representing the complex spatial and temporal variations in uncertainty arising from numerous sources (e.g. assumptions made about: the drop size distribution, wave propagation, variation in the vertical profile of reflectivity). To date, work has focused on the collection and analysis of large datasets of collocated, high resolution radar and disdrometer observations.

Work on the incorporation of an orographic enhancement scheme within STEPS will commence in October 2004.

Nimrod developments over the past six months have focused on preparations for the ingestion of Meteosat Second Generation (MSG) data, including improved cloud top height and cloud mask products. The existing operational feed of Meteosat-7 data from the Met Office's satellite data processing system, Autosat, was successfully switched to the MSG feed in August 2004.

1.2 Development of a post-processing system for a high resolution UK NWP model

Plans for the operational implementation of a high resolution (~ 4km) UK NWP model in spring 2005 and a convective scale (1 km) NWP model towards the end of the decade will require a much closer integration of these models with NWP post-processing algorithms such as those implemented within Nimrod, Gandolf, and the CDP [Convection Diagnosis Project]). This requirement stems from expected changes in NWP data assimilation and operation, and a blurring of the distinction between NWP and short-range forecasting (nowcasting) methodologies.

In April 2004 a new project was initiated to develop a UK NWP post-processing system for implementation on the NEC SX6 supercomputer. The first version of this system, to be implemented in April 2005, will incorporate Nimrod-based algorithms for the downscaling and nowcasting of the following key variables: surface precipitation, visibility including fog

probability, temperature and wind. Deterministic versions of STEPS' precipitation nowcast algorithms will also be implemented.

To date, several scoping studies have been undertaken to investigate the viability and cost effectiveness of migrating I/O intensive post-processing algorithms to a supercomputer platform. The impact of proposed changes in the IT infra-structure in the Met Office have also been considered in the preparation of a design specification for the system.

2. Hyrad and RFFS

An upgrade to the White Cart River Flow Forecasting System (RFFS), providing flood warning support to an area south of Glasgow (Scotland), has been completed with the system now on operational trial. The system encompasses Hyrad receipt of radar data from the Met Office, an RFFS upgraded to FloodWorks form using PDM rainfall-runoff and KW channel flow routing models, and with an ISIS hydrodynamic model at its downstream end. Training was included in the supply by CEH and Wallingford Software.

The Hyrad implementation for the Environment Agency has been configured to receive Mesoscale Model product data (rainfall and temperature at present): this is now operational. Hyrad supports functionality to display these data as images and catchment average time-series and pass the latter on to flood forecasting and modelling systems in use by the Agency. Hyrad receipt of MOSES-PDM products, supplied via the Nimrod environment, is in the process of being configured and trialled before going operational later this year.

3. Extreme Event Recognition

This Defra R&D Project involves a Met Office lead consortium encompassing inputs from CEH and the University of Salford. The overall objective is to improve the capability to provide warnings of extreme flood events via improving rainfall forecasts and flood forecasting models/procedures (including decision-support). CEH is developing spatio-temporal rainfall datasets, using radar and raingauge data from historical heavy rainfall events, enhanced to represent extreme events. These datasets are being used to evaluate and improve the performance of hydrological models under such extreme event conditions.

Work has progressed on identifying Case Study events and catchments associated with extreme convective, frontal and orographic rain. A methodology and software has been developed for transforming spatio-temporal rainfall datasets encompassing consideration of storm position, velocity, size, intensity and orientation. Critical flow associated with a return period (or damage level) has been related to a rainfall pattern/magnitude producing it, using a rainfall-runoff model as an intermediary tool. A Case Study convective storm over the Darwen (flooding Blackburn) has demonstrated remarkably good flow simulations using the PDM rainfall-runoff model, and without invoking model calibration at the two sites of interest. Indicative flow simulations have also been obtained using a distributed grid-to-grid model for the Boscastle convective storm (the flows were ungauged).

