IAHS workshop on informative data in hydrology

1 WORKSHOP DESCRIPTION

Workshop n°8: When are hydrological data informative (or not)? Testing for information content in the face of sources of uncertainty

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For decades, hydrologists have been using time series of rainfall, air temperature, water level and streamflow data to feed, calibrate and evaluate statistical and deterministic hydrological models. These models have many applications in hydrological engineering, such as estimating the mean annual streamflow of an ungauged catchment, flood frequency analysis at gauged and un-gauged sites, extrapolation of streamflow response in changing climate (e.g. extreme floods and droughts), etc. Unavoidably, the temporal series used within these methods are characterized by epistemic and aleatory errors (e.g. incorrect transcription of a handwritten value) and/or systematic inconstancies (e.g. change of the gauging location). These errors raise the issue of the (dis)informative content of the data used in hydrology and specifically in rainfall-runoff modeling: are all periods equally informative, are there seasonal trends? If some time series or periods can be considered as disinformative, how is it possible to detect them and what effects might they have on model identification and inference? Are there criteria or methods (quantitative and/or qualitative) that might be used to classify data in this way given different sources of uncertainty, independent of the model being used? Might the classification be different for catchments with more or less baseflow for example? And if we can avoid using these series or periods in model identification, will this have a significant impact on the performance of the considered models and thus on their robustness?

We propose to organize a collaborative workshop during 2022 IASH General Assembly to bring together a group of researchers around the following question:

Can we quantify the (dis)information content of the uncertain hydro-meteorological data series used in hydrology?

Participants will have to propose innovative solutions to identify informative or disinformative data taking account of sources of data uncertainty and to show how this classification might be used to produce more robust hydrological calculations and models. The participants are free to develop methods based on series analysis (e.g. analysis of runoff coefficients), statistical tests, rainfall-runoff modeling or machine learning. Contributions are welcomed in various domains: flood frequency analysis, regionalization, rainfall-runoff modeling (both lumped and semi-distributed), hydro-meteorological forecasting, modelling of climate change impact on water resources, etc.

Potential road maps for the development of methods to identify informative or disinformative data are given through the following types of questions:

- If some periods of data are disinformative in model identification, how can we validate or invalidate different potential model structures?
- If some periods of data are disinformative in model identification how can we assess predictability in flood frequency analyses or simulations of future flow regime on a catchment?
- If some periods of data are disinformative for model identification, how can we gain insight into the importance of different sources of uncertainty in the modelling process?

To answer one or more of these questions, participants are invited to test their methods on “their” catchment dataset or on catchment datasets available online (e.g. CAMELS), and to discuss the obtained results in terms of catchment characteristics (flashiness, baseflow or snow influence, etc.)

Finally, a “spot the differences” game will be proposed to each participant: a team of hydrologist experts is going to hide fake / made-man errors and inconsistencies within a specific dataset that will be made available to the participants in the coming weeks. The participants are then welcomed to use this specific dataset to test their methods, and spot the hidden errors to win a special prize: a bottle of local “rosé” wine!

The outputs of this workshop may be published in a special issue in a leading journal (e.g. Hydrological Sciences Journal) depending on the participation in the workshop.

2 ORALS

2.1 Anwar & Bárdossy

Is model calibration compensation for input errors?

Anwar (University of Stuttgart, faizan.anwar@iws.uni-stuttgart.de) & Bárdossy

All recorded data are measured with an error. Rainfall data more so as they are measured at relatively few points and then interpolated/extrapolated for the unknown locations. We pose the question as to what happens to model parameters if the data are erroneous. To do so, we propose the following experiment using SHETRAN and HBV as rainfall-runoff models.

Prepare input data for a reference model (SHETRAN) and run it to produce a runoff series. We consider this as the "literal truth". Instead of taking observed runoff data the reference model is chosen to avoid the problem of model error. Calibrate the target model (HBV) using the same input data and the runoff data from SHETRAN using Robust Parameter estimation (ROPE) to produce an ensemble of "good-parameters", instead of using one global optimum.

To simulate the error, make changes to the input data. This could be done by perturbing rainfall at multiple stations and/or by moving the station locations within a threshold distance. The movement of stations serves to simulate the effects of a gauge missing a high precipitation region. Then the target model can be recalibrated again and again but using the same runoff series (from SHETRAN). Due to change in data, the recalibrated HBV ensemble parameters would move in a certain direction away from the "good-parameters". Ideally, there should be no movement of any two parameter point clouds. By computing the intersection between multiple ensembles, we can give an indication of how much model parameters can move about when a given amount of error is present in the data.

