BHS 2014

Session 2: Hydrohazards; hydrology of the extremes (droughts and floods)

ABSTRACTS

Oral presentations

2-1L: Flood hydrologists – thoughts for the future

Craig Woolhouse[1]
[1]Deputy Director Flood Incident Management, Environment Agency, Deanery Road, Horizon House, Bristol, UK, BS1 5AH
Email: craig.woolhouse@environment-agency.gov.uk

The east coast surge of early December 2013 saw the highest coastal flood levels across an entire coastline for over 60 years. Record breaking winter rainfall in the south of the country led to significant river and groundwater levels in many locations.

Past investment in flood defences limited the numbers of properties flooded to around 8 000. Forecasting, warning and emergency response arrangements ensured lives were saved and disruption minimised. In January 1953 over 300 lives were lost during the east coast surge. Nobody died on the east coast in December 2013. Hydrologists have been central to this success but are rarely recognised by the public and politicians for their contribution.

Public and political expectations evolve quickly and there is a greater demand for opinion, information and advice before, during and after flood events. Flood hydrologists have the opportunity to raise their visibility, deliver better public services and influence key debates if they engage with and deliver on this expectation.

The paper will explore how the Environment Agency plans to develop its flood hydrology services to serve the public service needs of the future.

2-2L: Local flood forecasting – From data collection to communicating forecasts.

P. J. Smith[1] & K. J. Beven[2]
[1]Lancaster Environment Centre, Lancaster University, UK, LA1 4YQ
Phone: +44 524 592736 Email: p.j.smith@lancaster.ac.uk
[2] Lancaster Environment Centre, Lancaster University, UK, LA1 4YQ
Phone: +44 524 593892 Email: k.beven@lancaster.ac.uk

An important aspect of improving resilience to flooding is the provision of timely warnings to flood sensitive locations thus allowing mitigating measures to be implemented. For specific locations such small communities (often in head water catchments) the ability of traditional centralised forecasting systems to provide timely & accurate forecasts may be challenged in part due to the finite resources of monitoring and forecasting agencies.

One strategy to improve flood resilience at such locations is to develop automated location specific forecasts. In this presentation we outline a methodology to achieve this based on the installation of adequate telemetered monitoring equipment allowing the construction of a local flood forecasting model which may be coupled with available precipitation forecasts.

The construction of the hydrological forecasting model consists of a guided process which incorporates both data assimilation and the representation of the forecast uncertainty based on post processing. The guided process requires the modeller to make only a few choices thus allowing rapid model deployment and revision.

To be of use the derived forecasts must be made available in real time and updated frequently. Traditional practices in issuing warnings dependent on expert interpretation must therefore be altered so that those at the site of interest become their own `experts'. To aid this appropriate presentation of both the predictions and past performance of the model, designed to encourage realistic interpretation of the forecasts and their uncertainties is considered. The resulting forecast chain is demonstrated with case studies.

2-3L: Updating the ReFH flood hydrograph method: reconciling flood hydrograph and statistical estimates of design peak flows

A.R. Young[1], E.J. Stewart[2], T.R. Kjeldsen[3,] G.M. Vesuviano[2] & T.H. Haxton[1]
[1] Wallingford HydroSolutions, Maclean Building, Wallingford, Oxfordshire, OX108BB
e-mail: andy.young@hydrosolutions.co.uk, Tel: 01491 692660
[2]Centre for Ecology and Hydrology, Maclean Building, Wallingford, Oxfordshire, OX108BB
[3] Department of Architecture and Civil Engineering, University of Bath, Bristol Avon BA2 7AY

The Revitalised Flood Hydrograph (ReFH) method was originally developed in 2005 as a replacement for the FSR/FEH rainfall-runoff model. ReFH is an event-based rainfall-runoff model which can be used to generate design hydrographs or to simulate observed flood events.

This paper summarises recent research to update the ReFH design methods across the UK culminating in the development of a new version of the software; ReFH 2. One aspect of the research within England and Wales has been to reconcile estimates of peak flow over a range of return periods with estimates derived using the current generation of the FEH statistical methods. It has long been recognised that differences in the flood growth curves derived using the statistical methods and the rainfall growth curves predicted by the FEH DDF model result in a divergence of peak flow estimates between methods for a given return period, and particularly so at longer return periods. For practical application in England and Wales these differences are reconciled within ReFH through the invoking of a free model parameter, alpha.

The differences between peak flow estimates and the dependencies on climate and catchment type across the HiFlows-UK dataset are explored for a range of return periods. The use of local data can significantly reduce predictive uncertainty within generalised estimates. The influence of the practical use of both long and short record local data is also explored for both methods and with particular emphasis on the difference between peak flows estimates obtained using the methods.

2-4S: Overdispersion in peak over threshold (POT) flow data and its effect on flood frequency practice

Ilaria Prosdocimi[1], Lisa Stewart[1] and Gianni Vesuviano[1]
[1]Centre for Ecology & Hydrology - Benson Lane, Crowmarsh Gifford, Wallingford, OX10 8BB
Email: ilapro@ceh.ac.uk; ejs@ceh.ac.uk; giaves@ceh.ac.uk

The frequency of extreme flood events is generally assessed either via the analysis of block maxima (typically annual maxima) or via the analysis of the data points which exceed a fixed threshold (POT analysis). The analysis of annual maxima, combined with the assumption of a GLO distribution, is the most frequently used method in the UK. Flood frequency estimates can nevertheless vary considerably according to which probability distribution is assumed for the data at hand. This study discusses tools to better understand the properties of flow data and improve the choice of the probability distribution.

Under some general conditions, it can be shown that the analysis of block maxima and POT data are asymptotically related. In particular, if the threshold exceedance process can be assumed to be a Poisson process and the exceedance magnitude assumed to follow a GPD distribution, the annual maxima distribution is shown to follow asymptotically a GEV distribution. Under the assumption of a Poisson process, the number of threshold exceedances should have equal mean and variance. Nevertheless, overdispersion (a larger variance than expected) is often observed for a large proportion of the POT counts. Annual maxima for which threshold exceedances follow some overdispersed Poisson process can be shown to be asymptotically distributed as a GLO distribution.

This study investigates the observed overdispersion in the POT counts and the implications of such overdispersion on the distribution of annual maxima. The relationship between catchment descriptors and overdispersion is also investigated.

2-5S: Localism: new endorsement of an old paradigm for flood frequency estimation

T. R. Kjeldsen
Department of Architecture and Civil Engineering, University of Bath, Bath, BA2 7AY,
Phone: +44 122 5386298 Email: t.r.kjeldsen@bath.ac.uk

Design flood estimates in ungauged UK catchments are routinely obtained using the improved Flood Estimation Handbook (FEH) statistical procedure, and are based on a combination of regional methods and the national dataset of AMAX event available in the HiFlows-UK database. In this paper a relatively simple assessment of the uncertainty associated with FEH design events in ungauged sites will be presented. The assessment is based on a comparison, across a large number of gauged sites, the differences between design flood estimates obtained as-if a site is ungauged and the corresponding at-site estimates obtained by fitting a distribution directly to the available AMAX data at each site. The results are provided for a range of return periods, and it was found that the level of uncertainty of a design flood in an ungauged catchment with a return period of 100 years correspond to a factorial standard error value of 1.54. Using data transfer method for one or more nearby gauged donor catchments, it is shown that the factorial standard error associated with the generalised method can be reduced considerably by considering local data. Finally, results are presented to show that the information content in local data can be utilised to compensate for the lack of hydrologically relevant information contained in the available catchment descriptors. This result is potentially important when flood frequency estimates are required in regions outside the UK where only a limited number of catchment descriptors are available.

