Jeníček, M., Ledvinka, O., Tyl, R., Pavlík, P., Kavka, P., Vizina, A., Nedělčev, O., Acheampong, J. N., Fabečić, M., Vargas Godoy, M. R., Šercl, P., Bernsteinová, J., and Langhammer, J., 2026. CAMELS-CZ: a hydro-meteorological time series and attributes database for 453 catchments in Czechia. In: Tolasz, R., Šustková, V. (Ed.), Proceedings of the 2nd PERUN Project Conference (TA ČR, SS02030040). CHMI, Praha, s. 89–95, ISBN 978-80-7653-095-9. https://doi.org/10.59984/978-80-7653-095-9.12

CAMELS-CZ: a hydro-meteorological time series and attributes database for 453 catchments in Czechia

(CAMELS-CZ: databáze hydro-meteorologických časových řad a atributů pro 453 povodí v Česku)

Jeníček, M., Ledvinka, O., Tyl, R., Pavlík, P., Kavka, P., Vizina, A., Nedělčev, O., Acheampog, J. N., Fabečić, M., Godoy, M. R. V., Šercl, P., Bernsteinová, J., Langhammer, J.

Michal Jeníček, Department of Physical Geography and Geoecology, Charles University, michal.jenicek@natur.cuni.cz

Ondřej Ledvinka, Department of Physical Geography and Geoecology, Charles University; Czech Hydrometeorological Institute, ondrej.ledvinka@chmi.cz

Radovan Tyl, Czech Hydrometeorological Institute, Radovan.tyl@chmi.cz

Petr Pavlík, T. G. Masaryk Water Research Institute, petr.pavlik@vuv.cz

Petr Kavka, Department of Landscape Water Conservation, Czech Technical University, petr.kavka@fsv.cvut.cz

Adam Vizina, T. G. Masaryk Water Research Institute, adam.vizina@vuv.cz

Ondřej Nedělčev, Department of Physical Geography and Geoecology, Charles University; Czech Hydrometeorological Institute, ondrej.nedelcev@chmi.cz

Johnmark Nyame Acheampong, Department of Physical Geography and Geoecology, Charles University, acheampj@natur.cuni.cz

Mateja Fabečić, Department of Physical Geography and Geoecology, Charles University, mateja.fabecic@natur.cuni.cz

Mijael Rodrigo Vargas Godoy, Department of Physical Geography and Geoecology, Charles University, vargasgmi@natur.cuni.cz

Petr Šercl, Czech Hydrometeorological Institute, petr.sercl@chmi.cz

Jana Bernsteinová, Department of Physical Geography and Geoecology, Charles University, jana.kaiglova@natur.cuni.cz

Jakub Langhammer, Department of Physical Geography and Geoecology, Charles University, jakub.langhammer@natur.cuni.cz

Abstract: We introduce CAMELS-CZ (Catchment Attributes and MEteorology for Large-sample Studies – Czechia), a database containing time series and catchment attributes for 453 catchments across

https://doi.org/10.59984/978-80-7653-095-9.12

Czechia. The database will serve as a reference platform for analysis and modeling with a large sample of catchments. It provides catchment attributes, along with hydrological and meteorological time series, structured similarly to other CAMELS datasets worldwide. The database includes catchments with at least 15 years of daily runoff data, covering areas from 2 km^2 to 51 408 km^2, with diverse elevations (200–1 600 m a.s.l.) and runoff regimes (from pluvial to nival-pluvial). The observed data encompass daily runoff, precipitation, air temperature, potential evapotranspiration, and weekly snow water equivalent. Additionally, the observed time series are supplemented with simulated water-balance components generated by a semi-distributed HBV model. Version 1.0 of CAMELS-CZ will be openly available by the end of 2026.

