

**Catchment Change Network
International Conference,
Lancaster University**



STAKEHOLDERS, NEXT GENERATION MODELS AND RISK IN MANAGING CATCHMENT CHANGE

25th June - 27th June 2012

Lancaster University Management School (LUMS)

Over the last three years the Catchment Change Network (CCN) has organised a programme of workshops and meetings to discuss and develop guidelines for incorporating risk and uncertainty into the management of catchment change in the areas of flood risk, water scarcity and diffuse pollution. This final international conference will present the progress made in CCN and other projects during this time. A particular focus will be on the research needs in both modelling the impacts of change at scales of implementation and on stakeholder involvement in the management process.

Session1 - Monday 25th June, 14.00 – 18.00

UNCERTAINTY, RISK AND THE ROLE OF THE STAKEHOLDER IN MANAGING CHANGE

- 12.30-13.30 Registration and refreshments**
Lecture Theatre 3 and Breakout Areas 2 and 3, LUMS
- 14.00 Introduction and welcome**
Keith Beven, Lancaster University, UK
- 14.10 Keeping it real for agricultural stakeholders in catchment research programmes**
Phil Jordan¹ and Mark Treacy²
¹University of Ulster, Northern Ireland
²Teagasc, Republic of Ireland
- 14.30 Developing a plan for the Eden Catchment: inspiration - engagement - participation - co-ordination**
Simon Johnson, Eden Rivers Trust, UK
- 14.50 Defra catchment-based approach: emerging findings, support requirements and knowledge exchange**
Kieran Conlan, Cascade Consulting, Manchester, UK
- 15.10 Who are the water managers? Community catchment management at Loweswater**
Lisa Norton, Centre for Ecology and Hydrology, Lancaster, UK
- 15.30-16.30 Refreshments and poster presentations**
- 16.30 Sustainable flood risk management: facilitating communication between rural stakeholders**
Elizabeth Oughton (Newcastle University)
- 16.50 Using experiential knowledge in river management decision making, and the impact of scale on its effectiveness**
Carly Maynard, Durham University, UK
- 17.10 Bridging the gap between hydrological science and water management**
Lotta Andersson, Swedish Meteorological and Hydrological Institute, Sweden
- 17.30 Integrating Bayesian inference techniques with integrated catchment modelling**
George B. Arhonditsis, University of Toronto, Canada
- 17.50 Close**
- 19.30 Conference Dinner**
Dalton Suite, Lancaster House Hotel

Session 2 - Tuesday 26th June, 09.30 – 12.30

FRAMEWORKS FOR GOOD PRACTICE IN STAKEHOLDER INVOLVEMENT IN MANAGING CATCHMENT CHANGE

09.00-09.30 Registration and refreshments

Lecture Theatre 3 and Breakout Areas 2 and 3, LUMS

09.30 Policy into practice in adapting catchment management to climate change

Julian Wright, Environment Agency, UK

10.00 Piloting adaptive catchment management through stakeholder deliberation and co-production of knowledge

Laurence Smith, School of Oriental and African Studies, University of London, UK

10.30-11.00 Refreshments

11.00 A catchment scientist's view and experience of management, political and social science methods to support good practice in stakeholder involvement in managing catchment change

Kit Macleod, The James Hutton Institute, UK

11.30 Towards a climate impacts report card for future flood risk in the UK

Rob Wilby, Loughborough University, UK

12.00 Carry on up the catchment: collaborating and communicating?

John Fox¹ and Phil Haygarth²

¹Dead Good Guides, Cumbria, UK

²Lancaster University, UK

12.30-1.30 Lunch

Session 3 - Tuesday 26th June, 14.00 – 17.30

HYPER-RESOLUTION MODELLING OF THE IMPACTS OF CHANGE: UNCERTAINTY AND UNIQUENESS OF PLACE

- 14.00** **Hyper-Resolution, global land surface modelling: are there pathways for addressing this need and will such models improve predictive capabilities?**
Eric F. Wood, Princeton University, USA
- 14.30** **Accelerating the development of high resolution hydrological models: a case study in California and the Western U.S.**
Jay Famiglietti, University of California, USA
- 15.00** **Modelling water resources at continental scales**
Ad De-Roo, Joint Research Centre, Ispra, Italy and Utrecht University, the Netherlands
- 15.30-16.00** **Refreshments**
- 16.00** **Complementing Hyper-Resolved Modelling by uncertainty analysis: land surface parameter experiments with the coupled ECMWF seasonal forecasting system**
Florian Pappenberger, European Centre for Medium-Range Weather Forecasts, Reading, UK
- 16.20** **Why improved predictions with Hyper-Resolution models are possible: a data assimilation viewpoint**
Harrie-Jan Hendricks Franssen, Forschungszentrum Jülich, Germany
- 16.40** **A pilot Virtual Observatory (pVO) for integrated catchment science - demonstration of national scale modelling of hydrology and biogeochemistry**
Jim Freer and the EVOp Team, University of Bristol, UK
- 17.00** **Close**
- 19.30** **Evening discussion of Hyper-Resolution Modelling**
Training Room 1, Gordon Manley Building, Lancaster Environment Centre

Session 4 - Wednesday 27th June, 09.30 – 12.30

THE FUTURE IS NOT YET GAUGED: LESSONS FROM *PUB*, LESSONS FOR BUSINESS

09.00 – 09.30 Registration and refreshments

Lecture Theatre 3 and Breakout Areas 2 and 3, LUMS

09.30 **Changing catchments, changing contexts: the water industry in 2025 and 2050**

Adrian McDonald, University of Leeds, UK

10.00 **Managing risk and uncertainty within the water industry - an economic regulator's view**

Martin Furness, Ofwat, UK

10.30-11.00 Refreshments

11.00 **Dissemination and uptake of EC Framework Programme water research results**

Kerry Thomas, University of Oxford, UK

11.30 **Redundant information in the rainfall-runoff relationship**

William Castaings and Georges-Marie Saulnier, Université de Savoie, France

12.00 **Trading-space-for-time to link hydrologic predictions in past, present and future**

Thorsten Wagener, University of Bristol, UK and Pennsylvania State University, USA