2-6S: The new FEH rainfall depth-duration-frequency model: results, comparisons and implications

L. Stewart, I. Prosdocimi and G. Vesuviano
Centre for Ecology & Hydrology, Wallingford, OX10 8BB, UK
Phone: +44 1491 838800
Email: ejs@ceh.ac.uk; ilapro@ceh.ac.uk; giaves@ceh.ac.uk

A new model of rainfall depth-duration-frequency (DDF), originally developed in a Defra-funded project within the Reservoir Safety research programme, has been modified and extended as a replacement for the existing Flood Estimation Handbook (FEH) rainfall model, which is widely used in the UK for design hydrograph studies and post-event analysis. The model will be released towards the end of 2014 within a new FEH web service which will also deliver catchment descriptors for any UK catchment.

The main application of the new FEH DDF model will be to provide updated design storm inputs to the ReFH rainfall-runoff method to generate the flood hydrograph of a specified return period. The new DDF model will also provide estimates of catchment rainfalls of the very longest return periods for reservoir flood risk assessment, which still relies primarily on the FSR/FEH rainfall-runoff method.

The flexible form of the new DDF model allows the spatial and temporal variability of extreme rainfall to be easily visualised and comparisons between the new results and those from the FEH and Flood Studies Report (FSR) models will be presented to highlight regional differences across a range of rainfall durations and return periods. In addition, estimates of the return periods of a number of extreme storm events experienced in the UK will be assessed and discussed.

Finally, the implications of the use of the new DDF model for design hydrograph analysis will be discussed together with plans for future research and development of FEH methods.

2-7S: Effect of extreme rainfall characteristics within differing monsoon synoptic systems on flood response in headwaters

N. Vissa[1], M. Bonell[2,], N.A. Chappell[1], W. Tych[1], J. Krishnaswamy[3], R.S. Bhalla[4], & V. Srinivas[4]
[1]Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ
[2]Centre for Water Law, Policy & Science, University of Dundee, Dundee, DD1 4HN
[3]ATREE, Bangalore 560 064, India
[4]FERAL, Tamil Nadu 605 101, India
Phone: +44 1524 593933 Email: n.vissa@lancaster.ac.uk

Over 500 million people in India are at risk from flooding and vulnerable to climate or land-use change linked with livelihoods and economic development. There are indications that different synoptic –scale systems in the tropics differ in their rainfall characteristics (Howard, Bonell et al. 2010). If this is the case then adjustments within such systems to climate change (based on existing GCM scenarios) are likely will impact on flood occurrence.

This study, part of the ongoing NERC Changing Water Cycle (CWC) programme, uniquely quantifies the relationship between synoptic type and temporal variations of both rainfall intensity and indices of meteorological processes. As 70-80% of discharge enters channel networks in first- to third-order basins, then any understanding of the relationship between rainfall and flood hydrograph responses must consider the behaviour of headwaters. These basins respond quickly, particularly in the tropics and during rainfall extremes, demanding observations with sub-hourly sampling. Consequently, this study quantifies the relationship between short-term, rainfall characteristics and headwater response to separate under-researched rainfall effects from those of particular basin characteristics. Given CWC focus on India, the research has required intensive monitoring of headwaters within a part of tropical montane India - the Western Ghats. Following separation of observed rainfall time-series into different synoptic types, the CAPTAIN Toolbox is used to quantify the differing dynamic relationships between rainfall and streamflow for monsoon rain-events. The relationship between identified rainfall-runoff characteristics and synoptic type are then interpreted as a precursor to quantifying behavioural shifts resulting from climate and/or land-use change.

2-8S: Mapping Scotland's flood hazard and flood risk to inform flood risk management.

M. J. McLaughlin
Scottish Environment Protection Agency, Angus Smith Building, 6 Parklands Avenue, Eurocentral, Holytown, North Lanarkshire, ML1 4WQ
Phone: +44 1698 839452 Email: mark.mclaughlin@sepa.org.uk

In Scotland, the EC Floods Directive is transposed into law by the Flood Risk Management (Scotland) Act 2009. The Scottish Environment Protection Agency (SEPA) is a central 'responsible authority'. It supports and guides the delivery of new information, flood risk management strategies and plans. Key to the management of flood risk is understanding better the flood hazard and flood risk in the most potentially vulnerable areas (PVAs). In 2014 SEPA published the most comprehensive national mapping of flood hazard and risk in Scotland. In developing a suite of national flooding scenarios, significant methodological, time and data management challenges are addressed by innovative solutions to produce maps of flood extent, depth and velocity for rivers, the sea and surface water. Based on 2d modelling of 5000 domains, fluvial maps consider catchments greater than 3km^2. National datasets provide key inputs: a composite IFSAR-LiDAR DTM, CEH Flow Grid, and details of important defence structures. Hydrology inputs are augmented by local gauged information within established quality criteria. Map validation is supported by a database of over 15,000 records of flooding spanning several centuries. Effective flood risk management decisions are dependent on understanding the limitations of the information; a framework for tracking and communicating uncertainty supports decision-making. A rolling programme of development seeks to improve overall confidence through model calibration and validation. Crowd-sourced flood information will be an important contribution in future. Development of further climate change scenarios will support the maps as the national source of flood hazard and risk information for Scotland's communities.

2-9S: Development of a pilot surface water alerting tool for Glasgow and operational use during the Commonwealth Games

L.Speight[1], M. Cranston[1], R.J. Moore[2], S.J. Cole[2], B. Golding[3], C. Pierce[3], B. Wright[3], N. Roberts[4], S. Ghimire[5] and S.Dunn[5]

[1]Flood Forecasting and Warning Team, Scottish Environment Protection Agency, Perth, Scotland, PH2 OPA. Phone: 01738 627989 Email: linda.speight@sepa.org.uk

[2]Centre for Ecology & Hydrology, Wallingford, Oxfordshire, OX10 BBB

[3]Met Office, Exeter, Devon, EX1 3PB

[4]Met Office@Reading, Meteorology Building, University of Reading, Reading, RG6 6BB

[5]The James Hutton Institute, Craigiebuckler, Aberdeen, Scotland, AB15 8QA

In Scotland 38% of flooding impacts are from surface water (SEPA 2011) but at present there are limited forecasting tools available to identify the risk in real-time. As part of SEPA's commitments to developing approaches in forecasting pluvial flooding (SEPA, 2012), a new pilot modelling approach has been developed for Glasgow which forecasts the probability and potential impacts of surface water flooding. By involving relevant stakeholders throughout the project, the tool aims to balance the requirements of end users with emerging scientific capabilities. The new approach will be tested throughout the summer of 2014 including providing operational output during the Commonwealth Games.

Forecasting convective rainfall events that cause surface water flooding is challenging. For this reason a probabilistic approach is essential. The new Met Office MOGREPS-UK blended ensemble rainfall forecast (Golding et al, 2014) is linked to the Centre for Ecology & Hydrology's Grid-to-Grid model (G2G) to predict the surface water runoff (Ghimire et al, 2013). This runoff is used as a proxy for effective rainfall to establish a link between the real-time G2G surface water runoff forecast and a static database of SEPA's new surface water flood maps and associated impact assessments. Expected impacts are divided into low, medium and high categories and the probability of exceeding these thresholds on a 1km grid is produced. The hydrometeorological assessment of surface water flood risk for the next 24 hours will be communicated to responders by the Scottish Flood Forecasting Service through a new surface water guidance document.

