BHS 2014

Session 7: Hydrological data; advances in its collection, analysis and distribution

ABSTRACTS

Oral presentations

7-1L: The influence of logger bias on reported temperature trends: implications for the development of stream temperature networks

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Stream temperature networks often have multiple purposes. Where networks are specifically designed to characterise spatial variability, there is a limited requirement to consider logger biases given the range of temperature variability (e.g. 10 degrees across a 30km^2 catchment), the high signal to noise ratio and the potential to harmonise technology. However, networks designed to assess long-term temperature variability require greater care given the magnitude of temporal trends (often < 1 degree per decade), the low signal to noise ratio and the potential for bias across different makes, models and individual datalogger units. Previous studies of long-term temperature variability have not typically considered the potential effects of logger biases over the period of data collection. This has consequences for the reliability of their findings. This study investigated the influence of logger bias on reported temperature trends in the Girnock Burn, Scotland. The bias of temperature measurements made by different dataloggers (two makes and five models over >25 years) was assessed through cross-calibration against a reference datalogger. Long-term trends in stream temperature metrics (daily mean, max, min) were assessed using Generalised Additive Mixed Models (GAMM). Models were fitted to (1) the raw data and (2) data corrected for logger bias. Significant non-linear temporal trends were observed in the raw data. These trends were accentuated when corrected for logger bias. Given the potential to accentuate or remove small long-term trends, it is suggested that robust internal and external calibration and quality control procedures are established for current and future long-term temperature monitoring networks.

7-2L: Hydrology data – Transect or run of river? Using the latest data collection methods to understand the basic structure and functioning of river ecosystems to help establish the inter-relationship between hydrology and ecology. A view of a 4km stretch of the River Severn in Shrewsbury.

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Since the introduction of Acoustic Doppler current Profilers (ADP/ADCP) into riverine velocity measurement the procedure for making these measurements has always followed the time tested discharge measurement methods of a straight river crossing. Traditional use of the transect method of data collection will continue and whilst bathymetric uses of these

instruments have led to deployments in a broader section of the river we look at turning the whole data collection around from the transect to the longitudinal and some of the benefits of this.

Following on from the extensive work carried out at the Flathead Lake Biological Station developing the inter-relationship between hydrology and ecology, Session 1 – Froude Space, an Aquatic currency, we take a look at the implementation of the latest hydrological data and data collection methods, by way of a study of a 4km reach of the River Severn at Shrewsbury, to give an insight into how data collection is developing and producing wider application data uses. The methods combine various forms of measurement and include ADP, Lidar, RTK surveying, along with Multi-spectral Satellite and/or Unmanned Aerial Vehivles (UAV or Drone) for DEM and other with RGB and infra-red mapping and analysis.

This methodology will bring the link between hydrology and ecology together and make hydrological data truly accessible and useful to ecologists. Beyond that the benefits will come those interested in aquatic and floodplain ecologists, river conservationists and rehabilitation specialists, flood management, civil and environmental engineers, fisheries, hydrology and geomorphology teams and the numerical modellers.

7-3L: Capabilities, limitations and new horizons of Fibre-optic Distributed Temperature Sensing in ecohydrological and hydrogeological research

Stefan Krause, Lindsay McMillan, Tom Read, Silvia Folegot, Nick Kettridge, Rhoswen Leonard, David Hannah, Megan Klaar, Liliana Rose, Anibal Vivanco, Theresa Blume, Joerg Lewandowski, Karin Meinikmann, John Weatherill, Nigel Cassidy, Sarah Taylor

Fibre-optic Distributed Temperature Sensing (FO-DTS) has seen a rapid growth in technological development and interdisciplinary applications across the hydrological sciences.

