PUB

IAHS Decade on Prediction in Ungauged Basins (PUB)

IAHS PUB Working Group
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IAHS is an international association for hydrological sciences established in 1922, having about 70 country members and 3000 members in the world. As a science association IAHS is engaged in various activities to enable science to serve the society. One of them is the Prediction in Ungauged Basins (PUB). This is a celebrated policy-relevant science theme that arose out of the free discussion by IAHS members on the world-wide Web, based on current needs of the world, especially of developing countries, and the scientific readiness for a new commitment.

Reasons for PUB

Hydrological data are endangered species. The ground based observation network is declining in Africa, Central Asia, South-East Asia and elsewhere, including North America. Yet the hydrological data are more than never urgently needed, especially in developing countries, for water resources assessment and efficient management. In the last few decades, there have been considerable theoretical and technological advances in our ability to predict individual hydrological processes, in scaling up to the basin scale, in physically based hydrological modeling at the basin scale, and in remote sensing. As discussed below, it is our scientific responsibility to emphasize that the promising future developments will not only sensitively depend on the quantity and quality of in-situ data, but will also yield a much more productive use of these data, as well as the related remotely sensed data. At the same time, it is timely to propose a challenge that these scientific and technological advances, as well as their foreseen developments, can achieve, and thus demonstrate how science can be useful to society.

What is PUB?

PUB is an international research initiative to promote the necessary development of science and technology to achieve predictions in ungauged catchments. PUB will draw and develop contributions from theoretical hydrology, new methodologies for a more extensive use of remote sensing, *in situ* observations combined with modelling of water quantity and water quality, and capacity building for people in need of advanced science and technology to predict the hydrological phenomena of basins within their jurisdiction. PUB will have strong connections with existing programs in and out of IAHS that are concerned with predictions of hydrological responses, and will provide a forum, a network and the theoretical framework for integration of all existing related initiatives.

Role of IAHS

The PUB initiative constitutes a change in the policy of IAHS in the sense that it obliges to a continuous commitment for a ten-year period. The tasks of IAHS for this period are identified as:

- Develop a coordinating role as the voice of the international hydrological community in related programs

- Identify science needs and opportunities that can help to focus the attention of funding agencies
- Promote the initiation of national and multinational projects on the scientific issues of interest to PUB
- Promote and organize workshops and other activities directed towards capacity building and technology transfer to economically disadvantaged countries where PUB has its main mission
- Organize a series of scientific events (symposia, seminars, workshops) in support of the PUB scientific issues.
- Regularly publish the scientific achievements of the PUB activities in special issues of HSJ and Red Books.
- Facilitate agreements necessary to make data and model output freely available, and would develop protocols for archiving of catchment data and model output (e.g., via variation of GEWEX/ALMA)
- Facilitate "self testing" activities, in addition to coordinated inter-comparisons, through enhanced data access and archiving policy.
- Demonstrate the economic and environmental value of existing traditional gauging networks.

The PUB initiative is also a change of IAHS in the sense that IAHS strives to identify and promote a certain prioritized research field. A prioritization was made by the IAHS members through open discussions during scientific meetings and on the world-wide Web. The scientific aspects of PUB has been further elaborated to identify four themes:

(1) Theoretical Hydrology,

(2) Observational Hydrology and data processing methodologies,

(3) Model Diagnostics and Inter-Comparison, and

(4) Advanced Data Collection Technologies.

These four themes constitute a PUB Scientific Programme and its content is described in more detail below. This programme will serve as a guideline for planning of PUB activities during the IAHS Decade of PUB. Hopefully it will also attract the interest of researchers all over the world around the scientific challenges of PUB to identify how ongoing research can be a contribution to PUB and also generate new research activities. To promote joint research activities the ambition is also in collaboration with the GEWEX "Coordinated Enhanced Observing Period" (CEOP) to establish a PUB basins network, i.e. providing a list of basins around the world with open data bases. IAHS role is not to carry out research projects. It can only promote research and create a necessary framework for this in accordance with the bulleted list above. These latter aspects are elaborated within a PUB Implementation Programme. This is also divided into two themes:

(5) Applications Strategies and Connectivity, and

(6) Developing Countries and Capacity Building.

Together the PUB Scientific Programme, the PUB basins network and the PUB Implementation Programme constitute the PUB Operational Programme. This programme is described in more detail below.

