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Machine learning-derived predictions of river flow across Switzerland

Etienne Fluet-Chouinard[1], William Aeberhard[2], Eniko Szekely[2], Massimilano Zappa[3], Konrad Bogner[3], Sonia I. Seneviratne[1], and Lukas Gudmundsson[1]

[1]ETH Zurich, Institute for Atmospheric and Climate Science, Dept. of Environmental System Science, Switzerland
[2]Swiss Data Science Center, Switzerland
[3]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland

The prediction of streamflow in gauged and ungauged basins is a central challenge of hydrology and is increasingly being met by machine learning and deep learning models. With increase in data volume and advances in modeling techniques, the capacity for deep learning tools to compete and complement physics-based hydrological models over a variety of settings and scales is still being explored. Here, we present initial results of the MAchine learning for Swiss (CH) river FLOW estimation (MACH-Flow) project. We train machine learning models on daily discharge data from 260 gauging stations across Switzerland covering the 1980-2020 time window. The river gauging stations we included have catchment areas ranging between 0.1-3000 km^2, and average streamflow between 0.1-100 m^3/second. We also test a range of predictor features including: air temperature, precipitation, incoming radiation, relative humidity, as well as a number of static catchment variables. We evaluated multiple model architectures of ranging complexity, from models focusing on runoff predictions over individual headwater catchments, such as Neural Network, Long short-term memory (LSTM) cells. We also investigate Graph Neural Networks capable of leveraging information from neighbouring stations in making point location predictions. Predictions are generated at gauging locations as well as over 307 land units used for drought monitoring. We benchmark and compare deep learning methods against two process-based hydrological models: 1) the PREecipitation Runoff EVApotranspiration HRU Model (PREVAH) used operationally by Swiss federal agencies and 2) the comparatively streamlined Simple Water Balance Model (SWBM). We compared the deep learning and physics-based models with regards to predicting daily river discharge as well as of low-flows during drought conditions that are essential for water managers and planners in Switzerland. We find that most deep learning methods with sufficient tuning and lookback periods can compete with the streamflow predictions from process-based models, particularly at gauging stations on larger non-regulated rivers where hydro-dynamic time lags are significant. Finally, we discuss the prospects for generating discharge predictions across all river segments of Switzerland using deep learning methods, along with challenges and opportunities to achieve this goal.