4. Flood modelling for ungauged basins

The Environment Agency are seeking improved ways of providing warnings for ungauged and low benefit locations that presently receive only a general Flood Watch service. CEH has been commissioned, under the EA/Defra National R&D Programme, to develop and evaluate improved techniques for flood forecasting at such locations with the eventual aim of the Agency offering a more targeted and technically sound flood warning service. A Guidelines Report on best practice is being developed alongside prototyping of new improved methods.

5. Use of Nimrod in Flood Forecasting

Currently the Environment Agency's hydrological flood forecasting models are most often calibrated with data from raingauges rather than from radar products. This is a factor which limits confidence when they are used with very-short-range precipitation forecasts derived from radar analyses and other fields available within the Met Office's Nimrod system. Also, in many areas the precipitation amounts analysed from radars have better spatial representativity than those derived from raingauges which should make the former the 'best estimate' for input to rainfall-runoff models. This project aims to find out if there is a benefit to be derived from the use of Nimrod products in flood forecasting models, to quantify it and assess its sensitivity to changes and enhancements to the Nimrod products.

Work done by CEH Wallingford for the Met Office and the Environment Agency has shown that a lack of consistency in radar datasets over time can be a problem for use in routine rainfall-runoff model calibration. Variable under- and over-estimation of flood peaks is a typical error signature when radar data are used as input to a rainfall-runoff model. The results were obtained for the Hameldon Hill radar and application to four catchments in the Upper Calder in Yorkshire. Model calibration indicated that the same model parameters could be used for both radar- and raingauge-based models except for the rainfall factor (adjusting for raingauge representativity) parameter. This has a bearing on the optimal use of Nimrod rainfall forecasts for extending the lead time of a raingauge-calibrated rainfall-runoff model.

6. Development of a storm-scale NWP model for quantitative precipitation forecasting

A scientist at the JCMM, Reading who spends one day a week at the JCHMR, is working on a project, jointly funded by the Met Office and Defra, to assess the hydrological performance of the Met Office NWP model when experimentally run with a grid-lengths of 1-4 km.

A report (Forecasting Research Technical Report (FRTR) No.402) has been issued which documents the results from simulations of four convective case studies using the model with horizontal grid-lengths of 12, 4, 2 and ~1km (and 38, 45 or 76 vertical levels). In all four case studies, an increase in horizontal resolution produced more accurate forecasts.

A second report (FRTR No.407) has been issued, documenting the sensitivity of high-resolution model forecasts to the convection scheme. This highlighted problems when using a 4km grid, and further emphasized the benefits of the 1km grid.

The report for Stage 3 of the project has been issued (FRTR No.423). A variety of new precipitation outputs diagnostics were examined including: catchment average and ‘worst case scenario’ average rainfall accumulations, the probability of a catchment average rainfall

accumulation exceeding a threshold, possible extreme point precipitation accumulations and peak rainfall rates within regions.

The project board agreed a modification to the plan for Stages 4 and 5 to take account of dependencies on other work being carried out in the Met Office, and of the close relationship between analyses and forecasts. Stage 4, now completed, developed the tools for verifying both analyses and forecasts. The report (FRTR No.432) gives a description of the methodology to be used for quantitative evaluation of high resolution precipitation analyses and forecasts. The verification measures were tested in an idealised framework to determine the characteristics of different scenarios of forecast and radar differences.

Stage 5 of the project involved carrying out the actual evaluation of both the fit of the analyses to radar, and the accuracy of the forecasts against radar accumulations. This has been done both for 1 km resolution case studies and for a long series of operational 12 km mesoscale model runs. Recommendations are being formulated on the ways the very high resolution NWP model precipitation outputs could be used in hydrological runoff/flow models.

Final reports are being written summarizing the scientific findings of the whole project and recommending future work.

7. Post-event Evaluation

The 2002-03 New Year heavy rainfall and flooding event caused disruption over many areas. The meteorological and hydrological forecasting of the event have been analysed and a report has been written for the Met Office and the Environment Agency.