IAHS will establish a Working Group on Predictions in Ungauged Basins (WG-PUB) to be responsible for the execution of the PUB Operational Programme. It will have 10 members with rotating membership (say, every three years on average but with overlapping tenures), and a mandate for the period 2003-2012. The following is a suggested composition of the membership:

Member 1: Chairperson
Member 2: Theoretical Hydrology (Theme 1)
Member 3: Observational Hydrology and data processing methodologies (Theme 2)
Member 4: Model Diagnostics and Inter-Comparison (Theme 3)
Member 5: Advanced Data Collection Technologies (Theme 4)

Member 6: Application Strategies and Connectivity (Theme 5)
Member 7: Developing Countries and Capacity Building (Theme 6),

In addition representatives from different international programs such as CEOP, GPM, GEWEX, IHP, WMO, HELP …, will be invited to participate and to contribute.

At present the IAHS PUB initiative is still in its preliminary phase mainly devoted to planning activities. The Time Table for this preliminary phase is as follows:

- *April 2002, EGS, PUB open forum*
- *June 2002: Workshop on Scaling and Nonlinearity, Vancouver, Canada*
- *16 June 2002: Approval of IAHS Bureau, Paris.*
- 13-16 August 2002: XIX Congreso Nacional del Agua Villa Carlos Paz (Argentina)
- 2-6 September 2002: XXIst Conference of the Danubian countries on the hydrological forecasting and hydrological bases of water management, Bucarest
- 20-22 November 2002: Kick-off meeting in Brasilia, Brazil supported by UNESCO.
- 6-10 December 2002: AGU Fall Meeting, San Francisco
- 16-23 March 2003: Third WWF Kyoto, PUB workshop "Hydrology for Society: What can hydrology do in ungaged basins?".
- 7-11 April 2003: AGU-EGS-EGU Joint Meeting, Nice
- 30 June-11 July 2003: IUGG/IAHS SH-01, WH-07, Sapporo
- 14-17 July 2003: MODSIM Congress, Townsville, Australia
- Late 2003: New Delhi, PUB workshop
- 8-12 December 2003: AGU Fall Meeting, San Francisco
- 12-16 July 2004: BHS International Symposium, Hydrology: Science and Practice for the 21st Century, London

The intention is to divide the activities of PUB into say four more phases: Phase I: 2002-2003 – a preparatory phase with the goal to get prepared to generate the PUB initiative world wide. The consecutive phases and their goals are to be elaborated.

PUB Operational Programme

The PUB Operational Programme is divided into a Scientific Programme and an Implementation Programme and it also includes a PUB basin network. The PUB Scientific Programme is in turn divided into four themes:

(1) Theoretical Hydrology,
(2) Observational Hydrology and data processing methodologies,
(3) Model Diagnostics and Inter-Comparison, and
(4) Advanced Data Collection Technologies.

PUB Implementation Programme is also divided into two themes:

(5) Applications Strategies and Connectivity, and
(6) Developing Countries and Capacity Building. In an introductory part the motivations for PUB are elaborated and its different components are clarified.

1 INTRODUCTION

1.1 What is an Ungauged Basin?

An *ungauged* basin is one with inadequate hydrological instrumentation to enable computation of even the annual balance of a hydrological variable of interest (water, sediments, nutrients etc.), to the accuracy acceptable for practical applications.

For example, a basin with continuous measurements of precipitation and runoff will be deemed a *gauged basin* as far as water quantity is concerned, while one with no continuous measurements of either precipitation or runoff is an *ungauged* basin. A basin with partial or incomplete measurements on precipitation and/or runoff will be deemed a *poorly gauged* basin for water. A basin with no continuous measurements of nutrients and other water quality in streamflow will be deemed as ungauged with respect to water quality. A basin with no continuous measurements of erosion rates and sediment concentrations in streamflow in particular will be deemed as ungauged with respect to sediments.

1.2 Nature of Predictions

Prediction refers to an *a priori* estimation of the hydrologic response of a basin to observed, forecast or otherwise specified climatic inputs. In particular, it refers to the estimation of the hydrologic response *before* it happens, and is therefore different from mere fitting (mimicry) of past observations.

1.2.1 But what do we want to predict?

The hydrologic response we want to predict depends on the nature of the problem. Examples include prediction of floods of a given return period, extent and frequency of floods, mean annual water yield, reliability of water supply, crop yields, irrigation scheduling, and water quality (concentrations of contaminants: nutrients, heavy metals).

