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Uncertainties in water balance estimations due to scarce meteorological information: a case study for the White Volta catchment in West Africa

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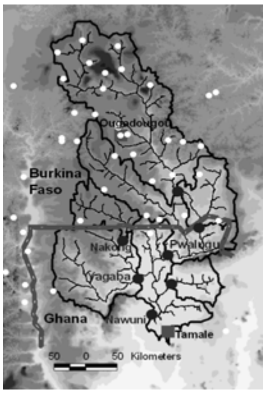
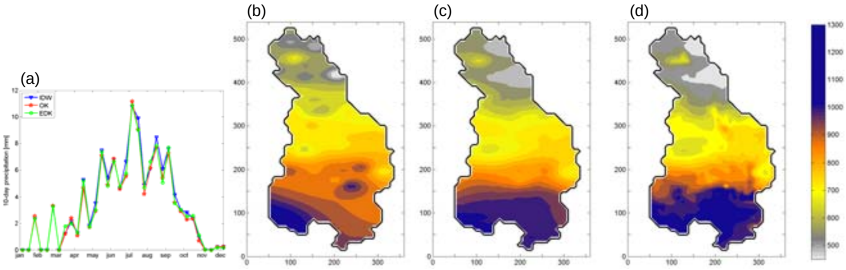


INTRODUCTION

- Scientifically sound decisions in sustainable water management are usually based on hydrological modelling, which can only be accomplished with meteorological information. Especially in regions with a weak infrastructure, where meteorological data are not available at a sufficient spatial and temporal resolution, spatial interpolations of coarse-resolution meteorological point observations are afflicted with uncertainties. This particularly applies to discontinuous variables like precipitation.
- These observation data (point measurements) have to be converted to areal information using various interpolation techniques, e.g. geostatistical methods like inverse distance weighting or kriging. Considering the requirements for an increasing accuracy of areal estimations, regions with a weak infrastructure are usually handicapped due to: (a) a sparse density of gauges, and (b) a variable length of periods containing large data gaps. This means that in general areal estimations in regions with a weak infrastructure are afflicted with larger uncertainties.
- In this study, the geostatistical interpolation techniques of inverse distance weighting and kriging were applied for the areal estimation of precipitation, and their effects on hydrological simulations were investigated.
- The area under study is the White Volta catchment (94 000 km2) in the semi-arid environment in West Africa, where precipitation intensities as well as annual rainfall amounts show a strong inter-annual and inter-decadal plus a spatially small scale variability.

APPLIED GEOSTATISTICAL METHODS ESTIMATING AREAL PRECIPITATION

• The accuracy of the estimation at each point or grid is a function of the distance from the nearest gauges. The simplest technique is an **inverse distance weighting** of gauge values for each point. Weights are calculated depending on the distances between the location requiring an estimate and the locations of the observations.
• **Kriging** is a geostatistical method that uses the variogram of the precipitation field (i.e. the variance between pairs of points that lie different distances apart) to estimate interpolated values. Kriging calculates the "best" estimate of the values (BLUE: Best Linear Unbiased Estimator).
• Apart from ordinary kriging described above, **external drift kriging** was applied, where external knowledge is incorporated in the system as external drift. The estimator thus depends on the additional variable.
• As external drift the digital elevation model was used.
• Further external drifts, e.g. spatial distribution of annual precipitation will be applied.

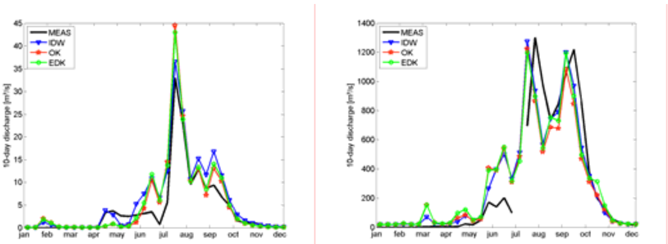


(a) Time series of precipitation (10-day mean) averaged over the entire catchment as obtained from the interpolation techniques of inverse distance weighting, ordinary kriging, and external drift kriging. Annual precipitation [mm] for 1968 using (b) inverse distance, (c) ordinary kriging, and (d) external drift kriging interpolation techniques.

➢Interpolation method has minor impact on time series averaged over catchment, but influences the areal precipitation field.

IMPACT OF PRECIPITATION UNCERTAINTIES ON HYDROLOGICAL MODELLING

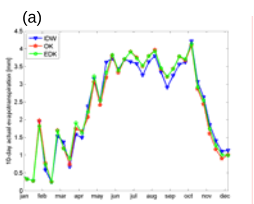
• For hydrological simulations, the Water balance Simulation Model WaSiM-ETH (Schulla & Jasper, 2000) was used which is a deterministic, fully distributed modular model.
• The spatial resolution of this study is 1 × 1 km2 which results in a regular grid of 411 × 631 grid points. The temporal resolution is 24 h.

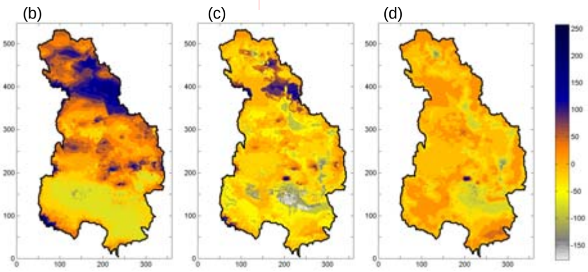


Time series of the routed discharge (10-day mean) for: (a) the source catchment of Nakong and (b) the complete basin in Nawuni as obtained from the interpolation techniques of inverse distance weighting, ordinary kriging, and external drift kriging.

➢ The general behaviors of all time series are comparable. But model efficiencies vary for routed discharge, without a general preference for any interpolation method.

➢ Spatial distribution of annual sum of actual evapotranspiration is influenced by interpolation method.





(a) Time series of real evapotranspiration (10-day mean) averaged over the entire catchment as obtained from the interpolation techniques of inverse distance weighting, ordinary kriging, and external drift kriging. Differences of the spatially distributed annual evapotranspiration sums [mm] resulting from the calculation of areal precipitation by (b) inverse distance weighting and ordinary kriging, (c) inverse distance weighting and external drift kriging, and (d) ordinary and external drift kriging.

CONCLUSIONS

• The geostatistical methods inverse distance weighting, ordinary and external drift kriging were applied for the areal estimation of precipitation in the White Volta catchment.
• The results of the areal estimation of both daily and annual precipitation show that the method selected influences the areal precipitation field. Compared to inverse distance weighting, ordinary kriging calculates smoother contours. External drift kriging increases spatial variability based on the selected external drift.
• The results of the impact study of the different interpolation techniques for areal precipitation on hydrological modelling show that the general patterns of the time series of water balance variables presented are comparable. But the comparison of Nash-Sutcliffe coefficients shows varying model efficiencies for the different inter-polation methods. The spatial distribution of the annual sum of real evapotranspiration is influenced by the interpolation method selected for the calculation of areal precipitation.

ACKNOWLEDGEMENTS

This work was funded by the BMBF (German Ministry for Education and Research) through the project GLOWA-Volta.

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