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Linking Time and Space Scales in Distributed Hydrological Modelling – a case study for the VIC model

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One of the famous paradoxes of the Greek philosopher Zeno of Elea (∼450 BC) is the one with the arrow: If one shoots an arrow, and cuts its motion into such small time steps that at every step the arrow is standing still, the arrow is motionless, because a concatenation of non-moving parts does not create motion.

Nowadays, this reasoning can be refuted easily, because we know that motion is a change in space over time, which thus by definition depends on both time and space. If one disregards time by cutting it into infinite small steps, motion is also excluded. This example shows that time and space are linked and therefore hard to evaluate separately.

As hydrologists we want to understand and predict the motion of water, which means we have to look both in space and in time. In hydrological models we can account for space by using spatially explicit models. With increasing computational power and increased data availability from e.g. satellites, it has become easier to apply models at a higher spatial resolution. Increasing the resolution of hydrological models is also labelled as one of the 'Grand Challenges' in hydrology by Wood et al. (2011) and Bierkens et al. (2014), who call for global modelling at hyperresolution (∼1 km and smaller).

A literature survey on 242 peer-viewed articles in which the Variable Infiltration Capacity (VIC) model was used, showed that the spatial resolution at which the model is applied has decreased over the past 17 years: From 0.5 to 2 degrees when the model was just developed, to 1/8 and even 1/32 degree nowadays. On the other hand the literature survey showed that the time step at which the model is calibrated and/or validated remained the same over the last 17 years; mainly daily or monthly.

Klemeš (1983) stresses the fact that space and time scales are connected, and therefore downscaling the spatial scale would also imply downscaling of the temporal scale. Is it worth the effort of downscaling your model from 1 degree to 1/24 degree, if in the end you only look at monthly runoff? In this study an attempt is made to link time and space scales in the VIC model, to study the added value of a higher spatial resolution-model for different time steps.

In order to do this, four different VIC models were constructed for the Thur basin in North-Eastern Switzerland (1700 km^2), a tributary of the Rhine: one lumped model, and three spatially distributed models with a resolution of respectively 1x1 km, 5x5 km, and 10x10 km. All models are run at an hourly time step and aggregated and calibrated for different time steps (hourly, daily, monthly, yearly) using a novel Hierarchical Latin Hypercube Sampling Technique (Vořechovský, 2014). For each time and space scale, several diagnostics like Nash-Sutcliffe efficiency, Kling-Gupta efficiency, all the quantiles of the discharge etc., are calculated in order to compare model performance over different time and space scales for extreme events like floods and droughts. Next to that, the effect of time and space scale on the parameter distribution can be studied. In the end we hope to find a link for optimal time and space scale combinations.