In general, the predicted hydrologic response can be a continuous time series of the quantity and quality of interest (e.g., storm hydrograph), or statistical measures of its variability on a wide range of space or time scales, e.g.: hierarchy of statistical moments, probabilities of exceedance of various thresholds, and their asymptotic behavior for maxima/minima (e.g. floods/droughts on given scales), etc.

1.2.2 Definition of "Prediction in Ungauged Basins"

PUB is defined as the prediction of the hydrologic response (e.g., streamflows, sediments, nutrients etc.) of ungauged or poorly gauged basins using all data sets *other than* past observations of the particular hydrologic response that is being predicted, i.e., climatic inputs (observed, forecast or otherwise specified), soils, vegetation, and topography, including any predicted or expected future climatic or land use changes, but with no allowance of *local tuning or calibration*.

1.2.3 Natural and Human-Induced Variability

It is clear that each of the prediction problems mentioned above is intimately connected, and is a special case of, making predictions of space-time variability of a particular hydrological response of a basin, at event, daily, annual and decadal scales, in other words. In other words, PUB is a scientific problem associated with enhancing our ability to understand and predict space-time variability over a wide range of scale of hydrologic responses of the land surface.

One of the challenges about predictions of PUB is that not only we are supposed to make predictions under current conditions (natural variability), but more importantly, our understanding of natural variability is indispensable and might be sufficient to also make predictions under changed conditions, including human-induced climate change, land use changes. Thus, in general, we are not only dealing with extrapolation in time and space, but also extrapolation to future changed circumstances. Methods and traditional practices based on the assumptions of stationarity, equilibrium and weak natural variability are no longer sufficient because of the paucity of data that fully reflect the changed conditions.

1.3 Available Options for PUB

In order to provide the necessary data to ungauged basins, the following five options are available. However, there are considerable difficulties with each of these options (these are presented within angle brackets, as in < …>, and will be described in the next section.

1. *Observe on site*: Requires intensive measurements and observations. <expensive, cutbacks to gauging >
2. *Extrapolate from gauged basins*: Involves statistical information transfer or regionalization. <heterogeneity of land surface, and thus lack of transferability, lack of availability of similar gauged basins nearby>
3. *Observe by remote sensing*: TRMM, GPM, IGOS-Water, NOAA, JERS, SAR, GPS, laser altimeter (TOPEX/POSEIDON), GRACE for GW monitoring etc. <coarse resolution, difficulty with hydrologic interpretation of measurements, lack of ground truth data>

4. *Hydrological model simulation*: Distributed physically based hydrological models. <unavailable climatic inputs: precipitation and radiation, landscape attributes, land use change, water use and regulation data, lack of basin response data for validation, parameter identifiability, model transferability>
1. *Integrated meteorological and hydrological model*: meteorological (4DDA + meso-scale nesting) models + hydrological models. <accuracy, data availability on landscape properties, ad-hoc parametrizations, model limitations (in scale and physics), parameter identifiability >

1.4 Causes of the PUB Problem: Scientific Challenges Ahead

Below is a list of major difficulties that stand in the way of our ability to make predictions in ungauged catchments. These are presented to provide the rationale for the PUB scientific agenda to be presented later.

1.4.1 Fundamental, Theoretical Deficiencies

- Inadequate understanding of climate-soil-vegetation-topography interactions that give rise to observed space-time variability of hydrological responses (within and between different biomes) over wide range of scales;
- Need of a consistent framework for the analysis of observations and the modeling over a wide range of scales. This framework is indispensable to obtain relationships between between landscape and climate features and basin responses, as well as to obtain consistent balance equations at basin scale.
- An over-emphasis on physically based models that treat the basins as mechanical and deterministic objects and a lack of emphasis on the chemical and biological co-evolution, and co-variation and co-evolution of climate-soil-vegetation systems.

1.4.2 Inadequacy of current Models and Modelling Approaches

- Inappropriate modeling frameworks currently used: conceptual models are inappropriate since they require calibration, physically based models because they are theoretically based on scales which are too much small to be numerically represented and/or observed. They therefore require ad-hoc upscaling and parameterizations , which at best could be tuned up with the help of intense data analysis,
- Inadequate appreciation that one needs to deal with incomplete descriptions and/or observations due to the wide of range scales and/or of interracting phenomena. Therfore, adequate models should be able to deal with uncertainties and randomness, as well as with limits of predictability.
- Over-emphasis in modeling on fitting of past observations, and under-emphasis on diagnostic studies, i.e., learning from data. Also, an overemphasis on streamflows hydrographs, and inadequate collection and analysis of other data, such as groundwater levels, saturation areas, bio-chemical and eco-hydrological conditions, tracers etc.