2-10S: Assessing risks of flash flooding using historical information – three examples from northeast England

D Archer[1] G. Parkin[2] & H.J. Fowler[2]

[1]JBA Consulting Engineers and Scientists, South Barn, Broughton Hall, Skipton, N Yorks, BD23 3AE,

Phone: +44 1661 834063 Email: davearcher@yahoo.com

[2]Water Resources Systems Research Laboratory, School of Civil Engineering and Geosciences, Newcastle University, UK NE1 7RU, Phone: +44 191 2086146 Email: geoff.parkin@ncl.ac.uk & h.j.fowler@ncl.ac.uk

Historical information has become widely used in Britain to improve estimates of flood discharges in rivers usually in association with estimates using gauged data. However, historical information has not yet been used to assess the risk of flash flooding. Flash floods result from intense short duration rainfall, usually convective, that exceeds drainage capacity in urban areas or infiltration capacity in rural areas and hence can cause pluvial flooding of land and property far from rivers. They also result in abrupt increases in river levels on small catchments and very rapid rates of rise may be transmitted downstream on larger catchments where they may cause danger to life of river users.

Three contrasting examples are described in this paper. 1) A comparison of an urban pluvial flood in Newcastle in June 2012 with historical events from the end of the eighteenth century, 2) Assessment of flood risk on the Cotting Burn a tributary of the River Wansbeck which suffered a severe flash flood in 1968 and 3) Assessment of the risk of extreme rates of rise in river level on the River Wansbeck near Morpeth by comparing the event of August 1994 with historical floods. The recently observed floods appeared to be unprecedented but three or more events of equal or greater magnitude were identified from historical sources in each case. Historical information is then used to improve estimates of the risk of recurrence. Problems of assessing the comparative magnitude of historical and recent flash floods events are discussed.

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2-11S: Resistance to the use of historic floods in order to estimate extreme floods

Colin Clark, CHRS Shute Lane, Bruton, Somerset. BA10 0BJ

Both the FSR and FEH contain reference to, details of, and some guidance regarding the use of historic floods to improve estimates of extreme floods. However, the guidance is not at all clear and there is no indication of the relative importance of historic floods as compared with other methods in the FSR and FEH. Three case studies are used to illustrate the need to use historic flood data as a matter of both urgency and priority. Although there is some uncertainty in estimating the peak discharge and volume of historic floods, important progress has been made in recent years. Three case studies will be described. The first is the design of Bruton flood detention dam in Somerset. The second is the Flood Risk Assessment on the Upper Stour at Bourton in Dorset. The third is the assessment of the flood hazard at Boscastle following the flood in 2004. In the first two case studies the estimate of extreme floods was underestimated. In the case of Boscastle, the estimate of the 2000 year flood is so high as to equal the extreme catastrophic flood, widely recognised as an upper limit.

The practical implications of the resistance to the use of historic floods are described in the case of the upper Brue, where the flood detention dam was upgraded at a cost of nearly £3M. The historic flood volume was not used in a comparison of the volume retained above the dam over a 20 year period, which would have affected the cost benefit analysis of the dam upgrade.

2-12S: A simplified approach to modelling surface water flood risks during extreme precipitation events at the city-scale: model development and spatiotemporal validation using crowd-sourced data

Dapeng Yu[1*], Jie Yin[2], Jianguo Chen[3], Shiyuan Xu[4], Zhane Yin[5].
[1]Centre for Hydrological and Ecosystem Science, Department of Geography, Loughborough University, UK LE11 3TU.
[2] School of Tourism and City Management, Zhejiang Gongshang University, China
[3] Department of Engineering Physics, Tsinghua University, Beijing, China.
[4] Key Laboratory of Geo-information Science of the Ministry of Education, East China Normal University, China
[5] Department of Geography, Shanghai Normal University, China

In this study, we describe the development and application of a simplified approach to the modelling of surface water flooding at the city-scale. The model (FloodMap-Pluvial2D) considers direct surface runoff overpassing sewer inlets to be the dominant source of flood water and simplifies the interaction between surface runoff and the storm sewer system using a drainage capacity coefficient. Distributed precipitation, drainage capacity and infiltration rate are used in the model to represent the key processes occurring during an urban storm-induced surface water flooding. Surface flow routing is represented with an inertial treatment using an existing model (FloodMap-Inertial). This approach was tested to simulate a high-intensity storm event occurred on 12 August 2011 in the Shanghai Municipality, China. The model predications were compared with an incident dataset "crowd-sourced" through a web-based portal, which contains 298 points with spatial and temporal information of flood incidents. The evaluation demonstrates that the model is able reproduce the broad patterns of flood areas at the city-scale, with over 91.6% of the reported points falling within the predicted inundated area. Temporal evaluation also suggests that the model is able to capture the dynamic nature of the flood, with a good level of agreement between the reported and model predicted flood timing. Micro-topography and the spatial & temporal accuracy of the precipitation are the two key factors that affect the predictive accuracy. Whilst the model is not designed for predicting local-scale sewer surcharge induced pluvial flooding, it can be used as a first-stage evaluation of areas vulnerable to surface water flood risks at the city-scale.

2-13S: Field methods for testing the theory of small scale riparian hydrology: implications for flood risk management and modelling

Linsey McLean[1], Dr. Lindsay Beevers[1], Dr. Mark Wilkinson[2] & Prof. Gareth Pender[1]
[1] Institute for Infrastructure and Environment, Heriot University, Edinburgh, EH14 4AS. Email: lm307@hw.ac.uk; l.beevers@hw.ac.uk; g.pender@hw.ac.uk.
[2] James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH. Email: Mark.Wilkinson@hutton.ac.uk.

Riparian buffer strips have traditionally been adopted for their ability to reduce diffuse pollution. More recently however, they have been accepted as a natural flood management (NFM) measure in the UK; defined as a soft-engineered approach to utilising the landscape's natural processes and features to reduce flood risk. Hydrological theory suggests riparian buffer strips are effective at reducing flood risk because of their ability to: increase infiltration; increase hydraulic roughness; attenuate runoff; as well as have many other influences (albeit minor) for example, interception and evapotranspiration. There is an ongoing debate on the optimal width of buffer strips and the spatial scale at which they are implemented, as well as the scale of flood event that riparian buffers can contend with over time.

Hitherto, research on the riparian buffer strips' influence on flood risk has been dominated by vegetation composition and hydraulics whereas; there is currently an urgent need for more evidence that riparian hydrology does reduce flood risk and to identify temporal, spatial and event scale thresholds for effectiveness. Empirical data collected from the field site in the agricultural Tarland catchment, Aberdeenshire, can inform the impact of catchment scale implementation through modelling, which will enable effective allocation of resources for statutory NFM appraisal. This experiment will set out a novel field experiment designed to test and quantify the hydrological response of riparian buffer strips and present preliminary results and analysis. This analysis will subsequently be compared to riparian theory and the usefulness of the data in a semi-distributed physically based hydrological model (SWAT) is also discussed.

2-14L: What do we talk about when we talk about drought?

J. Hannaford[1], J.P. Bloomfield[2], I.P. Holman[3], B. Lange[4], R. J. Ledbetter[5], M.P. McCarthy[6], T. McEnery[7], R.Pearce[8], S. D. Wade[6]
[1] Hydrological Status and Reporting Group, Centre for Ecology and Hydrology, Benson Lane, Crowmarsh Gifford, Wallingford, OX108BB Phone 01491 692234, Email: jaha@ceh.ac.uk.