12.30-13.30 Lunch and close

Abstracts

Session 1

Keeping it real for agricultural stakeholders in catchment research programmes

Phil Jordan¹ and Mark Treacy²

¹University of Ulster

²Teagasc, Eire

Demonstrating water policy – and its effectiveness – is recognised as being most useful at the catchment scale where biophysical and socio-economic considerations come together. However, as science-policy-manager partnerships pirouette around iterations of the diffuse pollution DPSIR framework, both policy and environmental lagtimes and layers of uncertainty have to be identified, dealt with and effectively communicated. Overriding in catchment research programmes dealing with agricultural best practise is the need to communicate at both policy and grass-roots level. Moreover, the most important aspect of any agricultural catchment programme for the farming stakeholder is profitability – and the water quality policy message is cargo to the primary concern. In Ireland, the Nitrates Directive policy evaluation is demonstrated and communicated at the small catchment scale and where the professional farm advisor is the crucial link between the science-policy sector and the farming community. It is a bottom-up solution to top-down directives and one that is suited to the Irish landscape and adaptations to new economic imperatives.

Developing a plan for the Eden Catchment: inspiration - engagement - participation - co-ordination

Simon Johnson

Eden Rivers Trust, UK

On March 22nd 2011 the Environment Minister, Richard Benyon announced that Defra would be committing to a more catchment-based approach to sharing information, working together, co-ordinating work and making the case for collaborative action to protect England's water environment. Defra's vision for this approach is to work with stakeholders (such as Rivers Trusts) to establish a framework for integrated catchment management across England by the end of 2013. This will support the second cycle of River Basin Management Plans to deliver the objectives under the Water Framework Directive.

In his announcement the Minister recognised that tackling land management and water issues effectively cannot be solely undertaken by, or the responsibility of, one organisation but requires many actors to work in conjunction. This very much supports the ethos and modus operandi of the third sector and that of Eden Rivers Trust.

Catchment scale operations will help ensure local knowledge is used to drive local change, through:

- identifying and understanding issues within a particular catchment
- involving local groups in decision making
- sharing evidence
- identifying priorities for action
- seeking to deliver integrated interventions in cost effective ways that protect local resources.

All of these activities will emerge from a mutually agreed vision developed by all stakeholders within an individual catchment. It will be captured within a 'catchment plan' which will be a jointly owned, living document that sets out future aspirations and the road map for achieving them.

The Pilot Phase

Defra recognises that this cannot be a prescriptive process, but is a strategy which needs to evolve and develop through collective learning and analysis. To kick start the approach, Defra is already running a Pilot Catchment Project phase until December 2012. The Environment Agency is hosting the approach in 10 catchments. Defra also invited expressions of interest from other organisations to host an additional 15 catchments. An independent evaluation of these 15 external pilots was undertaken in November 2011 to inform the strategy for future roll-out of the approach. Over 70 expressions of interest were submitted. Eden Rivers Trust's Expression of Interest was one of the 15 successful submissions.

This is an exciting time for river management. We are part of an initiative to put local organisations and local communities in charge of planning for the future of the river. Working in partnership we are taking action now to protect and improve the Eden. We are currently working on an independent plan to Save the Eden. We are trialing new ways of engaging with new and existing stakeholders (some difficult to reach) to participate in helping us shape the future of this very special river.

Defra catchment-based approach: emerging findings, support requirements and knowledge exchange

Kieran Conlan

Cascade Consulting, Manchester, UK

A series of catchment-level initiatives are being developed through a pilot phase (April 2011 – December 2012) to develop and test the catchment-based approach. Ten of these pilots are hosted by the Environment Agency (EA) and 15 are being led other stakeholders. The Government's aim is that the 25 pilots will provide a means for stakeholders including the EA to learn together how to develop effective, collaborative approaches for catchment improvement.

Defra has commissioned Cascade Consulting to undertake an independent review of the 25 catchment pilots. The team is working alongside government, stakeholders and communities, collating information provided by the pilots, and gathering views from all involved about what is working well, and what could be done better. The research team will be ensuring that we learn all we can from this vital pilot phase, sharing what we are learning now with each other, and making sure that we can pass on that learning to those taking forward catchment management approaches in the future.

A key purpose of the evaluation is to assess whether these potentially significant returns can be achieved through a relatively modest investment in the new, catchment-based approach, and if so, which approaches work best, where, for whom and why. To date the initiative has been focusing on the development of an evaluation framework, the rollout of a series of national and regional learning events and have recently reported progress and findings from the first quarterly reporting phase (January – March 2012).

To support the catchments during this pilot phase the Cascade team in conjunction with Lancaster University have been working on the development of a data and knowledge exchange hub which has recently been launched on a new section on the NERC funded Catchment Change

Network website. This includes information on the 25 pilot catchments, the evaluation process and related reports, invaluable tools and lessons learned and a blog detailing latest news and information. There are some important issues about how best to provide information support for stakeholder interaction and decision-making in future catchment management at a range of public to government policy levels. The aim is that the interim data hub will evolve to provide a longer term knowledge exchange hub to support wider rollout of the catchment based approach from 2013.

Further information can be found at: <http://www.catchmentchange.net/pilot-catchments>

Who are the water managers? Community catchment management at Loweswater

Stephen Maberly¹, Lisa Norton¹, Judith Tsouvalis², Claire Waterton² and Nigel Watson²

¹ Centre for Ecology and Hydrology, Lancaster, UK

² Lancaster University, UK

This project explored new methods towards understanding the issues resulting in poor water quality in Loweswater, UK. These included collecting information and data on agricultural, social, ecological and governance issues relating to the catchment. As well as taking a more holistic approach to data collection, researchers gave consideration as to how this different information can be integrated, used and presented to ensure that improved water quality in the catchment results from approaches which take into consideration social, economic and other ecological perspectives of the catchment.

Sustainable flood risk management: facilitating communication between rural stakeholders

Elizabeth Oughton¹, Andrew Donaldson¹, David Passmore¹, Louise Bracken², John Forrester³, Steve Cinderby³, Chris Spray⁴ and Brian Cook⁴.

