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Spatial Correlation of Radar and Gauge-measured Precipitation in Different Temporal Aggregation Steps

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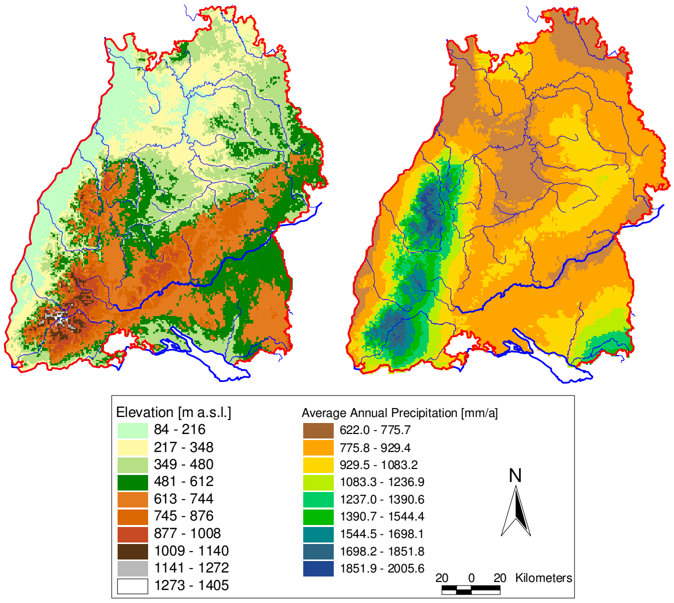
Introduction

The state of Baden-Wuerttem-berg (BW) in southern Germany has a very diverse topography. The dominating precipitation process is advective rain cells arriving from the south-west. The highest mountains of BW, located in the Black Forest, are situated 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 point precipitation time series generated 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, spatial correlation of two arbitrary points in BW is needed.



Elevation and Average Annual Precipitation

Correlation of Daily Precipitation

The correlation of daily precipitation is estimated using a 4D Ordinary Kriging model. First a exponential function is fitted to the correlation data:

$$f(x,y) = e^{-\frac{|x-y|}{a}}$$

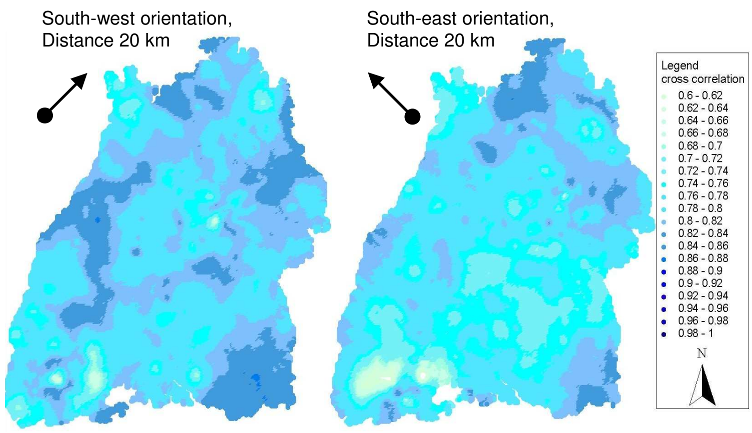
$\boldsymbol{x, y}$ denote here station pairs for which the correlation is measured. This function is evaluated and subtracted from the whole data set. The residuals are interpolated using Ordinary Kriging:

$$r^*(x,y) = f(x,y) + \sum_{i=1}^{n}\sum_{j=1}^{n}\lambda_{i,j}(x,y)\cdot\left(r(x_i,x_j) - f(x_i,x_j)\right)$$

This way, the correlation for daily values can be estimated for any arbitrary station pair in BW. Cross validations gain a value of 0.9477.

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 failed. Several variations were tested, but none of them were successful.



