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HELPing FRIENDs in PUBs: charting a course for synergies within international water research programmes in gauged and ungauged basins

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Introduction

Programmes to promote water-related research are expanding rapidly around the globe. Whereas many have unique mission and objectives, several share common and overlapping goals and have areas of potential intersection. Identifying overlap between initiatives allows recognition of potential linkages and areas where the programmes complement each other. This allows each programme to retain its focus while ensuring that the combined programmes cover all the important issues concerning sustainable drainage-basin management. The objective of this commentary is to describe the areas of intersection between three international water research efforts and to explore synergies between them. We start by describing the evolution of the two UNESCO activities (FRIEND and HELP) and the new initiative of the International Association of Hydrological Sciences (IAHS) called PUB. We then explore possible areas of intersection among FRIEND, HELP and PUB and list the hitherto unrealized opportunities for research that would add value to each programme and, consequently, hydrological sciences and integrated drainage-basin management. We end by defining tangible activities that can be accomplished in the next 1–5 years.

Historical Development

The International Hydrological Decade (IHD), which UNESCO led from 1965 to 1974 (see Batisse (2005)), was the first international water programme and established a global network of representative and experimental basins (Toebes and Ouryvaev, 1970) for an improved understanding of water balances for use in water resource management. The prime focus of the IHD was on water quantity rather than water quality. Amongst the achievements of the IHD was the development of experimental hydrology and the establishment of long-term data hydrologic data sets. These data sets have proved invaluable in the evaluation of climatic variability *vis-à-vis* land cover change impacts on drainage basin runoff.

Following the termination of the IHD, UNESCO launched the International Hydrological Programme (IHP) in 1975 (http://www.unesco.org/water/ihp). The IHP is an intergovernmental research and training programme structured around priority activities that

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are established in 6-year phases. Since the second IHP phase there has been a gradual shift to include water resources management and water–society interactions within the activities of the programme.

FRIEND (Flow Regimes from the International Exchange of Network Data, http://ne-friend.bafg.de/servlet/is/Entry.7397.Display/) is a UNESCO-sponsored international collaborative programme in regional hydrology. The programme was established in 1985 as part of IHP-III, and is now a major cross-cutting activity of IHP-VI (2002–07). Its aim is to develop a better understanding of hydrological variability and similarity across different regions in the world. The programme is technically oriented and aims to bridge the gap between research and operational water management (Gustard and Cole, 2002; van Lanen and Demuth, 2002). From a relatively modest beginning in 1985, the project now involves research institutes, universities and operational agencies from over 90 countries around the world. The FRIEND research programme has regional groups in the Alpine and Mediterranean region, Asian Pacific region, Caribbean (AMIGO), Hindu Kush Himalayan, Nile, northern Europe, southern Africa and West and Central African. In addition, there is an emerging group in South America. Although each regional group is organized and run independently, they all have the same general aims and organizational structure. These aims are:

- the mutual exchange of data, models and research between countries and regions;
- to understand hydrological variability and similarity through time and space;
- to advance the knowledge of hydrological processes and flow regimes, including processes that generate droughts and floods;
- to improve techniques for analysing scenarios of environmental change;
- to develop tools and methods for water resource management, including drought forecasting and flood control;
- capacity building.

