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Stochastic Simulation of simultaneous Precipitation Time Series in high temporal Resolution for multiple Locations

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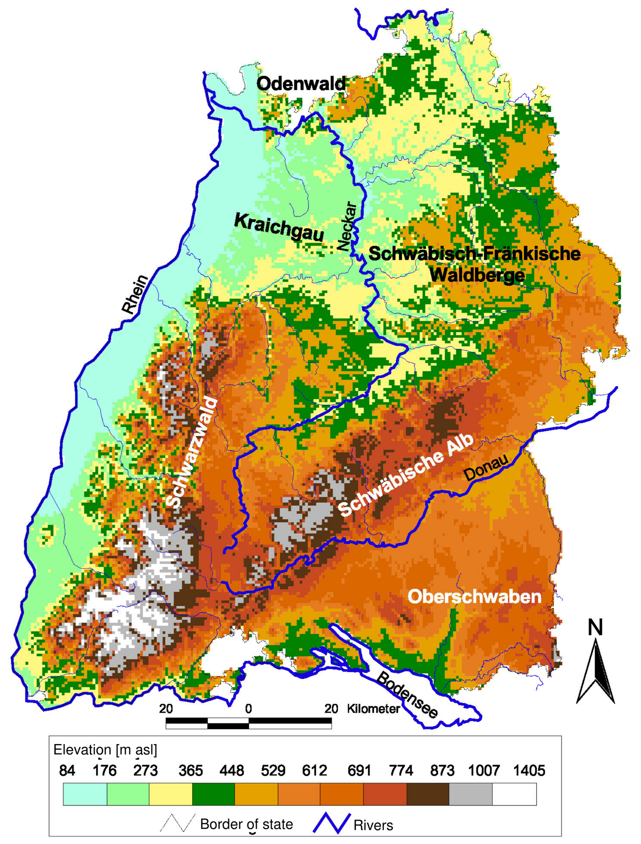
Introduction



Elevation in the project area

The state of Baden-Wuerttemberg (BW) in southern Germany has a very diverse topography. The dominating precipitation process is advective rain fields arriving from the south-west. The high mountains of BW are located in the Black Forest, which is in the south-west, thus they receive a lot of the arriving rain.

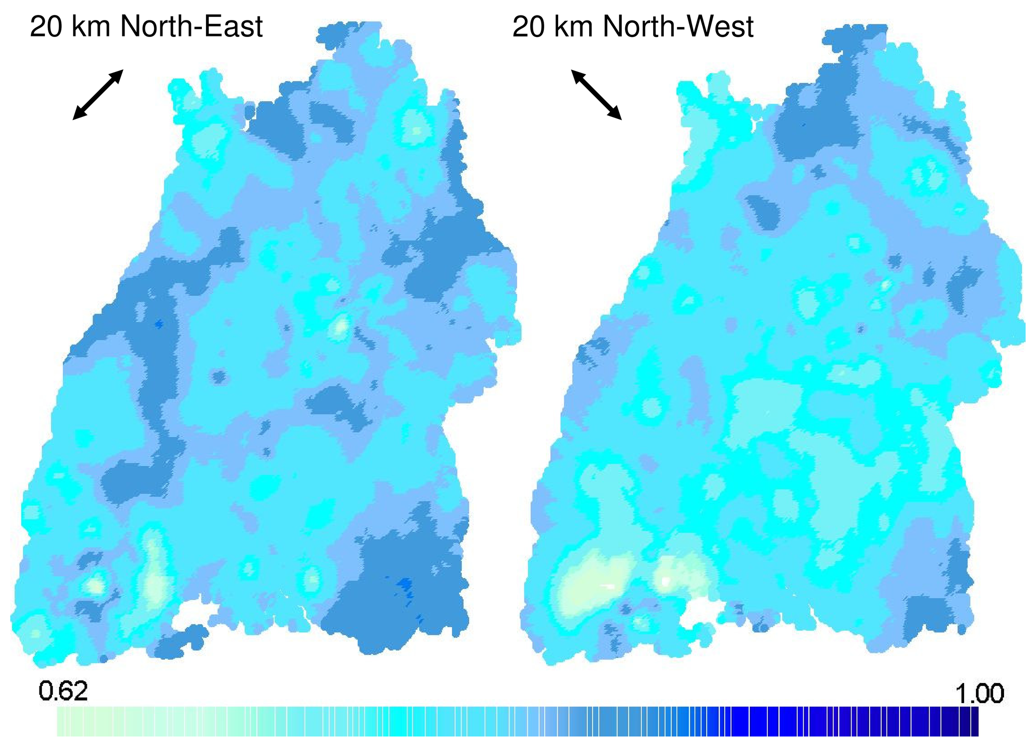
As a result, precipitation is very non-homogeneous in BW. To account for this in the layout of hydraulic structures, such as sewage systems, a stochastic precipitation time series generator has been developed. The generated point precipitation time series contains the local properties derived from measured data.