Location and direction dependent cross correlations in a south-west (left) and south-east (right) direction, 20 km distance, calculated on a 1 km² grid

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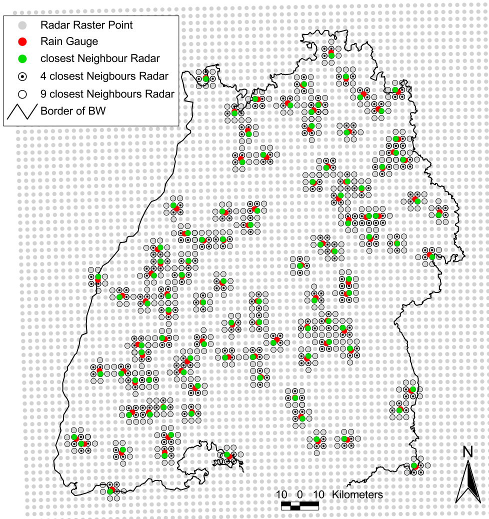
Correlation of Hourly Precipitation

The geostatistical approach, which uses only data from rain gauges, is not sufficient to estimate correlation of hourly precipitation. Thus radar data is incorporated as an additional information source.

For this project, the German Weather Service (DWD) provided 15 min radar images in 4 km² spatial resolution. These images contain censored reflectivity data in seven classes. Data is from July 1, 1997 until December 31, 2004. The overall failure rate is 1.55 %.

Radar raster and rain gauges



The easiest and most apparent approach to integrate radar information is to convert reflectivity into precipitation intensity and evaluate the spatial correlation of this data. This spatial behaviour has to be compared to the correlation of the gauge measured rain.

A ZR-relationship has been established at 101 rain gauges in BW.

$$R = \left(\frac{Z}{a}\right)^{\frac{1}{b}} = \left(\frac{10^{\frac{dBZ}{10}}}{a}\right)^{\frac{1}{b}}$$

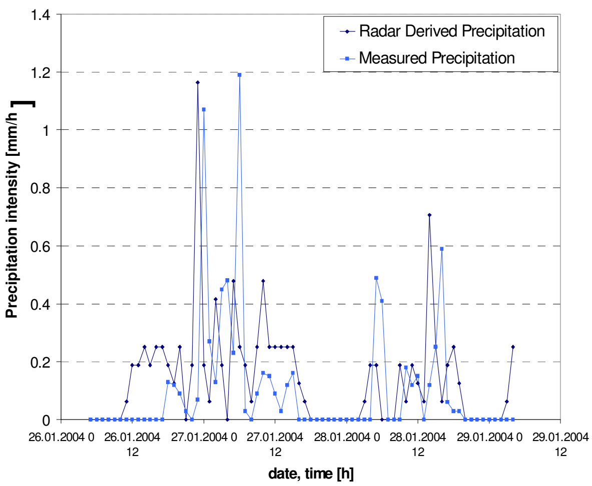
Z Reflectivity
R Rain intensity
a,b Parameters

Additionally two different conversions were used for comparison.

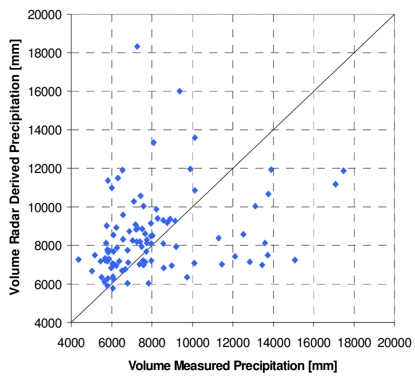
This approach gained no sufficient results. Problems identified are:
-rain volume, which is overestimated in the radar derived time series
-simultaneity of rain and radar

Established conversions radar → rain

Class	Class Limits [dBZ]	DWD [mm/h]	Internet [mm/h]	ZR-Relation [mm/h]
0	0 - 7	0.000	0.000	0.000
1	7 - 19	0.251	0.200	0.181
2	19 - 28	1.163	1.500	0.759
3	28 - 37	5.005	3.900	2.944
4	37 - 46	21.538	14.000	11.419
5	46 - 55	92.685	50.000	44.293
6	55 - 60	150.000	100.000	109.991



