APPLICATION OF SEASONAL FORECAST CLIMATE DATA FOR RESERVOIR OUTFLOWS IN THE DOURO BASIN, IN PORTUGAL

Babar MUJTABA[1], Paulo DIOGO[1], Pedro BEÇA [1], Sofia SIMÕES [2]

[1]*Mare-Nova Marine and Environmental Sciences Centre – FCT-NOVA and Dep. Of Envir. Sciences and Engineering, Faculty of Sciences and Technology, New University of Lisbon, 2829-516 Caparica, Portugal,*
[2] *Cense - Centre for Environmental and Sustainability Research Energy and Climate, NOVA School of Science and Technology - NOVA FCT and Laboratório Nacional de Energia e Geologia, I.P. 2720-999 Amadora, Portugal,* b.mujtaba@campus.fct.unl.pt.

ABSTRACT

Climate and meteorological conditions have a significant impact on energy demand. The project CLIM2POWER aims at developing a climate service (CS) including state-of-the art seasonal climate forecasts into the planning of the operation of the power production systems. This work presents part of the project, addressed at forecasting the production capacity of 13 hydropower plants in the Douro river basin. The seasonal (six months) climate data used in this project is produced by the German Climate Forecast System (GCFS 2.0), on a daily scale. Rainfall-runoff modelling using HEC-HMS was done on daily scale for Portuguese territory. For Spanish territory, flow scenarios were created based on observed data. Results show that outflows from Portuguese territory are highly dependent on the inflows from Spanish part of the basin but also that climate seasonal forecasting could be an added value for the management of hydropower production, although improvements are still required mainly on the climate forecast as results are yet subject to significant uncertainty. Ongoing work is focused on the identification and development of strategies for hydropower dam operation on the basis of seasonal climate forecast using hydrological modeling.

Keywords: Seasonal climate forecasting; Hydrological modelling; Reservoir outflows.

1. INTRODUCTION

Climate and weather conditions not only strongly influence energy demand but- with the strong development of the renewable energies - also increasingly electricity generation (Schaeffer et al. 2012). The changes of the European energy mix together with ongoing climate change raises several questions on the adaptation of the energy supply system to its environment. To address these issues, CLIM2POWER project aims to create a bridge between complex scientific model-based knowledge and targeted usable information for end-users by developing a web-based climate service, at a seasonal and long term timescale, to estimate how climate impacts hydro, wind and solar power operation, electricity demand and the whole power system. The web-service will connect climate data, hydrological models, renewable energy sources power simulation tools and energy system and electricity models in an interactive user-friendly layout to produce added value data on hydro, wind and solar resource availability, power demand changes and shifts of the entire power system to adapt to natural resource availability. These data are valuable to support decision-making of both private (e.g. Companies in the power market) and public end-users (e.g. power market regulators, and water & environment authorities), as well as market based water energy services providers.

The present study describes part of the CLIM2POWER project, addressing at forecasting the outflows from the hydropower dams (reservoirs) in the Portuguese Douro river basin. For that purpose seasonal daily precipitation forecasts for six months support hydrological modelling of the basin using HEC-HMS model (HEC, 2018). Although hydrological modelling procedure also includes Spanish territory, significant data limitations at this point determined, at present, the assumption of inflow scenarios from Span on the basis of historical measured flows. The resultant reservoir outflows were compared with observed outflows for the same time period.

2. METHODS

2.1. Study area

The Douro is the largest Iberian river basin (97,290 km^2) with 78,954 km^2 in Spain and 18,336 km^2 in Portugal (respectively 15.6% and 19.8% of each national territory), which corresponds to 17% of the Peninsular area. The Douro catchment represents around 50% of Portugal's hydropower production, there are in total 66 hydropower plants, of which 13 have an installed capacity above 15 MW. These 13 hydropower plants represent more than 90% of total installed capacity in the Portuguese Douro catchment. Out of these 13, five hydropower plants are located in tributary rivers (Fig. 1).

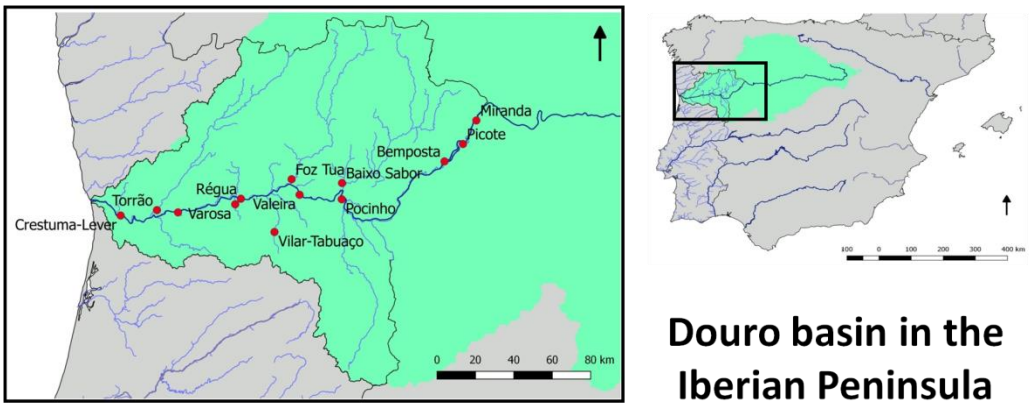

Figure 1 - Hydropower plants situated in the Portuguese Douro catchment.