Experience with these time series has shown that a single point is not representative for a sewage system that drains a larger area. Therefore two or more simultaneous time series need to be generated. For this purpose, a time series generator for simultaneous time series at multiple locations has been developed. It can generate time series in 5 minute resolution for a period of up to 30 years (1975-2003).

The intended application of the simultaneous time series leads to three spatial statistical properties, which should be considered in generation. Correlation on daily and hourly time scale, movement direction of rain fields and the simultaneous behavior of extremes at multiple sites. These properties are calculated state wide.

Correlation of Precipitation

The correlation of daily precipitation is estimated using a fourdimensional Ordinary Kriging model (Brommundt, Bárdossy, 2006). This approach uses correlation estimated from the data of 575 rain gauges throughout the state. An exponential function is fitted to the data to account for the overall behaviour. Kriging is done with the residuals between data and functional approach.



Cross Correlation of daily data estimated from the 4D Kriging model.

This model allows for heterogeneity and anisotropy of the spatial correlation of the daily data.

An adaptation of the model for the correlation of hourly data, calculated from 295 rain gauges in BW, failed. Several variations were tested.

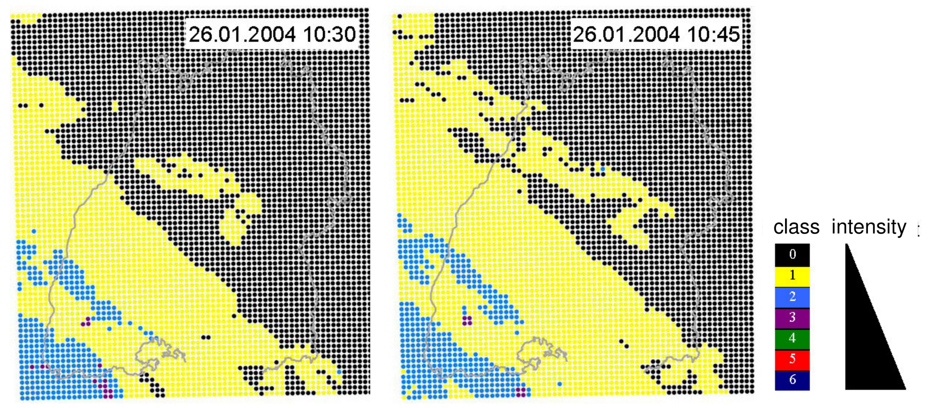
Hence a scaling approach using the model for the daily correlation was implemented. After several experiments, incorporation of the logarithm of the distance between stations yielded the best results.

$$r_{1h}(s_i, s_j) = r_{24h}(s_i, s_j) \cdot \left(0.983 - 0.116 \cdot \log\left(d_{s_i, s_j}\right)\right) - 0.072$$

r_{xh} correlation
d distance
s station location

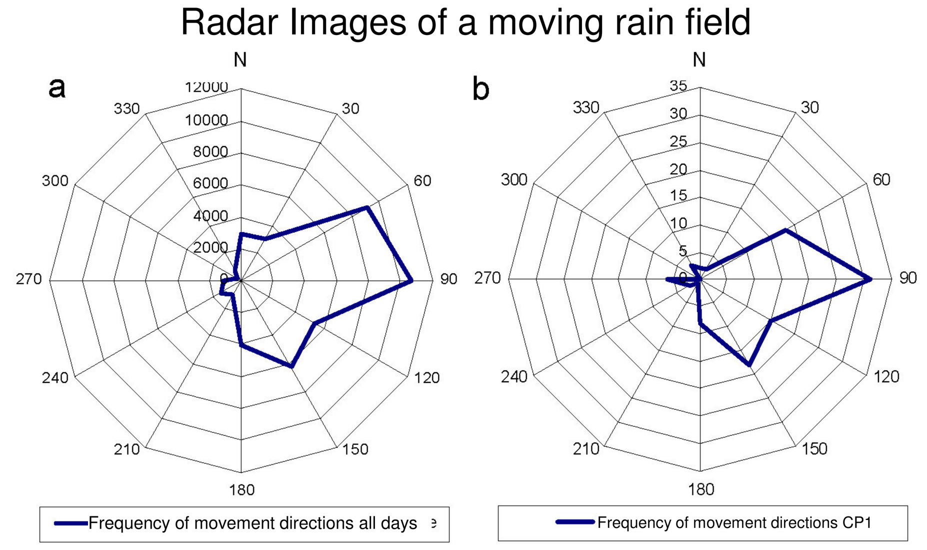
Movement of Rain Fields

Movement of rain fields has been derived from radar data. For this purpose German Weather Service provided 7.5 years (07.1997-12.2004) of 15 min radar images in 4 km² spatial resolution. These images contain censored reflectivity data in seven classes.