¹ Newcastle University

² Durham University

³ University of York

⁴ University of Dundee

This paper will present an overview of selected findings from a knowledge exchange study aimed at improving and facilitating communication between organisations and individuals concerned with flood risk management. The study focussed on the Tweed catchment, between England and Scotland and was carried out in partnership with the Tweed Forum. Flooding in rural areas affects land based businesses, as well as residents and business more widely, but low population density and a shift in policy from flood defence to flood risk management has meant little resource is directed towards protecting rural areas. Furthermore, climate change predictions suggest that this area of Britain may experience more severe weather conditions in the future; thus, there is a strong need to increase flood resilience in the region.

The study used both qualitative and quantitative techniques. Primary data were collected through a Q sort methodology carried out with both lay and expert stakeholders to investigate the underlying attitudes to flooding and flood risk management. The Q methods revealed two distinct positions for adaptive management practices, one stressing sustainable flood risk management and the other more traditional flood management techniques. The positions, or

attitudes, of the respondents could not be determined by their level of knowledge, involvement in flood management or previous experience of flooding and yet provided an important basis for discussions amongst stakeholders.

Local meetings held within two sub-catchments, Eddleston Water and Wooler Water, used participatory mapping to explore possible development of sustainable flood risk management within the catchments and the results were tested among the wider rural community through extended participatory mapping at two agricultural shows, Glendale in England and Peebles in Scotland. Approximately two thirds of respondents were in favour of natural flood management in some form, whereas in Scotland 17% chose traditional engineering techniques only 4% showed a preference for this option in England. In both cases the remainder chose mixed approaches. The findings from the Q methods together with the participatory mapping demonstrated clearly the ways in which local communities could contribute knowledge on flooding problems and produce options for flood management for consideration. The results of the analysis were taken back to stakeholders who identified significant outputs for further development.

Using experiential knowledge in river management decision making, and the impact of scale on its effectiveness

Carly Maynard

Durham University

It is now widely acknowledged that involving those with experiential knowledge in catchment management can have multiple benefits ranging from a more efficient decision making process to a greater sense of community ownership around projects. Within the UK and Europe, public participation in environmental management efforts is becoming increasingly popular as a result of legislative processes such as the EU Water Framework Directive and the Aarhus Convention. But to what level do we define 'participation' and can we realistically include public knowledge as part of an accepted scientific procedure? This paper presents a review of a number of cases operating on large (catchment) scales throughout North-West Europe, some of which encountered problems and raised questions such as: How can we convince others to trust work we do that involves public knowledge? How can we account for uncertainty in that knowledge? Who should be involved and to what level? Further questions arise around the relationship between scale of a project and its success. To explore this point further, the cases have been compared to some smaller scale projects, in particular, one which involves a case study of a competence group in the catchment of the Derwent River, Northumberland, UK, who have lobbied for the repair of a broken weir within their community. Their extensive knowledge coupled with scientific analysis of flow and geomorphology allows us to investigate potential immediate and future impacts of the restoration on flow and habitat. Results of the study suggest that the co-production of knowledge process can have great value at a local scale, but an increase in the number of people affected or involved can be to the detriment of the level of involvement possible. This can have major implications for environmental governing bodies who are increasingly expected to involve participants and account for local knowledge in procedure and planning.

Bridging the gap between hydrological science and water management

Lotta Andersson and Berit Arheimer

Swedish Meteorological and Hydrological Institute, Sweden

The Swedish National Committee of the International Hydrological Programme (IHP) was addressing the IHP VII phase with two workshops in 2011. The aim was to bridge the gap between hydrological science and water management. The first workshop evaluated model results and uncertainties and elaborated on recommendations of guidelines for best practices in model supported decisions. Hydrological scientist from Sweden and four other countries applied their own catchment water and nutrient models (altogether seven different models where applied) and modelling concepts to a common data set from a Swedish catchment. The second workshop explored the decision making process among water authorities and develop guidelines for an adaptive management process, where measures are taken although uncertainties are recognised. Water authorities, scientists, and other representatives discussed decision support needs in relation to the results of the initial modelling workshop. The three discussion themes were (i) what is needed in order to increase the use of models in water management? (ii) what can be achieved through increase of local participation in water management? (iii) what are the main messages to modellers and water managers?

Integrating Bayesian inference techniques with integrated catchment modelling

George B. Arhonditsis

University of Toronto, Canada

In the context of water quality assessment, the application of process-based models typically has a deterministic character, whereby single-value predictions at each point in time and space are derived from uniquely determined model inputs. Most of the existing calibration efforts aim at reproducing the average ecological dynamics, but fail to capture the entire range of natural conditions experienced. The credibility of these practices and their adequacy in addressing environmental management problems has recently been questioned for two main reasons. First, regardless of its complexity and supporting information, the application of any modeling construct involves substantial uncertainty contributed by model structure, parameters, and other associated inputs (e.g., boundary or initial conditions). Second, models parameterized to depict the average ecosystem behaviour are inadequate in addressing the type of percentile-based standards needed to accommodate the natural spatiotemporal variability and may bias (underestimate) the predictions of the frequency of standard violations under various management options.

For better model-based decision analysis that can effectively support the development of environmental standards and the policy making process, the uncertainty in model predictions as well as the full range of the expected system responses must be rigorously quantified and reported in a straightforward way. Model uncertainty analysis essentially aims to make inference about the joint probability distribution of model inputs, reflecting the amount of knowledge available for model parameters, initial conditions, forcing functions, and model structure. In this regard, Bayes' Theorem provides a convenient means to combine existing information (prior) with current observations (likelihood) for projecting future ecosystem response (posterior). Hence, the Bayesian techniques are more informative than the conventional model calibration practices, and can be used to refine our knowledge of model

input parameters while obtaining predictions along with uncertainty bounds for output variables.