2.2 Astagneau et al.

How to calibrate a function aimed at fixing a low-occurrence problem in a hydrological model? Investigating local and regional strategies to calibrate a function accounting for the hydrological impact of rare high-intensity rainfall

Astagneau (INRAE, paul.astagneau@inrae.fr), Bourgin, Andréassian & Perrin

Accurately simulating floods generated by high-intensity rainstorms on dry soils (e.g. typical summer or early-autumn storms) is a particular challenge. Specific functions are needed to represent the catchment behaviour under these conditions and, ultimately, to improve the predictive capability of hydrological models. The goal of this study is to improve the parameter identification of model functions that only activate on a few time steps during high-intensity rainstorms, in conditions where the uncertainties in rainfall and streamflow data are particularly large. We especially investigate whether there is sufficient information in the data time series to derive optimal values of the parameters controlling these functions.

To that end, we compared the performance of three calibration techniques: local calibration, regional calibration and the use of generic parameter values. We used the GR5H model at the hourly time step with a recently developed intensity-rate function for this analysis. The three calibration techniques were evaluated over a large set of 229 catchments where 10,652 flood events were selected. Performance in simulating floods was assessed against a benchmark model that does not integrate a rainstorm intensity function.

Results showed that the regional calibration technique and the use of generic parameter values perform better than the benchmark model but not as well as the fully calibrated model, although parameter uncertainty was reduced. The additional parameters were found to be poorly sensitive to the objective function but highly dependent on the duration of the rainfall events.

2.3 Belleville & Sevrez

Recalculation of historical streamflow series. Impact assessment and valorization

Belleville (EDF DTG, arnaud.belleville@edf.fr) & Sevrez

For safety reasons, energy production or regulation, water resources management is one of EDF's (Electricité de France) main concerns. To meet these needs, since the fifties EDF-DTG (Division Technique Générale) has operated a hydrometric network that includes more than 350 hydrometric stations. The process of producing streamflow series involves a succession of steps: acquisition of raw water level data, validation of these data, gauging operation, tracing of the rating curve, discharge calculation, criticizing and data banking.

The archiving of a discharge time serie into a database after the validation and criticizing phase is often considered by the field hydrologist as the final step in the data production process. However, during the subsequent valorization of these data in the context of hydrological studies (calibration of hydrological models, flood forecasting and warning, engineering design, etc.), new knowledges relating to the hydrometric station (high-flow gauges, hydraulic modeling, etc.) may be available and lead to the need to update discharges via the updating of the rating curves. Similarly, a historical succession of different practices of field hydrologists highlights heterogeneity in the data processing.

This communication presents a methodology to update and correct historical flood flows, so as to propose homogeneous and less biased data. The benefit of using hydraulic modeling is discussed. This methodology is applied to a large sample of hydrometric stations of the EDF network, and the impact on peak flows deviations is analyzed.

2.4 Paquet

Dealing with uncertainty of rainfall-runoff parameters in a stochastic simulation method for extreme flood estimation: milking the most of a calibration dataset

Paquet (EDF DTG, emmanuel.paquet@edf.fr)

The SCHADEX method aims at the estimation of extreme flood for dam design. It is based on a semi-continuous rainfall–runoff simulation, with the MORDOR conceptual model which provides a representation of the main hydrological processes of the catchment, including snow. Up to 20 free parameters are calibrated using the genetic algorithm and a composite objective function scoring various features of the modeled discharges (volumes, regime, distribution of flood, etc.).

The uncertainty of these parameters is of course significant, in relation with the calibration period, the hydrometric uncertainty of the observed discharges used for calibration, and the equifinality within the model's structure. Thereby, different sets of parameters can similarly simulate the observed hydrology, but will produce significantly different distributions of extreme discharges through the SCHADEX process, meaning that the asymptotic behavior of the rainfall-runoff model is sometimes not robustly inferred by the calibration of the hydrological model on observed data.

A method to evaluate this uncertainty and to compute a credible extreme flood estimation using the best of the available information is presented and illustrated with a French catchment. Two methods are used to explore the uncertainty of the rainfall-runoff model parameters: bootstrapping of the calibration data, and a censored random exploration of the acceptable range of flood-related parameters in order to produce a large set of "behavioral" parameters. This allows to generate an ensemble of simulated discharge distributions, which are combined to produce a single predictive distribution of extreme flood, accounting for this model uncertainty.

