Water Resource Management from Space

Satellite-based water monitoring solutions

Optimize your current and future hydropower projects – get faster data at lower cost and with less risk.

HYPOS is a game changer for hydropower planning and operation

HYPOS is a new online solution that builds on satellite technology. It creates important knowledge gain and decision support by combining space based information with in situ and modelling data. Hydropower managers and dam designers can count on standardized and consistent information on reservoirs or entire river catchments. The toolbox covers key parameters for planning or monitoring. HYPOS thus helps hydropower stakeholders to overcome the challenges posed by sedimentation an important step to sustainable hydropower management worldwide.

Benefits

Enjoy an overview
Vizualize sediment baselines and seasonal trends with near-real time data in a few mouse clicks – globally

Fill data gaps
Quantify sedimentation rates or flows at the scale of the whole river catchment, complement and validate in-situ data

Plan ahead
Monitor or model hydrological and sediment dynamics for operational planning and smart design of release structures

Assess and reduce impacts
Perform environmental monitoring from the very start of the planning process, during operations or in case of algae blooms

HYPOS provides

Operational Monitoring of reservoirs and river systems
EO-based monitoring of basic water quality parameter on a regular basis delivered as online accessible maps and time series

Near real time hydrological and sediment states
Up to date reporting on flows and sediment concentrations provide important information to managers in their daily operational decisions

Near real time monitoring of sediment management activities
Special targeted data gathering with VHR satellites will help to analyze fast dynamics of single events

Baseline environmental information based on historical data
Water quality and sediment data for catchment analysis

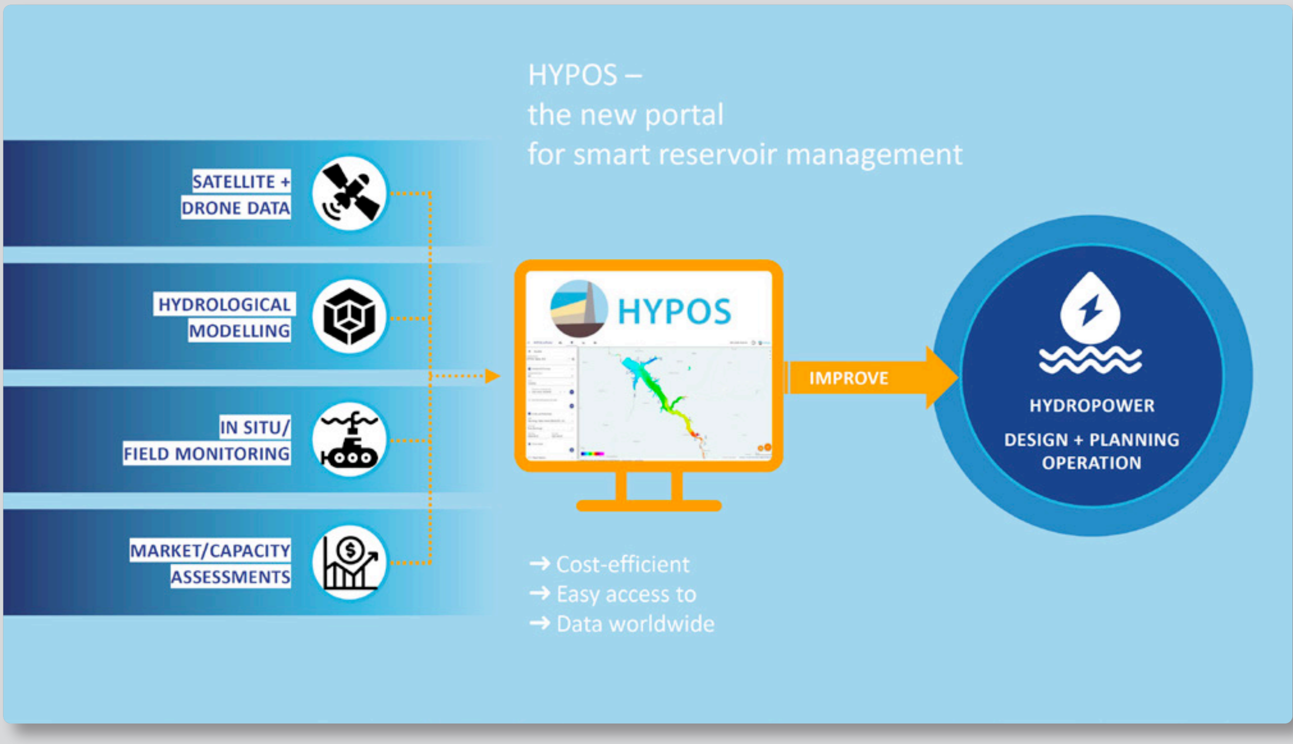
Content

The HYPOS Concept
Satellite-derived information

Operational processing services and satellite data analytics in HYPOS are supplied by EOMAP, based on its established Modular Inversion and Processing System MIP (Heege 2014), state-of-the-art when it comes to high and very high-resolution satellite-derived water quality. MIP imbeds sensor-independent algorithms and processing modules to derive consistent water quality parameters for multiple scales by using satellite sensors. The physics-based algorithms take all relevant environmental impacts into account and do so for each individual measurement and pixel.

