Implementation of a Long Short-Term Memory Neural Network based hydrological model in a snow dominated Alpine basin

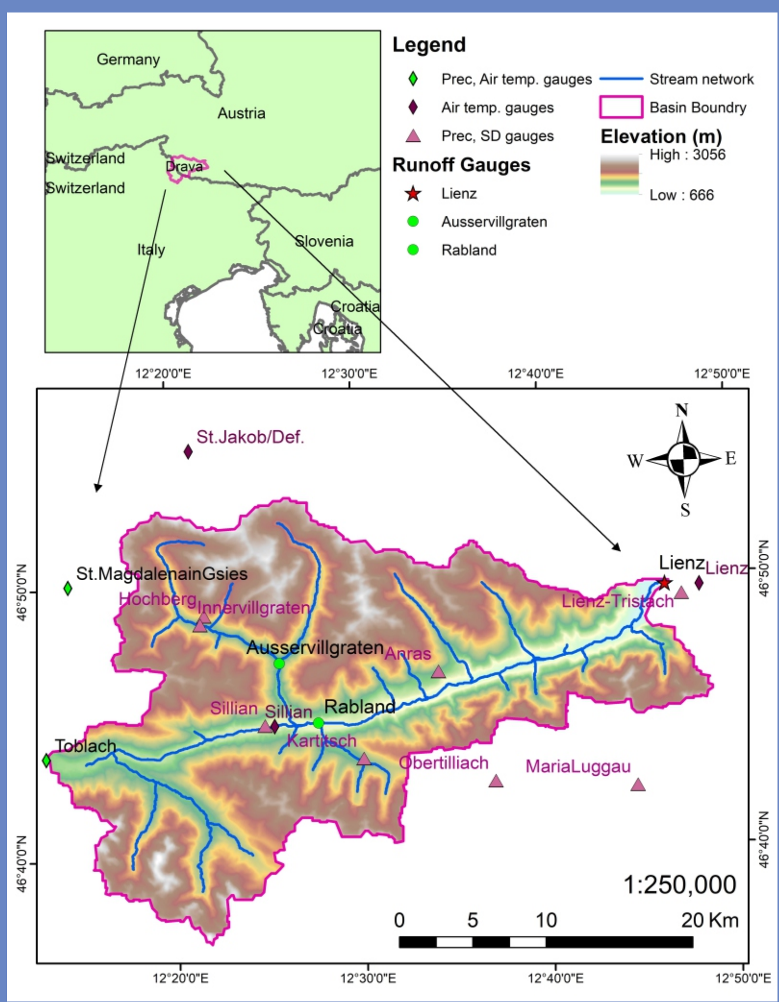
Karlo LESKOVAR[1], Damir BEKIĆ[2], Denis TEŽAK[1], Hrvoje MEAŠKI[1]
1 University of Zagreb, Faculty of Geotechnical Engineering, Croatia
2 University of Zagreb, Faculty of Civil Engineering, Croatia

ABSTRACT:

Snow dominated Alpine basins are of great importance for the surrounding areas. Due to complex terrain and weather phenomena, hydrological modelling in these areas is often difficult. In this article a state-of-the-art approach based on data-driven models, in form of Recurrent Artificial Neural Networks (ANN) is presented. In order to investigate the influence of different input data types three models were created. The results proved that adding more input data features can improve model prediction capabilities (R^2 increased from 0.91 to 0.93 for the testing period), although fine tuning of model hyperparameters is mandatory to achieve such results. The results of this study show that Long Short-term memory (LSTM) neural network based hydrological models can be used in mid to high elevation snowmelt dominated basins of the Danube tributaries.