[2] Groundwater Survey and Management Team, British Geological Survey, Wallingford. jpb@bgs.ac.uk
[3]School of Applied Sciences, Cranfield University. i.holman@cranfield.ac.uk
[4] Centre for Socio-Legal Studies, University of Oxford. bettina.lange@csls.ox.ac.uk
[5] Water Resources and Climate Change, HR Wallingford. R.Ledbetter@hrwallingford.com
[6] National Climate Information Centre, Met Office, Exeter. mark.mccarthy@metoffice.gov.uk
[7]Department of Linguistics and English Language, University of Lancaster. a.mcenery@lancaster.ac.uk
[8] Geography Department, University of Exeter. R.Pearce@exeter.ac.uk

Drought is a vague concept. Journal papers on drought invariably contain a sentence along the lines of "there is no universally agreed definition of drought...." and a recent study suggests a universal definition may simply not be possible in practice (Lloyd-Hughes, in press). 'Drought' is perhaps necessarily vague, reflecting the many different perspectives on the hazard and because all droughts are different: economic and social impact and management responses have a bearing on the outcome of a drought, alongside climate and environmental factors. This presentation will describe an exciting new project which has the potential to shed new light on the ways in which drought is defined, communicated and managed in the UK and beyond. The 'Historic Droughts' project is a joint Research Council (RCUK)-funded project that will address the concept of drought and how it has changed (from the late 19th century onwards) in the UK from a range of perspectives: hydrometeorological, agricultural, regulatory, social, cultural, linguistic. The project embraces diverse data sources, ranging from hydrological modelling reconstructions through to interviews in drought-affected communities and linguistic analysis of published newspaper resources and recent social media data. The project aims to develop a systems-based understanding of drought, reflecting the fact that droughts are complex hazards, a function of manifold human and natural drivers, impacts and their interactions. By learning from the past, a better understanding of these systems interactions can inform improvements in management and communication of droughts in future. We believe the project has the potential to challenge current theory and practice; a universal definition for drought may prove elusive, but we hope to develop a common language for understanding this complex phenomenon.

2-15L: Measuring the flow in a small irregular river using LS-PIV

M.Sterling [1]School of Civil Engineering, University of Birmingham, Birmingham, UK, B15 2TT
Phone: +44 121 4145065 Email: m.sterling@bham.ac.uk

In many cases, knowing the discharge of water in a river is of fundamental importance in terms of understanding how the river and local environment behave, e.g., flood hydraulics, water quality control and reservoir operation. Recently, there has been a growing interest in the use of non-invasive techniques such as Large Scale Particle Image (LS-PIV), in order to obtain an estimate of the discharge. LS-PIV measures the 2-D velocity field of the water surface and through some prescribed measure, often an empirical relationship, provides an estimate for the discharge. This approach has a number of advantages, particularly during flood conditions but relatively little work has been undertaken to examine its application to small, irregular rivers where cross sections and hence the hydraulics of the flow can change within short spatial distances. This work outlines the results obtained when LS-PIV was applied to a 300m reach of the river Blackwater, Hamspire, UK. Detailed velocity measurements were also undertaken using an acoustic Doppler current profiler (ADCP) and acoustic Doppler Velocimtery (ADV) for inbank, bankfull and overbank flows in order to provide information on the 2-D velocity field perpendicular to the water surface. Results from the latter were coupled with the LS-PIV in order to evaluate how successfully the discharge could be obtained from the LS-PIV.

2-16L: Real-time modelling of surface water flooding hazard and impact at countrywide scales

S. J. Cole[1], R. J. Moore[1], P. S. Mattingley[1], T. Aldridge[2], J. R. Millard[3,4] & S. Laeger[5]
[1]Centre for Ecology & Hydrology, Wallingford, Oxon, UK, OX10 8BB
Phone: +44 (0) 1491 692263 Email: scole@ceh.ac.uk
[2]Health and Safety Laboratory, Buxton, Derbyshire, UK, SK17 9JN
[3]Met Office, Exeter, UK, EX1 3PB
[4]Flood Forecasting Centre, Exeter, UK, EX1 3PB
[5]Environment Agency, Exeter, UK, EX2 7LQ

In response to the floods of summer 2007, the subsequent Pitt Review and more recent events, the demand is growing for more robust, accurate and timely forecast and alert information on surface water flooding (SWF) along with impact assessments at local, area and national scales. A major impetus for recent progress has come through the Natural Hazards Partnership (NHP) which aims to deliver coordinated assessments, research and advice on natural hazards for governments and resilience communities across the UK. Under NHP, a real-time Hazard Impact Model (HIM) framework is under development that includes SWF as one of three hazards chosen for initial trialling. In contrast to rainfall-threshold based SWF methods, the NHP HIM prototype approach uses dynamic gridded surface-runoff estimates from the Grid-to-Grid (G2G) hydrological model. G2G is already employed for operational fluvial flood forecasting across England, Wales & Scotland and thus its use for SWF is a natural extension to consider. Novel methodologies for generating dynamic real-time forecast maps and area-wide summaries of possible SWF impacts have been developed that can employ rainfall forecasts in deterministic and ensemble form. Use is made of national receptor datasets of population, infrastructure, property and transport along with the recent Updated Flood Map for Surface Water (UFMfSW) over England & Wales. The prototype approach is outlined and illustrated through case studies, including some events from summer 2012. Finally, a perspective on future developments and possible operational implementation is given.

2-17S:Analysis of drought characteristics from 1880s to 2012 for improved understanding of a water resource system

A. Lennard[1], S. Clark[2]
[1]School of Environmental Sciences, University of Liverpool, Liverpool L69 7ZT
[2]Severn Trent Water, Severn Trent Centre, 2 St John's St, Coventry, CV1 2LZ

Droughts are a reoccurring feature of the European climate; recent drought events (2004-2006 & 2010-2012) in the UK have highlighted a continued vulnerability to this hazard. The period 2010-2012 was characterised by departures from typical seasonal climatic conditions, resulting in a severe drought, which had a significant impact on water resources in some parts of the UK. This highlights the need for further understanding of extreme drought events, particularly from a water resource perspective.
The UK has a wealth of long series climate data that could be further used to inform water resource management. Severn Trent Water currently uses climate data from 1920-2010 in the modelling that informs its water resource management plans and drought plans. However, this period excludes significant droughts of the late 19th Century. This work uses the standardised precipitation index drought metric and hydrological modelling techniques using long series data from 1884-2013 to investigate whether this extended dataset has any implications for water resource management. Each drought has a unique set of characteristics (including onset, severity, duration and termination) so including more drought events in the modelling period may improve understanding of the impact of drought on the supply system.

2-18S: Operational groundwater level and river flow ensemble projections for national assessments

R.J. Davis[1] & K.James[2]
[1]Senior Technical Advisor Hydrology, Environment & Business Directorate, Environment Agency, Kings Meadow House, Kings Meadow Lane, Reading, UK, RG1 8DQ
Phone: +44 118 953 5324 Email: richard.davis@environment-agency.gov.uk
[2]Technical Advisor Hydrology, Environment & Business Directorate, Environment Agency, Manley House, Kestrel Way, Exeter, EX2 7LQ
Phone: +44 1392 352428 Email: karen.james@environment-agency.gov.uk

In the face of recent extreme weather events, there has been an increasing demand for forward look hydrological projections from government, contingency planners and incident management teams. These are required to give appropriate lead in time to allow risk mitigation measures to be implemented to minimise impact upon people, the environment and infrastructure.

While hydrological projections can be run successfully using short range, high resolution precipitation forecasts for flood forecasting applications, datasets are currently not available to extend these forecasts to weeks and months ahead.

