Hydrol. Earth Syst. Sci. Discuss., 9, C54–C59, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C54/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Estimation of future groundwater recharge using climatic analogues and Hydrus-1D" *by* B. Leterme et al.

B. Leterme et al.

bleterme@sckcen.be

Received and published: 2 February 2012

(RC) This paper describes a case study of future groundwater recharge in which analogue sites are used for projecting the future climate for a site in Belgium. The paper is well written and well organized but I do have a couple of concerns that need to be addressed before this is submitted. The IPCC's general projections are for an increase in rainfall for the next century but only one of the considered analogue sites has an increase in rainfall, I would suggest that a greater range of analogue sites needs to be considered to at least sample the range of projected climates that are generated from the various GCMs. The vegetation cover is assumed to be static with an LAI of 2 for every climate considered; it is more realistic to think that there is a feedback between a change in climate and a change in LAI.

–> The main purpose of the analogue stations is to obtain a long term average drainage through soil that is used for long-term safety assessments for a near surface radioactive waste disposal facility. We are interested in the leaching of contaminants from the repository to groundwater under average future climate, not in the effects of very dry or very wet futures (what seems to be what some GCMs are predicting).

(RC) P1390,L11 – The selection of a single analogue site for further modeling seems overly certain for a very uncertain future.

–> We will reformulate. We identified one analogue (e.g. Gijon) as the best estimate based on several climatic and geographic criteria, and the others (Huelva, Ourense, Cadiz) are considered as bounding cases accounting for uncertainty about the very far future; they are further used in sensitivity/uncertainty analysis .

(RC) P1392,L19 – 25 years of climate data is very short to produce a baseline. WMO recommend at least 30.

–> Yes that's true, but before 1985 rainfall data would need to come from another station more than 100 km away (Uccle). For our Dessel site we preferred not to mix different stations with different climatic behaviour. There is a similar problem with the analogue stations, not all have 30 years of data.

(RC) P1392,L19 – north rather than northern

–> ok

(RC) P1393,L19 – Was any consideration given to analogue sites that have higher daily rainfall intensities? The IPCC's general projections are for an increase in rainfall intensity and also for an increase in daily extreme rainfall. Changes in rainfall intensity can have an influence over recharge (Barron et al. 2011; Crosbie et al. 2012).

–> Rainfall intensity was not a criterion as we had no "predicted' reference to compare with. Note however that daily rainfall intensity and extreme daily rainfall increase for both Ourense and Gijon analogues, thus our assessments do give consideration to

HESSD

9, C54–C59, 2012

higher intensities (see Table in supplement).

(RC) P1395,L5 – I think the vegetation needs to be looked at in more detail. Assuming a uniform grass cover with a 30 cm rooting depth may be appropriate for what is on the site now, but in 1000 years time can you be certain that it will remain the same? Changes in vegetation can produce bigger changes in recharge than a change in climate (Crosbie et al. 2010a; Crosbie et al. 2010b)

–> The vegetation type chosen here is a kind of managed field. We adopt the same vegetation to have a sort of yardstick against the same type of managed vegetation. Recharge is expected to be lower in case of natural climax vegetation (pine forest-types of stand) than in agricultural fields including pastures (results not shown in this paper; see also Verstraeten, W.W., Muys, B., Feyen, J., Veroustraete, F., Minnaert, M., Meirsonne, L., De Schrijver, A., 2005. Comparative analysis of the actual evapotranspiration of Flemish forest and cropland, using the soil water balance model WAVE. Hydrology and Earth System Sciences 9, 225-241). The change in vegetation parameters was beyond the scope of this paper but it is acknowledged in another paper (in preparation) .

(RC) P1395,L8 – If there is a possibility that indurated layers may develop within the soil profile within the time period under consideration, then couldn't a simulation be run to see if it affects recharge?