2.5 Saadi et al.

Which range of discharge data is most informative in the calibration of a rainfall-runoff model?

Saadi (Forschungszentrum Juelich/IBG-3, m.saadi@fz-juelich.de), Furusho-Percot & Kollet.

The calibration of conceptual rainfall-runoff models depends on the choice of the objective function and the hydroclimatic specificity of the calibration period. For flood forecasting, model parameters are estimated with the aim of reproducing high flows, but for the reproduction of water balance and low flows, specific discharge transformations are needed to limit the weight of high flows. For either application, a precise definition of the range of high flows that predominately informs the calibration process would be useful. Using a large sample of more than 800 catchments located in France and the United States, with 16 years of data for each catchment, we calibrated an hourly, lumped hydrological model (GR4H) on the whole available data. Then, we calibrated the model on only half of the data, defined as the periods when the discharge values were between Qx% and Q(x+50)% ($0 \le x \le 50$), where Qx% indicates the xth percentile of the discharge values. Preliminary results show that, in most cases, little difference is observed between parameters extracted from the highest half of the discharge values and from the whole period. However, the parameter values extracted from the [Q40%,Q90%] range differ significantly from the whole period, indicating that most of the extracted information lies in the upper 10% of the discharge values, even when using a log transformation. The loss in validation performances was asymmetrical, with higher losses obtained when calibrating on the upper half and validating on the lower half than otherwise. This suggests that spurious discharge data would be more harmful for the calibration process if they hold high ranks within the discharge distribution. Using antecedent soil moisture measurements or proxies would help detect these values

2.6 Seibert & Westerberg

Hunting after shoals of red herrings - cataloguing disinformative data and their causes

Seibert (University of Zurich, jan.seibert@geo.uzh.ch) & Westerberg

Disinformative data may bias model results, obscure model parameter identification or, in the more extreme cases, make data useless for hydrological inference. With the aim to study subsequently the impact of disinformative data on hydrological model calibration using synthetically generated disinformation in controlled model experiments, we here discuss and catalogue the types of data uncertainties that may cause data to be disinformative.

We first review previous findings of disinformative data, including their reported causes and impacts on model calibration. Building on earlier work, we use five categories of data uncertainty to catalogue our findings on the causes of disinformative data: measurement uncertainty, derived data uncertainty, interpolation uncertainty, scaling uncertainty, and data management uncertainty. We consider the impact on model calibration regarding the magnitude of the disinformation and the longevity of the impacts on the model. We then discuss likely additional causes which have not yet been discussed much in literature and invite the participants of the workshop to contribute to this collection of important types of errors that deserve more attention. Finally, we discuss the implications of our findings on causes of disinformative data for the generation of plausible synthetic time series, including disinformative modifications of the 'correct' data for studying the impacts of such errors on model calibration.

2.7 Thebault et al.

Impact of erroneous data in streamflow time series in large-sample-hydrology modelling experiments

Thebault (INRAE, cyril.thebault@inrae.fr), Perrin, Andréassian, Thirel & Legrand

Although often neglected, many sources of error in data, such as precipitation data, estimates of evapotranspiration or flow measurements, can affect the results of hydrological models. Various studies have investigated the impact of errors related to climatic inputs (typically precipitation, evapotranspiration and temperature data). Comparatively, the impacts of errors in streamflow time series has been less studied, and was mainly limited to stage-discharge relationship issues. However, it is well known that several other types of errors may also exist in observed flow series and may ultimately affect modelling experiments. The automatic detection of these errors is often difficult and time series have to be checked by expert judgement, which may be tedious in case of large samples of catchments. Therefore, there is a need to better quantify the actual impact of such errors. The aim of this work is to answer the following question: do erroneous data commonly found in streamflow time series have a significant impact on the performance and parameterization of hydrological models?

To answer this question, 15 French catchments were randomly drawn from a large database of 147 catchments. Precipitation, evapotranspiration and flow data were gathered at the hourly time step over the 1998-2018 period. We used the lumped-conceptual GR5H hydrological model. The streamflow time series were inspected by two experts who identify possible errors in flow observations, which were sorted into four types. Sensitivity of modelling results to these errors in calibration and evaluation was analysed by leaving or removing these errors in observed series.

