Methods for spatial pattern comparison in distributed hydrological modelling

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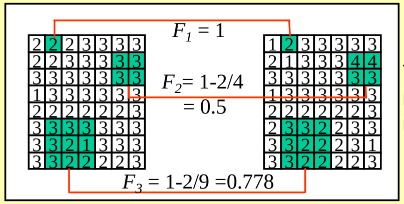
Objectives

This poster examines different algorithms for the quantitative comparison of categorical grid maps containing hydrological data.

Important features to be evaluated when comparing two maps

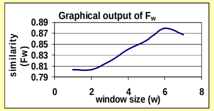
- how many cells are similar in category and location (cell-by-cell comparison)
- how many cells have the same category, but different location
- how far is the distance between the corresponding cells
- how can uncertainty of location be into account

Algorithm 1: Moving Window



The maps are scanned using a window of an increasing size (Costanza, 1989). The index is based on the difference between the total number of cells in each category in each window.

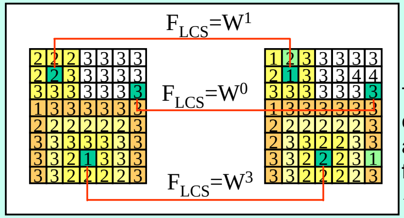
The values for the different resolutions can be summarized in one single value:



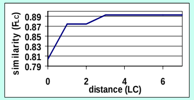
$$F_t = \frac{\sum_{w=1}^{n} F_w e^{-k(w-1)}}{\sum_{w=1}^{n} e^{-k(w-1)}}$$

k =0.1 (in this poster)

Algorithm 2: Layer Comparison (LC)



The algorithm searches for the closest cell of the same category (Kuhnert et al., 2005) .

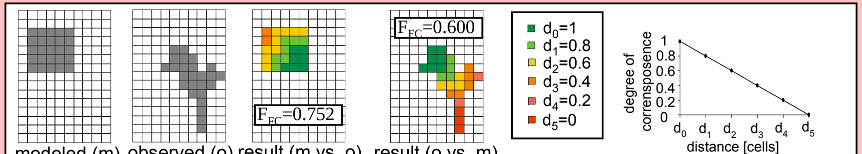


The graphical output shows the increase of map correspondence with distance and can be aggregated to a single value depending on the factor W:

$$F_{LCS}(W) = \frac{1}{N}\sum_{r=1}^{N} W^{LC}$$

N: Total number of cells
W = 0.5 (in this poster)

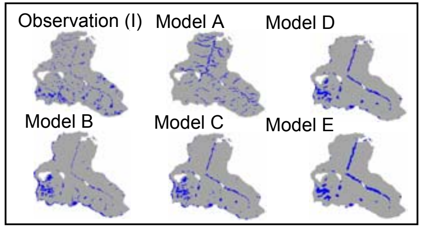
Algorithm 3: Fuzzy Comparison (FC)



modeled (m) observed (o) result (m vs. o) result (o vs. m)

The fuzzy criteria includes modeled areas close to observed areas with lower degree of similarity (Güntner et al., 2004). Hagen (2003) provides a Kappa-based fuzzy criterion considering location and category (F_{KF}).

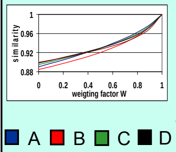
Example 1: Saturated areas



maps	F_{cbc}	F_K	F_{FC}	F_t	F_{KF}	F_{LCS}
A↔I	0.8904	0.7808	0.273	0.9255	-0.118	0.9297
B↔I	0.8847	0.7694	0.195	0.8900	-0.429	0.9202
C↔I	0.8950	0.7901	0.283	0.9126	-0.188	0.9289
D↔I	0.8984	0.7968	0.293	0.9119	-0.152	0.9296
E↔I	0.8996	0.7992	0.281	0.9177	-0.129	0.9271

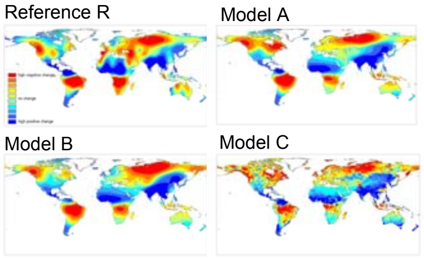
☐ Comparison with highest similarity

The similarity between modeled and observed maps is ranked differently by the single values that were obtained for the individual algorithms. One reason is that for each algorithm a different degree of similarity is assigned to corresponding cells at larger distances or at coarser resolution (see also figure below).



With increasing W, cell correspondence at larger distances has a larger weight for the single value F_{LCS}. Accordingly, the ranking of similarity among the simulated maps changes with W.

Example 2: Global patterns of seasonal water storage change



maps	F_{cbc}	F_K	F_{FC}	F_t	F_{KF}	F_{LCS}
A↔R	0.279	0.198	0.401	0.320	-0.515	0.333
B↔R	0.288	0.209	0.410	0.324	-0.499	0.347
C↔R	0.201	0.112	0.299	0.263	-0.644	0.303

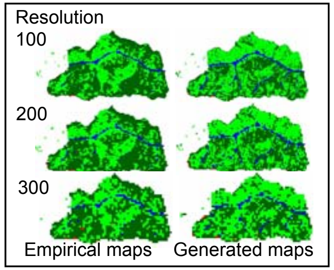
All comparison criteria rank the modeled patterns in the same order of similarity relative to the reference map. A reason can be that major differences between the patterns occur only for large distances.

The reversed direction of map comparison with criteria F_{FC} (see also box for Algorithm 3) results in the best performance for map C. This is due to its fine-grained structure, assuring a high probability that a cell with a certain category is close to the respective cell of the reference map.

maps	F_{FC}
A↔R	0.401
B↔R	0.410
C↔R	0.299

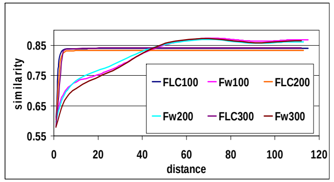
maps	F_{FC}
R↔A	0.371
R↔B	0.381
R↔C	0.481

Example 3: Classification of landscape units



maps	F_{cbc}	F_K	F_{FC}	F_t	F_{KF}	F_{LCS}
100	0.6039	0.286	0.897	0.7071	-0.043	0.7062
200	0.5962	0.275	0.903	0.7418	0.106	0.7066
300	0.5792	0.242	0.899	0.7466	0.154	0.7059

With increasing distance, the ranking varies according to both criteria F_w and F_{LC}.



F_{cbc}	is the cell-by-cell comparison
F_K	Kappa index
F_w	moving window (window size *w)*
F_{LC}	Layer comparison (for layer LC)
F_{LCS}	single value of Layer comparison
F_{FC}	Fuzzy comparison
F_{KF}	Kappa fuzzy

Conclusions

Going beyond the cell-by-cell comparison, the map comparison algorithms presented here allow to account for differences and uncertainties of location when comparing categorical maps. Results differ depending on the function that weights the degree of similarity for increasing distance between corresponding cells. The most suitable function depends on the maximum acceptable distance for a given application and level of data uncertainty. Additionally, empirical surveys (such as the map comparison at the side of this poster) can help to adjust functions and their parameters to human perception on the similarity of two maps.

References: Constanza, R. (1989). Model goodness of fit: A multiple resolution procedure, *Ecological Modeling*, 47: 199-215
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