Radar Images of a moving rain field

Using a ZR-relationship the information is transferred to rain and aggregated to hourly values. From this information movement direction and speed are estimated by displacing the consecutive



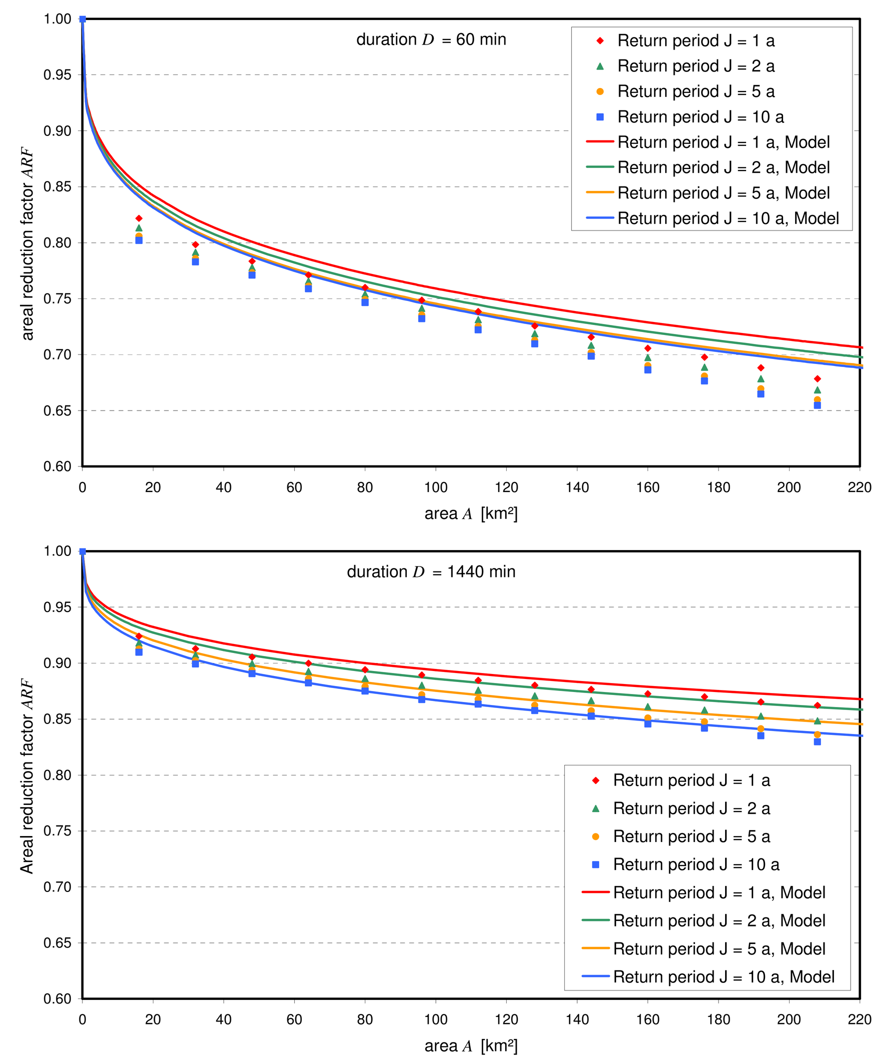
Distribution of speed and direction of rain fields

images until the correlation between them is maximal. This information is evaluated conditional to the overall weather situation at the day of the observation. Weather situation is formulated as a CP (Bárdossy et al., 1992), hence movement information is available as a function of the dominant CP at any day and not only for the radar observation period.

Extremes

Spatial behavior of extremes is considered by an areal reduction factor (ARF). This factor relates a point extreme value to the extreme value one has to expect when averaging over a certain area. The ARF depends on the area, the duration and the probability of the event.

Since data quality and spatial density of the rain gauges are not sufficient to estimate an ARF, radar data has been used to derive the ARF. In a regression a function has been fitted describing the ARF.