A heavy rainfall event on 19/20 May 2003 is being studied. The incident concerned the non-issue of a Heavy Rainfall Warning in northwest Wales on 19 May 2003, when significant rain fell.

The extreme rainfall events of 8th (southern England) and 16th (Boscastle) August 2004 are being studied and preliminary reports have been written describing the performance of the operational nowcast and NWP forecast systems during these events. Runs of the recently developed experimental Short-term Ensemble Prediction System (STEPS – see Nowcasting R&D section above) were done for both these events and assessed. Experimental high resolution NWP models (4 km and 1 km grid-length) were run and these demonstrated the benefits of the higher resolution. In particular, the Boscastle event required higher than currently operational resolution to simulate the localised processes producing the extreme precipitation.

8. Rainfall Forecast Performance Monitoring

This project undertaken by CEH, was commissioned jointly by the Environment Agency and the Met Office. It aimed to develop methodology and algorithms for monitoring the quality of rainfall forecasts produced for the Agency by the Met Office in the form of the Daily Weather Forecast, the Evening Update and the Heavy Rainfall Warning. The results of the study were summarised in the previous 6 month report. Final revisions to the PC Tool and User Guide for forecast assessment have been made and the Phase I project brought to a successful close.

9. Development of a soil state and surface hydrology model in Nimrod

Information on the hydrological state of the ground is required by a variety of customers: the Environment Agency need to know the antecedent soil state for flood forecasting and also for water resource assessments; the military need information to enable them to make decisions on the ability of the terrain (potentially anywhere in the world) to support and allow passage of heavy vehicles; water companies and farmers also benefit from knowledge of the amount of water in the soil and how much of it is evaporating into the atmosphere.

Work in previous years has resulted in improved surface runoff and hydrology in the Met Office Surface Exchange Scheme (MOSES) by including CEH's Probability Distributed Moisture (PDM) scheme and the implementation of MOSES-PDM in the Nimrod nowcasting system. The MOSES-PDM land-surface model produces estimates of soil moisture and runoff on a 5km grid covering the UK. Diagnosing the accuracy of these model outputs is not straightforward, as soil moisture and runoff are not routinely or easily measured, especially as integrated values over an area. River flow, however, is routinely measured as an integrated quantity and can be used to analyse the performance of land-surface models. A Grid-to-Grid model has been developed to route the gridded runoff estimates from Moses-PDM to form estimates of river flow which can be compared to gauged observations. The model now operates at a 1km resolution across the Nimrod domain, which includes the UK, Northern France and parts of Scandinavia. A Project Final Report produced by CEH details the development and performance assessment of the Grid-to-Grid model for use in remote terrain where knowledge of water courses is limited.

Recent work has included:
(i) Implementation of the flow routing and inundation scheme developed by CEH within the operational Nimrod-MOSES-PDM. The surface and subsurface runoffs generated from MOSES-PDM grid squares are used as input to a flow routing and inundation model. The flow paths are automatically delineated on a 1 km grid using a digital terrain model. Representation of inundation requires inference of bankfull discharge at any stream location based on readily available information. A relationship with area and average annual rainfall has been established allowing a notional bankfull discharge to be estimated for all 1 km grid squares over the Nimrod domain. Thus, as well as absolute flows, the Nimrod system can now show flow as a fraction (possibly > 1) of the estimated bankfull flow.
(ii) The van Genuchten formulation of soil hydraulics has now replaced the Clapp-Hornberger formulation in Nimrod-MOSES-PDM. This allows direct use of the van Genuchten soil hydraulic parameters from the IGBP data and thus more accurate characterisation of the soil.
(iii) Observations from two LOCAR catchments (the Pang/Lambourn and the Tern) are being assimilated to make comparison with soil moisture from the operational Nimrod-MOSES-PDM. The data are available from Spring 2003, through the dry summer of 2003 and into the winter. Routines have been written to extract soil moisture data from the Nimrod-MOSES-PDM outputs. The data from the LOCAR sites have been received. For the Pang/Lambourn catchment, neutron probe data are available (at roughly fortnightly intervals and down to depths in excess of 3 m) for the whole of 2003 but the profile data (hourly intervals down to 1 m depth) is available from mid-summer to the end of the year. Some inconsistencies in the profile data have been identified and reported to the LOCAR team for attention. For the Tern catchment, only neutron probe data are available for the second half of 2003.