Hydrological Modelling

HYPOS includes the World-Wide HYPE (WWH) model from SMHI, which provides spatially and temporarily dense information on various hydrological and water quality variables. WWH offers global coverage for longer time periods outside of the available instream or EO data, as long as meteorological inputs are available through monitoring, re-analyses, or forecasting or climate modelling. Model parameters linked to the catchments' physiographic properties determine the storages and fluxes of water and water quality constituents among the model components. Specific routines account for snow, glacier, reservoir regulations, flood- plains, and deep aquifer processes. WWH is used with Hydro-GFD operationally to calculate and deliver water balance variables and hydrological dynamics at a global scale up to the current day as well as forecasting flows daily for 1-10 days ahead. Seasonal forecasting and climate impact assessments can also be provided for hydrological and sediment variables.



HYPOS

Your online toolbox for Sediment Management

With HYPOS, operations managers of hydropower reservoirs gain quick access to robust and cost efficient water quality data, in particular to sediment related parameters. By combining satellite based with in situ and modelling data the online toolbox offers valuable decision support. HYPOS eases sediment management activities or helps detecting emerging algae blooms.

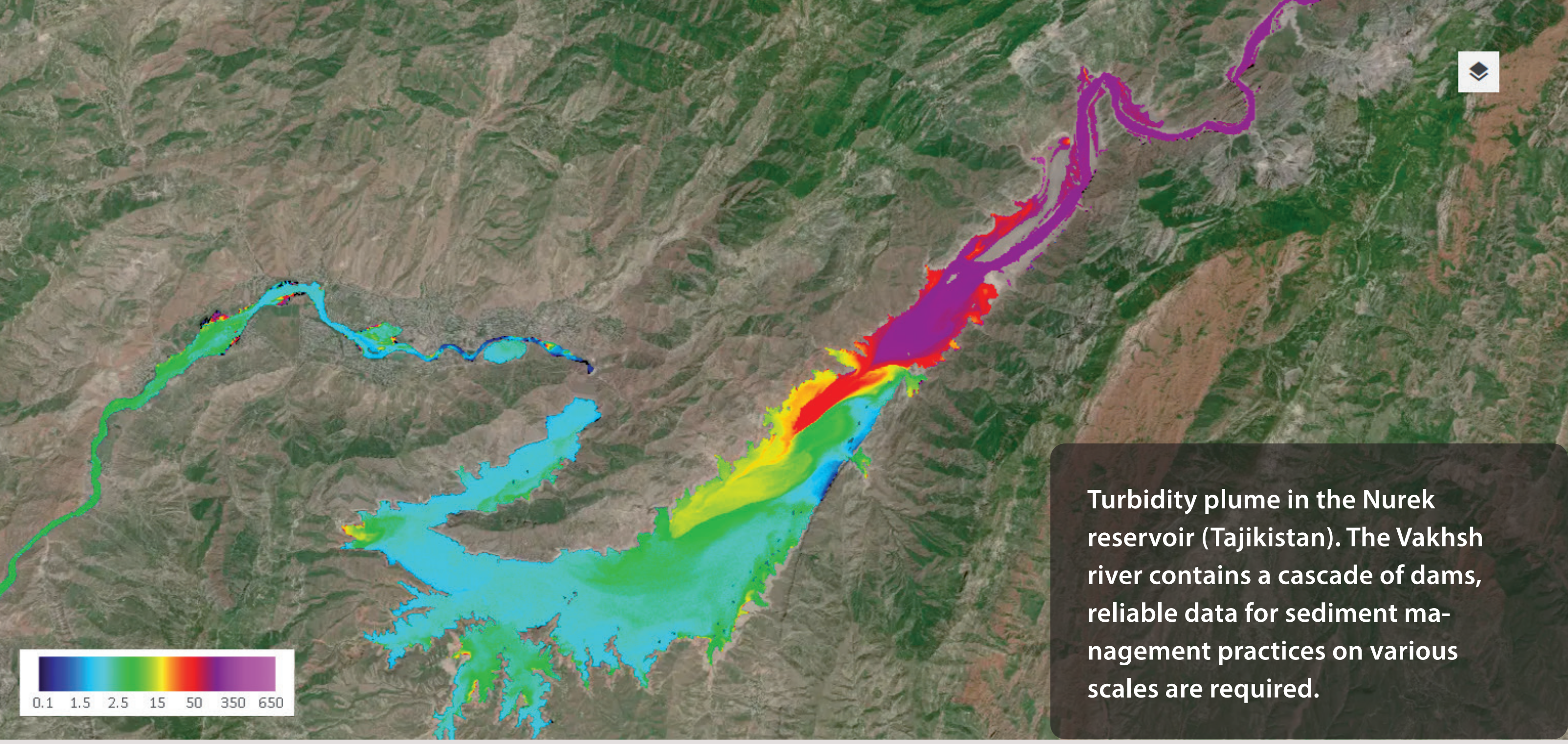
Improve your sediment management practices!

MAIN APPLICATIONS:

- **Operational monitoring of reservoirs and river systems**
- **Reporting and forecasting of flows and sediment states**
- **Flood control and damage prevention**
- **Discharge management: regulate water withdrawal and flushing events**
- **Sediment management: Optimise time and area of dredging operations**

KEY BENEFITS

+ Easy access to key water parameters
+ Operational data of even remote regions worldwide
+ Panoptic view on entire river systems
+ Robust data with high temporal and spatial resolution
+ Time savings due to speedy cloud processing and intuitive interface



Turbidity plume in the Nurek reservoir (Tajikistan). The Vakhsh river contains a cascade of dams, reliable data for sediment management practices on various scales are required.