In order to address this issue, the Ensemble Streamflow Prediction (ESP) methodology has been coupled to Catchmod, a lumped rainfall runoff model, to enable projections of groundwater level and river flow to be undertaken. This ensemble approach complements the traditional synthetic scenario approach by providing a range of projections from which probabilities can be assessed

The Environment Agency has been routinely publishing projections each month using this approach since February 2012. The methodology has been incorporated into one element of the UK Hydrological Outlook. The tool and methodology have also been recently used to assess the persistence of high groundwater levels in the chalk aquifers of southern England during spring 2014.

2-19S: Modelling the influence of flood event clustering on catchment scale bank erosion

V. Janes[1], I. Holman[1], G. O'Donnell[2], S. Birkinshaw[2] & C. Kilsby[2]
[1]Water Science Institute, School of Applied Sciences, Cranfield University, Cranfield, UK, MK43 0AL
Phone: +44 1234 750111 Email: v.j.janes@cranfield.ac.uk, i.holman@cranfield.ac.uk
[2]School of Civil Engineering and Geosciences, Newcastle University, Newcastle Upon Tyne, UK, NE1 7RU.
Phone: +44 1912 088836 Email: stephen.birkinshaw@ncl.ac.uk, g.m.o'donnell@ncl.ac.uk, chris.kilsby@ncl.ac.uk

Understanding and estimating sediment generation processes within river catchments is of great importance for managing river water quality and riverine habitats, as regulation of sediment levels is required under the EU Water Framework Directive. Channel bank erosion has been estimated to contribute a significant proportion of the sediment budget within some catchments but is poorly represented in most catchment models. As part of the EPSRC-funded FloodMEMORY project, this work describes the improvement and evaluation of bank erosion processes within the physically-based SHETRAN model. The updated bank erosion component within the model includes the influence of channel sinuosity and channel bank vegetation. Bank erosion increases with sinuosity up to a threshold value (related to channel curvature), above which bank erosion decreases. The effect of vegetation removal (and consequent increase in bank erodibility) as a result of large flood events has been incorporated within the model, with bank erodibility subsequently decreasing over time as vegetation reestablishes. The influence of further flood events during this recovery period is enhanced due to the increased erodibility of channel banks caused by lack of vegetation

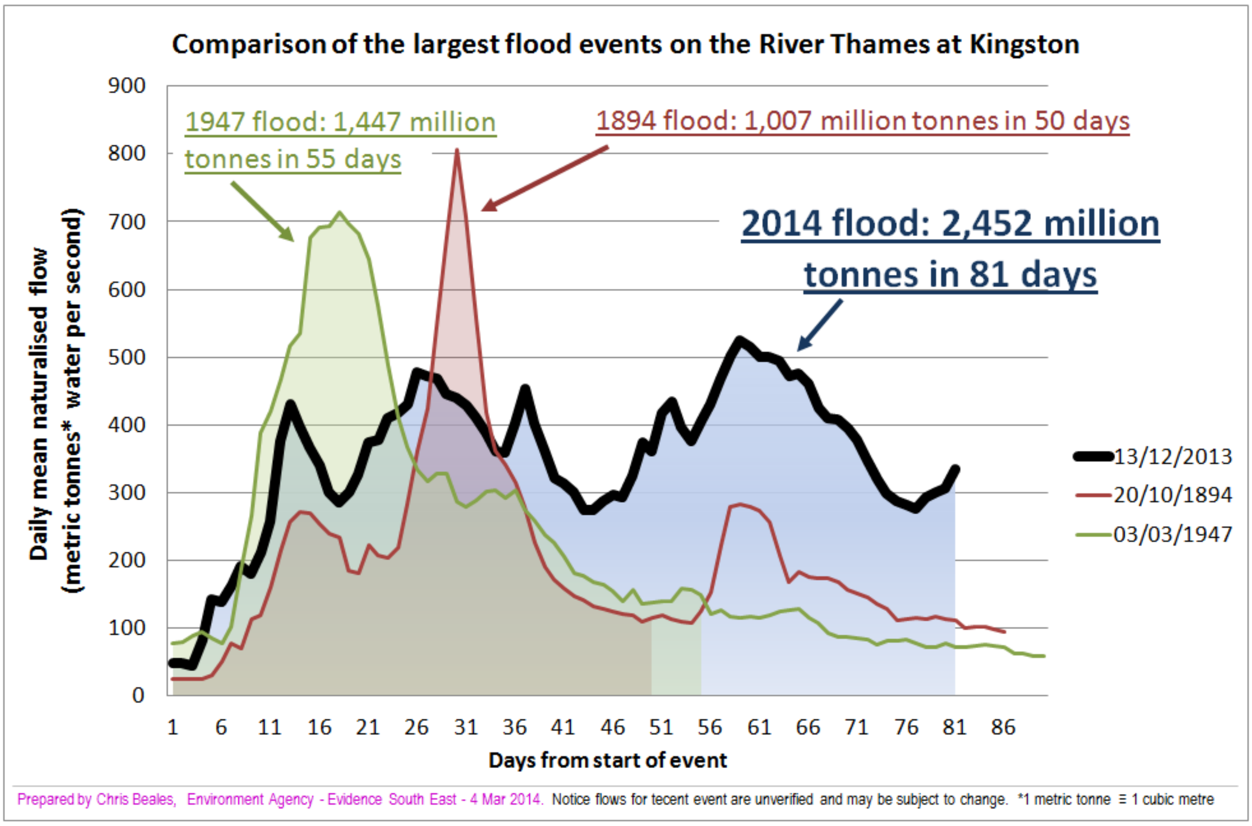
cover. The presentation will show how these developments provide an improved simulation of the spatial variability of bank erosion within catchments, and demonstrate the importance of flood event clustering to sediment budgets.

Poster presentations

2-1P: A climate change perspective on the recent flooding

Chris Beales
Environment Agency, Kings Meadow House, Kings Meadow Road, Reading, RG1 8DQ
Phone: 0118 953 5326
Email: chris.beales@environment-agency.gov.uk

It has been a record-breaking winter in the southeast, with over 62% average rainfall in just two-and-a-half months. There was significant river and groundwater flooding as a result of this, which meant a lot of work for Environment Agency incident staff. I produced a number of graphical comparisons of river flows, rainfall and groundwater levels during the incident. These helped to communicate the scale of the event against historic floods and what we might expect to see as a result of climate change.



2-2P: The importance of hydrological extremes for the Xepon III run-of-river hydroelectric project, Laos: Bringing confidence to local suspicions

T. Beskeen[1], P. Ede[2], J. Chan[3] and S. Sung Woo[3]
[1]Mott MacDonald, 1 Grange Road, #07-01 Orchard Building, Singapore, 239693
Phone: +65 63052830 Email: tom.beskeen@mottmac.com
[2]Mott MacDonald, Demeter House, Station Road, Cambridge, CB1 2RS, UK
[3]Korea Water Resources Corporation, 200 Beon-gil, Sintanjin-ro, Daedeok-gu, Daejeon 306-711, Korea

Crucial to the feasibility of any hydropower scheme is the availability of river flows for power generation both in terms of quantity and inter-annual variability. A secondary but important consideration is the impact of flood flows on the scheme infrastructure. Run-of-river hydropower schemes minimise upstream flooding, preserve habitats and reduce community displacement, but are more vulnerable to hydrological extremes due to a limited storage capacity. A thorough understanding of the hydrology is critical, but often challenging due to the scarcity and quality of existing hydro-meteorological information.

