Hydrology and Earth System Sciences Discussions

Interactive comment on "Ground-penetrating radar insight into a coastal aquifer: the freshwater lens of Borkum Island" *by* J. Igel et al.

Anonymous Referee #2

Received and published: 27 October 2012

General comments:

This paper is a case study employing ground-penetrating radar on the Island of Borkum in order to map sedimentary structures as well as the depth of the groundwater table. The data are intended to serve as input parameters for hydrogeological simulations. The paper is submitted for a special issue about the CLIWAT project and is related to other studies conducted on Borkum. The paper is well written, methods and analyses are mostly state-of-the-art and clearly described and supported by figures which are of an overall good quality. I am somewhat missing the originality of the research of the study but I think the paper could be published in the framework of the special issue. I have some comments which I think need to be worked out before the paper can be

published in HESS.

1) The main objective stated in abstract and discussion is to provide data for hydrogeological simulations which I think is basically the paper by Sulzbacher et al. (2012). However, I am missing the link between the GPR measurements of this study (small scale, one point in time, large error of estimated groundwater tables) and the rather large-scale investigation presented in the paper of Sulzbacher et al. (2012). Probably, there are also other studies planned in the framework of the CLIWAT project which may take advantage of the GPR measurements. This point should be elaborated in the introduction and discussion section of the article.

2) The structure of sections 2.2 to 4 is somewhat difficult to read since especially some features of the GPR profiles are already dicsussed in sect 2.2 while the details are hidden but presented in sect 4. I suggest to restrict sect 2.2 to the very technical details of the GPR measurements and add the discussion of the details including all the figures (4 to 6) to sect 4.

3) I have very some reservations regarding the discussion of the large deviations between groundwater table depths measured in the wells and those determined from the GPR measurements as presented in Sect 4.3. Overall, an RMS error of 50 cm with observation wells closer than 30 m to the GPR line is unacceptable. This clearly puts the applicability of GPR-measured groundwater tables for modelling studies into question, which would be unfortunate. In this study, the various error sources listed by the authors require further investigation and especially interpretation (e.g. by merging with other geological information about the spatial distribution of the confining layers, time series of data showing the temporal groundwater dynamics, data from other geophysical investigations conducted within the project, ...) in order to be able to reduce the measurement error. Especially groundwater table depths determined by GPR measurements cannot be compared to pressure heads of a confined aquifer as the authors state correctly. These areas would have to be removed from the comparison but still could contribute to the discussion of the hydraulic situation. Here I strongly encourage

the authors to carefully revise this section before publishing the paper.

Specific comments:

P 3693, L 16: Is there any overview paper about the CLIWAT project? If yes, please cite.

P 3694, L 4-6: Please specify this statement - I suppose the intention was to investigate the depth of the groundwater table but which property of the clayey/silty layers were explored (occurrence, depth, shape, erosion channels, leackages, . . .)? How does (or would) the information from the GPR measurements improve the model investigations presented by Sulzbacher et al. (2012)?

P3695, L 11: this should be volumetric water content

P 3695, L 13: Porosity can only be determined for saturated conditions. In this case θ_v = ϕ (see sect 4). Please clarify.

P 3695, L 15-16: Sentence misleading, please reformulate: "Two techniques that originally stem from seismics but had been adapted for GPR were used in this study to assess wave velocities."

P3696, L1: Please provide a number for "a couple of ..." .

P 3696, L 13-15: How has this fine tuning been done? Has any software been used for picking the signals or has it been done by hand? Please explain in more detail. If the fine tuning has been done by hand, what is the expected accuracy of the results?

P3696, L 19: For this CMP, I cannot extract a velocity of 0.065 m ns^{-1} from Fig 1c. To me the velocity below the groundwater table appears to be at least around 0.08 m ns^{-1}.

P 3698, L 7: Please add an introductory sentence explaining that results of a VRP sounding are shown in Fig 2 and explain observed velocity changes also for Fig 2. Alternatively one could also merge Figs 2 and 3 to a 3-column figure.