KEY TECHNICAL PARAMETERS

Satellite-derived information

Data are based on EOMAP's renowned MIP system and bio-optical modelling algorithms. In addition, the datasets have been validated in four hydropower sites across Europe.

+ Turbidity [FTU/NTU]
+ Water level [m]
+ Total Suspended Matter [mg/l]
+ Water Surface temperature [°C]
+ Chlorophyll a [µg/l]
+ Harmful Algae Bloom (HAB) Indicator
+ Evaporation rates [mm]
+ Land cover dynamics

Hydrological model information

HYPOS offers direct access to data based on the global HYPE model (WWH) by the Swedish Meteorological and Hydrological Institute (SMHI). Locally customized models are available upon request.

+ River Discharge [m^3/s]
+ Precipitation [mm]
+ Sediment Concentration [mg/l]
+ Sediment Load [kg/d]
+ Air Temperature [°C]
+ Soil Moisture [-]

SERVICE PACKAGES / PRICING

	Standard	Premium
Spatial Resolution	10 – 30 m	2 m
Temporal Resolution	up to 3x / week	up to daily
Coverage	since 1980s	since 2022
Data availability	NRT	NRT

Pricing example:
For a 10 km^2 reservoir, premium turbidity measurements will be 1,200 €/month - including full access to the HYPOS sediment analysis tool for online data hosting and analysis. Final prices depend on the area and parameters covered. Please request an individual quote at **wq@eomap.de**.

Try hypos.eoapp.de and monitor hydropower reservoirs from the comfort of your desk!

Your Online Toolbox for Hydropower Planning

HYPOS benefits planning engineers who design outlet structures, set up sediment management plans, evaluate upstream and downstream impacts, plan for activities like flushing or prevent environmental impacts. With HYPOS they gain quick access to robust and cost efficient water quality data. By combining satellite based with field and modelling data the online toolbox creates digital twins of river systems worldwide. This can simplify assessment and planning routines significantly.

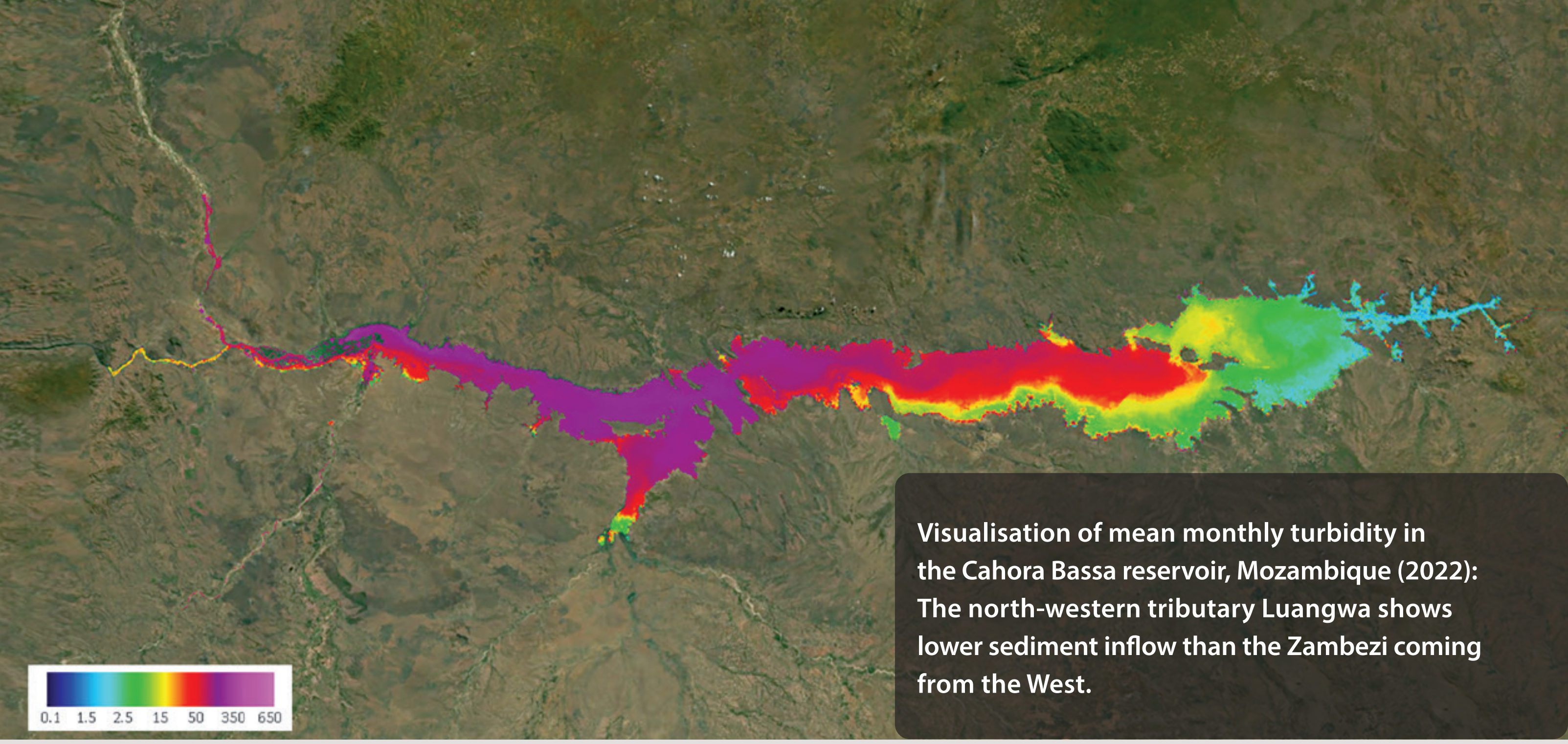
MAIN APPLICATIONS:

- **Baseline environmental information based on historical data**
- **Calculation of sedimentation rates and flows**
- **Design of release structures / gauging stations**
- **Environmental reporting and impact assessment**

KEY BENEFITS

- Planning data of regions worldwide
- Overcome knowledge gaps in data-scarce areas
- Robust data with high temporal and spatial resolution
- Historical data for +30 years back in time
- Time savings due to speedy cloud processing and intuitive interface

Understand sediment dynamics in the catchment



Visualisation of mean monthly turbidity in the Cahora Bassa reservoir, Mozambique (2022): The north-western tributary Luangwa shows lower sediment inflow than the Zambezi coming from the West.

KEY TECHNICAL PARAMETERS

Satellite-derived information

Data are based on EOMAP's renowned MIP system and bio-optical modelling algorithms. In addition, the datasets have been validated in four hydropower sites across Europe.

+ Turbidity [FTU/NTU]
+ Water level [m]
+ Total Suspended Matter [mg/l]
+ Water Surface temperature [°C]
+ Land cover dynamics

Hydrological model information

HYPOS offers direct access to data based on the global HYPE model (WWH) by the Swedish Meteorological and Hydrological Institute (SMHI). Locally customized models are available upon request.

+ River Discharge [m^3/s]
+ Precipitation [mm]
+ Sediment Concentration [mg/l]
+ Sediment Load [kg/d]
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+ Soil Moisture [-]

SERVICE PACKAGES / PRICING

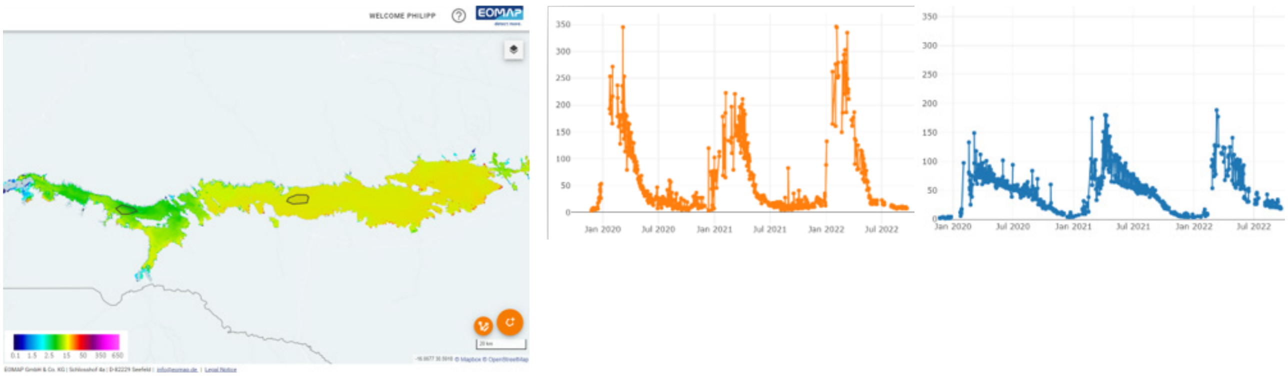
	Standard	Premium
Spatial Resolution	up to 10 – 30 m	2 m
Temporal Resolution	up to 3x / week	up to daily
Coverage	since 1980s	since 2022
Data availability	NRT	NRT

Pricing example:
For one station (1 km^2) a 5 years baseline with standard resolution including all HYPOS tool functions will start from 2,000 €/year. Final prices depend on the area and parameters covered. Please request an individual quote at **wq@eomap.de**.

Try hypos.eoapp.de and monitor hydropower reservoirs from the comfort of your desk!

Turbidity and Total Suspended Matter

Turbidity (TUR), a key parameter for assessing the water quality in reservoirs and rivers, is caused by organic and inorganic particles. Satellite-based turbidity is determined by the backward scattering of light in a range of 450 to 800nm, given in FTU or NTU. Mass concentrations of particles measured as Total Suspended Matter (TSM) are linearly related to turbidity at low to moderate values. In the hydropower context, turbidity and TSM products can identify spatial or temporal dynamics and serve as an input for sediment flow and rate calculations.



Seasonal trends in satellite-based turbidity in the Cahora Bassa reservoir, Mozambique (2020-2022) - Orange: Western part, blue: central part

Technical characteristics:
The main satellite data source are non-commercial satellite data from Copernicus missions Sentinel-2A/B and Sentinel-3A/B as well as Landsat 5-9 data provided by NASA/USGS, dating back until early 80ties, supplemented by commercial high-resolution satellite data with up to 2m resolution. Operational processing services and satellite data analytics in HYPOS are supplied by EOMAP.

Validation and accuracy:
Turbidity and TSM products < 5% over a large concentration range (0-30 g/m3). For concentrations + 200 NTU, the relative deviations from in situ data is typically up to 10-20%. When comparing satellite based turbidity against in situ measured total suspended matter the deviations can range up to 70%, most likely due to changing of sediment compositions the accompanied changes in the TSM vs. TUR relations.

Limitations:
The relation between TUR and TSM can vary on regional and seasonal scale based on the different particle compositions. For example, snow melt periods with higher discharge can introduce other particles than in low flow periods. A regional and seasonal calibration of TSM further assures the accuracy for TSM estimates.