The proposed Xepon III run-of-river hydropower scheme, with a catchment area of 464km^2, lies in a sparsely populated area in the Savannakhet province, Laos, close to the Vietnam border. Local villagers reported that the monsoon season was longer and rainfall higher in this part of Laos and that a recent extreme flood caused river levels to rise 11m.

Raingauges and a satellite-linked water level sensor were installed for a one year period and discharge measurements undertaken. The monitoring programme was essential for confirming the influence of the northeast monsoon from Vietnam on the catchment, a feature that is not picked up when considering Laos rainfall stations only. Confirming the duration and severity of the dry season had a significant impact on the understanding of the scheme power generation potential when compared to initial estimates.

The monitoring also picked up a significant flood event on 18 September 2013. 545mm of rainfall was recorded in 24hrs which resulted in an estimated flood peak of 3,000m^3/s, information which is valuable in the verification of the empirically derived design flood discharges.

2-3P: Recent application of ensemble projections for water resources management, flood forecasting and carbon reduction

D. Bubidge[1], S. Cook[2], T.Schnetler[3]
[1]Hydrology & Operations, Environment Agency, Kingfisher House, Goldhay Way, Orton Goldhay, Peterborough, UK, PE2 5ZR
Phone: +44 1733464493 Email: daniel.burbidge@environment-agency.gov.uk
[2] Hydrology & Operations, Environment Agency, Kingfisher House, Goldhay Way, Orton Goldhay, Peterborough, UK, PE2 5ZR
Phone: +44 1733464420 Email: steve.cook@environment-agency.gov.uk
[3]Environment & Business Directorate, Environment Agency, Manley House, Kestrel Way, Exeter, UK, EX2 7LQ
Phone: +44 1392 352438 Email: tom.schnetler@environment-agency.gov.uk

Development of software to run an ensemble of rainfall and potential evapotranspiration scenarios through warm start Catchmod river and groundwater models has helped the Environment Agency to assign probabilities to groundwater levels and river flows up to 1 year in advance. In the East of England these techniques have been used for a range of applications. These include:

- Assessing drought permits for the filling of major public water supply reservoirs.
- Saving money and carbon through optimising pumping in the Ely Ouse to Essex Transfer Scheme
- Informing irrigators about the likelihood of restrictions in the Prospects for Spray Irrigation Report produced by the Environment Agency.
- Calculating the risk of Groundwater Flood Alert Thresholds being breached along with the likely severity and length of the incident at sites in Newmarket and Bury St Edmunds.

The technique has brought benefits to the management of water resources and flood risk but an understanding of the assumptions made and its limitations has been critical for its successful application. Potential future uses include optimising abstraction and financial forecasting.

2-4P: New Guide to Flood Estimation: application to an historic event

Colin Clark, CHRS, Shute Lane, Bruton, Somerset. BA10 0BJ

The New Guide to flood estimation in England and Wales presents a major challenge to the way in which floods are estimated. It differs from current methodology in several ways: First it uses variable percentage runoff values based on measured soil hydraulic conductivity in the field; second it uses a variable time to peak which depends on the soil conductivity; third it uses a new suite of extreme rainfall estimates; fourth it uses estimates of soil moisture deficit for flood events which have been estimated from long term lysimeter measurements; fifth, it uses an empirically derived factor for the effect of permeable rocks on baseflow.

In trying to explain the method in detail the historic storm of 1912 over Norfolk was assessed using the new method. The results showed that the observed changes in riverflow during the flood were well predicted, and in particular the peak discharge, which had been measured by the Norwich City Engineer, was estimated to within 10%. The value of using an historic event to test methods of flood estimation ought to be taken up more widely, since in the past such as on the Upper Brue in East Somerset, and Boscastle in Cornwall, serious errors in the estimation of extreme floods have been made. The implications for engineering design are serious, since there is a tendency to underestimate floods on small catchments, which are often the site of storage reservoirs, and where public safety is most at risk.

2-5P: Battle of the rainfall extremes: four theories and three specific tests

Colin Clark, CHRS, Shute Lane, Bruton, Somerset, BA10 0BJ

There is a need to improve and verify estimates of extreme point and areal rainfall. Since 1975 the FSR has been used to give rainfall estimates. Having found to have regional and quantile deficiencies, it was replaced by the FEH in 1999 but this also contained serious anomalies. A study funded by Defra produced new estimates, but again the results were not tested against an objective standard. The New Guide for flood estimation in England and Wales contains alternative estimates of both point and areal rainfall.

The four estimates of extreme rainfall were tested using three objective tests. The first used the expected rarity of the largest one-day events, which was based on a regular grid of rain gauges over England and Wales. The second test compared the rarity of the flood producing rainfall wit the rarity of the resulting flood, at sites which have a reliable long term flood frequency relationship which includes historic flood data. The third test compared the observed depth area relationship with that produced by the four methods. For the first test the order of accuracy was New Guide and FSR equal, followed by the FEH and Defra. For the second test the order was New Guide, FSR, FEH and Defra. For the third test the comparison was between the New Guide and the other three methods which use the same ARF relationships. The New Guide produced areal estimates of rainfall which were close to those based on storm data.

These results have huge implications for the design of engineering structures in the future.

2-6P: Changes in field size over the last 120 years and possible implications for flooding

V.L. Coates, I. Pattison
School of Civil and Building Engineering, Loughborough University, Loughborough, UK, LE11 3TU
Email: v.l.coates@lboro.ac.uk

The intensification of agricultural practices has been shown to alter runoff magnitudes at the local scale. However this link is more uncertain at larger scales. Modern practices, including monoculture and overstocking have resulted in the removal of field boundaries and the subsequent increase in field sizes. This change in the rural landscape is likely to have changed hydrological pathways through and over the soil, potentially changing catchment scale flood risk. Firstly, this paper quantifies how significant changes in the density of field boundaries have been over the past 120 years for the Skell catchment, Yorkshire, northern England. Historical OS maps have been digitised and field sizes and densities have been extracted. The analysis has shown that field size has doubled in the Skell catchment since

1892, due to the removal of field boundaries. Secondly, the effect of field boundaries on local soil characteristics and hydrological processes is quantified. Field experiments have been conducted to measure the water balance at and up to 10 metres away from field boundaries. Initial result show that soil moisture levels are lower immediately next to the hedgerow compared to distances greater than 1m from the hedgerow. Data provided by this fieldwork will be used to parameterise and validate catchment scale hydrological models, which will be applied to test the upscaled effect of field boundary features on river flow extremes. This will determine how significant the change to the rural landscape has been and have implications for flood risk management.

2-7P: Are hydrologists superfluous to flood management in the Environment Agency?

J. Dent[1] and C Clark[2]
[1] Independent Consultant, 2 Bell Mews, Hadleigh, Suffolk, IP7 5AW Phone: +44 (0)1473 827134 email: jamesdent247@hotmail.com
[2] Charldon Hill Research Station, Shute Lane, Bruton, Somerset, BA10 0BJ Phone: +44 (0)1749 813513 email: colin4chrs@hotmail.com

Our experience in studying flood risk and extreme rainfall has caused us to be concerned that analytical hydrology and hydrometeorology within the Environment Agency are at risk of being sidelined in favour of a push-button approach. The methods for flood estimation have been largely developed outside the Agency by specialist researchers and consultants. To illustrate our concerns, we will consider some of the tools and sources that are used in a simple flood risk assessment, and then consider a few case studies.

The 'Product 4' output is widely used in flood risk assessment. However, users do not know the accuracy of the outputs, or details of the methods, data and assumptions used by the modeling consultants to estimate runoff from rainfall.