This paper investigates the technical capabilities and limitations of FO-DTS for temperature tracing and discusses benefits and disadvantages of different experimental setups, monitoring modes and experimental designs. We present examples of FO-DTS applications in surface hydrology, hydrogeology, soil physics, limnology and forest ecology to examine its capacity for predicting thermal patterns and hydrological fluxes at a range of spatial and temporal scales. Different monitoring schemes including single-ended and double-ended modes as well as newly developed two-way single ended averaging are investigated for their potential for high-precision monitoring and variability in signal to noise ratios. In addition to traditional passive FO-DTS we present new developments in active FO-DTS monitoring to trace environmental fluxes even in environments without variable temperatures.

7-4S: Winter 2013/14: The ‘Remote Control’ Flood, and other tales of the advancement of hydrological science through technology

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Upon its introduction into operational hydrometry in England and Wales in 2002, Acoustic Doppler Current Profiler (ADCP) technology transformed river discharge measurements. Flow gaugings could be done faster and with fewer people, with significant improvements to data quality. In 2011, the widespread introduction of remote control boats for deployment of ADCPs, combined with the introduction of high-precision GPS positioning systems and dual-frequency ADCP systems further improved effectiveness for flow gauging. During the significant winter flooding of 2013/14, these state of the art ADCP systems formed the backbone of the Environment Agency's flow measurement capability, providing vital information for flood incident management in near real-time.

A secondary benefit of these advances has been to unlock the latent potential of ADCPs to provide a highly efficient, low-cost system for conducting bathymetric and hydraulic surveys of rivers and other water bodies. This survey capability, with applications in support of hydropower proposals, hydro-ecology, geomorphology and fisheries management now forms the fastest growing area of ADCP use in the Environment Agency. It also presents great potential for expanding our ability to understand the processes and features in the water environment. Furthermore, the capability for swift, flexible and safe deployment has allowed remote-control ADCP systems to perform vital roles in responding to major environmental incidents such as the East Coast tidal flooding of late 2013 and the extensive fluvial flooding of early 2014.

7-5S: Is this the end for traditional gauging station design?

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Traditional gauging station design with a stilling-well, connected to the river by inlet pipes, dates from a time when all instruments were driven by floats. This requirement persisted even into the early digital age but has modern sensor technology at last caught up with the hydrologists' demand for millimetre accuracy? Are the costs of constructing and maintaining a traditional gauging network, whilst still conforming to modern environmental protection legislation, sustainable? More importantly, has deployment of modern instrumentation finally shown the extent of velocity-drawdown and time-lag impacts? Presenting examples from the hydrometric network in Scotland, this paper will demonstrate differences in recordings between in-stream and in-well monitoring to challenge some of the established principles of gauging station design and, in return, offer opportunities for readers to challenge their own thinking in this regard.

7-6S: How do we want to access hydrological data over the web?

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The National River Flow Archive (NRFA) provides public access to UK river flow data and associated gauging station and catchment information. Currently data is made available via a traditional website, allowing discovery of gauging stations, viewing of metadata, definitions, and related information, and providing simple text-file-based data downloads for analysis within the client software of the user's choice. Current efforts by international community groups representing a wide variety of subject areas are developing standards for data exchange, including in the area of hydrology. The Open Geospatial Consortium's Hydrology Domain Working Group published the WaterML2 standard for hydrological time series data in 2012. The group is jointly convened by the World Meteorological Organisation's (WMO) Commission for Hydrology who are currently investigating the adoption of WaterML2 as a global standard for water data transfer. Further developments in WaterML2 are currently considering data exchange for gaugings and ratings, and water quality data. The National River Flow Archive has been involved in the group developing these standards and has been testing the use of WaterML2 within its web-services, including application to its new National Peak Flow Data Service (formally Hiflows-UK). The development and use of consistent and standardised formats paves the way for new and more advanced client tools to access and analyse hydrological data. This paper provides a basic explanation of these data standards, describes the work undertaken by the NRFA in implementing them, and discusses how their use may change the way we access and analyse hydrological data in future.