ELDAS: The ELDAS project (European Land Data Assimilation System to predict Floods and Droughts) is supported by the European Union in the context of the Fifth Framework Programme. Scientists from the Joint Centre are involved in a case study to compare the

ELDAS soil hydrology to the operational data available for the Autumn 2000 floods affecting South East England.

10. Global water and carbon cycles

Development of a community land surface model. The land surface models that are used in climate simulations have detailed descriptions of the main physical processes of the exchange of heat, moisture and carbon dioxide between the surface and the atmosphere. However, there are potentially important processes that have still to be implemented within such models. Whilst the UK scientific community in general are able to model these additional processes, it is difficult for them to implement their ideas within a climate model and thus it typically takes a long time for these developments to be included within climate simulations.

To speed up the time taken for new developments to be trialled within a climate model, a new Joint UK Land Exchange System (JULES) has been designed. This land surface scheme has initially been based upon the Met Office Surface Exchange Scheme (MOSES). The intention is for this new community land surface model to be easy to use and develop, so that the UK research community can use it to try out the impact of new and improved parameterisations for climate applications.
Although running slightly behind schedule, the JULES model is nearing a first release. This first version of the model will be tested by "friendly" members of the community who are capable of dealing with complex code and can provide constructive feedback. A more user-friendly version will be made available to the wider research community after development work on the interfacing and modularisation of the code has been completed. There is currently a proposal being put together to address these issues under an e-science project.
The new community model forms important elements into other projects such as CLASSIC and QUEST. One of the aims of CLASSIC is to improve and further develop the JULES land surface model, with a focus on short-term energy and water fluxes. This project complements the longer-term (annual to century timescale) carbon cycle and vegetation dynamic activities in the QUEST bid.
A prototype version of the model has been released to the CLASSIC community who have helped to identify teething problems and have provided valuable comments. Coordination between CLASSIC and JULES is being undertaken by both Met Office and CEH staff in the climate part of the JCHMR.

Dynamic Global Vegetation Modelling. The aim of the terrestrial biosphere component of the QUEST project is to improve the vegetation description, dynamics and biogeochemistry in Dynamic Global Vegetation Models (DGVMs). As part of this initiative, staff within the climate areas of JCHMR (both Met Office and CEH) are involved in a second DGVM intercomparison project. The aim of the project is to couple 4 DGVMs within the UK research community (including TRIFFID) to the computationally inexpensive GCM analogue model of the Hadley Centre climate model developed by CEH.
Whilst the first intercomparison project involved driving the DGVMs with the HadCM2 future climate and IS92a emission scenario, this intercomparison will drive the 4 UK DGVMs with the GCM analogue climate of HadCM3 for multiple emission scenarios. It will include both on- and off-line carbon cycles, to estimate uncertainties in future land-atmosphere exchange and future carbon cycle feedbacks.
Work done to date has been to write the experiment protocol and to enable the analogue model to be coupled to the various DGVMs.

Future work will include the implementation of JULES within IMOGEN (the GCM analogue model with a simple ocean carbon cycle) in order to make global simulations for the intercomparison. In addition, we will help to coordinate the LPJ-DGVM's implementation and subsequent global simulations as part of the intercomparison, along with colleagues in Germany.
The intended outcome of the intercomparison will be to provide input for the next IPCC report.