As expected, the more erroneous a time series, the more the model is affected, whether in terms of parameterization or performance. However, these variations remain small, highlighting the stability of the GR5H model despite the presence of erroneous data. The model is also more sensitive when the errors affect high water, even if, on average on the sub-sample, the majority of erroneous time steps occur during low-flow periods. Finally, erroneous data in streamflow time series may be accepted as long as they do not reach outlier values. The implications of these findings in the use of large sample of catchments are discussed.

2.8 Lang et al.

Value of historical information for flood frequency estimation: case study on the upper Rhine River

Lang (INRAE, michel.lang@inrae.fr), Renard, Le Coz, & Darienzo.

We present a comparison of the flood distribution on the upper Rhine River in Basel, Switzerland, using historical information from several centuries. Including large historical floods may reduce the sampling uncertainty of the flood distribution. However, the final uncertainty on extreme flood estimates may also increase if historical flood discharges have large errors. A trade-off between additional information and additional errors must be sought.

We compare several ways of representing the uncertainty of historical floods in flood frequency estimation: 1/ perfectly known without error, 2/ unknown floods larger than a threshold or 3/ with uncertainty (floods within an interval or with a prior distribution) due to rating curve errors or water level errors. We also study the impact of the starting date of the historical period, or the heterogeneity of the flood collection.

A Bayesian framework allows the estimation of the posterior distribution of the parameters of a GEV distribution, with a comparison of uncertainty.

3 Posters

3.1 Brendel et al.

Choosing acceptable parameter sets when calibrating a continental rainfall-runoff model (E-HYPE v.4)

Brendel (SMHI, conrad.brendel@smhi.se), Capell, Musuuza, Isberg & Arheimer

Setting up continental-scale hydrological models and calibrating them involves trade-offs in (1) model simplification of local hydrological processes, both in spatial aggregation and process description, (2) forcing data accuracy in gridded (re-analysis-based) forcing products, and (3) model prediction in ungauged basins.

Here, we show results from the latest calibration of a HYPE model set-up for Europe (E-HYPE version 4). HYPE is a conceptual model targeting large-scale model domains, with spatial resolution in sub-basins and soil-runoff processes tied to hydrological response units (HRU). The model is calibrated against observed data, with parameters partly tied to physiography (in addition to domain-wide parameters), which allows to use HYPE for prediction in ungauged basins. E-HYPE uses pan-European and global data in the model set-up. For streamflow calibration, a total of 2700 gauges are included in E-HYPE, from various sources (e.g. GRDC), time-periods, sampling frequency and quality.

Calibration of such a model inadvertently leads to equifinality problems because of multiple uncertainty sources. To meet this challenge, we adopted a calibration approach which evaluates proposed parameter sets under various constraints, and allows us to continuously do so throughout the lifetime of the model set-up. We used a representative gauged basin (RGB) approach as primary calibration target, for which we selected a total of 162 gauged sites to represent 14 land use and 6 soil classes. For these sites, 9 soil type-depending and 4 land use type-depending parameters were calibrated, along with 12 general parameters. For this, 20000 parameter proposals were sampled a priory using Latin hypercube sampling, and acceptable parameter set candidates identified (informally and supervised, leading e.g. to exclusion of mal-performing "toxic" sites) through combined percent bias and NSE/KGE performances for available gauge data at RGB sites during a 20-year calibration period. The candidates were then further evaluated through performances in all available gauged sites across the domain, cutting the number of acceptable sets. We suggest that the resulting acceptable parameter set can be used in various assessments as part of further targeted model evaluation.

3.2 Hrachowitz

Why calibrate and average over time if we can directly estimate parameters and their temporal evolution from data?

Hrachowitz (Delft University of Technology, m.hrachowitz@tudelft.nl)

Vegetation is a first order control on the partitioning between evaporative fluxes and drainage in the critical zone. The root-systems of vegetation access water that is stored in the subsurface. This, in general, ensures sufficient water supply for vegetation to satisfy its transpiration demand. Changes in root systems as consequence of vegetation adaptation to a changing climate or anthropogenic disturbances such as deforestation, lead to changes in the subsurface pore volumes that are accessible to vegetation.

These changes in vegetation water supply partly regulate changes in transpiration. As transpiration is globally the largest water flux from terrestrial hydrological systems, changes therein can cause substantial shifts in the partitioning of water fluxes, which, in turn, has direct impact on other parts of the hydrological response, such as groundwater recharge or river flow.

