

Interactive comment on “Parameterization and quantification of recharge in crystalline fractured bedrocks in Galicia-Costa (NW Spain)” by J. R. Raposo et al.

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Interactive comment on “Parameterization and quantification of recharge in crystalline fractured bedrocks in Galicia-Costa (NW Spain)” by J. R. Raposo et al. Anonymous Referee #1 Received and published: 14 March 2012

Reply to Anonymous Referee #1. We greatly appreciate your constructive and thoughtful comments that will definitely help to improve the manuscript. We will take into account all of them. In the following, we give a point-by-point reply to your comments: General Comments. RC: The manuscript deals with estimation of recharge with a water balance model in hard rock regions, which is a challenge in hydrogeology and

C394

makes the contribution significant. The results are cross-validated with the chloride mass balance technique. The strength of the work is the comparison of results from nine investigation areas and the systematic analysis of the data and results. The assumptions seem to be valid and interpretations are supported by the analyses. The research is of interest for everybody dealing with the estimation of recharge and groundwater management in hard rock regions with a limited access to a distributed database. The weakness of the article is the presentation of the applied hydrological model and the sensitivity analyses. The authors should improve process description, parameter descriptions and parameter consistency between figures/tables. AC: Initially, model description was not included since there is abundant bibliography (cited in the paper) that made a comprehensive explanation of the methodology applied, and repeat it again in this paper might seem reiterative. However we agree that the paper should be understandable as stand-alone. Therefore, section 3 “Hydrological Model” will be rewritten and additional information about the equations and parameters used by the model will be included in the revised manuscript. Parameter consistency between figures and tables will be revised.

Specific Comment 1920 – 3. RC: Please specify: “high heterogeneity” for example, of the hydraulic parameter field. AC: Sentence will be rephrased in the revised manuscript as follow, “Quantification of groundwater recharge in crystalline rocks presents great difficulties due to high heterogeneity of the underground medium” (mainly, due to heterogeneity in fracture network, which determines hydraulic parameters of the bedrock like hydraulic conductivity or effective porosity).

Specific Comments 1920 - 13, 1929 – 14, etc. RC: “Chloride” to “chloride”. AC: Correction will be applied.

Specific Comment 1921 – 22. RC: “de” to “the”. AC: Correction will be applied.

Specific Comment 1921 – 23. RC: “Spanish Water Administration” instead of “Spanish water administration”. AC: Correction will be applied.

C395

Specific Comment 1922 – 17. RC: "estimates" to "estimate". AC: Correction has been applied.

Specific Comment 1922 - 18. RC: check grammar of the sentence. AC: Sentence will be rephrased in the revised manuscript as follow, "This wide range of recharge rates makes it difficult to carry out a regional characterization and quantification of groundwater resources".

Specific Comment 1923 - 9/10. RC: check grammar "large uncertainty in quantify the recharge in all Galicia-Costa". AC: Sentence will be rephrased in the revised manuscript as follow, "The last study about this topic (Xunta de Galicia, 2011) highlighted the large uncertainty in the process of quantification of recharge in Galicia-Costa, due to the high heterogeneity of the medium."

Specific Comment 1924 - 11, 1951, etc. RC: "District" to "district". AC: Correction will be applied.

Specific Comment 1924 - 19. RC: "Cl" to "chloride" or "Cl-". AC: Correction will be applied.

Specific Comment 1925 - 9, 1927 -3, etc. RC: "Hydrologic District" to "hydrologic district". AC: Correction will be applied.

Specific Comment 1925 - 17,19. RC: "Groundwater Bodies" to "groundwater bodies". AC: Correction will be applied.

Specific Comment 1925 - 24/26. RC: 38% + 54% = 92 %, what is with the remaining 8 %? AC: Granitic (38.4%) and metasedimentary rocks (54.3%) are the main geologies in Galicia Costa District and occupy 92.7% of total area. The paper focuses on estimation of recharge rate in these main geologies, and later these estimated recharge rates are used for the assessment of total groundwater resources in the whole district. The remaining 7.3% corresponds to quaternary deposits, water bodies and a minimal area of limestone. Detritic quaternary deposits occupy 6.8% of total district and although

C396

its recharge rate was not estimated in this paper, they were considered for regional groundwater resources assessment using bibliographic data; the remaining 0.5% corresponds to water bodies and a minimal area of limestone (<0.01%) which were not considered for the regional assessment due to the small area they occupy.

