Adjustment of a robust Q-Z/R-relationship for hydrological modeling using observed river discharge data

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INTRODUCTION

The quality of hydrological modeling is limited due to the availability of high resolution temporal and spatial input data. Rain gauge measurements give accurate information at a single point while radar measurements provide good spatial information. On the other hand, it is difficult to estimate areal precipitation from rain gauge measurements and absolute rainfall intensities from radar data. In this study, a method to calibrate a Z/R-relationship using observed river discharge data is presented. River gauge measurements from five subcatchments with sizes around 100 km^2 are used to estimate Q-Z/R-relationships using the calibrated hydrological model WASIM-ETH and the resulting spatially differentiated precipitation.

CALIBRATION of the HYDROLOGICAL MODEL

This study was performed in the Ammer catchment (*Fig.1*) in southern Bavaria, Germany. The simulated catchment size is 601 km². Due to the complex orography (*Fig. 2*), it faces very short reaction times of the river gauges to rainfall events.

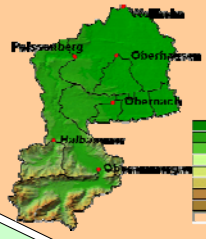


***Fig.2**: DEM of the Ammer catchment and position of the river discharge measurements*

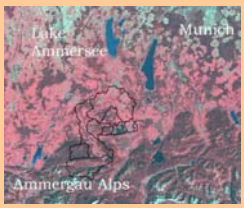


***Fig.1**: Location of the Ammer catchment, ~45 km southwest of Munich; black outlines show simulated subcatchments. Background: LANDSAT TM (7-5-3), 2001-06-19*

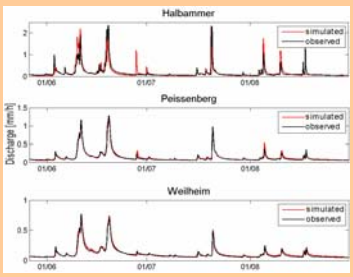


***Fig.3**: Results from the hydrological simulations using interpolated rain gauge measurements for the calibration period in Summer 2001 (June-August).*

River gauge	Area [km^2]
Oberammergau	114
Halbammer	43.5
Obernach	51.5
Oberhausen	117
Peissenberg	294
Weilheim	601

***Tab. 1**. Subbasin characteristics in the Ammer catchment.*

RADAR DATA

- Radar Data from Meteorological Observatory Hohenpeißenberg (MOHp)
- 3-min. precipitation scan
- ~ 65000 DX-scenes June-August 2001
- Standard Processing of Radar data *($Z=256R^{1.42}$)* and simplified after RADOLAN (2004): (Radar Online Adjustment), German Weather Service, Department for Hydrometeorology, http://www.dwd.de/de/wir/Geschaeftsfelder/Hydrometeorologie/a_href_pages/RADOLAN/radolan-online.htm

***Tab. 2**: Simplified split three-part Z/R relationship after RADOLAN (2004) which is used as input data for optimization process; Crossovers between parts depend on reflectivity values.*

dBZ	< 36.5	36.5 … 44	> 44
a	125	200	77
b	1.4	1.6	1.9

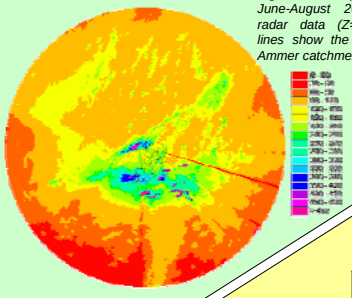
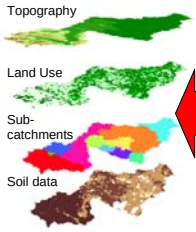


***Fig. 4**: Total precipitation sum June-August 2001 [mm] from radar data ($Z=256R^{1.42}$); black lines show the location of the Ammer catchment.*

Distributed Hydrological Model WaSiM-ETH

- after Schulla, J. & Jasper, K. (2000): Model description WaSiM-ETH. Institute for Geography, ETH Zürich, 167 pp.
- calculation of the vertical water fluxes in the unsaturated zone is done by the discrete Richards Equation.
- soil moisture content is parameterized considering suction head and hydraulic conductivity
- interflow is generated in defined different soil layers depending on drainable water content, suction, the hydraulic conductivity and gradient.
- surface runoff is routed using a subdivision of the basin into flow time zones.
- evapotranspiration is calculated following the approach of Penman-Monteith
- contains a simple 2D groundwater model which is dynamically coupled to the unsaturated zone.



