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Added value of smart storage operations on an alpine run-off-river HPP obtain from hydrological-hydraulic modelling

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Framework

Run-off-river hydro projects can create sustainable energy minimizing impacts to the surrounding environment. Among many advantages of these systems, whose development has in fact been largely supported during the past years by the confederation, their main limitation is that their functioning is dependent by the available discharge, as they do not have storage. In order to overcome this constrain and enhance their flexible use, the Smart Storage Operations (SSO) are introduced (Figure 1c). SSO consist on using temporarily some existed underground structures of the power plant, such as the settling basin, for water storage. This water can be used afterward to produce peak energy timed with the demand. This is particularly useful since it allows water accumulation in periods of the year when the discharge is too low for energy production, therefore minimizing water losses.

The aim of this study was to create a hydrological-hydraulic model in order to reproduce the HPP operations (both under normal use - Figure 1b - and SSO - Figure 1d). The elaborated framework was applied at the hydropower plant KW Gletsch-Oberwald (Figure 1a) located at Valais (Switzerland) but it can be applied to others HPP in the Alpine region with dominant glacier cover, or areas with an intermittent river. A validation of the model was possible thanks to the measurements which were collected at the HPP during one week of site tests.

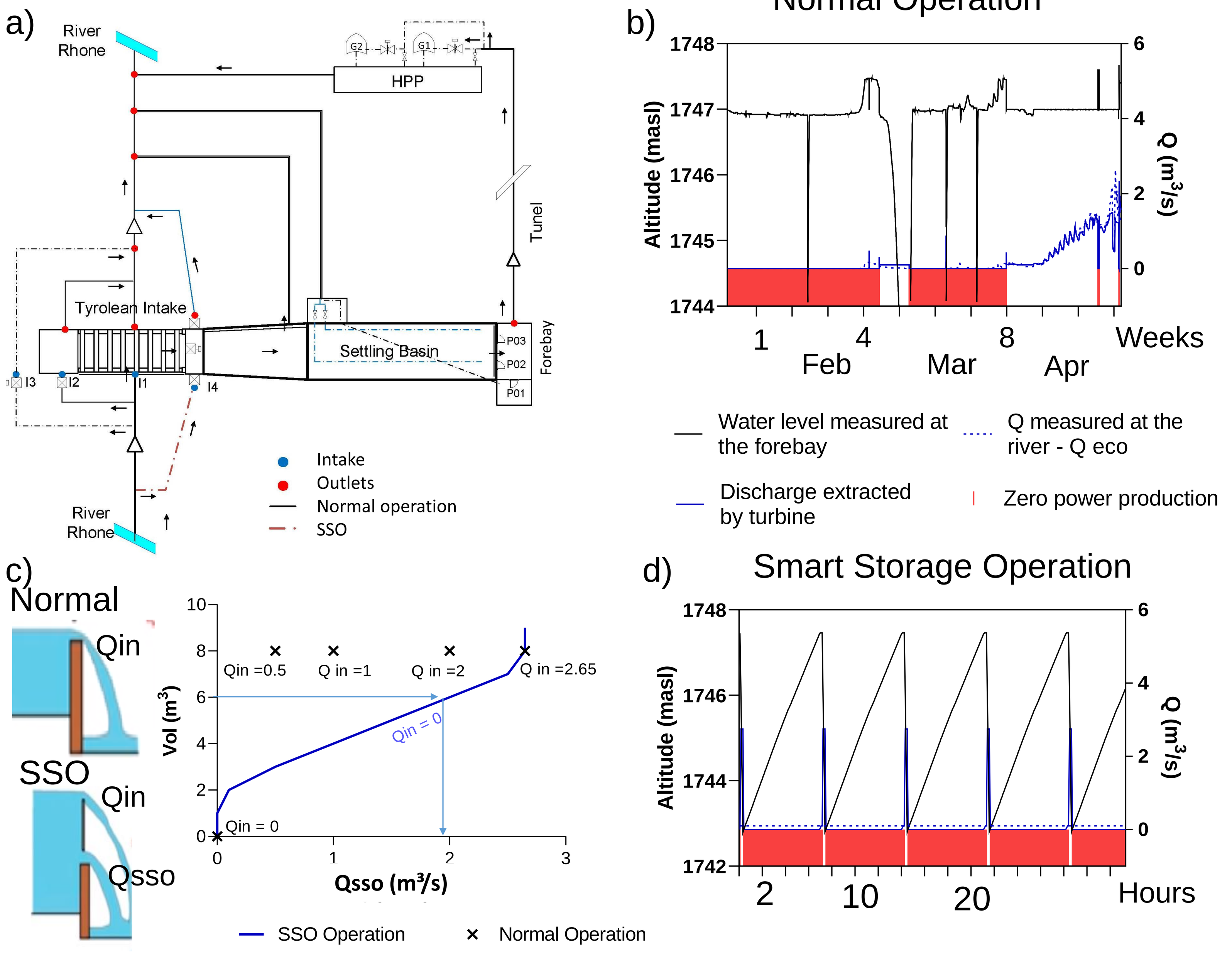

Figure 1: a) Schematic representation of the water infrastructure, and b) Measured water level at the forebay and turbine inflow during a normal operation at KW Gletsch-Obwerwald, c) Discharge and turbine inflow during the SSO operation, and d) Water level at the forebay and turbine inflow during a SSO.