Keywords: CAMELS-CZ – large-sample hydrology – runoff regimes – water cycle

Abstrakt: Představujeme CAMELS-CZ (**C**atchment **A**ttributes and **ME**teorology for **L**arge-sample **S**tudies – Czechia), databázi obsahující časové řady a charakteristiky 453 povodí na území Česka. Databáze může sloužit jako referenční platforma pro analýzy a modelování s velkým vzorkem povodí. Databáze nabízí charakteristiky povodí spolu s hydrologickými a meteorologickými časovými řadami, jejichž struktura je podobná jako u jiných datových sad CAMELS po celém světě. Zahrnuje povodí s alespoň 15letými denními údaji o odtoku, pokrývající plochy od 2 km² do 51 408 km², s různými nadmořskými výškami (200–1 600 m n. m.) a odtokovými režimy (od dešťového po sněhovo-dešťový). Denní pozorovaná data zahrnují odtok, srážky, teplotu vzduchu, potenciální evapotranspiraci a týdenní vodní hodnotu sněhu. Časové řady jsou navíc doplněny simulovanými řadami různých složek vodní bilance pomocí semi-distribuovaného modelu HBV. Verze 1.0 databáze CAMELS-CZ bude zpřístupněna ve druhé polovině roku 2026 jako otevřený datový soubor.

Klíčová slova: CAMELS-CZ – komparativní hydrologie – odtokový režim – vodní cyklus

Introduction

Hydrological methods that analyze data from numerous catchments with varied characteristics (large-sample or comparative hydrology) enable an in-depth analysis of the hydrological regime. They facilitate understanding of hydrological variability and how water balance components change across different regions and periods (Addor et al. 2020). Although these methods do not provide detailed insights into local specifics of runoff regimes in individual catchments, they offer a valuable understanding of hydrological processes influenced by environmental and climatic factors and support conclusions with broader applicability. Comparative hydrology is particularly useful for identifying differences and similarities among river basins, aiding their classification and regionalization (Kuentz et al. 2017). Additionally, hydrological models greatly enhance the efficiency of processing extensive data from multiple river basins (Jenicek et al. 2021; Jenicek and Ledvinka 2020). Results derived from large datasets can then be generalized and applied at broader scales.

In addition to runoff data and climate variables, understanding river basin properties – such as geology, soil, topography, and vegetation – is crucial for analyzing hydrological behavior accurately. While individual countries usually have data to calculate these features, processing this information for specific studies can be very time-consuming. Moreover, users aiming to study phenomena on regional or global scales often face challenges related to data availability and inconsistency across countries. To address this, the global hydrological community has recently developed several large, freely accessible datasets called CAMELS (Catchment Attributes and MEteorology for Large-sample Studies). These datasets typically provide comparable catchment attributes at the national level, along with hydrological and meteorological time series (Addor et al. 2017; Höge et al. 2023). The initiative is ongoing, with additional datasets from other countries being continuously added.

Catchments

The database includes all river basins closed by a water level and discharge station that meet the defined criteria, namely the duration of streamflow observations (at least 15 years). This condition is met by the

453 catchments included in the Czech Hydrometeorological Institute (CHMI) network (Fig. 1). Catchment area ranges from 2 km^2 to 51,408 km^2 and covers a variety of elevations (200–1,600 m a.s.l.) and runoff regimes (from pluvial to nival-pluvial). For catchment delineation, the official watershed boundaries provided by CHMI were used. These watershed boundaries were derived from the lidar-based digital terrain model DMR5G.

