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Understanding near-surface hydrogeological processes around Lake Velence (Hungary) – using mesh graph neural networks on multidimensional remote sensing data

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Lake Velence is a shallow soda lake in Hungary whose water budget is mainly driven by precipitation and evaporation. The lake has shown a deteriorating tendency recently, including extremely low lake levels and poor water quality, which indicates its vulnerability against changing climatic conditions. At the same time several water usage conflicts appeared in the catchment area. Until recently, the groundwater component in the lake's water budget and the hydrogeological processes in the catchment area have not been taken into consideration. Recent hydrogeological studies, however, show groundwater discharge into the lake. Thus, further investigating this question is of high importance, hence groundwater could reduce climatic vulnerability.

Our ongoing work aims at developing a model-based evaluation technique, utilizing all map-based geophysical information and time series of different satellite data products, having sufficient spatial resolution and providing information about parameters strongly connected to subsurface processes, showing up on the surface. The basic DEM raster layer is imported from Copernicus GLO-30 dataset, having vertical precision <4 m. The Region Of Interest is a rectangular part of the catchment area: 47.1–47.4N, 18.4–18.8E. The first segmentation of the ROI is done using elevation data combined with lithographic and soil type information, resulting in almost uniform Voronoi-like polygon tessellation, with cells classified by geostructure. Further refinement by land cover type is done using Sentinel-1 SAR data. Other fixed data of point and polygon layers are important terrain features, points of surface inflows, (known) water takeouts and monitoring wells.

The machine learning regression model has time series of measured data at all its layers, daily input from Agárd meteorological station, like precipitation, average temperature, wind speed and relative humidity. Another important input data comes from Sentinel-2 (GREEN-NIR)/(GREEN+NIR)=NDWI spectral index, available in about weekly time steps, varying between 2 days-2 weeks. A crucial feature of all remote sensing data used here is the spatial resolution being better (10 m) or similar to the resolution of the basic DEM model. During training a graph neural network is generated dynamically from the Voronoi tessellation, where cells are nodes and physical processes between neighbouring cells give edge attributes for the graph. We use rectilinear approximations for water runoff/subsurface water exchange between cells, vertical infiltration/discharge under cells and estimated evapotranspiration from them. Learnable parameters governing the intensity of these flows are connected to geostructure and land cover classes. Parameters are optimized with time interval cross validation, with one part of the time series data being left out from optimization in each epoch and used for evaluation against target water level data.

Automatic detection of spatio-temporal patterns, connected to near-surface hydrogeological processes helped visualizing and quantifying estimated physical flows. Comparison with field measurements confirmed theoretic results from MODFLOW basin modelling, proving topography as a driving factor for subsurface flows. Our model is also suitable to handle isotope tracers, and extension to deep learning model promises predictive functionality for water table level.

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