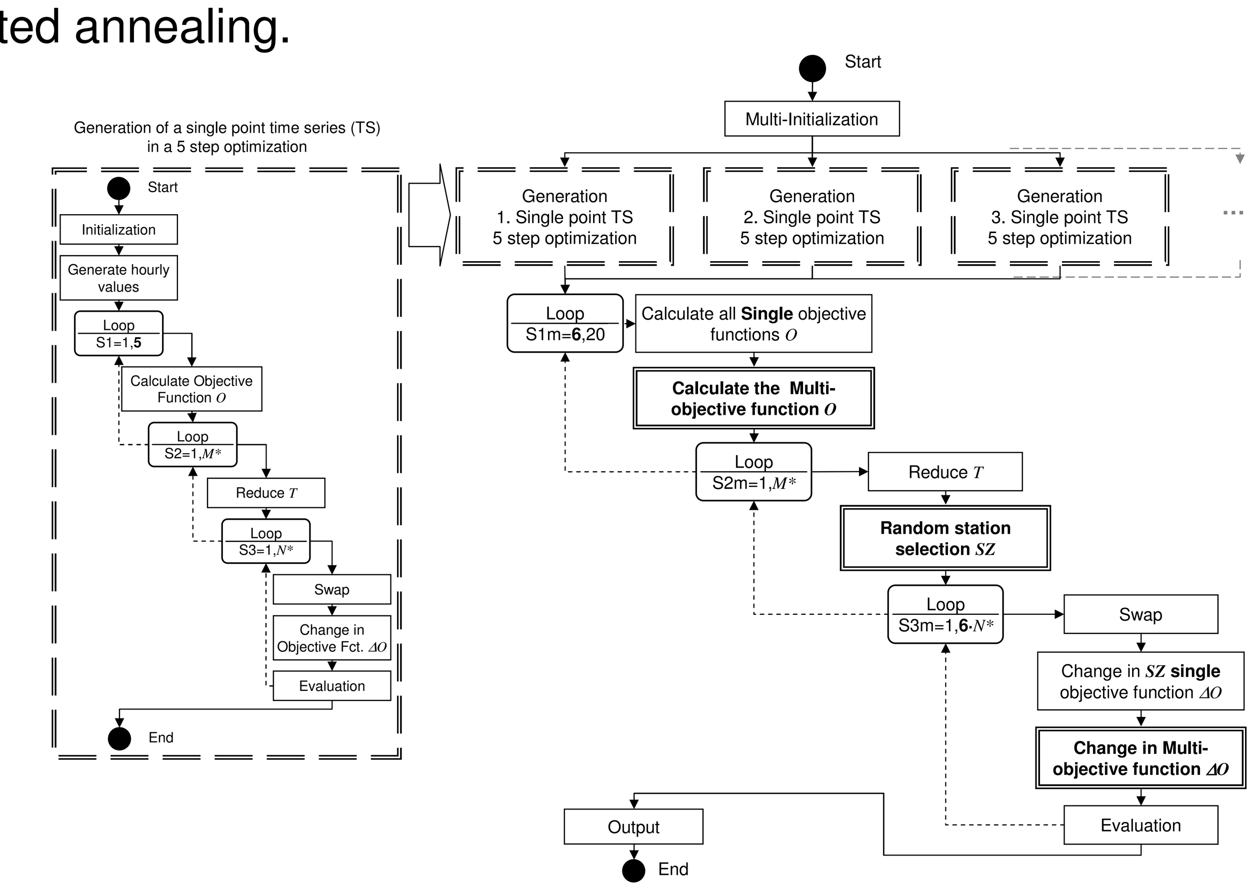


Areal reduction factor for 60 min event (top) and for a 1440 min event (bottom).

Time Series Generation

To create an annual precipitation time series for an arbitrarily chosen set of points in the project area the related statistical properties are culled from the database, which exists from the single point time series generator. These properties are considered at each of the multiple locations individually. Afterwards the three statistical properties describing the spatial relationship are estimated for the chosen set of points.

Hence a data set of statistical properties is available, which describes the individual and simultaneous characteristics of the time series to generate. This set includes parameters of the gamma distribution, from which independent time series for each location are generated. The flowchart below shows, how the generation works. The optimization technique used is simulated annealing.



Flowchart of the simultaneous generation

Results

- A generator for simultaneous time series of precipitation for multiple locations has been implemented successfully.
- Time series in a resolution up to 5 minutes can be generated for 30 years (1974-2003) for arbitrary sets of locations.
- Application of these time series in a urban sewage model showed, that these time series allow for a more reliable and economic design of urban drainage systems.

References

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