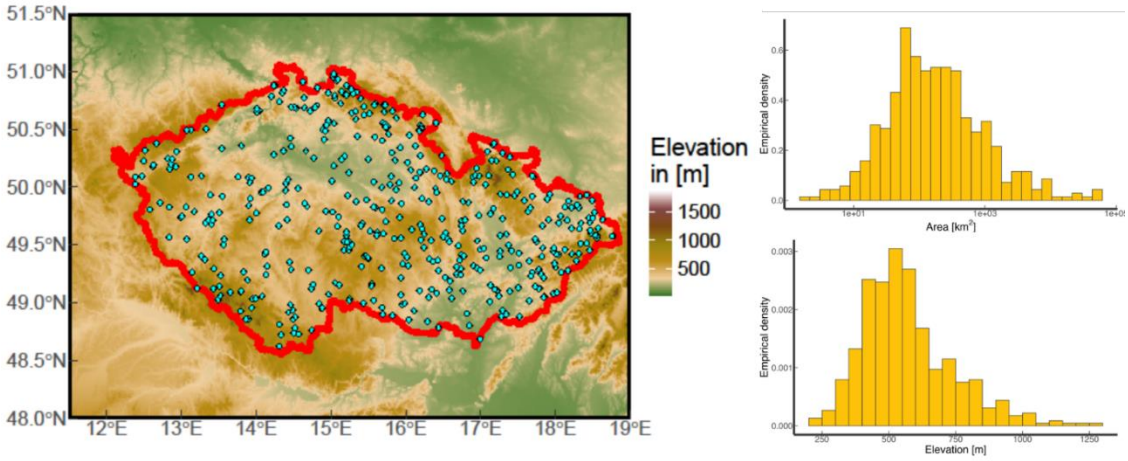


Fig. 1. Map of catchment outlets and their area and elevation distributions.

Catchment attributes

Catchment characteristics are divided into six main classes: topography, climate, hydrology, vegetation, soils, and geology. In addition, basic data (e.g., location, station ID, etc.) and the degree of anthropogenic influence are available for each catchment. Examples of characteristics and underlying data sources are provided in Tab. 1. Selected hydrological attributes are shown in the maps in Fig. 2. The catchment characteristics are aggregated for the entire catchment. Climate and hydrological attributes were calculated over the period 1991–2020.

Various data sources have been used to calculate catchment attributes. For topography attributes, the digital elevation model DMR5G was used, which is based on the most detailed lidar measurements available for Czechia provided by the State Administration of Land Surveying and Cadastre (ČÚZK). Soil attributes were calculated based on a gridded soil texture database. For landcover attributes, CORINE land cover data has been used. Geology and hydrology attributes have been calculated from digitalized geological maps available in 1:50,000 spatial resolution. For calculations of human influence attributes, data from CHMI and T. G. Masaryk Water Research Institute (WRI) have been used.

Table 1. Selected attributes included in the CAMELS-CZ database

Attribute class	Selected attributes	Data source
Topography	Elevation, slope, river network density, etc.	DMR 5G (ČÚZK)
Climate	Annual precipitation and air temperature, snowfall fraction, precipitation seasonality, etc.	Gridded data of precipitation and air temperature (CHMI)
Hydrology	Streamflow quantiles, slope of the flow duration curve, baseflow index, no. of days with low/high flows, etc.	Daily streamflow data (CHMI), spatial catchment data (WRI)
Soils	Porosity, soil texture fractions, saturated hydraulic conductivity, soil storage capacity, etc.	Gridded soil texture maps (Czech Technical University)
Vegetation	Forest fraction, wetlands fractions, Normalized difference vegetation index (NDVI), etc.	CORINE Land Cover (Copernicus)
Geology	Dominant geology, porosity, carbon rock fraction, etc.	Geology maps (Czech Geology Service)
Human impact	Reservoir volume, water abstraction, population, etc.	CHMI