Other useful data sets, such as Amax and PoT series in HiFlows, seem to lag by 2-3 years. Catchment Spatial Data provided by CEH also have not been updated for some while. Point and area rainfalls are usually obtained from FEH-CDROM, but the underlying data set is many years out of date, and estimating methods for pooling, growth factors may be in-appropriate.

Other assumptions now firmly entrenched within policy and procedures, but should be open to question on a case-by-case basis, such as the rationale behind applying 20% or 30% up-rating for 'climate change' for both rainfall and floods? How can the percentage be applied universally for minor streams and major rivers?

We appear to have become locked into data and methods that are fixed by protocol. Taking this to its logical conclusion, why bother with real local data and knowledge at all? This presentation is not intended as a curmudgeonly rant, but to suggest that we, as a group of scientific specialists, need to be more thoughtful about the way we make assessments in the future.

2-8P: Coastal Flood Risks in Bangkok: combined impacts of land subsidence, sea level rise and storm surge

Chanita Duangyiwa*, Dapeng Yu, Robert Leonard Wilby
Centre for Hydrological and Ecosystem Science, Department of Geography,
Loughborough University, United Kingdom
*C.Duangyiwa@lboro.ac.uk

Coastal mega-cities in Southeast Asia are facing increased risks of coastal flooding due to the combined impacts of: (i) a changing climate; and (ii) intensified human influences. According to the report published by the Organization for Economic Co-operation and Development (OECD), the Bangkok Metropolitan Region is one of the largest coastal mega-cities that are facing significant impacts due to climate change and variability. Floods from the river and coastal inundation due to high tides from the sea are typical phenomena in the region due to the relatively low-lying nature of its terrain and close proximity to the coast. Key factors affecting coastal flood risk in Bangkok include land subsidence, sea level rise and, to a less extent, storm surge. This research investigates the coastal flood risks in Bangkok, using a two-dimensional flood inundation model (FloodMap, Yu and Lane 2006), taking into account land subsidence, sea level rise and structural features such as flood defences. Scenarios were designed with projections of land subsidence and sea level rise to 2050s and 2080s. The 2011 flood in Thailand is used as a case study. Results suggest progressively increased risks of coastal flooding to key coastal infrastructures. This study improves our understanding of the potential impacts of climatic and anthropogenic processes on coastal cities in Southeast Asia, which are in particular vulnerable to coastal flood risks due to their fast changing climatic and anthropogenic conditions. The understanding gained through this study may inform decision makers with useful information to undertake appropriate adaptation measures for dealing with the potential flood risks.

2-9P: Application of a 2D hydrodynamic model in a dynamic upland river system in the Scottish Boarders.

S. Ghimire[1], S. J. Addy[2], M. Wilkinson[3]
[1]The James Hutton Institute, Craigiebuckler, Aberdeen, Scotland, AB15 8QA
Phone: +44 122 24395132 Email: sohan.ghimire@hutton.ac.uk
[2]Phone: +44 122 24395159 Email: stephen.addy@hutton.ac.uk
[3]Phone: +44 122 24395158 Email: mark.wilkinson@hutton.ac.uk

The Bowmont Water is a major tributary in the Tweed Catchment in the Scottish Boarders that drains the northern slopes of the Cheviot. The river system is one of the most diverse and changeable fluvial environments in the UK characterised by high rates of geomorphic changes associated with coarse sediment supply, large flood events and intensive land use. Extensive channel adjustments and management have led to increased risk of flooding. Identification of vulnerable areas at risk of flooding is therefore a priority in the catchment. Hydrodynamic modelling is a tool that can be applied for identifying areas at risk of flooding both within channel and its floodplain. However, modelling high flow events that cause flood inundation in a changing fluvial environment is challenging. Over the past decade, the use of advanced numerical modelling techniques have been boosted by advances in data acquisition techniques, the availability of high power computational facilities and development of efficient numerical solvers. In Bowmont, high resolution elevation data were acquired through an Unmanned Aerial Vehicle (UAV) survey recently. Using these data we created a Digital Elevation Model of the main channel and its floodplain and a two-dimensional model was developed to simulate flows within the complex topography of the river. Model parameters were optimised by simulating an observed high flow event and patterns of flow across the floodplain were verified using time series photographs taken by a webcam.

2-10P: Flood frequency analysis for the River Avon at Bath

T. Jerry and T. R. Kjeldsen
Department of Architecture and Civil Engineering, University of Bath, Bath, BA2 7AY,
Phone: +44 122 5386298 Email: t.r.kjeldsen@bath.ac.uk

The flood hydrology of the River Avon at Bath was investigated by combining data on past flood events from a number of different sources using a maximum likelihood function derived for use with censored events. The different data sources include: annual maximum series of peak flow from the HiFlows-UK databse (1969-2009), a literature survey of past studies (1725 - present), and physical flood marks found beneath the Widcombe footbridge located behind the Bath Spa railway station (1825-1947). Peak flow values for the historical events were derived by combining a survey of the water level marks with historical information on the cross-section geometry. The resulting data series contains 89 individual events covering the period 1725 – 2009. Defining a censoring threshold value of $250m^3/s$, the resulting at-site flood frequency curve was derived using a Generalised Logistic (GLO) distribution, and the recurrence interval of the maximum flow of 260 m^3/s observed during the winter 2013/14 estimated to be about 30 years. A sensitivity analysis of assumptions made to derive the historical events (Manning's number, hydraulic gradient, and level of historical floods not marked on the Widcombe Bridge) show that the resulting design flood estimates are most sensitive to assumptions made about the hydraulic grade when converting levels to flow using Manning's formula.

2-11P: A bivariate extension of the Hosking and Wallis goodness-of-fit measure.

T. R. Kjeldsen[1] & I. Prosdocimi[2]
1Department of Architecture and Civil Engineering, University of Bath, Bath, BA2 7AY,
Phone: +44 122 5386298 Email: t.r.kjeldsen@bath.ac.uk
2Centre for Ecology & Hydrology, Wallingford, OX10 8JB,
Phone +44 (0)1491 838800 Email: ilapro@ceh.ac.uk

The choice of a suitable flood distribution model is an important part of a regional (or pooled) flood frequency analysis, but one that has received relatively little attention in the scientific literature. When using the method of L-moments it is common practise to plot sample values of L-skewness and L-kurtosis in an L-moment diagram, and to judge the most suitable distribution by the proximity of the regional average values to a set of theoretical points and lines representing 2 and 3 parameter distributions. This study presents a novel extension to the widely used goodness-of-fit test developed by Hosking & Wallis for use with the method of L-moments. By taking advantage of the approximate joint normal distribution of the regional L-skewness and L-kurtosis estimates, a graphical representation of the confidence region on the L-moment diagram can be constructed as an ellipsoid based on Hotelling's T^2 distribution. Candidate distributions can then be chosen among the distributions where the theoretical lines intersect the confidence region, and the chosen distribution would be the one that minimises a specific distance measure. Using a set of Monte Carlo simulations it is demonstrated that the new test statistics is generally more able to select the true population distribution than the original method. Furthermore, results are presented to show that the method remains robust when applied to regions where the level of inter-site correlation is at a level that is found in real-world regions. Finally the method is applied to case studies using selected Italian and British catchments.