7-7S: Ensuring UK hydrometric data is fit-for-purpose through a national Service Level Agreement

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Access to hydrometric data of adequate quality, consistency and coverage to answer pressing research questions and manage operational freshwater systems use remains a major issue. In many parts of the world, despite recent technological advances and ongoing developments in data management and data sharing, many datasets remain inaccessible or have limited utility due to data accuracy and completeness issues. The UK introduced a Service Level Agreement in 2002 to control provision of data from the main hydrometric measuring authorities (SEPA, EA, NRW and Rivers Agency) to the National River Flow Archive. The Agreement sets out a framework for data provision which has the dual aims of improving the utility of data at individual monitoring points and also ensuring continuity of a core network of gauging stations across the country. Central to this framework is a set of quantifiable indicators of data quality, completeness and provision. The results from the first 10 years of the SLA indicators are encouraging, with improvements in both data quality and consistency. This presentation will outline the findings and discuss the benefits of such a system to the overall utility of UK national hydrometric data. The system, which could be applied to other data initiatives, constitutes one method of helping to ensure hydrological databases provide information of adequate quality to meet water management needs both today and into the future.

7-8S: Uncertainty in hydrological signatures

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Information about the characteristics of the runoff processes in a catchment is essential for most hydrological analyses, modelling and water-management applications. Such information derived from observed data is known as a hydrological or diagnostic signature, and have been used in a variety of studies for, e.g., change detection, catchment classification, model-structural identification, and model calibration. Different sources of uncertainty in the observed data – including measurement error and representativeness as well as errors relating to data processing and management – propagate to the values of the derived signatures and reduce their information content. Subjective choices in the method used to calculate the signatures create a further source of uncertainty. The aim of this study was to contribute to the community's awareness and knowledge of observational uncertainty in hydrological signatures, including typical sources, magnitude and methods for its assessment. We first reviewed the sources and nature of uncertainties relevant to the calculation of different signatures based on rainfall and flow data. We then proposed a generally applicable method to calculate these uncertainties based on Monte Carlo sampling

and demonstrated it for a number of commonly used signatures including thresholds in rainfall-runoff response, recession analysis and basic descriptive signatures such as total runoff ratio, and high/low flow statistics. The study was made for two data-rich catchments, the 135 km^2 Brue catchment in the UK and the 50 km^2 Mahurangi catchment in New Zealand that are both densely monitored. The resulting uncertainties were compared across the different signatures and catchments to understand how the uncertainties may change with the sources of the uncertainty in the observed data and the active runoff processes. Finally we considered whether the uncertainties found would change the interpretation of the signatures to give information about catchment response.

7-9S: Theoretical and practical insights gained from applying a four component hydrograph separation technique

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Traditional hydrograph separation techniques split an observed storm hydrograph into two main components representing "storm runoff" and "baseflow". Here a new technique is described which makes a first split into quickflow and slowflow components, which are each then split into two further subcomponents. Combining these four resulting subcomponents, in two different ways, allows an insight into the separation techniques employed in the FSR, ReFH and RIS methods of hydrograph analysis.

The FSR separation technique appears to be theoretically unsound, with its estimate of "quick response runoff" found to be a combination of arbitrary proportions of quickflow and slowflow storm runoff. Choosing the term "nonseparated flow", to describe the flow remaining after separating off the "quick response runoff", is to be commended.

The ReFH technique of separating the "direct runoff hydrograph" is found to have much greater theoretical justification, due to incorporating a linear conceptual reservoir to generate a slowflow response. But the quickflow preceding runoff contribution to the observed storm hydrograph appears to have been disregarded.

In the RIS technique, if the quickflow component can be isolated from that of slowflow, the subsequent procedure for estimating the "quickflow storm runoff" is considered to be not only exact theoretically, but also has been found viable as a practical procedure. While reasonable estimates of the pre-event and post-event slowflow recessions can be made, the method for interpolating the central portion of the slowflow hydrograph still needs strengthening.