Literature:
Heege T., Kiselev V., Wettle M., Hung N.N. (2014): Operational multi-sensor monitoring of turbidity for the entire Mekong Delta. International Journal of Remote Sensing, Special Issues Remote Sensing the Mekong, Vol. 35 (8), pp. 2910-2926

Hydrology: Water Level and Discharge

Hydrology represents a collective term for parameters, such as water levels and river discharge data which are critical to any form of hydrological monitoring. Satellite altimeters - primarily created to monitor global ocean levels - have ever developing potential to monitor inland waters. With the combination of altimeters and regular multispectral sensors, it became feasible to estimate water levels and river discharge. This opens a world of possibilities for hydrologists who wish to monitor ungauged basins.

Limitations:
Measurement areas are restricted to the orbit of the satellite altimeters. Not every place can be monitored. Accuracy for rivers less than 100m wide is severely reduced due to altimeter sensor limitations. Cloud cover can prevent river width measurements . Altimeter measurements are guaranteed every 10, 11, or 27 days (depending on the altimeter) as radar sensors aren't affected by clouds. Big reservoirs cannot be monitored for discharge as there are more elements driving water flow than the ones considered in this model. Accuracy for low-resolution multispectral satellites is low for smaller rivers.

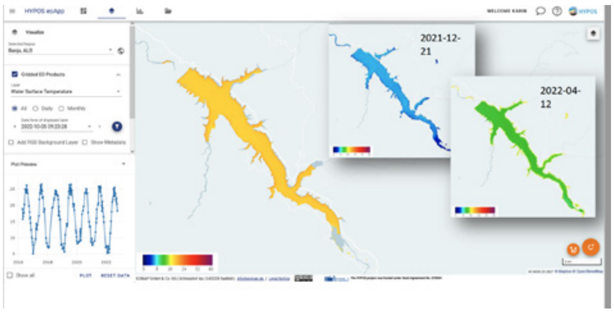
Literature:
Scherer, D., Schwatke, C., Dettmering, D., & Seitz, F. (2020). Long-term discharge estimation for the lower Mississippi River using satellite altimetry and remote sensing images. Remote Sensing, 12(17), 2693. doi:10.3390/rs12172693

Validation and accuracy:
In general, accuracy depends on the spatial resolution of the multispectral sensor. Validation is currently being done over several rivers in Brazil and in Germany, accuracy is shown to be inversely proportional to the river width. Results show water level correlations with field data of over 0.9 and around 20cm of root mean square error. For discharge, measurements using water level as input (altimeter data) also have correlations of over 0.9, but an estimated +20% relative error of overestimation error, reasons are being investigated.

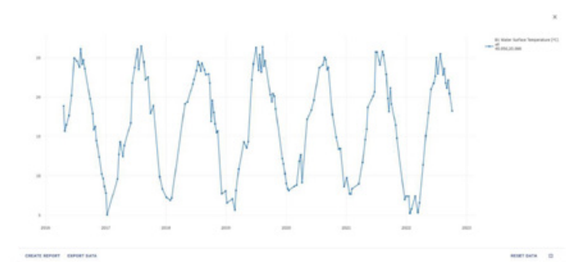
Technical characteristics:
A simulation of the river cross section is first constructed over an area of interest by combining concurrent radar altimeter (water level, in relation to ocean level) and multispectral (river width) measurements. With the simulated cross section constructed, every water level measurement corresponds to a river width and every river width measurement corresponds to a water level. With this information and auxiliary parameters, it is possible to estimate discharge and water levels with either altimeter or multispectral imagery.

Water Surface Temperature

Water Surface Temperature (WST, °C) corresponds to the temperature at the very surface of the water, also known as lake skin surface temperature. It is a fundamental parameter in the modelling of energy fluxes interesting the water-air interface. It also affects the quality of water, because it can contribute to the growing and proliferation of aquatic algae and cyanobacteria.



Visualisation of Water Surface Temperature (WST) in the Banja reservoir, Albania



Annual trends in WST 2017 - 2022

Technical characteristics:
Water Surface Temperature data are derived using thermal bands of the Landsat missions 5-9, delivered in 30m resolution with up to weekly coverage.

Validation and accuracy:
Comparison between WST and surface temperatures derived from the hydrodynamic model Delft3D shows a strong correlation (0.958) and high NSE (0.906) and RMSE of 1.745 °C (Matta et al., 2022). The validation analysis has been performed for the period 2004-2018 in Lake Garda.

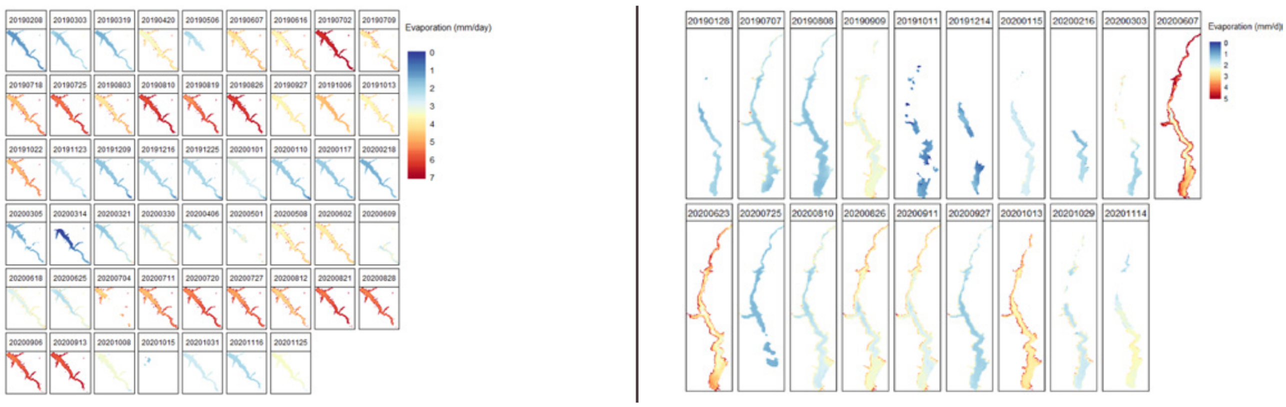
Limitations:
Water Surface Temperature needs clear sky conditions at the satellite overpass time and the spatial resolution of the sensor used.