The background to HELP (Hydrology for the Environment, Life and Policy, http://www.unesco.org/water/ihp/help) can be traced back to the IHD. There had been ideas for a new global, field-orientated initiative to address the states and processes connected with water quality (Peters *et al.*, 1998), a new Experimental Hydrology Decade (see EHD (1999)) and the launching of a second IHD led by UNESCO in collaboration with WMO ("Exeter Satement", British Hydrological Society Int. Conf. July 1998 (see HELP Task Force, 2001, p13). Entekhabi *et al.*, 1999). Based on these ideas, HELP was established in November 1999 as a joint UNESCO–WMO programme, led by the IHP (UNESCO–WMO, 1999; HELP Task Force, 2001). The mandate of HELP includes interfacing scientific research with the practical requirements of water resource management and water policy. HELP is creating a new approach to integrated catchment management through a framework where local stakeholders, water scientists, water resource managers, and water law and policy experts can work together on water-related problems (Andersson and Moody, 2004). From the technical perspective, the broad objectives of HELP are to strengthen field-oriented experimental hydrology using a drainage basin as the organizing framework (Bonell, 2004). These drainage basins range from 10 km^2 to 10^6 km^2 (median 10^4 km^2) and occur in 56 countries balanced in number between the developed and developing world. Both physical (hydrological, climatological, ecological) and non-physical (technical, sociological, economics, administrative, law) observations are made in these catchments to address the most critical policy and management issues as perceived by the basin stakeholders. HELP also focuses on sustainable development and requires activities on both policy and the involvement of water and land resource managers towards setting policy agenda. This is to ensure that scientific results are quickly incorporated through the revision of water resource management and water policy. HELP is currently in the second phase of implementation, and established a global international network of 67 basins in both developed and developing regions in mid 2004. As part of this global network, there are 51 basins nested within the eight regional groups of FRIEND.

The IAHS Decade on Prediction in Ungauged Basins (PUB; http://www.iahs.org) movement began in 2002. PUB's goal is to engage and energize the scientific community towards achieving major advances in our capacity to make hydrologic predictions in ungauged basins (Sivapalan *et al*., 2003). Specifically, PUB aims to advance the ability of hydrologists worldwide to predict, with estimates of uncertainty, the fluxes of water and associated constituents from ungauged basins. Although the central focus is on ungauged basins, the PUB Decade also aims to quantify the links between data and predictive uncertainty, demonstrate the value of hydrologic data, and provide a rational basis for future data acquisition. The six main science themes of PUB, which are addressed by various working groups around the world, are:

- basin intercomparison and classification;
- conceptualization of process heterogeneity;
- uncertainty analyses and model diagnostics;
- development and use of new data-collection approaches;
- new hydrological theory;
- new approaches to hydrologic models.

Charting a Course for Collaboration between FRIEND, HELP and PUB

Throughout the IHD and the subsequent IHP, there has traditionally been a close working relationship between the UNESCO programmes and the IAHS. Consequently, with the emergence of the PUB Science Plan in 2003 (Sivapalan *et al*., 2003), a joint IHP–IAHS (PUB) Technical Liaison Group (TLG) was established in Koblenz, May 2004, to identify potential synergies between these programmes. The need for such a coordination is also mentioned in the PUB Science Plan of 30 September 2003 (http://www.cig.ensmp.fr/∼iahs/) which states that:

> "The SSG [Science Steering Group] will also forge strong links with all IAHS Commissions and international programs such as HELP, FRIEND, CEOP and GEWEX, so that PUB can synergistically benefit from their activities, expertise, and associated people networks".

The TLG identified the following areas of collaboration:

- analysis of existing data and (re-)interpretation of patterns from a process-perspective;
- improved learning through the intercomparison of models in a variety of basins;
- establishing collaboration between modellers and experimentalists in meso-scale basins (∼1000–10 000 km^2).

This commentary charts a course following the initial Koblenz meeting and a subsequent meeting of the TLG in Corvallis, Oregon, in November 2005.

When comparing the overlap between the three programmes during the Koblenz and Corvallis meetings, it became apparent to the TLG that FRIEND, HELP, and PUB are all involved in quantifying the states, stocks and flow paths of water as it moves through the landscape and in understanding human alterations to the hydrologic cycle. Although all three initiatives have common interests, each of these three communities has a unique focus and user community (Figure 1). FRIEND is generally focused on exchanges between hydrologists primarily within a region. HELP is primarily focused on exchanges with scientists, stakeholders and policy-makers within a global network of drainage basins. PUB is focused on providing quantitative understanding and uncertainty reduction of hydrologic processes in ungauged basins. Although none of these initiatives aim to cover all water-related issues, there are several areas of complementary overlap (Figure 1). Moreover, both FRIEND and HELP use regional hydrology data for drainage-basin management. FRIEND, HELP and PUB; all seek a process understanding of local and regional hydrological processes. Finally, HELP and PUB have a common interest in understanding local basins. In the context of this collaboration, the bias is towards water quantity, but the IHP-VII is planning a strong focus on water quality processes, and this priority has already been taken up by HELP. Further, a better understanding of water quality processes requires equally a close attention being given to water quantity processes, the latter of which is a focus of the current collaboration.