Poster presentations

7-1P: The power of the variogram for characterising catchment responses to climate variability

A.J. Chiverton

Variograms are widely used in spatial statistics, as a way of examining correlations between points in space, but also have potential for application to time series. A variogram provides a robust and flexible way to quantify the temporal dependence (or autocorrelation, i.e. the dependence of flow on a given day with previous days) in daily river flow time series. There are, however, very few published examples of variogram techniques applied to hydrological datasets. The power of the variogram lies in its ability to characterise temporal dependence and, as such, describe the precipitation-to-flow relationship; as this is largely controlled by the catchment characteristics (e.g. elevation, soil type and rock type), it opens up a range of applications for regionalisation and hydrological change detection. This presentation describes a novel variogram-based method for investigating the influence that catchment characteristics have on moderating how a river responds to temporal changes in precipitation. The motivation is that, whilst heterogeneity in river flow responses to climate variations are widely reported for the UK, they have yet to be investigated and quantified in detail. In the new approach, catchments are first classified, based on the shape of river flow variograms, with the groups being predictable based on catchment characteristics; the clustering method therefore has potential for un-gauged site applications. Temporal variability is assessed using a moving-window approach to index changes in variogram properties over time. Results demonstrate that precipitation alone cannot explain the variation in flow responses: catchment properties have a substantial role in moderating climate variability.

7-2P: Combining geophysical and environmental tracer approaches for identifying shallow subsurface aquifer-river exchange

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The mixing between groundwater and surface water in space and time, leads to the creation of a saturation zone called the hyporheic zone. This mixing results in significant changes in water quality for both groundwater and surface water. The hyporheic exchange is dictated by two main factors: the total head gradients along and across the streambeds plus the streambed hydraulic conductivity of the streambed. The direct observation of exchange fluxes between aquifers and rivers at stream reach to catchment scale remains a challenge. The main purposes of this study is to establish the importance of small scale variability in streambed physical properties (e.g. spatial heterogeneity of the permeability field) in controlling flows in the hyporheic zone at a variety of field scales and cycling of nutrients and/or contaminants. A specific focus is on residence time distributions through permeable bed sections and bypass flows in an example stream section of a UK meandering stream, the River Tern, a branch of the River Severn in Shropshire. This poster presents a detail description of the study area, geology of the area, and the methods based on Ground

Penetrating Radar for imaging the type and extent of complicated spatial heterogeneity textural patches (grain size facies) of high and low conductive materials below water. As well as heat tracer approaches such as fibre-optical Distributed Temperature Sensing uses for tracing complicated patterns of exchange flow across groundwater – surface interface of larger lowland meandering rivers. These methods are accompanied by dilution tracer tests for estimating residence time distributions in different sections of the hyporheic zone.

7-3P: Calculation of gridded rainfall datasets for improved operational assessment and visualisation

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Over recent years there has been an increasing need to develop clear and concise visualizations of hydrological and meteorological data, coupled with continuing desire to improve the quality of the underlying datasets. A need was identified to improve the quality of provisional monthly rainfall data used to assess, and report upon, the water situation. In order to address this need, and to maximize the utility from the automatic rain gauge network, a new tool has been developed in ArcMap 9.3.1 to create improved provisional gridded datasets. The tool uses XML outputs from the hydrometric archive. These are semi automatically quality assured prior to the creation of a geodatabase using ordinary kriging. Shapefile areal rainfall totals can be directly produced from the tool for any period of record and the geodatabase manipulated using standard Arc GIS functions.

The tool uses VBA/ArcObjects code to link standard ArcGIS raster functions available with 3D Analyst and Spatial Analyst extensions together with Microsoft Excel and Access. It is capable of automatically processing and visualizing many weeks of data from hundreds of rain gauges in a short space of time.