OPTIMIZATION

Aim of the optimization process is to find a ***robust Q-Z/R-relationship*** for hydrological modeling in the Ammer catchment. It is applied in a way that the ***Nash-Sutcliffe-efficiency is maximized over a three-month period (over five subcatchments)***:

$$1-\frac{\sum_{i=1}^{N}\left(Q_{obs,i}-Q_{sim,i}[R(Z,a_j,b_j,c_1,c_2)]\right)^2}{\sum_{i=1}^{N}\left(\overline{Q_{obs}}-Q_{sim,i}[R(Z,a_j,b_j,c_1,c_2)]\right)^2} \overset{!}{\Rightarrow} \max$$

Q_{obs} observed river discharge data
Q_{sim} simulated discharge data
i subcatchment
c crossover between relationship parts

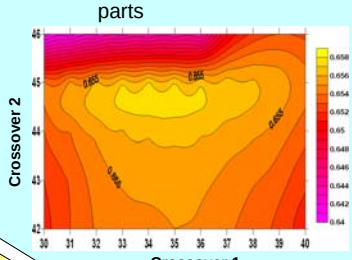


***Fig. 5:** Calibrating subcatchment Obernach: Optimization process was done iteratively calibrating always two parameters at the same time*

***Tab. 3**: Resulting **Q-Z/R-relationship** for the Ammer catchment based on river discharge data.*

dBZ	<36	36 … 44.5	>44.5
a	104	131	73
B	1.43	1.57	1.63

***Tab. 4:** Performance of river runoff simulations (Nash-Sutcliffe efficiency) using different radar rainfall estimates and station data for summer 2001.*

	Ober-ammergau	Halb-ammer	Ober-nach	Ober-hausen	Peißen berg	Weil-heim
Station data	0.2	0.58	0.68	0.18	0.9	0.92
$Z=256R^{1.42}$	0.538	0.536	0.414	-0.204	0.943	0.962
simpl. RADOLAN	0.561	0.619	0.588	0.35	0.967	0.967
Q-Z/R	0.582	0.71	0.659	0.471	0.956	0.969

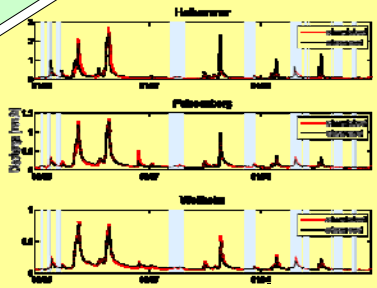


***Fig.6**: Simulation results using the calibrated Q-Z/R-relationship, blue background denotes radar data gap.*

***Fig.7**: Difference in rainfall sum [mm] over three months in Summer 2001 using the calibrated Q-Z/R-relationship (left) and interpolated (inverse distance weight) station data (right side).*

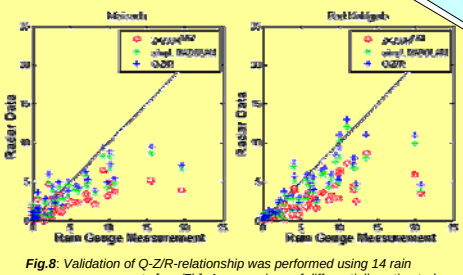


***Fig.8**: Validation of Q-Z/R-relationship was performed using 14 rain gauge measurements [mm/7h]. A comparison of differentially estimated radar rainfall showed good results although high rainfall intensities are still underestimated with the new method.*

RESULTS

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