HYPOS, an online decision support tool for sediment management in reservoirs

HYPOS, un outil d'aide à la décision en ligne pour la gestion des sédiments dans les réservoirs

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RÉSUMÉ

La suite HYdro-POwer (HYPOS) est à la tête de la prochaine génération d'outils de gestion des ressources en eau et des sédiments. Elle transforme la qualité de l'eau par satellite, la modélisation hydrologique et les mesures sur site en informations commerciales pertinentes pour l'industrie hydroélectrique, permettant une planification efficace des investissements environnementaux et économiques. Avec la sortie de cette première version, l'outil prend en charge la surveillance en temps quasi réel des sédiments et des paramètres hydrologiques dans les réservoirs et les systèmes fluviaux afin de faciliter les activités de gestion. Il permet à l'utilisateur d'effectuer ses propres calculs de flux de sédiments et de taux de sédimentation sur la base de données haute résolution et offre une analyse historique de base remontant au début des années 80, dans le monde entier. L'applicabilité de l'outil a été testée dans différents cas d'études pilotes en Europe et en Asie, notamment le barrage de Banja en Albanie, le barrage de Gebidem et Verbois en Suisse et la rivière Rioni et le barrage d'Enguri en Géorgie. Des données satellitaires et de modélisation opérationnelles assurent la surveillance du réservoir de Banja, entré en service en 2016. Le suivi en temps réel des flux sédimentaires de Verbois, Chancy-Pougny et Génissiat fournit un jeu de données complet pour évaluer les performances de HYPOS. L'outil est développé de la manière la plus flexible possible, la collecte des besoins des utilisateurs et les améliorations de l'outil étant effectuées par cycles, ce qui garantit une adaptation réussie aux flux de travail des parties prenantes de l'hydroélectricité.

ABSTRACT

The HYdro-POwer (HYPOS) suite leads the next generation of water and sediment **m**anagement tools. It transforms satellite water quality, hydrological modelling and on-site measurements into commercially relevant information for the hydropower industry, enabling effective environmental and economic investment planning. With the release of this first version, the tool supports near real-time monitoring of sediment and hydrological parameters in reservoirs and river systems to facilitate management activities. It allows the user to perform their own calculations of sediment fluxes and sedimentation rates based on high-resolution data and provides a basic historical analysis dating back to the early 1980s, worldwide. The applicability of the tool has been tested in various pilot studies in Europe and Asia, including the Banja dam in Albania, the Gebidem and Verbois dam in Switzerland and the Rioni River and Enguri dam in Georgia. Satellite and operational modelling data are used to monitor the Banja reservoir, which came into operation in 2016. Real-time monitoring of sediment flows from Verbois, Chancy-Pougny and Génissiat provides a comprehensive dataset to evaluate HYPOS performance. The tool is developed in the most flexible way possible, with user requirements being collected and tool improvements being made in cycles, ensuring successful adaptation to the workflows of hydropower stakeholders.

KEYWORDS

Hydropower production, Optimization, Reservoirs, Satellite data, Sediment management

1 BACKGROUND

Water quality products obtained through the analysis of Earth Observation (EO) and combined with hydrological modelling and in situ data can provide essential knowledge for a more sustainable business for the hydropower industry. The HYPOS consortium has developed an online accessible tool for the hydropower industry to enable environmental and economic investment planning and monitoring based on EO technologies and modelling and complemented by available on-site information.

2 HYPOS TOOL SET

The HYPOS tool includes three main modules: Ingestion, Visualization and Analysis, supporting a number of functionalities to analyse and calculate data relevant to hydrological studies in the hydropower sector. It includes for example the Ingestion of the worldwide SMHI hype model data to include river discharge data, precipitation, specific runoff and other variables. For the pilot areas, the backend ingests SMHI hype model data to the system every day and are immediately visualized in the portal.

Another important functionality is the calculation of sediment fluxes, representing the amount of sediments in the river. For the calculation in the HYPOS tool, Total Suspended Matter (TSM in g/m³) is multiplied with the amount of water that is flowing in the river, the river discharge available from the modelled data sets. The basic satellite derived turbidity products in Nephelometric Turbidity Unit (NTU) need to be calibrated to TSM, either through an existing formula or by conducting a calibration directly on the portal. The output correlation plot provides guidance of the quality of the correlation curve, enabling the user to further adapt to receive a better fit. The schema of the described sediment flux calculation is given in Figure 1.