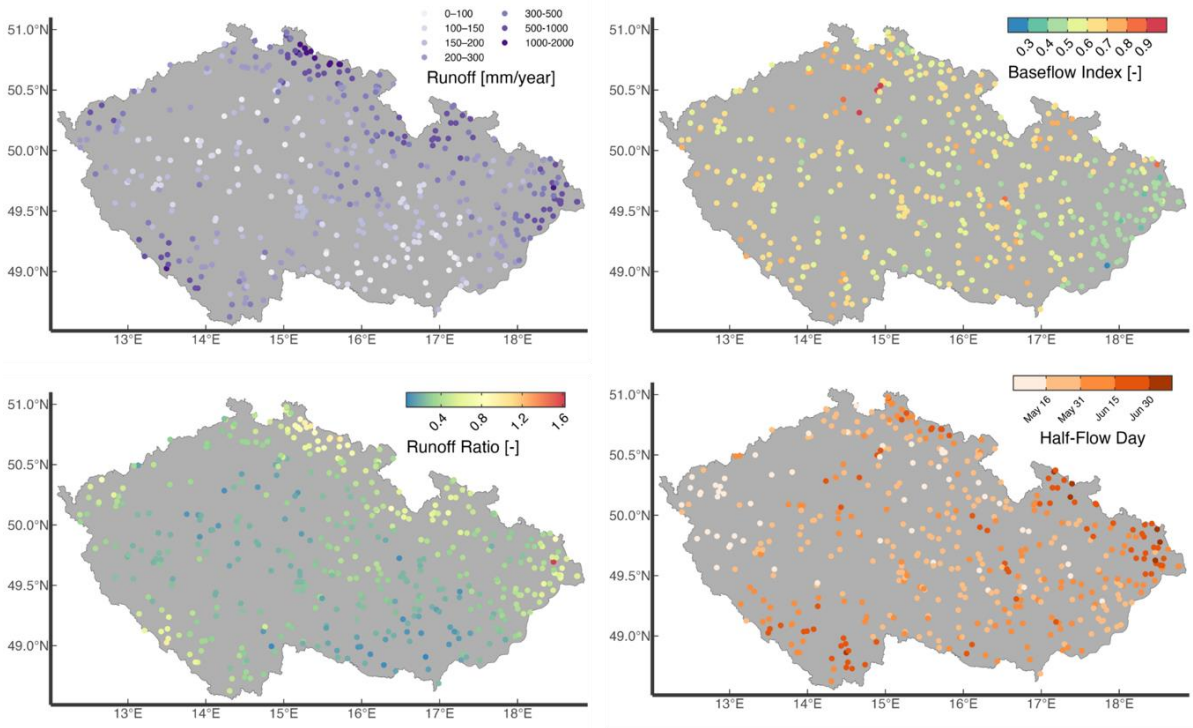


Fig. 2. Selected hydrological attributes calculated for CAMELS-CZ catchments: Runoff (top left), Baseflow index (top right), Runoff ratio (bottom left), Half-flow date (bottom right).

Time series

The CAMELS-CZ dataset includes both observation-based and simulation-based time series of several hydrological and meteorological variables. Daily observed discharge ($m^3 \cdot s^{-1}$) data were provided by CHMI for each catchment. As a national weather and hydrological authority, CHMI performs standard quality control of all data before they are made available to the public. Within the CAMELS-CZ dataset, the maximum possible time period available for each station is published, although hydrological attributes were calculated over a limited period from 1991 to 2020.

For each catchment, the daily mean air temperature (T) and daily precipitation sum (P) were extracted from the official CHMI gridded dataset (GriST). The GriST dataset covers the territory of Czechia at a spatial resolution of 500 m for the period 1961–2023 and was calculated using CHMI climate stations that measure T and P at daily resolution (Štěpánek et al. 2011, 2013). A daily gridded dataset of PET was created from GriST air temperature data using the Oudin equation (Oudin et al. 2005). This gridded dataset is in the same spatial resolution and covers the same time period as original air temperature dataset.

Weekly time series of snow water equivalent (SWE) were extracted for each catchment from the gridded SWE dataset (GriSWE). This dataset was created from CHMI station data (SWE is measured weekly on a long-term basis) using geographically weighted linear regression, using elevation as an independent variable. The gridded dataset was created in the same spatial resolution and for the same study period as GriST climate data.

The catchment means of all the above climate variables were calculated as the mean of the raster cells within the catchment polygon. For cells intersected by the catchment polygon, only the specific fraction of the cell area inside the polygon was considered.

In addition to observed data, the CAMELS-CZ time series was supplemented with simulated data for the different components of the water balance. A semi-distributed bucket-type HBV model (Seibert, Vis 2012) was used. The HBV model consists of four basic routines – a snow routine, soil routine, groundwater routine, and routing function to simulate the precipitation-runoff process. The input data are formed by a time series of daily mean air temperature, daily precipitation, daily PET and weekly SWE extracted from climate grids. Each catchment was divided into 100 m elevation zones, for which input data were distributed using calibrated lapse rates for both air temperature and precipitation.

Model calibration was performed independently for each catchment using a genetic algorithm optimization procedure (Seibert 2000) with the objective function incorporating both observed runoff and SWE to evaluate goodness-of-fit. The optimization employed a weighted combination of three performance metrics: non-parametric Kling-Gupta efficiency, Volume error, and Nash-Sutcliffe efficiency for SWE. This integrated approach to calibration strengthened the ability to accurately represent snow processes across the catchments. The stochastic nature of genetic algorithms leads to varying optimized parameter sets across calibration trials, leading to parameter uncertainty (equifinality). To address equifinality, we executed 10 calibration iterations, generating 10 optimized parameter sets.