Despite the compelling arguments for considering Bayesian inference techniques as an integral part of the model development process, their high computational demands along with the lack of analytical expressions for the posterior distributions was until recently a major impediment for their broader application. Nonetheless, the advent of fast computing has allowed the development of several methods for performing Bayesian inference and the most commonly used technique is called Markov chain Monte Carlo (MCMC); a general methodology that provides a solution to the difficult problem of sampling from high dimensional distributions for the purpose of numerical integration. In this paper, I will discuss several promising prospects of the application of Bayesian inference techniques, such as the averaging of predictions from different models and the integration of watershed with receiving water body models, which can be used from stakeholders and policy makers to guide the use of millions of dollars of restoration and to dictate the Best Management Practices.

Abstracts

Session 2

Policy into practice in adapting catchment management to climate change

Julian Wright and Harriet Orr

Environment Agency, UK

This presentation will set out the broad principles set out in the EU CIS guidance on *River basin management in a changing climate* and give an overview of the approach the Environment Agency is currently implementing to climate change adaptation in catchment management.

Climate change is now broadly recognised as a significant pressure on the management of water resources, water quality and flood risk. However there remains significant confusion as to the practical steps needed in the short term to start the adaptation journey. This stems in particular from a lack of communication of projections, philosophical difference in approaches to uncertainty and the long term nature of climate change, and poor scientific understanding of the resilience of measures.

The European Commission has published guidance under the Common Implementation Strategy (CIS) to support practitioners in approaching these challenges and starting to embed climate change adaptation in water management, particularly via implementation of the Water Framework Directive. This encourages a practical approach in which climate change is considered in each of the steps in the river basin management planning process, in particular the assessment of pressures, the choice of measures, and in planning monitoring.

In the first cycle of WFD implementation the Environment Agency included a discussion chapter on climate change as part of the first River Basin Management Plans. We are now in the second cycle of river basin management planning, and are attempting to take a more integrated approach based on the CIS guidance. This is concomitant with the shift to the “catchment approach” and includes using the Catchment Pilots as a way of engaging stakeholders in climate change adaptation.

Piloting adaptive catchment management through stakeholder deliberation and co-production of knowledge

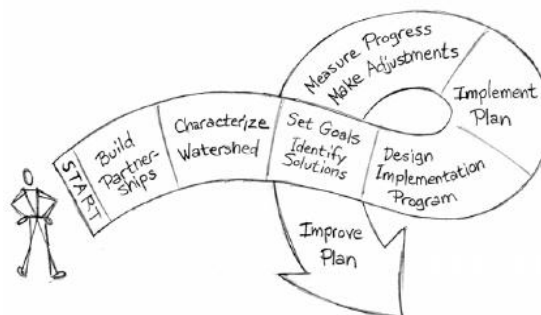
Laurence Smith¹, Alex Inman¹ and Tobias Krueger²

¹ School of Oriental and African Studies, University of London, UK

² University of East Anglia, UK

Work in two case study catchments in England adapted, applied and tested the catchment planning process illustrated in Figure 1.

Figure 1: Catchment planning and implementation process (US EPA, 2005)



Within this initial framework the methods applied evolved and developed in response to stakeholder engagement and their inputs. Activities included the following:

- Design and implementation of a best practice approach for inclusive public participation and stakeholder engagement.
- Four catchment stakeholder workshops corresponding (with adaptation) to the first four stages of Figure 1.
- Framing of catchment water quality problems and other goals with stakeholders.
- Compilation, ground truthing and analysis of secondary data for catchment water quality diagnosis and catchment characterisation.
- Development of data presentation and communications tools to aid collective data interpretation and catchment analysis with stakeholders.
- Rejection of existing catchment modelling tools and development of an innovative and participatory Extended Export Coefficient model (ECM+), based on co-production of knowledge with stakeholders from problem diagnosis and initial model conception to model application.
- With a focus on phosphorus pollution, use of the model and its interface to explore with stakeholders the scale and severity of the problem in each catchment, and to facilitate stakeholder led scenario analysis of efficacy of alternative control measures and management options.
- Scaling up and costing of management options, characterisation of governance arrangements, and assessment of implementation needs and feasibility.

Evaluation of this experience provides clear examples of the substantive, instrumental and normative benefits of well-planned and facilitated stakeholder engagement. Conclusions can also be drawn regarding the practical areas of best practice likely to contribute to success, and pitfalls and other weaknesses to be avoided.

A catchment scientist's view and experience of management, political and social science methods to support good practice in stakeholder involvement in managing catchment change

Kit Macleod

The James Hutton Institute, UK

To understand and manage catchment systems more effectively across temporal and spatial scales for an increasing number of demands from stakeholders requires integrative (interdisciplinary and transdisciplinary) research that spans a large number of natural and social science disciplines. It is unlikely that a single method with its theoretical and practical basis will provide the best approach for engaging and working with a broad diversity of stakeholders in every situation. It has been widely acknowledged in the management sciences that methodological pluralism and the tailoring of methodologies to situations is vital to inquire and understand complex socio-ecological and socio-technical systems. For example Peter Checkland's Learning for a User by a Methodology-informed Approach to a problem Situation (LUMAS) model sets out how a user's learning and perception of a real world problem-situation guides their use of a methodology to improve the situation. A wide range of stakeholder analysis methods provide systematic yet critical approaches to stakeholder analysis, which are sensitive to stakeholder positions and needs. The Cynefin sense making framework supports decision and policy makers to understand the relationships of a particular situation to five domains: simple, complicated, complex, chaotic and disorder. This informs the methods that are more likely to work. An important lesson learned from the operations research and risk

analysis communities is that analytical-deliberative methods are more likely to be successful at providing effective and sustainable solutions, than 'hard' systems analysis that have not identified and engaged stakeholders. Spanning the boundaries between research domains and between research, policy and practice is key to making more effective use of our data-information-knowledge to understand and manage catchment systems. In this paper I will provide an overview of a number of management, political and social science methods from the perspective of a catchment scientist, who has used these to engage stakeholders in understanding and managing catchment change.