–> This has already been assessed: based on daily time steps, decrease of groundwater recharge becomes significant only for a 3-order of magnitudes decrease in Ksat of the Bh horizon in the podzol profile. We suggest to modify the text accordingly: Simulations indicate (results not shown) that the average groundwater recharge is considerably affected (–25%) if the Ks of the Bh horizon is decreased by three orders of magnitude (4.5 and 6.1$\times$10-9 m/s for Zcg and Zeg profiles, respectively). an outcome that can be related to the average precipitation of the Dessel site, about 900 mm/y or $\sim$3$\times$10-8 m/s. This suggests that podzolisation may need to be considered together

HESSD

9, C54–C59, 2012

with other long-term changes (climate, land cover, vegetation). Therefore setting a Ks of ∼10-9 m/s provides an interesting limit for a sensitivity study. Recent landscape and soil evolution studies in the vicinity of the site have shown that cemented podzols may develop in several thousands of years with Ks values as low as ∼10-7 m/s (Beerten et al., 2012), which is almost three orders of magnitudes lower than the parent material. A Ks of ∼10-9 m/s is about two orders of magnitude lower that the absolute value presently observed in podzol soils in north-western Europe. However, these soils are mostly buried or truncated soils (i.e. soil development could not continue) while unburied podzols could further develop in the next few thousands of years

(RC) P1396,L20 – The depth to groundwater at which the water table influences ET is also dependent upon soils and vegetation. In a coarse textured soil with shallow rooted vegetation the calculated depth of 2.8 m may be enough that ET is independent of the depth to groundwater, see (Peck 1978).

–> We propose to modify as : “Deep groundwater tables would cause precipitation and land-surface processes to be the drivers of groundwater recharge (i.e. groundwater is disconnected from surface processes; Fig. 2 in Maxwell and Kollet, 2008). The depth at which groundwater becomes disconnected from surface processes is suggested to be 7-8m in Maxwell and Kollet (2008), but it could be less for example in case of coarse textured soil and shallow rooted vegetation (e.g. Peck, 1978). Therefore, a deeper groundwater table under warmer Gijon climate means that the influence of precipitation and land-surface processes on ET increases.”

(RC) P1398,L16 – If the IPCC’s general projection for northern Europe is for a 9% increase in rainfall, then why is the most extreme case considered only a 5% increase in rainfall? Some GCMs project more than 9% increase in rainfall by 2100 and looking ahead 1000 years is even more uncertain, I think a more extreme case needs to be considered.

–> In the selection of analogue stations we had to consider different parameters, in-

HESSD

9, C54–C59, 2012

cluding temperature, geographical location, precipitation. We did not find other potential analogues which would have a 9% increase or more and be equally representative for the other parameters (altitude and distance to the sea).

(RC) P1399,L6 – Dessel is the baseline not an analogue

–> ok

(RC) P1402,L4 – The assumption that LAI will not change is very simplistic especially as the range of climatic inputs range from a 2/3 reduction in P to a doubling of ET0. It has been shown that changes in climate variables can have a large effect on LAI and consequently recharge independent of any changes in rainfall (McCallum et al. 2010).

–> The change in vegetation parameters was beyond the scope of this paper (the analysis was done for a kind of managed field site). It is acknowledged that it should be taken into account. Appropriate references will be added.

(RC) P1402,L4 – How was the interception capacity of 55 mm determined? This seems extremely high for an LAI of 2. Using the FAO-56 definition of ET0 as being a grass of uniform height of 0.12 m, then the grass is half underwater before any water in the model reaches the soil. If this parameter was determined via calibration, is there the possibility that it is compensating for something else within the model?

–> Typo : the value is not 55 mm, but 0.55 mm so that the fraction of interception becomes ∼15% (Meyus, Y., Adyns, D., Woldeamlak, S., Batalaan, O. & De Smedt, F. (2004), Opbouw van een Vlaams Grondwatervoedingsmodel. Deelrapport 2: Totaal VGM-karteergebied en Vlaanderen. Vrij Universiteit Brussel, Brussel, België (in Dutch))

(RC) Table 1 – Why does Nuuk have 2 elevations?

–> There was a change in the location of the weather station during time series

(RC) Table 3 – Of the 8 analogue sites considered only 1 has an increase in rainfall

HESSD

9, C54–C59, 2012

even though the IPCC's general projections are for an increase in rainfall for northern Europe. Why were more sites with an increase in rainfall not considered?

–> See above.

(RC) Table 3 – The 3 sites with Cs climate have a lower percentage of interception than Dessel even though ET0 is higher and P is lower. Is this to do with daily rainfall intensity; are there fewer rain days but more rain per rain day?

–> It is the effect of higher rainfall intensity (see Table in supplement) and seasonality of the rainfall.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/9/C54/2012/hessd-9-C54-2012-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 1389, 2012.