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Groundwater modelling for time periods of up to hundreds of thousands of years.

Gerrit H. de Rooij[1] and Thomas Mueller[1,2]
[1]Helmholtz Centre for Environmental Research - UFZ, Department Soil System Science, Halle (Saale), Germany (gerrit.derooij@ufz.de)
[2]GEOMAR Helmholtz Centre for Ocean Research Kiel, FB2/MG, Kiel, Germany (th.mueller@ufz.de)

Occasionally, there is an interest in groundwater flows over many millennia. The input parameter requirement of numerical groundwater flow models and their calculation times limit their usefulness for such studies.

Analytical models require considerable simplifications of the properties and geometry of aquifers and of the forcings. On the other hand, they do not appear to have an inherent limitation on the duration of the simulated period. The simplest models have explicit solutions, meaning that the hydraulic head at a given time and location can be calculated directly, without the need to incrementally iterate through the entire preceding time period like their numerical counterparts.

We developed an analytical solution for a simple aquifer geometry: a strip aquifer between a no flow boundary and a body of surface water with a prescribed water level. This simplicity permitted flexible forcings: The non-uniform initial hydraulic head in the aquifer is arbitrary and the surface water level can vary arbitrarily with time. Aquifer recharge must be uniform in space but can also vary arbitrarily with time.

We also developed a modification that verifies after prescribed and constant time intervals if the hydraulic head is such that the land surface is covered with water. This excess water then infiltrates in areas where the groundwater level is below the surface and the remainder is discharged into the surface water. The hydraulic head across the aquifer is modified accordingly and used as the initial condition for the next time interval. This modification models the development of a river network during dry periods. The increased flexibility of the model comes at the price of the need to go through the entire simulation period one time step at a time. For very long time records, these intervals will typically be one year.

Given the uncertainty of the aquifer parameters and the forcings, the models are expected to be used in a stochastic framework. We are therefore working on a shell that accepts multiple values for each parameter as well as multiple scenarios of surface water levels and groundwater recharge rates, along with an estimate of their probabilities. The shell will generate all possible resulting combinations, the number of which can easily exceed 10000, then runs the model for each combination, and computes statistics of the average hydraulic head and the aquifer discharge into

the surface water at user-specified times.

A case study will tell if this endeavor is viable. We will model the aquifer below the mountain range north of Salalah in Oman, which separates the desert of the Arabian Peninsula from the coastal plain at its southern shore. Rainfall estimates from the isotopic composition of stalactites in the area indicate distinct dry and wet periods in the past 300 000 years. In combination with estimated sea level fluctuations over that period, this provides an interesting combination of forcings. We examine the dynamics of the total amount of water stored in the aquifer, and of the outflow of water from the aquifer into the coastal plain.