The successful development of the tool has resulted in many benefits, these have included the calculation and visualisation of daily and accumulated rainfall totals at a range of spatial scales which were used operationally during winter 2013/4.

7-4P: National Peak Flow Data – what next?

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Records of peak river flow are vital for developing our understanding of the flood events and improving our ability to predict, manage and mitigate their impact. The beginning of the 21st century has seen both a heightened demand for hydrometric information and technological advances in data collection, management and exchange. These developments pose challenges, but also significant opportunities, for improving the way we integrate, communicate and use hydrometric information.

In April 2014, responsibility for the provision of UK national flood peak data was transferred from the HiFlows-UK initiative to the National River Flow Archive (NRFA), which is maintained by CEH working in partnership with the UK's hydrometric measuring authorities (EA, SEPA, NRW and Rivers Agency). Provision of flood peak data is in the process of being integrated with existing services for daily mean flow data, providing for the first time a single national portal for key UK hydrometric information. These developments are however, only the start. Much remains to be done to maximise the potential of our national data. While significant updates to flow and metadata records for many gauging stations have recently been completed by JBA Consulting, the need to review, revise and update the archive remains a perpetual requirement. Furthermore the integration of the national databases provides new opportunities for enhanced tools and services, designed to meet user's changing data needs. This presentation will present an update on recent developments and provide the user community with an opportunity to challenge the theory and practice of what comes next.

7-5P: Reversing Hydrology: estimation of sub-hourly rainfall time-series from streamflow

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A novel method for estimating catchment rainfall from streamflow, measured at a sub-hourly resolution, is presented. It has been evaluated by comparing two basins with different flow pathways and rainfall regimes – Baru, Borneo (tropical) and Blind Beck, NW England (temperate). The method combines a continuous-time transfer function model with regularised derivative estimates capable of handling missing data. It is compared to the existing direct inverse transfer function method using a range of model metrics which include residual analysis as well as visual inspection and is shown to recover the salient features of the observed hourly rainfall sufficiently well to produce a precise estimate of streamflow which is indistinguishable from the output of the catchment in response to the observed catchment rainfall. Results indicate potential for use of this method in environment-related applications for periods lacking sub-hourly rainfall observations. Further work will include testing under a wide range of both rainfall regimes and catchment characteristics and analysis of the time resolution of the inferred rainfall output. Future applications may include investigation of the information content of the input data.

7-6P Data-driven, hydrological models: doing more than advanced curve fitting?

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Data-driven models are a class of inductive modelling methods that have emerged as an important category of hydrological models over the last two decades. They differ fundamentally from other hydrological modelling approaches because the responsibility for determining the form and strength of relationships between relevant hydrological variables (normally multiple inputs and a single output), and for integrating these relationships into a functioning model, is handed to computationally-intelligent algorithms rather than a human modeler. It has been asserted that data-driven models are just advanced curve fitting tools that have failed to deliver fundamental contributions to hydrological knowledge despite more than two decades of research activity. Underpinning this assertion is recognition of the

highly intrinsic approach by which data-driven models are learnt and validated and the limitations that this imposes on their use. Overcoming these limitations would enable data-driven models to advance their potential as transferrable agents of hydrological enquiry that are capable of supporting fundamental knowledge creation. However, to do this requires a different approach to model evaluation that considers questions of how the model performance is achieved alongside questions about the level of performance. In this paper we present and exemplify 'SenTriVal' – a combined metric and sensitivity-based evaluation framework for data-driven models that combines three core model assessment elements: 1. an intrinsic performance assessment that uses quantitative metrics to determine relevant aspects of the fit between observed and modelled data; 2. an abstract, extrinsic mechanistic legitimacy assessment that evaluates the magnitude, stability, coherency and consistency of a model's internal mechanisms and behaviours, 3. A concrete, extrinsic physical legitimacy assessment that evaluates the conformance between a model's behaviour and the behaviour that would be expected on the basis of *a priori* hydrological domain knowledge. The framework is exemplified through the development of a series of data-driven models for use in the prediction of median flood discharge in ungauged, UK catchments and the varying levels of model legitimacy are revealed.

