

Reviewer 1 (Andy Baird)

Dear Andy Baird, we thank you very much for your thorough review of our paper, which was very valuable for improving it. Specifically, we appreciate your a) knowledgeable statements on the phenological differences of *Sphagnum* species and b) your advices with respect to the terminology and hydrological functioning of peatland ecosystems. Moreover, we thank you for the careful attention to detail regarding methodology and the presentation of our manuscript. We have addressed and incorporated your comments in our revised manuscript, as indicated, point by point, detailed below. We have taken great care to make the manuscript more accessible to a broader audience.

Reviewers Substantive comments:

Title and use of word 'pedogenesis'

I am not comfortable with the use of the term 'pedogenesis'. The authors use the term to describe physical changes in a peat soil as litter decays and decomposes. Such use of the term would then imply that fresh litter or even partially-decayed litter ('fresh peat') is not true soil. I recommend changing the title of the paper and using a different term to describe peat decomposition and physical alteration.

We fully agree; the term 'pedogenesis' in the title is potentially misleading. To address this, we have changed the title to:

"A pore-size classification for peat bogs derived from unsaturated hydraulic properties"

, which we think now more directly reflects the adopted methods and obtained results.

The use of the word pedogenesis is now restricted to the abstract and the conclusions of the original manuscript. Since you raise a valid point concerning the applicability of the terminology to *Sphagnum* peat bogs, we have now added the following sentence to the introduction:

"In summary, the aforementioned processes constitute the entire continuous pedogenesis shaping the soil profile as an ongoing process (Blume et al., 2016). It should be noted that this includes the actively growing Sphagnum mosses, as Weber et al. (2017a) define the actively growing and living part of the Sphagnum mosses as part of the vadose zone, i.e. as part of the soil profile.",
now on P2 L14-18.

This specification is given directly after on P2 L3-13 where we present with great detail the principle pedogenic processes occurring in *Sphagnum* bogs is mentioned.

For this, we added the following reference to the reference list:

Blume, H.-P., Brümmner, G.W., Fleige, H., Horn, R., Kandeler, E., Kögel-Knabner, I., Kretschmar, R., Stahr, K., Wilke, B.-M.: Scheffer/Schachtschabel Soil Science, Springer Berlin Heidelberg, 618 pp., 2016, doi: 10.1007/978-3-642-30942-7.

Wider applicability of the results vis-à-vis different *Sphagnum* ssp found in peat bogs.

This is an important and valid interjection. First, we did not observe any *S. cuspidatum* in the samples from the Odersprungmoor bog on which we conducted our research on. However, in Fig. 1, the images Fig. 1b and Fig 1c do show *Sphagnum cuspidatum*. The intention of the

available images was to exemplify the general architecture of Sphagnum mosses. To address this, we now specify this in the caption of Fig. 1 which reads now:

Sphagnum moss structures and soil pore sizes. a) Sphagnum lawn with visible bleaching due to desiccation of the capitula (in German language Sphagnum is also referred to as 'Bleichmoos', which translates to 'bleaching moss'), a-b) images of Sphagnum cuspidatum H.Klinggr to exemplify the b) sampled and slightly spread out individuals with visible inter-connectedness of branches, [...].

Further, we follow your suggestion on potential limitations of our results in the light of different in situ phenologies different species might have. For this, the final paragraph of Section 4 "Proposal of a pore size classification for *Sphagnum* moss and peat" now reads:

A word of caution with respect to generalizing our findings: Michaelis (2011) describes 286 species of Sphagnum, occurring globally; thus, our results might not be applicable to all species, since the phenology of decaying Sphagnum might be different between species. Nevertheless, in line with these definitions, a pressure head delimitation of pore water into an active (inter- and intra-plant and inter-plant matrix pore space) in an inactive porosity (inner-plant and inner plant matrix) at a pressure head of $h = -100$ cm is suggested.

We have now added Michaelis (2011) to the reference list as:

Michaelis, D.: Die Sphagnum-Arten der Welt, Bibliotheca Botanica, Vol. 160, 408 p. (in German). 2011.

Shrinkage of the samples?