However, the majority of current-generation hydrological and land-surface models used to predict floods and droughts in a world under environmental change, relies on the assumption that vegetation, its root-systems and the associated accessible subsurface water supply do not evolve over time. The consequence is that the parameters representing this quantity in models are kept constant over time, while in reality the system is highly adaptive across multiple temporal and spatial scales. This assumption of stationary model parameters in a non-stationary environment has the potential to cause uncertainties in the modeled hydrological system.

In a step towards temporally adaptive models we here explore the utility of a water-balance-based method to estimate the catchment-scale subsurface volume accessible to vegetation and its historical evolution over time and to directly use it as parameter in hydrological models. This has the potential advantage that the parameter keeps a certain level of temporal flexibility and is thus not averaged over time. As additional beneficial effect, the direct estimation of this parameter (or at least a very narrow prior thereof) reduces the calibration parameter hyperspace and may thus also lead to reduced uncertainty in the remaining model parameters

3.3 Le Coz et al.

Errors and uncertainties in streamflow data

Le Coz (INRAE, jerome.lecoz@inrae.fr), Renard, Darienzo, Horner, Branger & Lang.

River discharge, or streamflow, is arguably the most informative data in hydrology. As measurement results, streamflow data come with errors that have to be corrected (if they can be detected and quantified) or estimated as uncertainties (otherwise). Errors can appear at all the stages of the data production process from field measurements to data publication in hydrological archives. Best practices, standardisation and quality assurance/quality control are necessary to avoid, detect and correct such errors. In the past decades, international research effort has been dedicated to the development of uncertainty methods for streamgauging measurements and stage-discharge models (or rating curves) used to establish streamflow time series at most hydrometric stations. We present a Bayesian approach (BaRatin) to establish rating curves and streamflow time series with quantified uncertainties. Other tools have been proposed for detecting rating shifts, i.e. changes in the stage-discharge relation due to bed evolution or other processes. We also illustrate the impact of the limited sensitivity of low flow controls on streamflow uncertainties, which are probably even more challenging for droughts than for floods. Of course, it is important that data users review the quality of the streamflow data, take their uncertainties into account, and provide feedback to the data producer (even when large datasets are processed) for the improvement and update of the publicly available streamflow data.

3.4 Lerat et al.

Use of data assimilation to improve rainfall-runoff model structure for climate change projections

Lerat (CSIRO, Julien.Lerat@csiro.au), Chiew, Zheng, Robertson

Data assimilation is a powerful tool that has been used to correct states and parameters of rainfall-runoff models based on recent streamflow, remotely sensed soil moisture or groundwater data. Data assimilation is now routinely applied by forecasting centres around the world to improve simulations and increase forecast skill. In this work, we are less concerned with the direct benefits of data assimilation on model outputs, but more on the nature of the corrections introduced and how they can be analysed to diagnose structural deficiencies in rainfall-runoff models.

Rainfall-runoff models have been shown to lack extrapolation capacity in simulating dry and wet periods that are more extreme than calibration conditions. This is particularly concerning in the context of climate change studies where more climate extremes are generally predicted or expected. This is the case in south-eastern Australia where annual rainfall is projected to decrease under climate change. Consequently, the improvement of rainfall-runoff model structures to better simulate dry flow regimes is critical to obtain robust estimates of future water resources.

In this study, we assimilated streamflow data in the GR2M monthly rainfall-runoff models for 100 catchments in south-east Australia. The assimilation was conducted during a wet period between 1970 to 1995 and used to identify model structure deficiencies, particularly in the function computing water exchanges with nearby catchments. An attempt of correcting these deficiencies was undertaken using a simple regression approach. Finally, the correction was applied during a dry period (1995-2010) and performance was compared with the original (uncorrected) model. The results suggest that the corrected simulations better capture streamflow extremes, especially low runoff volumes. Further work is also discussed related to the use of additional data such as LAI and groundwater data to better constrain the correction regression.

3.5 Neri et al.

Use of transfer entropy between streamflow and forcing time series for the identification of dominant rainfall-runoff dynamics and for the assessment of hydrological similarity

Neri (University of Bologna, mattia.neri5@unibo.it), Coulibaly & Toth.

