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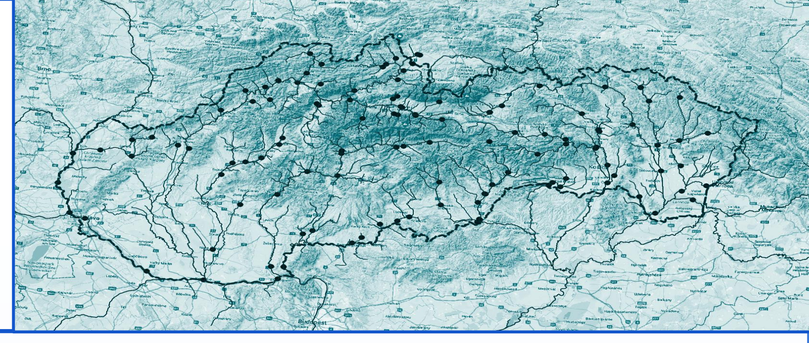

Implementing HEC-HMS: Hydrological Modelling at SHMU

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Martin Petraš, Zinaw D. Shenga, Roman Zehnal
(*martin.petras@shmu.sk, zinaw.shenga@shmu.sk*)

Introduction

Hydrological modelling and flood forecasting are essential for managing water resources and mitigating extreme weather impacts worldwide. Leveraging tools such as the Hydrologic Engineering Centre's Hydrologic Modelling System (HEC-HMS) and the Hydrologic Engineering Centre's Data Storage System (HEC-DSS), hydrologists can simulate processes and forecast floods within river basins using observed precipitation and temperature data for simulation, and forecasted precipitation and temperature data for forecasting. In our institution, the HEC-HMS is utilized as a hydrological model tailored for dendritic watershed systems, with a focus on forecasting hydrological events while also providing advanced simulation capabilities, recognizing that absolute accuracy may vary.

Objectives

- Develop a robust HEC-HMS hydrological modeling framework for forecasting floods across several sub-basins using temperature and precipitation as main input data.
- Utilize Python scripting to implement automated procedures for executing HEC-HMS models four times daily, including:
  - ➢ Preprocessing input data to meet model requirements.
  - ➢ Executing the models to forecast floods for the next 60 to 72 hours.

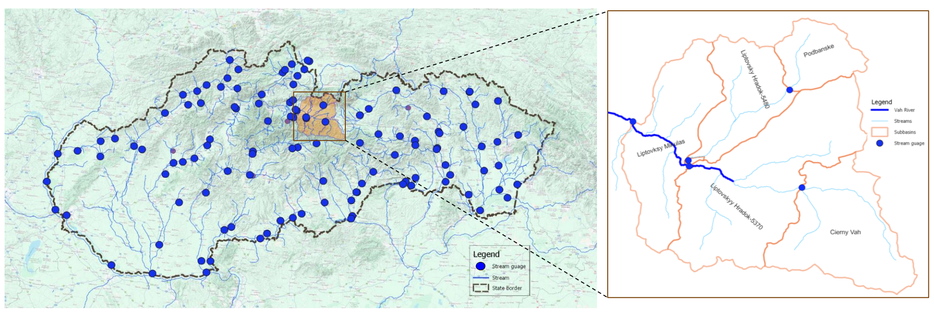

Figure 1: Sample model structure (subdivision of catchments) for Upper Vah River basin. All remaining basins undergo subdivision into smaller catchments to facilitate the development of semi-distributed models. These models utilize available meteorological and basin characteristics data for parameterization. Most parameters, those not obtained from these sources, are calibrated to ensure accuracy.

HEC-HMS operational system setup

Building upon the capabilities of HEC-HMS and HEC-DSS, our local high-performance computing (HPC) facility operates a fully automated model for all river basins in the Slovak Republic. This operational setup is managed by our locally developed 'run_app' system, utilizing Python scripting language to control model instructions. The system generates flood forecasts four times daily, providing timely updates on potential flood events. Additionally, seamless communication between models and data is facilitated by the Python module pydsstools, converting data into model-compatible formats and interfacing with the HEC-DSS data storage system (.dss). HEC-DSS, optimized for efficient data storage and retrieval, enhances the functionality of our flood forecasting system, offering a versatile set of utility programs for easy integration into our applications.

Figure 2 illustrates how generated forecasting is divided into three steps. Inputs must first be formatted. Grib files are outputs from meteorologist models, so these files need to be converted into model-knowing format, which is .dss file format.

The second part is the configuration model inputs. In order to run HEC-HMS without a GUI, an external program has to be developed. For this purpose, scripting environments are created. Scripting environments are used for setting up models, handling inputs and outputs, and executing models.