The authors do not say whether their peat samples contracted as they dried. Contraction can have quite substantial effects on the pore-size distribution and will, therefore, affect the fit of any model. It would be useful if the authors could comment on this effect in a revision of the paper. It is widely known that acrotelm peat contracts on drying and it is possible that the small samples used in the study were prevented from shrinking because of friction with the walls of the containers in which they were housed. If so, the results obtained may, to some degree, reflect an artefact of the laboratory setup rather than what happens in the field.

The effects of shrinkage certainly deserve further research; however, an in depth treatment is considered outside of the scope of this study, since it involves simultaneously simulating transient water fluxes and the change in sample volume.

To the case in point: First, we would like to point out that Weber et al. (2017) observed volume changes of less than 5-8% referenced to the initial volume for samples from the same bog and the same experimental setup. The experimental setup was reported by Weber et al. (2017) to consist of very thin and flexible latex membranes ensuring a snug fit to the sample, even during drying. We refrain from repeating all the methods which we explicitly addressed in the previous paper.

Secondly, a large effect cannot be expected as this small change will not affect the presented delimitations which differ in orders of magnitude of pressure head and related effective pore radii. In particular, the results delimiting the larger pores from the hyaline cells at $pF = 2$ is very distinct which can be seen in Fig. 6 of the manuscript

However, we are currently preparing a manuscript on a study addressing this topic and the preliminary results do not support a significant effect. In particular, the distinct and sharp differentiation between the larger pores and the hyaline cells at pF = 2 are unaffected by this.

To address the detailed statements above we summarise this by adding the following sentence to results section 4 on now P10 L23-26:

“In our analysis we assume that shrinkage does not affect our key findings. Shrinkage was observed to be around 5-8% on samples from the same depths and same bog, as referenced to the initial volume. Since the delimitations of our pore size classification span orders of magnitude in pressure head and related effective pore radii, we believe that shrinkage will not have a considerable influence on the derived soil hydraulic properties for the small scale”

Minor comments

Variables and parameters in the equations and text

Throughout the paper there is inconsistency in the italicization of variables and parameters. Typically these should be italicized in both the equations and the text (including labels in figures). Regardless of the convention used, the same form should be used in the equations, main body of the text, and figures.

We apologise for this circumstance and have now corrected it in all instances in the equations and text. We note the changes in the revised manuscript through the “track changes” option.

References

This should not happen. We have now double checked the consistency of the reference list and have made changes where applicable, but do not give the details here. We note the changes in the revised manuscript through the “track changes” option.

Minor comments from the comments of the pdf supplementary are listed in the table below:

Page(s) and Line(s)	Reviewer comment	Reply
P1,L18	“Pedogenesis” I am not sure this term is used correctly in the paper. Pedogenesis is the formation of soil from non-soil. In what way is the litter in the acrotelm non-soil?	We have made alterations to address this point in our reply to the major comments (see above).
P1,L21	“Peatland development” Not true for tropical peatlands. I suggest being more specific.	The sentence now specifies that this is the case for temperate and boreal peatbogs.
P1, L22	“Subsequent ombrotrophication”: Okay, but in many bogs ombrotrophication occurs first and then Sphagnum establishes. In UK bogs, for example, it is common to see an initial dominance by Eriophorum spp. after the fen-bog transition.	We have corrected the sentences to: “[...], growth of peat bogs and may lead to a manifestation of the ombrotrophication process (Balyea, 2009; Rydin and Jeglum, 2016).” We added the reference Balyea (2009) to the reference list: Balyea, L.R.: Nonlinear Dynamics of Peatlands and Potential Feedbacks on the Climate System, in: (eds)