Methods

RS Minerve was the computational selected tool. It allows to create a combined hydrologic and hydraulic model in a semi-distributed conceptual scheme. For the **hydrology model**, the snowmelt, glacier melt, snow accumulation and runoff process are reproduced by empirical models on daily base. The output was downscaled on an hourly basis, using climatic historical data of 28 years (Grimsel station). The **hydraulic model** was validated for normal operations and SSO using measured data.

These two models were joined to conform to a unique model. To evaluate the SSO, a yearly simulation was performed estimating the energy production and determining the economic revenues and the additional economic value of SSO with respect to normal operations.

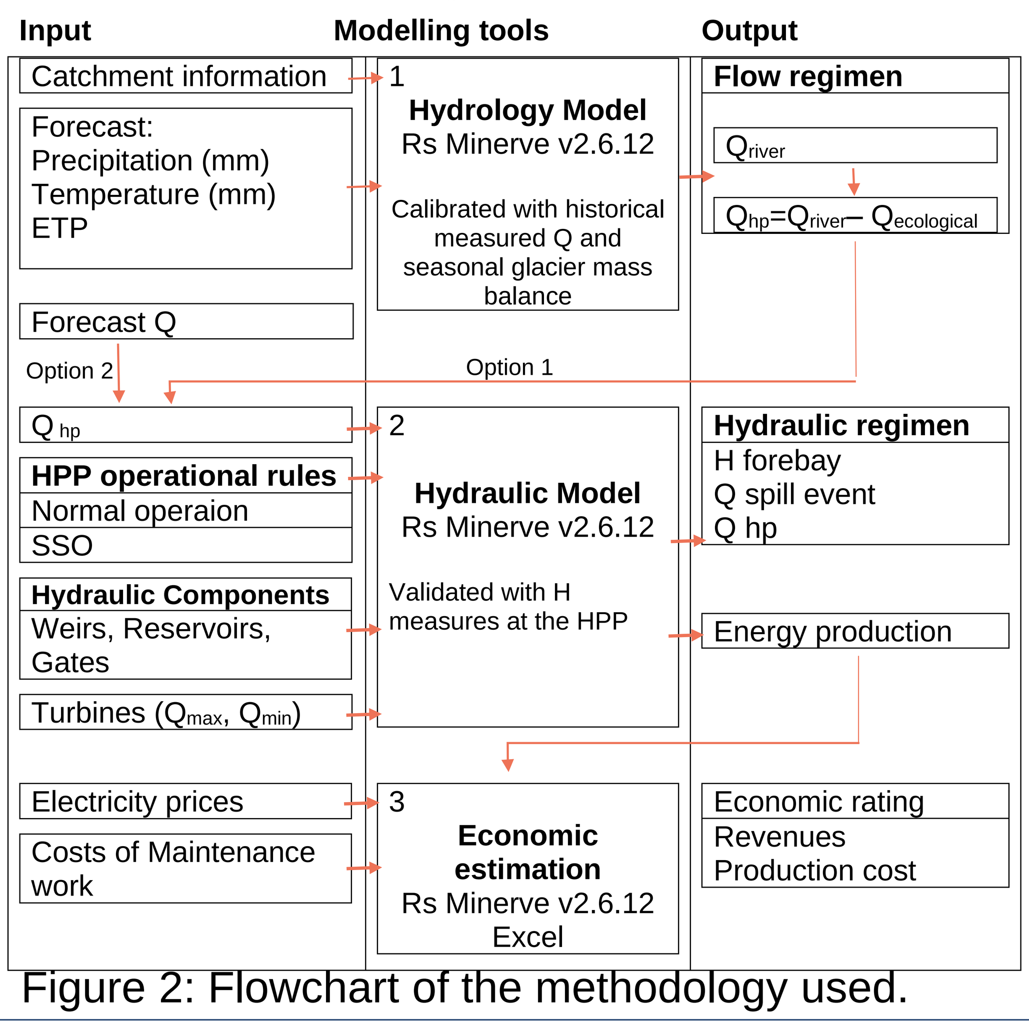

Figure 2: Flowchart of the methodology used.

Results and discussion

On this catchment of 39 km², the glacier (52% of the basin) and snowmelt have a direct influence in the hydrology. The final hourly calibration by the multi-objective function using 14 years (2005-2018) of measured discharge at Gletsch gave a performance indicator of Nash equal to 0.89 and a Relative Volume Bias of 1,1 e-3. The Figure 2b showed a good correspondence with the measured data.

The hydraulic model was validated with the measured water level inside the forebay tank, during normal operations, for winter 2017-2018 and the SSO for with the measurements collected during the site tests in November 2018. Both models showed a good correspondence with a Nash equal to 0.96 and 0.85 respectively.

