Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 453 (E-14), 2025, pp. 107–110
DOI: 10.25171/InstGeoph_PAS_Publs-2025-055
XLII International School of Hydraulics, Radocza, Poland, 20–23 May 2025

Forecasting the Flood in 2024 in SW Poland on Virtual Stations of Altimetry Satellites Based on the AltHydro System

Michał HALICKI✉ and Tomasz NIEDZIELSKI

Department of Geoinformatics and Cartography,
Faculty of Earth Sciences and Environmental Management, University of Wrocław,
Wrocław, Poland

✉ michal.halicki@uwr.edu.pl

A b s t r a c t

This study describes the AltHydro system, which is the first approach to calculate water level predictions at virtual stations (VS) of altimetry satellites. It has been developed for the middle Odra River basin, where 8 VS of the Sentinel-3A satellite have been selected. The system is based on a Vector Autoregressive Model, which is utilized to issue water level prognoses for gauge stations. The forecasts are later transferred to the neighbouring VS using (1) linear regression (vertical shift) updated whenever a new satellite measurement is available, as well as (2) flow velocity estimates (temporal shift), calculated hourly for each prediction. The system operates in real-time and its results are presented on the AltHydro map portal (http://althydro.uwr.edu.pl/). The accuracy assessment can only be based on nadir (Sentinel-3A) and wide-swath (SWOT) altimetry observations, as these are the only water level measurements available for the virtual stations. In this study we used the system to forecast water levels during the flood in September 2024 in SW Poland. A good accuracy of the AltHydro progoses was observed, with absolute error values ranging from 4 to 45 cm for forecasts with a lead time of 24 hours.

1. INTRODUCTION

Satellite altimetry is a technique of measuring elevation, that has been providing regular water level measurements over the recent decades. Although originally designed to monitor ocean dynamics, recent altimetry missions have proven to be suitable for monitoring inland waters, including medium and small rivers less than 100 m wide. Due to the nadir-looking nature of radar altimetry (unlike satellite imagery), water level observations are only obtainable at virtual stations (VS), specifically located where the ground track of the satellite intersects a river course. However, these observations cannot be used directly to predict water levels due to the poor temporal resolution of the measurements (e.g. 27 days for the Sentinel-3 satellites). On the other hand, given the decreasing number of gauging stations worldwide (Hannah et al. 2011) and the increasing accuracy and availability of satellite observations, the incorporation of remote sensing data into hydrological models seems to be a scientific goal of growing importance.

The goal of this paper is to present the AltHydro water level prediction system (http://althydro.uwr.edu.pl/) that has been developed at the University of Wrocław. AltHydro provides real-time forecasts of water levels at 8 VS of the Sentinel-3A satellite on the middle Odra River (Table 1). A short assessment of the accuracy of the AltHydro system during the flood in 2024 in SW Poland will also be presented.

2. DATA AND METHODS

The main idea of AltHydro is to calculate water level predictions for gauge stations and then transfer them to the neighbouring VS. For each hour, the system downloads the most recent gauge measurements. These observations are then analysed for potential outliers using the Isolation Forest algorithm (Liu et al. 2008) and interpolated with the LinAR method (Niedzielski and Halicki 2023). Altimetry observations are downloaded from the DAHITI database (Schwatke et al. 2015) and corrected for the river slope bias (Halicki et al. 2023) using the high-resolution water surface slopes calculated by Schwatke et al. (2024).

For each hour, the AltHydro system calculates water level predictions (based on gauge data only) in a 72-hour horizon for six gauge stations (Table 1) using a Vector Autoregressive Model (Halicki and Niedzielski 2024). To transfer the predictions to the neighbouring VS, two aspects have to be considered: (1) the vertical, and (2) the temporal shift. To account for the vertical difference between the stations, we calculate linear regression equations based on paired gauge and satellite observations. Each time a new satellite observation is available, i.e. every 27 days, the regression coefficients are recalculated and updated.

Second, to estimate the time needed for the water to flow from the upstream gauge to the neighbouring VS, we apply a statistical approach to determine the water velocity based on the time lag between two gauging stations (Halicki and Niedzielski 2022). Finally, the water level predictions for the upstream gauge are shifted in time and recalculated with the most current regression coefficients.

Table 1

Virtual stations included in the AltHydro system

VS name	Latitude	Longitude	Gauge upstream	Distance to gauge [km]
VS1 Lubusz	52.44061	14.57103	Słubice	11.880
VS2 Kunice	52.26289	14.65722	Biała Góra	24.748
VS3 Bieganów	52.19821	14.68858	Biała Góra	14.634
VS4 Pomorsko	52.0443	15.4924	Cigacice	8.453
VS5 Zabór	51.97289	15.73154	Nowa Sól	26.769
VS6 Dąbrowa	51.9007	15.7661	Nowa Sól	13.769
VS7 Bytom Odrzański	51.72609	15.84947	Głogów	21.668
VS8 Wyszanów	51.68025	16.2548	Ścinawa	45.628

