Analysis of confidence in continental-scale groundwater recharge estimates for Africa using a distributed water balance model


1 Introduction

Recent studies suggest that, if exploited, groundwater could help to meet the increasing demand for fresh water in Africa with an estimated total groundwater storage between 0.36–1.75 million km$^3$ (MacDonald et al., 2012). Quantifying groundwater recharge is vital as it forms a primary indicator of the sustainability of underlying groundwater resources. The complexity of recharge processes in Africa means that simulating these processes is often highly uncertain. This study is an initial exploration of the uncertainty of recharge simulations over Africa based on a preliminary sensitivity analysis using the ZOODRM distributed hydrological model code developed by the British Geological Survey.

2 Water balance model of Africa

ZOODRM is a distributed water balance model that implements simple conceptual representations of hydrological processes over the vegetation canopy, land surface, river network, soil zone and aquifer (Figure 2). Using readily available global datasets of surface topography, vegetation, soil and the underlying bedrock, a ZOODRM water balance of Africa was constructed. The aquifer storage and discharge parameters were drawn from the recent quantitative groundwater maps of Africa (MacDonald et al., 2012), National Oceanic and Atmospheric Administration and potential evapotranspiration (PET) products were used in conjunction with MODIS leaf area index (LAI) data to drive the model.

3 Model configuration

The model uses a 50x50 km Cartesian grid of equally spaced nodes. The model has been calibrated to available river flow data from the Global Runoff Data Centre (http://www.bafg.de). Sensitivity has been explored by perturbing model parameters and weather data by ±10%. Different recharge calculation methods including a ‘wetting threshold’ method and two modified FAO methods with different representations of vegetation root distribution (Figure 3) were also used to assess their relative influence on the simulated recharge.

4 Groundwater recharge simulations

For the control run, a soil moisture accounting recharge method was used with root distributions defined by Zeng (2001). The mean annual recharge was calculated as 0.829 km$^3$ yr$^{-1}$. A comparison with available field data shows that the model has an overall positive bias which is most pronounced in the tropics (Figure 4). The simulated annual recharge changes by >15% when using a perturbed rainfall input (Figure 5). Recharge simulations are also sensitive to the soil field capacity and root coeffcient parameters while the rooting depth, LAI and river bed hydraulic conductivity have a negligible impact on groundwater recharge.

Switching the root distribution to that proposed by Griffiths et al. (2006) and using the wetting threshold method reduced the simulated annual recharge by 2009 (-68%) and -1140 (-31%) km$^3$ yr$^{-1}$ respectively indicating that proper understanding and representation of recharge processes is vital to quantify groundwater recharge over Africa.

5 Future work

This preliminary sensitivity analysis indicates that large-scale simulations of groundwater recharge in Africa are likely to be subject to considerable uncertainty. Further research needs to be conducted to quantify this uncertainty through proper examination of model parameter and structure uncertainties. Furthermore, there is still little understanding of which recharge estimation techniques are most suited to contrasting environments over the African continent.

References