As soon as the sediment flux is calculated for e.g. the in- and outlet of the reservoir, users can directly derive the sediment yield, and the related sediment management costs. The cost-relation for the sediment management (e.g. yearly flushing or dredging) has to be provided by the user, otherwise present values can be used for first cost estimates.

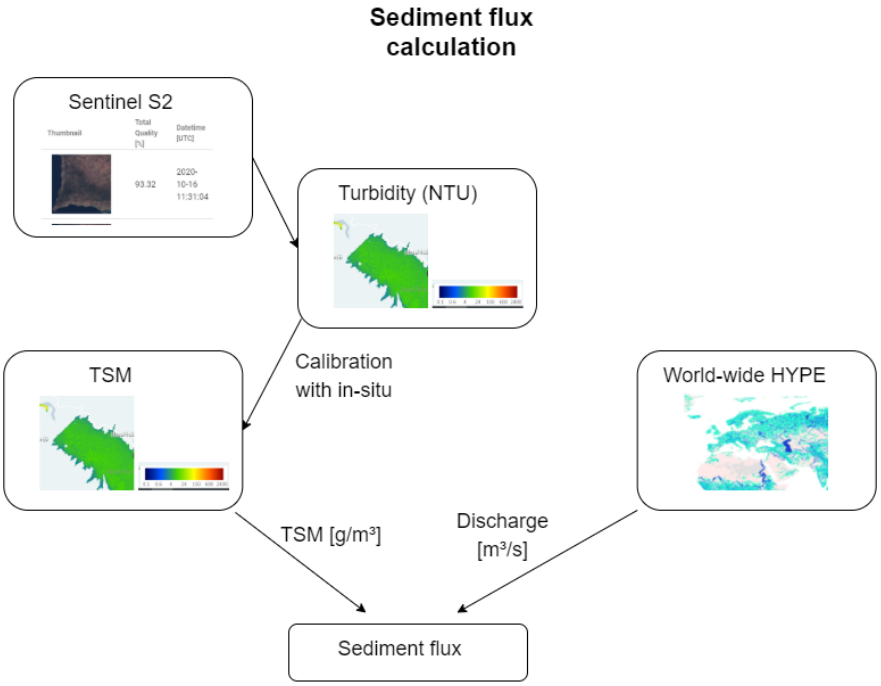

Figure 1. Schema of Sediment Flux Calculation

3 USE CASES OF WEB BASED SEDIMENT ANALYSIS

3.1 Sediment dynamics in new reservoir Banja, Albania

The Devoll project in Albania consists of two power plants, Banja and Moglicë. Banja hydropower plant is located in Cërrik Municipality in Elbasan County, 65 km southeast of Albania's capital Tirana. The power plant was officially opened in September 2016. Moglicë – located further upstream – opened in 2019. In total, the two plants have an annual production of around 700 GWh, which represents a 17% increase in Albania's total energy production. At the end of 2015 a sediment transport measurement research station has been installed to monitor the suspended load concentration (SSC) every 30 min. The station is logging continuously since January 2016 in periods where the river Devoll has a water depth of more than 1 m at Kokel bridge. The SSC data is used to calibrate the turbidity recorded in the Banja reservoir in order to ensure good data quality.

By processing archived satellite imagery from 2016 onwards, as well as conducting an operational monitoring of new acquisitions, the commissioning of the two power plants could be tracked from space. Additionally, the sediment dynamics in the two reservoirs and in the Devoll river are observed. Combining the spatial dimension with the temporal dimension proves a very effective mean to observe changes in the reservoir. Figure 2 shows the HYPOS portal with a timeseries overlay. This timeseries was extracted for the polygon at the shown location. The turbidity in the high-flow season in 2018 and 2019 peak at around 30 NTU for this location, however in early 2020, this peak is missing, barely reaching to 10 NTU. The commission of the Moglicë reservoir may be partly responsible for this missing peak, this must however be further investigated.