After review of the FRIEND–HELP–PUB main areas of intersection, the notion of states, stocks and flow paths of water is central to all three initiatives. We propose that interactions between the three groups should focus on science questions

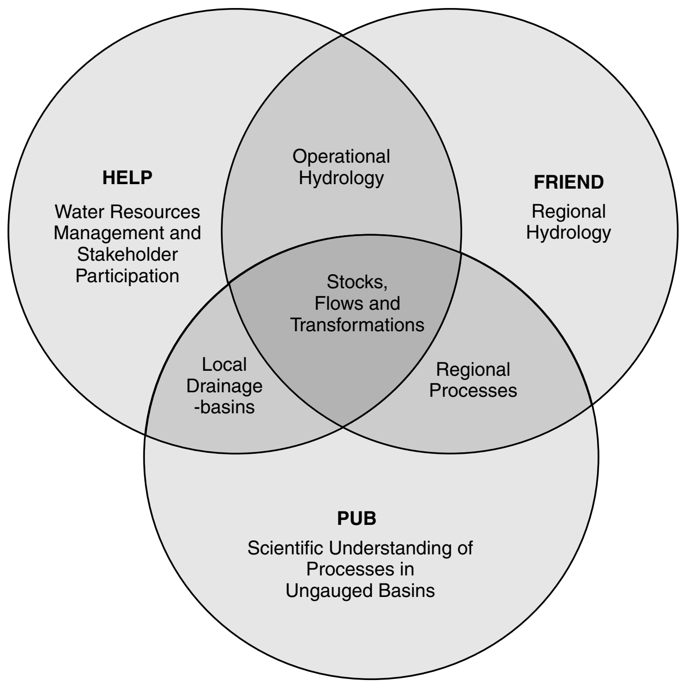

Figure 1. The common intersections of the programme interests of PUB, HELP and FRIEND

and information needs in which all members of FRIEND, HELP, and PUB communities can freely participate and contribute in this regard. Moreover, the focus should be on developing collaborative interactions that utilize and benefit the strengths of each community. We argue that interactions should be geographically centred on 'HELP basins and closely linked to the regional FRIEND networks in which the basins are embedded'. This document advances a unifying and cross-cutting theme for such interactions: *Understanding human alteration to hydrological regimes and flow paths.* Specific focus areas include baseline understanding of processes in pristine basins, drainage-basin classification, comparative model evaluation, prediction of extreme events in ungauged basins under changing circumstances, and new technologies for measuring and monitoring of groundwater.

Baseline understanding of processes in pristine basins

As part of a scientific evaluation of the impacts of global changes on the hydrology of basins, it is essential to have a good baseline understanding of hydrological processes of relatively undisturbed landscapes. Recently, a focus on 'hydrological time series from pristine/stable basins', which also includes the use of trend detection methods linked with runoff data sets to link with possible climatic variability signals (Kundzewicz, 2004), has been included in HELP (WMO, 2004). More than 16 sub-basins of the HELP drainage basin network have been identified as fitting within the 'pristine' category, and these include the parts of the UNESCO Man and the Biosphere Reserves and World Heritage Area sites (http://www.unesco.org/mab/index.htm). In addition, the IHP Integrated Science component of the IHP (the coupling of surface water, FRIEND–groundwater–ecohydrology–isotopes for application in HELP basins, see HELP Website section Water and the Environment) identified two areas of priority, namely water quality processes (which also requires a good understanding of water quantity processes; Turner *et al*., 2006) and scale issues linked with climatic variability *vis-à-vis* land-cover-change impacts on high and low flows (extreme events). Concerning

the latter, an expert group has been established (http://www.unesco.org/water/ihp/help, section Water and Climate; Bloeschl *et al*., 2006a, in press; 2006b, yet to submit.) and a special session will be held in the Fifth FRIEND International Conference (http://www.friend-amigo.org/conferencia2006/). Both these activities offer opportunities for joint PUB–HELP–FRIEND research collaboration within this theme.

