Multi-source data (satellite, in-situ, modelling) for hydropower planning and sediment management: The HYPOS decision support tool

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Intro

Easy access and targeted analysis on data such as sediment concentrations and hydrological parameters are essential for hydropower managers. Information on the sediment regime, sediment sources and sinks in the river network and basin are key to estimate major operation costs and investment risks. However, such information is usually rare in the planning phase of hydropower installations. The HYPOS online portal provides such information - to lower project risks with actual data – even data one couldn't get thinking just about traditional measurements. It provides direct online access to satellite-based water quality data worldwide, hydrological modelled data and in-situ data. Here, we will showcase and discuss the capabilities of the online system in the frame of concrete hydropower projects in Switzerland, Georgia, and Albania.

1. Background

The economic and ecological evaluation of new hydropower developments relies on several environmental parameters. Particularly, the major drivers of the reservoir storage capacity over time, reservoir lifetime (and related re-investment time), and operations costs are directly related to the sediment regime and sediment trapping and defined by the environmental conditions.
However, a typical situation at pre-planning stage is the absence of such data, especially when the river system planning and the hydropower facilities are part of a regional development. This introduces major risks for the sustainability of development plans.
Easy, remote and cost-effective access to suitable data and supportive analysis tools can therefore be a crucial element to estimate realistic investments risks or better operate dams – through solid decisions based on actual data.

1.1 HYPOS online portal

We designed the HYPOS portal (hypos.eoportal.eu) as an online application, which brings together high-quality historical and near-real time satellite-based observations with in-situ data and hydrologic models. Through easy-to-use online analytical and visualization functionalities, the portal can support integrated baseline environmental impact assessments, operational monitoring, and improved understanding of sedimentation regimes.
Access to satellite-based water-quality data is implemented, covering the best available data products in high spatial and temporal resolution for dams and rivers in headwater and downstream catchments. Hydrological data from global and customized local models can be connected via REST API, while in-situ project data can easily be uploaded.

The backend of the system includes a performant data base system to host the required data, user and data access management, interfaces to the eoLytics API for fully automated satellite data processing on request, which is again connected to satellite data archives (currently to access 35 years of data from Sentinel-2, Sentinel 3 and Landsat 5/7/8). Measurements based on other satellite sensors such as MODIS (500m resolution), Worldview-2/3 (2m resolution) or Planet Labs (2-5m resolution) are available on request.
The user-controllable data sources, the major functionalities of the portal and use-cases are presented in the following sections.

2. Data sources

2.1 Satellite based measurements

Due to the enormous increase of various multispectral satellite sensors, the basis for space-based in-water measurements with daily sampling rates and high spatial resolution is improving year by year. Landsat satellites have been monitoring the earth with 30m resolution since 1984. Sentinel-2 satellites with 10m spatial resolution were launched in 2015 and 2017, and more than 100 small satellites are being launched over the next few years, delivering 1 – 4m resolution from various providers at increasing data quality.

The raw data quality and the analysation capability of the algorithms is key important to generate valid information products on water constituents. Data on turbidity, chlorophyll, cyanobacteria blooms and further optical properties such as dissolved organic matter can be derived operationally nowadays by using different satellites with up to 10m resolution. Moreover, higher-resolved satellites provide radiometrically acceptable imagery, allowing also the provision of approximate turbidity quantitatively.

Just like data quality assurance processes and data consistency is relevant in all water-related applications, satellite-based data provided through the HYPOS portal are generated by the leading fully physics-based data analytics of the MIP processor [1]. This ensures long-term data consistency when different satellite generations are used, and provision of satellite-based data independent of in-situ data: Further calibration is not required for data products such as turbidity, which can be linear related to inherent optical scattering and absorption properties. Various studies investigated the increasing validity of products [2,3,4] and global applicability [5]. By now, water agencies [3] and environmental consultancies [6,8] are using these products in their daily business also in inland water applications.

2.2 Hydrological models

Two global and continental hydrological models, named WW-HYPE and E-HYPE respectively, already provide historic and near-real-time data, including discharge for major rivers and surface waters in catchment areas on a daily scale. Data can be subscribed and feeded via API into online applications

The use of custom hydrological models is available when intraday (hourly) time step data is required. The data will then be provided via APIs in the online application.