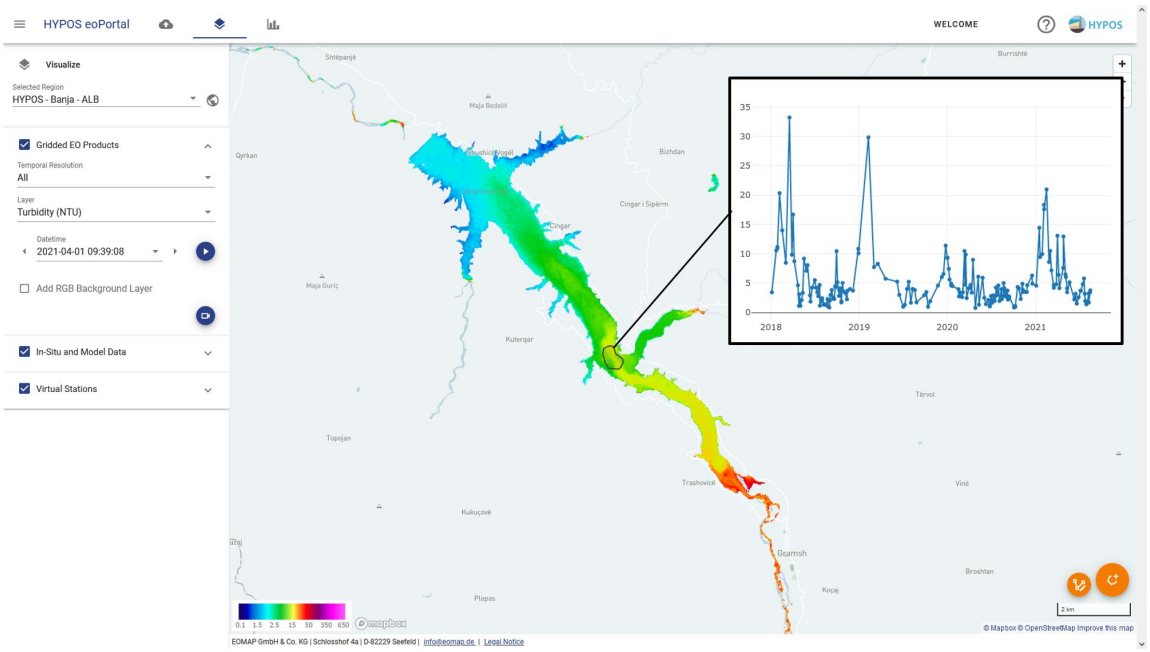

Figure 2.Timeseries extraction over polygon in Banja reservoir

When increasing the number of sampling locations from one to multiple in different areas of the reservoir, the calculation of the sedimentation fluxes and rate are the next steps in the development. After calibrating satellite-derived turbidity with the available in situ data, the sedimentation rate can be generated by comparing the values at the beginning of the reservoir to the area near the dam. As can be seen from the image shown above, the turbidity values greatly differ in their spatial distribution. In low-flow periods, the turbidity values over the entire reservoir do not differ as much, therefore hinting at different sedimentation rates throughout the year.

3.2 NRT monitoring of flushing activities Verbois, Switzerland

The Verbois and Chancy Pougny hydropower plants are 2 run-of-river power plant in a cascade on the Rhone river close to Geneva, Switzerland. Built in 1938 and 1925, with current installed capacities of 100 MW and 49 MW respectively they essentially provide 15% of the consumption of the Canton of Geneva which is approximately 700 GWh per year. Both Chancy Pougny and the Verbois power

plants are located just downstream of the confluence of the Arve and Rhone Rivers. The Arve River has a very high sediment content while the Rhone River running from Lake Geneva are clear of sediments. The accumulation of sediments within the Verbois reservoir results in risk of flood for the lowest quarters of Geneva. Flushing operations are conducted regularly to evacuate the sediment through the Verbois dam. The organization of such operations must be conducted with great care and cooperation between the Swiss and French counterparties as the sediments flushed through Verbois tend to accumulate in the Chancy-Pougny and Génissiat dam located downstream.

