Living Planet Symposium 2025

23-27 JUNE 2025 — VIENNA, AUSTRIA

AN ADVANCE INTEGRATION OF SATELLITE PRODUCTS FOR A GLOBAL PRODUCT OF RIVER DISCHARGE

Angelica Tarpanelli[1], Paolo Filippucci[1], Karina Nielsen[2], Alessandro Burini[3]

1 Research Institute for Geo-Hydrological Protection, National Research Council, Italy
2 Technical University of Denmark - National Space Institute, Denmark
3 EUMETSAT, Germany

What is river discharge?

It is defined as the volume of water flowing into a river in a unit time.

Why is it important?

From the 71% of the Earth surface covered by water, the 2% is freshwater and only the 0,7% is accessible for human use

Essential for water resources management

Important for flood prediction and hydraulic risk mitigation

A support for identifying and adapting potential effects of climate change

Rationale

Rivers are fundamental to the Earth's hydrological system, serving as conduits for freshwater flow and vital resources for ecosystems, societies and economies.
Monitoring river discharge is critical for understanding the dynamics of the global water cycle, managing water resources and addressing the growing challenges posed by climate change.
Traditional in-situ measurements are sparse and unevenly distributed, particularly in remote and ungauged regions.
Satellite observations provide an unprecedented opportunity to bridge this gap, enabling river discharge estimation across large spatial scales and diverse environments.

Study area

The analysis includes a selection of 300 sites across the world to capture a wide diversity in terms of land use, land cover, degree of anthropization, river width, drainage area, climate, and data availability. Figure 1 shows the global distribution of the selected sites, along with the distribution of flow regimes, By including both very small and very large rivers, we ensured that the methodology could be evaluated for its robustness and applicability across diverse flow regimes.
Climatic zones were also considered in the site selection, ensuring coverage across a broad spectrum of global climate conditions. The Köppen climate classification was used as a reference to guide this process, allowing us to include stations from tropical, arid, temperate, mediterranean and polar regions as shown in Figure 2, This diversity supports the assessment of the methodology's performance under varying climatic influences.

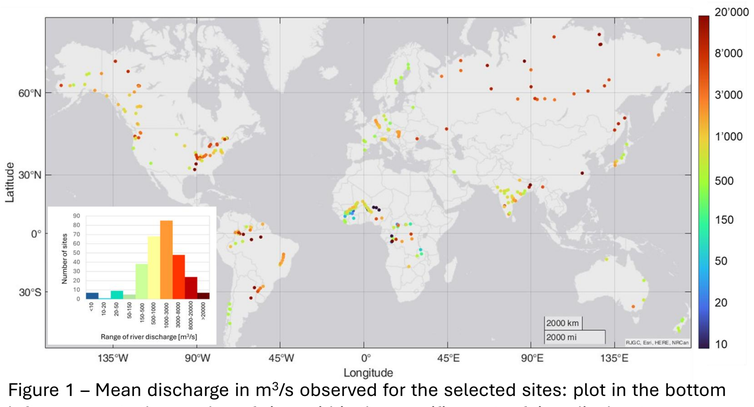


Figure 1 – Mean discharge in m³/s observed for the selected sites: plot in the bottom left, represents the number of sites within the specific range of river discharge.

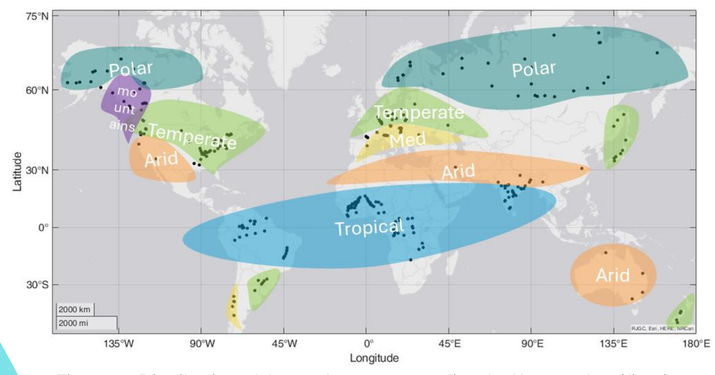


Figure 2 – Distribution of the study areas according the Kopper classification map.

Purposes

1. To develop a **daily global river discharge dataset** over 300 sites in the main basins of the world
2. To **assess and verify at global scale**, the river discharge product through the comparison with in-situ measurements when available, and modelled products
3. To **assess the long-time series** in terms of applications related to the water management and climate assessment and to evaluate the added value from the global product in ungauged basins
4. Investigate the limits of high-resolution discharge product for the monitoring of **small rivers**

The innovation content is the creation of a **new global scale and high resolution (daily) satellite discharge product** obtained by the combination of multispectral reflectance indices and altimetry data.

The approach will be improved, adapted to different climate environments and **extended to a large-scale application** demonstrating the potential and highlighting the limitations.

Method

This study introduces an advanced framework that integrates satellite data from optical and altimetry sensors to produce a global river discharge product suitable for hydrological assessments. Leveraging the capabilities of EUMETSAT's satellite systems and Copernicus contributing missions, the approach synthesizes data from multiple platforms to maximize information retrieval and improve accuracy compared to products derived from individual satellites. Key innovations include the integration of complementary datasets to enhance temporal and spatial resolution, particularly in regions with limited ground-based observations.