The identification of the most relevant catchment dynamics in the rainfall-runoff transformation process is paramount for the choice and parameterisation of a rainfall-runoff model. In particular, the assessment of similarity of the catchment behaviour at fine temporal scale is fundamental for the regionalisation of rainfall-runoff models, where the similarity should reflect the interaction between meteorological forcings and river streamflow time series. While previous hydrological research has identified basins with similar meteorological forcings (i.e. similarity of climate) or with similar streamflow time-series (i.e. similarity of runoff response), the present work proposes to quantify the interaction between the entire time-series of different forcing data and streamflow observations, to be considered as a novel hydrological signature and used as catchment similarity metrics.

This study proposes the use of a multi-variate entropy-based measure, the so-called transfer entropy, a quantity which analyses the interaction between different signals. The concept of transfer entropy is applied for identifying the dominant hydrological processes occurring in a catchment, measuring the directed transfer of information from different meteorological forcings over the basin to the corresponding streamflow time series at its outlet. The resulting transfer entropy values are then used as signatures to characterise the main catchment dynamics, and a classification of the basins in the study region (a large and densely gauged set of Austrian basins) is obtained assuming that similar values of transfer entropy identify similar basins.

The outcomes of the approach are promising and demonstrate the potential of transfer entropy: the method is able to distinguish the predominant or partial role of snow melt and evapotranspiration in the region, it helps to assess differences in catchment response time and to highlight the role of high orographic precipitation in snow-dominated catchments. Encouraged by such results, the novel classification approach is finally coupled to the application of a rainfall-runoff model regionalisation technique, and the results are evaluated against the use of a benchmark classification strategy based on typical streamflow signatures.

3.6 Orth & O

Efficiently exploiting the information content of in-situ soil moisture measurements with machine learning

Orth (Max Planck Institute for Biogeochemistry, rene.orth@bgc-jena.mpg.de) & O.

In-situ soil moisture measurements offer essential information on subsurface hydrological dynamics. However, their spatial and temporal coverage is scarce as their installation and maintenance are labor-intensive. Therefore, it is important to efficiently exploit the information content of these data through the application of suitable methods. Here, we employ machine learning in the form of a Long Short-Term Memory (LSTM) model to interpolate daily soil moisture dynamics across multiple depths in space and in time. We train the LSTM model with soil moisture from in-situ measurements and respective meteorological conditions from reanalysis data across climate regimes. The model is then able to estimate soil moisture globally by applying the established relationships with the reanalysis data. As a result, we derive the SoMo.ml dataset which provides multi-layer soil moisture data (0–10 cm, 10–30 cm, and 30–50 cm) at 0.25° spatial and daily temporal resolution over the period 2000–2019 (O and Orth 2021).

Further characterizing the potential of such machine learning approaches we find that they can efficiently determine the complex climate-hydrology interplay by learning simultaneously from spatial and temporal variability in the training data. However, they are not well suited to extrapolate beyond the range of conditions represented by the training data (O et al. 2020). In fact, physically-based land surface models are in a better position for e.g. future simulations or soil moisture analyses in climate regimes without sufficient in-situ soil moisture observations. Consequently, we should focus on both the exploration of the potential of novel machine learning based approaches as well as a continuous development of land surface models such that their performance can benefit from complete and accurate representations of relevant physical processes (Orth et al. 2015).

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3.7 Seibert et al.

Evaluating the value of crowd-based observations for hydrological modelling

Seibert (University of Zurich, jan.seibert@geo.uzh.ch), Schwarzenbach, Blanco, Scheller, Ze &van Meerveld

The CrowdWater project is a citizen science project in which we investigate how the public can be involved in the collection of hydrological data, such as streamlevels, soil moisture conditions and the presence of water in temporary streams. Another important part is to study what value the collected data have forhydrological forecasts. The project's long-term goal is to collect a large number of observations and thus improve the prediction of hydrological events, such as drought or flooding. We focus on evaluating the value of citizen science observations, which might be uncertain and spotty in time. More specifically, we discuss how synthetic and real data can be used to evaluate the potential value of the citizen science data.

3.8 Tallec et al.

Can quantitative hydrological models benefit from water quality measurements? Revisiting the baseflow separation issue

Tallec (INRAE, gaelle.tallec@inrae.fr), Tunqui Neira, Andréassian & Mouchel.