Towards a climate impacts report card for future flood risk in the UK

Rob Wilby

Loughborough University, UK

Climate change and fluvial flooding attract considerable attention from the research and policy communities alike. In contrast to the apparent lack of trends in UK river flows, most studies involving regional climate model output suggest increased risk of flooding under a changed climate. This talk begins by outlining the most significant uncertainties affecting regional climate change scenarios and hence outlooks for flood risk in the UK. A summary of expected changes in pluvial and fluvial flooding is provided after taking a much more critical look at the accuracy of climate predictions and underlying assumptions of the modelling. The presentation also considers the extent to which changes in future flood risk might even be detectable given large inter-annual and multi-decadal variations in peak flows. The concluding remarks make the case for a multi-driver, process-based perspective when monitoring and reporting climate-driven changes in flood risk.

Carry on up the catchment: collaborating and communicating?

John Fox¹ and Phil Haygarth²

¹Dead Good Guides

²Lancaster University, UK

John Fox is one of the two Artistic Directors of Dead Good Guides, a company of artists specialising in socially engaged art. His previous company Welfare State International (1968-2006) gained a worldwide reputation for pioneering prototypes of Celebratory Art with many communities. Such prototypes included site-specific carnivals, mixed media and sculptural installations, lantern parades and new ceremonies for rites of passage. From 2008 to 2011, when he was an AHRC Senior Research Fellow in the Creative and Performing Arts at Lancaster University, he worked with Phil Haygarth proposing ways to communicate scientific discoveries to audiences of non-specialists. Phil Haygarth is a Professor of Soil and Water Science at the Environment Centre at Lancaster University.

In this presentation, Phil Haygarth will start by reminding us of the complexities and the difficulties in scale and in attributing 'source' and 'impact' when dealing with catchment pollution, where there may be a large spatial and temporal disconnect between the downstream 'impact' and the upstream 'source'. Despite these challenges, it is imperative that we find new ways to communicate and nurture ownership of the issues and solutions from within the local communities that live and work in the catchments. John Fox will demonstrate principles of engaging communities in these issues through art, consider propositions for raising awareness of soil and water pollution in specific locations and use case studies of collaboration between artists, scientists and farmers. Themes include the geology, history and micro marine life of Morecambe Bay and a rural community on the island of Terschelling in the Netherlands.

Abstracts

Session 3

Hyper-Resolution, Global Land Surface Modelling: Are there pathways for addressing this need and will such models improve predictive capabilities?

Eric F Wood

Princeton University, USA

Monitoring Earth's terrestrial water conditions is critically important to many hydrological applications such as global food production, assessing water resources sustainability, and flood, drought and climate change prediction. Coupled Earth System models with spatial resolutions of kilometers are being developed for decadal and regional climate prediction. The need to include human activities (such as agriculture and its management or urbanization) increases as decision makers try and assess problems such as water and food security or climate change impacts on much of the global population; or as develop predictive capabilities that include water and ecosystems, or the intersection among water, food and energy. For all of these problems (and many other current research issues) understanding the terrestrial water cycle and its variability is a central need.

Scientifically, or ability to model the terrestrial water cycle, mostly through soil atmospheric transfer schemes (SVATS) or land surface models (LSM), hasn't changed significantly over the last 20 years. Most are formulated for coarse spatial resolutions (~10-to-100km) suitable for simulations over large regional to continental domains, even when applied at smaller domains. The representation of land surface elements is often weak and local-scale processes, which frequently play a dominant role in the generation of extreme events, are often not well represented or not represented at all. Intercomparison studies show wide predictive uncertainty among models, even when forced with the same data.

Wood *et al.* [2011] posed a Grand Challenge to the hydrologic research and science support communities "to endorse an effort to build a hyperresolution hydrologic modeling framework that will lead to a better understanding of the global terrestrial water, energy, and biogeochemical cycles and the anthropogenic impacts on the system." Construction of a hyperresolution framework is irrelevant if it fails to reduce the existing divergence in hydrological model estimates and with it the uncertainty in their predictions. This presentation will explore the need for a new land surface modelling paradigm for addressing critical water cycle science questions and applications. In doing so, we will explore possible pathways (or strategies) that include the work of Beven [2007] who "raises questions about system design requirements to allow modeling as a learning and data assimilation process in the representation of places", Clark *et al.* [2011] who argue for the "use of the method of multiple working hypotheses for systematic and stringent testing of model alternatives in hydrology", and others who recognize this scientific and hydrological challenge.

Accelerating the development of high resolution hydrological models: a case study in California and the Western U.S.

Jay Famiglietti, Jake Edman, Min Hui Lo and J.T. Reager

University of California, USA

While the development of hydrological and land surface models has progressed rapidly over the last few decades, a significant acceleration in model development is required in order to address critical societal issues of water, energy and food availability and security. In particular, major advances are needed in the areas of increasing model resolution, enhanced observations (e.g. of water cycle variability and change, of subsurface soils and hydrogeology, and of streamflow and groundwater levels), accelerated model development (e.g. of models that integrate the major components of the human and managed water cycles), innovations in data assimilation (e.g. of algorithms that can readily incorporate in situ and remote observations of asynchronous space-time frequency) and for establishing new frameworks for integrating models and data (e.g. for access to data and simulation results, for running models, and for performing analyses). In this presentation we discuss these needs in detail, and highlight recent efforts in California and at the national scale (i.e. with the Community Hydrologic Modeling Platform [CHyMP]) to develop a modeling and data integration framework that can be applied across scales up to continental and global scales.

Modelling water resources at continental scales

Ad De-Roo

Joint Research Centre, Italy and Utrecht University, the Netherlands

Current European Commission Policy – as defined in the 2012 “Blueprint to Safeguard Europe's Waters” - aims to ensure the availability of good quality water in sufficient quantities for all legitimate uses.

It is within this policy framework that JRC – close collaboration with DG Environment - carries out research on continental hydrological simulation modelling, aiming to provide scientific assessments of current and future available water resources, addressing water quantity including floods, droughts and water scarcity, as well as water quality and ecological aspects.

The main aim of the research activity is to assess current and future water availability versus current and future water demands from different economic sectors. Alternative scenarios containing mixtures of policy options are evaluated on their economic costs and benefits, as well as several water availability and water quality indicators.

The JRC activities are carried out at the continental scale at 5km regular grid scale, linking various modelling systems, including the agricultural sector model CAPRI, the future land use simulation model LUMP, the water quality model EPIC, the hydrological model LISFLOOD, and integrating model LISQUAL, and an economic optimisation routine linked in a Python environment to LISQUAL.

