Representation of spatial and temporal variability in large-domain hydrological models:

Case study for a mesoscale prealpine basin

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Summary

The transfer of parameter sets over different temporal and spatial resolutions is common practice in many large-domain hydrological modelling studies. The degree to which parameters are transferable across temporal and spatial resolutions is an indicator for how well spatial and temporal variability are represented in the models. A large degree of transferability may well indicate a poor representation of such variability in the employed models. To investigate parameter transferability over resolution in time and space we have set up a study in which the Variable Infiltration Capacity (VIC) model for the Thur basin in Switzerland was run with four different spatial resolutions 1x1, 5x5, 10x10 km and evaluated for three relevant temporal resolutions (hour, day, month), both applied with uniform and distributed forcing. The model was run 3,150 times using a Hierarchical Latin Hypercube Sample and the best 1% of the runs was selected as behavioural. The overlap in behavioural sets for different spatial and temporal resolutions was used as indicator for parameter transferability. A key result from this study is that the overlap in parameter sets for different spatial resolutions was much larger than for different temporal resolutions, also when the forcing was applied in a distributed fashion. This result suggests that it is easier to transfer parameters across different spatial resolutions than across different temporal resolutions. However, the result also indicates a substantial underestimation in the spatial variability represented in the hydrological simulations, suggesting that the high spatial transferability may occur because the current generation of large-domain models has an inadequate representation of spatial variability and hydrologic connectivity. The results presented in this paper provide a strong motivation to further investigate and substantially improve the representation of spatial and temporal variability in large-domain hydrological models.

1. Catchment, Data, Model

Thur basin (1703 km²), NE-Switzerland
Alpine/pre-alpine climatic regime
Average elevation: 765 m a.s.l. (2502 – 356 m)
Mean slope: 7.9°
Discharge data: hourly measurements (FOEN)
Forcing data: hourly measurements 9 stations
Spatial data: provided by WSL and FAO
Model: VIC 1.2.1 energy-balance mode
Routing: MusiRoute (Mizukami et al., 2015)

2. Experimental Set-up

I. Sensitivity analysis (DELSA) to identify most sensitive parameters, see Table.

II. Choose a sampling strategy: Hierarchical Latin Hypercube Sampling.

Figure 6. The panels show the distribution of the NSE(Q) fitted with a kernel density for 3,150 runs. On the left hand side of the arrow the red area represents the best 10% of the runs, each colour interval increasing with 10% to the full data set (100%, purple). The selected behavioural runs are indicated separately with a black line (best 1%). The panel on the right hand side of the arrow shows the distribution of the model performance for the coloured selections when evaluated at another spatial (left) or temporal (right) resolution. The data for the first two columns are based on hourly discharges, the data for the second two columns are based on the 1x1 km model.

3. Results

Figure 7(a) shows the coefficient of variation of the monthly streamflow outlet (for a selected number of model parameters) for the best 1% of model runs. The coefficient of variation for the parameter optimal for transferability from the 1x1 km model (1) is smaller than for the parameter optimal for transferability from the monthly (2) or hourly (3) model.

Figure 7(b) shows the density plots of the NSE(Q) and the KGE(Q) for the best 1% of runs. The density plots indicate that the model is very sensitive to the selection of parameter sets.

Figure 7(c) shows the cumulative distribution of the NSE(Q) and the KGE(Q) for the best 1% of runs. The cumulative distribution of the NSE(Q) is very similar for the 1x1 km, monthly and hourly model, indicating that the model is very sensitive to the selection of parameter sets.

4. Conclusion

The most important result of our study is that it showed high parameter transferability across spatial resolution, even when forcing was applied in a distributed fashion. A possible explanation for the low sensitivity to spatial resolution is the limited application of the most sensitive parameters. This is indicative of a substantial underestimation of the actual spatial variability represented by the VIC simulations. We did, however, construct our model according to current day standards for large-domain land-surface models, raising the point that the high spatial transferability may occur because the current generation of models have an inadequate representation of spatial variability and hydrologic connectivity. The results presented in this paper provide a strong motivation to further investigate and substantially improve the representation of spatial and temporal variability in large-domain hydrological models.