Exemplary time series of precipitation

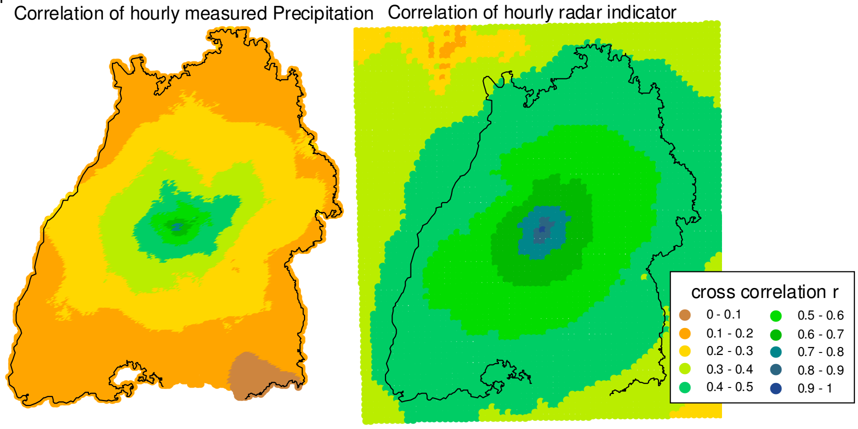


Scatter plot of precipitation

Indicator Correlation

Comparison between the correlation of rain gauges and the indicator (1 = rain, 0 = no rain) correlation of the radar data show, that the spatial structure is similar.

Correlation of hourly measured Precipitation Correlation of hourly radar indicator



Spatial structure of rain and radar correlation for the same reference station

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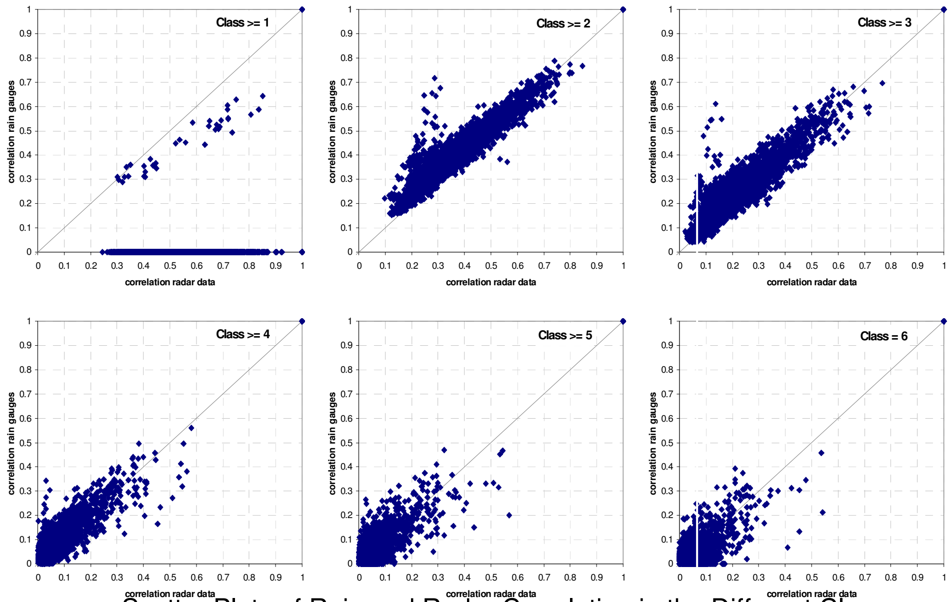
Indicator Correlation of Radar and Rain

To compare the spatial structure in both data, the rain measurements are divided into seven classes. This is done for each of the 101 rain gauges according to the frequency of the radar classes at the closest radar raster point. The correlation for six indicator time series is subsequently calculated for the radar and the rain data.

$$I(t, c_{ref}) = \begin{cases} 1 & \text{if } c(t) \geq c_{ref} \\ 0 & \text{else} \end{cases}, c_{ref} = 1, \ldots, 6$$

$c(t)$ time series of classes (rain and radar)
c_{ref} class to calculate indicator for

The correlation of rain and radar indicator time series is very similar in each class, thus it can be assumed that the spatial structure is also similar.



Errors are set to 0

Scatter Plots of Rain and Radar Correlation in the Different Classes

Results and Outlook

- The straight forward conversion from radar to rain data is not appropriate for spatial correlation estimation.
- The spatial structure of rain and radar indicators is similar.
- Radar data can be used to estimate spatial correlation of precipitation stations, if only the structure is used.
- A function has to be derived to calculate the spatial correlation from the indicator correlations.

References

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