3. RESULTS AND DISCUSSION

Since there are no *in situ* measurements at VS, the only data for assessing the prediction accuracy were the satellite observations themselves, including those from Sentinel-3A and SWOT. Here, we have analyzed only a short period between September and October 2024, when the flood in SW Poland occurred. In general, the absolute errors of predictions with a lead time of 24 hours ranged from 4 cm (VS4) to 45 cm (VS6) with a mean value of 19 cm. Longer predictions were characterized by greater errors, exceeding 1 m for the 72-hour predictions. The accuracy of the AltHydro forecasts at VS1 with lead time of 24 hours are presented in Fig. 1. A generally good agreement between forecasts and water level estimations at VS can be observed, although discrepancies occur at the most dynamic rise of the hydrograph. On the other hand, the very good accuracy of altimetry observations should be noted, both from the nadir (Sentinel-3A) and wide-swath (SWOT) altimetry mission.

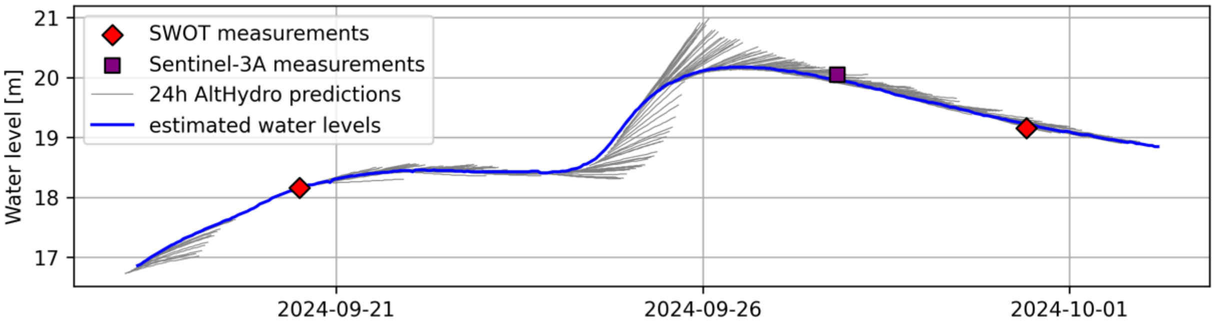

Fig. 1. Water level predictions with a lead time of 24 hours for the VS1 (Lubusz) during the flood in 2024 in SW Poland.

AltHydro is the first approach to forecast water levels at VS of altimetry satellites. It operates in real time and, for each hour, it provides predictions for 8 VS on the middle Odra River (http://althydro.uwr.edu.pl/). It allows to densify the network of water level forecasts, which can be valuable especially in sparsely monitored basins.

Acknowledgements. The research presented in this paper has been carried out in frame of the project no. 2020/38/E/ST10/00295 within the Sonata BIS programme of the National Science Centre, Poland. The research has also been supported by the Bekker Programme of the Polish National Agency for Academic Exchange, as well as by the program “Excellence Initiative – Research University”.

References

Halicki, M., and T. Niedzielski (2022), The accuracy of the Sentinel-3A altimetry over Polish rivers, *J. Hydrol*. **606**, 127355, DOI: 10.1016/j.jhydrol.2021.127355.

Halicki, M., and T. Niedzielski (2024), A new approach for hydrograph data interpolation and outlier removal for vector autoregressive modelling: a case study from the Odra/Oder River, *Stoch. Environ. Res. Risk Assess*. **38**, 2781–2796, DOI: 10.1007/s00477-024-02711-5.

Halicki, M., C. Schwatke, and T. Niedzielski (2023), The impact of the satellite ground track shift on the accuracy of altimetric measurements on rivers: A case study of the Sentinel-3 altimetry on the Odra/Oder River, *J. Hydrol*. **617**, A, 128761, DOI: 10.1016/j.jhydrol.2022.128761.

Hannah, D.M., S. Demuth, H.A.J. van Lanen, U. Looser, C. Prudhomme, G. Rees, K. Stahl, and L.M. Tallaksen (2011), Large-scale river flow archives: importance, current status and future needs, *Hydrol. Process*. **25**, 7, 1191–1200, DOI: 10.1002/hyp.7794.

Liu, F.T., K.M. Ting, and Z.-H. Zhou (2008), Isolation forest. **In:** *2008 Eighth IEEE Int. Conf. Data Mining*, IEEE, 413–422, DOI: 10.1109/ICDM.2008.17.

Niedzielski, T., and M. Halicki (2023), Improving linear interpolation of missing hydrological data by applying integrated autoregressive models, *Water Resour. Manage.* **37**, 5707–5724, DOI: 10.1007/s11269-023-03625-7.

Schwatke, C., D. Dettmering, W. Bosch, and F.Seitz (2015), DAHITI – an innovative approach for estimating water level time series over inland waters using multi-mission satellite altimetry, *Hydrol. Earth Syst. Sci*. **19**, 4345–4364, DOI: 10.5194/hess-19-4345-2015.

Schwatke, C., M. Halicki, and D. Scherer (2024), Generation of high-resolution water surface slopes from multi-mission satellite altimetry, *Water Resour. Res.* **60**, 5, e2023WR034907, DOI: 10.1029/2023WR034907.