Specific Comment 1926 - 8/10. RC: "Because the Galician aquifers are highly rain-recharge dependent and the residence time of the water in these aquifers is very short" - statement without reference. AC: We will include the following references for this statement: Soriano and Samper (2000), Samper (2003), Raposo et al. (2010).

Specific Comment 1927 - 17, 1930 - 14, etc. RC: "sunny hours" to "sunshine duration"? AC: The suggested correction will be applied.

Specific Comment 1929. RC: F_c seems to be an important parameter → please check its influence with a sensitivity analysis, there is no access to the cited master thesis Alcalá (2005), which is the source of the parameter value. AC: Effectively, F_c is a very sensitive parameter and the main source of uncertainty in the recharge rate estimation by chloride mass balance method. An sensitivity analysis for F_c was already carried out (page 21 lines 6-12). The thesis of Alcalá (2005) is available in <http://www.tdx.cat/handle/10803/6240;jsessionid=A4C27AD702E6C20580EED864246D3A1>. This web site will be incorporated to the corresponding reference in the bibliography.

Specific Comment 1931 -1. RC: "Thorntwhite" to "Thorntwaite". AC: Correction will be applied.

Specific Comment 1931-23/24. RC: "Curve number" to "curve number". AC: Correction will be applied.

Specific Comment 1931-23, 1974. RC: Are the calibrated parameters in the range of literature values? (For example, is the calibrated aquifer storage coefficient in the range of literature values from pumping tests?). AC: Initial model parameters were taken from bibliography or from field measurement. Most of them (especially soil parame-

C397

ters) underwent relatively small changes during the calibration process therefore they still remain in acceptable ranges according bibliographic values for similar terrains in the region. Aquifer parameters can undergo greater variations after calibration process due to the greater inherent heterogeneity of underground media in fractured bedrocks. However, they are still within the range of literature values for the region. Specifically in the case of storage coefficient, literature values from pumping tests in Galicia Costa ranges from 0.00032 to 0.1 on depending on the fracturing and weathering degree of the rock. Calibrated storage coefficients in the models ranges from 0.0027 to 0.013. It should be noted that aggregate models like Visual Balan use average values for the entire basin, compared with site-specific or local values obtained in a pumping test. Sentence will be rephrased in the revised manuscript as follow: "The main parameters changed during the calibration process were: soil depth, soil hydraulic conductivity, percolation, interflow and aquifer recession coefficients, curve number and the aquifer storage coefficient (Table 1). However they still remain in acceptable ranges according bibliographic values for similar terrains in the region (Soriano and Samper, 2000; INGEBAIRES, 2010)".

Specific Comment 1939. RC: How does the parameter sensitivity change between the different catchments? AC: A model parameter sensitivity analysis was carried out for each catchment. However, only average results were tabulated in the paper for a conciseness purpose. The parameters with higher standard deviation of sensitivity between the different catchments are soil field capacity and interflow recession coefficient (Figure 1). The high variability in these parameters is mainly caused by the high sensitivity observed in Gafos and Landro II catchments.

Specific Comment 1948. RC: Table 1: The aquifer storage coefficient is zero for some of the catchments? Why do you calibrate an aquifer recession coefficient for these catchments? AC: Visual Balan models can be calibrated using water table series, discharge series or both types of data. The calibration criterion used in each catchment is showed in Table2. Aquifer storage coefficient is only used by the model when water

C398

table data is available (Abeleda, Ferrol IV, Ferrol V and Landro II catchments). For the remaining catchments aquifer storage coefficient is not zero, but it cannot be computed, because the groundwater component of the model does not use this parameter for discharge calculations

Specific Comment 1952. RC: Legend of abbreviations is missing. Inconsistence: recession coefficients (table 1) etc. are not shown. The figure should be replaced by a figure, which shows the calibration parameters in table 1. AC: We agree the reviewer comment about inconsistence in parameter abbreviations. Legend of abbreviations used in Figure2 will be included in the figure caption. Since a more exhaustive explanation of the equations used by the hydrological model will be included in the revised manuscript (reply to General Comment), all parameters will be referred with the abbreviations showed in Figure2. Table1 will be rewritten in consistence with Figure2. According to Figure2, percolation and interflow recession coefficients will be renamed as K_v and K_h respectively.