Global soil wetness model intercomparison. The second Global Soil Wetness Project (GSWP2) is an intercomparison project that has used 17 years of observed/analysed data to force numerous land surface schemes. As well as comparing the standard land surface fluxes, this intercomparison experiment has used the water runoff fluxes to feed into a river routing model so that the derived river flow can be compared to observations.
As well as the simulations with various version of MOSES that were previously performed for GSWP2, work has included changing the soil scheme to use the Van Genuchten parameters, which were derived for MOSES from collaborative efforts within the JCHMR. Additional work has been done with various sensitivity experiments, which have involved variations to the forcing data.
Future work will continue to analyse the results from MOSES with the various versions and sensitivity to the forcing data to help understand the impacts within the land surface scheme.

Wetland methane emission feedback on climate change. A paper on the assessment of the feedback of wetlands methane emissions on climate change has been accepted in the Journal of Geophysical Research Letters.

Climate change: Detection and Attribution. One of the key questions to be asked in the climate change debate is whether the initial effects of increasing atmospheric greenhouse gas concentrations can be seen already. Most climate models estimate that some change has already occurred due to the burning of fossil fuels between pre-industrial times and the present, and that this will manifest itself in not just a general warming, but also in quite complex geographical patterns of change. These computer-derived estimates of variation help us to understand whether emerging patterns of change seen in global sets of measurements are due to natural climate variability, or a real long-term signal of global change. A statistical method called "detection and attribution" has been developed jointly between Oxford University (department of Atmospheric Oceanic and Planetary Physics) and the Met Office's Hadley Centre whereby climate signals are extracted from noise in observations by the global set of weather stations. This is looking for, or "detecting" change. The second part is "attribution", whereby a statement is made that there is a high probability that a particular observed trend is due directly to human activity. At present, the numerical methods are tuned to work with the Hadley Centre GCM. However, in an exciting development, CEH have been working under subcontract to the Hadley Centre (and in collaboration with Oxford University) to extend the methodology to include model uncertainty. This enhancement of the numerical code makes it possible to include the output from other climate modelling groups. This will help to increase our knowledge of climate change, and in particular it will allow us to make stronger statements about human influence on climate. At present, the statistical modelling structure is nearly completed for simple generic examples and the initiative is about to apply this tool to global climate model output from a large range of modelling centres from around the world. It is hoped that this work will be of direct relevance to IPCC activities. [Task partially done - initial plots taken to fourth assessment working group meeting, Italy September 2004]

11. JCHMR Fellowship

Recent work has focused on trying to simulate the initiation and evolution of a low pressure system over West Africa using the Unified Model. According to satellite observations and ERA40 reanalysis data, the system appears to be a response to anomalous gradients in surface fluxes on the fringes of the Sahara desert due to recent rain. The case was chosen as the system appears to play a role in the development of a tropical cyclone just off the coast. The utility of satellite data (TRMM, MODIS and METEOSAT) has been assessed in identifying patches of near surface soil moisture. Initial simulations show that the dynamics of the system are sensitive to the specification of soil moisture. Substantial boundary layer temperature biases rapidly develop when soil moisture consistent with ERA40 is applied. The introduction of wet patches in zones observed from satellite reduces these biases.

12. Flood prediction using the RCM

A flow routing model for coupling to a Regional Climate Model (RCM) has been developed by CEH under the Hadley Centre's research programme commissioned by Defra. The main inputs to the model are RCM rainfall and RCM-derived estimates of potential evaporation (PE) which are transformed via a simple runoff production scheme to obtain surface and subsurface runoffs. A progress report to the Hadley Centre and two reports to Defra were issued in April 2004 and two journal papers have been submitted to Journal of Hydrology.

Further collaboration between CEH Wallingford and Hadley Centre will develop the hydrological component of a prototype high-resolution (12km) coupled RCM for North West Europe. This new model will combine HadCRM1, the 1km resolution G2G routing model with MOSES-derived runoff, and the Met Office/POL shelf-seas model. The assessment of simulated river flow under current and future climate scenarios will continue using data from two RCMs driven by newly available ERA-40 data. The simulations for recent UK floods (including Autumn 2000) will be a focus of interest.

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