2.2. Hydrological modelling and reservoir water balance

For the calibration of the HEC-HMS model daily flows of seven main tributary of the Douro river, in Portugal were assessed for the period of 13 years - 1988-2000. All the system was modeled as a reservoir in series system (cascade), according to Figure 2. For the purpose of establishing the main criteria for the operation of the hydropower plants, water balance was done under the assumption that the total volume of water entering each reservoir in each day will result in electricity production, i.e., inflow will be equal to outflow; reservoir storage is considered constant.

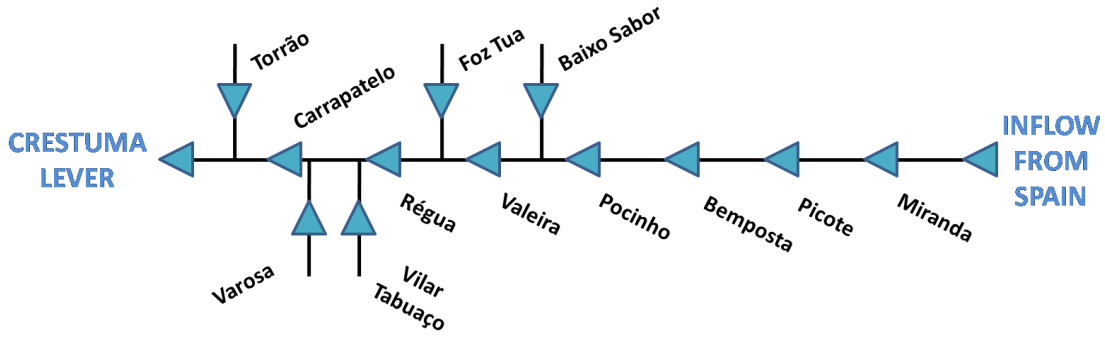

Figure 2. Reservoirs water balance in series modelling scheme.

2.3. Scenarios for seasonal forecast climate data

Seasonal daily climate data of six months (February – July 2019) was developed by German meteorological center (DWD) (CLIM2POWER partners) based on the German Climate Forecast System (GCFS 2.0)) (Baehr et al. 2015). The data is presented as a grid of 6 km^2 pixels for whole of Europe. Seasonal forecast climate data has 50 ensemble members i.e., data forecasted for same time period based on 50 different initial conditions. Accordingly, total precipitation in the Portuguese basin was obtained for each of these 50 ensemble members and three scenarios where defined based on the selection of three ensemble members which include values for minimum, average and maximum precipitation (for the case, 300 mm, 562 mm and 782 mm of six months precipitation). These scenarios where designated as DRY, AVERAGE and WET scenarios for Portugal. Daily hydrological modelling was implemented for the Portuguese watershed using the model HEC-HMS.

For the Spanish side, daily inflow data (14 years 2004-2017) from Miranda hydropower plant (reservoir that receives inflows from Spanish side) was used. First of all, daily inflow data was converted into monthly data and per hydrological year, i.e. from Oct-Sept. After that, the probability of occurrence of wet (2015/2016), average (2014/2015) and dry (2011/2012) years was estimated. These scenarios where identified as WET, AVERAGE and DRY scenarios for Spain. Three scenarios from each country resulted in a total of 9 arrangements.

3. RESULTS

Results herein presented are limited to the for Crestuma Lever hydropower dam, last downstream dam of the Douro basin (although results for all the dams are available. Observed and simulated total monthly outflows of six months for all nine arrangements are shown in figure 3. Three arrangements composed of maximum inflow from Spain (WET SPAIN) had the highest outflow in all the arrangements. With respect to observed outflow, minimum difference (5%) was found for the scenario DRY SPAIN DRY PORTUGAL and maximum was for WET SPAIN WET PORTUGAL (287%).Average monthly outflows of each month of observed and simulated nine arrangements are shown in figure 4. All nine arrangements outflows were closer to observed values in the months of June and July. Interestingly, these two months observed outflows were the lowest in all six months.

Our results reflect the fact that, outflow from Portuguese territory is highly dependent on the inflows from Spanish territory. Outflow prediction becomes better in dry months when influence of inflow from Spanish territory is minimized. However, further evaluation is needed using seasonal data of coming years. Hydrological modeling of Spanish territory is required in order to access the forecasting capability of seasonal climate data. The impact of reservoir operation procedures on reservoir outflows is to be studied.

