Downscaling of precipitation field for operational use

Anna Jurczyk, Katarzyna Ośródka, Jan Szturc
Institute of Meteorology and Water Management, Poland

1 Introduction

Hydrological rainfall-runoff models need precipitation input with different spatial resolution depending on catchment size. For small mountainous catchments where flash floods are the most severe hydrological phenomena, the very high spatial scale of precipitation data is required, even hundreds of meters. Therefore there is a need to downscale the large-scale precipitation fields to the smaller-scale ones. In the case of precipitation downscaling for small mountainous catchments the orography information, which is employed in many downscaling methods, is not useful. Their short response times require short accumulation period where orographic effects are not observed.

2 Downscaling techniques

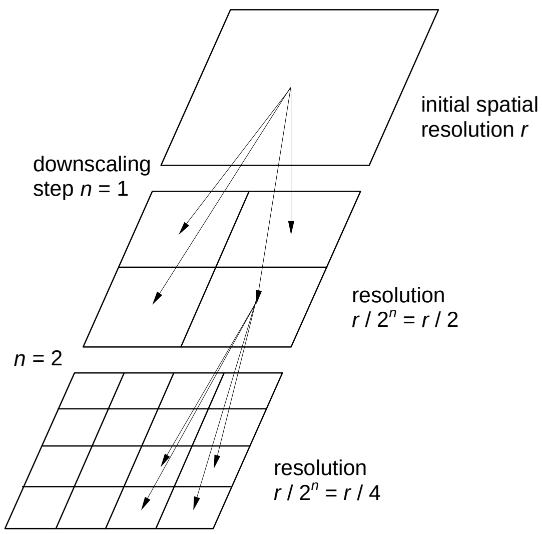

Fig. 1. Cascade approach for downscaling.

One of possible approaches is based on the theory of multiplicative cascades. This downscaling scheme consists on repeated division of the coarse-resolution precipitation grids into smaller ones following specified rules of the cascade (Fig. 1). In each cascade step the larger-grid precipitation value is redistributed among constituent grids using assigned weights with the constraint that the total amount of rainfall must be preserved.

There is a number of cascade-based downscaling methods with different ways of weights generation (Güntner et al., 2001; Pathirana et al., 2003; Schipper, 2005). The simplest way is to determine them in a random manner.

3 Deterministic cascade with dynamic weights

The task is to determine precipitation value in smaller-size $R_{0\text{-}1}$ grid basing on values in selected larger-scale grids R_i (i = 1, ..., n). For this purpose it is necessary to calculate all weights W_i (i = 1, ..., n) associated with the i-grids. The cascade generator defines the way of the weights' calculation.

In the proposed method precipitation in given smaller grid $R_{0\text{-}1}$ is calculated only from parent grid R_0, however its weight is a function of nearest coarse-resolution grids and the parent R_0 grid.

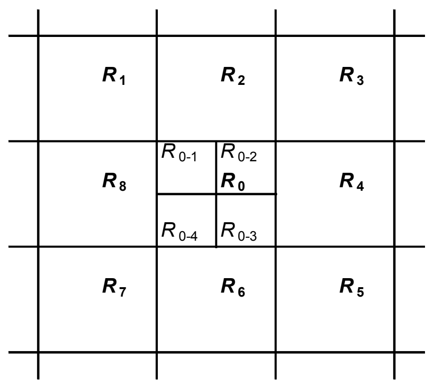

Fig. 2. Scheme of larger and smaller grids in one downscaling step.

Therefore the first step was to choose larger grids which influence given smaller grid. It was achieved in an empirical way by investigating the correlation between the rain values

Correspondence to: Anna Jurczyk
anna.jurczyk@imgw.pl

in smaller-scale grid and coarse-resolution grids within its nearest vicinity. As it was expected, the correlation was the highest for the parent grid and three closest ones, therefore it was assumed that the weights are proportional to their amount of rainfall (Fig. 2):

$$W_1 = R_0 + R_1 + R_2 + R_8$$

$$W_2 = R_0 + R_2 + R_3 + R_4$$

$$W_3 = R_0 + R_4 + R_5 + R_6$$

$$W_4 = R_0 + R_6 + R_7 + R_8$$

Next the weights are normalised to preserve the total amount of rainfall in the parent grid R_0:

$$\sum_{i=1}^{4} W_{0-i} = 4$$

Finally rainfall value in the smaller-scale constituent grid is computed through multiplying the parent value by the relevant calculated weight:

$$R_{0-i} = W_{0-i} \cdot R_0, \qquad i = 1,...,4$$

In each downscaling step the weights and precipitation values are calculated for each grid of the rainfall map. The process is repeated until the desired resolution is achieved.