Meeting the wishes of customers for higher spatial resolution modelling integrating quantity, quality, ecologic, demand and economic aspects, while uncertainty in data used and in modelling concepts remains, is our collective challenge.

Complementing Hyper-Resolved Modelling by uncertainty analysis: land surface parameter experiments with the coupled ECMWF seasonal forecasting system

Hannah L. Cloke^{1,2}, Florian Pappenberger² and Antje Weisheimer^{2,3}

¹ King's College London, London, United Kingdom

² European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

³ Department of Physics, University of Oxford, United Kingdom

The representation of soil moisture physics in land surface schemes is subject to uncertainty in parameterisation, but is known to have an importance influence on the quality of atmospheric predictions as well as land surface predictions of runoff and river discharge. Perturbed and stochastic parameterisation techniques in meteorology and hydrology are one way to try to capture this uncertainty. Here we evaluate the impact of land surface parameter perturbations on ECMWF seasonal forecasts. Several fully coupled ensemble seasonal forecast experiments were run to investigate the influence of the land surface perturbations in combination with the atmospheric stochastic physics on summer seasonal forecasts across the globe. The results show that land surface perturbations can influence seasonal predictions in some cases, but this is resolution and location dependent. This initial analysis demonstrates the potential of implementing a stochastic parameterisation of land surface equations in coupled atmospheric models. A move towards hyper-resolution modelling can only be justified if such uncertainties are routinely considered.

Why improved predictions with Hyper-Resolution Models are possible: a data assimilation viewpoint

Harrie-Jan Hendricks Franssen¹, Stefan Kollet², Clemens Simmer³ and Harry Vereecken¹

¹ Forschungszentrum Jülich, Germany

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³ Meteorological Institute, University of Bonn, Bonn, Germany

In order to make meaningful predictions with hyper-resolution models it is necessary to provide these models with good quality input data. Given the data requirements of hyper-resolution models (values for many different parameters and variables at a fine grid) the question has been raised whether predictions with such models can outperform predictions with simpler models and/or models with less data needs.

We argue that with help of data assimilation approaches which consider all relevant sources of uncertainty (parameter, model and forcing uncertainty, measurement errors) it is likely that physically based hyper-resolution (HR) models outperform other (N-HR) models. We think that the following aspects in this respect are important: (1) with help of a sound stochastic approach HR models will give at least as good (or as bad) predictions as N-HR models, but not worse predictions; (2) parameter identification in the context of data assimilation is sometimes - not always - meaningful, but the improvement of predictions with HR-models is also possible with the updates of states alone; (3) not a single best solution is sought, but a large number of equally likely solutions, all of them consistent with all available information; (4) many different data sources, containing complementary information, are available and have only been used to a limited extent for hydrological and land surface model predictions until present; (5) given the correlation of states, parameters and forcings over space and time, the effective number of degrees of freedom is much smaller than the number of unknowns. These points will be illustrated with help of a number of examples and a historical perspective.

A pilot Virtual Observatory (pVO) for integrated catchment science - Demonstration of national scale modelling of hydrology and biogeochemistry

Jim Freer and the EVOp team

University of Bristol, UK

There are many challenges in developing effective and integrated catchment management solutions for hydrology and water quality issues. Such solutions should ideally build on current scientific evidence to inform policy makers and regulators and additionally allow stakeholders to take ownership of local and/or national issues, in effect bringing together 'communities of practice'. A strategy being piloted in the UK as the Pilot Virtual Observatory (pVO), funded by NERC, is to demonstrate the use of cyber-infrastructure and cloud computing resources to investigate better methods of linking data and models and to demonstrate scenario analysis for research, policy and operational needs. The research will provide new ways the scientific and stakeholder communities come together to exploit current environmental information, knowledge and experience in an open framework.

This paper presents the project scope and methodologies for the EVOp work dealing with national modelling of hydrology and macro-nutrient biogeochemistry. We evaluate the strategies needed to robustly benchmark our current predictive capability of these resources through ensemble modelling. We explore the use of catchment similarity concepts to understand if national monitoring programs can inform us about the behaviour of catchments. We discuss the challenges to applying these strategies in an open access and integrated framework and finally we consider the future for such virtual observatory platforms for improving the way we iteratively improve our understanding of catchment science.

Abstracts

Session 4

Changing catchments, changing contexts: the water industry in 2025 and 2050

Adrian McDonald

University of Leeds, UK

The way in which catchments will be managed in the future is determined in part by drivers that cannot be readily modified, for example, climate change and markets for food, and in part by the demands placed on the catchments and the management structures through which they are managed. This talk considers, with evidence, the shape and structure of the UK water industry at two politically key dates. Integration and technology change, improved information and changed customer expectations will all influence the context in which catchment decisions are made.

Managing risk and uncertainty within the water industry - an economic regulator's view

Martin Furness

Ofwat, UK

The Water Industry may be deemed a fairly predictable, low risk service industry, particularly to investors and to customers who often take vital for life services for granted. Risks are interdependent on uncertainty which, for such a service, needs to be minimised and guidance based on sound evidence readily available.

This presentation looks at the current and future risks that challenge the decision making processes and the role played by uncertainty. Understanding /predicting/anticipating future change is critical for policy formulation. Currently the water industry deals in 5 year investment cycles but long term thinking and planning are integral and an adaptive regulatory assessment process is essential. Solutions of the past will not be enough to secure the services of the future.

The process of risk ownership in the water industry and how it is monitored is changing. Ofwat is moving to a more targeted, proportionate, risk based approach to regulation, which will be described.

Throughout the presentation, discussion points will be referenced to Climate Change and Catchment Management, in keeping with themes looked at in the CCN programme of studies. Finally, comments are offered on lessons learned to stimulate further discussion.

Dissemination and uptake of EC Framework Programme water research results

Kerry Thomas

University of Oxford, UK

The FP6-project (FUNDETEC) in its final report stated that “the typical length of time needed to complete the development cycle (in the water sector) is 10 years”. This means that research commissioned today will impact water management practice within about 12 years, far after the next milestones of the Water Framework Directive (2015, 2021).