Drainage-basin classification

The development and evaluation of drainage-basin and landform classifications systems that can assist in the selection of appropriate hydrologic models and management strategies is an emerging need in all three programmes. Within the FRIEND framework, classification schemes are needed to reflect the understanding of the intra- and inter-annual dynamics of meso-scale flow regimes. Within the HELP framework, classifications systems are needed to address climatic sensitivity of river flows and help assess current and future water stress (Bower *et al*., 2004). Within the PUB framework, classification systems are needed to assist in the selection of appropriate hydrologic models for predicting the hydrology of ungauged basins. Fortunately, these needs can be addressed by using HELP basins, regional FRIEND data, and PUB modelling approaches. The emphasis of this task is on selecting reference basins along a gradient from pristine to disturbed basins for comparative studies and developing diagnostic tools for identifying drainage-basin sensitivity to environmental change. Drainage-basin classification can then be an initial screening tool for making predictions about basin behaviour and a first step in model structural decisions (McDonnell and Woods, 2004).

Comparative model evaluation

Given the vast number of drainage-basin models, there is a growing need for guidance on the strengths, weaknesses, and uncertainties associated with different modelling approaches. Given this need, we propose that a comparative evaluation and review of hydrologic models and approaches (including the compilation of input data and the treatment of observation uncertainties) is needed. Fortunately, the existing HELP basins and FRIEND regions provide excellent opportunities for such comparative model studies. Moreover, by testing models on relatively data-rich basins in the existing FRIEND, HELP and PUB networks and linking these comparisons with drainage-basin classification systems, we can improve our abilities in applying models in basins with limited data, especially in developing countries. This might be called the PUB paradox, i.e. the need also to work in data-rich basins to improve our ability to make reliable predictions in data-scarce basins. A crucial question for all groups is what kind of observations might provide the highest marginal value when applying a model to a data-poor basin. For instance, what is the value of short periods of runoff observations or groundwater levels at strategic locations and times? How much can soft data, such as qualitative field experience, anecdotal evidence (e.g. interviews with stakeholders), palaeohydrology or regionalization, contribute to constrain our models? Such comparative model evaluations must not stop at comparing some measure of fit for the runoff series, but should also aim for addressing internal consistency of the simulations (i.e. are we right for the right reasons, as outlined by Seibert and McDonnell (2002)). In many cases (perhaps more than we usually admit!), our ability to model drainage basin fluxes depends more upon the quality of observation data than on which particular model structure we apply. The choice, for instance, on how to interpolate spatial precipitation maps from a limited number of stations might be more important than the question of which model to use. As another example, uncertainties in observed runoff caused by erroneous rating curves or incorrect groundwater levels due to levelling mistakes might cause more prediction uncertainty than the issue of parameter uncertainty. Consequently, it is important to include the collection and processing of measurements and their uncertainty in any comparative model evaluation.

Prediction of extreme events in ungauged basins under changing circumstances

The prediction and forecasting of hydrological extremes (river flow and groundwater) in ungauged basins is difficult, but is needed by all those involved with HELP, FRIEND and PUB. Regionalization techniques have been developed to estimate statistical properties of high and low stream flows (e.g. CEH, 1999; Tallaksen and van Lanen, 2004). Such techniques are also needed for groundwater droughts and smaller basins, for which regionalization approaches so far have been applied less frequently. The analyses are usually based on records from basins in the region and basin properties, but there is a lack of attempts quantifying the uncertainty of these techniques and incorporating uncertainty estimation into the prediction. Other challenges are climate variability and the issue of non-stationarity (e.g. Hisdal *et al*., 2001), i.e. historic observations might often not be representative for current or future conditions due to, for instance, land-use or climatic changes. New process-based techniques need to be developed and linked to statistical techniques; these should also consider soft data, as mentioned above. This will form the basis for more reliable prediction and forecasting in operational hydrology. This is of special importance for the most extreme, and thus rare, events, such as a 1000-year flood or multiple-year droughts with high deficit volumes.