In 2021, flushing has been conducted in May and high concentrations were recorded downstream from 19th to 29th May. Satellite images recorded from Sentinel-2 in 10m spatial resolution followed the operations, providing details about both the water extent and the turbidity in the flushed areas from Verbois down to Génissiat. The turbidity levels during the operation shown in the results from the 27.05.2021 are compared with the day after finishing the operation on the 29.05.2021 (Figure 3). The data is made accessible through the easily accessible online HYPOS tool, supporting the managers with latest information within a few hours from recording.

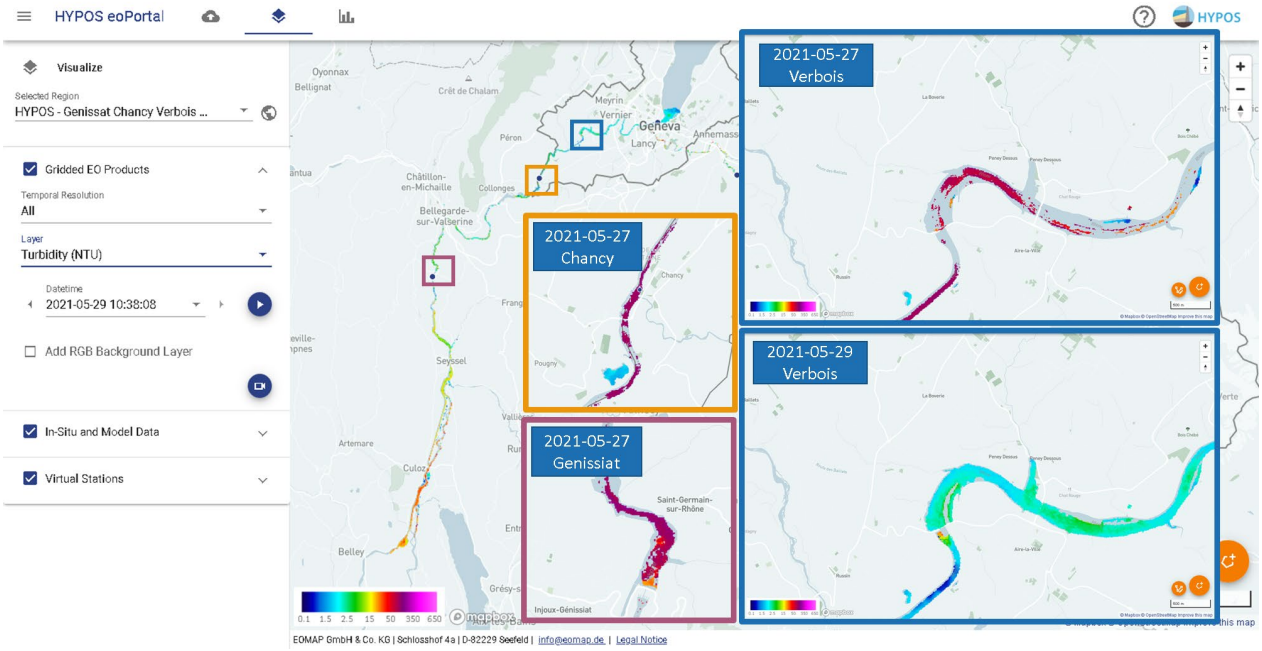

Figure 3. Online Visualization of flushing event in Verbois, Switzerland

4 CONCLUSION AND OUTLOOK

In the next development stage, the focus will on additional decision support analysis such as the deduction of potential energy losses and related monetary effects. The latter can be e.g. extracted from the implemented calculation of sediment rates by estimating the potential lifetime before dam filling. Also, based on the calculated sediment fluxes and rates the frequency of required flushing events can be proposed, a position with high cost on human and technical resources for the hydropower operators.

A forecast calculation of available satellite data sets for the different discharge and flux periods would be of high benefit both for estimating the quality of the output decision support products and also give an estimation of associated costs for e.g. generating new satellite products.

Moreover, together with the consortium partners, methodological refinements of the sedimentation flux calculation based on definition of high and low flood periods have been already identified for the next development cycle.

BIBLIOGRAPHIE (3 MAXIMUM)

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