Using CAMELS-CZ catchments for analysis of mountainous hydrological regimes

The subset of the prepared CAMELS-CZ database has been used several times to investigate the hydrological regimes of mountainous catchments in Czechia, with a focus on changes in snow, snowmelt, and runoff across the elevation gradient.

A study of 59 mountain catchments across Czechia simulated past and future changes in snowpack and their impact on runoff (Jenicek et al. 2021; Nedelcev and Jenicek 2021). Projections for the end of the 21st century suggest a 30% to 70% decrease in annual maximum SWE. Furthermore, snowmelt is predicted to occur 3 to 4 weeks earlier, shifting the peak streamflow of the melting season from spring into late winter. These changes are expected to intensify summer low-flow periods as less water becomes available to feed rivers during the driest months (Jenicek et al. 2021).

Research involving 59 mountainous catchments in Czechia investigated the sensitivity of rain-on-snow (RoS) events to climate perturbations (Hotovy et al. 2025). The warmest scenarios (+4 °C compared to the 1981–2010 reference period) projected a 75% decrease in the annual number of RoS days. Additionally, the contribution of RoS events to annual runoff is expected to decline from current levels (on average, 10%) to between 2 and 4%. Analysis of historical data from 40 Czech catchments (1965–2019) revealed regional inconsistencies: RoS days have increased slightly in the Eastern Sudeten mountains while decreasing in the Western Sudeten mountains and parts of the Bohemian Forest (Hotovy et al. 2023).

Quantification of snowmelt's effectiveness in Czech mountain catchments demonstrated that snowmelt contributes 17% to 41% of annual runoff (Jenicek and Ledvinka 2020). The research established that snowmelt is more effective for groundwater recharge than rainfall, providing a critical "memory effect" that sustains summer baseflow long after the snowpack has melted. Conversely, snow-poor years result in significantly lower seasonal groundwater recharge, particularly during the March-to-May period. A study by Šípek et al. (2021) determined how spring catchment storage (snow, soil moisture, and groundwater) influences summer low flows. While mean summer runoff is primarily driven by seasonal rainfall, low-flow indices – such as minimum discharge and deficit volume – are also influenced by catchment storage replenished by snowmelt and seasonal rainfall. The influence of catchment storage increases as the season progresses, becoming even more vital for autumn low flows.

Conclusions and future developments

The CAMELS-CZ, a database of catchment attributes and time series for 453 catchments within Czechia, will serve as a reference data platform for analysis and modelling using a large sample of

catchments. The database will enable analyses of precipitation-runoff regimes and their changes across different environments, and will allow for a better understanding of the main physio-geographical controls on runoff generation at different scales, including future projections. In addition, the database complements several other national databases existing worldwide, including those available for Central Europe.

The subset of the prepared CAMELS-CZ database has been used several times to investigate the hydrological regimes of mountainous catchments in Czechia, with a focus on changes in snow, snowmelt, and runoff across the elevation gradient.

We aim to publish the database as an open dataset (e.g. in the Zenodo repository) by the end of 2026, together with an accompanying journal article. In the future, when available, hourly runoff data for a subset of catchments are planned to be included. We will also continue to develop and update the existing website at http://www.camels.cz/ with additional data and visualizations. Further development is also associated with existing efforts to link CAMELS datasets into larger units (CARAVAN) using unified methodology and data sources (Kratzert et al. 2023).

Acknowledgments

The research was partially funded by the Technology Agency of the Czech Republic (grant no. SS02030040, PERUN).

References

Addor, N., Do, H. X., Alvarez-Garreton, C., Coxon, G., Fowler, K., et al., 2020. Large-sample hydrology: recent progress, guidelines for new datasets and grand challenges. *Hydrological Sciences Journal*, **65**(5), pp. 712–725. https://doi.org/10.1080/02626667.2019.1683182

Addor, N., Newman, A. J., Mizukami, N., Clark, M. P., 2017. The CAMELS data set: catchment attributes and meteorology for large-sample studies. *Hydrology and Earth System Sciences*, **21**(10), pp. 5293–5313. https://doi.org/10.5194/hess-21-5293-2017