Literature:
Matta, E., Marina A., Free G., Giardino C., and Bresciani M. (2022). A Satellite-based Tool for Mapping Evaporation in Inland Water Bodies: Formulation, Application, and Operational Aspects. Remote Sensing 14, no. 11: 2636. https://doi.org/10.3390/rs14112636

HYPOS

Evaporation Rate

Daily evaporation (mm/day) from water surfaces is controlled by water temperature (WST) and meteorological forcing: air temperature, relative humidity in the air, wind speed and incident shortwave radiation. Within HYPOS, evaporation is calculated using the so-called mass transfer or bulk transfer method (e.g. Fink et al., 2014), which estimates evaporation as directly proportional to the vapor pressure gradient between the water surface and the air. Evaporation is provided as raster maps of the water surface of the reservoir, from which water volumes evaporated in one day can be computed (as spatial average of daily evaporation by water surface area).



HYPOS shows evaporation rates in the Banja and Enguri reservoirs in Albania throughout the year 2020.

Technical characteristics:
Evaporation maps are generated using a specific tool (Matta et al. 2022), based on satellite-derived surface temperature maps provided by Landsat TIRS sensor, and on meteorological variables derived from global meteorological models such as the Global Land Data Assimilation System (GLDAS) dataset from NASA (https://ldas.gsfc.nasa.gov/gldas) or the ERA5-Land dataset (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5) from the European Centre for Medium-Range Weather Forecasts (ECMWF). Maps have a spatial resolution of 30m and an hypothetical temporal frequency of 8 to 16 days.

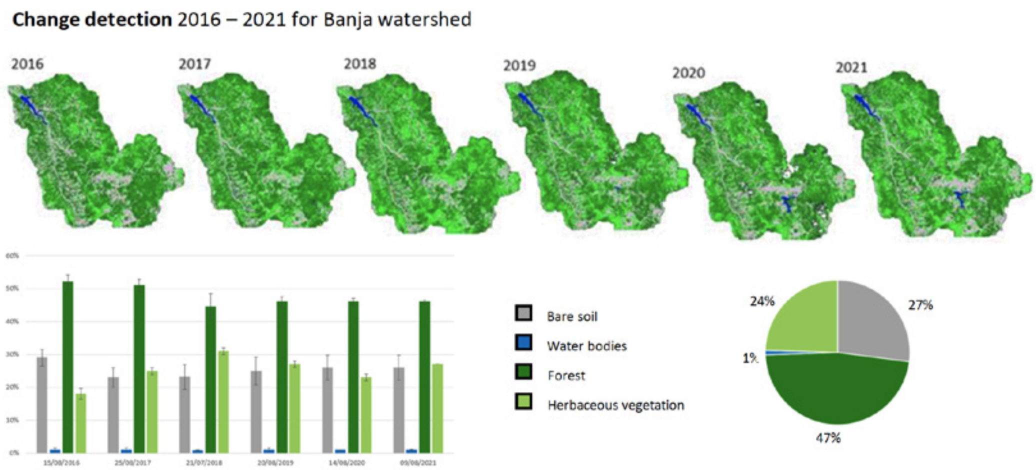
Limitations:
Cloud cover can prevent the computing of evaporation maps. The temporal frequency of evaporation data can decrease to more than 16 days.

Validation and accuracy:
The comparison of evaporation results obtained from the tool used in HYPOS and the 3D hydrothermodynamic model Delft3D by Deltares (Lesser et al., 2004) when using the same meteorological forces, gives a correlation of 0.9 and a root mean square error of 0.04. A comparable annual trend has also been observed between the evaporation series from ERA5 and the one from EO-LSEv (the tool implemented in HYPOS), for the 2019-2020 time range for Banja reservoir.

Literature:
Matta, E., Marina A., Free G., Giardino C., and Bresciani M. (2022). A Satellite-based Tool for Mapping Evaporation in Inland Water Bodies: Formulation, Application, and Operational Aspects. Remote Sensing 14, no. 11: 2636. https://doi.org/10.3390/rs14112636

Land Cover

Land Cover (LC) maps classify the land in different cover types describing the entity of the surface (e.g. vegetation, soil, water). This information is of relevant interest for the modelling of hydrological processes. Contrary to being stable, LC classes change over time, following for instance phenological or agricultural cycles. Within HYPOS specific LC classes have been chosen for each watershed separately, considering the specific land characteristics of the study site (e.g. mountainous or plain and anthropogenic influenced environments).