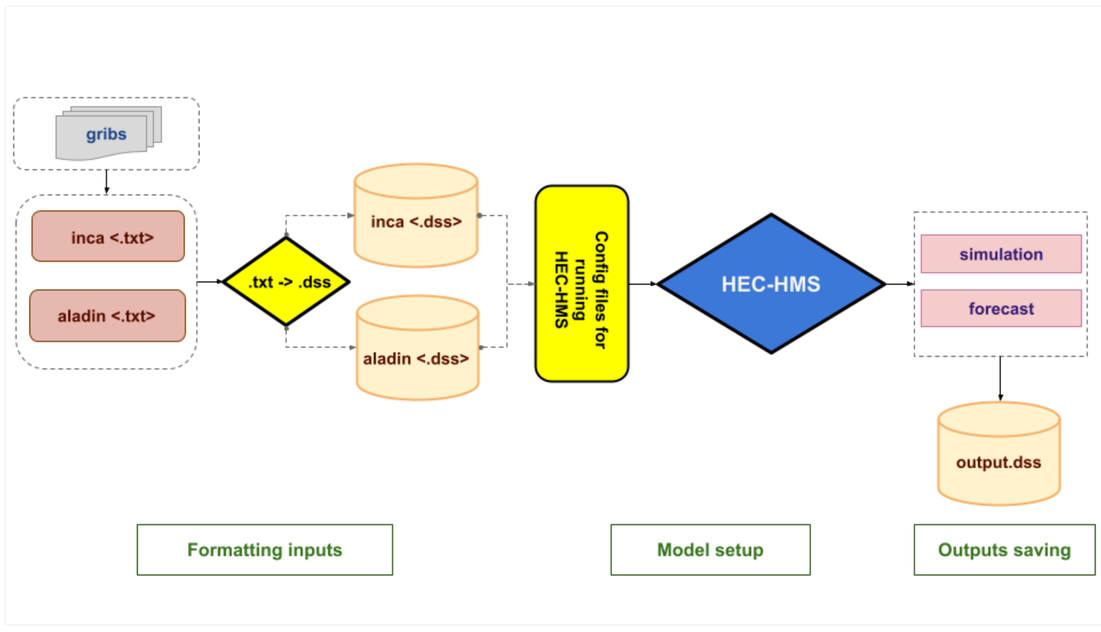

Figure 2: Automated system for producing HEC-HMS forecast

The last part deals with the outputs. Model simulations and forecasts are stored in .dss format. The .dss format allows for the easy sharing of results. The user can also create reports to visualize the results. Finally, the user can also export the results to other file formats.

HEC-HMS GUI interface

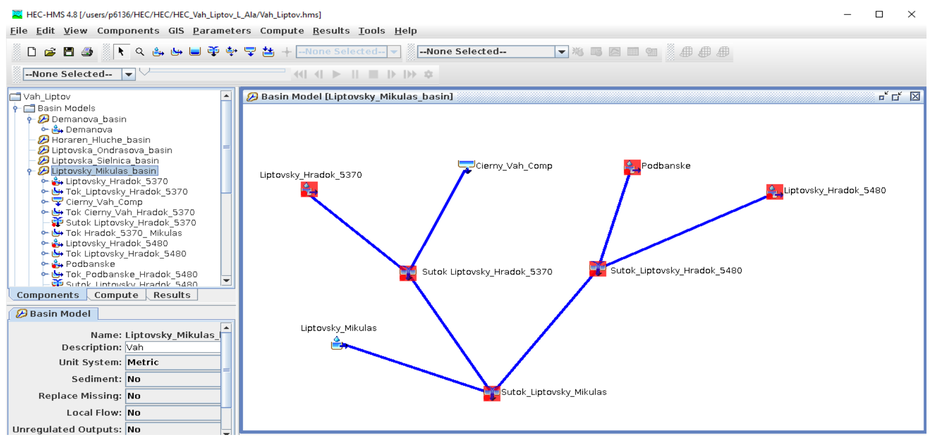

Figure 3: HEC-HMS GUI interface running on HPC

Configuration of the operational system is done through configuration files rather than GUI interfaces. The HEC-HMS is also available with a GUI for better user experience. This makes it easier for most users to work with models more effectively. The GUI interface also provides the ability to view the model output and simulation results in real-time. This helps to identify any issues or discrepancies in the model more quickly. Additionally, the GUI interface can be used to quickly modify model parameters and configurations.

Basin configuration setup

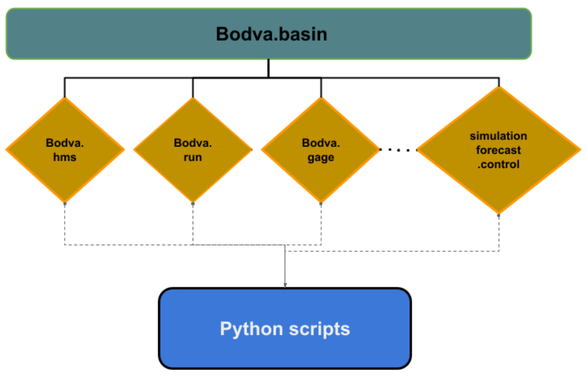

Figure 4: Every basin has own setup files

In Figure 4, the diagram illustrates the set-up of basins. Each basin has its own input configuration file. These configuration files contain setup time steps, export paths, input paths, etc. Each step is managed by a scripting environment based on Python scripts.