7-7P: Controls on Flood Risk: An assessment of changes to Stage-Discharge relationships at UK gauging stations through time and associated causal mechanisms.

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Flooding occurs when the water level exceeds the local bank height. This is controlled by multiple factors at a range of spatial scales; (a) upstream controls – the quantity of water delivered to the network which influences the flow magnitude; (b) in-stream controls- the local channel capacity and channel roughness affecting water conveyance; and (c) downstream controls – the backing up of flow. The first of these, the flow discharge, is influenced by changes to runoff within the upstream contributing area caused by potential climate and land management changes. However, flood risk is not just a function of the river discharge but how that discharge is conveyed through local channel cross sections. An assessment of the changes in the stage-discharge relationship at a specific location allow the in-stream controls to be isolated from the upstream controls. Preliminary analysis of UK gauging station rating equations and associated spot gaugings has shown significant errors between the actual and the predicted discharge associated with a given stage. Furthermore, using the specific discharge approach it has been shown that rating equations need to be dynamic through time. There are several processes explaining this, such as channel erosion or deposition altering channel capacity, or vegetation growth altering channel roughness. This has significant implications for monitoring of river flows, particularly for flood forecasting and return period estimation applications of gauged data.

7-8P: The Historical Snow Survey of Great Britain: Digitised data for Scotland.

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Mountain snowline is important as it is an easily observable measure of the phase state of water in the landscape. Changes in seasonal snowline elevation can indicate long-term trends in temperature or other climate variables. Snow cover influences local flora and fauna, and knowledge of snowline can inform management of water and associated risks.

Between 1937 and 2007, voluntary observers collected a subjective record of snow cover called the Snow Survey of Great Britain (SSGB). The survey was instigated by the British Glaciological Society under the direction of Gordon Manley, but collation of the data was taken over by the Met Office in 1953; original paper copies of the survey returns are held by the Met Office. This poster details the spatial and temporal extents of newly digitized SSGB data for Scotland between 1945 and 2007. The data are compared with records of the number of days with snow lying per month on a 5 km grid covering the UK, derived by the Met Office from in situ observations at low-lying stations.

7-9P Laser Flow non-contact flow meter

A revolution in open channel flow measurement – the LaserFlow

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Open channel flow measurement has historically relied on contact-based technologies or primary structures. Issues with location, installation and maintenance has meant that selecting the correct approach can be very difficult and unforgiving. The LaserFlow is the first non contact flow meter that can be mounted above or the side of the channel that is able to measure sub-surface velocities in open channels to provide highly accurate data. This laser based technology provides a paradigm step change in open channel flow measurement and allows applications that could not previously be measured to be done accurately and without maintenance. Data from a recent Environment Agency evaluation will also be presented

7-10P: Seasonal river flow forecasts for the UK

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A range of methods for seasonal river flow forecasting up to twelve months ahead is currently being developed for the United Kingdom (http://www.hydoutuk.net/). These methods include modelling approaches using either seasonal rainfall forecasts or historical rainfall series as input. Regression-based models for river flow forecasting using large-scale forcings, such as sea surface temperatures and climate indices, as predictors are also under development. Statistical methods using only past river flow data as input are presented here: forecasts based on persistence of the previous month's river flow, and forecasts based on historical analogy. The underlying assumption for the latter is that sequences of river flow in the historical record that are similar to the recent past will provide valuable information on what flows will occur in the near future. Forecasts are made for the coming one and three months, using either persistence or one of two historical analogue methods. A weighted mean of the five most similar analogues is used as one forecast method, and an alternative is to shift this forecast to fit with the observed flow in the last month of observations. For each calendar month, catchment and forecast duration, the one of the three methods that has performed best in the past is selected for making the forecast.