Höge, M., Kauzlaric, M., Siber, R., Schönenberger, U., Horton, P., et al., 2023. CAMELS-CH: hydro-meteorological time series and landscape attributes for 331 catchments in hydrologic Switzerland. *Earth System Science Data*, **15**(12), pp. 5755–5784. https://doi.org/10.5194/ESSD-15-5755-2023

Hotovy, O., Nedelcev, O., Jenicek, M., 2023. Changes in rain-on-snow events in mountain catchments in the rain–snow transition zone. *Hydrological Sciences Journal*, **68**(4), pp. 572–584. https://doi.org/10.1080/02626667.2023.2177544

Hotovy, O., Nedelcev, O., Seibert, J., Jenicek, M., 2025. Rain-on-snow events in mountainous catchments under climate change. *Hydrology and Earth System Sciences*, **29**(17), pp. 4199–4217. https://doi.org/10.5194/hess-29-4199-2025

Jenicek, M., Hnilica, J., Nedelcev, O., Sipek, V., 2021. Future changes in snowpack will impact seasonal runoff and low flows in Czechia. *Journal of Hydrology: Regional Studies*, **37**, 100899. https://doi.org/10.1016/j.ejrh.2021.100899

Jenicek, M., Ledvinka, O., 2020. Importance of snowmelt contribution to seasonal runoff and summer low flows in Czechia. *Hydrology and Earth System Sciences*, **24**(7), pp. 3475–3491. https://doi.org/10.5194/hess-24-3475-2020

Kratzert, F., Nearing, G., Addor, N., Erickson, T., Gauch, M., et al., 2023. Caravan – A global community dataset for large-sample hydrology. *Scientific Data 2023* **10**:1, 10(1), pp. 1–11. https://doi.org/10.1038/s41597-023-01975-w

Kuentz, A., Arheimer, B., Hundecha, Y., Wagener, T., 2017. Understanding hydrologic variability across Europe through catchment classification. *Hydrology and Earth System Sciences*, **21**(6), pp. 2863–2879. https://doi.org/10.5194/hess-21-2863-2017

Nedelcev, O., Jenicek, M., 2021. Trends in seasonal snowpack and their relation to climate variables in mountain catchments in Czechia. *Hydrological Sciences Journal*, **66**(16), pp. 2340–2356. https://doi.org/10.1080/02626667.2021.1990298

Oudin, L., Hervieu, F., Michel, C., Perrin, C., Andréassian, V., 2005. Which potential evapotranspiration input for a lumped rainfall–runoff model? *Journal of Hydrology*, **303**(1–4), pp. 290–306. https://doi.org/10.1016/j.jhydrol.2004.08.026

Seibert, J., 2000. Multi-criteria calibration of a conceptual runoff model using a genetic algorithm. *Hydrology and Earth System Sciences*, **4**(2), pp. 215–224. https://doi.org/10.5194/hess-4-215-2000

Seibert, J., Vis, M. J. P., 2012. Teaching hydrological modeling with a user-friendly catchment-runoff-model software package. *Hydrology and Earth System Sciences*, **16**(9), pp. 3315–3325. https://doi.org/10.5194/hess-16-3315-2012

Šípek, V., Jenicek, M., Hnilica, J., Zelíková, N., 2021. Catchment Storage and its Influence on Summer Low Flows in Central European Mountainous Catchments. *Water Resources Management*, **35**(9), pp. 2829–2843. https://doi.org/10.1007/s11269-021-02871-x

Štěpánek, P., Zahradníček, P., Farda, A., 2013. Experiences with data quality control and homogenization of daily records of various meteorological elements in the Czech Republic in the period 1961–2010. *Időjárás Quarterly Journal of the Hungarian Meteorological Service*, **117**(1), pp. 123–141. https://www.met.hu/en/ismeret-tar/kiadvanyok/idojaras/index.php?id=82

Štěpánek, P., Zahradníček, P., Huth, R., 2011. Interpolation techniques used for data quality control and calculation of technical series: an example of a Central European daily time series. *Időjárás Quarterly Journal of the Hungarian Meteorological Service*, **115**(2), pp. 87–98. https://www.met.hu/en/ismeret-tar/kiadvanyok/idojaras/index.php?id=34