2.4 In-situ measurements

In-situ data are of high value for any project development, and can include many sampled data that cannot be collected otherwise, such as suspended matter dry weight, grain size distribution or material / mineral composition. However, these data are the most labour- and cost-intensive of all data sources and they are hence usually sparsely and temporally restricted and only available for few local points. Therefore one major advantage to bring the three different data types together, is the spatio-temporal expansion of parameters through the spatially resolved satellite-based or model products. In-situ data will be very important in order to calibrate the model and to validate the products obtained.

3. Data access and visualization

The HYPOS portal, accessible at hypos.eoportal.eu, contains three major functionalities:

- **Ingestion**

  This functionality supports the upload of data, REST-API’s to assimilate external online data, and the on-demand generation of satellite-based products. Data are stored as part of the backend in the portals virtual data base (HvDB). The HvDB is realized as rasdaman data base, as this enables fast access and performant on-the-fly data operations, such as spatio-temporal aggregation of the gridded satellite data products.

- **Visualization**

  The visualization section supports most convenient and intuitive functionalities to: Search, limit, localize, select, combine and visualize various data. E.g., in-situ data can be directly combined and visualized jointly with satellite data time series. Gridded data may be aggregated spatially / temporally to define and store customized data into the Ingestion section, such as seasonal data, transect data or spatially expanded virtual stations, representative for larger river or reservoir sections.

- **Analysis and reporting**

  The analysis and computation of new data, and the addition of these products to the customized HvDB

  Data evaluation, setup of automated monitoring and reporting functionalities

The design of the visualization section was undertaken within different development cycles and now supports the major functionalities to access, visualize and assimilate data as shown at the actual pilot platform:

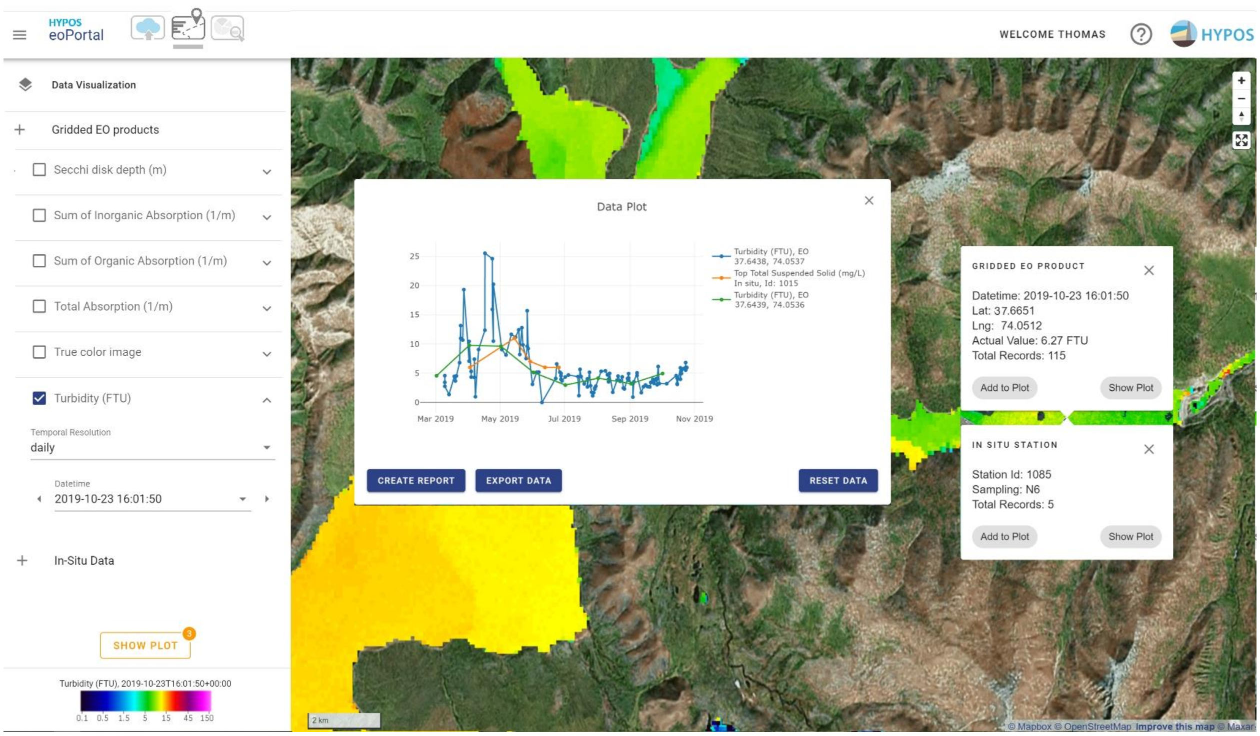

Figure 1. HYPOS portal for visualization and analysis supporting hydropower planning and management

4. Applications and Use cases

Applications based on satellite-based sediment and turbidity concentrations are already available to estimate the sediment trapping in reservoirs in Brazil [6] or reducing economic risks in hydropower developments through measurements within the country-wide river network of Georgia [7]. The business model and service integration of HYPOS is showcased for a set of hydropower applications in Switzerland, Georgia and Albania, through a close collaboration with the operators. It further provides support for the monitoring of sedimentation levels, both upstream and downstream of the reservoirs and river sections, and supplies data for flushing events in high spatial and temporal resolution.

With the analysis of historic satellite datasets of the Copernicus mission data from Sentinel-2A/B or USGS missions of Landsat 5,7 and 8, baselines of water quality parameters such as turbidity, chlorophyll-a or water temperature are calculated. Figure 2 shows an example of monthly means for Banja reservoir (Albania) in 2019 along a given transect.