C4971

P 3698, L 20: Why was exactly this part of the island chosen for the GPR measurements? Was there any specific demand from the groundwater model for exactly this area of the island? Please explain.

P 3699, L 19: Please mention depth of mean sea level in text "... (m.s.l.) at 12 m is marked ..."

P 3701, L 6: Please provide depth interval of the peat layer.

P 3701, L 19: This is a very rough method to determine the height of the capillary fringe. Did the authors make sure that the bulk density/porosity of the material in the tube was the same as in the field and that it does not change during flushing the tube with water? How representative is this single value for the complete area of investigation? In any case the authors should clearly mention that this is a very rough estimation of the height of the capillary fringe which may be different to some extent at other positions along the GPR line.

Sect 4.2: Again, here merging the information from section 2.2 to 4 would very likely make the discussion more readable. Please also discuss the sedimentary features indicated in the figures (foreset beds etc) as well as their extension along the profiles in the text.

P 3703, L 15: Please provide complete range of depths as provided in Fig 9.

P 3703, L 26-28: Does this mean that Fig. 10 was generated by using information from different antennas? Is there a fixed threshold value (depth) where the authors shifted from using data from the one antenna frequency to the other? Please explain in more detail how the different measurements contributed to the map shown in Fig 10.

P 3704, L 27 ff: The occurence of groundwater level (head) depression cones is a characteristic feature around every existing pumping well while its shape is determined by the pumping rate and the hydraulic properties of the surrounding aquifer. In this context, I do not understand the explanation provided in L 3-6.

C4972

P 3706, L 7-8: Please consider general comment No 3 regarding confined aquifers.

P 3706, L 16-27: This paragraph (except for the outlook) should be moved to sect 4. For a future interpretation of the data the authors may also want to consider the paper by van Dam and Schlager (2000).

P 3707, L 8-10: I am somewhat confused about the statement about the large spatial variability in the groundwater table depth since the groundwater table usually is an equilibrating surface with a larger-scale slope. Given the large RMS error in the analysis of the groundwater table depth mentioned in section 4 and the reasons given for the deviations, I wonder about the value of this statistical analysis. In any case, this analysis should be presented in more detail as part of section 4 in order to confirm this conclusion.

Figure 1: Resort order of figures a) CMP measurement, b) semblance plot, c) deduced velocity profile. Since HESS is not a geophysics journal, it potentially would help many less informed readers if the different waves discussed on P 3696 L 5-7 would be indicated in the CMP plot. What does the dashed line shown in Fig 1a represent?

Technical corrections:

P 3693, L 25 and other occurences: I am not a native speaker but I think it is "electrical resistivity" as well as "electrical conductivity" (see e.g. P 3694, L 16). Please check.

P 3694, L 17: please correct "whole"

P 3699, L8: this should be "down to 10 m"

P 3700, L 20: please correct "built"

P 3701, L 2, 6, 9, 10: please write "fine to medium sands"

P 3701, L 17: replace "good" by "well"

P 3703, L 28: replace "low" by "shallow"

P 3704, L 12: replace "dispersed" by "distributed"

P 3706, L 12: replace "hydraulically-tight" by "less conductive"

P 3706, L 14: please correct "... acts as an aquiclude..."

Figure 10: I cannot deduce start and end position of GPR profiles 1 and 2 as well as the profile sections shown in Figs 4 to 6. Please indicate.

Figures: Please increase font of most figure legends.

References:

van Dam, R. and W. Schlager (2000): Identifying causes of ground-penetrating radar reflections using time-domain reflectometry and sedimentological analyses. Sedimentology, 2000, 47, 435-449.

Sulzbacher, H., H. Wiederhold, B. Siemon, M. Grinat, J. Igel, T. Burschil, T. Günther, and K. Hinsby (2012): Numerical modelling of climate change impacts on freshwater lenses on the North Sea Island of Borkum. Hydrol. Earth Syst. Sci. Discuss., 9, 3473-3525.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 3691, 2012.