Specific Comment 1954. RC: Please explain the reason for the simulated water level plateau in Figure 4b? AC: The water level plateau in Figure 4b corresponds with the terrain surface. Water table in Ferrol V catchment is usually close to surface. During very rainy winters (like period 2005-2007) water table almost reach the terrain surface and ponding and soil saturation occasionally occurs. When water table reaches the terrain surface, infiltration dramatically decreases and the model forces all the new water inputs to flow as run-off.

Specific Comment about Figure 3, 7, 9. RC: Scale is missing. AC: A scale bar will be included in those figures in the revised manuscript.

Specific Comment about Figure 4. RC: Please check precipitation "(mm)" to "(mm/ : :)". AC: Correction will be applied. The Y-axis title will be rewritten as "precipitation (mm/day)"

Specific Comment about Figure 7. RC: "Groundwater" to "groundwater", legend sym-

C399

bol of bibliographic data and field campaign data is difficult to distinguish. AC: Corrections will be applied in the revised manuscript. More different symbols (in color and shape) will be used for distinguishing bibliographic data and field campaign data in the figure.

Specific Comment about Figure 10. RC: Please compare the parameters with table 1 and use the same descriptions (e.g. soil depth vs. soil thickness). Why does the FC end at 50 CP(%)? Please explain CP and AS also in the caption or figure. AC: Corrections will be applied in the revised manuscript in order to keep consistency between terminology in Figure10 and Table1. Field Capacity ends at CP 50% because it cannot be higher than total porosity, and that happened when the parameter was increased at 70%. The meaning of CP and AS will be explained in the figure caption, as it was done in the text (page 20, lines 20-21).

We will consider your contributions for improving the final manuscript and we hope that we have appropriately addressed your comments. Kind regards, Juan Raposo, Jorge Molinero and Jorge Dafonte.

Bibliography

INGEBAIRES: Estudio sobre las posibles causas de los daños en las edificaciones de un área del casco urbano de Ponteceso [Study on possible causes of damage to buildings in an urban area of Ponteceso] Technical report, Vigo, 2010. Available in <http://www.ponteceso.net/informe/informefinal.pdf>

Soriano, G. and Samper, J.: Hidrogeología de una pequeña cuenca piloto en medios graníticos: Cuenca del Valiñas (A Coruña) [Hydrogeology of a small pilot basin in granitic terrain: Valiñas basin (A Coruña)], in: Las Aguas Subterráneas en el Noroeste de la Península Ibérica, Samper, J., Leitão, T., Fernández, L. and Ribeiro, L. (Eds.), IGME, Madrid, 73-82, 2000.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 1919, 2012.

C400

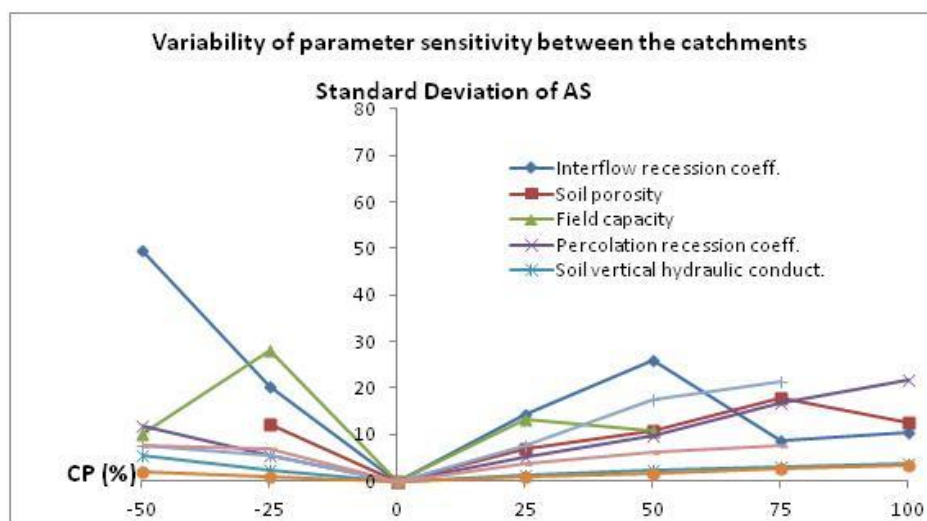


Fig. 1. Figure 1. Variability of parameter sensitivity between the studied catchments

C401