4 Results and discussion

4.1 Data

The downscaling method has been tested on precipitation rate analyses derived from NIMROD system. A spatial resolution of the data is 1 km, subsequent products are generated every 10 minutes. The domain is 1600x1600 km that covers Poland and much of Central and Western Europe. Five rainfall events that are listed in the Table 1 were selected for testing.

Table 1. Statistical characteristics of rainfall rate products composing precipitation events employed for downscaling analyses

Event date	Number of products	Mean (mm/hour)	Variance (mm/hour)
23/08/2005 2-7 UTC	30	0.09	0.24
12/09/2005 3-7 UTC	25	0.16	1.23
27/09/2005 3-7 UTC	25	0.03	0.09
27/09/2005 15-19 UTC	25	1.04	0.63
28/09/2005 15-19 UTC	25	0.14	0.34

4.2 Statistical analyses

Statistical analysis of the proposed downscaling method effectiveness is to give answer to a question: is it possible to deduce values in constituent smaller grids having only information about values in parent larger grid and its vicinity?

For this purpose the data was upscaled from 1-km resolution to coarser ones up to 32-km. In order to evaluate the dynamic downscaling quality two other methods were introduced:

– simple downscaling where constituent grids directly inherited values from the parent grid,

– random downscaling where all cascade weights are random values.

Mean values of precipitation fields are preserved during downscaling process as a consequence of the proposed method assumption. Therefore investigations have been focused on behaviour of variance.

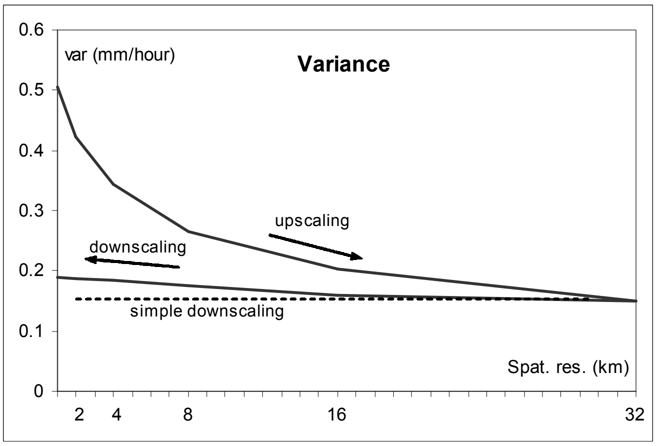

Fig. 3. Diagram of variance as a function of spatial resolution for upscaling and downscaling process with dynamic method.

Table. 2. RMSE and R as quality characteristics of downscaling from different initial spatial resolutions into 1-km map using deterministic cascade: dynamic method, simple method, and random method – the best and the worst realisation are shown.

Initial resolution (km)	Dynamic method	Simple method	Random method	
			best values	worst values
RMSE				
2	0.246	0.297	0.250	0.343
4	0.374	0.427	0.377	0.547
8	0.495	0.534	0.497	0.741
16	0.609	0.634	0.608	0.960
R (correlation coefficient)				
2	0.938	0.908	0.936	0.890
4	0.855	0.806	0.852	0.741
8	0.743	0.690	0.740	0.564
16	0.617	0.573	0.618	0.380

In Fig. 3 diagram of variance in dependence on subsequent upscaling and downscaling steps is shown. Decrease in variance is observed towards upscaling. Next increase in variance occurs with downscaling but to much smaller extent (note that the increase is not observed for simple downscaling).