1.4.3 Inadequate, Inappropriate Data and data processing methodologies

- Inadequate or incomplete datasets with which to develop and test new theories and to validate models, and inadequate analysis from a systems perspective to forge an insightful understanding of how the basin functions.
- Inadequate data processing methodologies, which are unable to deal with wide range of space-time scales, strong variability (e.g. the ubiquitous quasi-gaussian assumptions), sparse networks, measurement at different scales and of different dimensionalities (e.g. 1-D time series vs. 2-D satellite images, 4-D radar data sets), etc.

- Insufficient understanding of the effects of human impacts such as deforestation, and insufficient datasets to form hypotheses about the effects of human-induced land use and climate changes and to test models and theories, insufficient understanding of how nature adapts to human impacts.
- Prediction also requires us to know the future of climate variability and climate changes, as this is fundamental to future predictions of basin responses. These will not necessarily come from hydrologists themselves or by looking at the past data, or by modeling the past. This requires (bilateral) links to climate studies, including those performed with global models. However, one has to keep in mind the well-known limitations of global circulation models, in particular of clouds and precipitation modeling.

1.5 Opportunities that Can Assist: The Way Forward

So, how will we solve the problem of prediction of ungauged catchments? Given below are some of the approaches that will assist us in our predictions, the opportunities that we will need to exploit to resolve the PUB problem:

1.5.1 How to overcome Fundamental, Theoretical Deficiencies

- Better understanding of currently the observed variability over a wide range of time and space scales of rainfall and runoff processes (within and between catchments), including extremes (at time scales ranging from diurnal to inter-annual and even inter-decadal, and space scales ranging between 0.1 to 15,000 sq. km.), and their interpretation in terms of the underlying climate-soil-vegetation-topography interactions, including the effects of human-induced climate and land use changes.
- Development and use of advanced mathematical techniques for the characterization of space-time variability at multiple scales: fractal structures and multifractal fields, wavelets analysis, nonlinear dynamics.
- Derivation and validation of new balance equations at various scales and in particular at the basin scale, which can be the foundation for a new theory of hydrology at the basin scale.
- Development of measurement techniques, as well as new data processing methodologies, especially for remote sensing, to measure and estimate over a wider range of scales quantities, which are fundamental to the development and validation of these new theories and the remote monitoring of state variables such as saturated areas and groundwater levels.
- Improve our understanding of the interactions between runoff processes, and the chemical and biological processes, at all time and space scales, which is crucial for water quality predictions (salinity, sediments, nutrients, heavy metals etc.) at the basin scale.
- Development and advancing of the emerging focus on holistic thinking, *ecohydrology*, *Gaia* theory etc. that will enable more parsimonious descriptions of climate-soil-vegetation-topography interactions.

1.5.2 How to Overcome Inadequacy of Models and Modelling Approaches

- Assemble and analyze data from a variety of regions or “biomes” from around the world, and encourage innovative ways to analyze the data to learn from it: especially from the observed patterns. Data should not be used to validate previously complete models, but be used to understand and gain insights. Examples of analyses include wavelet analysis, fractals and multifractal analysis and modeling, characteriezation of universal vs. particular features/patterns, data based mechanistic modeling, empirical models, downward approach to modeling (Klemeš) etc.
- A suite of new process-based models to make predictions of both water quantity and quality with a common foundation and structure: in different regions of the world, starting out with many existing models and whittling them down to a few generic types, suitable for the different

hydrologic regions (or biomes) of the world: 1) validated in gauged catchments subject to natural and/or human-induced changes to climate, soil and vegetation, and 2) in a position to be used with reasonable, and quantifiable confidence in ungauged basins.