		Baird, A. J., Belyea, L.R., Comas, X., et al.: Carbon Cycling in Northern Peatlands, Geophysical Monograph 184, Geophysical Monograph Series, American Geophysical Union, 2009.
P2, L3	<p>“while SHPs accounting for these processes have only recently been identified by Weber et al. (2017a) for a limited number of samples.”</p> <p>It is not quite clear what is meant here by 'SHPs'. The hydraulic properties of the acrotelm have been investigated by a number of authors. I suggest rewording so that the intended meaning is more evident.</p>	<p>We have added the word ‘processes’ to the first part of the sentence, too. This should clarify, that the second mentioning of ‘these processes’ points at the water, film, and vapour flow processes for which Weber et al. (2017) identify SHPs. The sentence now reads (changes in italics): “The importance of capillary, film and vapour flow <i>processes</i> for upward water fluxes in moss and peat has been emphasized by Hayward and Clymo (1982) and Price et al. (2009) while SHPs accounting for these processes have only recently been identified by Weber et al. (2017a) for a limited number of samples”.</p>
P2, L4	<p>“Heavily decomposed”</p> <p>This is often the case, but layers of poorly-decomposed Sphagnum peat may be found throughout a peat profile. The classic acrotelm-catotelm model rarely applies fully to a peat profile and has recently been criticised in the recent scientific literature.</p>	<p>While we are aware of the oversimplification of this continuous change, we first introduce it as a general rule to ease the explanation of the conceptual understanding. At the end of the paragraph we explicitly state cases which cause perturbations to this gradual and smooth decrease: “Exceptions from this rule have been observed in cases where pipe flow (Holden, 2005), fire disturbances (Sherwood et al, 2013), and rapid climate change resulting in changes in vegetation and subsequent peat deposition history (Rydin and Jeglum, 2016, Hedwall et al., 2017) occur”. Therefore, we do not see the necessity to change the manuscript.</p>
P2, L17	“Parametrization”	We corrected all instances of the incorrect spelling.
P2, L17-18	“SHPs” vs “SHP”	We now SHP for soil hydraulic properties, regardless whether we address it in plural or singular.
P2, L17-18	Meaning of SHPs	It is defined on P1 L28 of the revised manuscript.
P2, L21-25	Ks as predictor and its depth relationship and position of first mentioning of the water retention	The paragraph starting with “However, [...] “ until the end of the

	curve and hydraulic conductivity curve in the manuscript.	<p>respective paragraph indeed lacks clarity. We changed it to:</p> <p><i>“While correlations of saturated hydraulic properties, i.e. Ks with depth have been inferred for the upper bog layers of up to 50 cm (Morris et al. 2015) this is not a sufficient predictor for the SHPs. Moreover, knowledge on the pore size density is required to effectively describe the water retention curve (WRC) and the hydraulic conductivity curve (HCC).”</i></p>
P2, L24-25	Introducing WRC and HCC earlier in the text	We think that introducing the abbreviations at this early place in the paper (page 2) is ok.
P2, L 34	PSD mentioned for the first time.	On first mentioning, PSD is now defined as “pore-size distribution.
P3, L11	Widening of PSD with depth	<p>Well spotted. Of course, the reverse is true.</p> <p>We replaced “widening” with “narrowing”.</p>
P3, L13	Is pedogenic the right use of word?	Thank you for double checking on this unusual word. Yes it is the correct word, in so far as it is the adjective of the word pedogenesis.
P3, L16	Wording of: “the research aims of this study are	'the research aims of the study reported in this paper were'.
P3, L21	Suggestion of deleting “as process model”	We have decided not to follow the suggestions, as we do like the explicit differentiation between the process model, the models for the soil hydraulic properties, and the likelihood model.
P3, L26	Definition of “soli-ombrotrophic”	We learnt that “soli-“ is a German prefix, but have now deleted it. The next comment gives greater detail to the hydrology of the peatland.
P3, L27	Minerotrophic influence and valley position (cf als reply to reviewer 2)	We are a little surprised to see that the description is misleading, since Figure 2 (top) very clearly shows the isolines, such that it is clear, that the sampling location is from the ombrotrophic part of the bog. However, since Reviewer 2 has also addressed this concern, we address it by describing the situation differently.