MATERIALS, METHODS & STUDY AREA:

- Drava river originates in the Italian Alps, 1450 m a.s.l, and mounds the Danube near Osijek, Croatia
- investigations of ANN frameworks in hydrological tasks have been conducted in recent years (Sit et al., 2020)
- input data was in form of two upstream runoff gauges (all models), measured precipitation (all models), air temperature (Model_2, Model_3) and snow depth (model_2, Model_3)
- model evaluation was done visually and statictically (MSE, R^2)



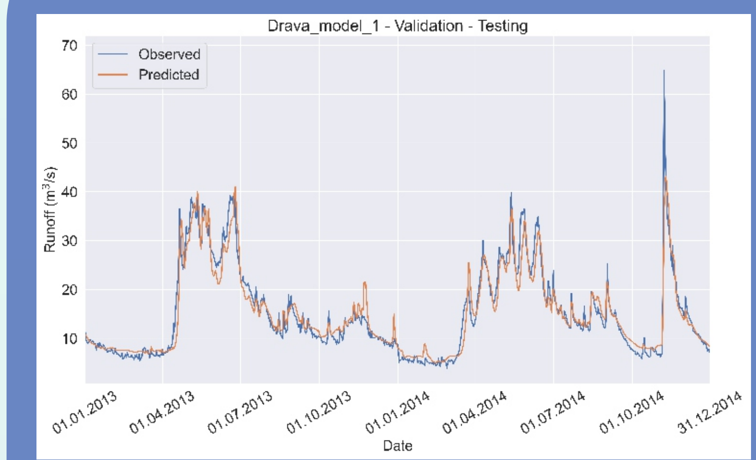
INTRODUCTION:

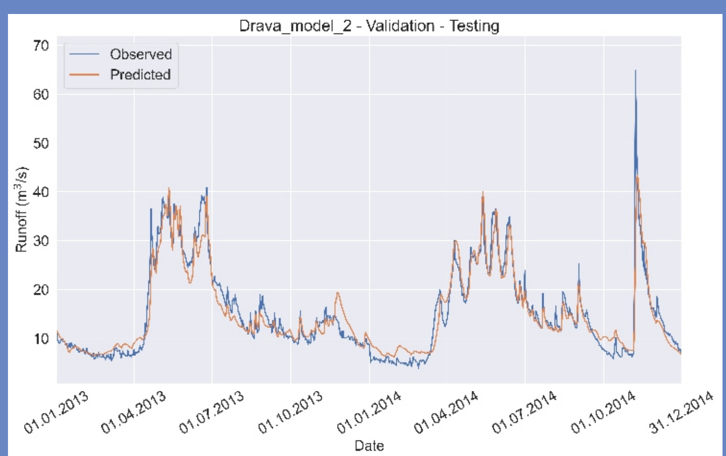
The melting of snow and ice in high altitude region of the Alps in the past has formed several large European rivers, such as Danube, Rhine, Sava, etc. Despite the importance of the European Alps, studies on snowmelt-runoff and/or rainfall-runoff modelling based on data-driven models are rare. Runoff models can be divided into energy-based models, temperature index (degree-day) models and, data-driven models (Thapa, et al., 2020). This study presents an implementation of an ANN with Long Short-Term Memory architecture in a mountainous basin in Tyrol, Austria (and partly Italy). The study compares the performance of Neural Network based model models trained on different datasets (runoff and precipitation, and runoff, precipitation, air temperature and snow depth).

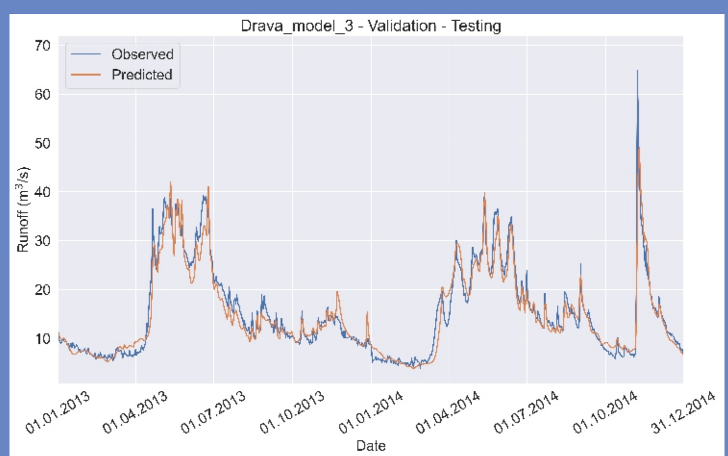
DISCUSSION & CONCLUSION:

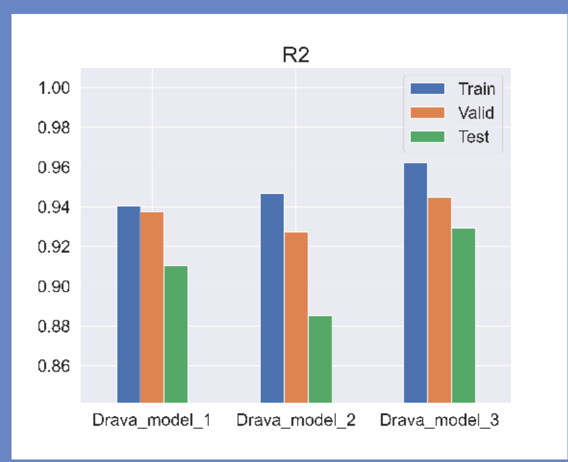
- training, validation and testing for an LSTM based hydrological model is presented
- additional features in training data can cause decrease in performance, without fine tuning (see Model_2 vs. Model_3)
- fine tuning in form of increasing model complexity (longer input period and more nodes in LSTM layers, and/or chenging the learning rate)
- data-driven models are applicable in complex terrain

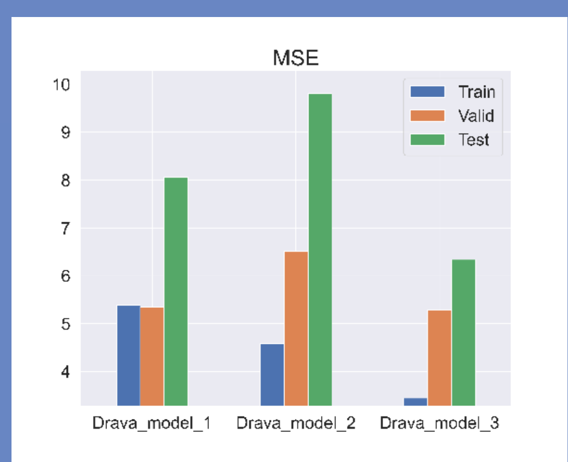
RESULTS:











Model_1 performance during mostly dry periods (baseflow) is very satisfactory while some underestimation can be noticed during spring and early summer (May, June, July) when the snowmelt and summer rainstorms often occur. Statistically the model performance was satisfactory. Model 2 was created with additional input data in form of average air temperature (5 gauges) and snow depths (7 gauges). The resulting hydrograph with same hyperparameters as with Model 1 shows that some of the underestimation was corrected, but on the other hand, now some overestimation in certain periods is noticeable (November, December 2013 and May, June 2014). The fine-tuning of hyperparameters of Model_2 resulted in Model_3. The length of the input sequence of data and the number of neurons in each LSTM layer is increased to 120. Also, to avoid overfitting to more feature rich training input data, the learning rate of the model was decreased to 3.5 x 10^{-4} from the initial 1.5 x 10^{-3} and the dropout of each LSTM layer was increased from 0.15 to 0.35.

Contact:
Karlo Leskovar
Asisstant
University of Zagreb, Faculty of Geotechnical Engineering
Hallerova aleja 7, 42000 Varaždin, HR
karlo.leskovar@gfv.unizg.hr

REFERENCES:

Thapa, S., Zhao, Z., Li, B., Lu, L., Fu, D., Shi, X., Tang, B. & Qi, H. (2020). Snowmelt-Driven Streamflow Prediction Using Machine Learning Techniques (LSTM, NARX, GPR, and SVR). Water. [Online]. 12 (6). p.p. 1734. Available from: https://www.mdpi.com/2073-4441/12/6/1734. [Accessed: 17 December 2020].

Sit, M., Demiray, B.Z., Xiang, Z., Ewing, G.J., Sermet, Y. & Demir, I. (2020). A Comprehensive Review of Deep Learning Applications in Hydrology and Water Resources. arXiv.