DSST for hydrological models

Research question:
Given the change projected by climate models, how capable are hydrological models to provide skillful hydrological simulations in a changing catchment? How suitable are their simulations to assess changes in the indicators used by climate services?

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).

Protocol
Differential Split Sampling Test for Hydrological models

Authors
Ernesto Pasten-Zapata, Paul Royer Garpard, Rafael Pimentel, Christiana Photiadou, Anthony Lemoine, María José Pérez, Torben O. Sonnenborg

Version date
February 2019

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).

Introduction

Projections of future changes in the availability of water resources are mainly based on the outputs of hydrological models driven by climate models. Therefore, it is important to evaluate the simulation skill of climate and hydrological models in the present to get an insight of their capability in simulating future conditions. Here, we focus in the evaluation of the hydrological models.

Traditionally, the simulation skill of hydrological models is assessed using a split sample approach. This approach divides a period of observations into two sub-segments of similar length, using one period for calibration and the remaining for validation. Selected model parameters are adjusted during the calibration with the objective of reaching an acceptable value of an objective function. Nevertheless, in a climate change context this approach might be inadequate because it assumes stationary conditions (Refsgaard et al., 2014; Li et al., 2012). A model with a good simulation skill over a period does not necessarily indicate that the model has a good skill to simulate changing catchments (Thirel et al., 2015).

Considering the above, one alternative is to evaluate the simulation skill of hydrological models in a changing climate context by using a Differential Split Sample Test (DSST) (Klemeš, 1986). A DSST uses historical periods of contrasting climate to calibrate and validate the hydrological model under non-stationary conditions found in the present (Refsgaard et al., 2014). The projections of climate models tend to indicate that in the future, current wet regions will get wetter and current dry regions will get drier (e.g. Arnell et al., 2013). These projections include scenarios that are outside the current available observations. Currently, DSST is one of the most appropriate methods to evaluate the simulation skill of hydrological models under changes in climate, using the available data (Thirel et al., 2015).

Although the DSST has been applied to hydrological models before (e.g. Broderick et al., 2016; Li et al., 2012; Thirel et al., 2015), these analyses evaluate the general simulation skill. Consequently, it is not clear whether models are skillful simulating metrics that are relevant for the users of water climate services, which are mostly interested on purpose-specific metrics for decision-making (Broderick et al., 2016).

In this paper, we evaluate the simulation skill of hydrological models in changing catchments using a DSST assessing different purpose-specific metrics that are relevant for decision-making in four study catchments across Europe. The approach assesses the simulation skill and usefulness of the hydrological models in a climate change context.

Methodology

DSST

We follow the normal DSST approach (Klemeš, 1986). The methodology applied in each site satisfies two key principles:

a) Identify periods in the present with contrasting conditions for a climate variable(s) of interest (e.g. precipitation, temperature, etc.)

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).

b) Application of the DSST. Considering for example precipitation, one dry period is used to calibrate the model and another dry period is used for validation. The transferability of the model to contrasting conditions is evaluated by assessing the simulation ability of the model during a wet period. This can also be done inversely.

Study cases

All three study sites focus on providing practical information for users of water climate services involved in decision-making. A short description of each case study is provided in the following paragraphs.

The climate change impacts on the foundation for agricultural production is assessed in the Skjern catchment on western Denmark. Focus is given to the soil wetness and groundwater levels. Changes in these variables affect the sowing as well as crop growth. For instance, waterlogged fields increase the drainage needs and dry conditions increase the irrigation needs. Therefore, both wet and dry periods and their impacts on the root zone moisture content, groundwater level and river discharge are relevant for the agricultural production within the catchment. Five different setups of the MIKE-SHE model are used to simulate the hydrological variables within the catchment.

The consequences of climate change on droughts and water resources allocation for tourism, agriculture and energy sectors is evaluated in the Guadalfeo River basin - one of the headwaters watershed in Sierra Nevada Mountain Range - southern Spain. The basin constitutes an example of alpine conditions in a semiarid area, due to its high submits and the proximity of the Mediterranean Sea, respectively. Different services coexists in the area: a small hydroelectric plant in the head of the mountains; an increasing tourism demand; small agricultural areas in the headwaters and big tropical crops farm located in the river mouth. Water availability is crucial for their development and all managerial decisions need to be taken in consequence. Historical trends show an extremely changeable pattern in annual precipitation with a tendency to the torrenciality, e.g. lower frequency of precipitation events but higher precipitation depth. Moreover, a significant increase in mean and maximum daily temperature without a clear pattern for the daily minimum is also observed (Pérez-Palazón et al., 2015). Four hydrological models are used to model the watershed: WiMMed (Watershed Integrated Model for Mediterranean Region), HYPE (Hydrological Prediction for the Environment), TETIS and SWAT (Soil and Water Assessment Tool).