		<p>We changed the sentence on P3, L27-28 of the original manuscript to:</p> <p><i>“The Odersprungmoor formed on a saddle with an average downslope of 3 % in the SE-NW direction. In the SW-NE direction it is located in a gentle trough position (Fig. 2; Jensen, 1990).”</i></p> <p>Additionally, we state more clearly the results of the hydrology of the very small minerotrophic influence by Broder and Biester (2015) and add more specifically:</p> <p><i>“The Odersprungmoor shows features of a poor-fen in some small areas where it is slightly influenced by of minerotrophic water which only occurs on a small strip on the North-Western flank (indicated by the arrows, Fig 1, bottom). Most of the incoming water from the shallow soils in the North-East is diverted past the bog along the northern rim of the bog towards the North-West (Border and Biester, 2015); thus our sampling location is situated in the ombrotrophic part of the bog. Broder and Biester (2015) provide information on the geochemical composition of the substrate and pore waters which supports this.”.</i></p>
P3, L29	“In shape” --> “in shape in plan”	Done
P3, L31	Give botanical authorities after first use of each Latin name? Also, the pictures from the site in Figure 1 suggest the main Sphagnum species was the terrestrial form of Sphagnum cuspidatum.	Done
P3, L31	On the existence of “ <i>S. cuspidatum</i> ”	We address this in the comment to the caption of Fig. 1.
P4, L1	<p>“Minerotrophic water flow into the bog on the North-Western flank”</p> <p>If there is minerotrophic water flowing into the peatland, it is more properly called a fen or 'poor fen'.</p>	cf reply to the comment on P3, L26 and P3, L27.
P4,L2	“On geochemical” → “on the geochemical”	Added ‘the’
P4, L5	“Nearby” → “at nearby”	Corrected.

P4, L6	Weak grouping	<p><i>"In the acrotelm, a profile characterization with depth is possible according to a weak grouping."</i></p> <p>Was replaced by <i>"In the acrotelm, a profile characterization with depth is possible as follows:"</i></p>
P4, L8	Humification (von Post)	We do not have this information, and thus refrain from following this suggestion, since we do mention the state of decomposition and give reference to a detailed studies on the geochemical signature of the soil parent material.
P4, L11	5x → n = 5, ...	Corrected as suggested
P4, L19	Explicit introduction of the experimental details	We refrain from giving additional details to make our paper concise. Also, the evaporation experiment is a standard measurement technique in soil physics, and the modifications which were particularly adopted to account for Sphagnum moss has been given careful detail here. However, we added the basic information: <i>Subsequently, transient evaporation experiments were carried out (Wendroth et al., 1993, Schwärzel et al. 2006) on samples 5 cm i.h. and 8 cm i.d., starting with full saturated samples that were exposed to free evaporation in the lab. Matric potentials were measured in two depths, and water fluxes were derived from weight changes with time.</i>
P5, L22	<p>"Pressure heads"</p> <p>How were pressure heads measured? If tensiometers were used, were problems encountered with the contact between the Sphagnum peat and the tensiometer cup?</p>	Yes, with tensiometers, and no loss in contact was observed.
P4, L25	"Model" → models	done!
P5, L19	"estimation circumvents the need to weight the data groups of $\theta(h)$ and $\log_{10} K(h)$." Unclear (to me) what is meant here. Perhaps add a line or two of explanation?	To make it clearer, the sentence now reads: <i>"The sequential parameter estimation circumvents the need to weight the data groups of $\theta(h)$ and $\log_{10} K(h)$, whereas if measured WRC and HCC data are used to</i>