The new FP7 project WaterDiss2.0 aims to speed up up the transfer of research outputs to water management institutions with a targeted time lag of only 3-5 years. The project intends to do this by analysing a selection of FP6/FP7 water research projects. It will examine the intended outputs of the projects, the dissemination strategies used and the aspects that facilitated and hindered the delivery of the intended outputs and outcomes.

WaterDiss will offer to support other projects with the uptake of their outputs and feedback its results back to influence the FP8 programme. This paper will present progress to date.

Redundant information in the rainfall-runoff relationship

William Castaings, Timothée Michon and Georges-Marie Saulnier

Université de Savoie, France

Some classical hydrological questions may be considered as single points in a common 3D "knowledge space" where first axe X1 would represent information content on forcing meteorological variables (e.g. rainfall), second axe X2 information content on prognostics hydrological variables (e.g. discharges) and third axe X3 information content on hydrological processes (e.g. model parameters values). Indeed model calibration problem use information on rainfall and discharges values and try to identify model parameters: for a given amount of rainfall and discharges data, model calibration may then be seen as a point in the (X1,X2) plan.

Model simulation problem use, for example, a given amount of rainfall data and the parameters values of a given model and try to estimate discharges: it is then a point in the (X1,X3) plan. It is suggested in this communication that some others hydrological questions may also be seen as other points in the same 3D knowledge space. For example, knowing the only rainfall events volume and the discharges time-series is it possible to identify both rainfall intensities time-series and model parameters values? Knowing rainfall intensities and the only river heights time series, is it possible to both identify model parameters values and the rating curve?

Placing these resolved questions in this common knowledge space helps to identify step by step a minimal information content surface. Problems above this surface contains redundant information: can they help to reduce uncertainty?

Problems below this surface are bad-constrained problems: which supplementary data would be help in reducing identifiability problems?

Trading-space-for-time to link hydrologic predictions in past, present and future

Thorsten Wagener

University of Bristol, UK and Pennsylvania State University, USA

An increasing population and improvements in lifestyle lead to enhanced water consumption, changing climate (emissions) and altered land covers (urbanization). These changes in turn cause important water security problems in many regions of the world, incl. increasing water scarcity, more frequent hydro-meteorological extremes, increasing hydrologic variability, as well as declining water quality. Science has at least two roles to play in our effort to solve these societal problems (Oreskes, 2004): [1] *At best it produces a robust consensus based on a process of inquiry (scientific method) that allows for continued scrutiny, re-examination, and revision.* [2] *Where consensus cannot be reached, science can play a role by providing informed opinions about the possible consequences of our actions (or inactions), and by monitoring the effects of our choices.* In many cases hydrologic predictions will be an important source of this information to understand a wide range of water resources services and hazards in this changing world. Such predictions need to be available everywhere and have to represent past, current and potential future conditions. To achieve credible predictions in these conditions, we need to ensure our models work for the right reasons, and use available data optimally. I claim in this talk that such credible models cannot be achieved in the historical framework in which environmental models have traditionally been identified, tested and applied. An important issue in this context is the question of the value of historical observations for model identification and testing under changing conditions. Trading-space-for-time provides a new idea for modeling in a changing world that overcomes limitations of our previous framework.

Posters

Water quantity and quality of Bosten Lake in China: catchment sustainable management is needed

Wei Chen

Lancaster University, UK and China University of Geosciences, China

Bosten Lake is the largest inland lake of freshwater in China, located at the northeast section of the Bayingolmongol Autonomous Area in the Xinjiang Uygur Autonomous Region northwestern China. Bosten Lake hydrological system (including the Kaidu River and the Peacock River) is vital for the oases in this region, as it supplies the industrial, agricultural and domestic water in Korla City and some adjunct areas. But for decades, both natural factors and anthropocentric impacts lead to the reducing of the water quantity and the declining of the water quality. The quantity reduce is mainly because the evaporation and the industrial and agricultural usage. The water quality decline is predominantly contributed by the salt accumulation and pollutants input from industrial and agricultural activities. The annual change of water level and salinity accumulation is about 10cm and 0.06g/L, respectively. Besides, some pollutants such as heavy metals and organic pollutants are emerging recently. Because of the water quantity reduce and quality decline, the water security of Bosten Lake is essential for the sustainable development in this region. As a result, the catchment sustainable management for Bosten Lake is necessary.

Integrated monitoring and modelling for flood-frequency estimation in an urban Swedish catchment

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Flooding in urbanised areas can affect a large number of people in a multitude of ways, e.g. through damages to buildings, property and infrastructure and in extreme cases through loss of lives. The consequences can also be considerable for aquatic ecosystems, which are already altered by urbanisation. Storm-water management and flood-protection planning therefore need to consider a range of local stakeholder interests and other aspects in an integrated way. The Riseberga Creek catchment in eastern Malmö, Sweden, is a highly urbanised small-scale catchment that repeatedly suffers from floods. Several local stakeholders and researchers are working in a project, GreenClimeAdapt, which aims at finding and demonstrating solutions to the flooding problems in the catchment.

This study aimed at quantifying the present flooding problems in the catchment through combined monitoring and modelling of the hydrological behaviour of the catchment. A high-resolution acoustic doppler discharge gauge was installed in the creek and the HBV-light hydrologic model was set-up to extend this short record for estimation of flood frequency. Uncertainties in the discharge data and model parameterisation were considered in the model calibration. The model was first used to study the flow variability during the period with available climate data. Then it was driven with long-period realisations from a statistical weather generator to estimate flood frequency.

When catchments are NOT changing

Keith Beven¹, Sarka Blazkova and Alena Kulasova²

¹ Lancaster University, UK

² T G Masaryk Water Research Institute, Prague, Czech Republic

We are living in the times of global change and are afraid of what might be happening in future. Nevertheless we would welcome some changes and they do not seem to be coming. The poster will show two such examples from the Czech Republic which possibly concern also other countries:

- The levels of phosphorus (and therefore also phytoplankton) in the river system.
- The acidification which persists in the area called “Black Triangle”.