1.5.3 How to Overcome Inadequate, Inappropriate Data and data processing methodologies

- New approaches (focused field experiments, remote sensing, tracers and surrogate measurements) to observing previously unobserved space-time variabilities of runoff processes and other hydrological processes, unifying the observations of hydrologic processes at various scales, in different geographic settings or biomes around the world, and thus completing the knowledge base and filling gaps in understanding of the underlying climate-soil-vegetation-topography interactions. The focus shall be on measurement of streamflows from multiple gauges, as well as measurement of internal variables that have a bearing on the water balance variability: groundwater levels, soil moisture, saturated areas, runoff partitioning through tracers (isotopes, geochemical signatures etc.).
- Development of new observational technology (ground-based field experiments, tracer techniques, as well as in remote sensing) for making space-time observations. Use of existing remotely sensed landscape properties (soils, vegetation cover, topography), and climatic data at large scales should be emphasized, as are mathematical techniques to characterize such data in an efficient manner and for downscaling these variables to basin scales to satisfy the data requirements of hydrological models.
- New data processing methodologies able to deal with wide range of space-time scales, strong variability, sparse networks, measurement at different scales and of different dimensionalities, etc.

2. PUB Scientific Programme

PUB Scientific Theme 1: Theoretical Hydrology Advance methods for characterizing variability and heterogeneity in climatic and landscape attributes (including in remotely sensed data), e.g. scaling, fractal multifractal, wavelet analyses

- Develop new governing equations at the basin scale to overcome the scale gap between current theories and applications: e.g., averaging and renormalization approaches
- Investigate the co-evolution of climate, soil, vegetation and topography (*Gaia* hypothesis), terrain attributes and surrogate variables for more efficient characterization of landscape variability
- Collect and analyze *existing data* on hydrologic responses (including from remote sensing data) at multiple scales in different “biomes” or “hydro-climatic regimes”
- Diagnostic studies: Interpret the observed patterns (within and between different biomes or regimes), in terms of the underlying climate, soil, vegetation, topography and land-use interactions.
- Analyze common and distinct features of basins, through investigating a sequence of basins corresponding to the full palette of hydro-climatology (e.g., humid tropical, mid-latitude temperate, high latitude, sub-alpine/alpine, arid, etc.) or biomes conditions.

PUB Scientific Theme 2: Observational Hydrology

- Carry out detailed field experiments for the collection of comprehensive datasets in a few biomes or hydro-climatic regimes than are currently available: nested measurements of streamflows, state variables, tracer analyses, soil surveys, terrain attributes etc.
- Heavily focus on hypothesis testing, gaining insights, and on development of parameterizations and scaling up

- Develop new data processing methodologies able to deal with wide range of space-time scales, strong variability, sparse networks, measurement at different scales and of different dimensionalities , etc
- Another focus shall be on model improvement and validation, and on quantification of predictability and predictive uncertainty

PUB Scientific Theme 3: Model Diagnostics and Inter-Comparison

- Greater efforts at uniformity/harmony of modelling approaches, guided by new theories of hydrology and new approaches to data analyses
- Approaches to improve model parsimony, fidelity, and transferability between basins
- Methodologies for improved parameter estimation, use of soft data, pedo-transfer functions, use of tracers, internal state variables etc.
- Model inter-comparison studies: focus on diagnostic studies and on relating model performance to understanding of climate-soil-vegetation interactions
- Focus more on learning from key signatures (patterns) of basin response and less on mere curve fitting.
- Model development and improved to be carried out in stages: – initially focusing on water quantity, later expanding to include chemistry, sediment, etc.
- Hierarchical approach: predictions of annual runoff in ungauged catchments, extending to monthly, then to daily and hourly etc.
- Similar approach to space scales: small basins first (lumped models), then gradually increasing basin size (distributed models to handle spatial heterogeneity)
- Apply to sets of catchments globally stratified by hydro-climatology (e.g., humid tropical, mid-latitude temperate, high latitude, sub-alpine/alpine, arid, etc.).

PUB Scientific Theme 4: Advanced Data Collection Technologies

- Extend the range of hydrological data collected in national and international operational hydrology monitoring networks by including hydrological data obtained using indirect sensing techniques and four-dimensional data assimilation methods
- Improved ability to estimate landscape attributes (soils, vegetation etc.) and surrogates by remote sensing, and conversion of these attributes to model parameters
- Analysis of remotely sensed data for multi-scale variability, and parsimonious characterization: up-scaling and down-scaling
- Improve ability to estimate/measure precipitation, soil moisture, saturation area dynamics, floodplain inundation, runoff, and evaporation through remote sensing and 4DDA data assimilation
- Join with CEOP initiatives and add relevant hydrological data to all CEOP sites where it is feasible and where these data will otherwise be missing, and to identify and propose new CEOP sites defined around hydrological basins

3. PUB Basin Network

The PUB basin network is a supporting activity to the four scientific themes by providing a list of basins around the world with open data bases. The idea is to promote researchers on PUB themes to jointly explore these common basin data sets. In a first phase the aim will be to foster the development by PUB of new, indirect gauging methods at a set of PUB "Development Basins". The establishment these basins is carried out in collaboration with the GEWEX "Coordinated Enhanced Observing Period" (CEOP) by

a) adding hydrological data at existing CEOP sites, where feasible and/or
b) identifying and proposing additional CEOP sites defined around hydrological basins.