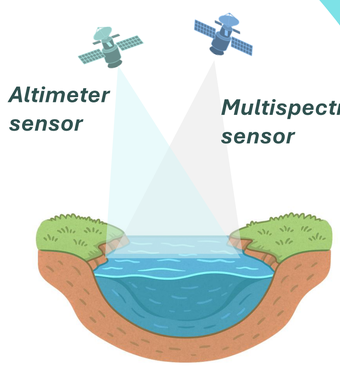


Figure 3 – Scheme of the satellite integration for the river discharge estimation

MAIN STEPS

- Retrieval of water surface elevation from multi-mission approach
- Retrieval of reflectance indices from multispectral sensors with multi-mission approach
- River discharge estimation from independent variables (altimetry and multispectral sensors)
- River discharge estimation by integration of the independent discharges.
- First test over selected and representative sites (20%) based on several climate and morphological conditions, ensuring a representative sample of different analysed environment.
- The selection of the basins allows for an accelerated process by enabling an earlier start of the generation phase, while postponing the comprehensive validation of the product to a later stage.
- The best algorithm is selected by considering the highest performances usually employed for the validation phase (correlation coefficient, RMSE, NSE…) will be applied to at large scale for all the 300 sites.

The expectation is to generate a global, long-term and operational river discharge product to be used for hydrological applications

Evaluation and validation

The objectives to fulfill in the definition of the validation plan are to **verify** that the **global product** provides a **stable, continuous, consistent, accurate and precise dataset** in order to maximize the use of the product for applications and services.

METRICS DEFINITION

- Correlation coefficient (R)
- Nash-Sutcliffe efficiency coefficient (NS)
- Mean absolute error (MAE)
- Relative root mean square error (rRMSE)

STATISTICAL ANALYSES

Statistical analyses of the global products will be performed to ensure the stability, continuity and precision of the dataset.

COMPARISON TO EXTERNAL DATASETS

The global product of river discharge will be compared to 1) other satellite discharge datasets, 2) models, 3) in situ data to ensure the stability, continuity and accuracy of the dataset on the specific surfaces.

IMPROVEMENT COMPARISONS

Comparisons of the global product with the currently existing versions of similar dataset to ensure the improvement of the products

Dataset

In-situ records

- Global Runoff Data Base (GRDB)
- Canadian database (HyDAT)
- Agenzia Interregionale del Fiume Po (AIPo)
- Brazilian National Water Agency (ANA)
- Bangladesh Water Development Board (BWDB);
- Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations (SCHAPI)
- U.S. Geological Survey's (USGS)

Satellite products

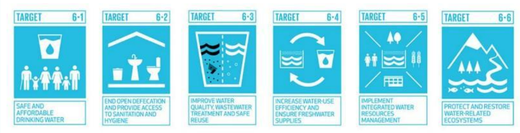
Altimetry products for water surface elevation retrieval

Multispectral sensors products for reflectance indices estimation

Modelled discharge products

Name	Description	Period	Website
NAQWA	Global dataset from ML for medium-small basins (<1500 m³/s)	Climatology	https://data.4tu.nl/
CARAVAN	Regional in-situ dataset harmonized for training ML	Hydrological variables (included river discharge)	https://github.com/kratzert/Caravan
GloFAS-ERA5	Global hydrological simulation at daily scale (LISFLOOD+ERA5)	1979–today	https://data.jrc.ec.europa.eu/collection/id-0054
GRADES	Global climatic dataset at monthly scale from hydrological model calibrated on GRDC	Climatology 1980–2016	Zenodo

Impact assessment



Sustainable Development Goal n°6 (GCOS, 2011)

Water management. In this context the Global Product will be evaluated based on its maturity for improving management strategies. The planning and optimizing of water resources help decision makers to balance the user needs in terms of demand and supply.

Climate analysis. Long time series of hydraulic variables (water level and discharge) are needed to carry out a comprehensive assessment of the present/future climate change impact particularly for extreme events such as floods and drought. The capability of the Global Product to provide additional information will be evaluated, with respect to in situ/modelled data, for long term climate analysis.

Ungauged rivers. The large number of satellite sensors allows for their use also where no other information is available. Even river discharge is hard to be obtained (regionalization methods can overpass the problems over ungauged basins) water level can be provided (multi-mission model)

Take home message

- The combination of the satellite sensors data for the river discharge estimation is necessary to overcome the limitations of the single sensors
- An optimized algorithm will be developed and tested over 20% of the sites and then applied at large-scale over 300 sites.
- A global river discharge database will be produced and tested to guarantee reliability.
- By exploring the scalability and consistency of satellite-based techniques, this research will advance the development of global hydrological datasets and contributes to the broader goal of sustainable water management.
- The findings highlight the potential of these technologies to transform river discharge monitoring, enabling more informed decision-making in the face of global environmental challenges.

References

Filippucci et al. (2022). Sentinel-2 high-resolution data for river discharge monitoring. Remote Sens. Environ., doi: 10.1016/j.rse.2022.113255
Sahoo et al. (2020). Copula-based probabilistic spectral algorithms for high-frequent streamflow estimation, Remote Sens. Environ., doi: 10.1016/j.rse.2020.112092
Tarpanelli & Domeneghetti (2021). Flow Duration Curves from Surface Reflectance in the Near Infrared Band, Applied Sciences, doi: 10.3390/app11083458
Tarpanelli et al. (2013). Toward the estimation of river discharge variations using MODIS data in ungauged basins, Remote Sens. Environ., doi: 10.1016/j.rse.2013.04.010
Tarpanelli et al. (2015). Coupling MODIS and radar altimetry data for discharge estimation in poorly gauged river basin, IEEE JSTARS, doi: 10.1109/JSTARS.2014.2320582

Acknowledgment

The Authors would like to acknowledge the support of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) through the projects GLOBAL RIVER DISCHARGE (Contract No. EUM/CO/24/4600002875/Abu Order n° 4500026151)

Contacts

angelica.tarpanelli@cnr.it

paolo.filippucci@cnr.it