What do we propose to do in such cases? To take all reasonable measures, CHECK that they really have been taken (e.g. the building of sewerage system might not cause less nutrients in a stream if people do not connect to it) and to be very VERY patient (e.g. in the case of legacy phosphorus).

The effectiveness of constructed wetlands in retaining pollutants from agricultural runoff: case studies from the UK

Clare Deasy¹, Nerilde Favaretto², Mary Ockenden¹, John Quinton¹, Chris Stoate³ and Ben Surridge¹

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² Universidade Federal do Paraná

³ Game & Wildlife Conservation Trust, Leicestershire, UK

Constructed ponds and wetlands are used extensively in Scandinavia as a tool for mitigating against diffuse pollution from agriculture. The wetlands can break or slow the connection between sources of runoff and the waterways, thus helping to prevent or reduce problems such as siltation and eutrophication.

The effectiveness and viability of constructed wetlands is currently being tested in the UK, as part of the Mitigation Options for Phosphorus and Sediment Project (funded by DEFRA, 2008-2013). Ten experimental wetlands have been built on four farms in Cumbria and Leicestershire. Water level and turbidity are continuously monitored at the inlet and outlet of each wetland, with water samples collected on a regular basis and during storm events. Sediment and phosphorus trapping rates are estimated from annual sediment surveys.

The results of monitoring since autumn 2009 are presented. The wetlands are shown to trap a substantial proportion of the sediment load (20 - 25 tonnes trapped at sandy site; 0.05 - 3 tonnes at less erosive silt/clay sites). Sediment total phosphorus concentrations are used to estimate phosphorus trapping rates of 0.01 kg/ha (clay) and 0.96 kg/ha (sand). For both individual storm events and regular sampling, concentrations of sediment and phosphorus in surface waters are shown to decrease between the inlet and outlet of the wetlands.

Overall, small field wetlands are shown to be an effective land management option for trapping sediment and nutrients, particularly where relatively unproductive land can be used. As well as being a nutrient sink, the wetlands provide additional benefits for wildlife.

The Multiple Interacting Pathways model - A scale-independent approach to modelling transport and flow in real soils and catchments

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Whilst classic continuum-based models of hydrological processes are in common usage, their applicability to structured soils at practical scales is questionable. Continuum equations require local equilibration of potentials and fluxes. If complex heterogeneities and preferential pathways that are present in most real soils are to be considered, then this requirement leads to impractically fine grid-scales.

The Multiple Interacting Pathways (MIPs) model is a dynamic, scale-independent approach, which represents water in the catchment as a large set of discrete particles. These particles carry with them information such as age and origin, allowing unified simulation of water flow and transport. Flow through preferential pathways is represented using velocity distributions, and movement between these pathways is simulated through use of exchange probabilities. In all, this provides a flexible, physically-meaningful modelling framework.

This formulation provides a platform for testing our understanding of catchment processes. In the poster, the capabilities and potential of the MIPs methodology for characterisation of complex, non-stationary, spatially variable run-off generation processes are illustrated and discussed.

The NERC Macronutrient Cycles Programme, stakeholder outputs, WQ Modelling and potential contributions to a Hyper-Resolution Model

Paul Whitehead

University of Oxford

NERC is funding a £9 million research programme on macronutrient cycles (Nitrogen, Phosphorus and Carbon- see <http://macronutrient-cycles.ouce.ox.ac.uk>) and how these cycles might change with changing Climate, Land use and Pollution Gradients. Whilst a lot of basic research is being undertaken, there will many outputs relevant to stakeholders and there will be new model developments which could be adapted for stakeholder use. These could include new integrated models that link N, P and C and could address policy issues such as EU Directives (eg Water Framework Directive) or issues arising from the Climate Change, environment and water legislation. The models could provide a useful contribution to the development of a Hyperresolution Model and some ideas and suggestions will be presented.

Exchanging environmental information and decision making: developing the local pilot environmental virtual observatory with stakeholder communities.

Mackay, E.¹, Beven, K.¹, Brewer, P.², Haygarth, P.¹, Macklin M.², Marshall, K.⁴, Quinn, P.³, Stutter, M.⁴, Thomas, N.², Wilkinson, M.³ and the EVOp team†

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Public participation in the development of flood risk management and river basin management plans are explicit components of both the Water Framework and Floods Directives. At the local level, involving communities in land and water management has been found to (i) aid better environmental decision making, (ii) enhance social, economic and environmental benefits, and (iii) increase a sense of ownership. Facilitating the access and exchange of information on the local environment is an important part of this new approach to the land and water management process, which also includes local community stakeholders in decisions about the design and content of the information provided. As part of the Natural Environment Research Council's pilot Environment Virtual Observatory (EVO), the Local Level group are engaging with local community stakeholders in three different catchments in the UK (the rivers Eden, Tarland and Dyfi) to start the process of developing prototype visualisation tools to address the specific land and water management issues identified in each area. Through this local collaboration, we will provide novel visualisation tools through which to communicate complex catchment science outcomes and bring together different sources of environmental data in ways that better meet end-user needs as well as facilitate a far broader participatory approach in environmental decision making. The Local Landscape Visualisation Tools are being evolved iteratively during the project to reflect the needs, interests and capabilities of a wide range of stakeholders. The tools will use the latest concepts and technologies to communicate with and provide opportunities for the provision and exchange of information between the public, government agencies and scientists. This local toolkit will reside within a wider EVO platform that will include national datasets, models and state of the art cloud computer systems. As such, local stakeholder groups are assisting the EVO's development and participating in local decision making alongside policy makers, government agencies and scientists.

† The EVOp team: L. Ball, K. Blackstock, G. Blair, R. Bol, W. Buytaet, J. Delve, Y. El-khatib, B. Emmett, J. Freer, A. Gemmell, S. Greene, R. Gurney, A. Impey, P. Johnes, K. Macleod, A. McDonald, N. Odoni, S. Reaney, G. Rees, D. Tetzlaff, C. Vitolo, J. Watkins, H. Watson, K. Waylen and B. Williams.

There will also be a selection of posters from postgraduate students from the Lancaster Environment Centre on display.