Hydrograph separation and the identification of the baseflow contribution to streamflow is an age-old topic (Boussinesq, 1904; Maillet, 1905; Horton, 1933; Beven, 1990) which, in hydrology, is “almost as universally decried as it is universally used” (Pelletier and Andréassian, 2020). Alternative methods exist to compute baseflow contribution to streamflow, based on different concepts, but there is no consensus on which method should be preferred…

Interesting results have been obtained with coupled methods, which combine the recursive digital filter (RDF) method, easy to implement and applicable over the long term, and the Mass Balance method which provides some information on the origin of water (Saraiva Okello et al., 2018; Stewart et al., 2007; Zhang et al., 2013). In almost all the above-mentioned studies, the electro-conductivity (EC) was the only chemical descriptor used, because it can be inexpensively measured concurrently with streamflow measurements.

We wish here to present a method to inform hydrograph separation with high-frequency chemical concentrations measurements. We try to calibrate the parameter of the recursive digital filter, via a mixing equation based on the concept of mass balance (MB), using a rather long series of high frequency chemical measurements on the Orgeval Research Catchment, which captures a wide range of hydrological conditions.

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3.9 Tian et al.

Can observed information be transferred from gauged to ungauged catchments?

Tian (Australian National University, siyuan.tian@anu.edu.au), Lerat, Renzullo & Pipunic

Understanding changes in streamflow is critical for water resources management and natural hazard mitigation. However, the sparse distribution hydrological stations, incomplete and inconsistent records limit the monitoring capability of streamflow over large areas. Hydrologic models play important role in forecasting streamflow and characterizing the spatial and temporal variability, but prone to several sources of uncertainties. The assimilation of gauged streamflow observations is a more direct way of improving short-term forecasts and provides a more automated and objective characterization of initial condition and uncertainty. However, spatio-temporal state updating in distributed models through streamflow data assimilation remains a challenge due to the large dimensional disparity between model state space and observation space.

This study explores the ability of a simple sequential data assimilation approach to use streamflow gauge measurements to impart spatial and temporal constraint on runoff prediction in a distributed operational landscape water balance model. The proposed method uses variance-covariance information derived from simulated climatology as a surrogate for model error, as a way of distributing constraint from gauge measurements spatially for grid cells within and surrounding gauged catchments. The proposed data assimilation method leads to a substantial improvement in performance and reliability compared to open-loop estimates of streamflow. We found that the proposed approach can improve streamflow estimates in ungauged catchments and the improvement can persist for more than a week and even longer for catchments with high mean annual runoff. This approach demonstrates the potential to improve streamflow simulation and flood forecasting for both gauged and ungauged catchments.

3.10 Andréassian et al.

On snow undercatch by raingages: looking for the missing information

Andréassian (INRAE, vazken.andreassian@inrae.fr), Gevorgyan, Misakyan & Azizyan

The hydrological analysis of high elevation catchments is often a nightmare, not only because precipitation measurements are scarce, but because even when there are precipitation measurements, the collected amounts are strongly biased due to the well-known effect of wind on snowflakes, resulting in a strong underestimation of precipitation.

Several formulations have been proposed to correct this wind-dependent underestimation of solid precipitation amounts. But parametrizing these formulas requires specific measurement setups (double-fenced shielded gages). At most locations, hydrologists have no way to guess the parameters of the correction relationship.

We suggest here to extract information from catchment-scale water balance studies. We base our analysis on several high-elevation catchments located in Armenia, with a precipitation gage network strongly impacted by snow undercatch.

3.11 Brigode et al.

On bad and good neighbors in a hydrological regionalization perspective

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The regionalization of hydrological information consists in transferring information available for a given gauged catchment to an ungauged one. It is one of the most difficult tasks expected from hydrologists. With a rainfall-runoff model, a common method consists in transferring the model parameters estimated on one or more catchment(s) that are close or considered similar to the studied ungauged catchment. During the last two decades, different criteria have been proposed for choosing the best neighboring catchments. Some of these studies have revealed the existence of “bad neighbors”, i.e. donor catchments inducing poor regionalization performance, while these donor catchments were considered close and/or similar to the ""recipient"" ones.

The objective of this communication is to develop a methodology to identify a posteriori bad donors and to understand why they behave so. Tests were carried out using a database of several hundred gauged catchments using GR4J rainfall-runoff model. The climatic, hydrological and geomorphological characteristics of the bad donors were classified and compared with those of the recipient ones, in order to try to predict hydrological dissimilarity. Finally, we estimate the performance improvement induced by the exclusion of a priori bad donor catchments in hydrological regionalization exercises.

3.12 Pechlivanidis & Musuuza

Customizing large-scale hydrological models for local applications: Is it a data information extraction challenge?