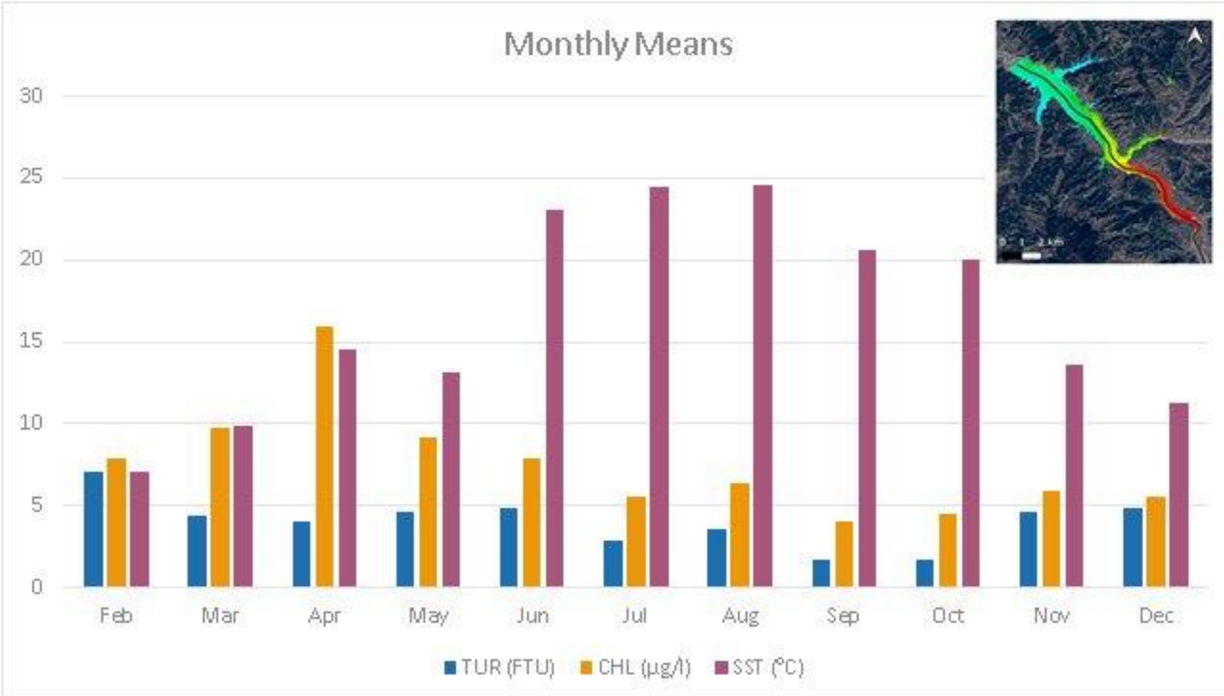

Figure 2. Monthly means of selected water quality parameters turbidity (TUR), chlorophyll-a (CHL) and water surface temperature (SST) in Banja from 2019, calculated from Landsat 8/USGS (EOMAP water quality products)

Figure 2 highlights the seasonal variability of observed environmental parameters, with the highest turbidity values recorded in the winter and spring months, and lower values seen across the summer months. Chlorophyll-a has its peak in April and water surface temperature is highest in the summer months.

Maps generated using high-resolution Sentinel-2 data in 10m pixel resolution from 2016 to 2019 clearly show the difference in water extent and water quality, specifically regarding turbidity range, over the years since the official commissioning in 2016 (see Figure 3).

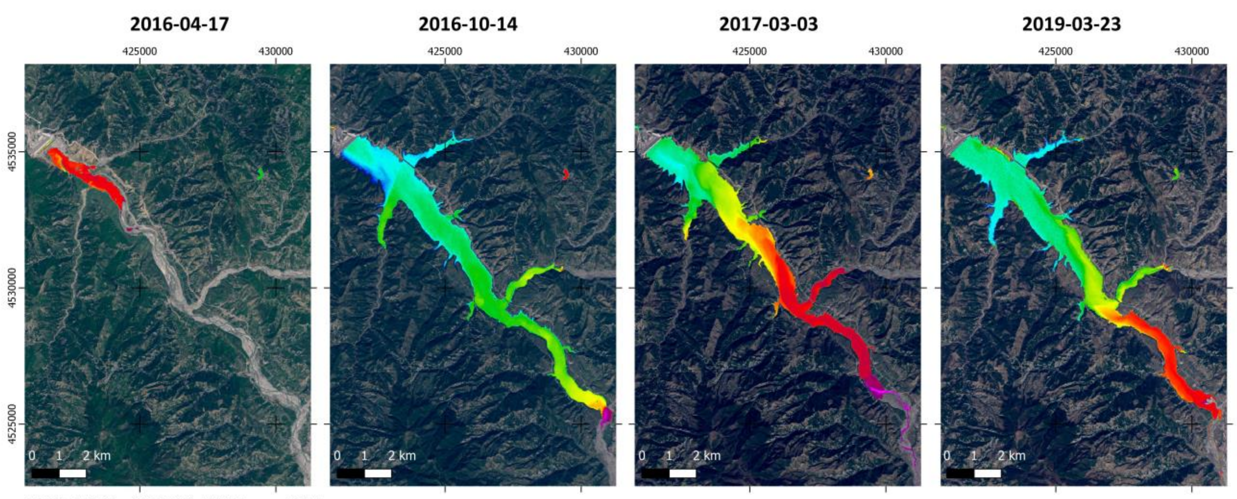

Figure. 3: Turbidity maps from 2016 to 2019 of the Banja Reservoir, Albania (© eoLytics EOMAP)

Furthermore, based on the analysis of transects across reservoir or river sections, sedimentation flows and sediment loads are estimated, for instance to be used for planning in commissioning of hydropower plants. An example from Gebidem dam in Switzerland is given in Figure 4, highlighting the seasonal changes in turbidity in a North-to-South transect, with values below 40 FTU in fall and above 100 FTU in summer after snow melt, as calculated from Sentinel-2 data in 10m resolution.