2-12P: Identification of flood-rich and flood-poor periods in flood series

L. Mediero[1], D. Santillán[1] & L. Garrote[1]
[1] Department of Hydraulic and Energy Engineering, Technical University of Madrid, Madrid, 28040, Spain.
Phone: +34 913365261 Email: luis.mediero@upm.es; david.santillan@upm.es; l.garrote@upm.es

Non-stationarity in flood series is generally assumed as result of changes in flood drivers, such as climate change, wildfires, volcanic eruptions, land-use changes, anthropogenic actions or relocation of gauging stations. Many studies to detect trends in flood series have been conducted recently, either at national or trans-national scales. In Spain, a study to detect flood trends at a national spatial scale has been presented recently, finding a generalised decreasing trend in floods. The largest available dataset of gauging stations in Spain where effects of dam regulation on flow regimes can be neglected was obtained. A multi-temporal analysis was conducted to identify given either starting or ending years that

could lead to the detected significant trends. A flood-rich period in 1950-1970 seemed to lead to the generalised decreasing trends, as it is placed at the beginning of the flood series. However, this multi-temporal test cannot identify accurately flood-rich and flood-poor periods. A methodology to identify flood-rich and flood-poor periods that are statistically significant is developed, based on comparing the expected sampling variability of floods when stationarity is assumed with the observed variability of floods in a given record. The methodology is applied to the series of annual maximum floods, peaks over threshold and counts of annual occurrences in peaks over threshold series in the period 1942-2009.

2-13P: The 2013/14 Winter Floods in the UK

Katie Muchan[1]*, Melinda Lewis[2], Mike Kendon[3], Simon Parry[1] and Jamie Hannaford[1]
[1] Centre for Ecology & Hydrology, Wallingford, UK
[2] British Geological Survey, Wallingford, UK
[3] Met Office, National Climate Information Centre, Exeter, UK
** Telephone: (+44) 1491 692670, Email: katmuc@ceh.ac.uk*

A vigorous Jet Stream across the UK in the winter of 2013/14 brought a succession of deep Atlantic low pressure systems, with the severe storms bringing widespread wind damage, and destruction to coastal areas. Whilst the rainfall totals for individual storms were generally only moderate, the frequency of events contributed to record-breaking rainfall accumulations for the winter. December was the wettest calendar month on record across Scotland and winter rainfall totals for parts of southern England exceeded the previous winter record by a wide margin. The persistent rainfall quickly saturated soils, and bought a rapid runoff and groundwater response across much of the UK. Although individual peak flows were generally not exceptional, floodplain inundations were widespread and sustained through the winter. Flows on the Thames remained high for more than twice as long as any previous episode since 1883. Impacts of the fluvial flooding were locally severe in parts of southern England (notably on the lower Thames and in Somerset), and the duration and extent of floodplain inundation resulted in wider impacts on transport networks, agriculture and the environment. Nevertheless, flood defences performed well and mitigated the severity of the flooding in many areas. Groundwater flooding occurred across the southern Chalk outcrop, causing severe impacts in some areas, and continued to be an issue into the spring. An important characteristic of the winter of 2013/14 was the joint occurrence of different types of flooding (tidal, flash, fluvial and groundwater) which, alongside the impacts of the windstorms, presented significant challenges for the emergency response.

2-14P: An analysis of high intensity, short duration, annual and seasonal rainfall maxima

Ilaria Prosdocimi[1], Lisa Stewart[1] and Gianni Vesuviano[1]
[1]Centre for Ecology & Hydrology - Benson Lane, Crowmarsh Gifford, Wallingford, OX10 8BB
Email: ilapro@ceh.ac.uk; ejs@ceh.ac.uk; giaves@ceh.ac.uk

An assessment of the frequency of extreme rainfall for short durations has been carried out within the scope of Environment Agency-funded Project SC090031 - Estimating flood peaks and hydrographs for small catchments (Phase 2).
The aim of the project is to expand the flow data available for small UK catchments and to use this to develop improved techniques for flood estimation. A key aspect of the project is an assessment of the applicability of the rainfall-runoff approach to design flood estimation in small catchments and plot-scale areas. The analysis reported here will complement existing models of rainfall depth-duration-frequency, which are largely based on data from hourly and daily reporting raingauges. Long series of time of tip have been acquired from a number of tipping bucket stations. The selected stations provide good coverage of England and Wales, and the minimum series length is 10 years. From the selected stations, annual and seasonal maxima for short durations of up to 15 minutes have been extracted. The resulting maximum

series have gone through quality control assurance to identify missing data and inconsistencies across the different accumulation periods.
A depth-duration-frequency (DDF) model is fitted to the data for each station. The estimation procedure is done under specific constraints to ensure that estimates for different durations are consistent: return curves for increasing accumulation periods should not cross.
Results for the different stations are discussed and compared; differences in return levels for specific durations in the different regions are also investigated.

2-15P: 'Future Flows' and future floods: an exploration of the implications of climate change for high flows in the UK.

N. W. Quinn
Centre for Floods, Communities and Resilience, Department of Geography and Environmental Management, University of the West of England, Bristol, BS16 1QY.
Phone: +44 117 3286562 Email: nevil.quinn@uwe.ac.uk

'Future Flows Hydrology' comprises an eleven member ensemble of equally probable hydrological outcomes using a nationally consistent method based on the Medium emission scenario (A1B), and the Hadley Centre's HadRM3-PPE-UK climate projections. Daily mean simulated flow is available for 281 catchments in the UK, covering the period January 1951-December 2098 (Prudhomme et al. 2012). These simulations represent the best nationally consistent expression of potential high flows over the medium to long term (146 water years). This paper explores the utility of this dataset in contextualizing potential future flooding, and dealing with the challenges of trend detection in recorded flood time series. Analysis is conducted on a representative selection of stations using three approaches (i) trends in the annual maximum of the simulated daily flow (ii) trends in the Richards-Baker Flashiness Index, and (iii) trends in flow above critical thresholds. Additionally, a new volumetric flood index is proposed and assessed in relation to conventional indices. Results are contextualized in relation to the published literature on flood trends in the UK and inferences are drawn regarding trend analysis and flood estimation practice.

2-16P: Use of very high resolution climate model data for hydrological modelling in southern Britain.

A.C. Rudd[1], A.L. Kay[1], S.M. Crooks[1], V.A. Bell[1]
[1]Centre for Ecology & Hydrology, Maclean Building, Benson Lane, Crowmarsh Gifford, Wallingford, Oxfordshire, OX10 8BB
Phone: +44 1491 838800 Email:

Previous work driving hydrological models directly with data from regional climate models (RCMs) used data on an approximately 25x25km grid, which generally required some form of further downscaling before use by hydrological models. Recently, higher resolution data have become available from a NERC Changing Water Cycle project, CONVEX. As part of that project the Met Office Hadley Centre has run a very high resolution (1.5km) RCM, nested in a 12km RCM driven by ERA-Interim boundary conditions (1989-2008). They have also run baseline and future climate scenarios, nesting the RCMs in a global climate model. Using these data, we aim to test the added-value of very high resolution climate model data for hydrological modelling of floods, and investigate the effect of climate model resolution on projections of flood change under climate change.

We first discuss the calculation of potential evaporation (PE), which is a main input for our hydrological models, alongside precipitation. We estimate Penman-Monteith PE from the RCM data, and present a comparison of ERA-driven RCM PE against observation-based PE. We also look at changes in PE under climate change, including the effect of changes in stomatal conductance. We then present initial results looking at daily mean river flows and flood peaks simulated using the ERA-driven RCM data, which show that performance for the 12km and 1.5km RCMs varies by catchment. We end by discussing further work, which will

look at sub-daily performance in smaller catchments and investigate the modelling of pluvial as well as fluvial flooding under climate change.