With the validated simulations of the Normal and SSO, it was possible to reproduce in detail the SSO in a week of 2018 and for a complete year.

The simulation approach with the proposed framework proved an evident increment of power productions for the season with lower discharge (winter season), that goes from 50 to 100 %, depending on the inflow (when the inflow is less than the minimum discharge for one turbine, the HPP would need to switch off, therefore the gain goes up to 100%).

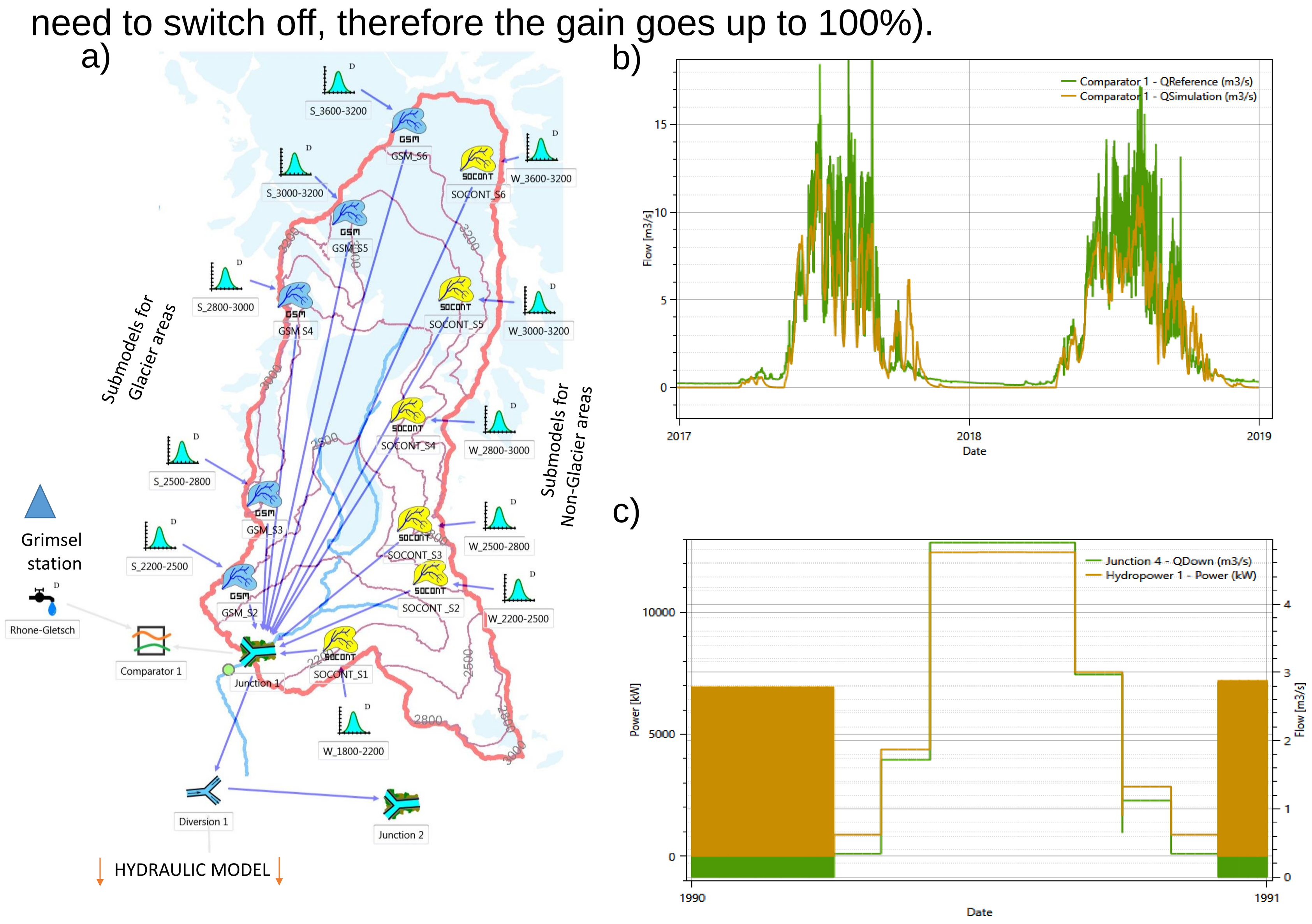

Figure 3: a) Schematic representation of the Gletsch catchment in the RS Minerve sotware, b) Observed and simulated discharge during 2017 and 2018, c) Power production simulated over one year using SSO operation.

Conclusion

- An integrated and numerically efficient hydrology-hydraulic model was developed in order to perform simulations of run-off-river HPP. The calibration of the hydrology model lead to the **accurate simulation** of the observations.
- The construction of a numerical model can easily reproduce different scenarios of energy production allowing for a good prediction of the HPP reaction for a certain inflow while adopting specific operational modes. It is therefore becoming a **relevant operational tool**.
- The **SSO benefit** was highlighted by comparing it with the power production resulted by normal operations. The simulations undertaken along a whole year have shown that the increment in power production during winter season doubles, reaching a gain of more than 700 MWh with respect to the adoption of normal operations.

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