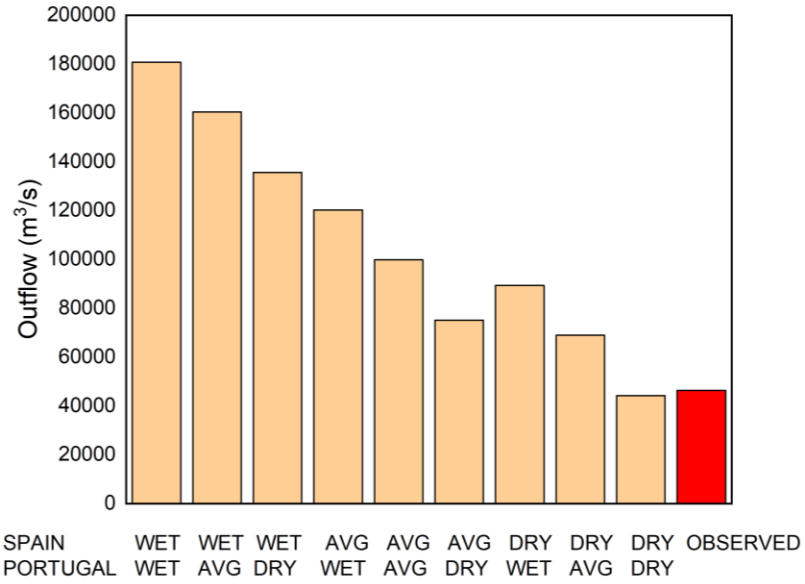

Figure 3. Observed and simulated total monthly outflows of six months for all nine arrangements at Crestuma Lever dam.

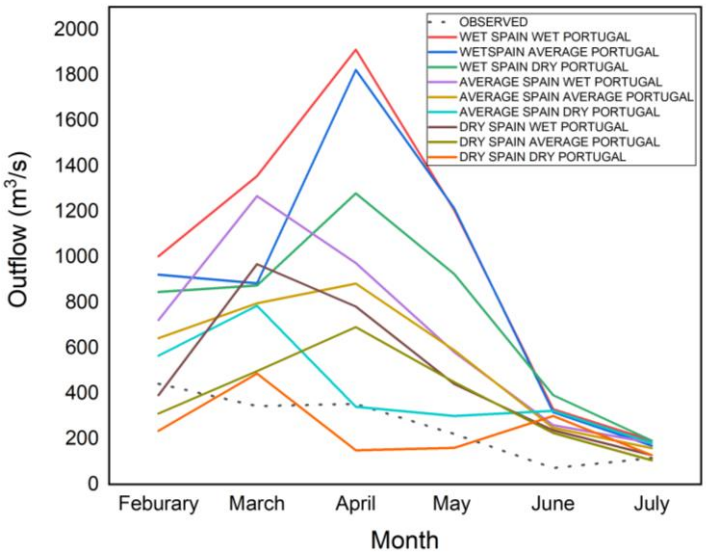

Figure 4. Observed and simulated monthly outflows for all nine arrangements at Crestuma Lever dam.

4. CONCLUSIONS

Seasonal climate data of six months was used for the prediction of outflows from 13 hydropower dams in the Douro basin, in Portugal. Results confirm that inflows from Spanish territory have strong influence on the outflows from Portuguese reservoirs but more important, the variations of flow obtained from the cascading of the models (climate, hydrological and water balance) are yet very significant.

Nevertheless seasonal forecast represent an important step to better anticipate available energy resources and therefore determine appropriate dam operation procedures which not only target more efficient energy production but also assure reservoir outflows in accordance with the goals of the water frame directive.

AGRADECIMENTOS

This research work was developed under the project CLIM2POWER, part of ERA4CS, an ERA-NET initiated by JPI Climate, and funded by the Portuguese Foundation for Science and Technology (ERA4CS/0002/2016), FORMAS (SE), DLR (DE), BMWFW (AT), EPA (IE), ANR (FR) with co-funding by the European Union (Grant 690462).

MARE, financiado pela FCT – Fundação para a ciência e Tecnologia, projecto estratégico UIDB/04292/2020.

CENSE, financiado pela FCT – Fundação para a ciência e Tecnologia, projecto estratégico UID/04085/2020.

REFERENCES

Baehr J, Fröhlich K, Botzet M, Domeisen DIV, Kornblueh L, Notz D, Piontek R, Pohlmann H, Tietsche S, Müller WA (2015). The prediction of surface temperature in the new seasonal prediction system based on the MPI-ESM coupled climate model, Climate Dynamics 44, 2723–2735. doi:10.1007/s00382-014-2399-7.

HEC – Hydrological Enginnering Center 2018. Hydrologic Modeling System HEC-HMS. User's manual. Version 4.3. US Army Corps of Engineers, Institute for Water Resources, Davis, USA.

Schaeffer R, Szklo AS, de Lucena AFP, Borba BSMC, Nogueira LPP, Fleming FP, Troccoli A, Harrison M, Boulahya MS (2012). Energy sector vulnerability to climate change: A review, Energy 38, 1–12. doi:http://dx.doi.org/10.1016/j.energy.2011.11.056.