Land Cover (LC) maps show shares and LC changes around the Devoll river, Albania from 2016 (construction of the power plant) to 2021

Technical characteristics:
Land Cover maps provided within HYPOS express the main LC classes of the watershed which includes the reservoir. These maps are representative of the summer season (peak of the vegetative season), and they have a different dedicated legend for each study site. Maps have been derived analyzing land surface atmospherically corrected reflectances from Sentinel-2 images, using supervised classification techniques. They are provided at a spatial resolution of 10m.

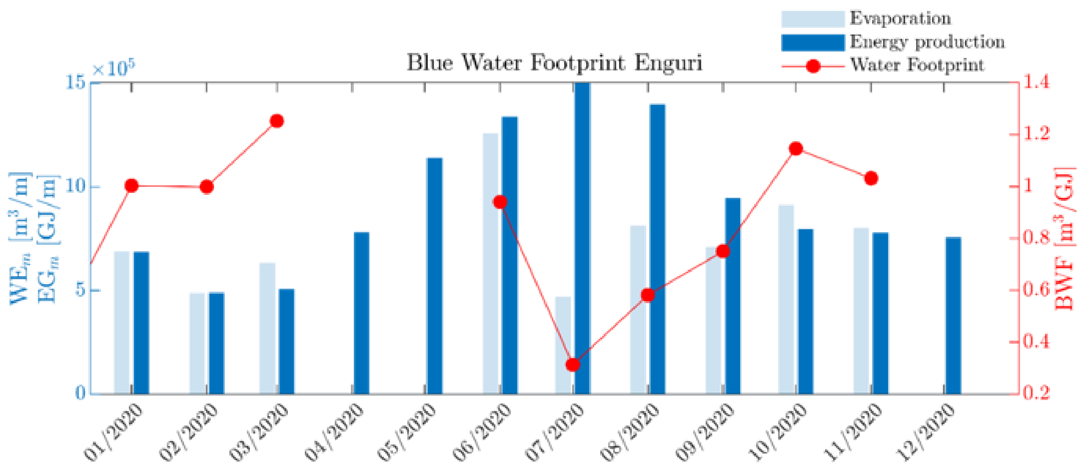
Limitations:
The precision and the accuracy of the product are inversely proportional to the watershed surface and to its land surface heterogeneity.

Validation and accuracy:
Accuracy of the classification process showed values of 77% to 98%, depending on the watershed and on the classification algorithm used.

Literature:
Matta E., Bresciani M., Tellina G., Schenk K., Bauer P. Von Trentini F., Ruther N., Bartosova A. (2023): Data Integration for Investigating Drivers of Water Quality Variability in the Banja Reservoir Watershed. Water, no. 15, 607. https://doi.org/10.3390/1503060

Blue Water Footprint

The Blue Water Footprint (BWF; [m3/GJ]) quantifies the impact of water evaporated from hydropower reservoirs on the production of hydropower energy and it represents the blue component of the total water footprint of the system (Hoekstra 2017). This is an interesting parameter for water managers, who have to manage the more and more scarce water resources. Moreover, it gives an indication of the efficiency of the production system.



Low evaporation rates with relatively high energy production results in a low BWF, an indicator for efficient hydropower production.

Technical characteristics:
The BWF is calculated following the formulation by Mekonnen and Hoekstra (2012), using as input the volume of water evaporated in a specific time (as derived from evaporation maps described above) and the energy power production of the hydropower system in the same reference time (as provided by dam operators). Hence, this parameter needs the interaction of users to be computed.

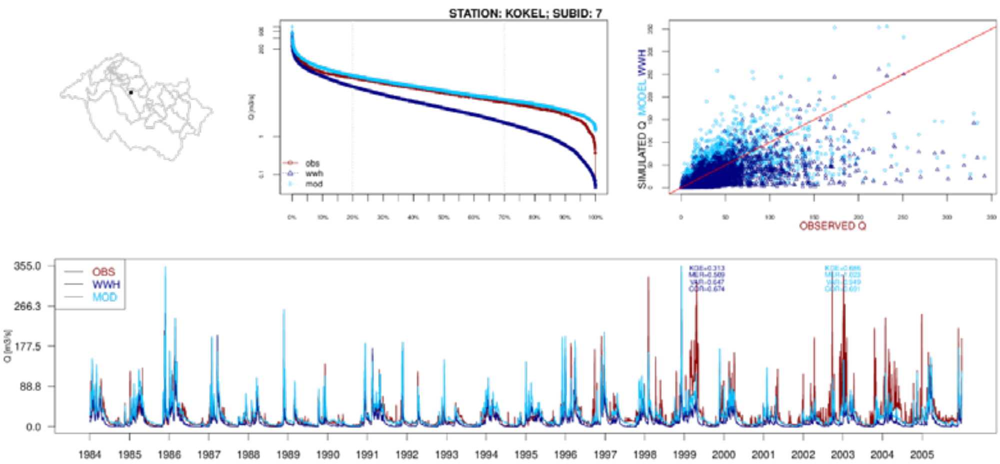
Validation and accuracy:
Its accuracy depends on the accuracy of the input parameters: evaporation and energy production. There is no intrinsic validation of the BWF.

Limitations:
Since being directly related to the evaporation estimates, a lack of images (for cloud coverage) can limit the evaluation of the water consumed in the evaporation process.

Literature:
Hoekstra A. Y. (2017) Water Footprint Assessment: Evolvement of a New Research Field. Water Resources Management 31, no. 10: 3061-3081.
Mekonnen M. M., Hoekstra A. Y. (2012). The Blue Water Footprint of Electricity from Hydropower. Hydrology and Earth System Sciences 16, no. 1: 179-187.