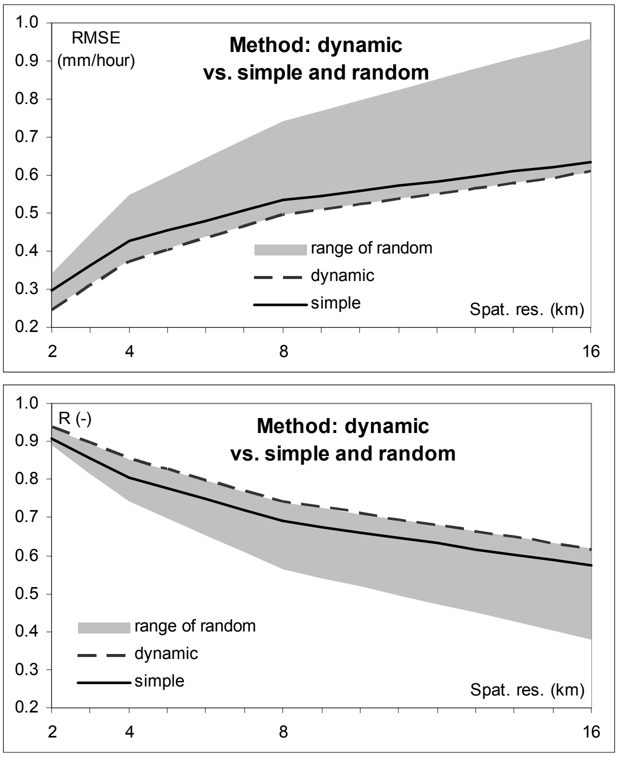

Fig 4. Evaluation of downscaling quality in terms of RMSE and R in dependency on initial spatial resolution (downscaling into 1-km map).

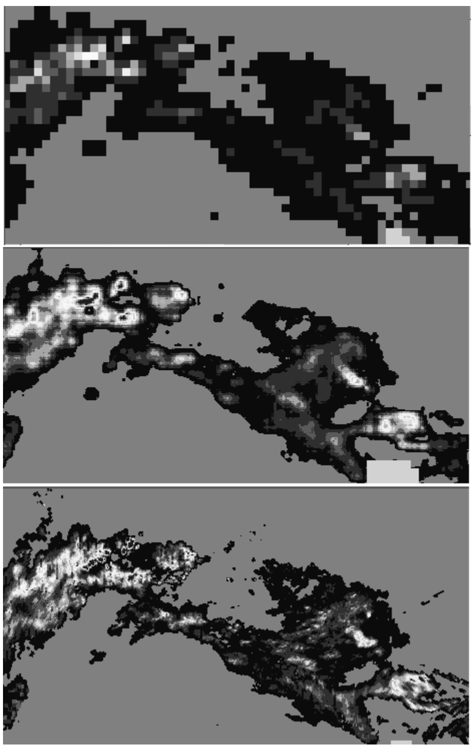

Fig. 5. Example of precipitation downscaling from 8 to 1-km resolution. Fields: (a) upscaled to 8-km resolution, (b) downscaled to 1 km, (c) real 1-km pattern.

In Table 2 quality of downscaling in terms of RMSE and correlation coefficient (R) is presented. It is also shown in diagram in Fig. 4.

The coarser the initial resolution, the worse the quality of downscaling to 1 km. Having analysed RMSE, R (Fig. 4), and variance (Fig. 3) there is observed difference in quality using dynamic and simple method, however it is not very significant. It may suggest that information about spatial distribution of precipitation fields is lost in upscaled field and can hardly be reproduced in downscaling process.

Results obtained using random weights are various and even after not big number of realisations are significantly different. The results may be either very bad or quite good as for dynamic method.

4.3. Example of the dynamic method running

In Fig. 5 one example of the method performance is presented. The precipitation field with initial 8-km spatial resolution (Fig. 5a) was disaggregated to 1-km resolution (Fig. 5b). As a reference the real 1-km field is shown (Fig. 5c). The algorithm reflected wet and dry grids quite well and the spatial distribution of precipitation was almost correctly reconstructed, as R = 0.79.

5. Conclusion

The presented dynamic method of precipitation data downscaling is not advanced because it does not use any information but radar-based data. As a result information about small-scale spatial precipitation distribution has to be inferred only from this data. In the proposed dynamic method an attempt of the precipitation pattern reconstruction has been made on the basis of precipitation variability in the near vicinity of the larger-scale grid. The results show usefulness of the method however its quality is limited and depends on initial spatial resolution.

Acknowledgement: The paper was prepared in the frame RISK-AWARE project ("Risk advanced weather forecast system to advise on risk events and management", INTERREG IIIB CADSES programme).

References

Güntner, A., Olsson, J., Calver, A, and Gannon, B., 2001. Cascade-based disaggregation of continuous rainfall time series: the influence of climate. *Hydrol. Earth Syst. Sci.*, **5**, 145-164.

Pathirana, A., Herath, S., Yamada, T., 2003. On the modelling of temporal correlations in spatial-cascade rainfall downscaling. In: Y. Tachikawa, B.E. Vieux, K.P. Georgakakos, E. Nakakita (Eds.), *Weather radar information and distributed hydrological modelling*, IAHS Publication no. 282, 74-82.

Schipper, J.W., 2005. *Downscaling of precipitation in the Upper Danube catchment area*, München 2005.