The impacts of climate change on the hydrological cycle raises a growing concern among the water manager community, especially in the hydropower sector which may face a strong evolution of water resources. In France, where 12.4% (in 2018) of the electricity production come from hydropower plants, the sector is constrained by a high energetic demand in winter and touristic restrictions in summer. It must therefore prepare to face future conditions that might potentially be marked by higher seasonal contrasts, drastic rain events and a reduced snowpack. Two hydrological models (GR4J, GR6J) associated to a snow module (CemaNeige) are used to simulate the hydrology of the catchment.

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).

Work plan and schedule

		2018			2019												2020						
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Task	**Protocol**																						
1.1	Update protocol based on GA feedback																						
1.2	Gather initial study case data																						
1.3	Prepare the final protocol																						
	Simulation																						
2.1	Define the periods to use																						
2.2	Setting up the DSST										B												
2.3	Coupling climate and hydrological models																		C				
2.4	Analysis of the scenario results																						
	Dissemination and publication																						
3.1	Presentation at EGU - Splinter meeting							A															
3.2	Paper and report preparation																						
3.3	Paper and report submission																						

A – Splinter meeting at EGU General Assembly on the 10th of April, 2019

B – Milestone to be submitted: Short progress on DSST Hydro

C – Expert elicitation workshop planned to be held on March 2020

Description of the tasks.

1.1 Updated protocol based on feedback from the General Assembly

Develop an updated protocol based on the feedback from the Aquaclew General Assembly held in October. This will help solving any doubts arisen during the General Assembly that were not fully explained. This also serves to confirm that all partners understand the objectives and related task as well as background for the next steps of the DSST approach.

1.2 Gather initial study case data

Gather information from each case study about the hydrological models, available climate and hydrological observations, variable of interest, length of the periods to use and possible metrics to employ during the application of the DSST.

1.3 Preparation of the final protocol

The final protocol is the result of the feedback from the online meeting held with the working group (which involved discussing task 1.1) and the data gathered from each case study. It includes a more detailed description of the tasks as well as a schedule of the framework required to complete the activity on time. The protocol's background information and methodology are organized as a draft version of the introduction and methodology section of a paper. This is expected to be completed on by the end of January, 2019.

2.1 Define the periods to use for DSST

Each partner of the working group will define their own periods for validation, calibration and assessment of the transferability of the hydrological model. This will be based on the available observation database from each case study.

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).

2.2 Setting up the DSST

This relates to the main calibration, validation and transferability assessment of the hydrological models. It includes an analysis of the simulation skill in the present based on the NSE and KGE (also the RMSE for GEUS) as well as an analysis of the simulation biases of the purpose-specific metrics from each study case.

2.3 Coupling climate and hydrological models

Generation of the future scenarios based on the climate projections from the selected climate model ensemble. These will be generated by coupling the climate model ensemble with the calibrated hydrological models. It should be considered that some of the climate models might require from bias-correction, but this has to be agreed among the working group in order to use the same kind of models.

2.4 Analysis of the scenario results

Analysis of the projected changes for the purpose-specific metrics defined in each study case. The analysis will be done by comparing future periods (2041-2070 and 2071-2100) compared with the reference period (1981-2010). If we have some preliminary results available, we can present those at 2019 EGU's General Assembly. Nevertheless, each study case should have available results from at least three hydrological models before the expert elicitation workshop that is planned on March 2020. We should keep in mind that before that we have to submit a milestone on July 2019 about our progress.

3.1 Presentation at EGU's General Assembly

A presentation of the protocol is planned at EGU's General Assembly. The Splinter meeting is scheduled on. Initial findings must be available by then and a presentation prepared. We should be able to have a meeting at EGU to plan future steps.

3.2 Paper and report preparation

Preparation and edition of the paper to be submitted in a scientific journal as well as the final report of the DSST activity.

3.3 Paper and report submission

Paper submission as final result of the research to be submitted be July 2020.

Frequency of online meetings

At least one monthly meeting to report the progress from each case study and to help each other in case some difficulties arise.

Project AQUACLEW is part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).