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The information content in the “traditional” data used in catchment modelling is not sufficient to diagnostically guide the parameter identification and improve process understanding in large-scale applications. The large spatial scales require many “unknown” features, e.g., lake extents, snowpack cover, reservoir regulations etc., that directly influence the hydrological response. Due to the large heterogeneity, the complexity of hydrological models and the limited data traditionally used, the current model identification practices in catchment modelling cannot accurately represent the physical processes and lead to a robust model for large-scale applications. Even when more sophisticated identification practices are applied, large-scale hydrological models are still over-tuned to capture the dominant processes and their spatiotemporal dynamics, and little attention is given to fluxes at the regional scale. To make large-scale models useful for local purposes, effort is needed to customize the models using local data from various sources and for various fluxes.

Here, we present a showcase for the Lake Hume catchment in Australia. We use the global World-Wide HYPE (WWH) hydrological model as a benchmark and quantify how much the model performance (hence process understanding) can be improved by fine-tuning the parameters through conditioning to local in-situ and earth observations (EO). WWH was setup using global datasets and with the objective to perform adequately over the entire globe, and show the information missed for application at this local scale; including mis-delineation and omission of reservoirs. In the local customization, the model was refined to include local lakes and managed reservoirs and recalibrated on local discharge measurements and the EO-based MODIS evapotranspiration (ET) data from NASA. The results show significant improvements for both discharge and actual and potential ET. Overall, we highlight the success of local customization of WWH through in-situ data and EO information extraction and use in model identification and setup.

3.13 Selles et al.

Critical approach on the trend analyses of groundwater levels time series: study case of Telangana state, India

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Groundwater fluctuation depending on space and time governs attention throughout the world for the purpose of sustainable management of water resources. Therefore, trend analysis is commonly used in treatment of groundwater level time series. Nevertheless, the spatial distribution and time period chosen can have a tremendous impact on the conclusion of trend analysis. This work intends to raise awareness about the strength but also the weakness of time series trends of groundwater level. This work uses the Telangana state in south India as a study case.

India is the biggest groundwater extractor in the world and has exceeded the total available water resources, which in turn have put a serious concern on food security. In Telangana state, according to the Groundwater board, district wise stage of groundwater extraction varies from 23 % to 94 % (State average: 65 %) (Excluding Hyderabad, the main city, where it is 340 %). Over the last 20 years, the state groundwater level shows a light declining trend of 0.8 m. However, this trend hides local and temporal disparities that cannot be neglected. Mann–Kendall and Sen's slope tests were accomplished on monthly groundwater level data from 2007 to 2020 over more than 1000 monitoring borewells to investigate the annual and seasonal groundwater-level trends. The trend information was mapped at Telangana state scale (110 000 km2) and made for different periods depending on climate conditions (very rainy year or at the opposite in drought condition). These results allow us to identify the impact of irrigation practises considering the hydrogeological setting and the resilient behaviour of groundwater users.

On a first hand, this work proposes to highlight the main misunderstanding conclusions that trend analysis could bring in this kind of groundwater system, and on another hand, to show the enhancement of knowledge that this technic allows. The results of trend analysis need to be adapted to the local context to raise alert and help the decision makers to improve groundwater management.

3.14 Royer-Gaspard

Do hydrological model errors spread across time and timescales?

Royer-Gaspard (INRAE, paul.royer-gaspard@inrae.fr)

From the point of view of a hydrological modeler, the perception of the hydrological content of a dataset is based on various aspects. Often, however, this perception is related to a simple question: does a model fail to reproduce the observation? Despite its obviousness, answering this question raises multiple issues that have to do with how model error are computed and aggregated. In particular, it has been shown that an important fraction of the total model error can be concentrated on only a few time steps or number of events, and thus strongly disturb model calibration (e.g. Berthet et al., 2010; Brigode et al., 2015). Blindly discarding these datapoints is certainly not a good idea, because their hydrological content can be high. An alternative is to screen model error on aggregated timescales, at the price of a loss of information.

We wish to study how model error at aggregated timescales relate to lower-timescale events. We use the daily GR4J model (Perrin et al., 2003) on a large set of French catchments. We analyze how model error spreads from daily to monthly and annual scales. We compare the distributions of model error computed on aggregated data and the distributions of aggregated model errors. We investigate the hydro-meteorological characteristics of episodes associated with timescale-crossing model errors.

Our study should help better inform the use of multiple timescales to evaluate hydrological models.

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