Streamflow

HYPOS is connected to the global scale application of the hydrological model HYPE, World Wide HYPE (WWH) (Arheimer et al., 2020). The model covering a domain of 135 million km^2 runs at a daily time step and has an average spatial resolution of 1,000 km^2. The operational production as well as historical analyses are driven by the HydroGFD meteorological forcing dataset, an observation corrected re-analysis (Berg et al., 2021). Climate change impact indicators can be provided for an ensemble of global climate models. WWH can be used to create a locally customized HYPE model to satisfy customer needs.



Comparison of streamflow characteristics derived from WWH (dark blue), locally customized HYPE (light blue), and observations (red) for Banja.

Technical characteristics:
The volumetric discharge at a single location in a river or stream expressed in volume per unit time. The generated discharge is routed through each sub basin using a river routing routine which simulates attenuation and delay using a flow wave and delay parameters. If lakes and reservoirs are present within a sub basin, the flow is routed in the lake or reservoir using a rating curve.

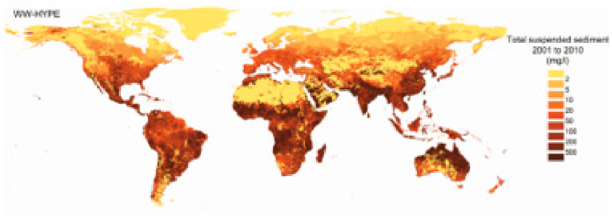
Limitations:
Accuracy can vary locally depending on the availability of data to calibrate the model. Daily values can be calculated for period 1971 – 2100.

Validation and accuracy:
Median monthly KGE = 0.4 globally. Median relative error = -20% globally. 57% stations have daily KGE > 0.25, 80% of stations have daily correlation coefficient > 0.5.

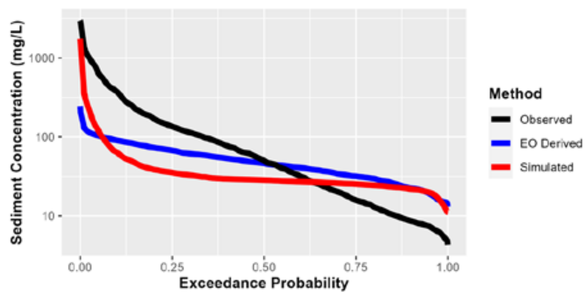
Literature:
Arheimer, B., Pimentel, R., Isberg, K., et al. Global catchment modelling using World-Wide HYPE (WWH), open data, and stepwise parameter estimation. Hydrol Earth Syst Sci. 2020;24(2):535-559. doi:10.5194/hess-24-535-2020

Modelled sediment

WWH was expanded in the course of the HYPOS project to include sediment simulations. (Bartosova et al., 2021). Erosion and sediment transport are provided at daily resolution for historical time periods, operationally for current conditions, as well as for long term and seasonal averages.



Long term average sediment concentrations from WWH (after Bartosova et al., 2021)



Sediment concentration: comparison between observed, EO-derived and simulated values.

Technical characteristics:
Average daily concentration at a single location in a river expressed in mass per volume. The modelled sediment concentrations are delivered as daily values at a asingle location in a river expressed in mass per volume. In addition, a 10 day forecast is available.

Limitations:
Accuracy can vary locally depending on the availability of data to calibrate the model. Daily values can be calculated for period 1971 – 2100.

Validation and accuracy:
Median relative error = 29% globally. 21% of stations have daily correlation coefficient > 0.

Literature:
Bartosova, A., Arnheimer, B., Lavenee, A., Capell, R. (2021): Large-Scale Hydrological and Sediment Modeling in Nested Domains under Current and Changing Climate. J. Hydrol. Eng., 2021, 26(5): 05021009

Satellite Data Sources

In HYPOS, the main data sources are non-commercial satellite data from Copernicus missions Sentinel-2A/B and Sentinel-3A/B as well as Landsat 5-8 data provided by NASA/USGS, dating back until the early 1980ties.

Satellite / Sensor	Spatial (max)	Resolution	Temporal resoltion	Start and end date
Landsat 5	30m		16 days	1984 – 2012
Landsat 7	30m		16 days	1999 – now
Landsat 8	30m		16 days	2013 – now
Sentinel-2 A/B	10m		5 days	2015/2018 – now
Sentinel-3 A/B	300m		daily	2016/2018 – now
MODIS Aqua/Terra	250m		daily	1999/2002 – now
MERIS	300m		2 – 3 days	2002 – 2012

BU: Overview standard satellite sensors and resolution used in HYPOS

For specific events, also very high-resolution satellite data from commercial service providers can contribute to remote monitoring, yet come with additional raw data costs. This will be assessed with a cost/benefit analysis for each case. In addition, Sentinel-1 will be used to overcome the gaps of passive optical sensors due to cloud coverage for the generation of water extent.

Sensor	Spatial resolution	Spectral resolution
WorldView 2/3	2m (50cm)	8 band VIS + NIR (pan)
Pleiades	2m (50cm)	4 band VIS + NIR (pan)
Planet SkySat	1m (0,7m)	4 band VIS + NIR (pan)
RapidEye	5m	5 band VIS + NIR
SPOT6/7	6m (1,5 M)	4 band VIS + NIR (pan)

Overview of extra data sets in Very High Resolution (VHR)

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Access the portal hypos.eoportal.eu
contact@hypos-project.eu

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