In proceeding phases of PUB this program can be extended by also providing a selection of basins

- to validate and demonstrate PUB's ungauged modelling capability, PUB "Proving Basins", and- to explore PUB's outreach and capacity building methods and the application indirect gauging and/or ungauged modeling, PUB "Outreach Basins".

PUB Development and Proving Basins will then be well gauged using traditional methods.

PUB Outreach Basins will be ungauged and preferably some will be near Development and Proving Basins to facilitate the use of new methods.

4. PUB Implementation Programme

The Implementation Programme define the direct tasks of IAHS in the PUB activities.

PUB Implementation Theme 5: Application Strategies and Connectivity

- Report on the state of PUB science and its value to real world operations (IAHS acting as the matrix for OHP and IHP). Organize PUB symposia, seminars and workshops: regional to national
- Promote National Studies (activated by IAHS national representatives):
  - Stimulate
  - Monitor
  - Review
  - Assess
- Encourage open databases
- Encourage open model bases
- Promote links with other programs, leading to synergy
- Put hydrology into CEOP: encourage adding hydrological data at existing CEOP sites where feasible, and identifying and proposing new CEOP sites defined around hydrological basins, the PUB Basin Network ("Development and Proving Basins").
- Encourage the establishment of a network of "blind test" sites (e.g. semi-arid, monsoon, humid tropical). Invite "ungauged estimates" for these sites, and define target evaluation criteria of performance, and then evaluate these estimates, the PUB Basin Network ("Outreach Basins")
- Explore methods for capacity building, education, scientific outreach, and generating interest and ideas for Phase II.

Connectivity to existing programs:

- MOPEX, DMIP – combined efforts to assemble data, parameter estimation techniques, model inter-comparison studies
- CEOP – identify and propose new CEOP sites around hydrological basins, provide meteorological inputs to PUBGEWEX – joint strengthening of weather-hydrology link, to strengthen water resources aspects
- OHP – has WYCOS, PUB needs to link and coordinate
- IHP – links to Theme 1 Global changes and water resources, Theme 2 Integrated Watershed and Aquifer Dynamics, Theme 5 Water Education and Training; recognition of the contribution of PUB to IHP VI
- HELP – overlap with HELP basins
- FRIEND – launch parallel PUB FRIEND projects
- CUAHSI – facilitate science, establish up to 8 research basins
- AGU, EGS, Asia Pacific HWR Association – organize meetings
- GLASS (CO_2 in new land surface schemes)
- GSWP2 (soil moisture)
- ISLSCP initiative 2 data sets (global data at 0.5 degree resolution)
- Joint Water Project of WCRP/IGBP/IHDP/DIVERSITUS

Connectivity to Existing Commission Activities:

- ICRS - influence D.C.T. program and facilitate PUB
- ICCE - provide direction for capacity building, emphasis in developing countries
- ICT – opportunity to integrate micro-processes to modeling parameters, tracers help define runoff processes and reduce uncertainty in models
- ICSW – working with FRIEND
- ICGW, ICSI, ICWRS, ICWQ, ICASVR
- WG GEWEX/BAHC – projects helpful for PUB:
    - GLASS (CO_2 in new land surface schemes),
    - GSWP2 (soil moisture)ISLSCP initiative 2 data sets (global data at 0.5 degree resolution)

PUB Implementation Theme 6: Developing Countries and Capacity Building

- Hold PUB workshops rotating around in developing countries
- Strengthen existing initiatives and start new initiatives to enhance north-south collaboration, exchanges of students and scientists
- Encourage the use of basins in developing countries in PUB initiatives: work to identify and assemble data from a number of basins for testing of new prediction methods
- Work with international agencies to offer scholarships for research students from developing countries to work on PUB-related projects
- Select a limited number of ungauged basins with the purpose of exploring methods for capacity building, education, and scientific outreach. The hydrological needs for each basin will be defined, any available relevant data distributed, and an invitation issued to hydrological scientists to participate in the ungauged prediction of these basins.