Geophysical Research Abstracts
Vol. 19, EGU2017-9351, 2017
EGU General Assembly 2017

Water, heat, and vapor flow in a deep vadose zone under arid and hyper-arid conditions: a numerical study.

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Groundwater recharge in arid regions is notoriously difficult to quantify. One reason is data scarcity: reliable weather records (rainfall, potential evapotranspiration rate, temperature) are typically lacking, the soil properties over the entire extent of the often very deep vadose zone are usually unknown, and the effect of sparse vegetation, wadis, (biological) soil crusts, and hard pans on infiltration and evaporation is difficult to quantify. Another reason is the difficulty of modeling the intricately coupled relevant processes over extended periods of time: coupled flow of liquid water, water vapor, and heat in a very deep soil in view of considerable uncertainty at the soil surface as indicated above, and over large spatial extents.

In view of this myriad of problems, we limited ourselves to the simulation of 1-dimensional coupled flow of water, heat, and vapor in an unvegetated deep vadose zone. The conventional parameterizations of the soil hydraulic properties perform poorly under very dry conditions. We therefore selected an alternative that was developed specifically for dry circumstances and modified another to eliminate the physically implausible residual water content that rendered it of limited use for desert environments.

The issue of data scarcity was resolved by using numerically generated rainfall records combined with a simple model for annual and daily temperature fluctuations. The soil was uniform, and the groundwater depth was constant at 100 m depth, which provided the lower boundary condition. The geothermal gradient determined the temperature at the groundwater level. We generated two scenarios with 120 years of weather in an arid and a hyper-arid climate. The initial condition was established by first starting with a somewhat arbitrary unit gradient initial condition corresponding to a small fraction of the annual average rainfall and let the model run through the 120-year atmospheric forcing. The resulting profile of matric potential and temperature was used as the initial condition for the warm-up period of the model (240 years) during which the weather record was repeated, which was then followed by the 120-year cycle we used for analysis.

We will present the initial results of our analysis:

- the dynamics (or lack thereof) of groundwater recharge and the role of wet years (or clusters of years) and droughts on the amount of recharge

- the speed with which the atmospheric input signal travels downward, and the damping of the signal on its way down

- the role of vapor flow under geothermal conditions