Session: C13 Poster: T16A

Application of a distributed hydrological model and satellite observations for soil moisture and groundwater level simulation

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As a result of the global climate change, ten to thirty percent decrease of available freshwater resources is expected in the semi-arid regions in the Mediterranean coast of North Africa, and the increasing water demand is likely to aggravate the water stress. In order to take adaptive measures, it is necessary to appropriately assess the current and future water resources that vary according to the area characteristics. Semi-arid regions are known to be dependant on groundwater resources for both agricultural and domestic use, but as the effects of climate change on groundwater is little known, detailed evaluation based on real hydrological processes is essential. The present study focuses on the application of a distributed biosphere hydrological model, WEB-DHM (Wang, 2007), for simulation of soil moisture and groundwater variations. Target area is the semi-arid basin of the Medjerda River in Tunisia with an area of 23,700km2. WEB-DHM couples a realistic land surface model SiB2 and the geomorphology-based hydrological model GBHM, and it can consistently describe the water, energy and CO2 fluxes with a realistic soil-vegetation-atmosphere transfer scheme. Furthermore, the hillslope representation enables an accurate calculation of water redistribution in the soil and in the aquifer. In the first step, the model performance is checked and the parameters are calibrated by using daily observed discharge. Next, satellite data from Gravity Recovery and Climate Experiment (GRACE) was extracted over the basin, which represents the variations of the sum of soil moisture and groundwater in this study. Although its reliability is confirmed by many studies, it is checked by comparing to the groundwater data observed at two wells inside the basin. Finally, soil moisture and groundwater simulation is done with WEB-DHM using the calibrated parameters, and by comparing it to the GRACE data, the model applicability is verified. Globally provided meteorological datasets (TRMM 3B42 version 6 for precipitation and JRA-25 reanalysis data for other atmospheric forcing) are used throughout the study. There are two major findings. Firstly, the seasonal and interannual variation patterns of GRACE derived soil moisture and groundwater matched quite well with the observed groundwater level even in a relatively small domain; therefore, GRACE can be used for model validation in this basin. Secondly, soil moisture and groundwater variations simulated by WEB-DHM and that observed by GRACE showed reasonable congruity as to their seasonal variation patterns (R=0.60), demonstrating the model's potential for assessment of groundwater resources. As this study uses widely available discharge data for calibration and globally available satellite data for other inputs, the same method can be applied to other similar poorly gauged basins. The present study is a first step towards an integrated system for assessing groundwater in semi-arid regions. As the simulated soil moisture and groundwater were validated without separating each component, the variations of groundwater itself could not be validated. Integrating data from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) into land data assimilation system, it is possible to calculate the long-term soil moisture variations. Then, the soil moisture and groundwater signals from GRACE can be separated, and the variations of groundwater can be verified.