		<i>estimate SHP model parameters simultaneously, it involves a weighted multi-objective problem."</i>
P5, L26	"Gravitational acceleration" → acceleration due to free fall	We have not changed this. To our understanding, the used terminology is correct.
P5, L26	$L T^{-1} \rightarrow L T^{-2}$	Thank you! We changed that.
P6, L12	'by the shape' - add 'the'	Done
P6, L21	'pressure' – singular	Done
P6, L21	„this this“ Repeated word.	Done
P7, L1	When not reporting data values, write numbers of nine or less as words? Later in this sentence 'three' and 'one' are used instead of '3' and '1'.	Correct! Changed 4 to four
P7, L16	Choice of word: “Amazingly”	Changed to “very” (reducing the sentence to a factual statement)
P7, L24	Abbreviation of “MSO”: What is this? It doesn't appear to have been previously defined.	MSO – multi-step outflow experiments. We have now given the full description of MSO and deleted the abbreviation.
P8, L25	“On the discussion of desiccation tolerance” (There is another way of 'reading' this. If water can be readily lost upwards, we might say the peatland (as opposed to the upper layers of peat) show *less* desiccation tolerance. A peatland that was desiccation-tolerant might be regarded as one where drying of surface peat leads to a hydraulic 'break' (or sharp increase in hydraulic resistance) so that less water is lost from the peatland to the atmosphere. It may be worth adding some more detail/explanation here.)	Since the capitula is exposed to the atmosphere with at times great vapour pressure deficits, evaporation will be an ongoing process. For the capitula not to dry out and get damaged, it is required that a certain pressure head is maintained. This can, in the absence of meteoric water, only be achieved by 1D water flow, vertically upward. To clarify, what we mean, we have now added the word “capitula”. The sentence now reads (changes in italics): <i>“The relatively high hydraulic conductivity in the pressure head range until $pF = 2.5$ ensures an upward flow of water to the capitula which contributes to the effective desiccation tolerance of the vegetation under field conditions.”</i>
P8, L15	Space between “(“ and “Table”	Done.
P8, L20	expression “Carve out”	We like it, too! We have decided to leave it in.
P8, L30	'This contrasts with reports' - add 'with	done
P9, L9	Pedogenic - See my earlier comments on the use of this term	See detailed comments in the specific section, where we state that

		we now give a definition of the word “pedogenic” and use it
P9, L8-9	I think what is written here is reasonable. However, I'm not sure this conclusion will apply in the same way to all the types of Sphagnum peat that can make up the acrotelm. See my separate report.	We treated this in great depth in the specific comments sections.
P10, L1	'exist' not 'exists'	done
P10, L10	'skeletal' – spelling	done
P10, L14	This should say 'and'.	done
P10, L23	Comma needed here.	done
P10, L25	A semi-colon or full stop (period) is needed here rather than a comma.	done
P10, L30	This should be 'of'.	done
P10, L31	Italics needed.	done
P11, L5	Delete „to“	done
P11, L13	“under different boundary conditions” delete“	done
P11, L14	Ratios → ratios	done
P11, L15	Ks predictions from C/N ratios: I don't think this is true. Saturated K does not show strong relationships with the listed metrics. If you disagree please add some supporting references.	Deleted “ <i>as is often done for saturated conductivity</i> ”, since, on double checking the literature, the statement is ambiguous.
P11,L17	Code and data availability	Sorry, but while we embrace the notion of open access (since we submitted this article to HESSD), we cannot do this with the current codes. However, we have uploaded the HYDRUS project files which contain all necessary data of the evaporation experiments and state this in the Data and code availability section.
References and acknowledgement		Done
Figure 1	S. cuspidatum vs S. magellanicum	Cf specific comments
Figure 2	Dimension and reference to elevation	
Figure 3	Italics “K”	Done
Figure 4	Suggestion to use y label only once.	We opted to repeat the y axis label in each row enabling other researchers to use some of the subplots for their own use in e.g. teaching. We did not change this.
Figure 5	Italics “K”	Done

Figure 6	subscript	Done, we have now added a second x axis at the top of the graph with the effective pore diameters
Figure 7	Different font sizes	Done
Figure 8	Different font sizes	This was intentional due to the long second x-axis label
Table 1, P26, L4-7	This is difficult to read. I suggest breaking it up into a couple of sentences or improving the punctuation. Also, what does 'L' refer to when mentioning heights?	Thank you for this sensible suggestion. We have reorganized the caption. It now reads: Table 1: Statistical evaluation results of the inverse parameter estimation for 31 samples of eight mid sampling depths. The definitions of the abbreviations are given as footnotes to the table
Table 2	Italics needed?	No. Was corrected.
Table 3	Font difference	We trust this will be sorted out in the typesetting, but MS Word gives us no indication on font size differences.
Table 4	Is it needed?	Yes. We think summarising this classification is very helpful to quickly capture the essence of the paper, as e.g. also Hayward and Clymo (1982) did when they presented their seminal work with results not unlike ours.

References used.

Hayward, P. M. and Clymo R. S.: Profiles of Water Content and Pore Size in Sphagnum and Peat, and their Relation to Peat Bog Ecology, Proc. Roy. Soc. B. Bio., 215(1200), 299-325, doi:10.1098/rspb.1982.0044, 1982.