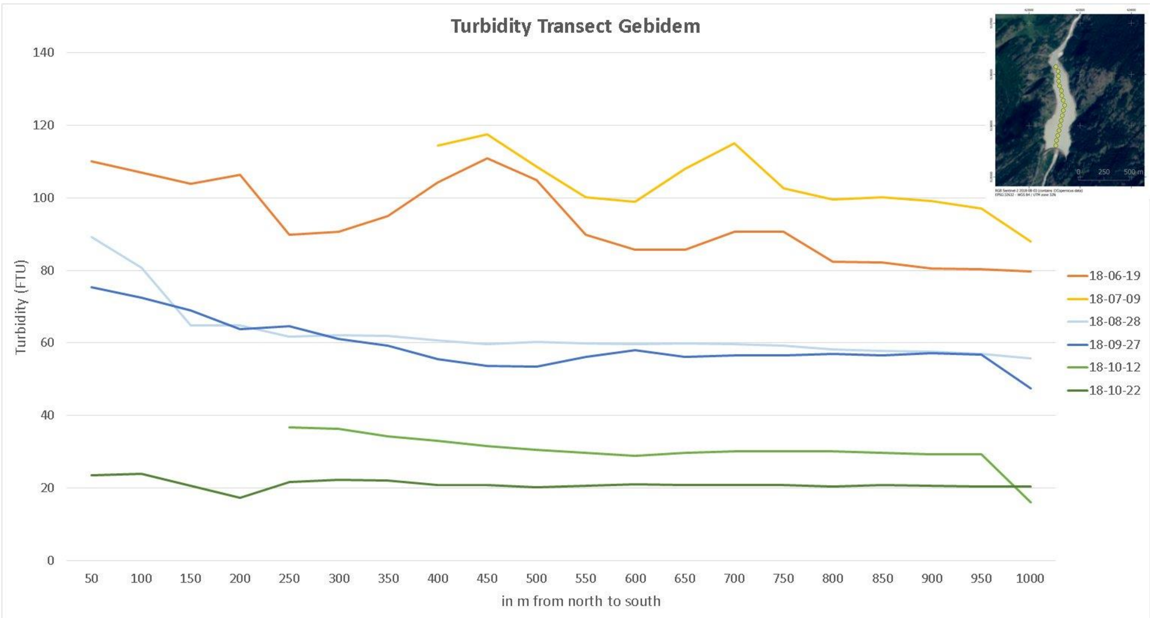

Fig. 4. Turbidity Transect Gebidem Dam Switzerland in 2018, processing: ©EOMAP-MIP, Sentinel-2 data © Copernicus

To ensure that the HYPOS services meet the requirements of a wide set of hydropower stakeholders, several dedicated activities are planned during the upcoming phases of the project. Moreover, the different integration examples will be demonstrated to customers in specific workshops and trainings on an international level.

5. Conclusion

We expect that hydropower projects in many locations worldwide can profit from the business design of the new tool. In summary we highlight:

- Gain in data and knowledge for hydropower related clients and projects, inter alia through data that otherwise would not be available such as EO based information products, and accordingly economic, ecologic and safety advances for clients.
- Benefit in user-friendliness to access, combine and analyse the various data sources, e.g. through an integrated online portal, the core of the DST: The HYPOS portal.
- Adaptability to project requirements and business preferences of the business partners through a modular offering with modular online interfaces, such as to subscribe to the required tools within the HYPOS portal; integrate REST-API's to access satellite products or the global hydrological SMHI-model data; add regional high-resolution forecasts from the Stucky model exclusively to dedicated projects.
- Gain in economic affordability and business scalability through a maximum of automation level of underlying online services, optimum of user-defined adaptation to automated processes, scalability of accounts and processing capabilities through the underlying cloud-based system, plus modularity and flexibility as described in the previous item.

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Dr. Thomas Heege graduated as Physicist and received the PhD in space sciences and environmental physics. He is managing director of EOMAP and has 25 years experience in aquatic remote sensing and environmental consultancy for offshore and water industries around the globe. Prior to founding the EOMAP in 2006, he has worked as a scientist and project manager at the German Aerospace Centre DLR (since 1996) and several limnological research institutes (since 1993).

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As Stucky Senior Project manager and Head of the Hydropower Schemes Department, he has been working on conception, design, technical-economic analysis and construction of different parts of a hydropower scheme (hydraulic structures, dams, etc.). Dr Marcelo has been involved in complex water resources studies, including hydraulic, hydrology and sediment transport analysis for a couple of years.

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