Python scripts are used to create an automated workflow for each step. These scripts also help to keep track of the progress of the system and provide log files for debugging. This allows for efficient management and control of the system.

Calibration and Flood Events: A Case Study of Váh River at Liptovský Mikuláš

To assess the performance of a hydrological model for the Váh River, Liptovský Mikuláš was randomly selected from among over 120 available river profiles. The model was calibrated from January 2017 to October 2023, achieving an overall Nash-Sutcliffe Efficiency (NSE) of 0.765 and a percent bias of 1.56%, indicating excellent performance (Figure 5).

During the calibration period, significant flood events were observed in the catchment, e.g., one notable event occurred from the end of April to the beginning of May 2017 (Figure 6).

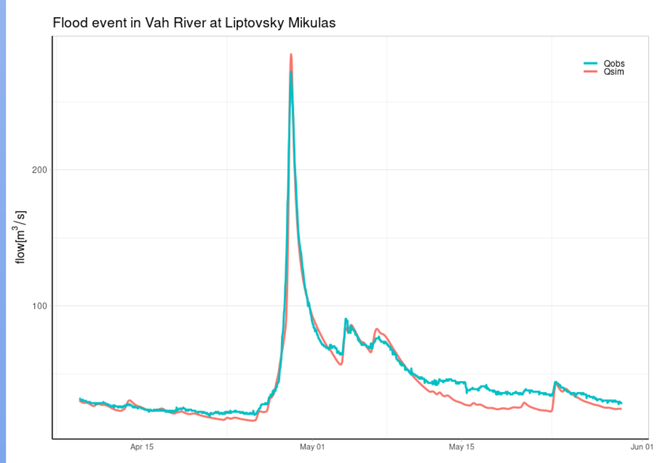

Figure 6: Flood Incident, Upper Váh River - Liptovský Mikuláš, April 2017

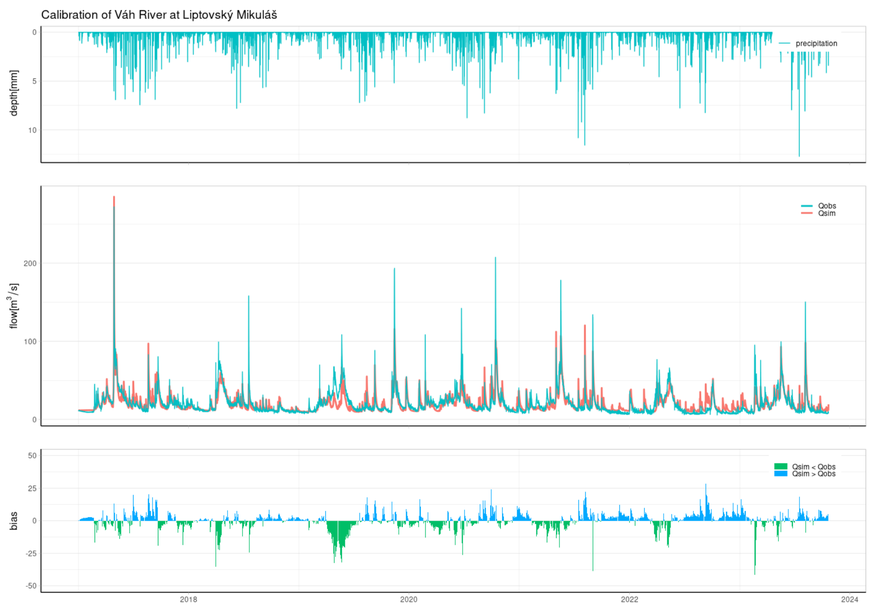

Figure 5: Calibration result at from 2017 to 2023.
(Top: Observed Precipitation, Middle: Observed and Simulated Flow, Bottom: Bias „Analysis)

The flood event (Figure 6) exceeded the 2nd flood threshold level (257.1 m3.s-1), both in observed and simulated results. The calibrated model accurately captured the dynamics of this flood event, demonstrating its ability to replicate real-world hydrological phenomena, though it's important to note that the model may not capture all less significant events

Future Plans

Moving forward, our primary focus will be to refine the calibration process for all catchments, improving specific details in the calibration procedures to ensure accuracy and reliability across all catchments. Additionally, we will work on refining our automated system to optimize model performance and resource utilization. Furthermore, we will explore the implementation of ensemble forecasting techniques to better account for uncertainties and enhance the reliability of flood forecasts.

Reference

USACE. (2000). Hydrologic Modeling System HEC-HMS: Technical Reference Manual. US Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center.