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Hydrology and Earth System Sciences Discussions

Interactive comment on "Analysis of the impact of climate change on groundwater related hydrological fluxes: a multi-model approach including different downscaling methods" *by* S. Stoll et al.

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The paper uses an integrated hydrological model (MIKE-SHE) and the results of 8 RCMs driven by various GCMs to assess climate change effects on groundwater levels. I feel that this is a very thorough study using state-of-the-art tools. I applaud the authors for being so very critical of their own results, basically coming to the conclusion that the quality of the GCM-RCM predictions, even when downscaled with various statistical downscaling methods, is not sufficient to be used in planning future water resources.

The paper is well written and can be published with little modifications. I do have some issues though, which are the following:

- The first method, where only the change factors per month are applied seems a little naïve. Usually when such a correction is used, also the number of rain days is corrected (see e.g. Sperna-Weiland et al., Hydrol. Earth Syst. Sci., 14, 1595–1621, 2010, for a recent example). If this is done by finding a threshold to reproduce the number of observed rain days and keeping this threshold constant for future projections, one is also able to account for the changes in wet days. If I am correct, this cannot be done with the cpdf methods where P(wet days) remains constant. This is rather critical when analyzing hydrological effects. I do not know how much trouble it is to include such a downscaling method, i.e. change factors per month including number of rain days, but it would certainly make the paper more complete.

- Related to that: the authors conclude that none of the corrections can do both: remove monthly bias and preserve inter-annual variability. This is precisely why people use weather generators to simulate future climate, i.e. where changes in the parameters of the weather generators are inferred from the GCM/RCM changes (see for instance Burton, Kilsby et al. Environ. Modell. Software 23, 1356–1369).

- I would like to have a more in depth analysis on why groundwater recharge and thus levels increase due to the climate projections. For instance, more precipitation in winter could have easily lead to more runoff and no noticeable increase of groundwater recharge if soils below the snow pack are frozen. Also if precipitation falls as snow, most of it will runoff if during melt the soil is saturated. The combination with increased temperature however may be the cause for less frozen soils (probably not accounted for in MIKE-SHE) and precipitation falling more as rainfall instead of snow causing a more gradual input of water and therefore increased groundwater recharge. Anyway, it would be good to show a full water balance (winter, summer and whole year) including precipitation, interception evaporation, transpiration, runoff and groundwater recharge for current climate and projected for 2100 to understand what happens.

- When it comes to analyzing changes in groundwater recharge, the response of vegetation to climate change may very important. This does not only pertain to the physiological response of vegetation to CO2 increase, but also the effect of frequent and prolonged summer drought stress on vegetation density and biomass (LAI) and through this on transpiration and interception evaporation. For instance, from our own work (Brolsma et al., 2010, Water Resources Research 6, W11503, doi:10.1029/2009WR008782), it follows that depending on the severity of projected summer droughts, groundwater levels can either increase or decrease depending on whether vegetation density decreases or not.

Some small remarks:

- In the review about climate change effects on groundwater levels, perhaps the following paper is relevant: Roosmalen et al (2007), Regional differences in climate change impacts on groundwater and stream discharge in Denmark, Vadose Zone J., 6, 554–571, doi:10.2136/vzj2006.0093.

- The spikiness of observed groundwater heads at Girhalden (Fig. 3) that cannot be reproduced by the model cannot be from pumping because it shows head suddenly rising, not falling. So the explanation in the text is not satisfactory.

- Page 2, column 1, line 11: change to “For instance, Fuhrer and Jaspen (2000) state that. . .

- The validation period is 12 years: is this sufficiently long to correctly estimate monthly biases of each GCM? Maybe this explains the poor performance of the cpdf downscaling methods?

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