New technologies for measuring and monitoring of groundwater

Water pathways through the subsurface systems are still poorly understood, because the processes are difficult to observe. Such knowledge is also critical towards a better understanding of surface water–groundwater interactions, i.e. a better quantification of recharge to aquifers. As an alternative to expensive borehole programmes, new technologies have to been introduced to capture more information on the hydrogeological framework of a region (aquifers, aquitards, hydrological water divide) and the state of groundwater (space, time quantity, quality). A palaeogeographic reconstruction of the landscape (hydrogeological reconstruction) is required as a basis for the identification of the hydrogeological framework. It delivers the likely distribution of water-bearing and transporting layers, semi-pervious and impermeable layers (including faults) and associated hydraulic properties. Methods developed for deep subsurface basins need to be investigated for their potential for characterizing the hydrogeological framework through a close cooperation of hydrologists with geologists (e.g. sedimentologists, structural geologists).

Hydrogeophysical methods offer great potential to understand more about the hydrogeological setting and state variables (Rubin and Hubbard, 2005). An evaluation of geophysical methods that are being developed and applied in the oil industry (reservoir modelling) is needed to explore the potential to obtain information for the shallow subsurface (resistivity, seismisivity, geo-radar, e.g. Sporry, 2004). Some of these methods are also valuable for monitoring the groundwater state (heads, quality). Detecting changes in water storage from temporal variation in gravity provides new observation opportunities. Successful studies have already demonstrated the potential of using data from the Gravity Recovery and Climate Experiment (GRACE) satellites (e.g. Rodell and Famiglietti, 1999) for the continental scale on a monthly time-scale. Only a few, but promising, studies have yet been performed on the catchment scale (e.g. Hasan *et al*., 2006). Another innovative approach is the use of so-called geological lysimeters, which utilize changes in hydraulic heads of confined aquifers to estimate storage changes in the overlaying soils (e.g. Bardsley and Campbell, 2000). These new measurement techniques, combined with a dedicated borehole programme and observations at groundwater–surface interfaces, are expected to have great potential for providing insights into the intrinsic properties of groundwater systems and their importance for surface water processes.

Conclusion and Implementation

There is great potential for FRIEND–HELP–PUB to complement and extend each other. The programmes are by no means distinct research communities, and there is already quite some overlap between researchers contributing to several programmes. Bridging between the programmes by research performed within and between the various programmes seems very promising for the future.

A critical step to achieving this goal is to implement all three initiatives into the IHP of UNESCO. During the current and sixth IHP phase (2002–07), the focus is on water systems at risk and the associated social challenges. In the next phase (2008–13), the IHP is proposing to concentrate its activities around 'Water Dependencies: Systems under Stress and Societal Responses'. This phase will have four themes: (i) global change, watersheds and aquifers; (ii) governance and socio-economics; (iii) environmental sustainability at the landscape level; and (iv) water quality, human health and food security. All these themes are relevant to aspects of HELP, FRIEND and PUB, and these existing programmes can be a significant contributor and focal area of IHP-VII.

Progress on the five areas identified in this commentary is achievable because of the complementarity and synergies of the three initiatives. Progress on individual projects will be advanced by individuals in ongoing and new efforts within and between the existing programmes. We plan to feature the initial progress in this regard at the "HELP Southern Symposium 2007: Local Solutions to Global Water Problems- Lessons from the South", hosted by the Department of Water Affairs (South Africa) and the International Water Management Institute, 4–9 November 2007, in Pretoria. There, sessions on 'Implementing HELP in Basins with Limited Resources and Capacity' will highlight some of the first tangible progress which is urgently needed for application in many developing countries. Of course, outcomes will also be reported elsewhere in other special sessions at upcoming international conferences. We encourage the hydrology community to contribute to these sessions. As all hydrologists know, many times *friends* need to *help* each other at the local *pub*. We hope that the community will become involved in HELP, FRIEND and PUB and their collaborations.

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